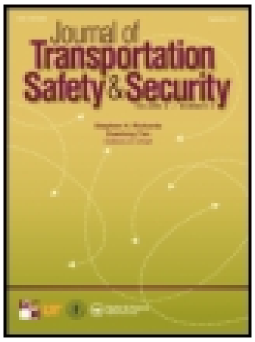

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Which factors affect accident probability at unexpected incidents? A structural equation model approach

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ABSTRACT

Considering that unexpected events are a major contributory factor of road accidents the main objective of this article is to investigate the effect of several parameters including overall driving performance, distraction sources, driver characteristics, as well as road and traffic environment on accident probability at unexpected incidents. For this purpose, a driving simulator experiment was carried out, in which 95 participants from all age groups were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in different road and traffic conditions. Then, in the framework of the statistical analysis, driving performance is estimated as a new unobserved (latent) variable based on several individual driving simulator parameters while a structural equation model is developed investigating which factors lead to increased accident probability at unexpected incidents. Regarding driver distraction, results indicate that cell phone use has a negative effect on accident risk confirming the initial hypothesis that when talking on the cell phone drivers find it difficult to handle an unexpected incident and as a result are more likely to commit an accident. Overall, a risky driving profile is developed, completing the puzzle of the effect of driver distraction on driver behavior and road safety.

KEYWORDS
road safety; driving performance; driver distraction; accident probability; structural equation models

1. Introduction

Considering that unexpected incidents are a major contributory factor of road accidents (World Health Organization [WHO], 2014), the investigation of driver characteristics with focus in the way that drivers react to unexpected and risky situations is of great importance. Within this scope, very useful tools for examining driving performance at unexpected events are driving simulator as they allow for the examination of a range of driving performance measures in a controlled,

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relatively realistic, and safe driving environment. This safe environment that they provide is necessary for the examination of various incidents that cannot be programmed in naturalistic or on-road experiments (Regan, Lee, & Young, 2008).

Furthermore, driving performance is a multidimensional phenomenon that means that no single driving performance parameter can capture all aspects of the overall driving performance (Young & Regan, 2007). The large number of parameters that are estimated in each experimental process indicates that the decision regarding which parameter or set of parameters is used should be guided by the specific research question. However, in many studies where the research question is the investigation of driving performance, individual driving parameters are considered to represent performance (Papantoniou, Papadimitriou, & Yannis, 2017). Instead, through a structural equation model (SEM) approach, a new latent variable can be developed based on the collected individual parameters and represent with a statistical significance the overall driving performance.

Based on the above, the present research relies on two main objectives. The methodological objective is to investigate whether latent model analysis through a SEMs can be implemented on driving simulator data to define an unobserved driving performance variable. Subsequently, the second objective and the core of the present research is to quantify the effect of several factors including overall driving performance, driver distraction, driver as well as road and traffic characteristics on accident probability at unexpected incidents and as a result to develop a risky driving profile in case of an unexpected incident.

For this purpose, a large driving simulator experiment was carried out, in which 95 participants were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in different road and traffic conditions. Then, in the framework of the statistical analysis, driving performance is estimated as a latent variable based on several individual driving performance parameters. In the next step, through a SEM, the effect of driving performance as well as several risk factors on accident probability is quantified and analysed.

1.1. Review

Road accidents constitute a major social problem in modern societies, accounting for more than 1.2 million fatalities in 2013 worldwide (WHO, 2014). Furthermore, human factors are the basic causes in 65% to 95% of road accidents (Sabey & Taylor, 1980; Salmon, Young, Lenné, Williamson, & Tomasevic, 2011). The remaining factors include the road environment (road design, road signs, pavement, weather conditions, etc.) and the vehicles (equipment and maintenance, damage, etc.), as well as combinations of these three contributory factors.

