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Development of Driving Simulation Experiment Protocol for the Study of Drivers' Emotions by using EEG Signal

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ABSTRACT

The Brain-Computer Interface (BCI) is a field of research that studies the EEG signal in order to elevate our understanding of the human brain. The applications of BCI are not limited to the study of the brain wave but also include its applications. The studies of human emotions specific to the vehicle driver are limited and not vastly explored. The EEG signal is used in this study to classify the emotions of drivers. This research aims to study the emotion classifications (surprise, relax/neutral, focus, fear, and nervousness) while driving the simulated vehicle by analyse the EEG signals. The experiments were conducted in 2 conditions, autonomous and manual drive in the simulated environment. In autonomous driving, vehicle control is disabled. While in manual drive, the subjects are able to control the steering angle, acceleration, and brake pedal. During the experiments, the EEG data of the subjects is recorded and then analyzed.

1. Introduction

The EEG research field was started in 1969 [1]. At first, Luigi Galvani of Bologna found that muscle contraction and nerve conduction produced the electrical pulse. The term Brain-Computer Interface (BCI) was first introduce by Professor Jacques Vidal in 1973 from UCLA in his paper "Toward Direct Brain-Computer Communication" [2]. Then, as the sensors and technology advance, the method of harvesting brain signals evolves from an invasive to a non-invasive method.

The simulations can recreate the real experience with the least cost, time and can ensure the subject's safety while driving the vehicle. There are certain rules in using simulation as a tool to stimulate the subject's emotions. The elements of audio and visual stimuli must be present for immersion to happen [3,4]. As stated by previous study [5], different types of music/sound and traffic situations can affect driving characteristics.

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Driving simulations are not widely used for EEG emotion classification. Aggressiveness [6,7], attention [8,9], sleepiness [10,11], and fatigue [12,13] are commonly studied for driver-related EEG research. Even though attention and focus are important for a safe driving experience, according to past study [14], unbalanced emotions can contribute to dangerous driving maneuvers.

The EEG data analysis starts by reducing or removing the unwanted noise. The noise is from muscle movement signals, EOG, ECG [15], EMG, skin artifacts, or technical errors such as dry electrodes and loose electrodes [16]. Then, the features are extracted. To reduce the misclassification rate, the features are selected based on the most significant p-values. Then, the classification uses the selected features as input to classify the emotions.

This paper discusses the proposed drivers' emotion classification method which focuses only on 5 different emotions (surprise, relax/neutral, focus, fear, and nervousness). The emotions of the subjects are analysed from the EEG signal during the simulated driving simulations. The simulated driving environment consists of two situations, manual and autonomous drive mode. During the experiments, the EEG signals of the subjects will be recorded and studied.

The paper is organised into three main sections. Section 1 discusses past research related to the classification of emotions. Section 2 discusses the proposed method for studying emotion classification while subjects drive in a simulated environment. Section 3 discusses the expected outcome of the proposed method.

2. Methodology

The flow chart for the design of the proposed methodology is shown in Figure 1. The research starts with develop a suitable research protocol by referring to related past research. There is a requirement from Universiti Malaysia Perlis (UniMAP) that all related research using humans as subjects needs to get ethical approval from the university ethical community. The experiments are conducted in two situations, autonomous and manual. In the autonomous drive, the simulation runs without any intervention from the subjects, and the EEG signals of the subjects are recorded during the experiments. In the manual drive, the subjects will control the simulation environment using the steering wheel, acceleration, and brake pedals provided. The EEG signals of the subjects were also recorded during the manual drive. The emotions of the subjects during the experiments were studied and classified. The classification of emotions is limited to only five emotions: surprise, relaxation, focus, fear, and nervousness. The classification performance of two classifiers (KNN and PNN) will be compared.

