"DRIVING WHILST USING IN-VEHICLE INFORMATION SYSTEMS (IVIS): BENCHMARKING THE IMPAIRMENT TO ALCOHOL."

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ABSTRACT

Using the Lane Change Task (LCT) a comparison of driving performance was made between normal (baseline) driving, driving whilst using an In-Vehicle Information System (IVIS) and driving while intoxicated at the UK blood alcohol level (80mg per 100ml). An attempt was then made to benchmark LCT performance while using IVIS to a well-established minimal level of acceptable driving performance (i.e. alcohol impaired but legally acceptable), both to provide a safety criterion for LCT performance and to illustrate the effect of IVIS on performance of the driving task. The results provided clear evidence for impaired performance of the LCT when performing an IVIS task in comparison to both baseline (LCT alone) and alcohol conditions [$F(5, 15) = 14.421$, $P<0.05$]. However, the LCT was found to be insensitive to the effects of alcohol in the absence of a secondary task. It is concluded that LCT performance can be impaired more when undertaking certain IVIS tasks than by having a blood alcohol level at the UK legal limit but the LCT requires further development before it can be used as a convincing proxy for the driving task. A tentative criterion is offered for minimum acceptable LCT performance when concurrently using an IVIS device based on lateral deviation from the normative model.

KEYWORDS: IN-VEHICLE INFORMATION SYSTEMS, DRIVER BEHAVIOUR, DISTRACTION, ALCOHOL, LANE CHANGE TASK.

INTRODUCTION

Driving with a blood alcohol concentration at the legal limit is an established indicator of increased risk of accident involvement. It is widely accepted that driving performance whilst under the influence of alcohol is impaired and as such legislation commonly exists that prohibits driving when above a given blood alcohol concentration (80mg of alcohol per 100ml of arterial blood in the UK). The same is not true with regard to in-vehicle information systems, which are widely regarded as a potential cause of driver distraction. With the rapid uptake and use of new devices this is of increasing concern to policy developers and regulators and as such is becoming a focus of current research efforts.

In the United Kingdom legislation regarding the use of hand held mobile phones while driving prohibits drivers form using any **“device, other than a two way radio, which performs an interactive communication function by transmitting and receiving data”** [1] including mobile phones. This amendment was passed on the strength of the research evidence that suggests driving while using a mobile phone is detrimental to performance of the driving task so much so that performance is degraded to unsafe levels.

Although there is little data about mobile phone involvement in crash statistics, and certainly not enough to form a conclusion about the real risk related to the use of mobile phones while driving, there are a number of epidemiological studies that have attempted to quantify this risk. An approximate nine-fold increase in risk of fatality has been proposed for drivers who use mobile phones while driving [2, 3, 4, 5, 6]. Furthermore, Violanti and Marshall [3] report that participants who spent greater than fifty minutes per month talking on their mobile phones while driving were six times more likely to be involved in a road traffic accident than those who used their mobile phones less frequently. The likelihood of fatality was doubled by the mere presence of a mobile phone in the vehicle [4], the risk of an accident is increased four fold when a mobile phone is present [5] and talking on a mobile phone is distinctly more risky than listening to the radio, talking to passengers and other activities commonly occurring in vehicles [7].

Phone use seriously impairs a driver’s ability to perform basic driving manoeuvres such as changing lanes and adapting speed [8, 9]. Performance of the driving task while simultaneously using a mobile phone becomes increasingly difficult as speed increases [10]. Redelmeier and Tibshirani [11] suggest that the “relative risk” of driving while talking on the phone is comparable to driving at the legal alcohol limit; however the dangers of driving while under the influence are considerably greater as drink drivers may be well over the legal limit. Further comparisons of performance between intoxicated drivers and those using mobile phones were undertaken by Strayer, Drews and Crouch [12]. They used a driving simulator to compare drivers’ performance in a car following task in a number of conditions (baseline, mobile phone and alcohol intoxication). It was found that drivers in each of these conditions exhibited different driving profiles. Drivers in the cell phone condition exhibited slower reactions than the base line group and compensated for this by increasing their following distance. Drivers in the alcohol condition demonstrated a more aggressive driving style in that they maintained shorter headways and produced greater brake force in the presence of an unexpected collision event. Controlling for time on task and driving difficulty, drivers talking on a mobile phone were more impaired than drivers under the influence of alcohol.

Using a driving simulator Burns, Parkes, Burton, Smith and Burch [13] attempted to benchmark the impairment of both hands-free and hand-held phone conversation in relation to alcohol. Results showed that performance when driving while intoxicated at around the legal limit was significantly worse than baseline driving performance. Poorest performance however, was on measures of driving behaviour (speed control and response time) when participants were engaged in mobile phone conversation (hand- held was significantly worse than hands free). It was concluded that driving behaviour was more impaired during a phone conversation than by having a blood alcohol concentration at the UK legal limit (80mg/100ml).

A number of safety critical principles regarding the time an IVIS task should take to complete have been proposed. The main guiding principle is the ‘fifteen second’ rule (J2364) proposed by the Society of Automotive Engineers [14]. This proposal suggests that a task can be considered safe to undertake whilst driving when it takes fifteen seconds or less to complete when executed without driving [static task time], given that there is a high correlation between task time, while driving, and total eyes off the road time, if the task takes 15 seconds continuous visual attention it is likely to impede performance of the driving task and therefore pose a significant threat to safety [15]. Alternatively, Zwahlen, Adams and Debald [16] recommend that for safety reasons drivers should not be distracted from the driving task for greater than two seconds. This is reflected in the European statement of principles [17], which recommends that a task should take no more than four glances, with maximum glance durations of 2 seconds (giving a total glance time of 8 seconds). Similarly, J2364 [18] recommends that the duration of a single task while the vehicle is in motion should not exceed 2 seconds. In addition, the task completion should not require more than a total of 20 seconds of total glance time to the system display or controls.

