Comparison of Wet and Dry EEG Electrodes Based On Brain Signals Characterization In Temporal and Anterior Frontal Areas Using Audio Stimulation

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Abstract. Electroencephalography (EEG) electrodes are divided into two types: dry and wet. In wet electrodes, a gel or saline liquid is used to increase the conductivity value, however, it tends to dry over time. On the contrary, gel or saline liquid is not required on the dry electrode. The use of certain types of electrode in EEG influences Power Spectral Density (PSD) of brain signals. Therefore, this study compared the EEG signal produced by Emotiv using the two different types of electrodes and a specific stimulus. This study was conducted using Emotiv EPOC (wet) and Insight (dry). The Temporal (T7 and T8) and Anterior Frontal (AF3 and AF4) electrodes from both devices were used to be compared. An audio stimulus that contains a story was chosen followed by a small task related to the story. The data acquisition was performed in 36 minutes to maintain the stability of the two types of electrodes. Three minutes of recordings in resting condition were conducted on both before and after given audio stimulus. Audio stimulation followed by a small task was performed for thirty minutes. The data analysis has consisted of EEG data pre-processing using centering and filtering the data, followed by PSD calculation using the Welch periodogram with Hanning window. The result showed that the decrement percentage of PSD after stimulation from wet was higher than dry electrodes.

1. Introduction

Audio is a sound that comes from the vibration of an object that can be caught by human ears. An audio stimulus is one of the variables that can affect the presence of electrical waves in the brain. An audio stimulus can affect the activity of electrical signals in the brain. Response part of the brain that arises due to audio stimulus are temporal and anterior frontal lobes. Electrical patterns in the brain can be recorded by Electroencephalography (EEG). EEG is an electrophysiological monitoring method to record the electrical activity of the brain [1]. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain [2]. The results of recording brain signals on the EEG are expressed in the form of electrical potential is a function of time. EEG measurement techniques can be divided into Invasive and Non-Invasive EEG. Invasive EEG is the EEG system by placing electrodes directly above the lining of the brain through surgery. But, Invasive EEG has a high risk of damage to body tissue and it takes a long time data collection process. In contrast to Invasive EEG, Non-Invasive EEG places electrodes directly on the surface of the scalp. EEG electrodes are divided into two types: wet and dry (Fig.1).
The wet electrode systems involve the application of a conductive gel or saline liquid to bridge the gap between the scalp. The Wet electrode is generally referred to as the disposable Ag/AgCl wet electrode, is more convenient to use and is preferred in electrophysiological signal detection due to its low cost, good fitting with skin and nice conductivity [3,4]. For instance, the abrasive paste and the electrolyte gel, despite being minimally invasive and barely harmful, are sticky products that make the hair and scalp dirty. Also, the time needed to reduce the impedance to an acceptable value, typically 5 to 20 kΩ, can take a long time. The use of a massive electrolyte to speed up the impedance reduction could cause electrical bridges between electrodes, especially with dense arrays, thus being counterproductive. However, these are not the only problems. Once an acceptable electrode impedance has been achieved, a countdown begins until the gel dries, thus causing the transductive properties to disappear. For instance in the impedance of wet electrodes deteriorated from 5 to 15 kΩ within 5 hours after gel application. For these reasons, wet electrodes are not suitable for long-term measures.

In recent decades, there have been several approaches to develop dry electrodes for application. The Dry electrodes are applied directly to the skin, do not require any gel or saline liquid and easy to attach the head, so do not require trained technicians. Besides, a dry electrode is more like a polarizable electrode due to its large contact capacitance. Thus, the air exists between the electrode and the skin surface in the form of a dielectric layer, which greatly increases the total impedance [4,5].

The use of electrodes in the EEG can affect the impedance matching between the scalp and electrodes. As a kind electrophysiological signal, skin impedance has the characteristics of a weak, large interference. Normally, the impedance signals collected by electrodes include the skin electrode contact impedance as well as the impedance of the skin itself. Thus, it is most important to choose suitable electrodes as the impedance detection sensors [6]. The impedance matching can be affected by the value of Power Spectral Density (PSD). A Power Spectral Density (PSD) is the measure of the signal’s power content versus frequency. This study is aimed to compare Power Spectral Density from Wet and Dry electrodes with audio stimulation.

2. Methods
2.1. Subjects
Seven males participants completed the study between the ages of 20 and 25 years. Each participant completed an identical session on separate days in each of the two types of electrode conditions (wet and dry electrodes). Participants were all right handed, no history of neurological problems and corrected normal hearing.
2.2. Tools
The measurement tools in this study used two types of EEG, namely wet (Emotiv EPOC) and dry (Emotiv Insight) electrodes with a sampling frequency of 128 Hz (Fig.2). The Wet and dry electrode specifications are shown in Table 1.

