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FATIGUE MEASUREMENT OF DRIVING ACTIVITY ON MALE MOTORCYCLE DRIVERS BASED ON COGNITIVE, PHYSIOLOGICAL, AND SUBJECTIVE APPROACHES

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ABSTRACT

Driver fatigue is one of the major causes of serious road accidents. The purpose of this research is to measure the effect of cognitive, physiological, and subjective approaches towards fatigue, while driving a motorcycle for 2 hours. Another objective of this research is to determine the differences in the level of fatigue in the studied age category. In this study, there were two age categories, namely the productive age category (16–35 years old) and the adult age category (35–60 years old). This research implemented three approaches: cognitive, physiological, and subjective. In the cognitive approach, levels of concentration and stress (tension) were measured by using Design Tools, such as Simple Reaction Time and Stroop Test. In the physiological approach, two measurements were taken: measurement of heart rate using Polar Heart Rate and measurement of blood pressure (systole and diastole) using the Omron Blood Pressure test. Meanwhile, the subjective approach was calculated using the 9-scale Karolinska Sleepiness Scale (KSS). Also, the correlation between the subjective approach and two other approaches (cognitive and physiological) used the Spearman-Rank test. Results obtained from this study on the influence of heart rate on the level of fatigue are significantly found in both age categories (productive and adult age category). Meanwhile, the significance (influence) of blood pressure on the level of fatigue is found only in the adult age category. Simple Reaction Time measurement results were found to be significant on the level of fatigue in the adult age category. Thus, it can be said that in the adult age category, there is a significant influence between the level of fatigue and concentration level.

Keywords: Cognitive; Fatigue, KSS; Motorcycle driver; Psychophysical; Subjective

1. INTRODUCTION

In the past two years, traffic accidents in Indonesia were judged to be the 8th biggest killer just under stroke, coronary heart disease and other diseases (World Life Expectancy, 2015). Data from WHO (2011) states, as many as 67 percent of the victims of traffic accidents are in the productive age group, which is from 22 until 50 years old. In general, traffic accidents occur because of several factors, such as human error, road conditions, vehicle negligence, and lack of optimization in traffic enforcement (State Intelligence Agency, 2011). Out of the various factors that may cause the traffic accidents, driver fatigue contributes the largest percentage at 29.91 percent, (Indonesia Statistics Agency, 2012). While in terms of time of occurrence, traffic accidents in Indonesia most commonly occur between the span of 12:00 to 18:00 P.M., when

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there is a lunch break and when people return from office to their home.

Fatigue is defined as the biological drive to rest, and is related to the performance decrement that affects accidents (Williamson et al., 2011). Factors affecting fatigue are the time of day (circadian rhythm), the waking hours (homeostatic factor), and task-related factors (work duration and workload), (Desai & Haque, 2006; May & Baldwin, 2009).

There are various approaches for measuring fatigue; however they can be categorized into three main approaches: physiological, cognitive, and subjective measurement (Dawson et al., 2014; Williamson et al., 2011). The physiological approach consists of brain wave measurement, oculomotor measurement, and other physiological methods, such as heart rate variability and blood pressure (Jagannath & Balasubramanian, 2014). In a study conducted by Verwey and Zaidel (1999), the level of fatigue influenced heart rate variability. Furthermore, when the duration of driving is increased, the heart rate will also increase (Egelund, 1982).

One of the cognitive approaches is the Psychomotor Vigilance Test (PVT). PVT measures the psychomotor and vigilance of drivers by responding to visual stimuli (Dinges & Powell, 1985). Data obtained from PVT are reaction time and 'lapses' (response time> 500 ms). PVT is validated as a device to predict fatigue related to accidents (Baulk et al., 2008).

One of the subjective approaches is the Karolinska Sleepiness Scale (KSS). One of previous research used KSS to validate brain wave signals and slow eye movement (Kaida et al., 2006). KSS is measured based on the subjective feelings about sleepiness. KSS has 9 stages; Scale 1 means very vigilant, and Scale 9 means very sleepy (Kaida et al., 2006).

Moreover, there has been an incremental increase in the number of motor vehicles in Indonesia, since 1986. Indonesia ranks first as the country that has the largest number of motor vehicles in Southeast Asia. Therefore, the level of traffic accidents continues to increase every year. Based on the types of vehicles involved in traffic accidents in 2013, the highest percentage was held by motorcycles (36%), which have killed up to eighteen thousand (18,000) people (Jakarta Globe, 2015). This result shows the importance of researching fatigue measurements in motorcycle drivers. Therefore, the purpose of this research is to measure the effect of cognitive, physiological, and subjective approaches towards fatigue on male motorcyle drivers, while driving a motorcycle.

