Impact of Immersion and Realism in Driving Simulator Studies

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ABSTRACT

Driving simulators emerged as a promising technology for the analysis of driving conditions and road users' behaviour in an attempt to tackle the problem of road accidents. The work presented herein demonstrates the design and development of a driving simulator that aims to contribute towards evaluating black spots in road networks by promoting rapid design of realistic models and facilitating the specification of test scenarios. A reliable driving simulator should be able to reproduce the driver's behaviour in a realistic way. In this study we examine different setups of the simulator to define the one that achieves highest levels of reliability. The chosen setup is then used to evaluate the impact of distractors (e.g. billboards) on driving behaviour of local road users for a chosen black spot in Limassol, Cyprus. Data collected from the experiments are analysed, and the main findings are presented and discussed.

*Key Words***:** *Driving Simulator, Virtual Reality, Computer Graphics, Realism, Immersion, Driver's Behaviour, Driver's Distraction.*

INTRODUCTION

3D Simulators have been widely used in various disciplines including transportation. They are used for various reasons, such as visualizations, training, testing conditions, etc. One of the main purposes of simulators, in transportation discipline, is for training and education. Such simulators (e.g. flight simulators) are used to train participants under difficult circumstances with no risk for participants or others' safety. Moreover simulators in transportation can be exploited for road safety, for example to examine different parameters that may affect drivers' performance.

Finding ways to reduce road accidents is a must. Facts show that they have become a daily hazard in Europe and worldwide (Konstantopoulos et al., 2010). According to Eksler et al. (2008), around 1.2 million fatalities and more than 50 million injuries occur in roads worldwide every year. Given the current trends, the accident fatalities are projected to become the second most common cause of death in 2020 if no drastic measures are taken. To that end, EU set the goal to reduce road fatalities and injuries by 50% by 2020. In addition to fatalities, traffic accidents result in high economic losses due to traffic congestion which in turn leads to a wide variety of adverse consequences such as traffic delays, supply chain interruptions, travel time unreliability, increased noise pollution, as well as deterioration of air quality.

The use of a driving simulator in studies aiming to reduce accident occurrences is inevitable, firstly due to ethical reasons and secondly, since controlling infrastructural parameters in the real world requires huge investment of time and money (Davenne et al., 2012) which is usually prohibitive. Driving simulators provide the researcher with a powerful tool to test driving behaviour under controlled settings.

The contribution of this work is three fold:

(a) Design and development of a 3D driving simulator: the method proposed herein demonstrates the design of a driving simulator that exploits 3D modelling tools in a module-based approach to promote realism and interactive 3D representation of road networks. The approach simplifies the process of implementing 3D road infrastructure models through the utilization of reusable modules. This simplifies the process of designing/modifying the simulation model by reusing model constructs in a plug and play fashion. This enables the analyst to easily design a range of experimental conditions to evaluate assumptions and hypotheses from different perspectives.

(b) Testing different setups of the simulator, related to computer graphics and virtual reality aspects, affecting its reliability: a key factor in an efficient simulator is to simulate in a realistic way, not only the 3D virtual environment (static or dynamic) that surrounds the participant, but be able to reproduce the participant's reactions in the same way as if the participant faces the same scenario in real life. In computer games and virtual environments it is generally accepted that integration of advanced illumination algorithms for the 3D geometry of the environment helps towards the increase of realism of the scene. Moreover, using virtual reality devices, such as Head Mounted Displays (HMD), increases the immersion of the user. An HMD device is mounted on the user's head and allows stereo display through the two screens, in front of user's eyes (Figure 1). HMDs allow high degree of immersion, since the user only sees the virtual environment without intrusions from the real world. Moreover, it has an integrated head tracker enabling the automatic update of the scene's virtual camera based on the orientation of user's head. Display device and illumination were the conditions tested in this study in regard of the validity of the simulator.

(c) Testing environment's infrastructure parameters affecting driver's performance: in particular, this investigation focuses on the impact of different types of driver distractions, such as advertisements, on the primary task of driving. The advertisements billboards are placed along a critical point of a road network in Limassol, Cyprus. Two types of traffic control (i.e. with and without traffic lights) are also examined under dangerous traffic conditions.

