Australian Journal of Basic and Applied Sciences, 9(28) Special 2015, Pages: 196-202

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

The Effect of Eye Massaging Device to Visual Processing Signal using Wavelet Approach

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ARTICLE INFO

Article history:
Received X X 201X
Received in revised form X X X 201X
Accepted X X 201X

Keywords:
Electroencephalography (EEG), electrooculography (EOG), eye massaging device, energy of approximation (Ea), Wavelet transform, ANOVA

ABSTRACT

Background: This study investigates the eye muscles electrical activities due to the effect of eye massaging device by using electrooculography (EOG) and electroencephalography (EEG) signals. Any eye movement or eyes changing position, several eye muscles is working so hard to obtain the visual. This activity could lead a biopotential signals; EOG is produced. This potential difference can be measured by placing two pairs of electrodes according to respective channels; horizontal and vertical based on the eye movements. For horizontal movement, the electrodes is places in left and right sided of the eye and for vertical movement, the electrodes is places in down and upper side of the eyes. Meanwhile for the EEG, a scalp with 19 fixed points of electrodes is used to record the brain signals. Another electrode is used to connect the ground. This electrode is functioning both in EOG and EEG test. The acquisition process is done by using Neurofax EEG-9200 machine. Data from each EEG signals acquired is analyzed based on the usage of their channels. This study is focused on two visual processing points in EEG signals, Channel O1 and Channel O2 which is related to eye muscles activities related to the eye movement. These channels are extracted and analyzed using wavelet transform. The frequency energy distribution is calculated for every signal. All the extraction parameter is constantly used for entire study. Based on the results obtained, it is shown that the approximation energy collected before and after using the eye massaging device has shown a decrement. Analysis of Variance (ANOVA) is used for further analysis in order to validate the data obtained. From the test, there is enough evidence to reject the fact that the data from before and after using the device are from the same group Thus, it is proved that the eye massaging device exhibit difference for each eye movement tested.

To Cite This Article: A. Alwi, F. A. Mansor, R. Sudirman, The Effect of Eye Massaging Device to Visual Processing Signal using Wavelet Approach. ***Aust. J. Basic & Appl. Sci.,*** *9(28): 196-202, 2015*

INTRODUCTION

Visual processing signal in a normal human brain can be recorded in many ways. The easiest way is by using the EOG test. EOG is a test to calculate the potential difference surrounding the eyes. There are several theories explaining this test. However, one of the most widely accepted is cornea-retinal dipole theory. This theory states that cornea is in positive charged while the retina is in negative charge that could lead to electric dipole. This dipole produced the electrical field that can be measured (Sheedy, J. and K. Larson, 2008). Meanwhile, EEG is one of the methods to collect the visual signals. It defines as a process of capturing brain signal in the form of electrical waveform at various interest points on the head. This waveform is easily described as voltage fluctuations for every ionic current flow within the neurons and the brain.

The analogy of process collecting data is similar to the EOG but the main difference is, in the EEG, the electrodes is replace by the scalp which have 19 fixed points of electrodes at specific location. Figure 1 shows the details of every point on the standard point of interest in the EEG scalp. Each and every part of these points represents different response area from the brain. There are two points; O1 and O2 used in this study since these two points are used in visual processing part. Besides, they are also highly suggested as they were involved with the eye muscles activity.

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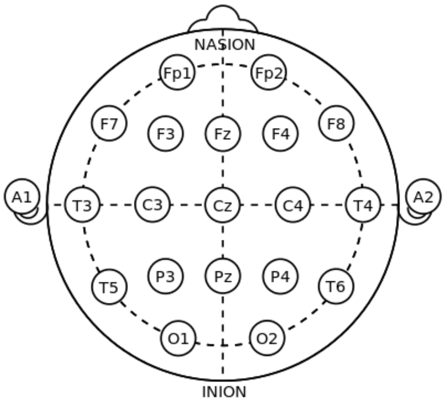

Fig. 1: Position of electrode on the EEG scalp with point labeled

MATERIALS AND METHOD

For this study, Neurofax EEG-9200 machine is used throughout the entire collecting data part. Raw collected data is produced in waveform before converted to the ASCII format.

This form is easy to access and readable to most of any analysis software included MATLAB. The data is then extracted and analyzed to produce frequency energy distribution for each signal. ANOVA statistical method is used to validate the results obtained. Figure 2 shows the flowchart of this study.

