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Subjective responses of mental workload during real time driving: A pilot field study

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Abstract. This study evaluated drivers' mental workload in real time driving to identify the driving situation's complexity influences in an attempt to further design on a complete experimental study. Three driving settings were prepared: Session A (simple situation); Session B (moderately complex situation); Session C (very complex situation). To determine the mental workload, the NASA-Task Load Index (TLX) was administered to four drivers after each experimental driving session. The results showed that the Own Performance (OP) was the highest for session A (highway), while Physical Demand (PD) recorded the highest mean workload score across the session B (rural road) and C (city road). Based on the overall results of the study, it can be concluded that the highway is less demanding compared to rural and city road. It can be highlighted in this study that in the rural and city road driving situation, the timing must be set correctly to assure the relevant traffic density. Thus, the sensitivity of the timing must be considered in the future experiment. A larger number of experience drivers must be used in evaluating the driving situations to provide results that can be used to draw more realistic experiments and conclusions.

1. Introduction

Driving can be pictured as the relationship between human and machine system environment (driver–vehicle) from the user's point of view. It symbolized an enclosed section that ends with an environmental modification (e.g., "free driving" turns over into "following") [1]. There are several elements of the environment affect the complexity of a driving situation. For example road design (motorways vs. rural roads vs. city roads), road layout (straight vs. with curves, even vs. inclined, junction vs. no junction) and traffic flow (high density vs. low density) [2]. Fastenmeier and Gstalter [1] discussed on the taxonomy of the situation complexity which then categorized a very complex situation as an urban road, with curves or junctions, and with a high traffic density. It is important and crucial to consider these situation characterizing elements in performing the driving task.

Mental workload is one of the critical elements involved in a driving task. Some definition of mental workload was simplified as the relationship between the mental demand of a task and the worker being [3, 4]. Demand can be defined as the effort to be made in order to achieve a certain goal. A human that was given a goal to achieve will allocate an amount of effort in terms of mental, physical and emotional effort. In a driving task, the destination here can be described as the goal of a demand. Ergonomists are concerned about the drivers' mental workload since an overload of information may lead to distraction while the driving task is performed [5, 6].

Generally, drivers of any vehicle have to go through various different types of conditions and environments while driving. A driving situation contributes as the main factor of the mental workload of drivers [6]. There are situations when a driver is overload and underload in performing the driving

task. For example, when a driver experiencing an overload situation such as he/she has to carry out several tasks concurrently while also having to pay attention to other vehicles in a high density traffic. This kind of situation can lead to stress and deteriorated performance [7]. On the other hand, when mental workload is much lower than the proper level, people will become bored and tend to make mistakes [8]. In an underload driving situation, monotonous driving can cause drowsiness for example long distance driving in a low density highway driving. Sleepiness when driving possibly will occur in situations such as stuck in traffic jams where sometimes vehicles on the road does not move at all for hours. Normal mental workload occur when a driver has enough capacity to perform the main driving activity, awake, focus with less distractions and confusion along the driving task.

Consequently, it is significant to evaluate mental workload in real driving conditions to identify more on the driving situations influences. This critical finding is important not only for young drivers, but also different population such as elderly drivers. Furthermore, it is valuable to have early identification of mental workload level in this pilot study to further design on the complete experimental study with more highlighted parameter and critical settings. In this study, it is hypothesized that city driving contributes low workload and considered as less complex, followed by rural road driving and city driving situation.

2. Procedure

A. Participants

The participants consisted of four healthy male volunteers. None of them have health problems that could potentially interfere with their ability to perform the driving task. The requirement of becoming a participant is holding a driver's license for at a year and having driven at least 10,000 km.

B. Experimental setup

The goal of the experimental study was to measure mental workload in real time and in real operational environments. The traffic intensity was not controllable and depends on the type of road setting. The route are identical to all participants (total driving distance is about 30 km), which took on the average about 45 minutes to complete. The classification of the driving environments is based on the classification pattern in terms of different complexities (low, medium, high), as proposed by Paxion [2] and partly from Fastenmeier [1]. Details of the environment setting are as in table 1.