Although human factors involve many specific factors that may be considered as accident causes, including driver injudicious action, driver error or reaction, behaviour or inexperience, driver distraction, driver impairment (Department for

Transport, 2008), in the last two decades, there has been a large focus on investigating the effect of distraction on driving performance. *Driver distraction* is generally 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" (Regan et al., 2008, p. 33)

Distracted drivers experience what researchers call "inattention blindness," like that of tunnel vision, as drivers are looking out the windshield, but they do not process everything in the roadway environment that they must know to effectively monitor their surroundings, seek and identify potential hazards, and respond to unexpected situations (Maples, De Rosier, Hoenes, Bendure, & Moore, 2008).

In the last decades, researcher have put a lot of effort for the investigation of the effect of different distraction factors on different driving performance measures (Bruyas, Brusque, Debailleux, Duraz, & Aillerie, 2009; Garay-Vega et al., 2010; Horberry, Anderson, Regan, Triggs, & Brown, 2006; Lansdown & Stephens, 2013; McEvoy et al., 2005; WHO, 2011). Driver distraction factors can be subdivided into those that occur outside the vehicle (external) and those that occur inside the vehicle (in-vehicle). This article focuses on in-vehicle distraction sources and more specifically on cell phone use and conversation with the passenger that have been found to potentially influence driver behavior (e.g., in terms of driver speed, lateral position, and headways) and road safety (i.e., in terms of reaction times and accident probability) (Bellinger, Budde, Machida, Richardson, & Berg, 2009; Collet et al., 2010, Maciej, Nitsch, & Vollrath, 2011; White & Caird, 2010; Yannis, Laiou, Papantoniou, & Christoforou, 2014).

More specifically, several studies attempt to compare the effect of cell phone use through driving simulator experiments (Laberge et al. 2004; Yannis, Papadimitriou, Karekla, & Kontodima, 2010). In Laberge et al. (2004) eighty participants were randomly assigned to one of three conditions: driving alone, driving with a passenger, and driving with a cellular phone, and results indicate that lane and speed maintenance were influenced by increased driving demands. Furthermore, response times to a pedestrian incursion increased when the driver was driving and talking compared with those detected when the driver was not talking at all. Rumschlag et al. (2015) examined the influence of driver age and other factors on the disruptive effects of texting on simulated driving behavior and found that cell phone texting during simulated driving increased the frequency and severity of lane excursions whereas the frequency and severity of lane excursions were correlated with the duration of the texting task but not with driver age for those self-identified as nonskilled texters. Li, Xuedong, and Wong (2015)) evaluated the effects of fog, drivers' gender and experience on curve driving. Results indicated that driving risk in curve increased as the increase of fog density whereas nonprofessional female drivers were the most vulnerable group in *S*-curve driving. Furthermore, in a driving simulator experiment Yan, Wong, Li, Sze, and Yan (2015) analyzed reaction time, driving lane undulation, and driving speed fluctuation while texting and found that driving performance was impaired significantly by reading and typing text messages. Based on Drews, Pasupathi, and Strayer (2008)) drivers while talking on the cell phone miss visual cues critical to safety and navigation. They tend to miss exits, go through red lights and stop signs, and miss important navigational signage. Several studies have also examined the interaction between the performance of an in-vehicle nondriving task and the complexity of the driving environment (Cooper, Vladisavljevic, Medeiros-Ward, Martin, & Strayer, 2009, Stavrinos et al., 2013).

Moreover, the workload of information processing can bring risks when unexpected driving hazards arise based on the study conducted by Horrey and Wickens (2006). Consequently, a driver's response to sudden events, such as another driver's behavior, work zones, animals or objects in the roadway, often is the critical factor between an accident and a near accident. When the brain is experiencing an increased workload, information processing slows, and a driver is much less likely to respond to unexpected events in time to avoid the accident (National Safety Council, 2010). At the same time, the increasing workload may enhance one's attention, which leads to better driving ability (Pavlou, 2016) indicating that the overall effect of increased workload is controversial.

