The multiple crashes in Indonesia are categorized into a frequently occurring accident, which often causes death. Indonesia’s existing traffic laws do not yet regulate safe driving distances. Meanwhile there has been a lot of research on the safety of distances between vehicles carried out only on technical factors. The aim of this paper is to examine the driver psychophysiology during braking in response to the vehicle in the front, which is varied.

The research was initiated with a literature review regarding the Electroencephalography (EEG), safe braking distance, Emotive Epoc+, and Central Nervous System (CNS). Research design with direct driving experiments on the road is used to analyze what happens to the driver’s brain when braking at a certain distance (psychophysiologic factor). The collected sampling data are from 4 male healthy drivers with the age between 20-40 years and average driving experience of more than 5 years. The measurement of brain activities into a spectrum of colors and Emotive BCI 16 electrodes through the performance matrices was conducted for the existing condition and condition suitable with the safety distance permitted. Experiments have been tested in 4 different road conditions of residential road (speed <30Km/h), city road (speed <50Km/h), rural road (speed <80Km/h) and motorway (speed <100Km/h). Safety distance measurement used standard data with residences road = 10m, city road = 29m, rural road 73m, and motorways = 115m. Results of brainwave signal have been recorded by Emotive Epoc Brain Activity map and Emotive BCI matrix and have been used to analyse the driver’s psychophysical.

The findings show that the level of stress in the existing condition is very wherein for the braking in the densely populated residence = 87, urban areas = 83, intercity = 76, and motorways = 60. In contrast, following the safety distance rules have successfully reduced mental stress to average 47 as proofed by lower beta signal especially on occipital lobe (vision function) and on frontal lobe (attention function). Improper infrastructure such as narrow road at heavy residential damaged driver relaxes and increased stress level as indicated by increasing brain signal significantly.

Meanwhile, driving while concerning the safety braking distance psychophysiologically through the identification of brain activity will be able to lower the driver’s stress and fatigue level.

**Key words:** safety driving, safety braking distance, Electroencephalography (EEG), Central Nervous System (CNS)
BACKGROUND

Currently, the number and impact of traffic accidents are still categorized as very high for developing countries. According to the data of police in Indonesia in 2018, there were 5,400 accidents with 524 casualties. These accidents were caused by multiple factors including the driver (skills, age, physique, etc.), vehicle, road infrastructure, and driving regulations. Transportation in Indonesia is regulated by Act No. 22 of 2019 which regulates the maximum speed limited to drive in residences (30 Km/h), cities (50 Km/h), intercities (80 Km/h), and motorways (100 Km/h). There has been no regulation that concerns on the safety distance between vehicles despite multiple crashes caused by this condition frequently occurs.

Conference of European Directors of Road (CEDR) stated the importance of car drivers to be able to maintain the gap distance to the car in front of them [1]. The report also mentioned an example of safety distance regulation between vehicles in European countries. For instances, Estonia used 2 seconds regulation wherein the gap distance must be at minimum can be reached by the car behind it for two seconds in accordance with the speed, drivers in Finland with gaps less than 1s in the speed beyond 60 Km/h without braking will be fined and if the gap is 0.25s, the drivers’ license will be suspended for 1 month, in Norway, the vehicle gap will be regulated if the distance < 0.3s for vehicles with a weight < 3.5t and 0.5 for a weight > 3.5t. Saffarzadeh, M. et al., [2] in their article explained the formulation of Time to Collision (TTC) toward the alternation of speed and acceleration. The utilization of TTC based on the acceleration linear assumption in attempts to avoid crash can lower driver errors. TTC is the main criterion in the attempt of decreasing traffic conflict to confront when and how drivers speed up and slow down their cars [3]. TTC is essential to avoid accidents and it can also be implemented in motorways [4]. Gaididei, Y. B et al. [5], in their article, examined the time modulation on the safe distance between vehicles that can be used to control the formation or pattern of traffic on main roads. Chen, Y. L. [6] in his paper elaborated the safe distance between vehicles into a complete formulation that involves the factors of car weight, aerodynamics resistance, tyre friction, and brake efficiency.

