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# FATIGUE MEASUREMENT IN CAR DRIVING ACTIVITY USING PHYSIOLOGICAL, COGNITIVE, AND SUBJECTIVE APPROACHES

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## ABSTRACT

Traffic accidents are the third largest cause of death according to the World Health Organization. Moreover, driver fatigue is the second largest factor that causes traffic accidents after traffic violations. The purpose of this study is to find out the significance of driver fatigue using physiological, cognitive, and subjective approaches, as well as a comparison of fatigue between male and female drivers. The study involved twelve respondents, which included six male respondents and six female respondents aged 17–25 years old, measured by physiological (blood pressure and heart rate), cognitive (psychomotor vigilance test), and subjective (Karolinska Sleepiness Scale) approaches. The result of this study is that heart rate is the most sensitive variable. However all of the variables in male and female respondents do not have a significant result. There is no big difference in fatigue levels in male and female car drivers. The conclusion of the study is that the approaches could not be a standardized way to measure fatigue for male and female car drivers because of the variation in results.

*Keywords:* Ergonomics; Fatigue measurement; Karolinska Sleepiness Scale; Psychomotor vigilance test

## 1. INTRODUCTION

According to Traffic Coordination Police data, in 2013, the highest number of traffic accidents occurred in time range of 12:00 to 18:00 o'clock, and every day an average of 87 accidents occurred. The accidents occurred between those times because it is a rush hour, when commuters are returning home via highways and major traffic arterials. If the number of vehicles on the road increases, the potential for accidents also increases.

In addition, young people aged 16–25 years old are in the age range that causes the most traffic accidents, which amounted to 26.61% in 2013. Meanwhile, 94% of the incidents in Indonesia are caused by male drivers. This is probably due to the higher number of male drivers in comparison with female drivers. But, on the other hand, the number of female drivers is increasing every year.

According to Law Enforcement Development Division Traffic Coordination Police data, driver fatigue is the second biggest cause of traffic accidents (37.9%), just under traffic violations (45.7%). The number of traffic accidents caused by driver fatigue is 34,657 cases (2013). This is consistent with studies of Smolensky et al. (2009) that mentions fatigue and sleepiness are two of the causes of driving accidents. It is also proven by the study conducted by the Virginia

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Tech Transportation Institute (2013), which showed that 20% of the accidents were caused by driver fatigue, almost a 10% increase from a previous findings of a survey citing only 2–3%.

There are various methods for measuring fatigue in terms of driving. The first is the measurement of the performance of neuro-behavioral characteristics (cognitive methods) with the use of the Psychomotor Vigilance Test (PVT). PVT measures the rate of continuous attention span. This measurement has become a major standard in detecting fatigue (Dinges & Powell, 1985). Individuals will provide a response to stimuli/visual stimuli by pressing a button on the computer screen during a period of 5-10 minutes. PVT measures reaction time and 'lapses' (response time> 500 ms). However, the PVT performance may not fit poor driving performance, due to the large individual differences in poor driving performance, which skew the test results. Thus, PVT is better at predicting fatigue-related accidents (Baulk et al., 2008).

The second method is the subjective approach by using the Karolinska Sleeping Scale (KSS). KSS was originally developed to form the dimensional scale measuring the degree of sleepiness validated with alpha and theta signals from an electroenchephalographic (EEG) test and slow eye movement activity in an electrooculographic (EOG) test (Kaida et al., 2006). KSS is measured based on the respondent's own opinions or feelings. KSS has 9 stages, ranging from 1, which means very vigilant or attentive to 9, which means very sleepy, (Kaida et. al., 2006).

In addition, it can also be used to measure the physiological approach, such as heart rate and blood pressure tests. Heart rate readings will measure changes in heart rate while Blood Pressure method will measure changes in blood pressure. In a study conducted by Verwey and Zaidel (1999), it was found that the level of concentration and heart rate, which varies between individuals, is influenced by the level of fatigue experienced by each individual. In addition, there are other case studies in which eight male drivers drove for 4 hours. It was found that the longer time driving times resulted in faster heartbeats because the male drivers experienced fatigue (Egelund, 1982).

Earlier studies have examined the level of driver fatigue associated with sleep deprivation, which proved that that lack of sleep or an increased waking time due prolonged driving will causes interference and a lower attention span, which in turn increases the rate of accidents. , These tests were conducted either during a driving simulator exercise (Jagannath & Balasubramanian, 2014) or a real driving experience (Philip et al., 2005). The aim of this research is to investigate fatigue conditions without the sleep deprivation factor by way of various methods, namely PVP (cognitive method), Karolinska Sleeping Scale (subjective method), as well as blood pressure and heart rate (physiological method).

## 2. METHODOLOGY

In this study, there are three types of approaches that are measured: physiological, cognitive, and subjective. The physiological approach consists of blood pressure and heart rate measurements using medical equipment, such as an Omron Automatic Blood Pressure Monitor HEM-7221 and a Polar FT7 Heart Rate device.

For the cognitive approach, a software program called Design Tools uses two types of tests, namely the Simple Reaction Time and the Psychophysics test. Simple Reaction The response time of the stimulus is measured as soon as possible in the Simple Reacion time test, while Psychophysics test serves to measure accuracy in determining lines, which have different lengths in order to determine driver’s sense of perception.

In conducting the research, city type cars with an automatic transmission were used. Respondents are expected to drive the car for 120 minutes or 2 hours, with a break every 40 minutes, during the period from 12:00 to 18:00. The homogeneous route chosen for the research is in the Universitas Indonesia, Depok campus. During the test drive survey, the respondents were not allowed to speak with investigators, listen to the music or use a mobile device, so that the data obtained are valid.

