Comparison of EEG sleep characteristic with music and aromatherapy stimuli

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Abstract. The quality of human's sleep can be determined by reading the bio-potentials signals in the brain, commonly called as electroencephalograph (EEG). In order to detect this signal, we placed an EEG sensor at some points around the head. In this research, we investigated the effect of Sundanese music and aromatherapy bio-composite from Myristica Fragrans on day sleep quality. We compared the EEG sleep characteristic with music and aromatherapy stimuli. The feature extraction uses wavelet transform. Finally, the experimental result shows that EEG signal frequency with music stimuli is higher than aromatherapy stimuli statistically.

1. Introduction
Sleep is a natural activity in human life. In general, adults need to sleep for 7-8 hours every night to keep the body on top form. In addition to adequate sleep, good sleep quality is also an important factor. The better quality of someone's sleep will have a positive impact in the morning such as feeling calm and not easily drowsy. While poor sleep quality will have a negative impact such as feeling tired, easily agitated, lethargic, difficulty concentrating, etc. Poor sleep quality is usually caused by several factors, such as insomnia, sleep apnea, snoring, circadian rhythm abnormalities, shift work system, parasomnia, etc.

Medical researches reveal that the smells have a significant impact on feelings. Smells directly affect the brain [1, 2]. In previous studies, lavender and sandalwood aromatherapy has proven to help depression, anxiety, insomnia and headaches [1 - 4].

When sleeping, the human brain will keep working, especially when dreaming, the brain will work as it is doing activities during the day. From this fact, we knew the condition of the body and the quality of one's sleep through brain signals. The brain signals commonly referred to as electroencephalograph (EEG) are wave signals that have low voltage amplitude, which is in the order of microvolts (100 µV-1 mV). The humans produce five EEG signals, namely Gamma (30 Hz-45 Hz), Beta (15 Hz-30 Hz), Alpha (8 Hz-15 Hz), Theta (4 Hz-8 Hz) and Delta (0.1 Hz-4 Hz). Each brain signal has a frequency that varies according to the activity being done, whether it is during sleep or awake. The shape and activity of each brain signal are shown in figure 1.

In this research, system testing will be done with aromatherapy and music stimulation. Aromatherapy is the use of a variety of essential oils derived from plants in helping to treat various
physical and emotional health problems. Each type of aromatherapy has different benefits to the body, one of them is to make the body relax and easy to fall asleep. Music or sound stimulation is one of the variables that affect the electrical waves in the brain. Therefore, the purposes of emotional and psychiatric therapy is often used voice stimulation to achieve the increase of certain waves in the brain. Although a person's perception of the sound received is different, but in general, a sound stimulus will form a certain pattern on the EEG signal.

| Frequency Band Name | Frequency Bandwidth | State Associated with Bandwidth | Example of Filtered Bandwidth |
|---------------------|---------------------|--------------------------------|-------------------------------|
| Raw EEG             | 0-45 Hz             | Awake                          |                               |
| Delta               | 0.5-3.5 Hz          | Deep Sleep                     |                               |
| Theta               | 4-7.5 Hz            | Drowsy                         |                               |
| Alpha               | 8-12 Hz             | Relaxed                        |                               |
| Beta                | 13-30 Hz            | Engaged                        |                               |

![Figure 1. Shape and activity of EEG signal. Source: Conorrus Somanno.](image)

2. Physiology of Smell and Auditory
Aromatherapy and music stimuli are related to smell and auditory in which the physiology field has a specially region in the brain as presented in figure 2. An olfactory bulb explains how the nose to receive the odor information in which it has a glomerular cell as a receiver and data storage of them to send to a special area on frontal lobe [5]. Figure 3 illustrates the principle of ear operation when it received sound. Theoretically, there are two types of auditory receptor, i.e inner and outer auditory hair cell. The hair cells form synapses with dendrites of bipolar neurons whose axons bring auditory information to the brain and their location at Brodmann Area (BA) 41 and 42 or temporal lobe [5, 6].

