Chapter xx

Impact of subjective factors on driver vigilance: a driving simulator study

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Introduction

Humans errors are implicated as a causative factor in almost 85% of drivers' crashes (ATC, 2004). Lack of vigilance decreases drivers' performances thus reducing safe driving tolerances, as well as the ability to react to unexpected events and increasing the likelihood of a crash (W. W. Wierwille, 1994; Walter W. Wierwille et al., 1996). In Australia between 1995 and 2005, vigilance decline has been estimated as a contributing factor in 7% of all reported crashes and 15% of fatal crashes. Thus, assessing and preventing vigilance decline has been a major focus of road safety research (Bekiaris, Amditis, & Wevers, 2001).

Existing technology-based solutions used to assess vigilance show deficiencies when deployed in real driving situations. They are often based on a single device (PERCLOS, Lane Position, Time to Line crossing, etc) and they offer a limited representation of the driving context which has been pointed as a critical aspect of the reliability and user acceptability of such systems.

Deeper analysis of the problem suggests that combination of several devices should provide a more reliable estimation of the driver's state, through a more complete representation of the driving situation. To date, little research has examined this approach, but recent ones tend to support it (Zhu, Ji, & Lan, 2004)

Three main kind of factors that impact on vigilance have been identified. They are task factors, environmental factors and subjective factors (Johns & Counselling., 2004; Wellbrink, Zyda, & Hiles, 2004). In this context, our approach consists in combining information related to factors and consequences of vigilance coming from the driver, the vehicle and the environment in order to build a reliable and robust system able to assess and prevent driver vigilance decline (Gruyer, Rakotonirainy, & Vrignon, 2005a, 2005b)

This paper investigates the impact of subjective factors on driver's vigilance, using the driver's psychomotor performances assessed using an unobtrusive Psychomotor Vigilance Task (PVT). We first described our experiment, with the design of the scenario used on a driving simulator, and the designed of a non-obtrusive Psychomotor Vigilance Test enabling to assess performance of the driver while driving. Then, the impact of subjective factors reported by participants is analysed with ANOVA. Finally, the outcomes of this study are discussed to estimate the potential of each of the subjective factors in a multi indicator vigilance estimation system.

Methodology

Participants

A panel of twelves drivers (6 females and 6 males) took part in the study. Participant were recruit through media release and were required to hold a current full driver's license for at least 1 years, and drive a car on weekly basis. They gave their written informed consent and received 20 Australian dollars incentive. Ethics approval for the study was granted by the Human Research Ethics Committee of the Queensland University of Technology.

Driving Simulator

Experimentations were conducted on the SiVIC™ driving simulator supplied for the proposed research by the LIVIC laboratory (Laboratory on Vehicle-Infrastructure-Driver Interaction located in Versailles, France). The rendering capabilities of this simulator enable to display a realistic driving environment of highways and country roads. The SiVIC™ enables to program and monitor all the elements of the environment (point of view, mirror, speedometer, car, pedestrian, tree, building, road sign, lights, smog, etc). Participants sat in front of 2 meters by 2 meters screen where the driving environment was displayed with a projectors. The field of view was 120 degrees which provided a realistic visual motion and a proper perception of the driving environment (Allen, Cook, & Park, 2005). Six audio speakers system was used to reproduce the sound of the vehicle, the driving environment, including Doppler Effect and three-dimensional position of sources, and with a disposition which insured audio immersion of the driver in the driving environment. Then a view from the inside of the vehicle, with a speedometer and a rear mirror was displayed. Participants were driving an average automatic sedan car using a computer’s steering wheel which provides a force feedback, and a two pedals set (brake and accelerator).

Psychomotor Vigilance Test

We used Psychomotor Vigilance Test (PVT) to assess performance of the participants all along the experiment. According to the aimed of the entire project in which this research was conducted (as explained in section Introduction and Discussion), the PVT used was specifically designed in order to minimise its intrusiveness on driving behaviour. For this design, we took into account the multiple resources model proposed by (Wickens, 2002), as well as experimental results which supports part of this model (Sigman & Dehaene, 2005). The resulting

PVT exploits the parallelism of perception stage and response stage in order to interfere as less as possible with the driving task.

