

Detecting and Changing Brain Waves Using Sound Wave Interception

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Abstract: *Currently, a lot of people complain from stress and tension and require a device or method for stress relief. At the same time, similar problems of people not being able to make their mind active and feel lazy and bored to do tasks have also been found. Recently, the research for a system that is able to obtain the relaxation effect has been actively performed. For example, in a system where the user is presented with various sounds, the relaxation effect is measured from the brainwaves, heartbeat, and so on. Thus it was proved to be possible to change the state of brain by providing sound input to the users. In this research, we aim to construct a system to adjust the automatic operation of providing the necessary sound to obtain the required state of brain depending on users' current state of brain. The appropriate sounds will be provided by detecting the brain waves and calculating the appropriate sound frequency to provide the user to change their state of mind. The forthcoming effects on the brain waves will then be analyzed and the sound input to user will be varied so as to send the brain to the required state.*

Keywords: *brain computer interface, brain waves, EEG, Electroencephalography, fuzzy logic, neural networks, sound, supervised learning.*

I. Introduction

In today's time, the circumstances of living of many people are affected by stress. The stress levels of an average person have increased by a lot in the past few decades. Also, it is found that a lot of people are not able to concentrate on their work or make their mind active enough to reach an optimal state of working. Thus we intend to develop a system that will help its users to reduce their stress levels and help them calm their mind along with making their brain active and effective for work.

The project is a combination of hardware and software that will help the user achieve a required state of mind, that can be either high activity, or meditation/concentration, or sleep. The system will first detect the brain waves; provide it to the software present in the user's mobile phone which will then compute the appropriate sound necessary for the user's current state of mind to reach to the required state of mind. The result will be analyzed repeatedly and this process will go on continuously until the goal state of the brain is achieved.

The project is applicable to each and every person, whether they be teenage kids stressed by the studying or by old businessmen stressed by their work and needing a time for rest. This project can be used by Attention Deficit Hyperactive Disorder patients to improve their attention for any certain task which will help them in their work. It can also be used by insomnia patients to help them put into a drowsy state to help them sleep. Thus, the system can be used in various mental health facilities and mental health centers. The system can also be used for meditation and calming the mind. Thus it can be used in various yoga institutes for people finding it difficult to meditate.

II. Brainwaves

All our thoughts, emotions and behaviours of our brain are the result of the communication between neurons within our brains. The brainwaves are produced by such electrical pulses from masses of neurons communicating with each other. These waves can be detected by placing sensors on our scalp. The brainwaves are divided into bandwidths to describe their functions (as shown in table 1), but are best thought of as a continuous spectrum of consciousness; from slow, loud and functional - to fast, subtle, and complex. Our brainwaves change according to what we're feeling and doing. When brainwaves with less frequency are dominant we can feel slow, tired, or dreamy. The higher brainwave frequencies are dominant when we feel active, wired, or hyper-alert [1].

Thus, these brainwaves can be used to find out the current state of the brain. The brain waves are measured in hertz (Hz). The various types of brainwaves classified with respect to their frequency bands are:

TABLE I. BRAINWAVE CLASSIFICATION [1]

Type	Frequency range	Description
Delta waves (δ)	0.2Hz to 3Hz	Delta brainwaves are slow, loud brainwaves with low frequency, and are deeply penetrating, like a drum beat. They are generated in deepest meditation and dreamless sleep.
Theta waves (θ)	3Hz to 8Hz	Theta brainwaves occur most often in sleep when we are dreaming but are also dominant in deep meditation. In theta, our senses are less focused on the external world and are more focused on signals originating from within.
Alpha waves (α)	8Hz to 12Hz	Alpha brain waves are dominant during quietly flowing thoughts, when we are calm, and in some meditative states. Alpha is the resting state for the brain. Alpha waves help in overall calmness, mental coordination, alertness, mind/body integration and learning.
Beta waves (β)	12Hz to 27Hz	Beta brain waves dominate our normal awakened state of consciousness when our attention is directed towards certain cognitive tasks and the outside world. Beta is a 'fast' activity, that is present when we are attentive, alert, engaged in decision making, problem solving, judgment, and in focused mental activity.
Gamma waves (γ)	27Hz and above	Gamma brainwaves are the brain waves with highest frequency and relate to simultaneous and continuous processing of information from different brain areas. It passes information very rapidly, and as the most subtle of the brainwave frequencies, the mind has to be quiet to access it. Although, gamma is above the frequency strength of neuronal firing, so how it is generated remains a mystery to the scientists.

