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DRIVER WORKLOAD ANALYSIS USING AN INTERACTIVE 3D DRIVING SIMULATOR

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ABSTRACT

Diagnosing the causes of road accidents and the development of effective countermeasures to reduce accident rates is of key importance in road safety. Human error is one of the principal influencing factors that leads to road accidents, and is attributed to increased mental workload induced by distractions. Workload, however, is characterized by intrinsic properties that are difficult to observe. Hence, phenotype behaviours, such as lane deviations, could act as good predictors of driver workload. 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, using a 3D game engine 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. The developed simulator was employed to evaluate the impact of distractors on driving behaviours of local road users for a chosen black spot in Limassol-Cyprus. Data collected from the experiments are analyzed, and the main findings in regards to the above relationships are presented and discussed.

KEYWORDS: Driving Simulator, Workload, Distractions.

INTRODUCTION

Road accidents 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.

Road accidents are caused by many factors, and the problem is approach 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 factors 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., 2004). 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) and workload (Gregoriades et al., 2010). The analysis of accidents accounting for human error can be carried out from two perspectives: the designers' and the users'. The former addresses the system designing flaws that hinder human activity due to usability problems whereas the latter analyzes internal cognitive processes of human operators to identify decision making bottlenecks caused by reduced situational awareness (Endsley, 1995) due to increased workload. Mental workload constitutes an important influencing factor of road accidents and is directly related to human performance (Gregoriades & Sutcliffe, 2007) and attention. According to Bailey (1996), workload is defined as the demand placed upon people which could be a behavioural response to events, communication and interactions among humans or between humans and technology, or humans and the environment. High levels of workload degrade the driver's concentration, information processing and decision making, leading to increased errors, which might have catastrophic effects (Williams, 1988; Endlsey, 1995; Norman, 1988).

The focus of this study is on driver workload analysis of local drivers in Cyprus using a driving simulator that was designed for this purpose and has the capability of easily being reconfigured. The analysis is based on phenotype driver behaviour data collected through experiments in controlled settings. The workload assessment method used is task-performance based. In particular, this investigation focuses on the impact of different types of driver distractions, such as advertisements, on the primary task (driving). The advertisements 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 examined under dangerous traffic conditions.

The use of a driving simulator in studies, like this, 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. Moreover, ruling out confounding effects to examine the influence of control measures on workload is very difficult in field experiments. Driving simulators provide the researcher with a powerful tool to test driving behaviour under controlled settings. Apart from the usually high cost of the simulator, outsourcing of experiments to analyze driving behavior using native users is difficult, if not impossible in some cases, due to the large number of subjects needed for reliable results. On the other hand, low cost driving simulators do not provide a sufficient level of realism to analyse human factors. Unrealistic conditions may affect the driving behaviour which effectively could influence the validity of the experimental study. The method proposed herein demonstrates the design of a driving simulator that exploits 3D modeling 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.

The paper is organized as follows: related work is firstly reviewed, followed by the presentation of the driving simulator design along with the design of the experiment. The paper concludes with the analysis of the results and a discussion of their implications.

RELATED WORK

Road accidents are usually attributed to human error (Gregoriades et al., 2010). Humans have limited information processing abilities and must rely on three fallible mental functions: perception, attention and memory (Fuller, 2002). Drivers commit errors because a situation exceeds the limitations of one or more of these three functions. At the same time, the bandwidth of their information processing capabilities declines with age. Human factors in driving are usually distinguished in those addressing driving behaviour and driving task. Task-related factors relate to information perception, analysis, decision making and action at the operational level while behaviour-related factors concern the tactical and strategic level. The driving task requires information processing and motor skills, which improve with time while, driving behaviour refers to the style of driving that is not necessarily time-dependent. Driving behaviour is manifested by phenotype behaviours such as speed, gap acceptance and lane changing while the primary driving task is supported or hindered by secondary tasks induced by visual, tactile and auditory information.

Drivers' information processing needs increase with distractions from endogenous and/or exogenous parameters. 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). 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 to critical information on the road. Humans, as information processing systems, have number of information flow channels (visual, auditory, tactile) processing various information sources (e.g. a navigation system display, the forward view through the windscreen) of varied bandwidths (e.g. high-density traffic will require a higher sampling rate than low-density traffic). Our cognitive capacity is limited, and in return there is an upper threshold to the amount of information we can process per second and channel (Gregoriades et al 2007, 2010). Therefore, we tend to share our attention among a few information sources. An overloaded driver is less likely to deal effectively with an unexpected event. Fuller (2005 & 2002) also expresses accident risk as a function of the driver's cognitive resources and task-demand in the driver-road system.