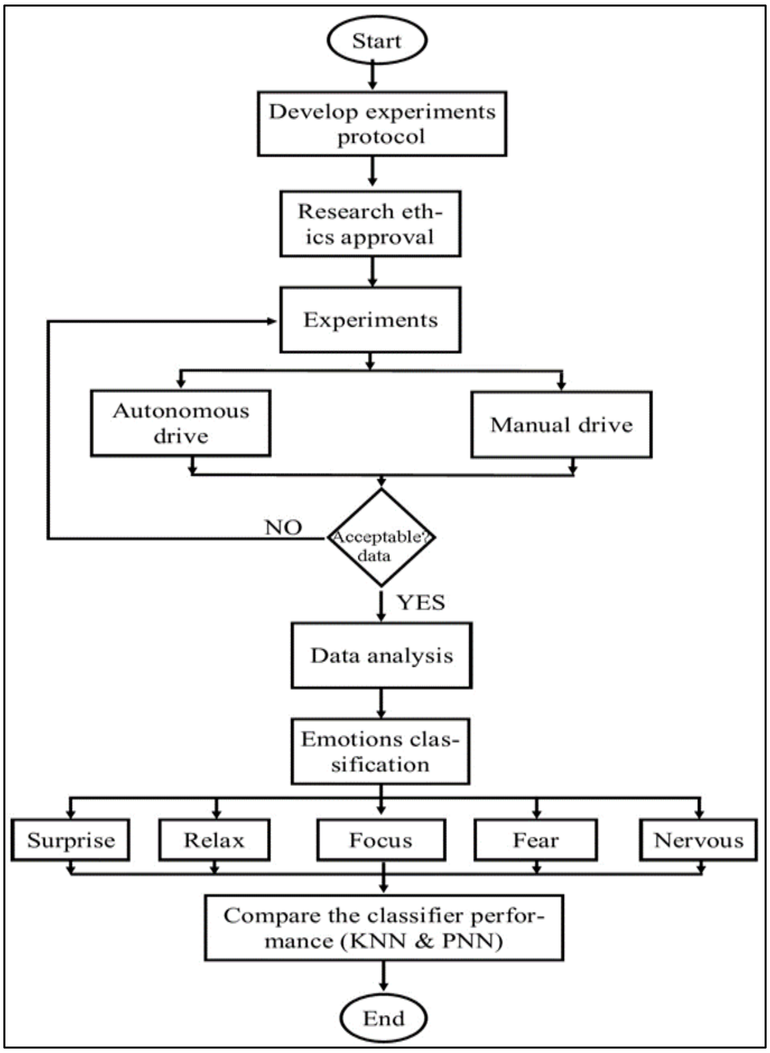


Fig 1. Flow chart for the proposed research

2.1 Design of Experiment Protocol

The process flow for the proposed experiment protocol is shown in Figure 2. There are two driving conditions developed for the experiments: autonomous and manual drive. The additional condition develops within the simulation environment in order to stimulate the driver's reaction and emotions, as mentioned in Sub-Chapter 2.2. If the developed driving situation is monotonous, the studied emotions cannot be stimulated.