Figure 1. A Head Mounted Display (HMD) allowing head tracking and stereoscopic viewing of the 3D virtual environment

The paper is organized as follows: related work is firstly reviewed, followed by the presentation of the driving simulator design. Description of the experimental designs for both parts of the study follows and the paper concludes with the analysis of the results and a discussion of their implications.

RELATED WORK

3D driving simulators have been used in training and evaluation of driver's performance. Training simulators (Roanker et. al., 2003) are usually for training drivers under difficult conditions or for training impaired users (Akerstedt et al., 2005) while evaluation has to do with testing drivers' performances and responses in different conditions (Banks et. al 2004; Greenberg et al, 2003; Kemeny et al., 2003).

One of the key factors for the success of a simulator is its validity (Godley, 2002). Physical validity (Trigs, 1996) refers to the physical reaction of a stimulus while behavioural validity (or predictive validity) refers to the correspondence in driver's behaviour in simulated driving and real driving (Blaauw, 1982).

Simulators are often integrated in Virtual Reality (Bayyari et al., 1996; Schultheis & Mourant, 2001) setups and use realistic graphics (Dutre et al., 2003; Michael & Chrysanthou, 2010) aiming to increase the feeling of presence in the virtual environment (Slater et al., 2010; Yu et al., 2012) and thus increasing the validity of the simulator.

Driving simulators aim to reduce road accidents. Exploring the reasons causing road accidents is a necessity thus simulations take into account relevant parameters. Based on the literature, road accidents are caused by many factors, and the problem is approached from different perspectives. Eksler et al. (2008) argue that accidents are influenced by demographic, infrastructural and political factors. At the other end of the spectrum human factor experts associate accidents with human error. Human error is defined as the human activity or absence of activity that leads to incorrect system behaviour (Hollnagel et al., 2007). It may occur due to human beings' physical, perceptual and cognitive limitations (Montella et al., 2010) and is directly related to visual attention (Konstantopoulos et al., 2010).

Distraction in driving is a frequently reported cause of road accidents. According to Dingus et al. (2006), distractions contribute to 78% of accidents and to 65% near-crashes. Distractions can emerge from outside or inside the car. Exogenous parameters relate to the environment, the vehicle, the road infrastructure and the traffic conditions, whilst endogenous parameters include, but are not limited to, passenger distractions, noise, mobile phones, and using in-vehicle information systems (Young et al., 2003). While, much research has investigated in-car distractions (Jamson et al., 2004), relatively little work has been reported for exogenous distractions emerging from outside the car (Young et al., 2003).

According to Miller (1996), people can process 7 (plus or minus 2) discrete information chunks at a given point in time. This approximates the boundary of our cognitive capacity in terms of memory. Therefore, increased demand for cognitive resources may result in drivers failing to attend critical information on the road.

Roadside advertising billboards are one of the many distractions, which could pose a crucial risk for road safety. The evidence that accident risk increases with roadside advertising is increasing, with estimates making advertisements responsible for up to 10% of all road traffic accidents. According to Young et al. (2009) roadside advertising affects lateral control which is one manifestation of driver's overloading.

This consequently yields support to the claim that drivers' visual attention is distracted by advertisements (Horberry et al., 2004). This increases significantly the risk of accident in the case that the driver's visual workload is already compromised. As a result, the driver may fail to sufficiently respond to the needs of the primary task (i.e. driving) and hence make errors that could lead to a hazard. This work aims to shed more light into this debate through the empirical analysis of the effect of distractions on drivers' performance and the consequences on accident risk, using native road users. The use of Cypriot drivers tailors the analysis on native driving behaviours and helps to investigate how these could vary in different contexts of domestic relevance.

3D DRIVING SIMULATOR DEVELOPMENT

The first part of this work involved the design and development of a modular driving simulator that would enable the analysis of traffic conditions and driving behaviour of native users. Given these needs it was imperative that the method for designing the simulator and its inherent models should have been generic, utilizing libraries of components, representing assets that make up the driving conditions and infrastructure in Cyprus. The design and development of the simulator in its prototype version with preliminary results can be found at (Christodoulou, 2012; Christodoulou et al., 2013). For purposes of completeness of this manuscript, a description of the full version of the simulator is provided here.