Measures based on static task time can be criticised, as many of the proposed limits are somewhat arbitrary. Much of the evidence available supports maximum times well under the fifteen-second limit [19, 20, 21, 22, 23] In particular, the 15-second rule cannot be used to reliably predict the acceptability of a device, although it has been found to be effective at identifying the most distracting tasks. However, much of the evidence evaluating the diagnostic sensitivity of J2364 has concluded that, in general, the probability of accurately classifying unsafe performance is around chance level and in this regard, the discrimination accuracy is comparable to far greater time limits e.g. 30 or 45 seconds [24]. It is important to note that lower task time limits (<10 seconds) further reduce the distraction potential of IVIS, but may be too restrictive in terms of the tasks that would be allowed. It is for this reason that new metrics such as the occlusion technique and the LCT are being developed as replacement measures. A practical result of the 15-Second Rule is that most destination entry tasks will not be allowed in moving vehicles.

Currently, the major alternate approach to assessing the distraction potential of IVIS is the occlusion technique. The occlusion technique is designed to reproduce the visual time-sharing between the road and IVIS devices [25]. The main apparatus used to run the occlusion method are PLATO goggles (Portable Liquid-crystal Apparatus for Tachioscopic Occlusion; [26]), the lenses of which can switch between transparent and opaque states on the passing of an electronic trigger signal, thus obstructing the view of participants within a matter of milliseconds. The key premise of the occlusion technique is that the periods when participants’ vision is occluded are representative of their glances to the road scene when using IVIS. It is recommended that in-vehicle tasks should be completed in less than twenty-seven seconds, comprising six 1.5-second viewing opportunities and six 3.5-second occlusion periods. Using a task designed to meet the static criterion of a total task time of fifteen seconds Baumann, Keinath, Krems and Bengler [27] argued that the occlusion tool is an appropriate method for evaluating the safety of IVIS. The task involved the presentation of short text messages on a hand held computer suitable for in-car use (containing the names of German highways). The texts were presented at a rate of three words per screen and each screen was presented for an occlusion period lasting 0.7 seconds. The participants were required to recall the names of the highways included in the text and answer questions regarding the content of the text message. Degradation in performance was observed in the occlusion condition where the task was interrupted at two-second intervals. Around one third of answers in the occlusion condition were correct. Information presented during the interruption phase of the trial was lost and could not be recovered making it difficult to complete the task. This illustrates that a task can meet Green's (1999) fifteen-second criteria but at the same time participants fail to complete the task within Zwahlen et al's [17] requirement that each interaction with the system should take no more than two seconds. Recommendations regarding acceptable values for un-occluded vision (Total Shutter Open Time, TSOT) have been made; however, research suggests that many driver support systems seriously exceed these [28]. Conversely the recommended TSOTs may not allow certain tasks, that have not been found to adversely influence driving performance, pass such a criterion.

There is limited research that has successfully established the validity of the visual occlusion technique as a measure of driver distraction. The research that does exist lacks consensus regarding the best means of achieving occlusion, the length of the interval periods [29], whether the occlusion and inspection intervals should be computer or self-paced [30] and if they should be fixed or variable [31], the level of training given to participants [28] and whether a distracter task is necessary during the occlusion interval to prevent participants from rehearsing their next move or operation during this period (Monk and Kidd, 2007). It is important to recognise that key aspects of time-sharing are ignored by the occlusion technique [32]. Participants are able to maintain their task goal state during the occluded periods without interference from another task. This is contrary to naturalistic driving where drivers perform several tasks while looking at the road, such as monitoring the road and traffic and looking for navigational cues. The technique therefore produces an estimate of performance that fails to account for any attentional cost when switching back and forth between two tasks. Therefore, it is difficult to know if participants are able to resume the IVIS task without any attention switching latency.

Furthermore, the occlusion technique does not take into account the interruptability of the task [33, 34, 35]. The problem with assessments based on total glance time is that a high value implies that the task would be unsafe, however a task that can be completed with multiple short glances will not affect performance in the same way as a task that can be completed quicker but requires much longer individual glances. For example, a task with a total glance time value of 10 seconds comprising of 10 individual 1 second glances is more desirable than a task that takes 5 seconds to complete but comprises a single 5 second glance. Chaing, Brooks and Weir [36] found that participants took longer than 15 seconds to complete a number of destination entry tasks; however 92% of all glances lasted less than 2 seconds indicating that drivers can accommodate tasks that are user paced and interruptible even if they exceed the prescribed 15 second limit.

Rather than relying on design principles such as the 15 second rule an alternate approach is to make comparisons with the impairment due to an accepted safety critical criterion, in this case alcohol. There is a long standing legal precedent regarding the consumption of alcohol and driving. The same is not true with regard to in-vehicle information systems. The current study using a comparable methodology to the study of Burns et al [14] is a first step towards establishing a similar benchmark for IVIS devices. The purpose of this study is twofold; firstly it will establish the potential for distraction that may be evident in the use of IVIS devices and secondly it will establish a safety critical value for the Lane Change Task (LCT) above which performance can be considered unsafe and would be considered unacceptable. Without this process there will be a difficulty in quantifying performance of the lane change task. Currently the only LCT comparison undertaken is between dual and single task performance. This does not inform us as to whether the difference in performance is significant, nor does it reveal whether IVIS will become a significant problem for the modern driver. Worse than normal driving when using IVIS devices does not necessarily mean that driving is dangerous.

METHOD

Participants

15 participants (7 Female, 8 Male) were selected at random from a volunteer database; a pool of 1300 drivers that represent a cross section of the driving population. Participants were required to have a full UK driving licence and normal or corrected vision. Participants with possible alcohol problems were excluded; however participants were required to be regular consumers of alcohol. Alcohol abstaining drivers have little or no tolerance to the effects of alcohol. In contrast excessive drinkers are able to tolerate increased levels of alcohol in the body without demonstrating the outer symptoms associated with alcohol consumption (loss of concentration, impaired vision, loss of balance etc.). Drivers drawn from either of these sub-groups would produce behaviour that was not representative of the majority of the driving population. Participants were paid £30 for their involvement in this study. Due to the nature of this study they were also provided with transport to and from the experimental facility.

Design

A within subjects 'repeated measures' design was used with, each subject completing each of the three conditions. This was a part counterbalanced trial design, so that learning effects could be controlled for in the statistical analysis. The only condition that was not counterbalanced was the alcohol condition as it was impractical to wait for participants BAC to return to zero before completing further sessions. The alcohol condition was, therefore, always the last part of the experiment.

Alcohol

Participants were required to consume an alcoholic drink comprising vodka (40%) plus a masking mixture (e.g. cream-soda) prepared using the adjusted Widmark formula [37] so that participants become intoxicated at the legal limit (80mg/100ml) with the volume of the mixer adjusted to maintain a 20% volume. A breathalyzer was used to confirm the level of intoxication experienced by each participant.