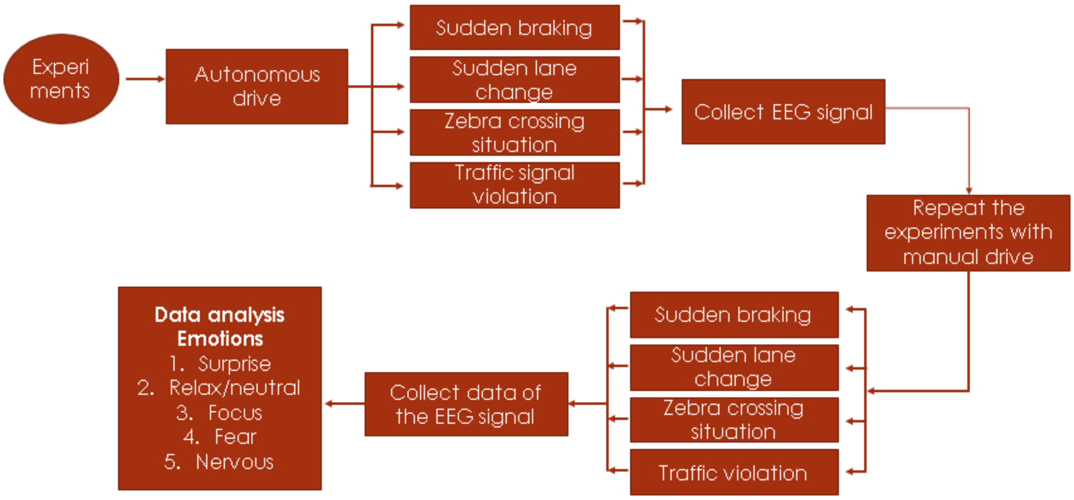


Fig 2. Process flow for the proposed experiments protocol

The experiment protocol is shown in Figure 3. First, the Emotiv Epoc X and Head Mount Display (HMD) which is the Oculus Quest 2 are attached to the subjects. Then, the subjects were given a series of instructions about the flow of the experiments in the form of a video tutorial. After that, the subjects are instructed to rest for 3 minutes. While resting, the relax EEG signal baseline is recorded. The experiments begin with autonomous driving and progress to manual driving. In between the experiments, the subjects are instructed to rest for 3 minutes. The electrode placement of the Emotiv Epox X follows the 10-20 system as shown in Figure 4.

Set-up	Instruction	Rest	Autonomous drive experiment	Rest	Manual drive experi-ment

Fig 3. Experimental protocol [17]

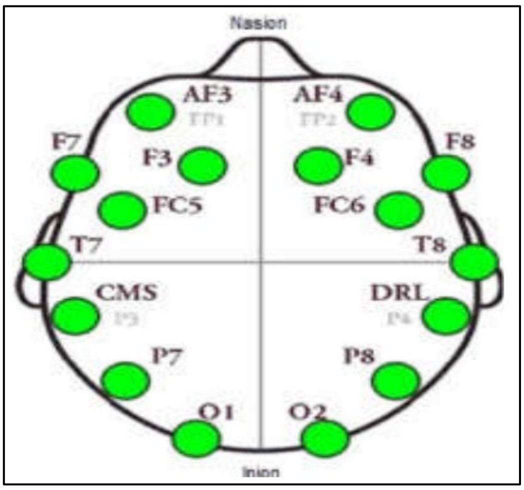


Fig. 4. Emotiv Epoc X electrode placement [18]

Figure 5 and Figure 6 show the proposed hardware setup for the experiments. The experiments use Oculus Quest 2 as a display for the fully immersive experience. The data from Emotiv Epoc X was transmitted wirelessly to the main computer. The experiment was conducted in two conditions: manual and autonomous drive. In the manual driving experiments, the subjects can control the steering wheel, acceleration, and brake pedal of the simulated vehicle using the Logitech G29 Driving Force Racing Wheel. The vehicle controls are disabled while driving autonomously.

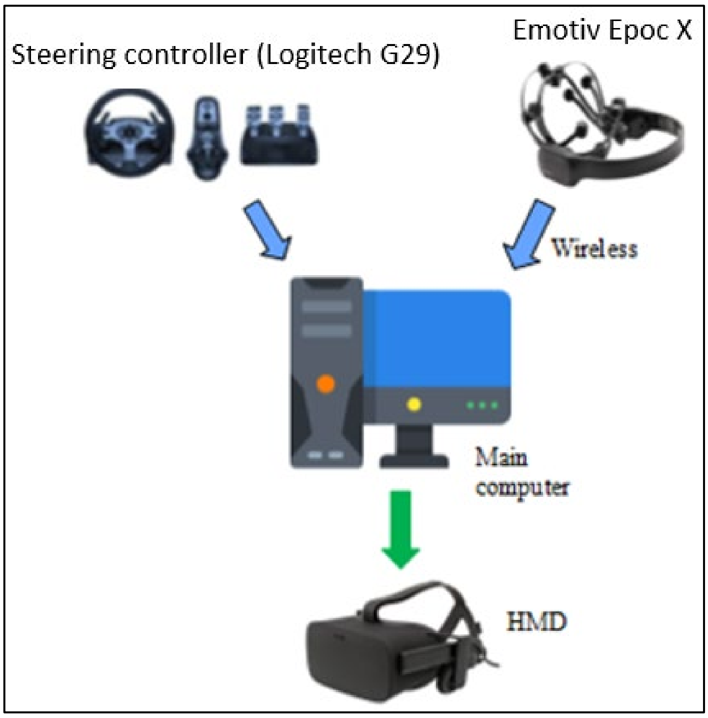


Fig 5. The proposed hardware architecture for the research

Fig 6. Proposed set-up of the experiments [19]

2.2 Simulation Design

The simulation was designed using Unity software. The simulation was designed to imitate and include real life situations. The situations added were chosen because it can stimulate the subjects' reaction/emotions. The simulation was designed with additional conditions added. Four situations were added into the simulation to trigger the driver's emotions and actions. The situations added are shown in Figure 7.