The main steps followed for the development of the simulator are listed below:
(a) City reconstruction
(b) Details modelling and texturing
(c) Adding interactivity

The first challenge was the city reconstruction. To achieve this we extracted a section of the Limassol road network from OpenStreetMap (http://www.openstreetmap.org) by cropping the area. Subsequently, the extracted GIS data were imported into the CityEngine (http://www.esri.com/software/cityengine), a 3D procedural modelling software, specializing in the generation of 3D urban environments. The CityEngine was used to convert 2D GIS data to the 3D reconstructed city (Figure 2) using CGA shape grammar.

In the reconstructed city 3D model, details were added. Using a 3D modelling tool, static and animated assets such as cars, traffic lights, billboards (static and animated), vegetation, etc. were created. In creation of the assets, the local characteristics have been taken into account, such as the right hand driving system existing in Cyprus, Mediterranean vegetation and so on. For all the 3D models used in the simulator, attention was paid to keep the geometric complexity relatively low, thus allowing us to have the simulator running in real-time frame rates.

Figure 2: Based on the GIS data of the black-spot (left) the city has been reconstructed (right) using procedural modelling

Besides the creation of the assets, the 3D modelling tool was used to specify the routing of traffic. The vehicle paths specified were based on a preliminary analysis of traffic routing on the selected black-spot. The distribution of accidents based on time, at the black spot was used to pinpoint the most critical time. This was necessary in order to replicate the conditions when the majority of the accidents occur. In the same manner, some additional hazardous vehicles manoeuvres were also modelled to mimic critical safety scenarios. These were used to stress test drivers' behaviour under overloading.

Figure 3: The interface of the developed driving simulator with mono viewing for a standard monitor display (left) and stereo viewing for an HMD (right)

The final step of the simulator design was the development of the functionality that would enable the interactivity between the user and the simulator and that was realised using the game engine Unity3D (http://unity3d.com/). The interaction can be performed using a joystick while the simulation can be displayed using mono viewing on a standard monitor display or stereo viewing for VR devices (Figure 3).

EXPERIMENTAL DESIGN

In this section we describe the experimental design of this study. There were two main research aims:

(a) To determine a setup whereby (i) the driving simulator is able to simulate realistically the operation by users, and (ii) participants are driving within the simulator in a similar way as they would do in the real life

(b) To examine how different parameters within the environment (e.g. billboards on the road sides), affect driver's concentration.

The experimental designs of the two parts are described in 'Immersion and Realism' and 'Driver's Distraction' subsections respectively.

Immersion and Realism

As far as the first part is concerned, the aim is to examine whether the user handles the virtual car in a different way under the two conditions: (i) display: standard display monitor or immersive virtual reality device (HMD); (ii) illumination: basic computations (without shadows) or advanced computations (with shadows).

For this part, a group of twenty (20) participants (10 male, 10 female) took part in the study. Firstly, the participants were familiarized with the navigation controller (a joystick used in our case) that allows the user to turn, speed up and slow down the car. Then, all participants used the simulator four times, for the same scenario but with four different setups. The scenario takes place in a simulation of a real area. The participant is within the virtual car, seeing the environment from a driver's first person perspective. He is asked to drive as he would normally do. In his route he encounters four challenges: a car stopped on one side of the street, a car that is going relatively slowly, red traffic lights and after traffic lights another car stopped on one side of the street. This scenario is a reproduction of a case that is commonly observed in the real street that corresponds to the street simulated in the study. The street is along the sea and many drivers are driving lazily while enjoying the see view. Taking into account that almost all drivers in the real life are able to encounter successfully such challenges, based on validity theory for simulations (Blaauw, 1982), that means in a simulator, users should be able to encounter challenges in a successful way as well.

The four different setups that each participant experienced in a random sequential way were the combinations of the two conditions (i) using either an HMD or a standard monitor display, and (ii) advanced or basic illumination computations, that is, shadows either appear or not appear in the virtual scene.

The HMD that was used in this study was a Sensics zSight which weighs about 450grams. As far as the illumination is concerned, the integrated 'Soft Shadows' algorithm provided by Unity3D game engine was used, allowing dynamic shadows at real time.

A pre-test questionnaire was given to all participants to gather demographic data while the post-test questionnaire was answered by all participants after each experience of each of the four setups. Post-questionnaires included questions on user's experience on a Likert Scale (1-5). Data were also collected through observation. The display showing the simulation was recorded while participants were driving the virtual car, and the videos were analysed by the experimenters after the experiment, thus there was no intrusion at the participant during the experiment.