The resulting PVT was analogical to a choice reaction time task. Stimuli provided were audio, and participants were asked to response verbally to the stimuli. Two kinds of stimuli, called signal and noise, were provided to the participants who were asked to answer respectively ‘yes’ or ‘no’. Stimuli were displayed through a pair of dedicated stereo speakers placed on both side of the steering wheel.

The stimuli were simple tones of 15 ms, with frequencies of 440 Hertz and 300 Hertz for respectively the signal and the noise. Frequency, regularity, and probability of the stimuli were the same for each participant, in order to avoid impact on performance of these known confounding factors. Stimuli were displayed every 8 seconds, with a standard deviation of 1.3 seconds to avoid anticipation from the participants. The signal-to-noise ratio was 0.69. These parameters were chose during a pilot study in order to get the best compromise between impact on driving behaviour, temporal definition and subjective bias.

Procedure

Test period of 15 minutes was conducted for each participant before the experiment. The aim of this test period was for the participant to feel comfortable with the simulator and the PVT in order to limit their impact on his normal driving behaviour.

Firstly, each participant ran a free drive session of 15 minutes on the simulator, in order to get familiar with the driving interface. This training session uses the same scenario than the experiment described in the section *Driving Scenario*.

Secondly, each participant completed a training phase for the PVT performed without driving. This phase starts with the adjustment of the volume of the stimuli in order to enable a proper perception from the participant. Performance feedbacks are continuously provided to the participant during practise. Performances of participants were then expected to increase during PVT practise. Hence, after approximately 5 minutes of training, the performance of the participant converge to a maximum of performance and stop increasing (Benedetto, Blasiis, & Benedetto, 2004; Lamond & Dawson, 1999) ending the training phase.

Thirdly, the participants run a driving session with PVT, to practise dual task for approximately 5 minutes.

After this test period, the participant started the experiment as describe the section Driving Scenario, and while performing the PVT.

Driving Scenario

The driving scenario was identical for each participant. It was designed to induce decreasing vigilance without interfering with fatigue effects in a stimulated environment.

The driving environment was monotonous, with little and repetitive stimulus, reproducing the driving condition that can be found on rural road in Australian.

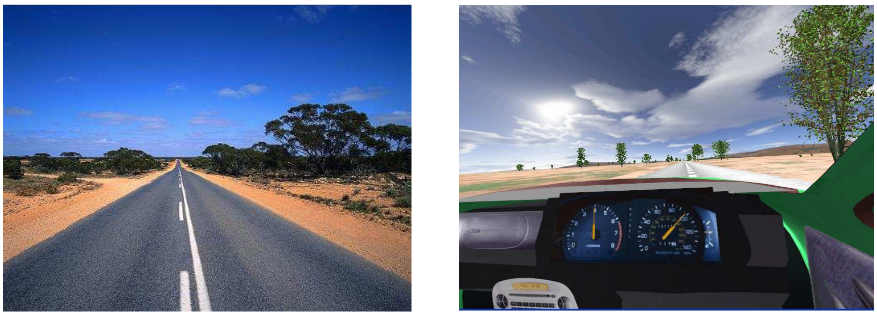
Such monotonous environment have high crash exposure, and vigilance decrement are among the factors contributing to these crashes (Meuter, Rakotonirainy, Johns, Tran, & Wagner, 2005; Thiffault & Bergeron, 2003).

The driving itinerary consisted of a two-way rural road with a speed limit of 100 km/h, one lane in each way, and width of the road, lane marking and road shoulder width reproducing real driving condition (Figure 1). Road trajectory was inspired from a real road, with light curve which avoid impact on car speed.

Experiments took place during the afternoon, between 1 p.m. and 4 p.m., at a critical phase of the circadian cycle in terms of vigilance decrement (Lenné, Triggs, & Redman, 1997; Loh, Lamond, Dorrian, Roach, & Dawson, 2004).

Finally, road sign were added respecting the frequency of road sign in rural environment and in order to insure the knowledge of the driver of the speed limit, car in the opposite direction were added in average every 2 kilometres, and participants were asked to drive in the centre of the left lane.

