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Monitoring distraction through smartphone naturalistic driving experiment

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Summary: Accurate monitoring of driving distraction has been proved to be a difficult task in the past. However, the rapid technological progress, especially in telematics and Big Data analytics, along with the increased penetration of information technologies to the drivers (e.g. smartphones), provide new potential for driving behaviour monitoring and analysis. Concerning driving distraction, one of the most influencing factors that has a significant effect on driver behaviour, is mobile phone usage. The objective of this paper is twofold, to analyse and assess the impact of mobile phone usage on driving characteristics such as the number of harsh events that occur while driving and to investigate the predictability of mobile phone usage. An innovative data collection scheme is implemented in this research by recording driving behaviour analytics in real time, using smartphone device sensors. Over a hundred drivers participated in the designed experiment during a 4-months timeframe. The number of harsh events occurred when driving was found to be influenced by several factors including mobile phone usage. Additionally, mobile phone usage is found to be predictable by a few factors such as driving duration and percentage of speed limit exceedance. The results of this research substantiate herein that distraction through smartphone has a serious impact on driving characteristics and subsequently on the relative crash risk. Further analysis of the data collected is implemented through statistical and econometric techniques and is leading to the quantification of the factors influenced by mobile usage that causes an alteration in driving risk.

Background: Accurate monitoring of driving distraction has been proved to be a difficult task in the past. The rapid technological progress, especially in telematics, and Big Data analytics, along with the increase in the information technologies' penetration and use by drivers (e.g. smartphones), provide new potential for driving behaviour monitoring and analysis. First results from related applications [1,2,3,4,5] have confirmed the efficiency and usefulness of such big data collection schemes. As for driver's distraction, one of the most influencing factors that has a significant effect on driver behaviour is mobile phone usage [6]. Since mobile usage is a standard part of everyday driving process and is expected to increase over the years [7], its impact on driving behaviour in traffic and road safety is particularly important and should be further investigated. Literature so far has showed that when the driver is using the phone while driving his/her behaviour alters significantly. Therefore, mobile usage is banned in many countries [8] as the distraction caused is considered the main risk while driving [9,10,11].

Objective: The objective of this paper is twofold, to analyse and assess the impact of mobile phone usage and therefore driving distraction on driving characteristics as well as to examine the predictability of mobile phone usage. More specifically, by continuously collecting data from smartphone devices while driving, this study aims to examine the way that driving metrics recorded such as harsh events (braking, acceleration, cornering) are influenced by driving distraction in the form of mobile phone usage and therefore predicting the number of harsh events that take place. Moreover, exploiting the information collected regarding the number of harsh events that took place in each trip, a variable representing the number of harsh events per distance travelled is calculated to account for driver's performance. It should be highlighted that this study is investigating the macroscopic driving characteristics within a trip and as a result all indicators that were taken into consideration such as harsh events and mobile usage might have not been recorded simultaneously. Furthermore, the potential of predicting mobile phone usage while driving through recording of driving related metrics is also examined herein.

Method: An innovative data collection scheme using a Smartphone Application that has been developed by OSeven was exploited for the purpose of this research. Driving behaviour analytics is recorded in real time, using smartphone device sensors. Over a hundred drivers participated in the designed experiment during a 4-months timeframe and a large database of several thousand trips is created. The solid integration platform for collecting, transferring raw data and recognizing the driving behaviour metrics via ML algorithms is also developed by OSeven. This ensured a smooth transition from the data collection to the data analysis procedure. All data received is evaluated and filtered when deemed to be necessary. The steps of the standard procedure developed that is followed every time a new trip is recorded by the App, are clearly shown in Figure 1.

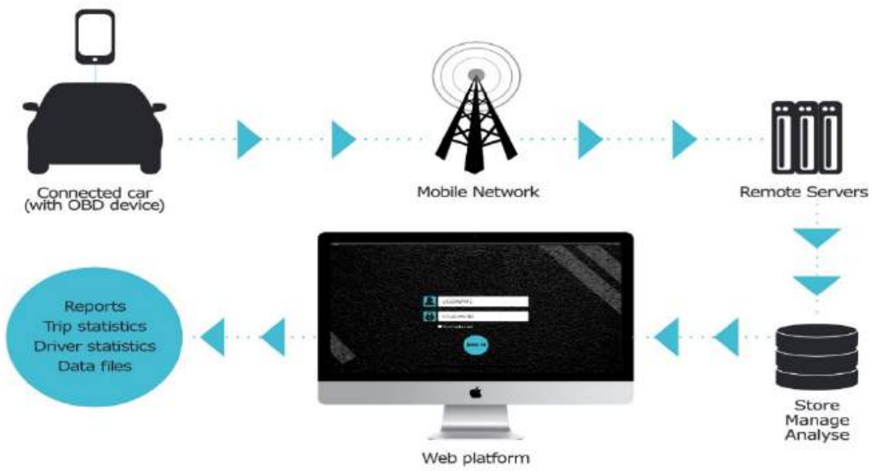

Figure 1 - OSeven data handling chart

Driving measures collected include indicatively distance travelled, speed, accelerations, braking, steering, cornering and smartphone usage (dialling, talking, texting etc.) in different driving environments (urban, rural, highway). During data processing, new variables were created in order to define the time of the day driving (daylight, morning rush, afternoon rush). A correlation matrix to check the correlation between variables used in the analysis and pivot charts of the data collected were created, and illustrated bellow.