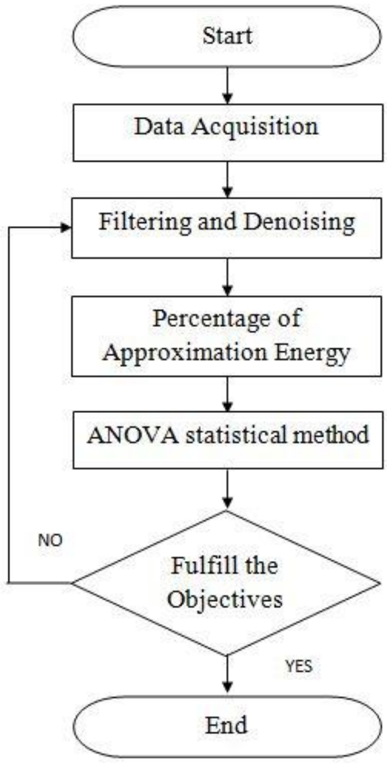

Fig. 2: Flowchart of the study

A. Data Acquisition:

In this study, total of 20 subjects which are randomly selected from which fulfill the expected criteria in range of age and didn't have any eyesight problem is undergo several test to obtain the data. Setup of all the equipment with the condition of the room is carefully controlled to remain same to all the subjects. For the test room, it is completely sealed with black cupboard to minimize outside disturbance. The materials and instruments utilized are fixed for the entire time. Neurofax EEG-9200 machine and

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bipolar jack (see Figure 3) are joined together to collect the EEG signals.

Fig. 3: Neurofax EEG-9200 machine and bipolar jack

Fig. 4: Position setting of the experiment (Alwi, A., F. Afiqa and R. Sudirman, 2015)

There are several procedure needs to be taken care of the subject before starting the test. Firstly, phone or any magnetic device is advice either to turn off or keep away during the test. Then, a simple colour blind test is conducted with a set of questionnaire regarding the personal information such as activity before coming to the test. Then, a scalp with five electrode is placed to appropriate position (see Figure 5) to collect the signal to the EEG machine.

Fig. 5: Positions of scalp and electrodes (left) and eye massaging device (right) (Alwi, A., F. Afiqa and R. Sudirman, 2015)

During the test, another strictly procedure is applied. Subject is obliged to sit still and prohibited to speak or move any part of their body. Even a single small movement could trigger the noise. Firstly, an EEG data in duration of 60 seconds is recorded. Subject need to remain still with eyes

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closed in the rest mind. Then, EOG tests consist of three tests and recognition for the artifact that could happen due the blink of the eye. For the artifact recognition, subject need to blinks five times in an interval of five seconds for each blink. The signal is recorded and used to detect similar signal in the test. While at rest, the average blink rate is within the range of 12 and 19 blinks per minute7 and they are influenced by environmental factors; relative humidity, temperature or brightness and physical activity; cognitive workload or fatigue ((EOG), 2004).

Secondly, in smooth tracking test, subject needs to look at the pen that is placed at the centre of the screen. This position is marked as the reference point. The pen will move slowly to the right side and coming back to its reference point. The time taken for this movement is 30 seconds. From the reference point, the pen moves slowly to the left side of the screen for another 30 seconds (see Figure 6). The total time duration for this test is 60 seconds

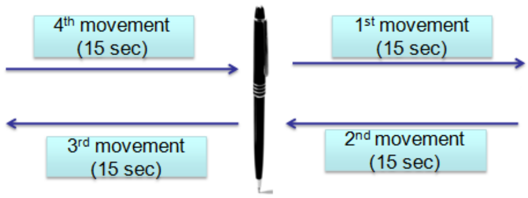

Fig. 6: Reference point and the direction of the pen for smooth tracking test

Thirdly, eye movement detection test is designed to look for another four eye movements; looking up right, looking up left, looking down right and looking down left. At the first moment, a red dot is appeared at the centre of the screen. This position is marked as the reference point. The dot is then disappearing and it was consecutively re-appear at different position randomly (see Figure 7). The red dot is reappearing at the centre of the screen after the eighth point. The total time duration for this test is 60 seconds.