The link between overloading and driver distraction is established within the existing literature, (e.g. Dingus et al., 2006; Jamson et al, 2004; Gregoriades 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. 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). 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 adversely affects lateral control which is one manifestation of driver overloading. In the same vein, visual search reaction times increase with distractors (Holohan, 1978). Hence, distracted drivers take longer to react to stimulus. This consequently yields support to the claim that drivers' visual attention is attracted 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 attend to the needs of the primary task (i.e. driving) and hence make errors that could lead to a hazard. Driver phenotype behaviours associated with workload include, but are not limited to, the following: lane position deviation, number of lane departures, lane departure durations and speed deviation. Hence, monitoring these phenotypes can give a good estimation of driver workload.

While there is evidence that roadside advertisements potentially affect driver attention, it is difficult to conclude about the specific risks. Results from field studies and controlled experiments seem to conflict. Hence, more empirical research is required. This work aims to shed more light into this debate through the empirical analysis of the effect of distractions on drivers' workload 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.

DESIGNING THE DRIVING SIMULATOR

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 behaviours 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. Therefore, the design and development of the driving simulator utilized software packages to enhance the quality and reduce implementation time. The software applications that were used include: Unity game engine (Unity Technologies), City Engine (ESRI), Autodesk Maya (Audodesk inc.), and Tree[d] (Frecle).
Unity is a 3D game engine software application that enables the development of 3D computer games and interactive virtual environments. The software comes with a combined functionality that enables changing the graphical environment ether by using an editor or by manipulating it directly in graphical view. It also provides the designer with the ability to define behaviours through a powerful scripting language. In our case JavaScript scripting was used to define the interactivity between the user and the assets of the simulator. The main steps followed for the design of the simulation environment are listed below:

1. Model objects and design the non-interactive animation objects (static and moving):
   (a) Create road network infrastructure and surrounding buildings using ESRI CityEngine;
   (b) Create asset models, such as vehicles, traffic signals, advertising billboard etc, in Autodesk Maya;
   (c) Model vegetation using tree[d]
   (d) Composition of the scene using the above mentioned 3D models in Unity;
2. Enhance realism by simulating lighting conditions, shadows, and sound effects within Unity;
3. Add interactivity within Unity through scripting

The first challenge was the modeling of the road network. To achieve this we extracted a section of the Limassol road network from OpenStreetMap by cropping the area of interest using a polygon on the map. Subsequently, the extracted XML file was imported into the CityEngine, a 3D procedural modeling software application, specializing in the generation of 3D urban environments through the manipulation of objects and existing GIS data. In our case, City Engine was used to manipulate the XML file from OpenStreetmap and the conversion of its 2D format into 3D using CGA Shape Grammar. Through the use of the grammar, the tool's codes were adjusted accordingly until the required result was achieved. The final model was exported into fbx format that is recognized by Unity (Figure 1).
Autodesk Maya software was also chosen for 3D modeling and animation. Maya was utilized for the development of the vehicles and other assets (e.g. traffic lights, advertisement billboards) imported into the game engine. The next step, after the development of the city model, was the specification of the static and dynamic models. These refer to traffic lights, street lamps, street signs, the traffic signs, road stakes and advertising billboards in Unity. In respect to advertising billboards static and dynamic models, designed in Autodesk Maya, have been used to represent static and motion-based advertisements. 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 high frame rates. Additional car assets have been imported in the simulator through car models in existing digital libraries, to provide variety. The imported car models were modified accordingly to abide with the regulations of the Cypriot authorities that state that the

steering wheel has to be on the right hand side. The selection of the car models was based on car types and brands currently used in Cyprus. This was a criterion so as to enhance the realism of the simulator. Colour modifications and textures manipulations helped the design of the car models to become more realistic.

Figure 1 The GIS model of the black-spot (top picture) and its realization in the driving simulator with the road divided into sections A-G (bottom picture)

The final step for the simulator environment was the specification of the routing of traffic. For this task the Maya software was utilized to create car movements as overlay animation. Firstly, the customized city model was imported into Maya and the cars were added accordingly. To have a realistic view of the cars while moving, their wheels were manipulated using MEL scripting language (Expression Editor), to make them rotate according to speed. The movements of cars were specified through the Motion Path. Upon specifying the motion-path cars were imported in Unity. 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.

