Study of Electroencephalogram Pattern from Eye Response to Flickering Light

Meda C. Fitriani¹, Siti N. Khotimah², Freddy Haryanto², and Suprijadi²

¹Master Program in Physics Teaching, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Bandung, Indonesia
²Department of Physics, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Bandung, Indonesia

E-mail: mechafee@gmail.com, snkhotimah102@gmail.com

Abstract. Electroencephalograph (EEG) has been widely used in brain wave mapping studies with several subject conditions, such as in evaluations of dementia and encephalopathy, screening for possible epileptic spikes, investigative for clinical use in mental disorders. In addition, the EEG has also been used to investigate the response of human brain in listening to music, movement of arm, and turning of neck. In this study, electroencephalograph was used to study the eye response to a 20 Hz flickering light. Brain waves recorded during the subject watching flickering light by using wireless electroencephalograph 14 channels. By recording the brain waves of the subject in the “Edf’s” format, the electroencephalogram was then analyzed using tools such as centering, filtering, and Welch’s power spectral density estimation. Using Power Spectra Density (PSD) graph, we can assess the active part of the lobes as eye responds to flickering light, i.e. parietal and occipital lobes. We found that the occipital lobe of six subjects from 9 subjects has higher average intensity in the right side than in the left. Parietal lobe of all subjects also has higher average intensity in the right side than in the left.

1. Introduction
Brain is the most complex organ in the human body. It has two hemispheres. Each hemisphere divided into four lobes. The Frontal lobes, located behind the forehead, are involved with speech, thought, learning, emotion, and movement. Behind them are the parietal lobes, which process sensory information such as touch, temperature, and pain. This lobe also involved with vision. At the rear of the brain are the occipital lobes, dealing with vision. Lastly, there are the temporal lobes, near the temples, which are involved with hearing and memory[1, 2].

The brainwaves are established by the electrophysiological processes of the nervous system. Neural function is maintained by neuronal membrane in order to establish ionic gradients between inside and outside the neuron. Recognizing the generator sources and electrical fields of propagation are basis for discerning electrographic patterns that underlined the expressions of the brain waves[3].

There are two forces acting on a given ionic species. The driving force of the chemical concentration gradient tends to move ions down this gradient (chemical potential). Electrical signals (receptor potential, synaptic potential and action potential) are all caused by transient changes in the current flow into and out of the neuron that drives the electrical potential across the plasma membrane away of its resting condition. On the other hand, the electrostatic force due to the charge separation across the membrane tends to move ions in a direction determined by its particular charge. A stimulus
makes ions can flow in and out of neuronal membrane. It yields action potential which will move down along axon. Neither electrically or chemically, electrical signal will be communicated in the neuron junction\(^4\)-\(^6\). The electrical activity of the neurons in the human brain produced brain wave that can be recorded by Electroencephalograph (EEG)\(^7\). The human brain wave has a frequency range of 0.5 – 45 Hz. There are five categories of these brainwaves based on its frequencies, ranging from higher processing tasks and cognitive functioning (higher frequency) to the least ones (lower frequency). In this study, we interested in alpha frequency (8 – 13 Hz) for relax condition of the subjects. In this work, a wireless 14 channels Electroencephalograph is used to record brainwave of 9 subjects in relaxed condition in order to find the active part of the brain lobes corresponding to the eye response for 20 Hz flickering light.

2. Tools
To conduct the experiment, we used Electroencephalograph with 14 electrodes and 2 reference placed according to the 10-20 placement standards. We used MATLAB and the EEG toolbox to further analyze the signals.

2.1. Hardware
A USB powered Bluetooth dongle was used to connect the Wireless Electroencephalograph headset to Emotiv EEG software in the computer. The signal quality can be seen on the software with colour indicators. Green for good signal, yellow for fair signal, orange for poor signal, red for very poor signal and black for no signal. Its resolution is 0.51\(\mu\)V and its sampling rate is 128 Sampling Per Second. Electroencephalograph has 14 electrodes and 2 reference (CMS and DRL) placed according to the 10-20 placement standards (see Figure 1).