There are several factors that can contribute to traffic accident, one of it was the sudden braking and unexpected change lane maneuver [20]. The accidents that occur at the zebra are due to the uncertain and unpredictable passerby [21]. The phrase "traffic violation situation" refers to a scenario in which other vehicles break the rules of the road and may collide with the dummy vehicle. The simulation is intended to mimic the conditions of urban traffic, including the presence of pedestrians, following cars, and approaching vehicles.[22] also stated that improper overtaking maneuver increase the chances of road accidents. These circumstances were chosen so that the research could track and examine the subject's response to the abrupt change.

(c) (d)

Fig. 7. Simulated situation added in the driving simulation (a) The sudden braking situation by the lead car (b) Dangerous maneuver by the nearby vehicle (c) Pedestrian suddenly cross the zebra crossing (d) A vehicle violates the traffic light and may cause accident to the simulated vehicle

2.3 EEG data analysist

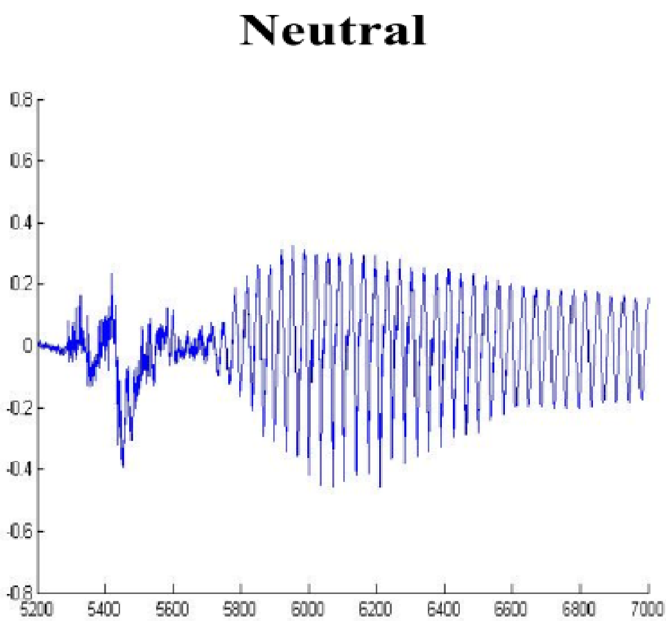
The raw EEG data amplification method is used to increase the amplitude of the raw EEG signal. To reduce signal noise, the amplified EEG signal was then filtered with a 6th order Butterworth filter. The signal between 0.5 Hz and 49 Hz was used for the analysis. The time domain signal is then converted to the frequency domain by using the Fast Fourier Transform method. The power spectrums of delta (1-3 Hz), theta (4-7 Hz), alpha (8-13 Hz), and beta (14-30 Hz) were used as features. The redundant features are reduced to decrease the classification error. The features with a p-value less than 0.05 are selected for the classification stage. The classification performances of the KNN and PNN classifiers will be compared. The classification only focuses on 5 emotions, which are surprise, relax/neutral, focus, fear, and nervousness.

3. Expected Results

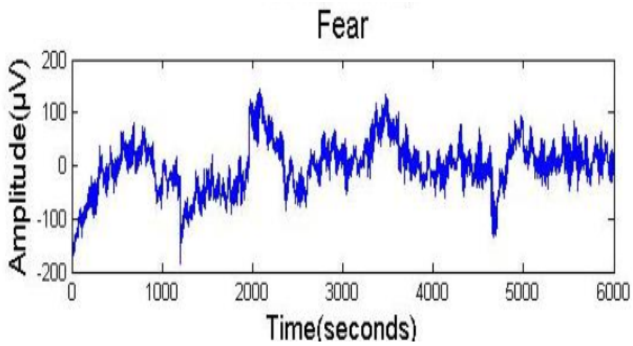
The simulation that was designed (Figure 8) was expected to stimulate the drivers' emotions by combining the visual (from the display on the HMD) and audio (the surrounding sound) as close as possible to the actual environment. The classification rate of the designed system is expected to achieve more than 80% of emotion classification accuracies [18,23].