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 this was realised in Unity through JavaScripting. A screenshot of the simulator's user interface from the driver's perspective is illustrated in Figure 2.

Figure 2 The interface of the developed driving simulator

RESEARCH DESIGN

The aim of this 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. Using this simulator, as presented in the previous section, the research design then employed an experimental evaluation to test the aforementioned (and other) effects. Participants drove a pre-specified route in the designed road network both with and without billboards and traffic lights at a major intersection that has been identified by the police as a critical safety point. The driving conditions near the billboards were purposefully dangerous to stress-test the effect of distraction on driver's workload. Specifically, cars were cutting in or crossing the traffic light at high speed. The conditions tested during the experiment were the use of static and animated advertisement for the billboards, and absence and presence of traffic lights. Figure 2 illustrates a sample screenshot of the virtual road design in Unity from the driver's perspective. 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 experimental conditions: with/without traffic lights and with/without animated advertisements (as also shown in Table 1).
Data were collected at different stages: before, during and after the experiment. The pre-experimental data collection stage concentrated on participants' demographics, driving experience and historical data relating to driving. The post-experimental data collection focused on recall of advertisement types and location. During the drivers' engagement with the experimental conditions, information was recorded relating to driver workload. In particular, manifestations of workload, such as lateral deviations, crash location and speed, were recorded on a time-location plot. Data were captured through analyst observations along with video recordings. Speed was automatically recorded by the simulator, while lateral deviations were counted based on lane departures during and after the experiment by studying the video recordings. To facilitate the data collection task the road was divided into 7 sections as illustrated in figure 1. The specification of these sections was based on infrastructural properties and billboard locations. With the completion of the experiment, the analyst studied each video and verified the correctness of the recorded data during the experiment. In sum, the following data have been collected for each participant, at each road section: speed, lane deviation, and accident occurrence. It should be noted that the observations were stopped once an accident occurred. Speed measurements were based on an inflated scale to examine the effect of an exaggerated

speedometer reading on driving speed. Under normal conditions drivers will constantly monitor their speedometer to maintain the desired/legal limit. In this experiment users were presented with overrated speed on the speedometer to find out if they will abide by the law enforcement.
There were 20 participants (10 male) in the present study, with a mean age of 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. During the experiment, participants were asked to drive as they normally would, given the conditions and the posted speed limits. After the experiment, participants were asked to recall if they saw any advertisement, the type of advertisements (static/dynamic), their location and content.

DATA ANALYSIS AND RESULTS

As can be deducted from the aforementioned description of the experiment, this involved a repeated measures experimental design since each of the 20 participants took part in 4 tests/experimental conditions. The data collected during the different stages of the study were merged into one dataset, which included the necessary information for both the participants (e.g. gender, age, driving experience) as well as their behavioural measures during the four experimental conditions (e.g. accident occurrence, speed, lane change, etc). The design, is illustrated schematically in Table 1, and shows how we resulted with 80 (correlated) observations in total.

Table 1 The repeated measures experimental design

Traffic Lights YES		Traffic Lights NO	
Advertisement Static	Advertisement Animated	Advertisement Static	Advertisement Animated
Subject 1-20	Subject 1-20	Subject 1-20	Subject 1-20

Both descriptive/exploratory data analysis as well as inferential statistical analysis employing regression modeling, were applied to this dataset with the help of the widely used statistical package SPSS (version 20). In particular, we explored how (a) relevant factors, such as driving speed and lane deviation, which is considered in the literature as good predictor of accident, are affected by the experimental conditions, (b) how the outcome variable (i.e. accident occurrence) is associated, if so, with the driver's background characteristics, the two experimental conditions tested and other behavioral factors relevant to driving (as of (a)), and (c) how all the relevant variables can be accounted together for the prediction of accidents in a multivariate repeated measures model.
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 80 observations in the above conditions, 25 (31.25%) accidents were recorded. The vast majority of them (24 corresponding to 96%) happened at Section D of the road. The high accident rate is attributed to the hazardous traffic conditions simulated in the scenarios and is considered for the interpretation of the results.. However, it should also be noted that a new variable was constructed including information of whether an accident occurred or not, independently of location, and this was used for further statistical modeling.

