



Room Steering Temperature Determination with Variable Concerned of Driver Conditions Who are Sleep Deprived and Road Condition

Ryan Ferdinand¹, Daniel Siswanto², Sani Susanto^{3*}

^{1,2,3}Universitas Katolik Parahyangan, West Jawa, Indonesia

*Corresponding author: ssusanto@unpar.ac.id

Abstract. Among the main reasons for the high death rate worldwide are traffic accidents. The most common cause of road accidents is driver fatigue. Not getting enough sleep is one thing that makes people tired. A study on how sleep-deprived sleep-deprived drivers felt about themselves was conducted, and the results showed that they were tired. A potential preventive measure against the driver's extreme weariness is the room steering temperature. The goal of this research is to find the room temperature range that produces the most minor drowsiness is this research's goal. The research used six treatments in a 40-minute driving simulator: hot, cold, pleasant room temperature steering, and monotonous and non-monotonous road conditions. With the Electroencephalogram, one may measure one's state of sleepiness by monitoring brain wave activity. Six treatments were administered to each of the study's four young adult male participants. Teta, alpha, and beta wave powers are derived by processing data from brain wave activity using Matlab R2009A. An ANOVA test is used to discover which factors affect the degree of drowsiness by using the ratio of sleepiness level, which is determined using the equation $(\theta + \alpha) / \beta$. ANOVA test results indicated that while road conditions and room steering temperature impacted sleepiness, their interaction had no effect. Just the hot-cold level is found to be significantly different by the Tukey and Newman Keuls tests. For sleep-deprived drivers, the temperature differences between hot and cold conditions result in varying drowsiness. The research's practical conclusion is that, for sleep-deprived drivers, a hot temperature range ($>26^{\circ}\text{C}-29^{\circ}\text{C}$) can result in the lowest level of tiredness.

Keywords: Electroencephalogram, KSS, Room Steering Temperature, Shortage of Sleep Duration

Introduction

One reason for most deaths worldwide is traffic accidents. The Global Status Report on Road Safety (2015) reported 1.25 million deaths annually. In Indonesia, car accidents accounted for 41% of all fatalities, according to data from the World Health Organization in 2015. The World Health Organization's 2015 assessment indicates that up to 40.000 victims may die in Indonesia annually. To minimize the number of accidents, it is crucial to carry out accident prevention measures.

Three primary categories contribute to traffic accidents: surroundings, vehicles, and humans (Hadon, 1980 in Peden, Scurfield, Sleet, Mohan, Hyder, Jarawan, & Mathers, 2004). Fatigue and

other human variables are among the many elements that significantly increase the probability of road accidents. Williamson et al. (2011) state that a driver's reduced performance may increase the chance of an accident due to weariness brought on by the time of day, length of time awake, and task-related factors. Thus, to lower the chance of an accident, effort must be made to prevent high levels of weariness. According to Meiliani and Mayawati (2012), room steering temperature is a component that can affect drivers' levels of weariness.

Before conducting this study, drivers must be sleep deprived to cause weariness. Lack of sleep in the previous 24 hours might worsen weariness and have the highest effect on driving safely, according to Williamson et al. (2011). Active and passive tiredness are the two categories into which Gastadi et al. (2014) divide the exhaustion felt during driving. Excessive driving, frequently observed on non-monotone roads, can lead to active weariness, but a lack of load on monotonous roads can lead to passive fatigue. Thus, each of the two road conditions was employed in this study as an independent variable. The room steering temperature, which has three levels—hot, chilly, and comfortable—will also be examined as one of the independent variables.

This research aims to find the room steering temperature range that can result in the least amount of sleepiness. It also attempts to ascertain the impact of road conditions and/or room steering temperature on driver weariness. According to Johnson et al. (2011), the gold standard for detecting shifts in the phases of consciousness from alert to drowsy or even fall asleep is electroencephalography (EEG), which is used to quantify sleepiness levels objectively.

A driving simulator and an EEG sleepiness level measurement will be used together to reduce the chance of an accident. According to Zhao et al. (2012), driving simulators are the preferred method for collecting data in mental fatigue research due to their ease of use, affordability, safety, and ability to create altered conditions. Reed and Green (1999) made this decision. Based on references from Larue et al. (2011) and Gastaldi et al. (2014), which also utilize a driving simulator in conjunction with EEG, the driving duration is forty minutes.