![Figure 2: EEG Emotiv (a) Wet and (b) Dry electrodes](image)

| Description                  | Wet Electrodes                          | Dry Electrodes                           |
|------------------------------|-----------------------------------------|------------------------------------------|
| Sensor Count                 | 5 (+2 references)                       | 14 (+2 references)                       |
| Sensor Technology            | Long life semi-dry polymer              | Saline soaked felt pads                  |
| Sensor Locations             | AF3, AF4, T7, T8, Pz                    | AF3, AF4, F3, F4, FC5, FC6, F7           |
|                              |                                          | F8, T7, T8, P7, P8, O1, O2              |
| References                   | CMS/DRL references on left mastoid process | CMS/DRL references at P3/P4; left/right mastoid process alternative |
| Sample Rate                  | 2048 internal downsampled to 128 SPS    | 2048 internal downsampled to 128 SPS or 256 SPS (user configured) |
| Impedance                    | 5 kΩ                                    | 16 kΩ                                    |

The Emotiv EPOC uses 16 sensors to detect the electric signals produced by the brain. The sensors are saline soaked felt pads. It reads brain activity via the scalp. In contrast, the Emotiv Insight uses dry EEG sensors to detect the electric signals produced by the brain. The headset will be capable of detecting facial expressions such as blinks, winks, frowns, surprise and smiles. Insight is fully compatible with mobile devices. For EEG measurements, the electrodes were positioned according to the international 10-20 system [7] which is placed in the Anterior Frontal and Temporal parts (Fig.3)

![Figure 3: The position of electrodes](image)

2.3. EEG recording
The EEG data process is measured by the electrical activity of the brain using an audio stimulus shown in Figure 4. An audio stimulus that contains a story was chosen followed by a small task
related to the story. The data acquisition was performed in 36 minutes to maintain the stability of the two types of electrodes. Three minutes of recordings in resting condition were conducted on both before and after given audio stimulus. Audio stimulation followed by a small task was performed for thirty minutes.

![Figure 4: The illustration of EEG record](image)

2.4. The signal processing
The signal processing using centering and bandpass filtering techniques in the EEGlab toolbox. Furthermore, the identification of Power Spectral Density (PSD) in both EEG types using the Welch Periodogram method with Hanning window. Welch method is a nonparametric method that includes the periodogram that has the advantage of possible implementation using the Fast Fourier Transform. The Periodogram technique based on the Welch method is capable of providing good resolution if data length samples are selected optimally. The PSD based on Hanning window has been designed and simulated using MATLAB.

3. Results and Discussion
Data were collected with a sampling frequency of 128 Hz and bandpass filtered between 8 and 30 Hz before to analysis. The results after centering data using rmbase function and bandpass filtered (8-13 Hz) are shown in Figure 5.

![Figure 5: Graphic before and after centering data and bandpass filtering on 8-13 Hz to obtain alpha band](image)
Figure 5 shows that the signal has an increase in amplitude of 4000 (µV). The increase in amplitude is caused by the amplification of the measured signal from EMOTIV, so the centering process is needed so that the EEG signal oscillates at point 0 (µV). Furthermore, the signal transformation process was performed using the Welch periodogram to obtain the PSD values (Fig.6).

![PSD in the Pre and Post stimulus conditions](image)

Figure 6: The results of PSD obtained using wet and dry electrodes

Figure 6 describes the average and standard deviation of PSD in wet and dry electrodes. The average value of PSD changes on the wet and dry electrodes are indicated by the graph blue and orange. The wet electrodes have the highest average of PSD in AF3 2.47 ± 0.81 (µV)². The lowest average of PSD in T7 with a value of 1.40 ± 0.16 (µV)². AF3 and T7 have a position on the left side of the electrode. AF3 and T7 have a percentage difference in the average value of 43%. The percentage indicates that the difference in the average of PSD in AF3 and T7 is higher. However, the standard deviation values in AF3 and T7 have a smaller value. So, it can be said that the data is well distributed.

The average of PSD on wet electrode is greater than dry electrode. This shows the characteristics of the PSD value owned by the wet electrode tend to change. These changes are caused by the use of saline as a matching impedance on the electrode that can affect the electrical contact between the electrodes and the scalp. Giving amount of saline fluid in this study as much as 5 to 10 drops. It is intended to increase the electrode conductivity value. The measured signal is not derived from another electrical signal. However, the electrical properties of the wet electrode can be changed over time due to the use of saline fluid that begins to dry.

The Wet electrodes have the disadvantage, it cannot be used in the long-term recording process because it can affect the characteristics impedance of the electrodes due to the saline fluid that begins to dry. This condition can cause the PSD value to change fluctuation. Impedance on dry electrodes results in PSD values two to three times greater than PSD wet electrodes. As a result, the average of PSD values for dry electrodes are higher than wet electrodes.

4. Conclusion

We conclude that the percentage difference between the highest and lowest PSD from the Alfa wave in the pre and post conditions of giving audio stimulus for wet and dry electrodes is 43% and 30%. The percentage value of the difference in the average PSD change on the wet
electrode is greater than the dry electrode. These changes can be influenced by the characteristic impedance factors between the electrodes and the scalp and the subject’s condition during the measurement process.

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