Findings of the first part of the study, as came out from the analysis of aforementioned collected data and are describing later in the section 'Data Analysis and Results', were used to design the second part of the study.

Driver's Distraction

The second aim of the study was to determine the effects of roadside advertising (billboards) and traffic signalling on driver attention and crash risk at an accident black-spot in Limassol, Cyprus. For this part, the simulator has been setup based on the results of the aforementioned study, that is (as will be explained in the next section), using a standard monitor display with advanced illumination.

The conditions tested during this experiment were the use of static or animated advertisement for the billboards, and absence or existence of traffic lights. Participants drove a pre-specified route in the designed road network at a major intersection that has been identified by the police as a critical safety point. The driving conditions near the billboards and the crossroad were purposefully dangerous to stress-test the effect of distraction on driver's concentration. Specifically, cars were cutting in or crossing the traffic light at high speed.

Prior to the experiment, participants were familiarized with the simulator and briefed on the task they had to perform. The road network used for the simulator training was different from the model used during the experiment. Each participant had to complete a set of four scenarios to cover the different combinations of the experimental conditions. Data were collected in a similar manner as the first part of the study, using pre- and post- questionnaires, as well as video recordings.

The experimental designs for both parts of the study are demonstrated at the accompanying video which can be found at: http://www.youtube.com/getlabchannel.

DATA ANALYSIS AND RESULTS

The data from both parts of the study were entered into separate spreadsheets, which included the necessary information for participants' characteristics (e.g. gender, age, driving experience) as well as their behavioural measures during the different experimental conditions.

Both descriptive/exploratory data analysis as well as inferential statistical analysis employing regression modelling, were applied to these datasets independently, with the help of the widely used statistical package SPSS (v.20) (http://www.ibm.com/software/analytics/spss/). In particular, data analysis and reporting, includes frequencies and percentages, bar charts and regression modelling. The latter, accounts for the inter-relationships between different variables, and models their effect on an outcome/dependent variable of interest. The ultimate aim of this model is usually to make predictions for either a continuous variable or the probability of an event happening with a regression equation. The equation can be formed with the help of the regression coefficients which are estimated with the analysis.

As can be deducted from the description of the experiments in both studies, both involved a repeated measure experimental design since each of the twenty (20) participants took part in four (4) tests/experimental conditions, resulting in eighty (80) correlated observations in total, for each study. Consequently, during modelling we also accounted for the repeated measures study design and the resulting correlation between the observations, and thus we employed a generalized linear modelling framework for our regression models (Hutcheson & Sofroniou, 1999).

Immersion and Realism

The first part of the study aimed to identify the best setup that made the simulator more valid in the manner of being able to reproduce realistic behaviour by the participants. The validity of the simulator was measured with the number of successfully handled challenges (slowing moving cars, red traffic lights etc.) by the participants.

In order to check for the effectiveness of the different simulator setups, as well as some relevant user characteristics (i.e. short-sight correction glasses), in respect to the number of challenges the user achieved, we employed a generalised linear regression model, with a Poisson distribution, which allows to account for the fact, that the response variable is measured in counts. In addition the regression model also took into account the dependence of measurement due to the repeated measures design. Moreover dummy variables are used since the explanatory variables are all categorical/binary (0=No, 1=Yes). Results of this model are demonstrated in Table 1.

Table 1. A linear regression model for the number of successful challenges achieved

Variables	Coefficient (b)	Std. Error	t	Sig.	95% Confidence Interval	
					Lower	Upper
Intercept/Constant	3.789	0.088	42.914	0.000	3.613	3.965
ImmersiveDevice(Yes)	-0.852	0.163	-5.228	**0.000**	-1.177	-0.527
Illumination (Yes)	0.015	0.108	0.136	0.892	-0.200	0.229
Glasses (Yes)	0.135	0.110	1.228	0.225	-0.085	0.354
Probability distribution: Poisson Link function: Identity Reference categories: Immersion=No, Illumination =No, Glasses = No						