In-Vehicle Information Systems (IVIS)

The IVIS used in this experiment was a Hewlett Packard iPAQ (PDA) and an 8 Inch TFT LCD Monitor running a popular satellite navigation system application and a bespoke data display application. These were situated on the desktop in a location that reflects their location in the vehicle cockpit. In the IVIS conditions participants were required to complete four LCT trials. Each of these trials was dedicated to one of four IVIS tasks; entering a destination by selecting a "point of interest" using the PDA, entering a destination by "address" function using the PDA and a *scrolling share task*, which comprised a three letter stock code presented verbally which had to be located within a single-column scrolling display located on the dashboard display. When participants had located the target stock code they were required to report the price located to the right of the code [32]. To increase the demands placed on the driver in terms of workload there was a second version of this task in which participants were required to locate a share price embedded within three columns of ten stock codes. This task is primarily a visual task. As such, it competes for resources with the visual elements of the driving task (e.g. event detection obstacle detection, sign reading etc.). In terms of the LCT the scrolling shares tasks compete for resources that would otherwise be dedicated to event detection.

Lane Change Task

The LCT [38] is a laboratory based combined control and event detection metric based on the dual task paradigm. The dual task paradigm assumes that primary task performance will degrade with the introduction of a secondary task. In this case LCT performance can be viewed as the primary task and it is designed to be analogous to the driving task.

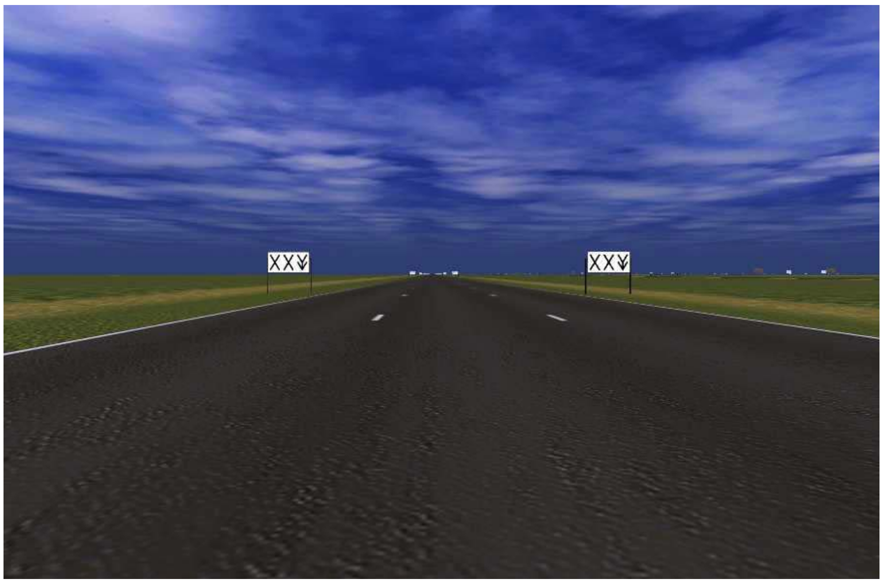

Figure 1: Screen shot from the LCT. In this instance the driver has to change from the centre lane to the right lane.

The LCT requires participants to 'drive' a 3000m long section of three-lane highway presented on the monitor of a desktop driving simulator. Participants are instructed by signs on the roadside (150m apart) to perform a lane change manoeuvre. During this task participants are required to perform a specific secondary task. To avoid speed confounding the results it is controlled by the program and is kept at a constant 60kmph. The illumination reflects daytime driving with a constant light level. Visual information is presented using an egocentric (front) view; no visual information is presented regarding side or rear views.

Participants are required to change lane when instructed. When not performing a lane change manoeuvre they are required to maintain a central position within the lane. Performance of the lane change task by itself is used as a measure of baseline performance for comparison with performance of the LCT and a secondary task.

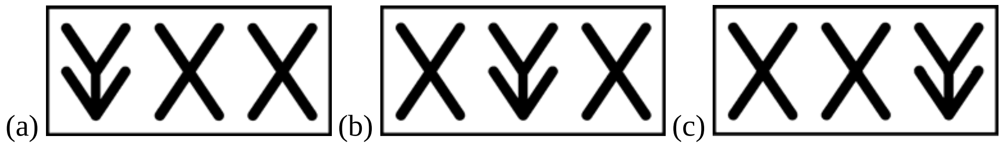

Figure 3: LCT signs; (a) Left, (b) Centre, (c) Right.

During a trial the LCT program automatically records data to the computer on which it is running. From this data the LCT analysis program can calculate a number of performance measures. These include; mean deviation from the normative model, standard deviation from the normative model, mean steering angle, as well as time course and distance information to allow for standardisation of experimental runs.

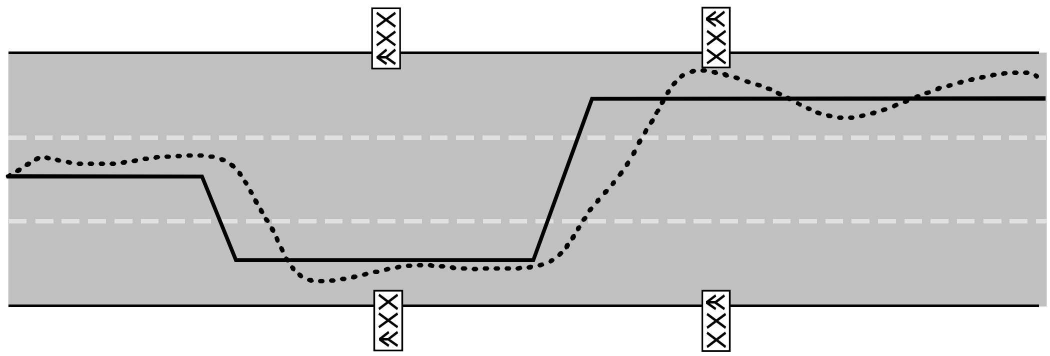

Figure 4: The LCT compares the normative model (solid line) to the participants driving course (broken line).

Procedure

Informed consent was sought from participants prior to commencement of the experiment. Upon giving consent participants were required to complete a health questionnaire to ensure that they were fit to proceed with the study. All participants were breathalysed before the experiment started to ensure they were not already intoxicated.