Table 1. The routes and environment setting

	Session A: Simple Situation	**Session B :Moderately Complex Situation**	**Session C :Very complex Situation**
Road design	Highway	Rural Road	City Road
Speed limits	110km/h	90km/h	60 to 90km/h
Road layout	Straight	Few curves	Many curves
Traffic flow	Low density	Moderate density	High density

C. Task description

The protocol was approved by the Medical Ethics Committee, University Malaya Medical Centre. Upon arriving at the setup station, the participants were informed on details of the experiment and signed an informed consent and filled out a demographic questionnaire. Participants were then given the opportunity to familiarize themselves with the vehicle and environment by driving around on a two-lane practice road without any other traffic. Participants were told that their first priority was to

drive safely. Subsequently, the participants were instructed to drive according to the route that has been set. A research associate was seated in the rear of the vehicle and was responsible for providing driving directions, ensuring safe vehicle operation. In each end of the A, B and C session, participants received the instruction to pull-over and park the car. This break lasted around five minutes throughout which the participants were asked to subjectively rate the NASA- Task Load Index (TLX) scales based on that particular session.

D. Subjective measures – NASA Task Load Index (TLX)

The NASA-TLX [9] is used to evaluate the operators' subjective workload. The participants will be asked to self-report his mental workload after finishing every primary task of each route session. The participant takes approximately 5 to 10 minutes to complete the subjective assessment. The NASA-TLX method includes six sub-scales (table 2). The mean (raw TLX) and weighted mean (weighted workload) of these six sub-scales were calculated using paired comparisons.

Table 2. NASA-TLX scales [9].

Title	Descriptions
Mental Demand	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting, or forgiving?
Physical Demand	How much physical activity was required (e.g., turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration Level	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

E. Statistical Analysis

The descriptive statistics and difference between subjective responses of the three conditions during the driving task for all sub-scales and overall workload of the NASA-TLX were analyzed using the IBM Statistical Package for Social Science (SPSS) for Windows version 23.0 (IBM SPSS Statistics for Windows Version 23.0, Armonk, NY: IBM Corp).

3. Results

A. *Subjective workload attributed to situation complexity*

The average age and driving experience of the participants were 38.5 ± 14.5 (SD) and 17.5 ± 11.7 (SD) years, respectively. The results of the subjective ratings of workload measured by NASA-TLX across the A, B and C sessions are summarized in table 1. The NASA-TLX scores ranged from 0, representing no demand, to 100, representing maximum demand. The mean subjective workload ratings for each subscale for Session A, B and C is summarized in tables 3 and the graphical compositions are shown in figure 1 to 3. For session A (highway), Own Performance (OP) was the highest score followed by Temporal Demand (TD). Overall, the Physical Demand (PD) recorded the highest mean workload score across the session B (rural road) and C (city road). The y-axis of the figure 1 to 3 shows the weighted ratings as the dependent measure while the x-axis represent the six workload subscales as the independent measures. Meanwhile, the width of the subscale bar reflects the weight (or the relative importance) assigned to it, with the value of the weight on top of the bar; the height of the bar represents its rating. The adjusted workload rating is, therefore, the area of the subscale bar obtained as the product of the weight and the rating. On the other hand, the overall weighted rating for each driving session was acquired by dividing the sum of the adjusted workload score across the six subscales by 15. These are summarized shown graphically in figure 4. Session B had the highest overall workload score, followed by Session C and Session A respectively.

Table 3. NASA-TLX data summary for Session A, B and C.

Session	Subscale	Weight	Raw Rating	Ajusted Rating (Weight x Raw)
A	MD	2	8.75	17.50
	PD	3	7.50	22.50
	TD	4	11.25	45.00
	OP	4	23.75	95.00
	EF	2	10.00	20.00
	FR	0	8.75	0.00
B	MD	1	27.50	27.50
	PD	4	43.75	175.00
	TD	3	33.75	101.25
	OP	5	13.75	68.75
	EF	3	32.50	97.50
	FR	1	17.50	17.50
C	MD	1	10.00	10.00
	PD	4	35.00	140.00
	TD	3	28.75	86.25
	OP	5	11.25	56.25
	EF	3	12.50	37.50
	FR	1	10.00	10.00

MD: Mental Demand, PD: Physical Demand, TD: Temporal Demand,

OP: Own Performance, EF: Effort, FR: Frustration.