Before the driving starts, the driver's (respondent's) blood pressure will be measured. In addition, the driver will undergo the Simple Reaction Time test and the Psychophysics test. The goal is to obtain a comparison of the change in levels of fatigue over a period of time before driving, during driving, and after driving. Then, the respondents are asked to use the Polar Heart Rate Monitor to measure their heart rate during the driving exercise. Drivers are required to stop every 40 minutes to be measured again. The time sequence for every measurement was selected based on previous research. It was found that fatigue begins to be detected after driving for 40 minutes. Overall five data measurements were taken, including the Polar Heart Rate Monitor which was lit up at the start of driving and stopped every 10 minutes.

In addition to these measuring devices, the fatigue level of the driver will also be measured by using a subjective approach with the Karolinska Sleepiness Scale (KSS) questionnaire, which has 9 scales. To determine the correlation or the relationship between the subjective approach (KSS) with the cognitive approach and the physiological approach, the Spearman Rank correlation will be used. This correlation is most suitable for measuring the correlation between the three approaches, especially since the results obtained from the SCC are an ordinal, non-parametric, value.

Data obtained from the KSS questionnaires will be processed using a descriptive statistics method to determine the driver's fatigue level changes that occur during the survey. Meanwhile, the data obtained from the cognitive and physiological approaches will be processed using a Linear Regression method to recognize the significance level of fatigue with each respective approach. In addition, as previously described, the Spearman-Rank correlation will be used to determine the correlation between the subjective approach and the cognitive and physiological approaches.

## 3. RESULTS AND DISCUSSION

This section will explain the analysis and discussion of the results from the data processing. Table 1 shows the example of the data taken from measurements on the various approaches.

Table 1 Measurement of blood pressure

| Time (minute) | Systole (mmHg) | Diastole (mmHg) |
|---|---|---|
| 0 | 132 | 81 |
| 40 | 130 | 74 |
| 80 | 118 | 69 |
| 120 | 125 | 68 |

After the data are collected, the next step is to conduct a normality test. The normality test is measured using P-value on the Probability Plot using Minitab 16 software. All data including Systole, Diastole, average reaction time in the Simple Reaction Time test, average reaction time in the Psychophysics test, and the heart rate measurements will be analyzed in the normality test. Data is considered normal if it has a P-value of >0.05. After that, a simple linear regression was conducted to determine the strong-weak relationship between the independent variables with the independent variables. In this regression, the dependent variables (Systole, Diastole, average reaction time on the Simple Reaction Time test, and average reaction time in the

Psychophysics test) will be compared with the independent variable. Independent and dependent data is strongly correlated (significant), if it has a P-value of <0.05.

Based on the Analysis of Variance (ANOVA) model and the data obtained in the study, there is only Respondent 6 had a significant relationship between the Systole date with time. The other data is not significant. On the other hand, in the Diastole data, only Respondent 3 (third male respondent) and Respondent 8 (second female respondent) experienced significance.

In the average reaction time data for the Simple Reaction Time test, only two male respondents experienced significance. The results tend to be random data retrieval and do not form a specific pattern. On the other hand, no data are significant in the average reaction time data for the Psychophysics test.

Finally, in Heart Rate data, the majority of respondents experienced a significant relationship. Heart Rate data tends to fall or stagnate at some time, but for certain respondents, the Heart Rate Data is spotty and unpredictable, so it becomes insignificant. The recap of all regression data is shown in Tables 2 and 3.

Table 2 Recap of regression results for male respondents

| Respondent | P-Value | Interpretation Result |
|---|---|---|
| Systole | 0.192 | Not significant |
| Diastole | 0.432 | Not significant |
| Simple Reaction Time | 0.427 | Not significant |
| Psychophysics | 0.691 | Not significant |
| Heart Rate | 0.195 | Not significant |

Table 3 Recap of regression results for female respondents

| Respondent | P-Value | Interpretation Result |
|---|---|---|
| Systole | 0.598 | Not significant |
| Diastole | 0.963 | Not significant |
| Simple Reaction Time | 0.629 | Not significant |
| Psychophysics | 0.256 | Not significant |
| Heart Rate | 0.255 | Not significant |

Meanwhile, in the regression test results in each gender category, it can be seen that all have a P-Value, which is greater than 0.05, so it can be concluded that all variables have no significant relationship with the time factor.

After ANOVA and regression analysis were conducted, the Spearman Rank test is conducted to measure the relationship between the subjective variables from the Karolinska Sleepiness Scale, which is ordinal data compared with other variables and the time factor. The result of Spearman Rank test is that most of the data are not significant in relation to the values of the Karolinska Sleepiness Scale.

Most of the data analysis results were not significant, compared to previous literature, such as Egelund (1982), Jagannath and Balasubramanian (2014), and Verwey and Zaidel (1999). It is because the driving duration limitation of two hours in this study, which is much shorter than the study by Egelund (1982), that tested eight male drivers for 4 hours. The study also has a limited number of respondents,compared to studies conducted by Verwey and Zaidel, (1999) and Jagannath and Balasubramanian, (2014) that have higher number of respondents (>20 people). In conclusion, for future research, the driving duration and number of respondents could be extended to obtain better results.

## 4. CONCLUSION

Based on the research results, it can be concluded that based on the Systole data, male and female respondents did not show any significance, although the data often decrease at 0 to 80 minutes, but at 120 minutes the increment data becomes insignificant. Furthermore, the results of the Diastole data, the average reaction time with the Simple Reaction Time test and the average reaction time in the Psychophysics test have no significant relationship to the time factor, due to fluctuating data. The Heart Rate data significantly affects the majority of male and female respondents. However, because the data is divided into gender categorizations, the relationship becomes insignificant. Based on data from the Karolinska Sleepiness Scale, the majority of male and female respondents found a significant relationship, when compared with the driving duration. However, the relationship with other variables was less significant.

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