Figure 1 Road condition reproduced in the driving simulator



Australian rural road — Driving Simulator Scenario

Subjective Factors

Subjective factors were collected for each participant before the experiment using standard questionnaires. The questionnaire consists of:

- personality profile was assess using an abbreviated form of the EPQR (Eysenck, Eysenck, & Barrett, 1985) proposed by Francis, Brown and Philipchalk (1992), enabling to assess four personality dimensions: Extraversion, Neuroticism, Lie Scale, and Psychoticism;
- cognitive failure score was collected using the Cognitive Failure Questionnaire (D. E Broadbent, Cooper, FitzGerald, & Parkes, 1982);
- general information about participant related to age, gender and Body Mass Index (BMI).

Participant Vigilance

We base our approach on existing works on Human Information Processing Model (Donald E. Broadbent, 1958a; Mackworth, 1950; Sigman & Dehaene, 2005; Wickens, 2002). We then assumed that vigilance influence the allocation of attention needed to perform any task, and that several factors (environmental, subjective or link to the task) can influenced vigilance level, impacting on the ability to perform tasks.

During the experiment, participants performed the unobtrusive Psychomotor Vigilance Task (PVT) detailed in section *Psychomotor Vigilance Test*. According to the model of Human processing (Donald E. Broadbent, 1958b), and experimental findings (Mackworth, 1950; Meuter et al., 2005; Wellbrink et al., 2004) performance on such a task were expected to be influenced by the vigilance of the participant.

Various performance metrics have been proposed in previous research to study performances on similar tasks. Mackworth (1950), studied participants' vigilance through the evolution of reaction time and misses. Wellbrink et al. (2004) assessed vigilance in terms of mean reaction time and standard deviation of percentage of false alarms and misses. Loh, Lamond, Dorrian, Roach, & Dawson (2004), studied the validity of short psychomotor test. They used the mean RT, the fastest 10% of RT, the lapses percentage, and the slowest 10% of RT. Williamson et al. (2000), combined the Reaction Time (RT) and the accuracy in order to make a analogy between effect of alcohol and effect of sleep deprivation on several psychomotor task. Meuter et al. (2005) analysed the mean reaction time to investigate the effect of monotony on vigilance, and found variation of up to 50% of RT depending on the monotony of the performed task. Sigman & Dehaene (2005) analysed the mean and the inter-quartile range of reaction time to investigates effect of task manipulation on performance.

For the present research, we computed the following performance metrics for each participant: most probable reaction time, mean Reaction Time, standard deviation of Reaction Time, lapses percentage, misses percentage and errors percentage. Each metrics were computed for each participant using the data collected all along the experiment. These performance metrics were then used in analysis to evaluate how vigilance is impacted by the different subjective factor collected, according the expected impact of a low vigilance on these performance metrics (Table 1).

Statistical Analysis

In order to investigate the effect of subjective factors on performance metrics, the effect of subjective factors on the six performance metrics were analysed across groups based on subjective factors using separate repeated measures analyses of variances (ANOVA).

Table 1 Expected impact of low vigilance on performance metrics

Metric	Consequence of a low vigilance
Mode of RT	Low
Mean of RT	Low
Standard deviation of RT	High
Errors %	High
Misses %	High
Lapses %	High

In order to run ANOVAS, participants were divided in two groups for each subjective factor. For Age, participants were divided in two groups based on the median age of the entire pool (Age=45). For the Body Mass Index, participant were divided in two groups based on the median of the entire group (Age=27). It happen that this separation is equivalent to separate participant in normal weight participant (BMI<25) and overweight participant (BMI>25). For each of the Personality dimension extracted from the EPQR-test, as well as for the cognitive failure scores, participants were each time separated in two groups based on the median value of the entire groups.

For the responses of participants, transformation were made in order to insure normality of distribution according to assumptions of ANOVA analyse method. Inverse of square roots was used for Mode and Mean of Reaction Time, and square root was us for percentage of error, misses and lapses.