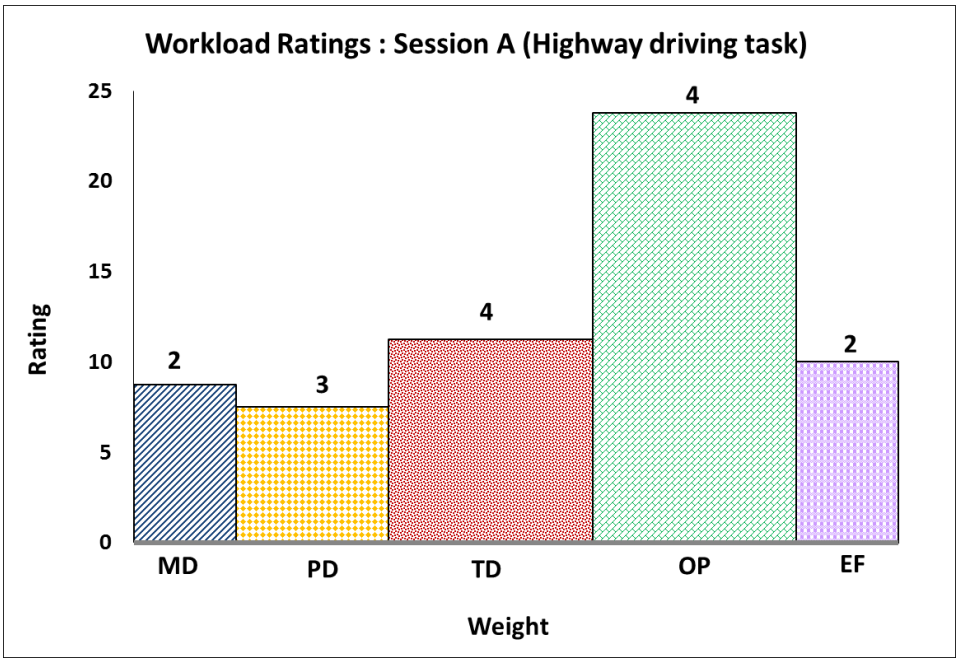

Figure 1. Plot of NASA-TLX workload ratings for Session A.

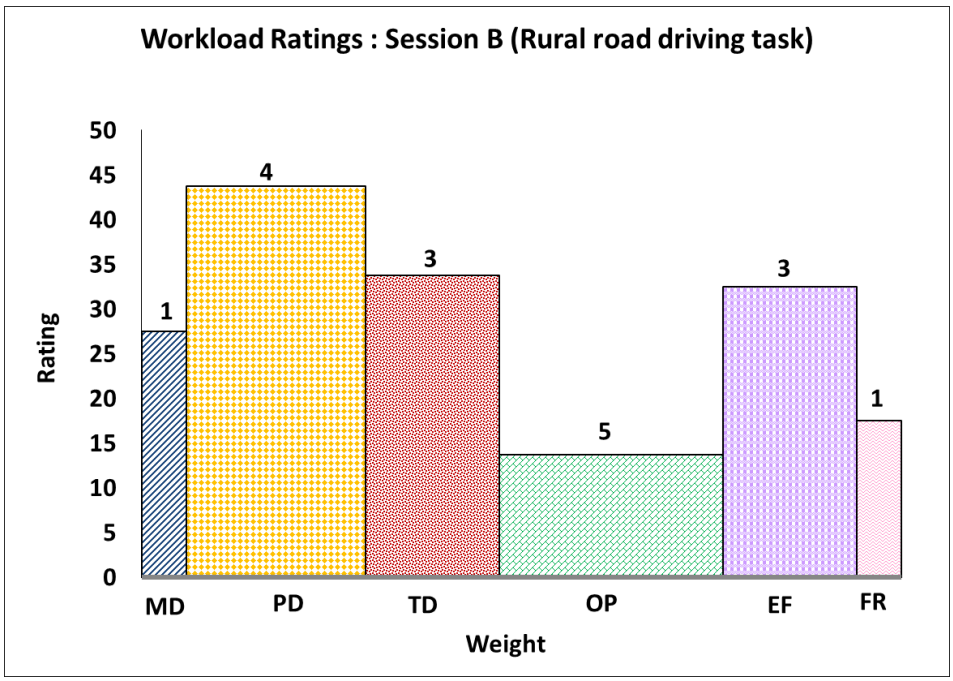

Figure 2. Plot of NASA-TLX workload ratings for Session B.

