Driver’s Response Towards Different Road Complexity: A Preliminary Study

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Abstract

Nowadays, detection of driver’s comfort and fatigue is a major concern in vehicle design, road safety and transportation research. Driving tasks require full attention from the drivers while controlling the vehicle. This study aims to analyse the driver’s performance via three types of physiological measurements in a simulated condition. An integrated approach by combining subjective and objective methods were used in this study. There are Karolinska Sleepiness Scale (KSS), Electroencephalogram (EEG) and Heart Rate (HR). Twelve participants were recruited to evaluate their responses in 25-minutes of driving activities under monotonous road by using suburban area in simulated condition. The findings showed that there are differences in physiological responses for this driving session. KSS value, HR and event-related power modulation at Beta activity shows higher values at the end of the driving activity compared to the beginning and mid of driving. In conclusion, the road environment, driving condition and driving duration plays significant role in determining drivers’ response. This study can be used as reference to drivers and related agencies by taking into account the physiological effects of driver’s performance based on road complexity and driving duration.

Keywords: Comfort; Fatigue; Safety; Behaviour; Physiological

Introduction

Driving comfort are among the main factors in automotive design and manufacturing where related issues such as driver’s discomfort and driver’s fatigue are the main focus. Even though many studies related to driving comfort had been done over the past decade, there are many unanswered question and problems yet to be solved regarding this matter [1-5].

Driving activity may expose to road accidents, where the main factors based on the past studies are due to the lack of drivers. Driving discomfort is also often experienced when the drivers drive after prolonged period in continuous and get physical disorders. As a result, causes of accident usually accident caused by fatigue rather than the other causes. Fatigue driver react more slowly and their and deliberations in driving are easily disrupted. This causes frequent injuries and death each year, which in fact it can be avoided. [1, 6, 7, 8].

Issues related to driver’s condition particularly are discomfort and fatigue, have been particularly concentrate in automotive industry, where comfort driving is one of the priorities in the design and manufacture of cars. Many studies have been carried out on the driver’s situation in the last decade [9-12]. However, many studies were conducted on this issues, there are still unanswered red questions and probes that cannot be solved in relation to the driver’s condition. This may be because there is no emphasis given to the driver’s condition in the past and existing studies. In addition, the findings from studies conducted so far are not clearly stated and addressed comprehensively.

Different types of workload other than driving task which includes manual and visual task such as processing driving information, operating and understanding the vehicle operation as well as focusing on the roadway environment while going through heavy traffic, poor road condition and time constrain will contribute to the fluctuating of the driver’s workload and will affect the driver’s emotion which in turn will decrease the driving performance [13-18].

Secondary task distraction has been widely discussed and according to previous studies, drivers requires 7 to 12 second to regain awareness when encounter an event that might lead to hazardous driving and road crashes despite the driver being fit before the drive. Secondary task distraction includes using the mobile phone either to make calls or to reply text, in-vehicle technology such as global positioning system (GPS) and radio, eating and drinking, reaching for objects in the vehicle, conversation with the passenger, and smoking [19, 20].

Furthermore, characteristic of road geometry and traffic density plays an important role in driving alertness among drivers. Previous studies has shown that monotonous roads can cause drowsy driving and worst, it can cause accident due to the slow information processing and lack of vigilant. It is found that the risk of falling asleep is higher on monotonous road where boredom is easily occurred. Other than that, it is observed in a simulation study that the driving performance
decrease faster on straight roads rather than curve roads [21].

The prolonged drive can affect the increased fatigue, task disengagement, distress and worry [22]. Besides, driving on monotonous environment can cause a passive fatigue. Rapid task engagement declined was associated with passive fatigue [23]. In the monotonous environment with straight roads with small speed variability, driver’s cognitive fatigue can be successfully elicited in the period 60-min of prolonged driving [24].

Therefore, the assessment towards the driver’s condition, according to the task and driving position is important to ensure a safe and comfortable driving experience while handling to control the car. Car simulator is used in related research to the interaction between driver and the environment has many advantages over the naturalistic driving. Its advantages include more experimental control, efficiency, cost savings, safety and convenience in data compilation [25, 26]. Such that, this study was conducted to examine the impact of the road environment towards the driver in the simulated condition. Furthermore, the results of this study can be applied by the agencies or the related bodies with the road safety.