Research Methods

The study team used a driving simulator and an EEG in a lab experiment. Equation $(\theta + \alpha) / \beta$ calculates the dependent variable, weariness, depending on the sleepiness level. The study includes room steering temperature range, pleasant temperature range (23°C–26°C), hot temperature range (>26°C–29°C), cold temperature range (20°C–<23°C), and road circumstances (monotonous and non-monotonous) as independent variables. Only one night before the experiment, the participants' sleep duration—less than five hours—was the control variable. Apart

from room temperature, the other control factors are the participants' age and sex, the time they drove and how often they did so, the data collection method, and alcohol and caffeine use. Four factors can confuse the time to sleep and wake up, the learning curve, motivation, and activities other than gathering data. Every participant will receive every treatment because the experimental design approach is within the subject design. Combining room steering temperatures with the state of the road, there are six treatments available:

1. Consistently comfortable and between 23 and 26°C
2. A cozy temperature of between 23 and 26°C, Not boring
3. Consistently hot (>26–29°C).
4. Warm (>26–29°C), non-monotone temperature
5. A constant, chilly 20 to 23°C
6. Cold temperature, non-monotonic (20–23°C).

Taker

Four male research participants, ages 18 to 25, with an A license, are enrolled in this study. Due to the within-subject design method, four volunteers were chosen, and each person had to receive all treatments. Twenty-four data were obtained with four participants. The scope of data collection is in line with the quantity of this data.

Furthermore, although using fewer treatments, Foong et al. (2015)'s comparable study also involves four subjects. The effect of the order in which participants received treatments on the research findings is one of the drawbacks of the within-subject design. As a result, the counterbalancing strategy is used to reduce the impact of the treatment order. When using this technique, each participant will receive the same treatments in the same order. The result of counterbalancing is shown in Table 1.

Table 1. Result of Counterbalancing Application

Participant	Treatments					
	1	2	3	4	5	6
1	1	2	6	3	5	4
2	2	3	1	4	6	5
3	3	4	2	5	1	6
4	4	5	3	6	2	1

Filling out a sleep diary form is necessary to track participants' sleep duration, quality, and activities after waking up the night before the experiment. Participant compliance with regulations regarding the consumption of alcohol, caffeine, and cigarettes is required prior to using a driving

simulator. Only one treatment is administered to one subject daily during the experiment's implementation. Stated differently, the research findings were less affected by time differences if only one data set was collected each day at the same time and location.

The KSS Survey

In order to determine the driver's state of sleepiness prior to the experiment, a subjective measurement utilizing the KSS questionnaire is used. On a scale of 1 to 9, participants completed the KSS questionnaire. Johns (2009) explains the scale from 1 to 9. The following is a breakdown of the nine scales:

The following scales describe different states of alertness: vigilant (scale 1), very alert (scale 2), alert (scale 3), relatively alert (scale 4), neither alert nor sleepy (scale 5), some indication of sleepiness (scale 6), sleepy with no effort to stay awake (scale 7), sleepy with some effort to stay awake (scale 8), and highly sleepy with great effort to stay awake and fight sleep (scale 9).

Using an EEG to Measure Sleepiness LevelThe 16 observation points of the EEG used in this study are from the Emotiv Epoc. Emotiv Xavier TestBench is software used to record brain wave activity. The subject's head must have an EEG installed for data collection, and all of the sensors must be correctly detected, as shown in Figure 2 by the green color at two reference points and fourteen observation sites. The driving software's terms "monotonous" and "not monotonous" refer to different road conditions. A monotonous road has few bends, few other drivers, and no traffic lights. A non-monotonous road has many bends, other drivers, pedestrians, and traffic lights. The room steering temperature settings were achieved by modifying the air conditioner until the temperature reached is within the intended temperature range. The room steering temperature should be within the intended temperature range before and throughout the experiment, which can be checked with a thermometer.

Results and Discussion

The outcomes of the collected and processed data are explained below.