The participants were required to complete 15 LCT trials lasting 45 minutes in total. Five of these trials were completed without the presence of a secondary task and without the influence of alcohol. These trials served to act as a baseline measure of driving performance. In the IVIS conditions participants were required to complete 4 LCT trials, one for each of the four IVIS tasks.

In the alcohol condition participants were given 10 minutes drinking time in which to consume the intoxicant, followed by a brief waiting period (40 minutes from finishing the drink). The justifications for such a waiting period are that the effects of alcohol take around 20-65 minutes to reach their peak and it may take this long for any residual alcohol on the breath to disperse. Participants were breathalysed again prior to beginning the LCT section of the experiment to ensure that they were at, or over, the legal limit. Participants were then required to perform a further 5 three minute LCT trials lasting a total of 15 minutes. Instructions were provided to participants as to how to complete the LCT trials. Participants were required to remain in the facility for some time after completion of the alcohol condition LCT trials to allow the BAC to return to a normal level.

RESULTS

A one-way repeated measures ANOVA was calculated for mean deviation from the normative model on the LCT across the six conditions (Baseline, PDA POI, PDA Address, Shares short, Shares long, and Alcohol). There was a significant main effect by condition for mean deviation from the normative model [F (5, 15) = 14.421, P<0.05]. A Tukey post-hoc comparison of the six treatment conditions was conducted. There were a number of significant comparisons (Baseline and shares short, Baseline and Shares long, Baseline and PDA POI, Baseline and PDA Address, Alcohol and Shares short, Alcohol and Shares long, and Alcohol and PDA Address, P< 0.05).

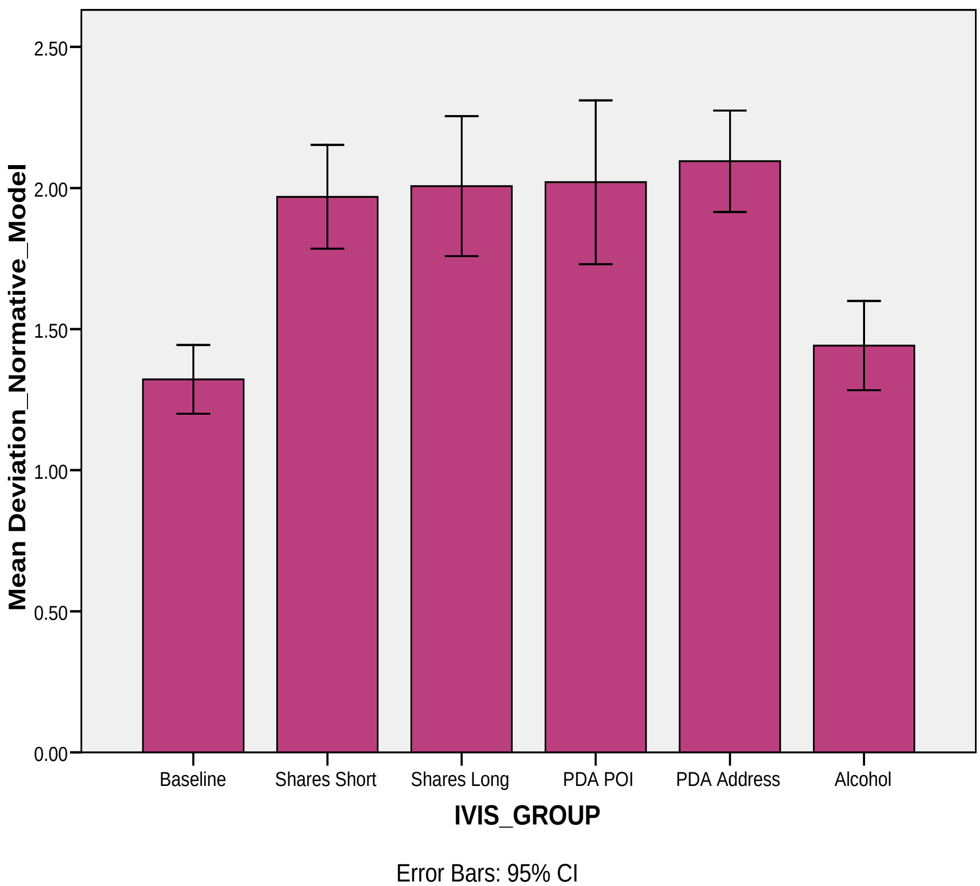

Figure 5: Mean deviation from the normative model by LCT condition

Figure five shows the mean deviation from the normative model by LCT treatment condition. It shows that there was only a marginal difference between baseline performance of the LCT and performance of the LCT under the influence of alcohol. This was supported by the post-hoc comparison.