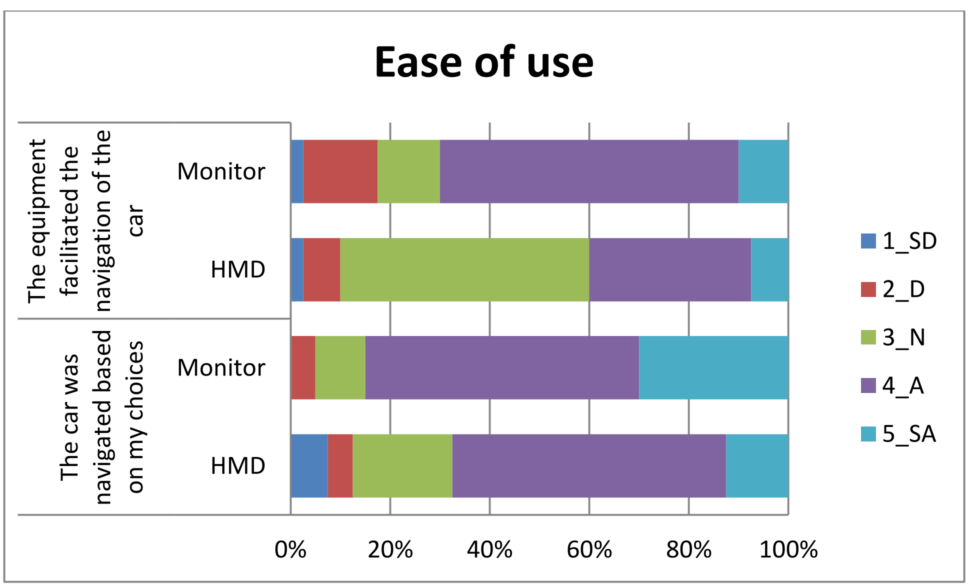
A regression equation (Equation 1) can be formed with the regression coefficients of the above model:

$$\mathrm{Num.\,Successful\ Challenges} = 3.789 - 0.852 * \mathrm{Imm.\,Dev.} + 0.015 * \mathrm{Illumination} + 0.135 * \mathrm{Glasses}$$
(Equation 1)

Based on the above model and equation, the estimated success when using an HMD immersive device (ImmersiveDevice = 1=Yes) are decreased by 0.852, compared to a standard monitor, when keeping all other variables in the model the same, and this effect is also statistically significant. The effects of illumination and short-sight are much smaller but also not statistically significant. The latter (i.e. short-sight) even though insignificant in the model, is important for the validation of our simulator, and especially the explanation why performance is decreased when using an immersive device. As part of this process we wanted to ensure that the results were not affected by the fact that some of our participants are short sighted since is not feasible to put HMD on top of the glasses. Results (Table 1) indicated that there was not a statistically significant difference between short sighted participants and participants with no vision problems. This is what we expected since the HMD provides the ability to change the focus length of the displayed image and be adapted based on the participant.

In Figure 4, questions, indicating the ease of use of the simulator, were selected and the distribution of users' answers based on a Likert Scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree) are plotted. Results show that participants had difficulties to navigate the car when wearing the HMD device. This may explain the reason of getting worse performance in regards to the challenges successfully achieved, when the HMD was used.

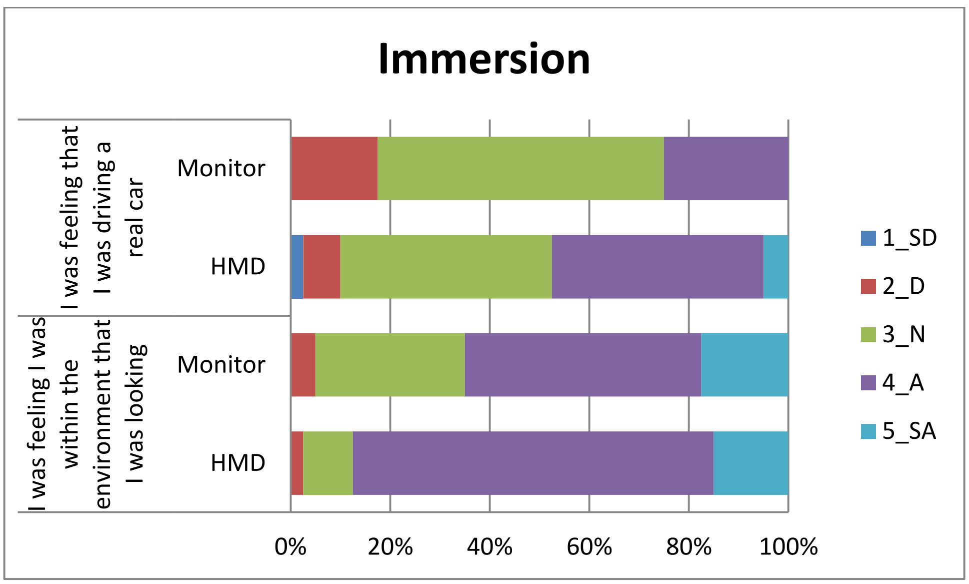
Figure 4. Plot for questions indicating the ease of use of the simulator