Original Condition Data for Sleepiness

Table 2 displays the initial sleepiness condition data, including the KSS score before the experiment and the amount of sleep each participant received on a single night before the trial. As a preliminary step before processing the data, the results of the KSS questionnaire are required. The participant's initial KSS score, indicating whether they were awake or tired, was used to collect their brain wave activity data. In order to guarantee that participants have experienced exhaustion

due to inadequate sleep duration, this questionnaire is designed to verify that the research purpose is to prevent the high fatigue that drivers experience.

Table 2. Data of Driver Initial Sleepiness Condition

No	Participant	Treatment	Sleep duration	KSS Score
1	1	1	3 hours	6
2	1	2	3 hours 45 minutes	5
3	1	3	3 hours 30 minutes	7
4	1	4	3 hours 45 minutes	7
5	1	5	3 hours 15 minutes	6
6	1	6	3 hours 45 minutes	6
7	2	1	4 hours	6
8	2	2	4 hours 30 minutes	6
9	2	3	4 hours 15 minutes	7
10	2	4	4 hours 15 minutes	6
11	2	5	4 hours 45 minutes	7
12	2	6	4 hours 30 minutes	7
13	3	1	4 hours 20 minutes	7
14	3	2	55 minutes	8
15	3	3	2 hours 30 minutes	7
16	3	4	1 hours 50 minutes	7
17	3	5	4 hours 20 minutes	5
18	3	6	3 hours 25 minutes	8
19	4	1	4 hours 40 minutes	8
20	4	2	4 hours 15 minutes	8
21	4	3	4 hours 30 minutes	8
22	4	4	4 hours 20 minutes	8
23	4	5	4 hours 20 minutes	8
24	4	6	4 hours 20 minutes	8

Brain Wave Activity Data

Brain wave activity data obtained through recording during doing a driving task by using an EEG. To obtain the data of brain wave activity, so participant have to drive on a driving simulator while using EEG for 40 minutes. Participant condition and tools that used during data collection can be seen in Figure 1.



Figure 1. Participant Conditions During Experiment

All proceeds recording of brain wave can not be displayed because brain wave activity is continuous, in the form of recording. Data example of brain wave activity that obtained during experiment can be seen in Figure 2. Data of brain wave activity that recorded in (.edf) format will be converted into a (.csv) format. Data of brain wave activity in the (.csv) format will be processed further using the MATLAB R2009A.

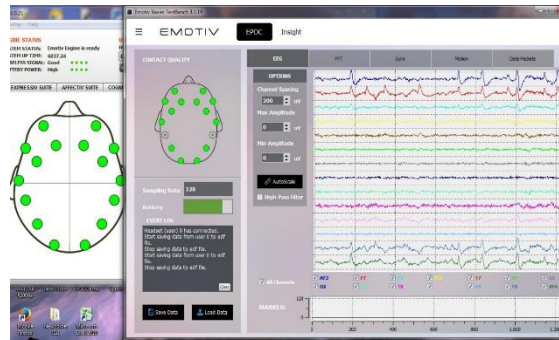


Figure 2. Data recording result of brain wave activity

Processing of Brain Wave Activity Data with MATLAB R2009A

Once brain wave activity data has been translated into a (.csv) format, data processing is done by entering the programming code for each data set. The programming code referred to is the code utilized in Pascawati's (2016) research. The initial procedure using that code involved splitting the 40-minute data on brain wave activity into ten segments of observation, with the average power of the brain wave activity for four minutes being the value in each segment. Following data input, definitions are made for the same brain areas:

$$F \text{ (frontal)} = (AF3+AF4+F7+F8+F3+F4$$

$$+FC5+FC6) / 8 \tag{Eq. 1}$$

$$O \text{ (occipital)} = \frac{O1+O2}{2} \tag{Eq. 2}$$

$$P \text{ (parietal)} = \frac{P7+P8}{2} \tag{Eq. 3}$$

$$T \text{ (temporal)} = \frac{T7+T8}{2} \tag{Eq. 4}$$

Only the brain's theta, alpha, and beta waves will be observed in this study. According to Zhao et al. (2012), research findings, collected brain wave data must therefore be pre-sorted into three EEG frequency components: theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz). In order to facilitate the reading of the entered brain wave activity data, the EEGlab component is required as an extra feature when processing data using MATLAB R2009A. A table similar to Figure 3

would result from entering the programming code and obtaining the power (μv) of the alpha, theta, and beta waves.