Focusing on the methodological framework of the research, a key remark, concerns the measures used to express driving performance in driver distraction studies and in general. The parameters for assessing driving performance vary significantly, and the driving-related outcomes have been analyzed in several studies as presented below: speed (Beede & Kas, 2006; Collet, Guillot, & Petit, 2010; Yannis et al., 2010), accident probability (Papantoniou et al., 2015; Caird, Johnston, Willness, & Asbridge, 2014), lane position (Engström, Johansson, & Östlund, 2005; Horrey & Wickens, 2006; Liang & Lee, 2010), number of eye glances (Liang, Reyes, & Lee, 2007), headway (Ranney, Harbluk, & Noy, 2005; Strayer, Drews, & Johnston, 2003), reaction time (Hancock, Lesch, & Simmons, 2003; Horrey & Wickens, 2006; Ishigami & Klein, 2009). Certainly, a more holistic approach would be beneficial, whereby many independent variables used in concert will describe the overall performance capturing the effect of many variables together with their interrelationships.

However, a significant gap can be identified in scientific studies that examine driving performance at unexpected incidents and concerns the fact that the vast majority of studies examine individual driving performance parameters but cannot attribute them to an overall driving performance. This gap can be fulfilled by implementing latent model analysis and more specifically by SEMs that have been very rarely implemented on data extracted from a driving simulator.

SEMs have been previously applied to many areas of transportation including transit system quality of service analysis (Karlaftis, Golias, & Papadimitriou, 2001), travel behavior modelling (Golob, 2003), mode choice modelling (Johansson, Heldt, & Johansson, 2006), driver behavior modeling (Hassan & Abdel-Aty, 2011), and public acceptability analysis of new technologies for traffic management (Chung, Song, & Park, 2012). SEM models may be viewed as a generalized case of multivariate classical statistical models and suffer from similar constraints as classical statistical models (Karlaftis et al., 2001).

Considering that in a driving simulator experiment the effect of a particular human factor of road accident causation such as cell phone use can be investigated especially in line with unexpected incidents, what is missing from the literature is the application a methodology (SEMs) on driving simulator data that will estimate a new variable representing overall driving performance and then the estimation of this new variable along with other factors on accident probability at unexpected incidents. These are the gaps in the literature that the present research is dealing with and will be analysed in the following chapters.

2. Method

2.1. Experiment design

Within the present research, a driving simulator experiment took place including an urban driving environment with six trials and a rural driving environment another with six trials. These trials aimed to assess driving performance under typical conditions, with or without external distraction sources. 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 FPF is located.

The driving simulator consisted of 3 LCD wide screens 40" (full HD), total angle view 170 degrees, driving position, and support base. The dimensions at a full development were 230 × 180 cm with a base width of 78 cm. It featured adjustable driver seat, steering wheel 27-cm diameter, pedals (throttle, brake, clutch), dashboard, and two external and one central mirror that appeared on the side and on the main screen and displayed in real time objects and events that were happening behind the "vehicle." The controls available to the driver were five gears plus reverse gear, flash, wipers, lights, horn, brake, and starter.

2.2. Instructions

The first step of the procedure was to inform the participant orally and in writing about the full procedure of the experiment (completion of the questionnaire, total duration, driving preparation, etc.). The need to maintain their usual driving behavior without being affected from any other factors (stress, fear, etc.) was emphasized to the participants.

2.3. Experiment

The experiment started with a practice drive. The driving simulator provided a "Free Driving" scenario that familiarizes the participants with the demands of an everyday drive. The greater part of the drive was designed in an interurban environment, but there was also a short crossing through a small city with traffic lights and junctions. During the practice, the participant practiced on handling the simulator (starting, gears, wheel handling, etc.), keeping the lateral position of the vehicle, maintaining constant speed appropriate for the road environment, as well as braking and stopping the vehicle. When all the above-mentioned criteria were satisfied (based on the coordinator researcher who was assisting and evaluating the participants during their familiarization drive), the participant moved on to the next phase of the experiment. It should be highlighted that there was no exact time restriction within this procedure.

After the practice drive, each participant drove six individual trials on the urban driving scenario and another six individual trials on the rural driving scenario as described below:

- Rural environment 2.1-km long, with mixed traffic, lane width 3 m, zero gradient and mild horizontal curves.
- Urban environment 1.7-km long, with mixed traffic, separated by guardrails, and lane width 3.5 m. Moreover, narrow sidewalks, commercial uses, and parking are available on the roadside.