Fig. 8. The designed simulate environment

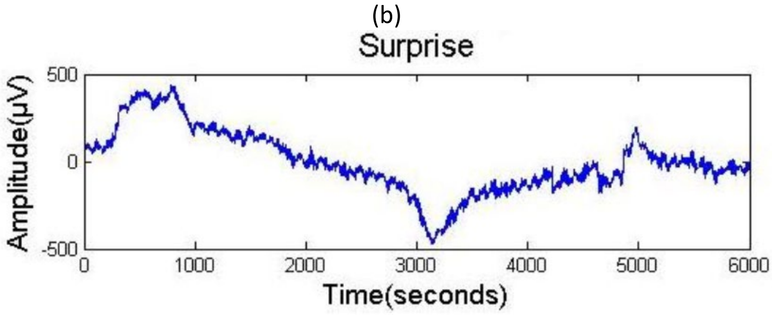
The emotion classification of the proposed method only focuses on several emotions (relax, fear, surprise, focus, and nervous). The expected EEG brainwaves for these emotions are shown in Figure 9. The EEG brainwaves of the emotions were referred to by the previous researcher.



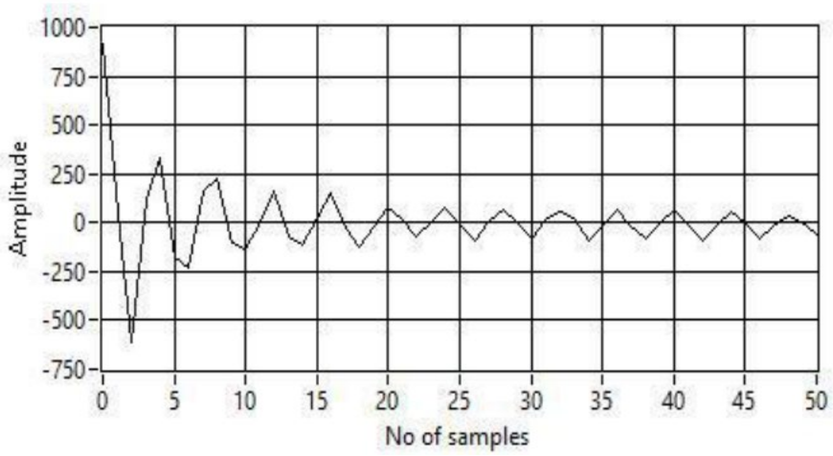
(a)



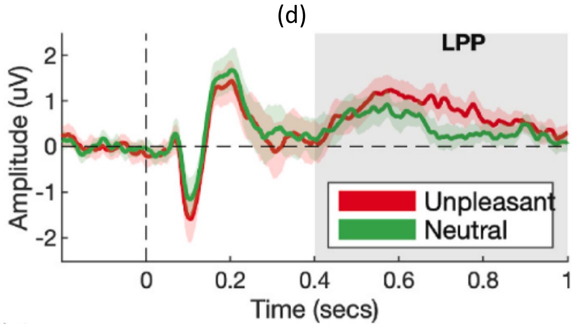
(b)



(c)



(d)



(e)

Fig. 9. Expected emotions classification from EEG signal (a) Relax/neutral emotion [24] (b) Fear [25] (c) Surprise [25] (d) Focus[26] (e) Nervous[27]

4. Conclusions

For the conclusion, the experimental protocol that were developed specifically to study the drivers' emotions. The emotions are triggered by create the suitable situations in the virtual environment. The situations designed were based on past research to study the driver behaviour.

The EEG signal analysis of the subjects can give new insight about the emotions occur during driving in autonomous and manual mode. In the autonomous mode experiments, the perception and emotions during the experiments are examined. While in the manual mode experiments, the emotions occur when certain situations occur are examined.