Table 2 presents the association of accident occurrence with the subject's gender. As can be seen, the majority of accidents (68%) observed is attributed to male drivers. This association was found to be statistically significant (chi-square=4.713, p=0.03). Of crucial importance is the investigation of the association between the two experimental conditions and the outcome variable of interest. Table 3 presents these associations.

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

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 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 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)

Other measured variables of interest, which are also considered as explanatory variables in further modeling, are the driving speed and deviation from lane (as an indicator of loss of focus/attention). Speed was recorded separately for each of the seven road sections. The table in Table 4 shows the descriptive statistics for the driving speed at each section, and as can be observed, the average is consistently increased as the driver proceeds in the road section.

Table 4 Descriptive statistics of speed (in km/h) by gender

Road section	**N**	**Overall Mean (SD)**	**Male Mean (SD)**	**Female Mean (SD)**
Section A	80	60.70 (19.8)	60.5 (19.9)	60.9 (20)
Section B	80	102.61 (52.1)	94.35 (49.8)	110.9 (53.7)
Section C	80	122.56 (80.9)	100.67 (81.6)	144.5 (75)
Section D	80	130.6 (84.5)	110.12 (86.2)	151.1 (78.7)
Section E	56	143.98 (90.6)	123.78 (81.8)	158.1 (94.8)
Section F	55	149.13 (112.2)	127.8 (95.3)	164.47 (122)
Section G	55	151.58 (126.6)	149.35 (133)	153.2 (123.5)

Speed measurements were based on an overrated scale to examine the effect of an exaggerated reading on the speedometer on driver behavior. Results from this analysis revealed that female drivers were not affected by the overrated speedometer readings and were driving 24% faster than male. This could be attributed to low situational awareness (Endsley, 1995) of female in comparison to male drivers and hence, failure to recognize the indicated high speed readings. It is probably more interesting to explore how the average speed is affected by the experimental conditions. Figure 3 illustrates the association of the two conditions and their interaction with the speed.

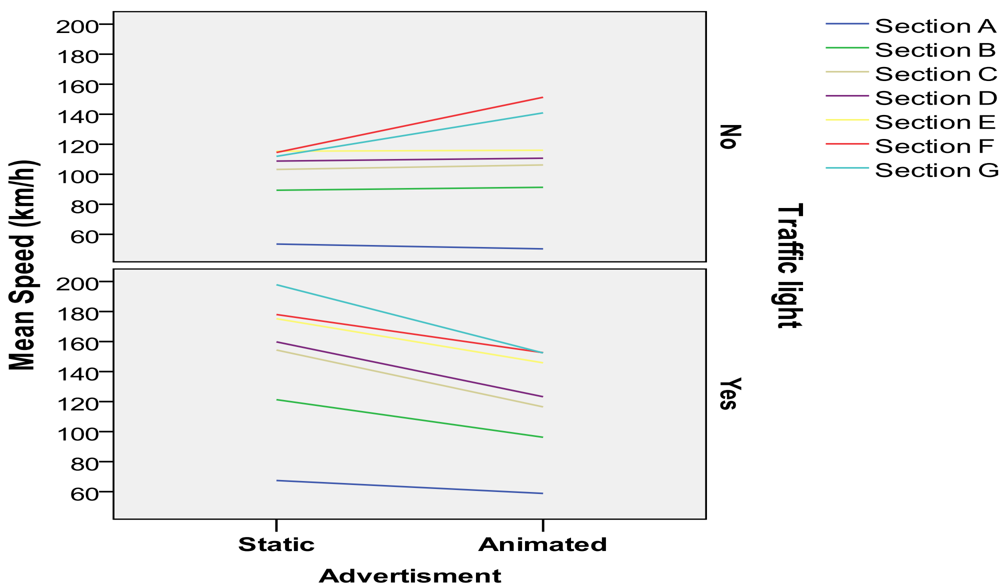

Figure 3 Mean speed (km/h) by traffic light and type of advertisement conditions.