Results

Variance of Reaction Time

Separate ANOVAs indicated that mode of reaction time distribution was significantly affected by age [F(1,12)=5.81,p<.05], gender [F(1,12)=5.35,p<.05], extraversion score [F(1,12)=4.4,p<.1], and Body Mass Index (BMI) [F(1,12)=3.22.4,p<.1] (Table 2). Results shown that younger participants, females, participants with low extraversion score and participants with BMI inferior to 25 get a shorter reaction time than, respectively, older participants, males, participants with high extraversion score, and participants with BMI superior to 25 (Figure 6). No other significant impacts or relations were found for the others subjective factors.

Standard Deviation of Reaction Time

Standard deviation of reaction time distribution was significantly impacted by age [F(1,12)=9.11,p<.05], extraversion score [F(1,12)=5.81,p<.05], gender [F(1,12)=4.41,p<.1] and BMI [F(1,12)=4.98,p<.05] (Table 2), with younger participants and males getting less variation of their reaction time than respectively older participants and females, and high extraversion score and high BMI participants getting less variation of reaction time than respectively low extraversion score and low BMI participants (Figure 6).

Table 2 Impact of extraversion on performance metrics

	Age		Genre		Extraversion		BMI	
Metric	*F* (1,12)	*p*	*F* (1,12)	*p*	*F* (1,12)	*p*	*F* (1,12)	*p*
Mode RT[a]	5.811	.033*	5.355	.039*	4.406	.057	3.224	.098
Mean RT[a]	9.105	.011*	4.417	.057	5.808	.033*	3.953	.070
Variance	5.887	.032*	5.205	.042	5.402	.038	4.978	.045*
Lapses %[b]	5.217	.041*	4.937	.046*	7.539	.017*	9.869	<.001

Note: [a] ANOVA conducted on transformed data ($1/\sqrt{x}$). [b] ANOVA conducted on transformed data ($\sqrt{x}$). * p<.05

Mean Reaction Time

Significant impacts were found on mean reaction time for age [F(1,12)=5.89,p<.05], gender [F(1,12)=5.20,p<.05], extraversion score [F(1,12)=5.40,p<.05], and BMI [F(1,12)=3.95,p<.1] (Table 2, figure 6). No other significant impacts or relations were found for the others subjective factors.

Percentage of Lapses

Percentage of lapses has been found significantly affected by age group [F(1,12)=9., p<.05], extraversion [F(1,12)=4.21, p<.1], gender [F(1,12)=3.71, p<.1], and BMI [F(1,12)=9.87, p<.001] (Table 2). High extraversion score participants were then found more vigilant than low extraversion score participants. Older participants and females were found more sensitive to vigilant decrement than respectively younger participants and males (Figure 6). All other subjective factor did not have any significant impact on this vigilance metrics, and no significant interactions were found between any of the collected subjective factors.

Percentage of Error and Misses

For Percent of error and percent of misses, no significant impacts or relations were found for any of the subjective factors.

Discussion

Our aim was to investigate the impacts of subjective factors on driver vigilance. We collected data on a driving simulator and asked the participants to perform a non intrusive psychomotor vigilance test while driving. This test enabled us to identify and assess performance metrics. Subjective factors were collected for each participant using standard questionnaires. ANOVA analysis identified significant impacts of some subjective factors on performance metrics.

Age and gender have been found as reducing significantly mean reaction time, most probable reaction time, standard deviation of reaction time and percentage of lapses. Analysis indicates that younger participant perform better than older ones, and that male perform better than female. An interaction between age and gender has also been found, and female performances on these metrics are significantly more affected by age than male performances. However, no impacts of these two subjective factors have been found on error percentage and lapses percentage.

Cognitive failure, which was expecting to impact on performance metrics, has not been found as having a significant impact on any of the performance metrics collected during the experiment.

Each participant answered the EPQR-A test (Francis et al., 1992), a shorter variant of the Eysenck personality questionnaire which enables to assess four personality dimension: Neuroticism, Lie Scale, Psychoticism, and Extraversion. From these four subjective factors, only Extraversion has been found as impacting on performance metrics. Significant impact has been found on mean reaction time, most probable reaction time, standard deviation of reaction time, and percentage of lapses. Analysis showed that participant which perform a high extraversion score performed better than participant which performed a low extraversion score.