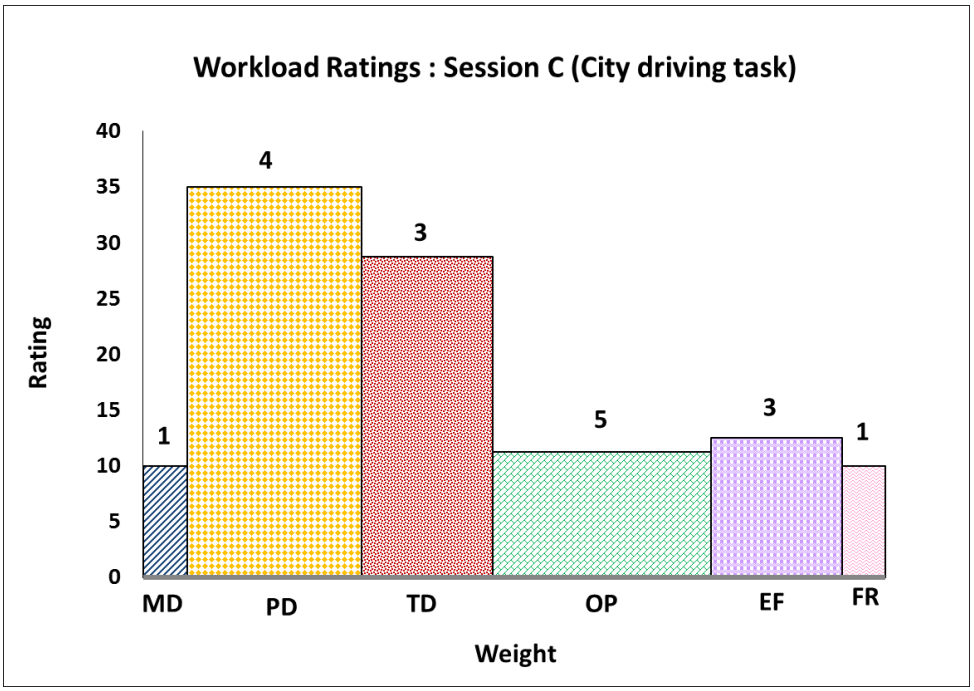

Figure 3. Plot of NASA TLX workload ratings for Session C.

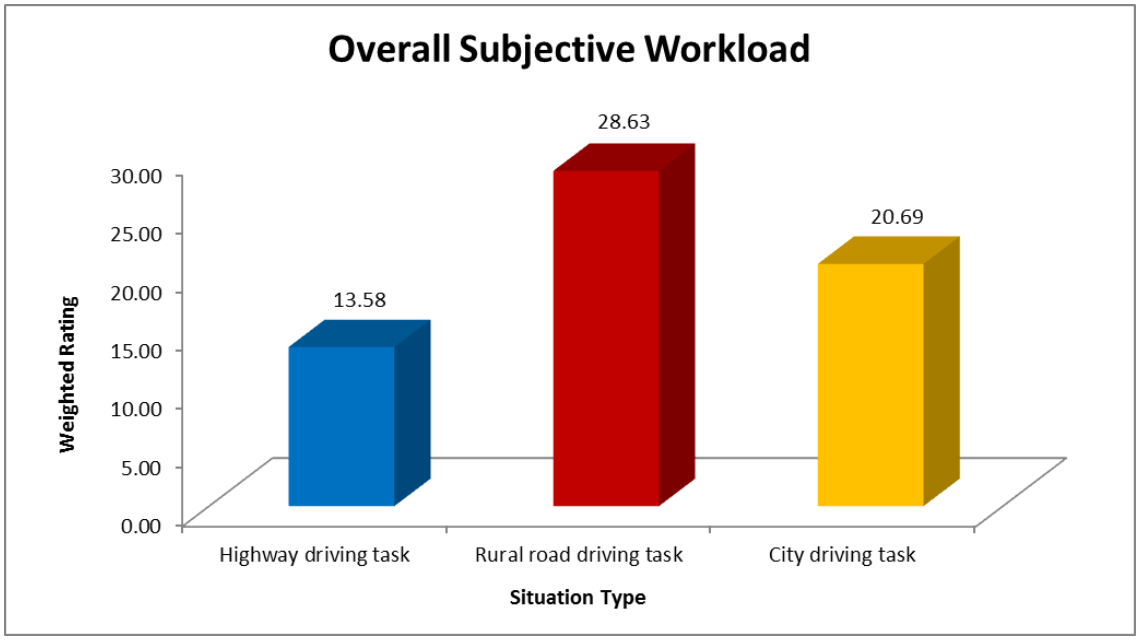

Figure 4. Plot of overall workload ratings for Session A, B and C.