Within each road environment, two traffic scenarios and three distraction conditions were examined in a full factorial within-subject design. The distraction conditions examined were driving while conversing with a passenger, driving while conversing on a cell phone, and undistracted driving. The design of the 12 driving trials is presented in Table 1.

The traffic scenarios refer to:

- Q_L: Low traffic conditions – with ambient vehicles' arrivals drawn from a Gamma distribution with a mean of 12 sec, and variance of 6 sec^2, corresponding to an average traffic volume of 300 vehicles/hour.
- Q_H: High traffic conditions – with ambient vehicles' arrivals drawn from a Gamma distribution with a mean of 6 sec, and variance $\sigma^2 = 3$ sec^2, corresponding to an average traffic volume of 600 vehicles/hour.

Furthermore, to remove bias and other sources of extraneous variation that are not controllable, randomization in the driving trials was implemented. Randomization was used to determine which road environment (urban/rural) the participant was going to drive, as well as in the order of the traffic scenarios and distraction scenarios presented to the driver. As a result, one half of the

Table 1. Within-subject full factorial design parameters.

	Urban Area		Rural Area	
Distraction Sources	Q_L	Q_H	Q_L	Q_H
No distraction condition	•	•	•	•
Conversation with passenger	•	•	•	•
Conversation through cell phone	•.	•.	•.	•.

Note. Q_L = Low traffic; Q_H = High traffic; Q_L = Low traffic; Q_H = High traffic.

participants drove first in the rural and then in the urban area whereas the rest drove first in the urban and then in the rural area.

Finally, regarding the trials that included distraction, the following conversation topics have been used: family, origin, accommodation, travelling, geography, interests, hobbies, everyday life, news, business. One researcher was responsible for performing all the distraction tasks during the experiment by sitting as a passenger near the simulator or calling the participant on the mobile phone.

2.4. Unexpected incidents

As the target of the present research is to estimate accident probability at unexpected incidents, a key component of the overall driving simulator experiment was the design of the unexpected incidents. During each trial of the experiment, two unexpected incidents were scheduled to occur at fixed points along the drive (but not at the exact same point in all trials, to minimize learning effects). More specifically, incidents in rural area concerned the sudden appearance of an animal (deer or donkey) on the road (Figure 1) and incidents in urban area concerned the sudden appearance of an adult pedestrian or of a child chasing a ball on the road (Figure 2).

2.5. Questionnaire

After the driving simulator experiment, participant were requested to fill in a questionnaire that included questions on their driving habits and behavior. The questions were chosen carefully based on the existing literature on drivers' self-reported behavior reports (Vardaki & Karlaftis, 2011).

2.6. Sample

Within the framework of the present study 111 participants started the driving simulator experiment. Almost 18% (16 participants) were eliminated from the study because they had simulator sickness issues from the very beginning of the driving simulator experiment. As a result, 95 participants comprised the sample of

Figure 1. Unexpected incident – donkey crossing the lane.

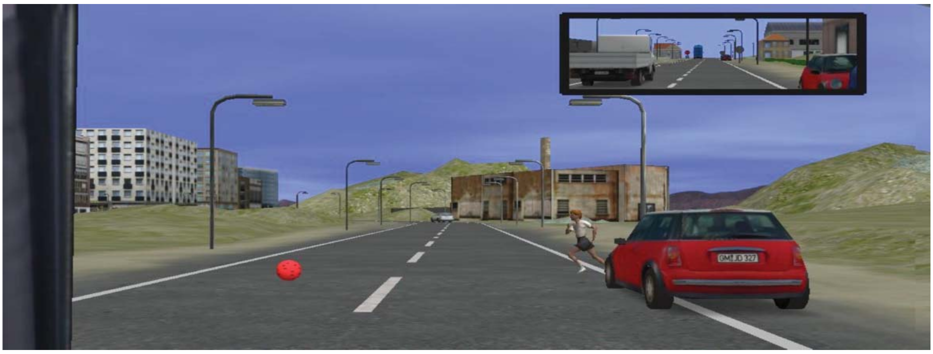

Figure 2. Unexpected incident – child with ball crossing the road.