The braking timing that is sudden and high-risk for crash surely will impact the driver’s psychophysiology. Therefore, it is necessary to conduct an investigation that measures how far the impact of the braking process as seen from the nervous system. Several studies examined stress and its impacts on the nervous system. Stress can cause a change in the structure of different brain parts [7,8]. The change in brain structure can cause a difference in the response toward stress, cognition, and memory. Heavy stress can endanger the brain physique including a decrease in brain weight [9]. Electroencephalography (EEG) can depict the electrodermal activity of the brain [10,11], negative effects activate the right side of the prefrontal cortex [12]. Furthermore, Kalas, M. S., & Momin, B. F. [13] explained the utilization of EEG for the reduction of human stress that can be very useful in developing products.
In examining the relationship pattern between the psychophysiological condition of drivers while braking and brain activity, it is divided into two main parts according to the theoretical approach, which include: the gap distance between cars and the BCI system by identifying it through the Emotive EPOC+.

**Safety Distance Between Car**

In the future, the measurement of safe distance and alarm system will be the basic instruments in a vehicle even though not all vehicles are currently armed with these systems. Only fancy modern cars are provided with a warning system. Driving with a very short distance with the car in the front is the main problem in traffic that causes fatal accidents. A survey on proactive steps to be able to continuously monitor the safe distance showed that there has been a serious lack of tools. Many of these tools are not easy to be installed in vehicles [14]. The distance of moving vehicles in a period of reaction time is known as reaction distance. Reaction distance = Reaction time * Vehicle speed. The proportion of accident behind a vehicle in a traffic accident is almost 1/10. If there is minor attention to the front part of the vehicle and unstable emotion, the proportion will become 4/10, which will cause casualties and economic loss [6].

Braking system and braking distance are the main concerns when calculating the Time to Collision (TTC). Danish Road Standards and Guidelines investigate the friction value on tires and roads. The braking distance acquired from the factors of speed, friction coefficient, and road slope is formulated as follows:

\[
l_{brake} = \frac{v^2}{2.g.(\mu_{brake} + s).3.6^2}
\]

wherein:
- \(L_{brake}\) = braking distance (m)
- \(V\) = vehicle speed (Km/h)
- \(G\) = acceleration due to gravity (9.81 m/s\(^2\))
- \(\mu_{brake}\) = mean coefficient of friction
- \(s\) = roadway grade

Another study by Chen, Y. L., & Wang, C. A. [6] explained the driver safe distance to hit the brake. In the formulation, it is already involved multiple aspects including the vehicle weight, aerodynamics resistance, brake efficiency, road slope, and roll factor. The distance of braking timing can be formulated as follows:

\[
d_s = \left[\frac{W}{2gC_{ae}}\right]\ln\left(\frac{1+C_{ae}v^2}{\eta\mu W + f_i W\cos\theta + W\sin\theta}\right)
\]

wherein:
- \(W\) = Vehicle weight (Kg)
AASHTO Green Book [15] calculated the car braking distance with the following formulation:

\[ ds = 0.039 \frac{v^2}{a} \]

wherein:
- \( d_s \) = braking distance (m)
- \( v \) = speed (Km/h)
- \( a \) = deceleration (m/s\(^2\)), recommended = 3.4 m/s\(^2\)

Based on the calculation of maximum speed in residences 30 Km/h, it is acquired a braking distance of 10.3m, maximum speed in cities 50 Km/h with a braking distance = 28.68m, maximum speed in intercities 80 Km.h with a braking distance = 73.41m, and for the maximum speed in motorways 100 Km/h with a braking distance = 114.71m.

**Brain Computer Interface (BCI) System**

Neuroergonomics is an application of neuroscience in the field of ergonomy which analyzes the relationship of human – machine – work environment. Neuroergonomy directly addresses what happens in the brain as a psycho – physiology in conducting an activity. Brain Computer Interface (BCI) works depending on the brain signal reception and the channeling of it to the computerized electronic devices [16]. Brain Computer Interface (BCI) is widely used in biomedical to change individuals who lost their ability to communicate or move. Febo Cincotti *et al.* [17] in their study investigated the non-invasive brain computer interface system to operate the aid tools for fourteen patients with severe motor defects due to a progressive neurodegenerative disorder. Marcin Kolodziej [18] in his journal reported that the genetic algorithm (GA) is useful to implement the efficient method of feature and electrode selection. This paper also shows the frequency of the EEG spectrum, which is the most important. Fig. 1 explains the main principle of the BCI working system and non-invasive Emotive Epoc+ [19].