![Figure 2. Physiology of smell [2].](image)
3. Material and Method

3.1. Data Acquisition

Ten subjects were selected for this experiment which consisted five male and five female. Characteristics of subjects are students with average of age is 20.6 years. The EEG signal of ten subjects were recorded on daytime by NicoletOne EEG with 23-channels according to 10/20 principle (Fp1-F7, F7 - T3, T3 - T5, T5 - O1, Fp2 - F8, F8 - T4, T4 - T6, T6 - O2, Fp1 - F3, F3 - C3, C3 - P3, P3 - O1, Fp2 - F4, F4 - C4, F4 - P4, P4 - O2, Fz - Cz, Cz – Pz) as shown in figure 4. We divided the experiment into three steps, sleep without treatment, aromatherapy treatment and music treatment. We recorded all the treatments for 20 minutes. Properties of aromatherapy based on essential oil from bio-composite Myristica Fragrans (MF) and properties of music based on Sundanese music (SM) from Bandung, West Java, Indonesia. The experimental setup given in figure 5.

The ideas of experiment is to provide chairs especially for relax, so that subject would give several information of acquisition. When the information of acquisition take places, the subjects do not allowed to moving their limb because it could produce a noise and artifact of EEG signal. To obtain information of acquisition, subjects sleep without treatment (non-aromatic and music) for 20 minutes during the day. After 20 minutes, they have to be awakened and then we put the MF bio-composite as stimuli in a few minutes to let the subject sleep again for the next 20 minutes. We repeated the same treatment using sound stimuli SM for 20 minutes.

3.2. Feature Extraction

Figure 6 is scheme of signal processing in which wavelet transform (WT) become feature extraction. Theoretically, WT is a mathematical basic for signal processing to several applications included EEG Figure 4. EEG-Bipolar Montage. Figure 5. Experimental Setup.
data. In general, it provides to signal analyze by time-scale signal analysis, signal decomposition and signal compression [7]. Type of analyze commonly used to signal processing is Discrete Wavelet Transform (DWT) which generate a signal into two type of signals. Equation (1) describes the approximation and detail coefficient of DWT.

\[ \psi_{(a,b)}(t) = 2^a \psi(2^a (t - b)) \]  

Where (a) is scales and (b) positions of the wavelet mother (\( \psi \)) t [8]. The original EEG signal is time domain signal, the signal energy distribution is scattered and non-linear.

The EEG signal characteristic was analyzed using function wavelets (\( \psi_{a,b} \), mother wavelet) described in equation (2).

\[ \psi_{a,b} = \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right) \]  

where \( a, b \in \mathbb{R}, a > 0 \), and \( \mathbb{R} \) is the wavelet space [6].

The signal features are buried away in the noise. In order to extract the features, the EEG signal is analyzed to give a description of the signal energy as a function of time and frequency. Based on previous studies, the feature extracted in the frequency domain is one of the best to recognize the mental task based on EEG signals [9]. EEG signal is nonstationary that means its spectrum changes with time, such a signal can be approximated as piecewise stationary, a sequence of independent stationary signal segments [9].

The Fourier transform converts time domain signals into frequency domain representations defined in equation (3).
\[
X(f) = F\{x(t)\} = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}dt
\]  

(3)

And similarly, the DFT converts discrete-time sequences into discrete-frequency versions derived by equation (4).

\[
X_k = \sum_{n=0}^{N-1} x_n e^{-j2\pi nk/N} \quad \text{for } k = 0,1,\ldots,n-1
\]

(4)

In equation (3), \(x(t)\) is the time domain signal, and \(X(f)\) is its Fourier Transform. In equation (4), \(x\) is the input sequence, \(X\) is DFT, and \(n\) is the number of samples.

The Fast Fourier Transform (FFT) is an optimized implementation of a DFT that takes less computation to perform. In 1965, J.W.Cooley and J.W.Tuckey reinvented the FFT for fast computation of the DFT. We apply FFT to those signals with \(N=2^n\) number of samples. Benefit of FFT algorithm is reducing the computation time by a factor of the order \(N/\log_2N\), i.e. more than 100 times for a sample of 1024 samples.

