ORIGINAL ARTICLE

A PRELIMINARY STUDY ON DRIVER'S MENTAL WORKLOAD IN URBAN AND RURAL ENVIRONMENT

Nurainaa KABILMIHARBI[1], Nor Kamaliana KHAMIS[1*], Madihah MUJAINI[2]

[1]*Department of Mechanical and Manufacturing Engineering, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia*
[2]*Mechanical Engineering Department, Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor, Malaysia*
[*]*email: kamaliana@ukm.edu.my*

ABSTRACT

Statistics showed that mental workload is among the top 10 causes of accident in Malaysia which leads to more than a thousand deaths from 2011 to 2018. Driving distraction forces the driver to focus on causes other than driving thus, this condition will increase the mental workload among the drivers. Factors that can contribute to the increment of driver's workload includes vehicle, human-related and external factors. This study aims to assess the driver's mental workload using two types of subjective evaluation namely the NASA TLX and Karolinska Sleeping Scale (KSS) on different types of road environment complexity.
Methods: Six healthy participants performed a simulated driving task for two different road scenes which are urban and rural road where the NASA-TLX and KSS score were recorded.
Results: Results show that the different road environment complexity affects the driver's mental workload differently where NASA-TLX average score for urban road is higher compared to the score for rural road. On the other hand, KSS level indicates a higher score on sleepiness level when driving on the rural road compared to driving on the urban road.
Conclusion: These findings might be useful as a reference to further understanding of driver's mental workload when driving on different type of road environment complexity.
***Keywords**: Driver's Mental Workload, Road Environment Complexity, NASA-TLX, KSS*

INTRODUCTION

Mental workload has a significant effect on drivers, especially during peak load. This behaviour tends to distract drivers from focusing on their main task which is driving. Distraction while driving may cause unwanted accidents or in worst condition can cause death. Referring to fatal accident statistics in Malaysia, mental workload is one of the top ten causes of transport accident which records a total of 1041 deaths from 2011 until 2018 (PDRM, 2019).

Despite the interest of workload has no clearly defined meaning for the past 40 years, yet it is a universally accepted definition. Before the 1970s, the term "workload" was not common and the organizational meanings of workload from different fields remain incompatible with its tools, processes, effects and measurements (Huey & Wickens, 1993). Workload characteristics come in three detailed categories; the amount of work to be done and the number of tasks to be performed, time to be completed and time to be spent, and the human operator's subjective psychological experiences (Lysaght & Hill, 1989). The main reason for measuring the workload is to compute the mental rate of performing tasks to predict the performance of operators and systems. It is therefore a temporary measure and should provide insight into where increased demand for tasks can lead to unacceptable performance.

The cause of accidents in transport can be categorized into three different types of variable, namely, vehicle factors, human factors (human error) and external factors (including road conditions) (Soehodho, 2017). These aspects include mental stress, physical and psychological state; sleep, fatigue and alertness; and health status (Taylor & Dorn, 2006).

Vehicle Factor
The introduction of the information system (car-radio, multimedia and route guidance systems etc.) in the vehicle today creates a great challenge of increasing drive requirements. All of these In-Vehicle Information System (IVIS) require the attention of the drivers to be divided between the system and the main task of vehicle control. Automation of vehicles in this century is another compelling phenomenon with obvious benefits. The early automation research has been performed in the 1990s on mental workload. An analysis of automation and the reduction of cognitive workload linked to some types of automation have been described in a study (Stanton & Young, 1998). Since then, a considerable amount of effort has been placed into particular automation systems. The results of the analysis were different from that of the previous studies that showed the use of the adaptive cruise control (ACC) program to improve performance and understanding of situation awareness (SA) under

typical drive conditions and to reduce drivers mental workload (Ma & Kaber, 2005). On top of that, most studies found that high workload effect is due to auditory and visual distractions such as the IVIS (Koo et al., 2009; Liu & Wen, 2004; Young & Stanton, 2007; Ward et al., 2006; Young & Stanton, 2002).