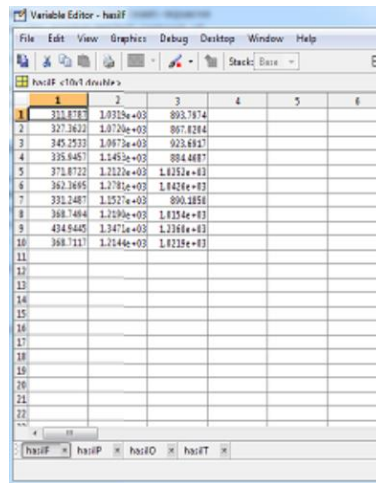


Figure 3. Example of Programming Result With Matlab R2009A

The Matlab process would generate the power of alpha, theta, and beta waves in the frontal, temporal, occipital, and parietal regions of the brain. The brain's frontal region is the sole one that is utilized and processed by Ms. Excel. The reason for this is that driving is a task that necessitates both physical and cognitive activity simultaneously, and the brain's frontal region controls both of these functions in humans. Furthermore, the frontal cortex is the brain region most involved in daily human activities.

Sleepiness Level Ratio Calculation

The power of alpha, theta, and teta brain wave that obtained at Figure 3 would be an input in calculating of participants sleepiness level ratio with using an equation from Jap et al. (2009), that is:

$$\text{Sleepiness Ratio} = \frac{(\text{power alpha} + \text{power theta})}{\text{power beta}} \quad \text{Eq. 5}$$

Before calculating the ratio of sleepiness level, it's needed to calculate in advance the average power for alpha, theta, dan beta wave from 10 parts of existing observation. The example of calculating the average wave power for data X16 (participant 1st and treatment 6th) can be seen in Tabel 3.

Table 3. Calculating Result of Average Power

X16			
Part	Alpha (µv)	Beta (µv)	Tetha (µv)
1	156,7034	451,0913	390,6027
2	148,0372	454,1872	404,9676
3	143,7392	424,6459	358,8660
4	151,8626	425,3908	385,3489
5	132,2140	400,0703	348,9712
6	124,5640	399,9607	346,7497
7	130,0382	380,6695	352,1513
8	127,9737	372,1292	324,5409
9	121,4931	379,5621	324,9644
10	133,5356	399,5166	355,0033
Average	137,0161	408,7224	359,2166

The value of average power that have been obtained will be an input for calculating the ratio of sleepiness level, that is ratio between slow wave and fast wave activities. For the above example, the ratio of sleepiness level for data X16 is $(137,0161 + 359,2166) / 408,7224$, that is 1,2141. The same process is also conducted for the another 23 experimental data. Result recap of sleepiness level ratio calculation for the entire data can be seen in Table 4.

Table 4. Recap of Sleepiness Level Ratio Calculation

Ratio of Slow Wave and Fast Wave			Temperature (B)		
			23-26 °C	>26 - 29 °C	20 - <23 °C
			Comfort	Hot	Cold
Road Condition (A)	Monotonous	S1	1,4599	1,1379	1,4200
		S2	1,2407	1,0910	1,6585
		S3	1,6530	1,2784	1,4382
		S4	1,4695	1,4185	1,6466
	Not Monotonous	S1	1,1597	1,1471	1,2141
		S2	1,1597	1,0339	1,0754
		S3	1,4043	1,2341	1,3348
		S4	1,3639	1,3534	1,4760

Processing Data with Statistics

To achieve the desired aim of this research, so it requires to do a variance test and significant test through the sleepiness level ratio that obtained. To determine the effect of room steering temperature and/ or road condition on the level of sleepiness, ANOVA test of the sleepiness level ratio data must be conducted. Anova test that will be conducted is two factor within subject with the calculation process based on theory from Montgomery (2013) and Maxwell & Delaney (2004). ANOVA test result that obtained can be seen in Table 5.