the driving simulator experiment. In Table 2 the gender and age distribution of participants is presented. It is shown that almost one half of the participants are males and one half females indicating that the there is a total balance in the sample regarding gender. Furthermore, to investigate age characteristics, three age groups were created. Out of the 95 participants, 28 were young drivers age 18 to 34 years, 31 were middle aged drivers age 35 to 54 years, and 36 older driver age 55 to 75 years.

2.7. Analysis methods

SEMs belong to latent model analysis. This type of analysis is used to deal with several difficult modeling challenges, including cases in which some variables of interest are unobservable or latent and are measured using one or more exogenous variables (Washington, Karlaftis, & Mannering, 2011). SEMs have two components, a measurement model and a structural model.

The measurement model is used to determine how well various measured exogenous variables measure latent variables. A classical factor analysis is a measurement model that determines how well various variables load on several factors or latent variables. The structural model represents how the model variables are related to one another. SEM allow for direct, indirect, and associative relationships to be explicitly modeled, unlike ordinary regression techniques with implicit model associations. The structural component of SEM enables substantive conclusions to be made about the relationship between latent variables and the mechanisms underlying a process or a phenomenon (Washington et al., 2011).

Table 2. Distribution of participants per age group and gender.

Age group	Total	Mean	*SD*	Female %		Male %	
18–34	28	28	3.6	9	18.7	19	40.4
35–55	31	47	4.8	19	39.6	12	25.5
55+	36	64	6.5	20	41.7	16	34.1
Total	95	50	16	48	100.0	47	100.0

Furthermore, a very useful tool for the interpretation of the results is path analysis, a method for studying the direct and indirect effects of variables. The quintessential feature of path analysis is a diagram showing how a set of explanatory variables can influence a dependent variable under consideration. The way the paths are drawn determines whether the explanatory variables are correlated causes, mediated causes, or independent causes. Finally, though model goodness-of-fit measures are an important part of any statistical model assessment, goodness-of-fit measures in SEM are an unsettled topic, primarily as a result of lack of consensus on which goodness-of-fit measures serve as "best" measures of model fit to empirical data (Arbuckle & Wothke, 1995). Several research studies are implemented discussing these debates and a multitude of SEM goodness-of-fit indexes exist including: standardized root average square residual (SRMR), root average square error of approximation (RMSEA), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), root mean square error of approximation (RMSEA) (Hatcher, 1994; Lee, Chung, & Son, 2008; Lee, Jin, & Ji, 2009; Ma, Yan, Huang, & Abdel-Aty, 2010; MacCallum, 1990; Mulaik et al., 1989; Steiger 1990).

Finally, considering the large data set from the driving simulator experiment, information regarding the data processing aim to conclude to the final database which was used for the statistical analyses. 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 that means that each second measured value for each variable up to 30 times. It should be also mentioned that all the statistical analyses were implemented using the R Development Core Team, 2005, a language and environment for statistical computing and graphics.

3. Results

Before proceeding to the main statistical analysis, a correlation table is developed to investigate any of a broad class of statistical relationships between driving simulator parameters. For this purpose, a Pearson's correlation coefficient table is created and presented in Table 3 regarding all continuous variables extracted from the driving simulator.

Pearson's correlation coefficient (r) is a measure of the strength of the association between the two variables. Positive correlation indicates that both variables increase or decrease together, whereas negative correlation indicates that as one variable increases, so the other decreases, and vice versa. It should be also noted that under each correlation value, the respective p value is presented in parentheses.

Results indicate that that the highest correlation is between average speed and average gear (0.715) as expected. Furthermore, average speed is highly correlated with the lateral position of the vehicle. On the other hand, the reaction time of

Table 3. Correlation table.