Human-Related Factor

Human related factors are factors that affected the drivers that cause the driver to concentrate on doing something other than driving such as eating, texting, making calls, smoking or talking to passengers (Almahasneh et al., 2014). These tasks are also known as a secondary task where it will lead to dual working conditions (Liu, 1996). Increasing the demand for visual scans of the drivers while undergoing secondary task, often interferes more with a parallel spatial task than with a verbal task. The results in studying the effects of mental workload on visual search, discrimination and decision making in real traffic conditions have indicated that the increased workload produce endogenous distraction and spatial gaze concentration, affecting the capacity to process visual stimuli (Recarte & Nunes, 2003). High mental workload contributes to eye limitation and pupil size increase (Reimer, 2009). Other than that, age is another factor that relates to decreases in perceptive, response times, mental memory, attention, intensity and quality of dexterity. Therefore, many researchers have analyzed cognitive workload with age as the main driver property where differences in reaction time of different age groups were investigated to determine the impact of reaction time by the mental workload and the findings indicated that high mental workload increases the average reaction time for each age group and in addition, influences aged drivers reaction times significantly (Hakamies-Blomqvist et al., 1999; Makishita & Matsunaga, 2008). Certain aspects of driving characteristics such as accident history, driving skills and training were also considered. In the simulated driving activities of road risk management, the subjective cognitive load of experienced drivers was significantly lower than the novice driver (Wang et al., 2010).

External Factor

External factors such as the road design and road environment are crucial to the driver's visual and psychological workload (Verwey & Zaidel, 1999). Environmental features such as road curvature, road signs, roadside signage, billboards, traffic, weather and many others, were studied separately. For example, there are studies done on the rate of change in road curvature was introduced as an independent variable and was used as a test for objective road problems and the psycho-physiological variables (heart rate, blink rate, skin conductance response) and the velocity of driving output parameter based on the curvature changes in the road sections and the visual demand increased dramatically as the radius decreased. Other finding includes the billboards or the advertisements on the roadside have a direct adverse effect on lateral control, increase cognitive workload and may distract attention on some routes from more important road signage (Young & Stanton, 2007).

Many types of assessment measures are being used in the literature in order to identify the driver's mental workload which is subjective workload and physiological workload that include driving performance. This paper focuses on the use of subjective assessments particularly the NASA-TLX and the Karolinska Sleeping Scale (KSS). NASA-TLX is a subjective workload assessment process based on a multidimensional model for a maximum workload score that is based on six subscales of weighted average ratings: mental demand, physical demand, temporal demand, performance, effort and frustration level. NASA Task Load Index (NASA-TLX) is commonly used to evaluate the participants' reaction and response to driving performance. Studies show that different types of factors as discuss previous-ly contributes to increment of mental workload among the drivers (Kong et al., 2017; Horberry et al., 2006; Shakouri et al., 2018). Meanwhile, KSS is a self-report sleepiness level felt by the driver which is also using a scale of 1 to 9 where 1 is being extremely alert and 9 being very sleepy. KSS is used to measure the sleepiness level of the driver and is mostly used in research related to long driving duration and road environment condition (Kong et al., 2017; Ahn et al., 2016). Studies that used these assessment measures show that different types of road environment affect the driver's mental workload in one way or another thus, the objective of this study is to identify the driver's mental workload on different types of road environment using two subjective evaluations which are NASA-TLX and KSS.

This study is a preliminary study where the goal of this study is to assess the driver's mental workload on different road environment which are the urban road and the rural road by using two different subjective evaluations that are the NASA-TLX and the KSS.

METHODOLOGY

Participants

Since this study is only a preliminary study and was conducted mainly to see the difference of driver's mental workload while driving in the different road environment, there were only 6 participants were involved in this preliminary study with an average age of 27.5. All participant required to make sure that they had at least 6 hours of sleep and not to consume any type of caffeine and alcohol 24 hours prior to the experiment because studies have shown that caffeine can affect driving performance (Biggs et al., 2007). The driving sessions were being conducted using a car simulator as shown in Figure 1 which is located in the Ergonomic Laboratory, Faculty of Engineering and Build Environment, University Kebangsaan Malaysia. This study was granted permission to be conducted from the UKM Ethics Committee with reference number UKM PPI/111/8/JEP-2019-529. All participants involved voluntarily and signed an informed consent form in accordance with the institutional guidelines.