Methodology

Participant’s criteria

There were 12 participants involved in this study with mean age of 23.5 years old. This sample size is adequate for this type of study because as suggested by Sekaran & Bougie [27], the minimum sample size involving experimental studies is 10 participants. Participants are advised to have normal sleep patterns and not to take any type of caffeine in 24 hours before conducting the experiments. This is because the previous studies show that the caffeine can affect the driver performance [28]. In addition, participants need to keep their hair in dry condition and free from any hair cream or hair gel to facilitate the electroencephalogram (EEG). Participants drive using the car simulator located at the Ergonomic Laboratory, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM). The UKM Ethics Committee granted with permission to this study with reference number UKM PPI/111/8/JEP-2016-200. All the participants involved voluntarily and had signed an informed consent form in accordance with the institutional guidelines.

Design of experiment

Basically, this study employed three types of physiological measurements comprise of one subjective method namely Karolinska Sleepiness Scale (KSS) and two objective methods namely EEG and Heart Rate (HR) in order to evaluate driver’s reaction and response towards driving performance. All participants need to attend the driving session twice on the different days but at the same time. This stipulation is inline to the previous studies that state the different experimental repetitions need to be carried out at different times and days because it can affect the drivers [26]. Before the actual drive is carried out, the participants need to drive and familiarize themselves with the design of the simulation car and the applied environment as shown in Figure 1. Participants should drive using manual transmission gear while driving a car simulator as shown in Figure 1. This experiment is operated in a controlled and secure environment. Simulated driving has been used by many researchers in the past study to determine the performance of drivers when applied to different types of driving scenarios [25, 29-31].

Figure 1: Car simulator and road environment used

Figure 2 shows the experimental flow chart. An EEG measurement tool was fitted to the participants before the experiment was recorded. Participants should ensure they are driving with a steering and hand steering position at 10-2 and driver’s seat position in comfortable condition. The speed limit when driving was set at a speed of 70 km/h. The drive need to drive for 25 minutes on the monotonous road with light traffic flow in the suburban area.
Electroencephalogram (EEG)

Figure 3 shows the wireless Emotiv Epoc EEG is used in this experiment to measure brain activity during driving. There are 14 active channels on this equipment that attached to the head of participants to get the reading of brain wave subject. EEG measures the electrical impulse in the brain by using some electrode that place on the scalp. The electrode (Ag / AgCl integrating electrode) is conductor whose electrical current enters or leaves. The raw data obtained is uploaded to the computer and analyzed. Figure 3 shows the components of the EEG tool used and Figure 4 shows the raw data of EEG. For this experiment, only Alpha and Beta values are take into account because the purpose of the experiment is to see the implications of interference imposed on driving performance. Therefore, the active channel at the head is taken for this purpose which channel on the frontal head.

By using Epoc control panel software, raw data were obtained. Raw data were obtained from the Emotiv Epoc tool is then stored into the European Data Format (EDF). Through the EDF format, data obtained from this format is imported into the Brain Vision Analyzer software by different channel types. Next, filter the data first. All the artifacts are removed such as eye blinkers and unwanted movement.

The resulting waves are Alfa, Beta, Delta and Theta. Next data is imported to Microsoft Excel for Event-related power modulation (%) or ERpow (%) by using the formula below:

\[
\text{ERpow} = \left( \frac{\text{Pow event} - \text{Pow baseline}}{\text{Pow baseline}} \right) \times 100
\]

The transform of ERpow is defined as an increase or decrease in the percentage of Power Density by comparing the basic data and the data while driving. Therefore, the ERpow increase is expressed as a positive value and ERpow decrease as a negative value. Referring to sources from Brain Works Neurotheraphy, function human brain lies in five different frequency groups as described in Table 1. The frequency waves are Delta, Theta, Alpha, Beta and Gamma.