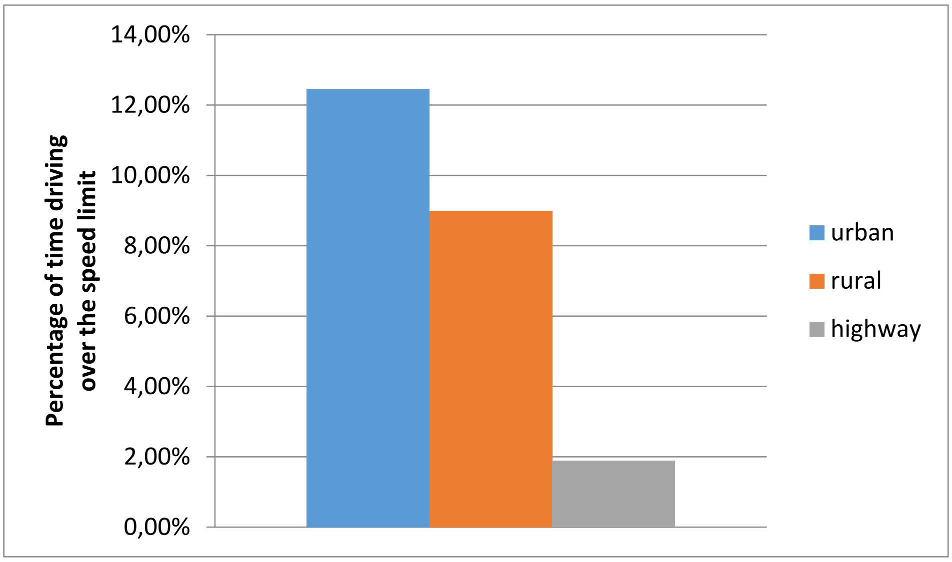

Figure 2- Average Speeding per road type

Figure 2 shows the average percentage of time driving over the speed limit per road type where it is evident that the percentage of exceedance of SL is lower for highways than urban and rural roads. Figure 3 shows the average mobile phone usage percentage (duration of mobile usage / driving time) per road type demonstrating again a lower percentage of mobile usage for highways. A linear regression model is developed to model the driving characteristics that influence the number of harsh events per distance travelled including mobile phone usage that is one of the components of driver distraction. The influence that each variable has on the number of harsh events occurring in each trip separately are quantified and consequently, the relative risk for each trip can be identified. A binary logistic model is also utilized to predict the situation of using or not the mobile phone while driving through the observation of different driving measures.