	Speed	Lateral position	Direction	Average brake	Average gear	Motor revolution	Space headway	Time headway	Time to line	Reaction time
Speed	1.000 (0.00)[a]									
Lateral position	−0.689 (0.00)[a]	1.000 (0.00)[a]								
Direction	0.290 (0.00)[a]	−0.093 (0.00)[a]	1.000 (0.00)							
Average brake	−0.140 (0.00)[a]	0.429 (0.00)[a]	0.234 (0.00)	1.000 (0.00)						
Average gear	0.715 (0.00)[a]	−0.574 (0.00)[a]	0.092 (0.02)	−0.279 (0.00)[a]	1.000 (0.00)[a]					
Motor revolution	0.561 (0.00)[a]	−0.385 (0.00)[a]	0.268 (0.00)	−0.010 (0. 62)[a]	−0.079 (0.04)[a]	1.000 (0.00)[a]				
Space headway	0.272 (0.00)[a]	−0.569 (0.00)[a]	−0.106 (0.00)	−0.497 (0.00)[a]	0.277 (0. 00)[a]	0.168 (0.00[a]	1.000 (0.00)[a]			
Time headway	−0.258 (0.00)[a]	−0.002 (0. 99)[a]	−0.161 (0.00)	−0.176 (0.00)[a]	−0.175 (0.00)[a]	−0.107 (0.00)[a]	0.499 (0.00)[a]	1.000 (0.00)[a]		
Time to line crossing	−0.617 (0.00)[a]	0.647 (0.00)[a]	−0.068 (0.07)	0.432 (0.00)[a]	−0.498 (0.00)[a]	−0.380 (0.00)[a]	−0.487 (0.00)[a]	0.029 (0.32)[a]	1.000 (0.00)[av]	
Reaction time	−0.034 (0.34)	−0.145 (0.00)[a]	−0.077 (0.03)	0.220 (0.00)[a]	−0.041 (0.00)[a]	0.098 (0.00)[a]	0.281 (0.00)[a]	0.203 (0.00)[a]	−0.194 (0.00)[a]	1.000 (0.00)[a]

[a] *p*-values.

Table 4. Estimation results of the structural equation model.

	Est.	*SE*	*t* Value.	*p*(>|z|)
Latent Variable				
Driving performance				
Average speed	1.000	—	—	—
SD Lateral position	−0.085	0.004	−23.803	0.000
Average gear	0.048	0.002	21.836	0.000
Average Time to line crossing	−0.109	0.005	−20.046	0.000
Regression 1				
Accident				
Driving performance	−0.007	0.002	−3.119	0.002
Gender – Female	0.074	0.034	2.198	0.028
Traffic – Low	0.104	0.033	3.142	0.002
Distraction – Cell phone	0.081	0.033	2.463	0.014
Regression 2				
Driving performance				
Gender – Female	−1.147	0.307	−3.737	0.000
Environment – Urban	−15.614	0.468	−33.386	0.000
Distraction – Cell phone	−1.099	0.343	−3.208	0.001
Traffic – Low	1.131	0.286	3.956	0.000
Age	−0.156	0.028	−5.593	0.000
Experience	0.083	0.032	2.557	0.011
Summary statistics				
Minimum function test	352.62			
Degrees of freedom	31			
Goodness of fit				
Standardized Root Mean Square Residual	0.061			

drivers at unexpected incidents has low correlation coefficients with the variables indicating that there is not a strength correlation between these pairs of variables.

Proceeding to the core of the statistical analysis the objectives of the research should be recalled. The first is to define driving performance as a new, unobserved variable, based on specific driving simulator parameters and the second is to investigate which risk factors including driver characteristics, road environment, as well as distraction sources affect accident probability at unexpected incidents that is estimated as the probability for the driver to have an accident at an unexpected event.

Both objectives are dealt by latent model analysis and more specifically by the implementation of a SEM as presented in the Table 4 and analyzed below.

Results in Table 4 present all the statistically significant factors that are critical for accident probability at an unexpected incident. The obtained value of SRMR (.061) for this model is statistically accepted (< 0.08) indicating that the overall SEM is suitable. Furthermore, several other goodness-of-fit parameters that are examined are close to their respective limits (RMSEA = .136, CFI = .867, TLI = .807). In addition, the respective path diagram is presented in Figure 3.