Finally, Body Mass Index (BMI), which is computing using the reported mass and size of each participant, as been found as having a significant impact on several performance metrics (on mean reaction time, most probable reaction time, standard deviation of reaction time, and percentage of lapses). Results of analysis suggested that participant which report a BMI superior to 25 (overweighted person) perform better on these metrics than participant reporting a BMI inferior to 25 (normal weighted person).

This result enables to get an estimation of the performance of a driver according to subjective factors. Thus, female, older driver, low BMI and low extraversion driver are more likely to show low psychomotor performance which can then reduce their safe driving tolerance. In a next stage of our project, evolution of psychomotor performance along the experiment will be correlated with existing vigilance indicators (such as PERCLOS, Lane Position, Time to Line crossing, etc) Combination of these information (Gruyer et al., 2005a, 2005b) should then enable us to get a better estimation of the driver performance while driving.

Figure 5 Interaction of age group and gender on sigma

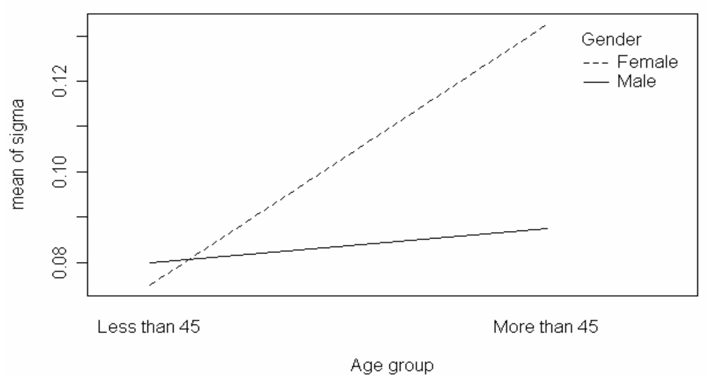
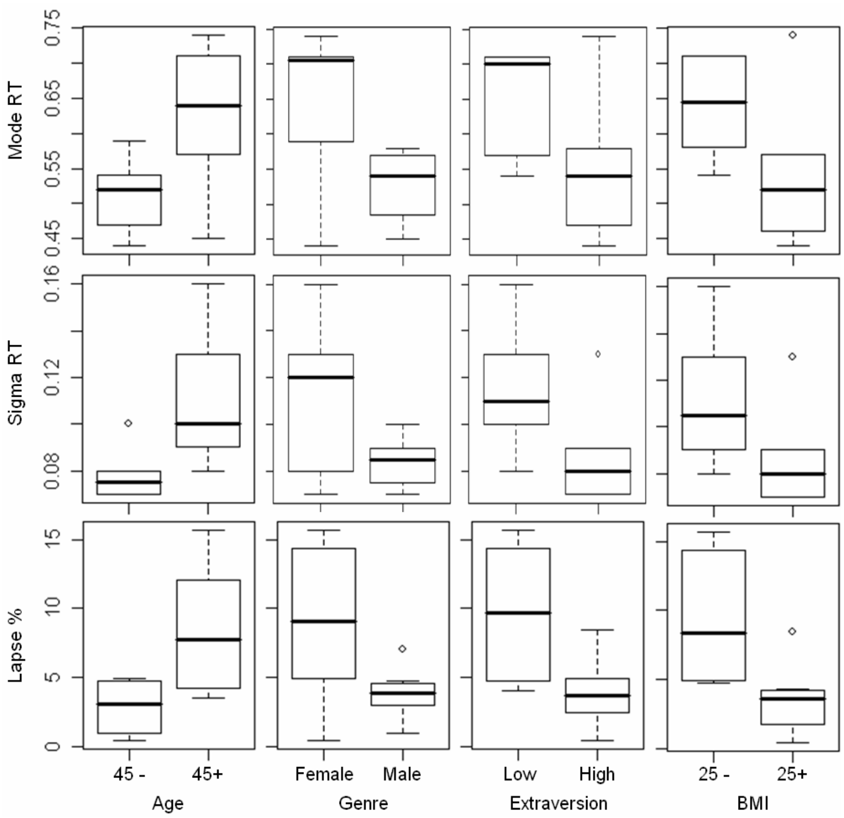


Figure 6 Effects of subjective factors on performance metrics



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