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References
[1] K. I. T. Mario Tudor, Lorainne Tudor, "[Hans Berger (1873-1941)--the history of electroencephalography] - PubMed," *Acta Med Croatica*, 2005.
[2] Vidal, Jacques J. "Toward direct brain-computer communication." *Annual review of Biophysics and Bioengineering* 2, no. 1 (1973): 157-180. https://doi.org/10.1146/annurev.bb.02.060173.001105
[3] Juan, M. Carmen, and David Pérez. "Comparison of the levels of presence and anxiety in an acrophobic environment viewed via HMD or CAVE." *Presence: Teleoperators and virtual environments* 18, no. 3 (2009): 232-248. https://doi.org/10.1162/pres.18.3.232
[4] Redlinger, Eric, and Claudia Shao. "Comparing brain activity in virtual and non-virtual environments: a VR & EEG study." *Measurement: Sensors* 18 (2021): 100062. https://doi.org/10.1016/j.measen.2021.100062
[5] Halim, Zahid, and Mahma Rehan. "On identification of driving-induced stress using electroencephalogram signals: A framework based on wearable safety-critical scheme and machine learning." *Information Fusion* 53 (2020): 66-79. https://doi.org/10.1016/j.inffus.2019.06.006
[6] Hu, Hongyu, Zheng Zhu, Zhenhai Gao, and Rencheng Zheng. "Analysis on biosignal characteristics to evaluate road rage of younger drivers: A driving simulator study." In *2018 IEEE Intelligent Vehicles Symposium (IV)*, pp. 156-161. IEEE, 2018. https://doi.org/10.1109/IVS.2018.8500444
[7] Li, Guofa, Weijian Lai, Xiaoxuan Sui, Xiaohang Li, Xingda Qu, Tingru Zhang, and Yuezhi Li. "Influence of traffic congestion on driver behavior in post-congestion driving." *Accident Analysis & Prevention* 141 (2020): 105508. https://doi.org/10.1016/j.aap.2020.105508
[8] Yeh, Shih-Ching, Chung-Lin Hou, Wei-Hao Peng, Zhen-Zhan Wei, Shiuan Huang, Edward Yu-Chen Kung, Longsong Lin, and Yi-Hung Liu. "A multiplayer online car racing virtual-reality game based on internet of brains." *Journal of Systems Architecture* 89 (2018): 30-40. https://doi.org/10.1016/j.sysarc.2018.06.004
[9] Horrey, William J., Mary F. Lesch, Angela Garabet, Lucinda Simmons, and Rammohan Maikala. "Distraction and task engagement: How interesting and boring information impact driving performance and subjective and physiological responses." *Applied ergonomics* 58 (2017): 342-348. https://doi.org/10.1016/j.apergo.2016.07.011
[10] Moradi, Ali, Seyed Saeed Hashemi Nazari, and Khaled Rahmani. "Sleepiness and the risk of road traffic accidents: A systematic review and meta-analysis of previous studies." *Transportation research part F: traffic psychology and behaviour* 65 (2019): 620-629. https://doi.org/10.1016/j.trf.2018.09.013
[11] Jiao, Yingying, Yini Deng, Yun Luo, and Bao-Liang Lu. "Driver sleepiness detection from EEG and EOG signals using GAN and LSTM networks." *Neurocomputing* 408 (2020): 100-111. https://doi.org/10.1016/j.neucom.2019.05.108
[12] Karuppusamy, Naveen Senniappan, and Bo-Yeong Kang. "Multimodal system to detect driver fatigue using EEG, gyroscope, and image processing." *IEEE Access* 8 (2020): 129645-129667. https://doi.org/10.1109/ACCESS.2020.3009226
[13] Krajewski, Jarek, David Sommer, Udo Trutschel, Dave Edwards, and Martin Golz. "Steering wheel behavior based estimation of fatigue." In *Driving assessment conference*, vol. 5, no. 2009. University of Iowa, 2009. https://doi.org/10.17077/drivingassessment.1311
[14] Kadoya, Yoshihiko, Somtip Watanapongvanich, and Mostafa Saidur Rahim Khan. "How is emotion associated with driving speed? A study on taxi drivers in Japan." *Transportation research part F: traffic psychology and behaviour* 79 (2021): 205-216. https://doi.org/10.1016/j.trf.2021.04.020
[15] El-Gamil, Nancy S., Sherin M. Youssef, and Marwa ElShenawy. "Computer-Aided Model for Abnormality Detection in Biomedical ECG Signals." *J. Adv. Res. Comput. Appl* 1, no. 1 (2018): 7–15.
[16] Khatun, Saleha, Ruhi Mahajan, and Bashir I. Morshed. "Comparative study of wavelet-based unsupervised ocular artifact removal techniques for single-channel EEG data." *IEEE journal of translational engineering in health and medicine* 4 (2016): 1-8. https://doi.org/10.1109/JTEHM.2016.2544298