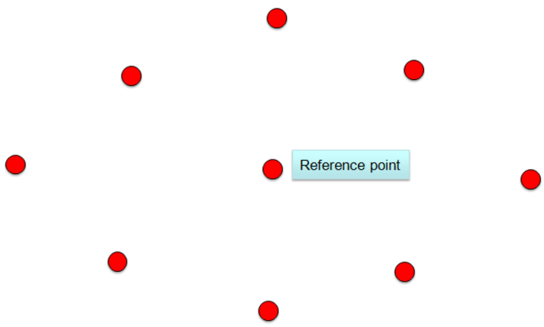

Fig. 7: Reference point and the direction of the red dot for smooth tracking test

For the last test, saccade is defined as fast and non-smooth tracking movements of the eyes (Duchowski, A.T. , 2007). One of the easiest ways to observe this type of eye movement is when the subject reads a text of paragraph. In order to stress out the eye muscles, the text is designed based on these specifications; small font size text and light grey contrast (see Figure 8).


United States; To borrow Money on the credit of the United States; To regulate Commerce with foreign Nations, and among the several States, and with the Indian Tribes; To establish a uniform Rule of Naturalization, and uniform Laws on the subject of Bankruptcies throughout the United States; To coin Money, regulate the Value thereof, and of foreign Coin, and fix the Standard of Weights and Measures; To provide for the Punishment of counterfeiting the Securities and current coin of the United States; To

Fig. 8: Text of paragraph for saccades test

Then, the eye massaging device is used to massage the subject (see figure 5) for 15 minutes with the set fixed type of vibration for each subject. The device have seven different set of vibration with three different set of timer (Alwi, A., F. Afiqa and R. Sudirman, 2015). Then, the EEG test is repeated to collect the signal after using the eye massage device.

B. Signal Processing:

For the analysis of collected data, a program in MATLAB software is used. For each signal recorded, an algorithm to calculate the frequency energy distribution is applied. The energy can be simplified as in equation (1) to equation (6).

$$\psi_{ab}(t) = \frac{1}{\sqrt{a}} \Psi\left(\frac{t-b}{a}\right) \quad (1)$$

Where $\psi_{ab}(t)$ a scaled and translated version of wavelet transform, a is scale, b is translation parameter, $\Psi(t)$ is mother wavelet. For Continuous Wavelet Transform (CWT),

$$C_{ab}(t) = \int_{-\infty}^{\infty} s(t) \frac{1}{\sqrt{a}} \Psi^*\left(\frac{t-b}{a}\right) \mathrm{d}t \quad (2)$$

$$C_{ab}(t) = \langle s(t), \psi_{ab}(t) \rangle \quad (3)$$

Where $C_{ab}(t)$ is CWT signal, $s(t)$ is signal which $s(t) \in L^2(\Re)$, L^2 is space of square integrable function, $\Re$ is set of real number. Meanwhile, for Discrete Wavelet Transform (DWT) where, $a = 2^j$, $b = k2^j$ with $j,k \in \mathrm{Z}$

$$d_{j,k} = \int_{-\infty}^{\infty} s(t) 2^{-j/2} \Psi^*(2^{-j} t - k) dt \quad (4)$$

$$d_{j,k} = \langle s(t), \psi_{j,k}(t) \rangle \quad (5)$$

Where $\psi(t)$ is the mother wavelet, and $\psi_{j,k}$, $j,k \in \mathrm{Z}$ is collection function. Total energy for overall signal can be define as

$$E_{total} = \sum_{j=1}^{m} \sum_{k=0}^{2^{m-j}-1} \left| d_{j,k} \right|^2 \quad (6)$$

Then, all the significant parameter is extracted to be analyze using Microsoft Excel. The whole process is repeated again to obtain the data after using the eye massaging device.

RESULTS AND DISCUSSION

The data recorded from the EEG Acquisition Machine mostly in waveform signal. It is easier to use after converted to ASCII format before transferred to the analysis part. ASCII format recorded value for the signal based on specific time interval in .txt format. The data can be transforming back to the waveform signal using software such as MATLAB. One of the sample data from the machine is shown in Figure 7. Although the EEG signal is very small, the machine will record each and every tiny details of the value in signal. The setting configuration for the machine is fixed for every test conducted. Sensitivity for the data is set at 20 uV to get better result.