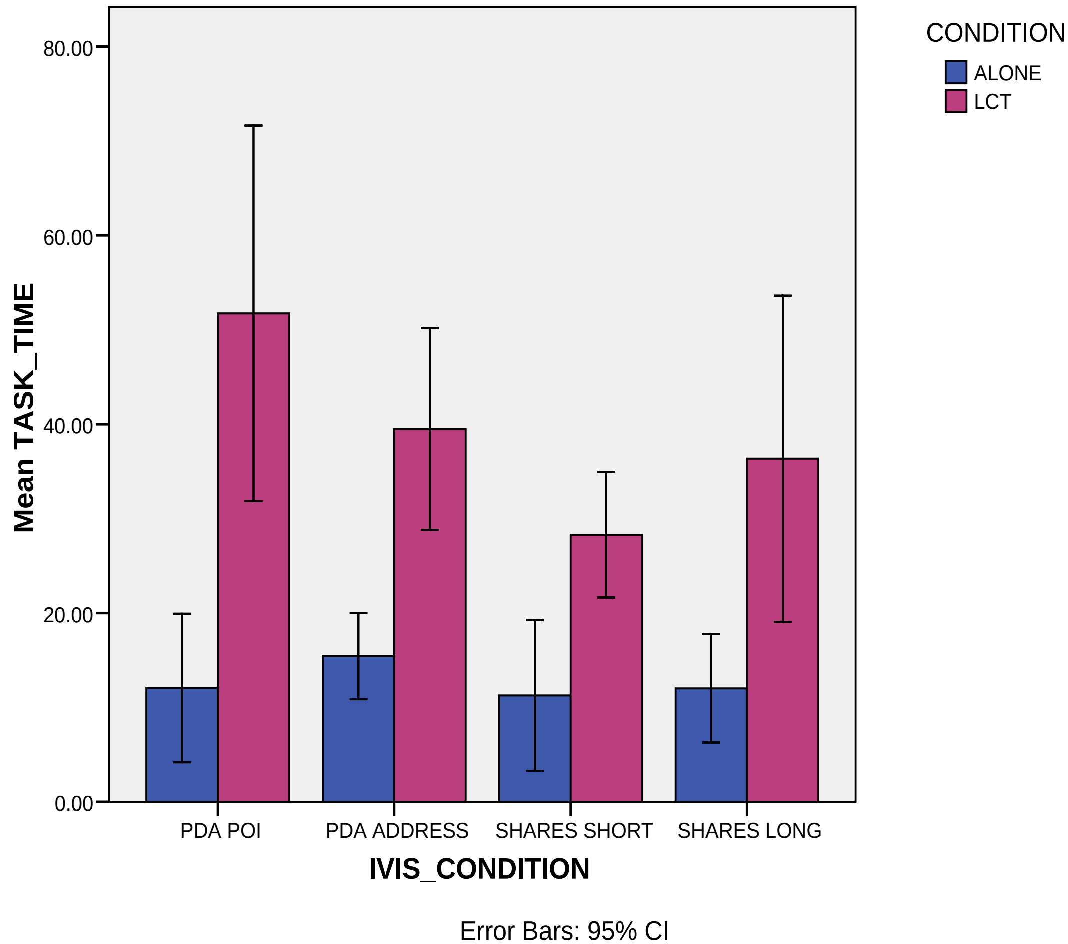

Figure 6: Mean total task time alone and under dual task (LCT) conditions

Comparison of the four IVIS conditions revealed no significant difference in the mean deviation from the normative model for LCT driving between any of the tasks. There was however, an increase in mean total task time in dual task conditions. A paired samples t-test revealed a significant difference in the mean total task time when performed alone and under dual task conditions, t (3) = -4.129, P< 0.05. This indicates that the mean total task time was significantly higher in the LCT condition (M = 24.566) than when performed alone (M = 12.711).

DISCUSSION

Previous research has established the negative effects on driving performance of mobile phone usage. This risk has been quantified by benchmarking the effects to the impairment caused by alcohol at the legal driving limit (80mg / 100ml of blood). The aim of this study was to extend this to include other In-vehicle information systems. Results indicate that as task difficulty increases there becomes a point where impairment is greater than that caused by alcohol intoxication. In the PDA POI condition, identified in the expert review as the least demanding task, participants were similarly impaired in the alcohol and IVIS conditions; however as the difficulty of the secondary tasks increases driver's performance of the Lane Change Task both alone and under the influence of alcohol, was significantly better than performance of the LCT with an IVIS task. The best performance of the LCT task was observed in the baseline (LCT alone) condition. LCT performance under the influence of alcohol was significantly worse than baseline performance but significantly better than performance of the LCT whilst using IVIS. The critical finding of this study is that using an IVIS system while driving impairs the driver's ability to perform the LCT more so than alcohol. The key elements of the LCT are lateral control and event detection. In the driving task there may be some leeway in terms of lateral control. Event detection, however, is a critically important task for safe driving.

Comparison of the four IVIS tasks revealed no significant differences in mean deviation from the normative model. This suggests that despite poorer performance, participants could maintain a consistent level of performance across the four IVIS tasks (evidenced by no significant difference in LCT performance). There is however, a significant increase in mean total task time (TTT) in dual task conditions. The largest differences were observed in the PDA Address entry and Shares Long conditions. The same is true of the Shares Long task as it is the most visually demanding task; again it is reasonable to suggest that this task would compete for resources with the visual elements of the LCT (event detection) as illustrated by poorer performance in dual-task conditions. There is, however, no difference in LCT performance between this and the less demanding shares short task. Expert analysis [39] did not identify any operational differences between the two share price tasks; however there will be a difference in the visual search strategies required on the part of the participant as there is an increase in visual workload due to three scrolling lists rather than one. This is exacerbated by the fact that these tasks are not interruptible, but are system paced and if participants miss the target they have to wait for it to scroll round. These elements would seem the most likely causes of the increases in TTT for the Shares Long task illustrated in Table 3.

One of the aims of this research was to establish a performance value for the LCT beyond which performance should be considered unacceptable. There was however, no significant difference between baseline performance of the LCT and performance under the influence of alcohol. There are a number of possible reasons for this. Firstly, the dosing procedure may not have produced the required blood alcohol level in all participants as the complex interaction of moderating factors makes it difficult to achieve the desired 80g per /100ml rate in every participant. Ideally a participant's blood alcohol concentration would not be directly calculated from the adjusted Widmark factor as, this can be inaccurate [40]. Experimenters should initially calculate intoxication using the Widmark formula and then adjust the amount of alcohol over repeated sessions plotting intoxication-elimination curves for each participant in order to ensure that a precise dosage is given at the time of the experiment. There was a limit to the accuracy of BAC measurement in this study due to the limitations placed on resources. They did not allow for the repeated intoxication of participants and therefore there is an element of unreliability in the BAC measurement. Secondly, the quasi-experimental nature of the design may have introduced a confound. As participants always completed the alcohol condition last, combined with the fact that participants were novice users of the LCT, there may have been a practice effect introduced in the alcohol condition i.e. participants were better at the LCT by the time they completed the intoxicated trials. Therefore, it must be accepted that the mean deviation from the normative model may be lower than its true value due to artefacts introduced by the methodology. Finally, the LCT mimics only two aspects of the driving task (event detection and lateral control). Speed is held constant by the software and so the driver does not have to manage longitudinal control. It is possible that the task demand created by the LCT on its own is insufficient for an impairment effect to be shown at the level of intoxication achieved.

Although no alcohol effect was found there is a well-established method for defining an LCT performance criterion. Based on the findings of this research a value based on the mean deviation from the normative model of the alcohol condition is proposed (1.442 metres). This criterion can be refined as the findings of this study are replicated, extended and as more studies using the LCT are produced[1].