Green lines express a positive correlation whereas red lines express a negative one. Furthermore, dashed lines indicate which variables create the latent one (driving performance) whereas continuous lines indicate which variables exist in the regression part of the SEM. Finally, the label values represent the standardized parameter estimates.

The measurement part of the model indicates that driving performance (the latent variable) is positively correlated with average speed and average gear and

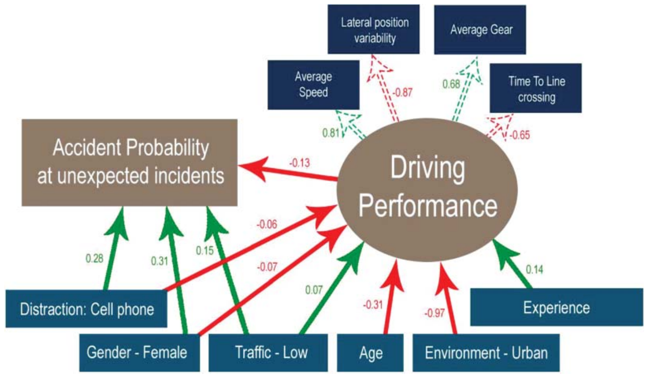

Figure 3. Path diagram of the Structural Equation Model.

negatively correlated with time to line crossing and lateral position variability. In order to interpretate the results the defininions of the variables are presented:

- *Average speed* refers to the mean speed in km/h of the driver along the route, excluding the small sections in which incidents occurred and excluding junction areas
- *SD Lateral position* refers to the variability (standard deviation) of the lateral position of the vehicle
- *Average gear* refers to the average chosen gear (0 = idle, 6 = reverse) of the simulator gear-box along the driving route
- *Time to line crossing* refers to the time until the road border line is exceeded in seconds

Based on the above, a first methodological finding is that from the 10 examined driving simulator parameters, only four participate in the development of the new unobserved driving performance variable including a longitudinal (speed) measure, a lateral (*SD* of the lateral position) measure, average gear and the time until the road border line is exceeded. The above-mentioned categories should be a guide on similar latent model analyses on driving behavior.

In the structural part of the model, two regression analyses are developed. In the first, driving performance is the dependent variable whereas the independent variables consist of age, experience, gender, road environment, traffic conditions, and cell phone use. Furthermore, another regression is dealing with the main objective of the article, correlating accident probability at anexpected incidents with driving performance, cell phone use, gender, and traffic conditions.

4. Discussion

The first methodological contribution of the present research concerns the successful development and application of latent model analysis through SEMs. Considering that driving performance is a multidimensional phaenomenon, the results of this analysis allow an important scientific step forward from piecemeal analyses to a sound combined analysis of the interrelationship between several risk factors (including driver distraction) driving performance and accident probability. Within the framework of the present research driving performance is not estimated in terms of individual driving parameters but as an unobserved variable that captures a statistical significant part of overall performance. Based on this, the quantification of the effect of several risk factors on overall driving performance and on accident probability at unexpected incidents is achieved and analyzed below.

Focusing on driving performance, conversation with the passenger was not found to have a statistically significant effect indicating that drivers do not change their driving performance while conversing with a passenger compared to undistracted driving. Considering that in the literature conversation with the passenger is supported either to affect (Drews et al., 2008; Laberge, Scialfa, White, & Caird, 2004; Maciej et al., 2011) or not to affect (Charlton., 2009; Yannis et al., 2010) specific driving measures, this finding highlights the importance of defining and investigating overall driving performance and not individual parameters. On the other hand, the effect of cell phone on driving performance is negative that is in line with the literature that cell phone use affects significantly individual driving-performance parameters (Rakauskas, Gugerty, & Ward, 2004, Strayer et al., 2003, Yannis et al., 2014).