Figure 1: Ergonomic Laboratory car simulator

Experiment Design
Participants had to undergo the experiment flow as shown in Figure 2. The flow started with the participant filling up the consent form. Then, each participant was given 10 minutes to familiarize with the simulator driving where they had to drive on manual transmission and with a speed of not more than 70km/h. Next, participants had to state their level of alertness by referring to the KSS scale before, during and after drive for each road scene based on their level of sleepiness while for NASA-TLX, they had to fill it in only after each driving scene. All participant had to drive on two different road scenes for 15 minutes each which firstly on scene A: the urban road scene and then followed by scene B: the rural road scene. During the mid-drive of the driving session, participants were asked to state their alertness level based on the KSS scale. At the end of the first driving scene, they were given a 10-minute break in between before they started to drive on the next road scene.

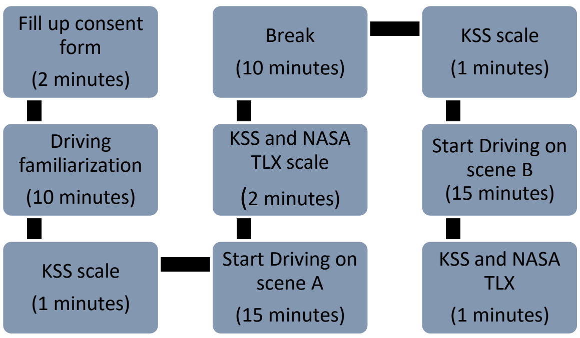

Figure 2: Experiment Flow

Each participant took about an hour to complete the whole experiment. The urban road consists of a 2-lane road with overcoming traffic. The roads have a higher complexity of road environment where it consists of a high density of buildings by the roads, cars parked on the side of the roads and a more overcoming traffic. The rural road scene also consists of 2-lane road with overcoming traffic but with very low to no road environment complexity which a monotonous environment is assumed. The results of NASA-TLX questionnaire and KSS scale for the two different road scene were recorded from each participant to be analyzed.

RESULT & DISCUSSION

NASA-TLX
NASA-TLX is the most commonly used subjective workload measurement and the results are as shown in Figure 3 below where the average mental demand for the participants to drive in an urban environment is slightly higher than the mental demand while driving in the rural environment. The results for physical demand, temporal demand, performance and frustration level also shows a higher score for urban drive compared to the rural drive while the average score for effort is the same. This subjective workload suggests that driving in an urban environment requires a greater information processing thus requires a higher mental demand, physical demand, temporal demand, performance and can cause higher frustration among the drivers. The results prove that urban driving demands more visual attention among the drivers compared to the rural drive as discussed earlier above. Thus, different road environment complexity affects a driver's mental workload differently which is parallel with the finding by Foy and Chapman (2018).