Table 5. Result of Anova Test Calculation

Source	dof	Sum of Square	Mean Square	F ₀
Between				
Subjects (S)	3	0,2341	0,0780	
Within				
A (road condition)	1	0,1593	0,1593	33,9729
AXS (error of road condition)	3	0,0141	0,0047	
B (room steering temperature)	2	0,1694	0,0847	7,0723
BXS (error of room temperature)	6	0,0719	0,0120	
AXB (interaction factors A and B)	2	0,0526	0,0263	2,1107
AXBXS (error of interaction)	6	0,0747	0,0125	
Total	23	0,7761		

$F_{tableA} = 10,13$; $F_{tableB} = 5,14$; $F_{tableAxB} = 5,14$

From Table 5, it can be concluded that road condition factor and room steering temperature factor affect the driver’s sleepiness level. That are because the value of F₀ for both factors is greater than the value of F_{table}. Meanwhile, interaction of both factors doesn’t affect the sleepiness level because the value of F₀ is smaller than the value of F_{table}. The result of interaction of these two factors is also in accordance with the plot data that has been conducted. From Figure 4, it can be seen that there is no interaction between two factors.

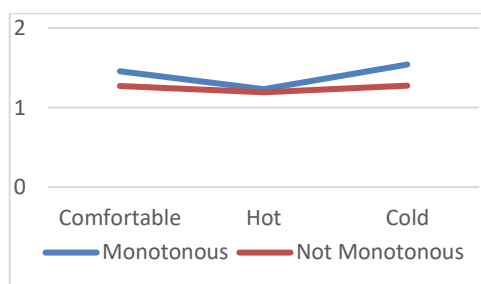


Figure 4. Graph Plot Result of The Average Sleepiness Ratio

Only the temperature or the state of the roads influenced the degree of drowsiness found by the ANOVA test. The road quality aspect is undoubtedly much different because there are only two levels. Nevertheless, there are three degrees of room steering temperature, and it needs to be clarified at this point whether or not these differences are substantial. The following procedure is a comprehensive temperature factor test comprising three stages. This major test is carried out to ascertain whether there is a substantial difference between the three room steering temperature settings. Since the road conditions and room steering temperature do not interact, the calculation method is carried out by integrating the data from both road conditions. Thus, a different computation for every road condition is optional.

The Newman Keuls and Tukey tests are the two techniques used for a significant test. To produce the same conclusion, both approaches employed the same table, precisely the percentage points of the studentized range statistic table. Table 6 shows the findings from the Tukey test, while Table 7 shows the results of the Newman-Keuls test.

Table 6. Tukey Test Result

Road Condition	Level factor B	Average difference	T_α	Conclusion
Monotono-us and not monotono-us	Comfort-Hot	0,1521	0,1681	Not Significant
	Hot-Cold	0,1961		Significant
	Comfort-Cold	0,0441		Not significant

From Table 6, it can be seen that only level of hot temperature and cold temperature that has a significant differences. This is because the value of average difference between both levels is greater than the value of T_α . Meanwhile, level of cold-comfort and hot-comfort don't have a significant differences.

Table 7. Newman Keuls Test Result

Road Condition	Level factor B	Average difference	T_α	Conclusion
Monotono-us and not monotono-us	Comfort-Hot	0,1521	0,1681	Not Significant
	Hot-Cold	0,1961		Significant
	Comfort-Cold	0,0441		Not significant

Only the degree of hot and cold temperature ranges show significant variations in the results obtained from the Newman-Keuls and Tukey tests. This is because, while the levels of hot and cold comfort do not significantly differ, the average difference between the two levels is more significant than the K_p number. The substantial shifts in the hot and cold levels suggest that variations in the hot and cold temperature ranges are responsible for the variation in the sleepiness level ratio. In order to meet the research goal, it is necessary to identify the room steering temperature range that causes the most minor drowsiness in sleep-deprived drivers. The hot temperature range and the cold temperature range are the temperature levels that differ significantly, according to the significant test.