Regarding driver characteristics several parameters such as age, gender, and experience have a significant impact on the final statistical model indicating that driver characteristics play a crucial role in overall driving performance (Papantoniou, 2017). Furthermore, road environment is another key factor affecting driving performance based on the estimation results of the SEM. The effect of road environment in driving performance is explained by the fact that the more complex road environment in urban areas has a negative effect on the overall performance whereas in rural areas drivers achieve more stable driving behaviors (Pavlou, 2016). In addition, traffic conditions also influence driving performance as the variable *low traffic* has a positive sign in the model. This is probably explained by the fact that in high traffic, the complicated road environment including a lot of interactions between vehicles has a totally negative effect on driving performance. It should be noted that results regarding road environment are in line with the literature that complicated road environment has a negative effect on several driving performance parameters (Cooper et al., 2009; Papantoniou, Papadimitriou, & Yannis, 2015; Stavrinos et al., 2013).

Focusing on the core of the present research, model results indicate the statistically significant factors that negatively affect accident probability at unexpected events. A first interesting finding refers to the fact that the critical factors consist of different categories, that is, a distraction source (cell phone use), a driver characteristic (gender) and a road enironment characteristic (traffic conditions). With respect to distraction findings confirm the literature (Fowles, Loeb, & Clarke, 2013; Yannis et al. 2014; O'Connor, Shain, Whitehill, & Ebe, 2017) and authors' hypothesis, that cell phone use has a significant negative effect on accident probability demonstrating that drivers while talking on the cell phone find it difficult to handle an unexpected incident due to the fact that one hand is handling the cell phone and as a result are more likely to get involved in an accident.

Focusing on driver characterics, the effect of gender on accident probability at unexpected events was not clear through the literature considering that based on several studies male drivers are involved in more accidents, receive more traffic fines, and self-report more traffic violations, whereas female drivers tend to commit more errors (González-Iglesias, Gómez-Fraguela, & Luengo-Martín, 2012, Oppenheim, Oron-Gilad, Parmet, & Shinar, 2016, Özkan, Lajunen, & Summala, 2006, Wickens, Toplak, & Wiesenthal, 2008). Results of the present study indicate that female drivers hough generally drive less aggressive and slower than male ones are more likely to get involved in accidents ut unexpected events due to the fact that they cannot handle an unexpected situation the way male drivers do.

The third critical parameters that was found to affect accident probability refers to road environment and suggests that low-traffic conditions lead to increased accident probability at unexpected events. This finding confirms the literature (Pavlou, 2016; Stavrinos et al., 2013) and indicates that in low-traffic conditions drivers achieve higher speed compared to conditions with higher traffic and in addition can be more easily less concentrated due to the usually longer duration of their trips. These two main reasons lead to the higher accident probability at unexpected incidents occuring in low-traffic conditions.

5. Conclusions

Overall, the proposed methodological approach and statistical techniques of the present research are proved to significantly improve the potential of the analysis and provide new insights on driver behavior and safety. The added value of the methodology, through the consideration of latent variables and the implementation of SEMs, is found to be useful and promising, allowing a new apporach on the investigation of driving behavior in driving simulator experiments and in general.

By the succesful implementation of SEMs, driving behavior is assessed in terms of the overall performance and not through individual performance measures. A direct contribution of this methodology relies on the development of a driving profile that achieves the lowest driving performance that can be a very useful positive reference on road safety stakeholders, especially those that deal with cell phone use. In addition another risky driving profile is extracted indicating that more likely to be involved in an accident at an unexpected incident are female drivers in low traffic conditions while talking on the cell phone. These findings can potentially contribute to a significant reduction of road accidents and fatalities, if they will be exploited by the authorities to implement appropriate road safety policy directions with focus on vulnerable road user as well as on the effect on cell phone while driving.

In the next steps of the present research, the present methodological approach could be further developed and applied in more general driving behavior scientific fields. Within this framework, the effect of several other parameters such as fatigue or alcohol can be estimated on the unobserved variables that underline driving performance or accident risk. In addition, several other latent variables can be created and examined (i.e., accident risk) depending on the experimental data and the specific research questions.

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