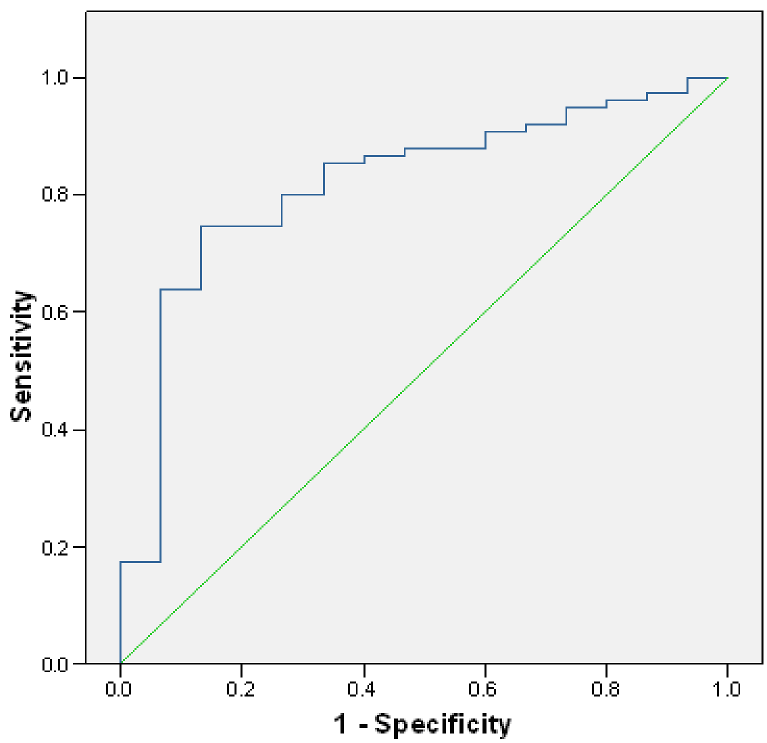

Figure 7: Receiver Operating Characteristic for recommended safety critical criterion value of 1.442 in all conditions.

Signal Detection Theory (SDT; [41]) was applied in order to evaluate the optimal safety critical criterion. Figure 7 is a Receiver Operating Characteristic (ROC) for the recommended safety critical criterion in all conditions. To generate ROC curves the probability that a given

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[1] It has yet to be verified that different hardware configurations (e.g. different graphics processors or steering-wheel input devices) would yield similar measurements and work to standardise critical elements of the technique are ongoing within the ISO standardisation process.

LCT score will correctly identify an unsafe driver (i.e. the probability of a hit or, more formally, the sensitivity of the test) is plotted against the probability that at this score level the driver will in fact be safe (the probability of a false alarm or the specificity of the test). It is possible for the area under the ROC curve to vary between 0.5 (indicating no power to distinguish signal from noise) and 1.0 (indicating almost complete separation between signal and noise distributions). The null hypothesis of any ROC curve is that the true area under the curve is 0.5. ROC curves that bow above the diagonal toward the upper left (as is the case here) denote increasingly sensitive or discriminating diagnostic systems, independent of the decision criteria used. The greater the separation of noise and signal distributions, the greater the area under the ROC curve. In this instance, the area under the curve is calculated to be .820, significantly greater than the 0.5 level. On this evidence in must be concluded that the proposed value of 1.442 as a safety critical criterion for LCT performance is a more than satisfactory indicator of whether the signal is present (unsafe driving).

Criticism of alcohol trials

There are a number of important caveats that must be considered when benchmarking performance to alcohol impairment. Although the impairments caused by IVIS can be as significant as those associated with driving while legally intoxicated, the mechanisms that underlie these phenomena are fundamentally different. Driving while using an IVIS is a measure of a driver's ability to accommodate two tasks (divided attention) whereas alcohol acts as a central nervous system depressant. Alcohol directly impairs a driver's judgment; phone use might delay or challenge judgement, but it does not impair it as such.

Using the benchmarking technique it will not be possible to assess all the effects on safety in driving from the distraction caused by IVIS, as it is necessary to consider a participant's exposure to distraction. Whereas alcohol intoxication imposes a continual risk, distraction imposes only momentary risk. Redelemeir and Tibshirani [5, 11] concluded that cumulative risks associated with alcohol intoxication are much greater than those associated with using a mobile phone. The most significant factor in this difference is the relatively short duration of most mobile phone calls compared with the number of hours in which alcohol stays in the blood stream [50]. When engaging in an IVIS task, drivers can disengage from the task as workload increases. This is illustrated in this study through increased total task times in the four IVIS conditions despite no differences in LCT performance. If participants were constantly engaged in these tasks it could be expected that there may be differences in mean deviation from the normative model across the four tasks as they are designed to differ in terms of difficulty. In contrast, alcohol intoxicated drivers cannot disengage from being impaired in situations of increased workload. Alcohol intoxicated drivers may also consume amounts that result in blood alcohol concentrations far exceeding the legal driving limit.

Pettit, Burnett and Stevens [42] define distraction as a "Delay by the driver in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (**Impact**) due to some event, activity, object or person, within or outside the vehicle (**Agent**) that compels or tends to induce the drivers shifting attention away from the fundamental driving tasks (**Mechanism**) by compromising the drivers auditory, biomechanical, cognitive or visual faculties or combinations thereof (**Type**)". Considering this definition in terms of alcohol intoxication, the impact of alcohol (Agent) on driving performance is primarily poorer lateral and longitudinal control of the vehicle (other impacts associated with alcohol include; increased speed variability, [43]; reaction times, [44]; brake reaction time and body sway, [45]. This is due to the consumption of alcohol, and the driver's subsequent intoxication through the metabolism of alcohol (Mechanism). By compromising the biomechanical and cognitive abilities of the driver (Type) performance is reduced. In contrast, in terms of IVIS use, the impact of IVIS (Agent) on driving performance is primarily poorer lateral and longitudinal control of the vehicle (other impacts associated with IVIS use include; variability in speed, Chaing, Brooks and Weir [36]; reduction in the useful field of view, [46]; variation of accelerator use [47] and brake response times [9]. This occurs through the division of attention (Mechanism) by compromising the physical capabilities and visual performance of the driver (Type). Discussing the two phenomena in these terms leads to the conclusion that the impacts on driving performance are the same even though the mechanisms and agents by which these impacts occur are not. Furthermore, dependent on the IVIS task in question, the Type of distraction may be comparable.