We then examined whether the immersion was feasible using the HMD device, based on the responses to the post-questionnaires. In Figure 5, questions indicating the immersion of the user to the environment have been selected and plotted. As can be seen, participants indeed found the HMD device more immersive.

The results of the analysis of the first part of this study, determined the setup to be used in the second part of the study. As explained above, the setup that uses a standard monitor display was a more successful setup due to difficulties that the HMD was causing. Advanced illumination did not affect in any significant way the success of the simulator; however, for consistency reasons, in all scenarios examined in the second part of the study advanced illumination was used.

Figure 5. Plot for questions indicating immersion of the user within the virtual environment



Driver's Distraction

In the second study, there were also twenty (20) participants (10 male, 10 female), with a mean age of twenty-four (24) (SD = 4.0). All participants had held a full driving license. The age range of participants in the experiment was based on the mean age of drivers that had accidents on the black-spot under study, as this was calculated from historical data provided by the police. All participants were Cypriot residents and hence familiar with the right-hand traffic regulations.

In this section we explore how: (i) the accident occurrence is associated, if so, with the driver's background characteristics and with the two experimental conditions tested, and (ii) how lane deviation, which is considered in the literature as a good predictor of accident, is affected by the experimental conditions.

First we explore some descriptive analysis demonstrating some relationships between some background variables of interest with the outcome variable as well as some potentially confounding variables. The outcome variable of interest for this analysis is the occurrence of an accident. Out of the eighty (80) observations in the above conditions, twenty-five (25) (31.25%)

accidents were recorded (Table 2). The high accident rate is attributed to the hazardous traffic conditions simulated in the scenarios and is considered for the interpretation of the results.

Table 2 presents the association of accident occurrence with the subject's gender. As can be seen, the majority of accidents (68%) observed are attributed to male drivers. This association was found to be statistically significant (chi-square=4.713, p=0.03).

Table 2. Cross-tabulation of accident occurrence by gender

	Gender Frequencies (row %)		
Accident	**Female**	**Male**	**Total**
No	32 (58.2%)	23 (41.8%)	55
Yes	8 (32%)	17 (68%)	25

Of crucial importance is the investigation of the association between the two experimental conditions (advertisement billboards, traffic lights) and the outcome variable of interest. Table 3 presents these associations. As can be seen, there are no notable differences in the distribution of accidents when we compare traffic light conditions, under the static advertisement scenario (in both cases there were six (6) accidents recorded). In contrast, there are some apparent statistically significant differences (chi-square= 5.584, p=0.018) when we consider the distribution of accidents under the animated advertisement condition (i.e. significantly more accidents occur without traffic lights).

Table 3. Two-way cross-tabulation between advertisement and traffic light conditions with the occurrence of accidents

		Traffic Lights Frequencies (row %)		
Advertisement	**Accident**	**No**	**Yes**	**Total**
Static	**No**	14 (50%)	14 (50%)	28
	Yes	6 (50%)	6 (50%)	12
Animated	**No**	10 (37%)	17 (63%)	27
	Yes	10 (76.9%)	3 (23.1%)	13
Total	**No**	24 (43.6%)	31 (56.4%)	55
	Yes	16 (64%)	9 (36%)	25

As mentioned earlier lane deviation is usually considered an indicator of loss of concentration during driving. A binary variable was thus created to account for the occurrence of lane deviation (or not) up to the point of accident occurrence (or till the end), and this was further modelled to check the effect of other variables. Regression modelling allows for the combined effects of various explanatory variables to be taken into account when modelling the outcome variable. We thus modeled the binary variable of interest (i.e. lane deviation) based on various explanatory variables including the experimental conditions and participants characteristics, as presented in Table 4. Since the explanatory variables were all categorical, dummy variables are used in the model to define the categories. The estimated coefficients are then interpreted comparatively to the reference categories (i.e. the dummies whose coefficients are set to zero; Light=Yes, Animated=Yes, Gender=Male, as denoted with the parentheses in the Table 5). This allows to check the effect of the remaining category(ies) on lane deviation.