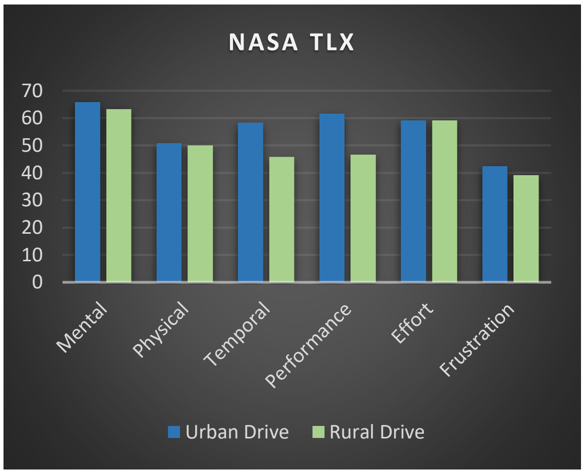

Figure 3: NASA-TLX

Karolinska Sleeping Scale (KSS)
The KSS result is shown in Figure 4. KSS was initially developed to measure the subjective sleepiness level which is due to sleep deprivation (Schmidt & Bullinger, 2017). In terms of subjective ratings, the average KSS level of the participant before driving for both scenes are either 2 (which indicates 'very alert') or 3 (which indicates 'alert'). After about 8 minutes of driving, the participant was asked to give their feedback on KSS level and it shows that the sleepiness level increased during both scenes with the rural drive being slightly higher than the urban. These levels indicate that the participants are in a condition between 4 (which indicates 'rather alert') to 6 (which indicates 'some sign of sleepiness'). Finally, after 15 minutes of driving session on each scene, each participant's KSS level reduces for both scenes between 3 (which indicates 'alert') and 4 (which indicates 'rather alert'). This shows that initially before they started their experiment session for each road scene, participants are in a state of alert or rather alert. Afterwards, while driving, their level of sleepiness started to increase. Then, when the sessions are about to end, their sleepiness level started to reduce. The result obtained is aligned with the findings of previous studies where driver's

sleepiness levels are always low at the beginning of a drive and increases along the way but started to reduce again when the drivers are about to reach the destination. Furthermore, the rural drive produces higher sleepiness level compared to the urban drive and this is also similar to finding in previous studies (Ahlstrom et al., 2018). This shows that different road environment complexity affects the driver mental workload differently.

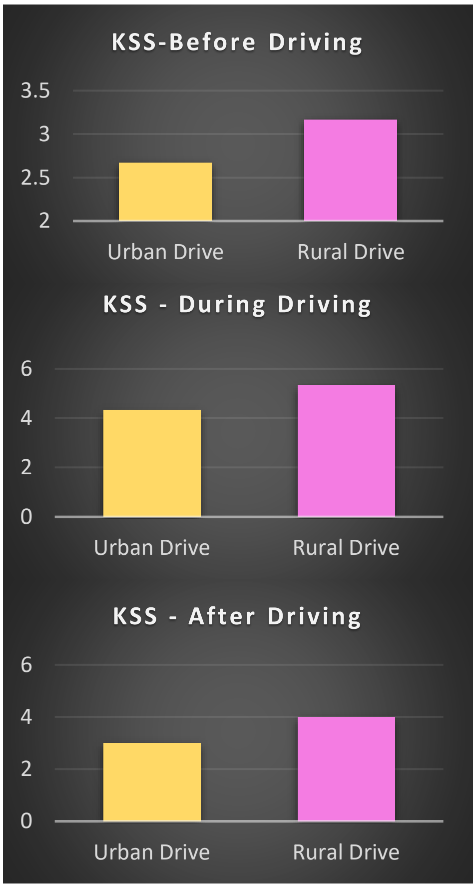

Figure 4: KSS result

CONCLUSION

This study shows that road environment complexity plays an important role on drivers mental workload and are in line with previous studies even though the results represents a small number of participants as it is a preliminary study and are similar to other preliminary studies done on assessing mental workload for drivers previously (Foy & Chapman, 2018; Schmidt & Bullinger, 2017; Ahlstrom et al., 2018; Hallvig et al., 2013; Chen et al., 2019; Mohid et al., 2019). Driving task done on two different road environments namely rural and urban road shows the different mental workload demand on the drivers. According to the results obtained from NASA-TLX and KSS, there are significant differences between the effect of different road environment towards the driver. NASA-TLX results show that urban road causes higher workload demand compared to rural road mainly due to urban road having higher road complexity and can easily causing visual distraction among the drivers compared to the rural road. On the other hand, KSS results show that driving on rural road causes a higher score on the sleepiness scale compared to urban road which is not new when driving on a monotonous road. The results from this study can be of a guideline for advance study on the effect of different road environment complexity towards the driver's mental workload. Further research needs to be done with a larger number of participants and different types of assessment measures in order to narrow the gap and tackle the mental workload issues among the drivers.

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