| Waves | Frequency (Hz) | Mind Condition                        |
|-------|----------------|---------------------------------------|
| Delta | 0.5 – 3.0 Hz   | Deep sleep                            |
| Theta | 3.0 – 8.0 Hz   | Drowsiness                            |
| Alfa  | 8.0 – 12 Hz    | Relaxed but alert                     |
| Beta  | 12 – 38 Hz     | Highly alert and focused              |
| Gamma | 38 Hz and above| High level information processing     |

Karolinska Sleepiness Scale (KSS)

This study used KSS to determine driver’s alertness before and after driving. It consists of nine point scale where 1 = extremely alert, 2=very alert, 3 = alert, 4=rather alert, 5 = neither alert nor sleepy, 6=some signs of sleepiness, 7 = sleepy, but no difficulty remaining awake, 8=sleepy but some difficulty to keep awake, and 9 = extremely sleepy, great difficulty to keep awake, fighting sleep.

Heart Rate (HR)

Wahoo Fitness equipment has been used in this study to detect driver’s response in term of cardiac activity while driving. The HR fitness tracker as illustrated in Figure 4 will be mounted on the participant chest. The data will be transferred by using Wahoo Fitness application and it can collect the data in heart rate per
second.

Figure 4: Wahoo Fitness

Result and Analysis

KSS analysis

Based on the findings, the average KSS before driving is 3 (alert), then after driving, the KSS value increase to 5 (neither alert nor sleepy). It indicates the participant still alert and not yet sleepy after 25 minutes of driving activity. It may be due to the road and driving condition which is no disruption is given in this study.

HR and EEG analysis

Figure 5 shows the findings for HR and EEG. The HR value decreases at the mid of driving activity. However, there is an increment of HR value at the end of driving activity, which is after 20 minutes of driving. Past study highlighted the HR will increase when the person is experiencing the mental stress and in high-demand situation [32].

![HR and EEG findings](image)

Figure 5: HR and EEG findings

In term of EEG analysis, this study only considered the data from the Frontal lobe and Occipital lobes. Both lobes take into account the visual focus and stimuli. In terms of beta frequency in this study, ERpow is low in three phase of normal driving conditions (up to 20 minutes) compared to alpha frequency, from 62.14%:80.75% to 28.63%:47.52% (beta:alpha) except for fourth phase (20 to 25 minutes of driving) with 60.55%:50.67% (beta:alpha). The increment of alpha frequency and decrement of beta frequency from beginning to the mid of driving indicate that the drivers are sleepy and less alert to the driving task. The lowest value of ERpow at the frequency beta was recorded at third phase (15 to 20 minutes of driving) with 28.63% and the highest was recorded at the beginning of driving activity with 62.14%. The value for beta frequency is higher and alpha frequency is lower at the end of driving condition compared to the mid-driving, possibly due to the situation where the drivers know that they will arrive at the destination after 25 minutes of driving. It is in line with study carried out by Ahlström et al. (2018) which mentioned that the driver will feel more alert when the final destination is almost there.

Conclusion

Performing driving activity without any disruption and secondary task may degrade driving performance. Another factors that been considered are driving duration and complexity of road environment. This study shows driver's physiological performance and condition affected by the road condition and driving duration. A 25-minute drive without disruption under monotonous road with light traffic condition shows different physiological effects on drivers. KSS findings show that the driver was neither alert nor sleepy at the end of the driving activity. This findings is supported by the results from HR and EEG, where are there are quite significant differences that can be seen between beginning, mid and at the end of driving. The findings from HR in average indicates that HR value is higher compared to the mid of driving activity. However, there is an increment of HR value at the end of driving activity, which is after 20 minutes of driving. Regarding EEG result, it shows similar trend with HR, when there is also decrement of ERpow value at both alpha and beta frequency from beginning to mid of driving. Then, the ERpow is increase at the end of driving. In term of the driver’s condition with regards to the ERpow at both frequency, it shows that the drivers feel quite sleepy at the mid of driving and become alert at the end of driving. Generally, the findings of this study provide direction for future studies and for the development of fatigue prevention equipment and detectors. In addition, it can provide a guideline for the related agencies to improve the road safety issues.

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