4. Results and Analysis

In general, the raw data resulted from NicoletOne EEG is shown in figure 7 which has three signals, i.e. non-treatment, aromatherapy treatment and music treatment and each signal separated by line signal for each treatment. We obtain raw data in figure 7 because we recorded EEG directly and one-time for all treatments. Typical of acquisition is one of disadvantages in our experiment.

![Figure 7. Raw data EEG from Subject 1.](image)

The raw data in figure 7 has been discovered noise and artifact so it requires signal processing to remove them. The goal from signal processing is to yield the real signal and exactly to obtain EEG sleep characteristic. We used Band Pass Filter (BPF) with cut-off frequencies alpha band (8-15 Hz) and theta band (4-8 Hz) because those frequencies involved significant in sleep stages. Furthermore, analyze EEG data by WT with function of mother wavelet "Daubechies D8" levels 7 resulted detail coefficient and sleep characteristic. The results from WT is shown in figure 8.

Figure 9 shows brain activity before and after giving treatment. It shows that giving treatment decrease brain activity until ten minutes, while the before treatment phase show a random brain activity. We assumed that by using Sundanese music as a sleep treatment could make someone feel calm and relax.

Figure 10 shows the chart of data of signal processing for amplitude and frequency of alpha and theta wave with music stimuli, aromatherapy stimuli, and non-stimuli. The green color show the results with aromatherapy stimuli, while the red and blue color show results with music stimuli and non-stimuli, respectively. The processes signal was taken at 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 minutes. The result of this signal processing is then tested by T test to know its significance.
Figure 8. Brain activity for average subjects (Pre, post aromatic and music treatment).

Figure 9. EEG Signal pattern before and after giving treatment.

The result of the T test is shown in table 1. The T test is to analyze whether giving stimulus music and aromatherapy affect the quality of one's sleep. Significant value is indicated when p value less than or equal to 0.05. From the results of T test shows that the existence of music stimuli have greater significance compared with aromatherapy stimuli. The effect of music stimulation for sleep quality is seen after 12 minutes.

Figure 10. The Result of Average EEG Signal according to band range (alpha and theta).
Table 1. The Result of T test of music and aromatherapy stimuli to alpha and theta wave.

| t  | Alpha Wave | Theta Wave | Alpha Frequency | Theta Frequency |
|----|------------|------------|-----------------|-----------------|
|    | Aromatic   | Music      | Aromatic        | Music           | Aromatic        | Music           |
| 2  | 0.937      | 0.223      | 0.710           | 0.304           | 0.616           | 0.222           | 0.791           | 0.079           |
| 4  | 0.872      | 0.527      | 0.580           | 0.756           | 0.824           | 0.338           | 0.955           | 0.991           |
| 6  | 0.952      | 0.519      | 0.729           | 0.882           | 0.420           | 0.108           | 0.760           | 0.771           |
| 8  | 0.182      | 0.815      | 0.148           | 0.247           | 0.590           | 0.228           | 0.356           | 0.909           |
| 10 | 0.277      | 0.575      | 0.128           | 0.431           | 0.891           | 0.168           | 0.238           | 0.154           |
| 12 | 0.208      | 0.022      | 0.396           | 0.004           | 0.327           | 0.156           | 0.892           | 0.882           |
| 14 | 0.065      | 0.034      | 0.268           | 0.122           | 0.915           | 0.957           | 0.041           | 0.050           |
| 16 | 0.083      | 0.078      | 0.178           | 0.061           | 0.594           | 0.558           | 0.988           | 0.300           |
| 18 | 0.403      | 0.091      | 0.548           | 0.051           | 0.357           | 0.744           | 0.777           | 0.529           |
| 20 | 0.129      | 0.784      | 0.328           | 0.551           | 0.559           | 0.170           | 0.446           | 0.030           |

5. Conclusions
The Experiments to test the effect of music stimulation and aromatherapy on sleep quality have been carried out. The T test gives the result that the existence of music stimuli is significantly greater than aromatherapy.

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