[17] Halin, Hafiz, Wan Khairunizam, Wan Azani Mustafa, Muhajir Ab Rahim, Z. M. Razlan, and S. A. Bakar. "Design of Experiment (DOE) for the Investigation of Human Emotions while Driving in a Virtual Environment through Brain Signal (EEG)." In *2021 6th International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS)*, vol. 6, pp. 254-257. IEEE, 2021. https://doi.org/10.1109/ICIIBMS52876.2021.9651565

[18] Choong, W. Y., W. Khairunizam, W. A. Mustafa, M. Murugappan, A. Hamid, S. Z. Bong, R. Yuvaraj et al. "Correlation analysis of emotional EEG in alpha, beta and gamma frequency bands." In *Journal of Physics: Conference Series*, vol. 1997, no. 1, p. 012029. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1997/1/012029

[19] Abdelgawad, Kareem, Jürgen Gausemeier, Jörg Stöcklein, Michael Grafe, Jan Berssenbrügge, and Roman Dumitrescu. "A platform with multiple head-mounted displays for advanced training in modern driving schools." *Designs* 1, no. 2 (2017): 8. https://doi.org/10.3390/designs1020008

[20] Petrović, Đorđe, Radomir Mijailović, and Dalibor Pešić. "Traffic accidents with autonomous vehicles: type of collisions, manoeuvres and errors of conventional vehicles' drivers." *Transportation research procedia* 45 (2020): 161-168. https://doi.org/10.1016/j.trpro.2020.03.003

[21] Wakabayashi, Daisuke. "Self-driving Uber car kills pedestrian in Arizona, where robots roam." *The New York Times* 19, no. 03 (2018).

[22] A. Ismail, S. Y. Gan, and M. K. I. Mohd Zain "Study on drivers' behaviour relationships to reduce road accidents in Puchong, Selangor Darul Ehsan." *J. Kejuruter* 27 (2015): 81-85. https://doi.org/10.17576/jkukm-2015-27-11

[23] Bong, Siao Zheng, Khairunizam Wan, M. Murugappan, Norlinah Mohamed Ibrahim, Yuvaraj Rajamanickam, and Khairiyah Mohamad. "Implementation of wavelet packet transform and non linear analysis for emotion classification in stroke patient using brain signals." *Biomedical signal processing and control* 36 (2017): 102-112. https://doi.org/10.1016/j.bspc.2017.03.016

[24] Krishna, N. Murali, Kaushik Sekaran, Annepu Venkata Naga Vamsi, GS Pradeep Ghantasala, P. Chandana, Seifedine Kadry, Tomas Blažauskas, and Robertas Damaševičius. "An efficient mixture model approach in brain-machine interface systems for extracting the psychological status of mentally impaired persons using EEG signals." *Ieee Access* 7 (2019): 77905-77914. https://doi.org/10.1109/ACCESS.2019.2922047

[25] ZHENG, BONG SIAO. "Pattern Recognition Based Emotional Deficits Assessment in Stroke Patients Using Time Frequency Analysis." PhD diss., UNIVERSITI MALAYSIA PERLIS, 2018.

[26] Velnath, R., V. Prabhu, and S. Krishnakumar. "Analysis of EEG signal for the estimation of concentration level of humans." In *IOP Conference Series: Materials Science and Engineering*, vol. 1084, no. 1, p. 012003. IOP Publishing, 2021. https://doi.org/10.1088/1757-899X/1084/1/012003

[27] Nikolin, Stevan, Nicholas Chand, Donel Martin, Jacqueline Rushby, Colleen K. Loo, and Tjeerd W. Boonstra. "Little evidence for a reduced late positive potential to unpleasant stimuli in major depressive disorder." *Neuroimage: Reports* 2, no. 1 (2022): 100077. https://doi.org/10.1016/j.ynirp.2022.100077