![Figure 1. Placement of electrodes in Emotiv Epoc+ [14].](image)

The name of the electrode begins with one or two letters showing the general brain region or lobe where the electrode is placed (Fp = Fronto-polar; F = Frontal; C = Central; P = Parietal; O = Occipital; T = Temporal). AF-prefrontal on Emotiv is located between Fp and F. Each electrode name ends with a number indicating distance to the center line, larger numbers indicate distances farther from the midline (F3 and F4 closer than the center line compared to the distance F7 and F8 from the center line). The odd number is used in the left hemisphere and the even number in the right hemisphere.

2.2. Software
An interactive MATLAB toolbox for processing continuous and event related EEG known as EEGLAB and BioSig need to be installed in order to be able to load the EEG raw data recorded using Emotiv EEG software. The BioSig is an open source software library for biomedical signal processing\(^8\).
3. Instruction
The scalp of the subject should be clean (no hair cream or gel applied). Data collection is done in a quiet room with the lights on. Before taking the data, subjects are encouraged to relax.

The subject should not blink (if not prompted), move their eyes or move other parts of the body (to avoid noise in EEG measurements)\(^9\), and they have to stay relaxed and not tense. The main purpose of this is to avoid artifacts in relevant brainwave recordings\(^8,10\). The brainwave recorded about 5 times for each subject with the same instruction, every recording requires 10 seconds. While the brainwave recorded, the subject is watching the 20 Hz flickering light.

Every brainwave recording will have a cooling down period for about 2 minutes; the subjects are conditioned to be relax and back to neutral state and are treated as follows\(^9\).

   a. Use time to blink and move. Movement of shoulders, neck, jaw, and face (if necessary) to relax.
   b. For the last 5 seconds, count down mentally (to let the user return to a neutral emotional state).
   c. Before the second activity is implemented, focus your view on the available screen, where the stimulus will be displayed (to prevent unnecessary eye movements).

4. Experiment
There were 9 male subjects in this experiment. There were subsequently named as A, B, C, D, E, F, G, H and I. They were told to do the instruction a day before recording their brainwave. Beside getting the subject ready, Electroencephalograph should be set up. The electrode probes where the sensors were located must be amply hydrated using drops of saline to ensure good contact. The sensors must be individually inserted into the black plastic headset arms by turning each one clock-wise one-quarter turn until a click was felt\(^11\). After connect it to the computer and attach it on the subject’s head, signal quality was checked. The recording begins after we got all green or at least yellow on the colour indicator (see Figure 2).

![Figure 2. The subject is on relax state right before brainwave recording](image)

The brainwave recording on relax condition were allotted only 10 seconds each. Only the mid five-seconds relax condition would be used for data extraction but the other five-seconds were merely treated as intervals for the next change of condition. After open the raw data on MATLAB, we need to sliced the data to get the mid five-seconds. The slicing of data was done using a feature in the EEGLAB toolbox. After choosing the “Select Data”, there would be a prompt to enter the minimum and maximum time range.

Centering is an effort to process the data so that all recorded waves begin from zero at y coordinate, it is done by averaging all the existing data and then each of the data was reduced by the averaged data. After do the centering, the EEG data is filtered from noise, artefacts and into alpha frequency range. The power spectral density was processed using the \textit{pwelch} \(^{12,13}\) function from the signal processing toolbox within the MATLAB software. \textit{Pwelch} returns the power spectral density (PSD) estimate of the input signal, found using Welch’s overlapped segment averaging estimator. Hamming window was used in the \textit{pwelch} function. Figure 3 is the graphic we got after processing the raw data.
Figure 3. Power Spectra Density for first data of Subject E

Results from \textit{pwelch} are then stored in .txt format and tabulated with Excel software to facilitate data analysis. Based on the graph in figure 4.1, the graphic value is represented by the peak value. The peak value for one channel can be searched and compared with the peak value of the other channel so that the most active lobes at the time of the stimulus are known\textsuperscript{14}.

5. Results

The results of channel spectrum and maps of two data can be seen in figure 4. The color bellow is indicated the highest to the lowest electrical activity, i.e. Red – Orange – Yellow – Green – Light Blue – Dark Blue. Figure 4a shows that occipital lobe has high electrical activity. Figure 4b shows that parietal lobe has high electrical activity.

Figure 4. Channel Spectra and Maps of (a) the Subject C’ s Second Data and (b) the Subject G’s Third Data.

From the tabulated data we can see the peak value of the PSD from all channels in each data. Based on these data which measured 5 times, the number of occurrences of channel as top three of peak Power Spectra Density values for every subjects are tabulated in Table 1.