2. METHODOLOGY

In this research, there are three approaches that were implemented. They are physiological, cognitive, and subjective approaches. The physiological approach was conducted by measuring the heart rate using the Polar Heart Rate Monitor and measuring the blood pressure of the motorcycle driver (also known as the research respondent) using the Omron Blood Pressure test. There is a categorization in terms of the driver's age that is being researched in this study. According to Ministry of Health (2009), these two categories are the productive age category (17–35 years old) and the adult age category (35–60 years old).

Meanwhile, the cognitive approach was conducted by measuring the level of concentration and stress/tension of the respondents with Design Tools. With these devices, there are several tests that can be used to determine the cognitive changes that occur. However, in this study, the Simple Reaction Time test was used to find out the changes in the driver's concentration level. The Stroop Test was used to determine the changes in stress/tension experienced by the driver in the two categories being studied.

Drivers (research respondents) were asked to drive an automatic transmission motorcycle for about 120 minutes or 2 hours. Respondents were asked to drive the motorcycle in areas surrounding Universitas Indonesia and to keep on traversing a homogeneous path. This research

started at 14.00 until 16.00 WIB (Western Indonesian Time). While driving, the research respondents were not allowed to speak or listen to the music, in order to maintain the validity of the research results. Before the research started, there were several things to consider when selecting the respondents in this study, as follows:

1. Respondents are male drivers with two appropriate research data categories that already have a driving license (SIM C)
2. Respondents are chosen who do not smoke and/or drink alcohol
3. Respondents are in good condition (with a minimum of 6 to 9 hours of sleep the night before the research was held)
4. Respondents do not drink coffee or any other drink with caffeine for at least 24 hours prior to the study.

Before starting to drive a motorcycle, the respondents' blood pressure was measured with an Omron Blood Pressure test. Besides that test, the Simple Reaction Time and the Stroop Test were applied to the respondents. The aim is to make comparisons and alterations to the conditions, during the period of time before driving, while driving, and after driving. Then, respondents were asked to use the Polar Heart Rate Monitor in order to undergo physiological measurements. Respondents were asked to stop every 40 minutes to do the same measurements again. This time duration is selected because driver fatigue appears after 40 minutes of driving, based on previous research, (Gastaldi et al., 2014). Overall, there were five instances of measurement in this experiment. The Polar Heart Rate Monitor was lit up at the start of driving and was stopped every 40 minutes.

Furthermore, the subjective approach was conducted by measuring drivers' fatigue level using KSS (Karolinska Sleepiness Scale) questionnaire which has 9 scales. To obtain the correlation or connection between the subjective approach (KSS) with another approach (either the cognitive approach or the physiological approach), the Spearman-Rank correlation was used. This correlation method is considered as the most appropriate to measure the correlation between the three approaches, since the results obtained from the KSS questionnaire were on an ordinal scale (non-parametric).

Data obtained from the KSS questionnaire were processed using a descriptive statistics method to determine the level of fatigue that occurred. Meanwhile, the data obtained from the cognitive and physiological approaches were processed using the Linear Regression method to determine the significance between the level of fatigue and the three approaches that were being implemented in the research. In addition, as previously described, the Spearman-Rank correlation test was used to find out the correlation between the subjective, cognitive and physiological approaches.

3. RESULTS AND DISCUSSION

After collecting subject data, the next step was to test data adequacy. The steps were a normality test, an independent test, and an homogeneity test. Data adequacy checking was made by using Minitab 16. The normality tests can be seen in Figure 1.

From Figure 1, it can be seen that all data that were collected passed the normality test. Where the p-value of each data from the Simple Reaction Time, the Stroop Test, heart rate, and blood pressure were above α (0.05) and the data have been equally spread (no outliers were found in the data).

From those tests, it can be seen that the residual plots are related to the observation order of the individual data, indicating that data in the plot are in an unstructured form. This observation corresponds with the basic statistics of the design of the experiment that if data are

unstructured, then data are independent. This shows that there is no correlation between the residual plots of collected data. It also can be seen that residual plots to the data collected shows that data in the plot are unstructured (it does not have a specific pattern), corresponding with the basic theory that if data are unstructured, then the data are homogeneous. The results show that all collected data pass the homogeneity test.