In this study, the filter used is Butterworth band pass filter with order of 2 to remove the unwanted signal with irrelevant frequency. Wavelet decomposition algorithm with level 8 detail coefficient is used to the EEG signal to obtain the frequency energy distribution for each of the signals. From Table 1, the average of energy collected for 20 samples of different data is shown. From the result, the average of difference between energy between before and after using the eye massaging in channel O1 is 6.760 and for the channel O2 is 6.064.

The values of energy in the table indicate the energy of approximation in the signal calculated using MATLAB for every required channel in the test conducted. The values are decreasing between before and after using the eye massaging device. From the result, we can observe that some of the value would drop in insignificant values which mean the difference between signal before and after is inconsistent for different subject.

Table 1: Average energy of approximation collected for 20 sample data

Subject	Channel O1		Difference of Energy	Channel O2		Difference of Energy
	Before	After		Before	After	
1	7.237	0.058	7.179	2.127	1.919	0.208
2	14.342	11.305	3.038	14.053	13.238	0.816
3	3.932	1.634	2.298	3.721	0.190	3.531
4	9.241	0.515	8.726	9.746	1.129	8.617
5	20.357	0.240	20.117	7.727	3.506	4.221
6	11.253	9.078	2.175	13.466	5.826	7.640
7	3.483	0.910	2.574	3.049	1.100	1.949
8	29.190	11.735	17.455	21.135	7.028	14.107
9	16.291	7.116	9.174	15.166	4.975	10.191
10	5.348	1.709	3.639	1.125	0.724	0.401
11	5.111	1.365	3.746	0.129	0.101	0.028
12	4.482	0.058	4.423	3.078	1.919	1.159
13	4.232	0.712	3.521	8.228	0.880	7.348
14	7.036	5.706	1.330	6.365	4.597	1.768
15	18.999	9.180	9.819	16.211	4.648	11.564
16	13.178	6.908	6.270	16.708	2.400	14.307

17	2.543	0.608	1.935	1.644	0.700	0.943
18	28.306	4.041	24.265	29.294	1.059	28.234
19	2.527	1.107	1.420	3.918	1.928	1.990
20	4.160	2.071	2.088	4.168	1.903	2.265
Average	10.562	3.803	6.760	9.053	2.989	6.064

Table 2: ANOVA Single Factor for Channel O1

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Ea Before	20.000	211.247	10.562	68.763		
Ea After	20.000	76.054	3.803	16.064		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	456.927	1.000	456.927	10.773	0.002	7.353
Within Groups	1611.701	38.000	42.413			
Total	2068.628	39.000				

Table 3: ANOVA Single Factor for Channel O2

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Ea Before	20.000	181.056	9.053	60.699		
Ea After	20.000	59.770	2.989	9.770		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	367.758	1.000	367.758	10.438	0.003	7.353
Within Groups	1338.898	38.000	35.234			
Total	1706.655	39.000				

In order to validate the result, both results are tested using ANOVA in Data Analysis, Microsoft Excel. The output from the test from the Channel O1 and Channel O2 is display as in Table 2 and Table 3 respectively. The average (mean) value shows the different although it is not quite large number. The other things that take interest to discover are the p-value. In this analysis, p-value in Channel O1 is 0.002 which is small and less than alpha value, 0.01. It means that, there is a small chance of getting this data if no real difference existed and therefore it can be decide that the difference in all those groups' data is significant. The null hypothesis for the test suggested that there is no difference between both signal before and after is rejected. The null hypothesis in Channel O2 also can be rejected because of the p value recorded is 0.003 which is less than the alpha value in the test.

Conclusion:

This study has identified the differences between eye muscles activity after the effect of eye massaging device for each of desired eye movement. Analysis is done using variation of eye movement instead of basic four movements in the previous study. Results obtain indicates that there are significant differences in signal before and after using the eye massaging device. Mostly, the energy value for the signal is decreasing after using the eye massaging device. The ANOVA proved that the data is difference between the energy before and after using the eye massaging device for both visual processing channel O1 and O2.

For the future study, it is highly recommended that the signal collected depends more on the regular eye movement in human nature. The analysis done should include several testing in getting the comparison of the signal with highly attention to the surrounding factor to avoid noise since the signal is small.

ACKNOWLEDGMENT

We would like to express sincere gratitude to Universiti Teknologi Malaysia to allow and supporting this study. Our appreciation also goes to Ministry of Education for supporting and funding this study under vote project number 05H37.

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