Table 1. The occurrence of channels as top 3 channel locations with the highest peak values measured 5 times

| Channel/Subject | AF3 | F7 | F3 | FC5 | T7 | P7 | O1 | O2 | P8 | T8 | FC6 | F4 | F8 | AF4 |
|-----------------|-----|----|----|-----|----|----|----|----|----|----|-----|----|----|-----|
| A               | 0   | 2  | 0  | 0   | 0  | 0  | 0  | 2  | 5  | 3  | 3   | 0  | 0  | 0   |
| B               | 0   | 0  | 0  | 0   | 0  | 0  | 5  | 5  | 0  | 0  | 0   | 5  | 0  | 0   |
| C               | 0   | 0  | 0  | 0   | 0  | 0  | 0  | 5  | 5  | 5   | 0  | 0  | 0   |
| D               | 5   | 2  | 0  | 0   | 0  | 0  | 0  | 5  | 0  | 0   | 0  | 3  | 0   |
| E               | 5   | 0  | 0  | 0   | 0  | 0  | 5  | 0  | 5   | 0  | 0  | 0   |
| F               | 5   | 5  | 0  | 0   | 0  | 0  | 5  | 0  | 0   | 0  | 0  | 0   |
| G               | 5   | 5  | 0  | 0   | 0  | 0  | 5  | 0  | 0   | 0  | 0  | 0   |
| H               | 5   | 5  | 0  | 0   | 0  | 0  | 5  | 0  | 0   | 0  | 0  | 0   |
| I               | 0   | 3  | 0  | 0   | 0  | 0  | 5  | 5  | 0   | 0  | 0  | 2   |
| Total           | 25  | 22 | 0  | 0   | 0  | 0  | 17 | 40 | 13  | 8  | 0  | 10  |
Based on Table 1, from 45 data for 9 subjects, P8 channel referring to the right Parietal lobe becomes part of 3 channels with the highest peak value for about 40 times. Furthermore, AF3 and F7 located in the left frontal lobes and O2 channels located in the right-sided occipital lobe are monitored as channels that often have the highest PSD value in a data. From this tabulation it can be seen that the majority of channels with high PSD values are located in the right hemisphere.

Average peak value of Power Spectra Density each channel for every data represented on Table 2.

**Table 2** The average peak values of Power Spectra Density each channel for every subjects

| Subject/PSD on Channel | A    | B    | C    | D    | E    | F    | G    | H    | I    |
|------------------------|------|------|------|------|------|------|------|------|------|
| AF3 (μV)               | 1.70 | 3.19 | 1.70 | 6.04 | 3.25 | 7.10 | 7.10 | 7.10 | 2.27 |
| F7 (μV)                | 8.04 | 3.81 | 1.52 | 3.88 | 2.29 | 5.63 | 5.63 | 5.63 | 8.94 |
| F3 (μV)                | 0.68 | 1.59 | 0.66 | 1.46 | 0.90 | 1.85 | 1.85 | 1.85 | 1.07 |
| FC5 (μV)               | 1.14 | 2.09 | 1.25 | 2.08 | 1.21 | 2.66 | 2.66 | 2.66 | 1.47 |
| T7 (μV)                | 0.69 | 1.48 | 0.88 | 0.99 | 1.33 | 0.69 | 0.69 | 0.69 | 0.81 |
| P7 (μV)                | 1.19 | 2.34 | 1.47 | 1.89 | 1.29 | 2.40 | 2.40 | 2.40 | 1.32 |
| O1 (μV)                | 1.26 | 4.94 | 1.07 | 3.51 | 3.24 | 4.30 | 4.30 | 4.30 | 2.88 |
| AF3 (μV)               | 2.89 | 8.23 | 1.78 | 4.60 | 3.73 | 3.62 | 3.62 | 3.62 | 5.93 |
| F7 (μV)                | 48.30| 4.98 | 78.10| 7.23 | 2.41 | 7.28 | 7.28 | 7.28 | 3.93 |
| F3 (μV)                | 2.56 | 4.95 | 2.12 | 4.34 | 4.17 | 4.22 | 4.22 | 4.22 | 3.60 |
| FC6 (μV)               | 1.69 | 4.56 | 2.18 | 3.95 | 0.89 | 2.88 | 2.88 | 2.88 | 2.32 |
| F4 (μV)                | 1.53 | 2.97 | 1.60 | 2.45 | 2.46 | 2.11 | 2.11 | 2.11 | 1.92 |
| F8 (μV)                | 2.09 | 6.15 | 2.08 | 5.55 | 2.13 | 4.93 | 4.93 | 4.93 | 3.60 |
| AF4 (μV)               | 1.48 | 3.04 | 1.85 | 3.38 | 2.51 | 3.65 | 3.65 | 3.65 | 1.74 |