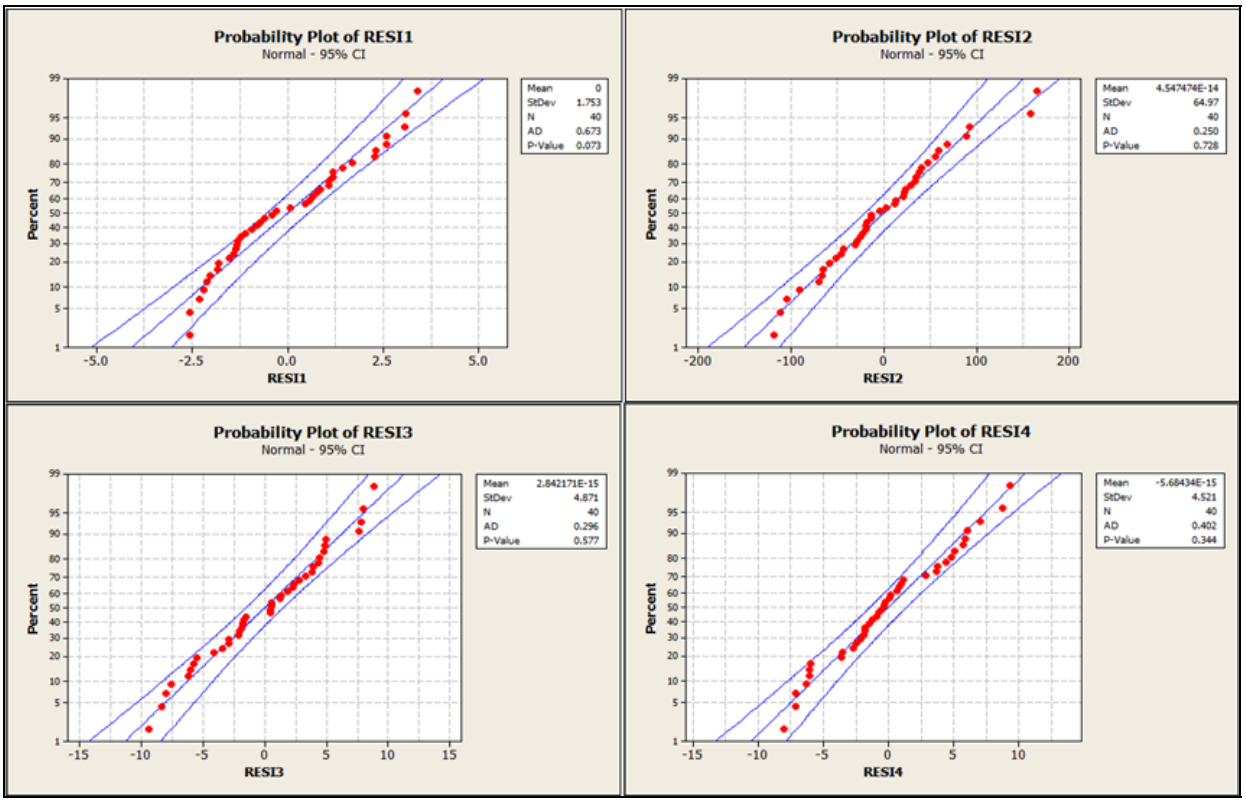

Figure 1 Normality test on driver (respondents) data

Data obtained from the result of the subjective measurement (KSS) will be in an ordinal pattern. Therefore, these data will then be processed using a descriptive statistics method to determine changes in the level of fatigue during driving for 120 minutes. Table 1 shows an example of the data obtained from the KSS measurement results.

Table 1 Subjective approach (KSS) measurement result

Karolinska Sleepiness Scale	
Duration (minutes)	Score
0	1
40	6
80	7
120	8

Before determining the appropriate statistical methods used in processing the data, first thing to do is to determine the type of data collected and the results to be obtained from the calculation. In this study, the Simple Reaction Time, Stroop Test, heart rate, and blood pressure data were obtained as a type of parametric data. The objectives to be obtained were to know the

significance of the data obtained on the level of fatigue. Therefore, the most appropriate method used was the Linear Regression Method. In the next section, the table consists of data obtained from the measurement result of the approaches implemented and it will be presented.

The result of data processing obtained from the subjective approach, using the KSS questionnaire shows that the longer the duration of driving, respondents will experience fatigue which is emphasized by the KSS scale graphs that are continually increasing. Figure 2 presents the results of the KSS data, processed by using the descriptive method statistics. The graph shows that the longer the duration of driving, there is an increase in fatigue levels experienced by the drivers (respondents).