Based on the mean ratio of sleepy level generated by the two temperature ranges, it can be observed that the hot temperature range yielded a lower average ratio of sleepiness level than the

cold temperature range. The excellent ratio of tiredness level suggests that individuals were most sleepy in a calm room environment. An increased risk of traffic accidents might arise from this higher level of weariness, which can cause drivers to perform less well and experience slower reaction times. Drivers who experience sleep loss the night before should adjust the room steering temperature to a hot temperature range ($>26^{\circ}\text{C}$ – 29°C), as this temperature range results in the lowest ratio of sleepiness level. This is the practical recommendation of this research. The air conditioner or heater in the vehicle can be used to establish the recommended room steering temperature.

Conclusion

Following data collection and processing, the following conclusions were drawn:

1. The road condition or room steering temperature can impact a sleep-deprived driver's degree of sleepiness. A sleep-deprived motorist will suffer some drowsiness despite simultaneous manipulation of the road condition and room steering temperature. The shift in one factor, the temperature or road condition factor, results in a different sleepiness ratio value. When road condition and room steering temperature factors are adjusted simultaneously, there is, nevertheless, no discernible change in the ratio of sleepiness level.
2. The temperature range of $>26^{\circ}\text{C}$ to 29°C , or hot, is the room steering temperature range that can result in the lowest ratio of sleep level for both types of driving circumstances. The rationale behind this is that out of the three-room temperature levels, the only two that exhibit notable variations are hot and cold. Put differently, the difference in temperature between comfortable and hot does not affect the degree of drowsiness. The average ratio of sleepiness induced by the hot temperature is smaller than that caused by the cold temperature in this temperature range, which is distinguished by a substantial difference.

Bibliography

- Foong, R., Ang, K. K., Quek, C., Guan, C., & Wai, A. A. P (2015). An analysis on driver drowsiness based on reaction time and EEG band power. *IEEE*, 15, 7982.
- Gastaldi, M., Rossi, R., & Gecchele, G. (2014). Effect of driver task-related fatigue on driving performance. *Social and Behavioral Sciences*, 111, 955-964.
- Jap, B. T., Lal, S., Fischer, P., & Bekiaris, E. (2009). Using EEG spectral components to assess algorithm for detecting fatigue. *Expert System with Application*, 36, 2352-2359.
- Johns, W. M. (2009). What is Excessive Daytime Sleepiness. Melbourne : Swinburne University of Technology.
- Johnson et al., (2011). Drowsiness/alertness algorithm development and validation using synchronized EEG and cognitive performance to individualize a generalized model. *Biological Psychology*, 87, 241-250.

- Larue, G. S., Rakotonirainy, A., & Pettitt, A. N. (2011). Driving performance impairments due to hypovigilance on monotonous roads. *Accident Analysis and Prevention*, 43, 2037-2046.
- Maxwell, S. E., & Delaney, H. D. (2004). *Designing Experiments and Analyzing Data. A Model Comparison Perspective Second Edition*. London : Mahwah, New Jersey.
- Meiliani, R & Maywati, S. (2012). Studi komparasi dampak penggunaan AC (air conditioning) pada bus terhadap tingkat kelelahan pengemudi. *Jurnal Kesehatan Komunitas Indonesia*, 8.
- Montgomery, D. C. (2013). *Design and Analysis of Experiments 8th Edition*. Arizona : Arizona State University.
- Pascawati, R. (2016). *Studi Kelelahan Aktivitas Mengemudi pada Simulator Kereta Api dengan Memanfaatkan Electroencephalogram (EEG)*. Tesis Teknik Industri. Bandung : Institut Teknologi Bandung.
- Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A. A., Jarawan, E., & Mathers, C. (2004). *World Report on Road Traffic Injury Prevention*. Geneva, Switzerland: World Health Organization.
- WHO. (2015). *Global Status Report on Road Safety 2015*. Geneva, Switzerland: World Health Organization.
- Williamson, A., Lombardi, D., Folkard, S., Stutts, J., Courtney, T., & Connor, J. (2011). The link between fatigue and safety. *Accident Analysis and Prevention*, 43, 498-515.
- Zhao, C., Zhao. M., Liu, J., & Zheng, C. (2012). Electroencephalogram and electrocardiograph assessment of mental fatigue in a driving simulator. *Accident Analysis and Prevention*, 45, 83-90.