In some data, the PSD value on channel P8 is much higher than other channels. This can be seen in Table 3. The high value of PSD in the lobe corresponds to several theories which suggest that the Parietal lobe plays a role in visual terms equivalent to the occipital lobe [2, 3].

Channel AF3 and F7 are also activated. The activation of this channel is not due to lateral eye movements, this can be ensured through video recording of data retrieval process on each subject. Based on this video note that the blink of the eye does not give effect to the amount of Power Spectra Density in the alpha frequency range. In addition, the right temporal lobe has a high Power Spectra Density value almost on the entire subject. If it is associated with a data retrieval situation, this is because the outdoor situation is not quiet. If the data in Table 2 are sorted to get 4 channels with the highest PSD value, then the results can be tabulated as in Table 3.

**Table 3** The top 4 channel locations with the highest average peak values

| PSD / Subject | 1st | 2nd | 3rd | 4th |
|---------------|-----|-----|-----|-----|
| A             | P8  | F7  | O2  | T8  |
| B             | O2  | P8  | T8  | O1  |
| C             | P8  | FC6 | T8  | O2  |
| D             | P8  | AF3 | O2  | T8  |
| E             | P8  | O2  | AF3 | O1  |
| F             | P8  | AF3 | F7  | O1  |
| G             | P8  | AF3 | F7  | O1  |
| H             | P8  | AF3 | F7  | O1  |
| I             | F7  | O2  | P8  | T8  |

From Table 3 it can be seen clearly that the PSD on channel O1 is always smaller than the intensity on channel O2. Tables 2 and 3 make it clear that the left occipital lobe also experiences high electrical activity during watching flickering light.
6. Conclusion
Based on the analysis of the results of brain wave measurements on 9 subjects with wireless Electroencephalograph, it can be found as follows. The activated lobes when the eye watching 20 Hz flickering light are Parietal and Occipital lobes. The occipital lobe of the six subjects from 9 subjects has higher average intensity in the right side than in the left. The right Parietal lobe is also more active than the left for all subjects.

References
[1] National Geographic, Brain, https://www.nationalgeographic.com/science/health-and-human-body/human-body/brain/ [5 May 2017].
[2] SpinalCord.com, Parietal Lobe https://www.spinalcord.com/parietal-lobe [3 August 2017].
[3] Tatum W O 2008 Handbook of EEG Interpretation (USA: Demos Medical Publishing)
[4] Giancoli D C 1991 Physics Principles with Applications (USA: Prentice Hall International, Inc)
[5] Membrane potential. http://www.ifc.unam.mx/Brain/mempot.htm [10 August 2017]
[6] Kalat J W 2015 Introduction to Psychology (USA: Cengage Learning)
[7] Sörnmo L and Laguna P 2005 Bioelectrical Signal Processing In Cardiac And Neurological Applications (Amsterdam: Elsevier Academic Press)
[8] “The Biosig Project”, http://biosig.sourceforge.net [4 August 2016]
[9] Bos D O 2007 EEG-based Emotion Recognition;The Influence of Visual and Auditory Stimuli Department of Computer Science, University of Twente.
[10] EEG Artifacts, http://emedicine.medscape.com/article/1140247-overview#a2 [1 May 2017],
[11] Emotiv “Emotiv Epoc Quick Start Guide” https://www.emotiv.com/files/Emotiv-Epoc-Quick-Start-Guide-2015.pdf [7 January 2017]
[12] MathWorks “pwelch”, http://uk.mathworks.com/help/signal/ref/pwelch.html [4 August 2017]
[13] Akbar Y, Khotimah S N and Haryanto F 2016, Journal of Physics: Conference Series, 694 012070
[14] Lup C W, Khotimah S N and Haryanto F 2017, ARPN Journal of Engineering and Applied Sciences, 12 5168