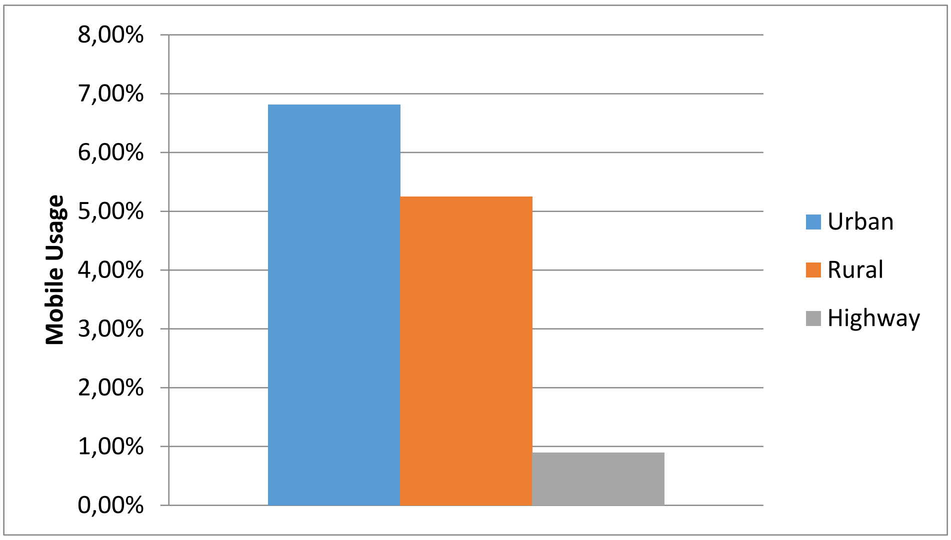

Figure 3- Mobile Usage per road type

Results: Overall, a change in driving behaviour and more specifically in the number of harsh events occurred such as harsh brakings, accelerations and cornerings is proved to be predictable using as an indicator the mobile phone usage while driving. The linear regression model that originated from the above analysis, illustrates a significant dependence between driver's distraction (total harsh events / total distance) and percentage of mobile usage, the standard deviation of speed, the average exceedance of the speed limit as a percentage of the speed limit, the driving period during a day (morning, afternoon rush) and the total duration of the trip. As shown in Table 1, the most significant predictors among the others is found to be trip duration and average speed limit exceedance.

Table 1- Linear Regression model output for the estimation of Harsh Events

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
Constant	.408	.008		54.374	0.000
Driving during morning rush hour	.050	.007	.051	7.023	.000
St. Deviation of Speed	-.001	.000	-.023	-2.680	.007
Average Speed limit exceedance	.193	.024	.068	8.231	.000
Mobile Usage	.039	.015	.019	2.580	.010
Duration (hr)	-.163	.009	-.144	-18.943	.000
a. Dependent Variable: **total number of events per kilometres travelled**					

Additionally, mobile usage was shown to be realistically predictable through the observation of the driving behaviour. A dummy dependent variable of mobile phone usage is created which equals to 0 when the time of mobile phone usage is 0 and 1 otherwise. The binary logistic model shows that the probability of mobile phone usage is significantly influenced by the duration of the trip, the average angular speed, the driving period during a day (morning, afternoon rush) and the percentage of driving duration above the speed limit. As shown in table 2, the variables that affect the most the probability of a user using the mobile phone are trip duration and the percentage of driving duration above the speed limit. More specifically, duration shows an odds ratio of 3.930 and percentage of speeding an odds ratio of 1.907. The interpretation of this is that increase of the duration by 1 hr and speeding by 0.1 increases the possibility of someone using the mobile phone over not using it by 3.9 and 0.2 respectively. The binary logistic regression model illustrated a 60.0% predictability of mobile usage using a cut-value of 0.46.

Table 2- Logistic Regression model output for mobile phone usage

Variables in the Equation						
	B	S.E.	Wald	df	Sig.	Exp(B)
St. Deviation of Speed	.007	.002	8.852	1	.003	1.007
Driving during morning rush hour	-.209	.042	25.310	1	.000	.811
Driving during afternoon rush hour	.126	.036	12.140	1	.000	1.135
Duration (hr)	1.369	.064	461.442	1	.000	3.930
Average Angular Speed	.117	.006	366.534	1	.000	1.124
Average percentage of time driving over the speed limit	.646	.138	21.910	1	.000	1.907
Constant	-1.898	.076	616.145	1	.000	.150
Refers to the Utility function of mobile phone usage = 1						

Impact: The results of this research substantiate that distraction originating from smartphone usage has a serious impact on the number of harsh events that occur per kilometre and subsequently on the relative crash risk. Further analysis of the data collected is implemented through statistical methods and led to the quantification of this influence. The quantification of change in driving behaviour can constitute a measure of evaluating driver's performance and thus, it can potentially lead to the implementation of a driving risk model based on driving behaviour and degree of exposure. It may also contribute towards the practice of evaluating driver's traffic and safety behaviour as well as to classify drivers in different safety categories depending on their relative level of risk. It is also found that it is feasible to predict mobile usage solely by some driving characteristics such as duration, time of the day driving, speeding etc. The outcomes of this research will also benefit industry and particularly the road and vehicle industry. By identifying the key risk factors in driver distraction accidents, vehicle manufacturers will be able to develop new systems that will directly improve the safety of vehicle occupants and other road users through primary and secondary safety features. One specific application area for the industry relates to the development of targeted advanced automatic driver distraction preventing systems. Furthermore, the opportunity of forecasting the use or no use of mobile phones according to the observed driving measures facilitates the detection of distracted drivers. Finally, it is expected that considerable gains for the society can be achieved, since the stakeholders including policy makers and industry could rely on the results and recommendations regarding risk factors that appear to be critical for safe driving. As for further research, microscopic data analysis of the database collected could be implemented through econometric techniques such as time-series analysis which could potentially quantify the influence of mobile usage on other microscopic factors, such as speed, that causes an alteration in driving risk. Future research should also focus on the analysis of the separate impact of each noticed behaviour on driving risk, as well as the possibility of reducing the effects of distraction due to the mobile phone usage.

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Keywords: Driving Behaviour; Big Data; Smartphone Data; Time-series Analysis

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