4. Discussion

The results of the subjective workload scores from the NASA-TLX showed that Own Performance (OP) induced the highest workload in Session A. However, the score is still much lower from the highest score of the other two sessions. This partially confirms the research hypothesis that the highway is less demanding compared to the rural and city driving. The result highlighted that there is no frustration at all during the session while the participant rated low workload on the mental demand.

Mental demand is expected to be low due to the straight road layout and high speed limit. However, Thompson [10] found in their study that percentage of drivers seriously injured or killed by crashes increased with the increase of speed limits in South Australia. It is reflected here that when the situation is low demanding, the performance may impaired due to underload condition.

Meanwhile, for rural (Session B) and city (Session C) driving situation, it is surprisingly recorded that physical demand scored the highest workload. The score translated to users feeling that they had to exert a substantial amount of physical movement to accomplish the goals of the task. The reason that can be attributed to this outcome is that the rural area may have car, pedestrian, cyclist crossing and appearing during the driving sessions plus houses on both sides of the road. The city driving situation was extended from those conditions with more shops and houses, traffic lights and parked busses and cars along the road. Overall, there was significant different in the mental workload of the three types of situations which Session B scored the highest overall subjective workload. When compared to Session B, the mental workload was reduced by 52.57% for Session A, and 27.73 % for Session C. This finding is consistent with the emphasized findings by Verwey [6] stating that a driving situation constitutes the major determinant of the mental workload of drivers. Similarly, Paxion [11] reported that an increase of subjective workload was globally observed when the situation complexity increased, with a tendency to higher self-assessment of the workload in very complex situation than in the simple one. It is anticipated in this study that city driving will score the highest workload, however, the result is contradict which it is probably due to lack complexity of the traffic density of the city during the experimental session. City road traffic density usually is at most congested condition in the weekday morning where people are travelling to work. It can be highlighted here that the experiment timing is very important to see clearly driving situation complexity differences. Furthermore, the lack number of participants in this study probably led to the result achieved.

5. Conclusion

This study described the effect of driving situations on subjective workload demands. The goal of the research was to obtain an early identification of mental workload level with respect to the situation complexity to further design on a complete experimental study. Three driving situations were formed and compared. The six subscales of the NASA-TLX subjective workload assessment tool was used to obtain the workload ratings for characterizing each driving situation setting. The results showed Own Performance (OP) was the highest for Session A (highway), Physical Demand (PD) recorded the highest mean workload score across the Session B (rural road) and C (city road). Based on the overall results of the study, it can be concluded that the highway is less demanding compared to rural and city road. It is highlighted that the timing must be set correctly in the rural and city road driving situation. Thus, future experiment will have to consider the sensitivity in the experimental timing. More number of experience drivers must be used in evaluating the driving situations in order to provide results that can be used to draw more realistic experiments and conclusions.

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References

[1] Fastenmeier W and Gstalter H 2007 *Saf. Sci.* **9** 952-79
[2] Paxion J, Galy E and Berthelon C 2014 *Frontiers in Psychology* **5** 1344
[3] de Waard D 1996 *The Measurement of Drivers' Mental Workload* (Groningen: Groningen University)
[4] Leung A W 2006 *Neurophysiological Correlates of Performance and Fatigue in Study of Mental Workload* (Hong Kong: The Hong Kong Polytechnic University)
[5] Mayser C, Piechulla W, Weiss K E and König W 2003 Driver workload monitoring *50th-Anni. Conf. of the GfA and XVII Ann. ISOES Conf.*
[6] Verwey W B 2000 *Ergo* **2** 187-209
[7] Gáspár P , Szalay Z and Aradi S 2014 *Eng. Psychol. and Cog. Ergo.: 7th Int. Conf. EPCE 2007 Proc.* 316-23
[9] Hart S G and Staveland L E 1988 *Adv. Psychol.* **52** 139-83
[10] Thompson J P, Baldock M R J, Mathias J L and Wundersitz L N 2013 *Accid. Anal. Prev.* **50** 768-75
[11] Paxion J, Galy E and Berthelon C 2015 *App. Ergo.* **51** 343-49