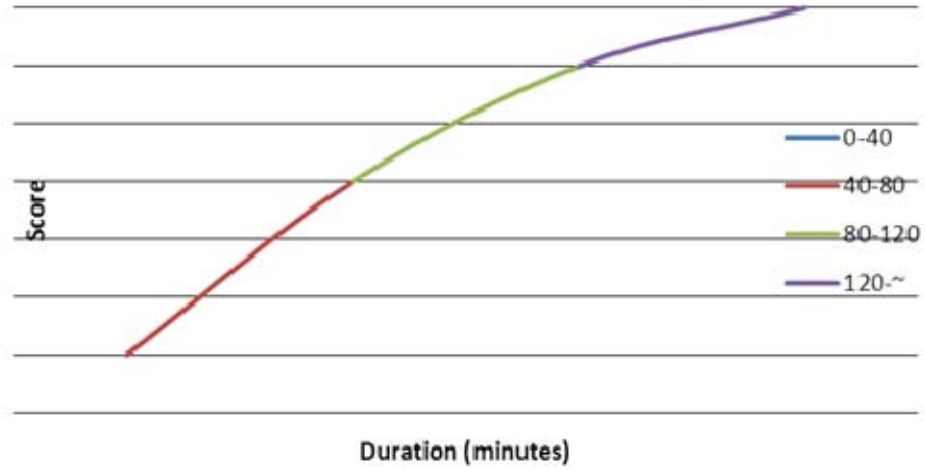

Figure 2 Processing result of KSS data using descriptive statistics

From the results of the significance processing to the Simple Reaction Time, Stroop Test, heart rate, and blood pressure data, results were obtained that represented the significance of each respondent from each age category, which as observed, varied from one to another. As mentioned before, to obtain the significance from each respondent's data, the Linear Regression method is used. Minitab 16 is used to help in processing the data. In Figure 3 below are presented the results of the significance of each respondent for Simple Reaction Time, Stroop Test, heart rate and blood pressure measurement. After calculation of significance to each respondent is done, the next step is to count the significance of each data based on age categories as set before. Thus, the respondents data obtained will be incorporated according to the two age categories. The result of this calculation will be the reference to the appropriate retrofitting to be used as a benchmark in determining the level of fatigue according to the predetermined.age category. Respondent 1 to Respondent 6 are drivers (research respondents) in the productive age category. Meanwhile, Respondent 7 to Respondent 12 are drivers in the adult age category. Hereafter, the recapitulation table of significance data processing from the drivers (respondents), using Linear Regression method in Minitab 16 is presented in Figure 3.

In addition to the descriptive statistical method and the Linear Regression method, correlation between the subjective approach (KSS) and the other approaches (cognitive approach and physiological approach) are also being researched using the Spearman-Rank correlation method which contained in the statistical software SPSS (Statistical Package for Social Sciences). This correlation is being calculated to determine whether there is possible correlation between the measurements using KSS compared with the measurement results from the Simple Reaction Time, Stroop Test, heart rate, and blood pressure measurement obtained from the drivers

(research respondents). Below in Figure 3 is shown one of the Spearman-Rank correlation measurement results.

Correlations

			KSS	StroopTest
Spearman's rho	KSS	Correlation Coefficient	1.000	.800
		Sig. (2-tailed)	.	.200
		N	4	4
	StroopTest	Correlation Coefficient	.800	1.000
		Sig. (2-tailed)	.200	.
		N	4	4

Figure 3 Spearman-rank correlation test interpretation result between the KSS questionnaire and driver's stroop test data

From Figure 3, we can conclude that the coefficient correlation is positive, whereas the correlation obtained is aligned. This indicates that if the KSS (Karolinska Sleepiness Scale) increases, the level of stress/tension a driver experienced will also increase. However, in order to test the hypothesis related to the significance of the data, we must examine the results. The results of the criteria for the relationship between the two variables are not significant, because the significance value is 0.200 (greater than 0.05) at the 95 percent confidence level. Therefore, the decision is rejected, because the data is not significant. The conclusion obtained based on the interpretation of Figure 3 is that there is no association between the KSS scale with the level of stress/tension (Stroop Test).

4. CONCLUSION

This study was conducted to determine the significance (influence) of male motorcycle driver's fatigue level compared with the three approaches implemented in the study (cognitive approach, physiological approach, and subjective approach). In addition, this study also aimed to have a comparison of male driving fatigue level in the age categories studied. The expected impact of this research can reduce the rate of future traffic accidents that could occur in Indonesia, especially motorcycle accidents.

All processed data have passed the adequacy test, which consists of a normality test, an independent test, and an homogeneity test. Data obtained from each respondent (data from Simple Reaction Time, Stroop Test, heart rate, and blood pressure measurement) were then processed using the Linear Regression method in Minitab 16 to find out the significance of each piece of data. The results from the significance test show that the significance from each respondent, either from the same age category or not, vary from one and another.

Results obtained from this study are that each age category has a significance related to the respective results from the cognitive approach and physiological approach measurements. The significance (influence) of heart rate on the level of fatigue is found in both age categories (productive and adult age category). Meanwhile, the significance (influence) of blood pressure on the level of fatigue is found only in the adult age category. The Simple Reaction Time measurement results found a significance related to the level of fatigue in the adult age category. Thus, it can be said that in the adult age category, there is an influence between the level of fatigue and concentration level.

Meanwhile, significance in the Stroop Test was only found on the productive age category. This indicates that there is an influence between the level of stress/tension and the level of fatigue in that age category. Furthermore, for the interpretation of the results of the two approaches (cognitive approach and physiological approach) and the KSS (subjective approach) as tested, using the Spearman-Rank correlation, there was found to be a strong correlation. This indicates that the more tired the driver, then the subjective measurement result (KSS) will increase.

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