As can be seen, under the ‘animated advertisement’ condition the speed was constant in most sections (apart from Section E) independently of whether there were traffic lights or not. Under the static advertisement scenario, however, there was an observed increased speed when there were traffic lights compared to the scenario without. This could be attributed to the driver being attentive to the animation and hence reverting from driving fast. This however, could be considered as an indirect distractor to the main task of driving. Similar behavior is observed when drivers revert from the driving task due to distraction, such as mobile phone use. In such cases driving speed degrades so as the driver would be able to attend the information requirements of the distraction. The increased speed with the presence of traffic lights could also be attributed to the fact that the light timing was set to change to red when the simulated vehicle was approaching the traffic signals and users were accelerating to pass without stopping. In order to simplify further the analysis involving the effect of speed, a new variable was created to capture average standardized speed across all sections, up to the point of accident occurrence.

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). Various variables were found to influence the probability of lane deviation as shown in the results of a binary logistic regression model. Binary logistic is the appropriate regression model of binary outcome variables, as is lane deviation for our analysis. Regression modelling allows for the combined effects of various explanatory variables to be taken into account when modelling the outcome variable (Hutcheson & Sofroniou, 1999); the ultimate aim sometime is to make predictions for the probability of an event happening (i.e. lane deviation) with the regression equation which can be formed with the help of the regression coefficients, presented in Table 5.

Table 5 A logistic regression model for the probability of lane deviation

Variables	Coefficient B	S.E.	Wald	df	p-value (Significance)	Exp(B)
Light(Yes)	-3.662	1.069	11.748	1	.001	.026
Animated(Yes)	-1.298	.841	2.382	1	.123	.273
Gender(F)	1.407	.621	5.124	1	.024	4.082
Animated(1) by Light(1)	4.000	1.446	7.651	1	.006	54.624
Z-Average Speed	1.540	.454	11.487	1	.001	4.664
Constant	.667	.618	1.164	1	.281	1.949

According to the results of this model, average driving speed, gender, the traffic light experimental condition as well the interaction of traffic lights with animation (or not) have a significant effect on the probability of lane deviation, as indicated by the significance values for this variables (i.e. p-value<0.05). The direction of this effect is better explained with the exponential of the coefficients. For example after controlling for all other variables in the model, female drivers are four times more likely (exp(b)=4.082) to deviate from the lane compared to male drivers. Similarly when average speed increases by 1 (standard) unit the odds of lane deviation increase by more than 4 times (again assuming we control for all other variables). The effect of the interaction between the two experimental conditions is also significant and can be interpreted as follows: even though without traffic lights the probability of lane deviation is significantly higher for the static advertisement condition, this trend is reversed under the traffic lights condition, when the probability of lane deviation becomes higher for the animated advert condition.

What is also interesting is to explore the association of lane deviation and speed with the main outcome of interest; that is accident occurrence. To check for this we split the 80 observations into those with accident observed and those without and we then compared the means of average speed and lane deviation (i.e. the probability of lane deviation) for the two groups. The results are presented in Table 6, and show a statistically significant higher probability for lane deviation when no accident was observed. The increased speed in the case of no accident compared to the accident cases was not found to be statistically significant.

Table 6 Comparison of average speed and probability of lane deviation by accident occurrence

	Accident	N	Mean	Std. Deviation	Std. Error Mean	t-test (significance)
Lane Deviation	No	55	0.636	.49	.065	5.541 (p<0.01)
	Yes	25	0.12	.33	.066	
Average Speed	No	55	120.9	66.36	8.95	0.649 (p=0.52)
	Yes	25	111.10	60.92	12.18	

The above associations between the accident occurrence and other variables, even though indicative of some patterns, have two main limitations: they fail to account for the inter-relationships between different variables, and they do not take into account the repeated measures design and the resulting correlations between the observations for each subject. These limitations are overcome with a more advanced regression model. In particular, we employed a generalized linear modeling framework (Hutcheson & Sofroniou, 1999) to model the binary variable of interest (i.e. accident occurrence) based on various explanatory variables including the experimental conditions and participants' characteristics. The appropriate model was a logistic regression model, which also deals with the repeated nature of our experimental design. Technically, we used the mixed generalized linear modeling tool of SPSS and resulted in the model with the main effects shown in in Figure 4 It should be noted that different variations of the model were run checking for the effects of other background and behavioral measures (e.g. speed and lane deviation) however these were not found to be effective for the response variable (i.e. accident occurrence). The model in Figure 4 is considered to be robust and concise accounting for both experimental conditions and their interaction as well as driver's gender which was found to have a significant effect. 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=1, Animated=1, Gender=m). Hence controlling of the categorical variables in the model is achieved by setting a dummy variable for one of the categories to zero and check the effect of the other category(ies) on accident.