The BCI Emotive Epoc+ is an aid tool that can catch human brain signal with a non-invasive method, which is a collection of electrodes that can measure the
considered low voltage potentials (5 -300 µV) from the surface of a skull. The BCI Emotive device works in the system of 10/20 with 16 scalp sensors. The EEG is very popular among researchers to acknowledge the relationship between what happens to the brain signal during the physical and mental activities implemented. The use of the EEG signal as a communication vector between human and machine is one of the challenges that are currently in signal theory research. The characteristics of electricity from human nerves system have been admitted for more than a century. It has been known well that the variation of potentials distribution on human head scalp reflects the functional activities occurred from the brain which underlies. The surface potentials variance can be recorded by putting an array of electrodes to the head scalp and measure the voltage between these pairs of electrodes, which then is filtered, strengthened, and recorded. The form of EEG waves is generally classified according to the frequency, amplitude, and shapes, as well as the sites on head scalp wherein they are recorded. The most well-known classification uses the frequency of EEG waves (such as alpha, beta, theta, and delta). The delta wave on the frequency range of 0-4 Hz, Theta 4-8 Hz, Alpha 8-13 Hz, Beta 13 - 30 Hz dan Gamma > 30 Hz.

The brain generally can be divided into 4 parts (see Figure 1a) including the cerebrum, cerebellum, brain stem, and limbic system. Cerebrum has functions...
to make humans do logics, have thinking capabilities, learn languages, planning, and decision-making. Besides, it also functions as a reminder and visual ability in the human body. The cerebrum comprises of the frontal lobe, parietal lobe, temporal lobe, and occipital lobe. Frontal lobe functions for planning and decision-making, parietal lobe functions for sensing, temporal lobe functions for emotions, memory, and hearing, and occipital lobe functions for visual [21].

Methodology

The objective of this research is to acknowledge the drivers’ behavior during braking in a variance of gaps to the car in front of them from the perspective of psychophysiology. The EEG Emotive Epoc+ as explained previously is a scanning device based on the non-invasive method. The experiment conducted comprises of two main scenarios, including: the existing condition of the main road in several city segments in Indonesia and condition with a steering distance in accordance with the safety distance regulation. There are four types of road conditions including residences (Vmax = 30 Km/h), cities (50 Km/h), intercities (80 Km/h), and motorways (100 Km/h) for the measurement in accordance with the safety is residences distance = 10m, cities distance = 29m, intercities distance 73m, and motorways distance = 115m.

Fig. 3 depicts the steps of investigation of the impacts of car braking distance on the drivers’ psychology through the identification of brain signal. On the EEG

![Diagram](image-url)
installation step, it must be assured that the EEG connection with brain is good enough, which is marked by green color on all 16 electrodes. If needed, it can be added a lubricant to improve the connection. During the analysis and discussion regarding the result using the application of Emotive Brain Activity Map v3.3.3 and 3D brain Visualizer. Five respondents with short hair were chosen to be driving samples.

RESULTS

The result of the measurement is based on brain activity visualization for each experiment. Orderly, it is shown the brain activity for the existing condition wherein the delivery happens on the driver’s regular distance and the second is with the delivery of the driving in accordance with the safety distance regulation between vehicles.

Braking Psychology on the Existing Condition

The absence of a law regulating the distance between vehicles and the culture of driving safety that remains low cause an irregularity in the arrangement of the vehicles in the main road. This irregularity causes a level of stress and high physical fatigue. The test on the psychological impact of the delivery was firstly conducted in residence. The track in residences is characterized by the density of vehicles passing along, the volume of vehicles going in and out, a high number of pedestrians, and narrow roads (± 4m). This condition causes the drivers to be unable to brake when the vehicle in front of them slowed down, yet also braking when passing against other vehicles.