Considerable individual differences in the metabolism of alcohol have been reported [48]. Friel, Baer, and Logan [49] illustrate the variability in absorption time in a study examining time to peak alcohol intoxication in 115 college students who exceeded legal intoxication levels at least twice a month. Participants received a standardised alcohol dose (lower for females than for males) over 10 minutes after which BAC was measured for two hours. The time to peak BAC varied between 10 and 91 minutes after the onset of absorption. Mean BAC were significantly lower in females than in males. Furthermore, a comparison between calculations of alcohol intoxication, using the Widmark equation, and the actual dose given to participants show that the calculated dose 105 and 120 minutes after consumption did not overestimate the true dose, but could underestimate it by as much as 30 ml.

Despite the outlined criticisms and factors that affect alcohol trials the comparison between alcohol impairment and the impairment due to secondary tasks will continue to attract researchers' interest. This is because clear social norms, established thresholds and risks exist for alcohol impairment, which can be used as a benchmark of the distraction potential caused by such devices. Any activity, including the introduction of IVIS, that causes a change in safety-related driving behaviour equal to or greater than alcohol intoxication, should be of concern to society.

CONCLUSION

Driving while intoxicated is a clearly established hazardous activity. The results of this study have demonstrated that the performance of tasks central to the functioning of in-vehicle information systems impair drivers significantly more than alcohol intoxication at the UK drink driving limit. If it is accepted that performance at this limit is unacceptable then it must be concluded that the completion of some IVIS tasks while driving is also unacceptable and it is clear that further research to quantify the demand of different IVIS tasks to determine what tasks are safe to execute while the vehicle is in motion and what tasks are not.

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REFERENCES

[1] *The Road Vehicles (Construction and Use) (Amendment) (No. 4) Regulations 2003*, The Stationery Office Limited, ISBN 0110480171.

[2] Dragutinovic, N. and Twisk, D. (2005). *Use of mobile phones while driving – effects on road safety; a literature review.* R-2005-12. SWOV, Leidschendam.

[3] Violanti, J.M. and Marshall, J.R. (1996). Cellular phones and traffic accidents: an epidemiological approach. *Accid Anal Prev*, 28, pp. 265- 270.

[4] Violanti, J.M. (1998). Cellular phones and fatal traffic collisions. *Accid Anal Prev*, 30(4), pp. 519-524.

[5] Redelmeier, D.A. and Tibshirani, R.J. (1997a). Association between Cellular-Telephone Calls and Motor Vehicle Collisions. *N. Engl. J Med.*, 336(7), pp. 453-458.

[6] McEvoy, S, Stevenson, M, McCartt, A, Woodward, M, Haworth, C, Palamara, P, Cercarelli, R. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. *BMJ*, 428, pp. 331.

[7] Redelmeier D.A. and Tibshirani, R.J. (2001). Car phones and car crashes: some popular misconceptions. *CMAJ*, 164(11), pp. 1581- 1582.

[8] McKnight, J.A. and McKnight, S.A. (1993). The effect of cellular phone use upon driver attention. *Accid Anal Prev*, 25, pp. 259-265.

[9] Hancock, P.A. Lesch, M. and Simmons, L. (2003). The distraction effects of phone use during a crucial driving manoeuvre. *Accid Anal Prev*, 35, pp. 501-514.

[10] Shinar, D., Tractinsky, N., and Compton, R. (2005). Effects of practice, age, and task demands, on interference from a phone task while driving. *Accid Anal Prev*, 37, pp. 315- 326.

[11] Redelmeier, D.A., Tibshirani, R.J. (1997b). Is using a car phone like driving drunk? *Chance*, 10, pp. 5-9.

[12] Strayer, D.L., Drews, F.A. and Crouch, D.J. (2003). *Fatal Distraction? A comparison of the cell-phone driver and the drunk driver.* Proceedings of the second international driving symposium on human factors in driver assessment, training and vehicle design, pp. 25-30.

[13] Burns, P.C., Parkes, A., Burton, S., Smith, R.K., and Burch, D. (2002). *How dangerous is driving with a mobile phone? Benchmarking the impairment to alcohol*. TRL report 457.

[14] Society of Automotive Engineers (1998). *SAE Standard for Calculating the Time to Complete In-Vehicle Navigation and Route Guidance Tasks (SAE J2365),* Committee Draft of November 23, Warrendale, PA: Society of Automotive Engineers.

[15] Tijerina, L., Palmer, E., and Goodman, M.J. (1998). *Driver workload assessment of route guidance system destination entry while driving: a test track study*, Proceedings of the 5th ITS World Congress, Berlin, Germany: VERTIS (CD-ROM).

[16] Zwahlen, H.T., Adams Jr., C.C. and DeBald, D.P. (1988). *Safety aspects of CRT touch panel controls in automobiles***.** In Gale, A.G., Freeman, M.H., Vision in Vehicles II, Elsevier Science, Amsterdam, pp. 335-344.

[17] European Commission (2006). *Commission Recommendation of 22 December 2006 on safe and efficient in-vehicle information and communication systems: Update of the European Statement of Principles on human machine interface*. Commission document C (2006) 7125 final, Brussels.

[18] Society of Automotive Engineers (2002). *SAE Recommended practice calculation of the time to complete in-vehicle navigation and route guidance tasks. (SAE J2364),* Warrendale, PA: Society of Automotive Engineers.

[19] Dingus, T.A. (1988). *Attentional Demand for an Automobile Moving-Map Navigation System,* (unpublished PhD dissertation). Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Industrial Engineering and Operations Research.

[20] Campbell, J.L., Carney, C., and Kantowitz, B.H. (1997). *Draft Human Factors Design Guidelines for Advanced Traveller Information Systems (ATIS) and Commercial Vehicle Operations (CVO),* Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration.

[21] Tijerina, L., Palmer, E. and Goodman, M. (1998). *Driver workload assessment of route guidance system destination entry while driving: a test track study,* Proceedings of the 5th ITS World Congress, Berlin, Germany: VERTIS (CD-ROM).

[22] Green, P. (1998). *Visual and Task Demands of Driver Information Systems* (Technical Report UMTRI-98-16), Ann Arbor, MI: The University of Michigan Transportation Research Institute.

[23] Tijerina, L., Johnston, S., Palmer, E., Winterbottom, M.D., and Goodman, M. (2000). *Driver Distraction with Route Guidance Systems (Technical Report DOT HS 809 069),* East Liberty, OH: National Highway Traffic Safety Administration.