Model Term	Coefficient ▶	Sig.	Exp(Coefficient)
Intercept	-1.226	.031	0.293
Light=0	1.883	.014	6.573
Light=1	0[a]		
Animated=0	0.948	.218	2.580
Animated=1	0[a]		
[Light=0]*[Animated=0]	-1.883	.083	0.152
[Light=0]*[Animated=1]	0[a]		
[Light=1]*[Animated=0]	0[a]		
[Light=1]*[Animated=1]	0[a]		
gender=f	-1.314	.020	0.269
gender=m	0[a]		

Probability Distribution: Binomial
Link function: Logit
[a] This coefficient is set to zero because it is redundant

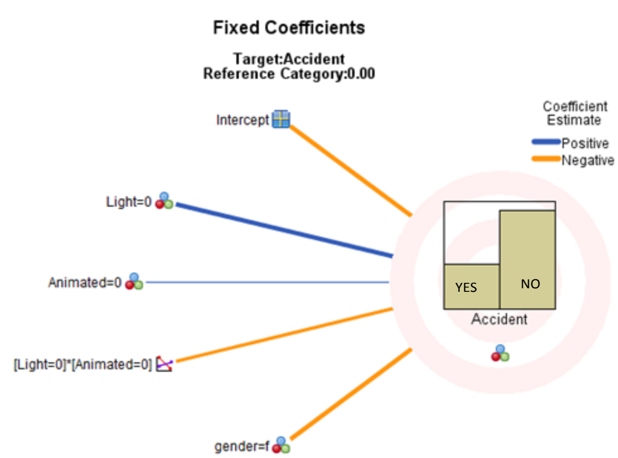

Figure 4 A model for predicting accident occurrence. A zero score for a variable denotes absence of the condition (i.e. light=0 implies no traffic light, and animated=0 implies static advert).

The coefficients of the explanatory variables in regards to their effect on the response variable are interpreted similarly to those from a multiple logistic regression (i.e. based on the change in odds ratio using the exponential of the coefficient, as for Table 5). For instance, what we could say for gender given the above results is that, controlling for all other variables in the model, when we move from male to female driver we reduce the odds of an accident by 0.269 (in other words, for males the odds of accident are almost 4 times those of female). Similarly the odds of an accident are increased by more than 6 times when we remove the traffic lights.

CONCLUSIONS

Driver workload should always be maintained at optimal levels to ensure adequate level of vigilance. Experimental work in this field is often ethically unacceptable, if not impossible, if performed in actual driving conditions. Therefore, driving simulators enable the study of realistic conditions, without any objective risks, while at the same time lend themselves to a variety of human factors analyses. The three categories of methods used to assess driver workload, according to the literature are: measures of task performance, subjective reports and physiological measures (Brookhuis et al., 2002). Our approach falls under the task performance group. Lateral deviation is also identified in previous research as one of the most critical driving performance indicator relevant to safety (DOT, 2006). Our contribution lays in the correlational analysis of phenotype driver behaviors, such as lane departures, for the assessment of the primary task of driving, under different infrastructural conditions to identify if billboard distractions are increasing the risk of accidents.

To 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 behaviors 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 straightforward fashion.

Preliminary results from this study highlight a weak relationship between lateral deviations of road users and advertisement. Overall the results highlight a significant difference between gender groups on accident likelihood which verifies earlier findings in the literature (DOT, 2011). Additional results highlight the relationship between speed and animated advertisements, and speed with accident occurrence. The former indicate that animated advertisements consume more attentional resources than static advertisements and this is manifested by reduced speed to compromise for the reduced cognitive resources available. The latter reinforces the finding that speed increases accident risk and this is more critical with male drivers. Finally, fake reading on the speedometer seems to affect only male drivers who appear more contextually aware, as also suggested by their observed superior lateral control in contrast to females.

The implications from these preliminary results highlight the need to examine in more detail the impact of animated advertisement on driving behaviour and its link to accidents. Moreover the situational awareness difference between genders needs to be analysed further. However, due to the limited immersive properties that laboratory methods provide, the driving behaviour of participants might be affected. To that end, we are aiming to recreate the experiment in virtual reality settings for improved realism and hence enhance driving conditions which in return will affect participants’ driving behaviour. This will improve observational accuracy and thus yield more robust results.

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