Fig. 4 shows a general overview of driving in densely populated residences. Fig. 4a explains the moment of passing against other vehicles while slightly slowing down. From the picture, it can be explained that the brain activity is dominated by beta frequencies (13–30Hz) which was produced by the channels of FP1, FP2, F3, F4, F7, F8, FC5, FC6, T7, and T8. While passing against other vehicles in a narrow road, the drivers are in alert position and forced to imme-

Fig. 4a. Going through residence while passing against other vehicles, b. when braking
diately decided braking moves. Meanwhile, for fig. 4b, it is very clear that for braking due to the slowdown of the vehicle in the front, the brain signals in all electrode positions were heightened. The brain functions for planning, moving, decision-making, hearing, and sight work optimally. Overall, it can be assumed that the vehicles in dense residences, narrow road, and 2 – 5 m gap distance between cars cause the brain to work optimally as marked red on all electrode positions. Besides, from all indicators of BCI matrix, it is acquired that the range of stress for drivers in residences are on the score of 87 when braking, 82 when passing, and 74 when there is no obstacle. The almost similar thing also happened when braking for the road condition in cities (83) and intercities track (76). The process of braking produces big energy of beta wave (dominant) and also a high level of stress.

A slightly different psychophysiological response happened during the braking process in a motorways. Fig. 5 explains two different conditions while crossing normally and when braking. From Fig. 5a, it can be explained that while going on, the drivers’ brain wave is not very big and there is low activity on theta (4-7 Hz). The level of stress apparent from the matrix of emotive BCI is 53. In Fig. 5b, the process of braking increased the beta brain wave quite significantly yet still far lower compared to other 3 road conditions. The brain activity in the occipital lobe, represented by the electrode 01 and 02, for the visual process toward the road situation is quite low due to the less complex road condition and the quite far distance between vehicles. The average level of stress for drivers who did braking in motorways is 60.

**Braking Psychology on safety distance**

As explained before that the braking safety distance is varied for different road conditions. The field experiment measuring the change of brain waves for the regulated safety distance is 10m, 39m, 73m, and 115m. from the measurement result, it can be concluded that the average brain activity decreases significantly due to the drivers having quite the time to slow down. Fig. 6 depicts the change
of brain activity primarily for the beta wave when going normally and when braking. Therefore, minding the distance between cars and cars in the front is very important to maintain the physical and psychological rhythm which eventually will lower the level of stress. Based on the value of Emotive BCI matrix, the stress value with the braking distance in accordance with the regulation is on average 47.

This research provides an option to complement the studies on safety distance for braking by not only measuring the technical factors, such as vehicle weight, drag force, and other technical factors but also the psychophysiological factors through the identification of brain wave changes using the electroencephalography (EEG) instrument. In the future, the assessment of brain wave other than to assess the stress level can also be used as a correction factor toward the determination of braking safety distance. Therefore, it is not only able to avoid crash among cars but also able to reduce the drivers’ physical and psychological fatigue. Besides, this research also provides a recommendation to pay attention to the infrastructure factor as the main part in improving the humanistic transportation quality. The narrow size of the road in residences, which significantly increases brain activity during passing, is the evidence. Jones, P [22], UK Department for Transport [23], and Davis, C., & Huxford, R. [24,25] explained the regulation of distance between vehicles that can be used as the foundation to determine the road width. This paper has already considered the type of entity that uses the main road, such as pedestrians, bicycles, motorcycles, cars, and trucks.

**CONCLUSION**

This paper has managed to heighten the utilization of the BCI application in the field of transportation. The EEG Emotive Epoc+ is able to show the difference in the drivers’ psychophysiological condition within a range of speeds and braking distances. The results of the brain activity visualization can be used as a foundation of alternative determination of driving safety distance either the ones going in residences, cities, intercities, and motorways. From the analysis result of the Emotive brain activity map, it can be concluded that the behavior of the existing condition which violates the safety distance regulation is very risky to constitute
a higher stress level, this is marked by the beta waves brain activity which is quite dominant and high. On the contrary, by following the recommended safety distance, the drivers have a controlled level of brain activity. The good humanistic infrastructure can improve the transportation quality which has prioritized healthy and safety thoroughly. In the future, it needs to be conducted further research that considers other factors, such as weather (dry or wet), driving time (morning, noon, afternoon, evening), and the road density.

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