According to the results of this model, the gender and the traffic light experimental condition have a significant effect on the probability of lane deviation, as indicated by the significance values for these variables (i.e. $p\text{-value}<0.05$). The direction of this effect is better explained with the exponential of the coefficients. For example after controlling all other variables in the model, female drivers are about seven times more likely ($\exp(1.95)=7.027$) to deviate from the lane compared to (the reference category of) male drivers. Similarly, with the no-traffic lights experimental condition the odds of lane deviation considerably decrease ($\exp(-2.034)=0.131$) compared to the traffic light condition (again assuming we control for all other variables).

Table 5. Probability of lane deviation based on the logistic regression model

Variables	**Coefficient B**	**S.E.**	**t**	**p-value (Significance)**	**Exp(B)**
Light (No)	-2.034	0.642	-3.170	**0.002**	0.131
Animated (No)	0.346	0.593	0.584	0.561	1.413
Gender (Female)	1.95	0.601	3.243	**0.02**	7.027
Constant	-0.063	0.586	-0.108	0.914	0.939
Probability distribution: Binomial Link function: Logit Reference categories: Light =Yes, Animated =Yes, Gender=Male					

CONCLUSIONS

A 3D Driving Simulator is a useful tool to examine parameters affecting driving performance, with no risks in human lives and with low costs by changing virtually environment's infrastructure for testing different scenarios.

In this work we presented the development of a 3D simulator allowing testing distractor's parameters. The developed simulator allows us to modify the environment in an interactive way, making the implementation of new designed testing scenarios an easy task. To the best of our knowledge this is the first study that was conducted in Cyprus for black spot analysis using a driving simulator and local road users. The method provides local authorities with a cost effective solution that enables the involvement of native driving users for the analysis of local driving behaviour~~s~~ and road design challenges. The method enables the design and customization of the road infrastructure for what-if analyses in a modular fashion. This enables the design of the experimental settings for the analysis of a variety of conditions such as the use of dynamic and static advertisement of billboards and traffic signals in a straightforward fashion.

The simulator has been tested among different parameters in regards of validity. Results showed that when an HMD is used, even though supposed to be the most immersive Virtual Reality device, the validity of the simulator lacks in that case, comparing to using a standard monitor display. This was mainly attributed to the discomfort of the participants' feeling while they wear the HMD. On the other hand the increase of immersion level was verified through the study, in the setup using the HMD, but it seems that immersion parameter was not able to overcome the negative impact of discomfortability. Moreover it is shown that advanced illumination does not affect the reliability of the simulator, despite the fact that illumination highly correlated with realism in a virtual scene. These findings are consistent with previous studies (Zimmons & Panter, 2003; Slater et. al, 2010)). As far as the distractive parameters are concerned, it has been shown that under traffic lights condition (that is the real representation of the simulated area), animated advertisement billboards cause higher levels of distraction compared to static billboards. Moreover, the overall results highlight a significant difference between gender groups on accident likelihood which verifies earlier findings in the literature (Department for Transport, 2011).

The study can be extended in various ways. Besides behavioral validity, physical validity of the simulator (Trigs, 1996) can be explored. A gaming steering wheel and automobile pedals can be used to allow interactivity in a more natural way. Experimental conditions examined, in regards of the validity of the simulator, can be extended to other senses besides visual input (Holohan et al., 1978) that has been explored here (display and graphics realism). Sound can be explored in regards of mono or stereo sound. Moreover, as far as the touch sense is concerned, specialized equipment simulating car vibrations can be used to increase the physical realism in the simulation. We speculate that these integrations will increase the validity of the simulator allowing us to examine further scenarios in a more accurate way. Concerning the parameters affecting accidents occurrences, besides distraction parameters other conditions may be examined. Specifically it would be very interesting to find the reasons why the specific location point is a black spot (i.e. accidents occur in a more frequent way than other areas). Towards this direction, the infrastructure of the road network should be tested under different scenarios. An exhaustive study of parameters affecting driver's performance may be able to give clues to authorities for specific actions that should be taken to reduce accidents occurrences in the specific area.

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