[24] Parkes A.M. and Hooijmeijer V. (2000). *The Influence of the Use of Mobile Phones on Driver Situation Awareness.* Driver Distraction Internet Forum. Available at http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm. Accessed on 24/06/05.

[25] Goujon, S. (2001). *First evaluation of possible occlusion technique criteria.* LAB PSA, Peugeot-Citroen/ Renault. Workshop on Occlusion, Torino, Italy, 12-13th November 2001.

[26] Milgram, P., and van der Horst, R. (1984). *Field- sequential colour stereoscopy with liquid crystal spectacles.* Proceedings Fourth International Display Research Conference. Paris: Societe des electriciens, des electroniciens et des radio-electroniciens**.**

[27] Baumann, M., Keinath, A., Krems, J.F. and Bengler, K. (2004). Evaluation of in-vehicle HMI using occlusion techniques: experimental results and practical implications. *Appl Ergon*, 35, 3, pp. 197-205.

[28] Stevens, A., Bygrave, S., Brook-Carter, N. and Luke, T. (2004). *Occlusion as a technique for measuring in-vehicle information systems (IVIS) distraction: a research*

literature review. Transport Research Laboratory (TRL) report no. TRL609. TRL, Crowthorne, Berkshire, UK.

[29] Gelau, C., Henning, M.J. and Krems, J.F. (2009). On the reliability of the occlusion technique a tool for the assessment of the assessment of the HMI of in-vehicle information abd communication systems. *Appl Ergon*, 40, pp. 181-184.

[30] Rolle, C. (2006). *Augmented reality for driving assistance in cars – usability tests.* Unpublished seminar report, Technische Universitat Munchen, January 2006. Online at http://campar.in.tum.de/twiki/pub/Chair/TeachingWS05DrivingAssistanceHauptseminar/Usability_Tests_Report.pdf

[31] Altmann, E.M., and Trafton, J.G. (2002). Memory for goals: An activation-based model. *Cogn Sci*, 26, 39-83.

[32] Lansdown, T.C., Burns, P.C. and Parkes, A.M. (2004). Perspectives on occlusion and requirements for validation. *Appl Ergon*, 35, 3, pp 225-232.

[33] Noy, Y.I., Lemoine, T.L., Klachan, C. and Burns, P. (2004). Task interruptability and duration as measures of visual distraction. *Appl Ergon*, 35, pp. 207-213.

[34] Chaing, D.P., Brooks, A.M. and Weir, D.H. (2004). On the highway measures of driver glance behaviour with an example automobile navigation system. *Appl Ergon*, 35, pp. 215-223.

[35] Pettitt, M.A., Burnett, G.E., Bayer, S., and Stevens, A. (2006) Assessment of the occlusion technique as a means for evaluating the distraction potential of driver support systems. *IEE Proc Intell Trans Syst*, 153(4), pp. 259-266.

[36] Chaing, D.P., Brooks, A.M. and Weir, D.H. (2001). *An experimental study of destination entry with an example automobile navigation system.* Society of Automotive Engineers, paper 20011-01-0810.

[37] Watson, P.E., Watson, I.D. and Batt, R.D. (1981). Prediction of blood alcohol concentrations in human subjects: updating the Widmark equation. *J. Stud. Alcohol*, 42(7), pp. 547-556.

[38] Horberry, T., Stevens, A., Robins, R., Cotter, S. and Burnett, G. (2007). *Development of an occlusion protocol with design limits for assessing driver visual demand*, TRL, PPR 256.

[39] Pettitt, M.A., Burnett, G.E. and Stevens, A. (2005). *Extending the keystroke level model (KLM) to assess the visual demand of an in vehicle information system (IVIS).* Proceedings of the World Congress on Intelligent Transport Systems.

[40] Mattes, S. and Hallen, A. (2009). *Surrogate distraction measurement techniques: The Lane Change Task*. In M.A., Reagan, J.D. Lee, and K.L. Young (eds.). Driver distraction: theory, effects and mitigation. CRC Press: Taylor & Francis, London.

[41] Brouwer, I.G. (2004). The Widmark formula for alcohol quantification. *SADJ*, 59(10), pp. 427- 428.

[42] Tanner, W.P. Jr, and Swets, J.A. (1954). A decision- making theory of visual detection. *Psychol Rev*, 61(6), pp. 401-409.

[43] Carsten, O. and Brookhuis, K. (2005). Issues arising from the HASTE project. *Trans Res F: Traffic Psych Behav*, 8(2), pp. 191-196.

[44] Pettitt, M., Burnett, G. and Stevens, A. (2007). *An extended keystroke level model (KLM) for predicting the visual demand of in-vehicle information systems*. Proceedings of the SIGCHI conference on Human Factors in computing systems, San Jose: California.

[45] Gawron, V.J. and Ranney, T.A. (1988). The effects of alcohol dosing on driving performance on a closed course and in a driving simulator. *Ergonomics*, 31(9), pp. 119-1244.

[46] Zwahlen, H.T., (1976). The Effects of Ethyl Alcohol on a Driver's Driving Skill, Visual Perception, Risk Acceptance, Choice Reaction Times and Information Processing Rates. *J Occupat Accid*, 1, pp. 21-38.

[47] Liguori,A. and Robinson, J.H. (2001). Caffeine antagonism of alcohol-induced driving impairment. *Drug and Alcohol Depend*, 63, pp. 123-129.

[48] Ward, N.J., Parkes, A. and Crone, P.R. (1995). Effect of Background Scene Complexity and Field Dependence on the Legibility of Head-Up Displays for Automotive Applications. *Hum Factors*, 37(4), pp. 735-745.

[49] Rakauskas, M.E., Gugerty, L.J. and Ward, N.J. (2004). Effects of naturalistic cell phone conversations on driving performance. *J Safety Res*, 35, pp. 453-464.

[50] Dubowski, K. M. (1985). Absorption, distribution and elimination of alcohol: Highway safety aspects. *J Stud Alcohol*, 10, pp. 98-108.

[51] Friel, P.N., Baer, J. and Logan, B.K. (1995). An evaluation of the reliability of Widmark calculations based on breath alcohol measurements. *J Forensic Sci*, 40(1), pp, 91-94.