III. Related Work

In the paper by M. Teplan, A. Krakovska, S. Stolic [2], "EEG response to long term audio-visual stimulation", linear and nonlinear electroencephalogram (EEG) changes due to long-term audio-visual stimulation (AVS) were investigated. In the course of 2 months, 25 repetitions of a 20-min AVS program with stimulation frequencies in the range 2–18 Hz were applied to six healthy volunteers. EEG data were recorded from six head locations during relaxed wakefulness prior to AVS. Then linear spectral measures (total power, frequency band powers, spectral edge frequency, and spectral entropy), nonlinear measures of complexity (histogram-based entropy and correlation dimension), interdependency measures (linear correlation coefficient, mutual information, and coherence), and measures of subjective assessment were estimated. Evolution of these measures during the whole experiment period was analyzed with respect to the significance of their linear regression. The results confirm that repetitive training with audio-visual stimulation does induce changes in the electro-cortical activity of the brain. Long-term AVS significantly increased power in theta-1, theta-2, and alpha-1 bands in the frontal and central cortex locations. Total power increased in the right central region. Interhemispheric coherence in alpha-1 band displayed a significant increase between frontal parts in contrast to the decrease of both linear correlation and mutual information. Correlation dimension significantly decreased in some locations while entropy displayed an ascending trend.

In the paper by Yoichiro Maeda [3], "Interactive sound generation for relaxation based on heartbeat and brain wave", the aim was to develop the relaxation sound generation system by using multiple biosignals, and the relaxation estimation method by fuzzy reasoning based on heartbeat fluctuation was proposed. Experiments were performed to generate a relaxation sound so the subject might feel relaxation adopting interactive sound generation system. The degree of relaxation was calculated by fuzzy rules using RRI data of heartbeat and was compared with the relaxation degree based on brain wave and the questionnaire evaluation. As a result, the evaluation degree R_{bw} of brain wave was almost better than the relaxation degree R_{hb} of heartbeat. However, heartbeat relaxation degree was useful for only one subject with a medium correlation for questionnaire, so as to plan to improve the fuzzy inference rule for various subjects. In this research, the sound provided to the test subjects were fixed and not based on their current state of mind. Also, it only tested for relaxation of mind.

In the conference paper by Akinori Nishihara, J. Chinrungrueng, Juti Naraballoh [4], "EEG Based analysis of Auditory Stimulus in BCI", the aim of the research was to observe and analyze the EEG-Based method with a statistical approach to find the significant difference of each brain wave type. The result was computed using several conditions of brainwave providing the auditory stimulus including the binaural beat and the instrumental relaxing music. The binaural beat and instrumental relaxing music induced the mental state in a similar way. However, the effect depends on the range of age. For instance, instrumental relaxing music is beneficial to age group 31-50 whereas binaural beat provides less effect in imagination and consciousness. On the other hand, listening to binaural beat improves meditation of people in age group 51-70 but the effect of

relaxing music is less for imagination and meditation. Although no research was done on people of age group below 31, which includes students and inexperienced workers where the need of relieving stress and relaxation and meditation to improve their work quality is most.

In the conference paper by G Guruprasath, S Gnanavel [5], “Effect of continuous and short bursts Binaural beats”, the subjects were provided with continuous and short bursts of binaural beats and the difference in effects of both of these were recorded. Binaural beats are perceived when two slightly different frequencies of sound are presented to each of the ear. The difference between the two frequencies would be the frequency of the binaural beats. Binaural beats of different frequency ranges were found to influence the brain waves producing cortical entertainment and was reported to affect the subject behavior and cognitive functions. The continuous presentation of binaural beats for a prolonged time has been found not to cause any significant changes. Hence the aim of this paper was to find the effect of continuous and short burst presentation of binaural beats on EEG signal. Eighteen participants were divided into two groups and one group was initially exposed to 12 Hz short burst beat stimulus followed by continuous beat stimulus and the other group was exposed to 18Hz short burst beat and continuous beat stimulus. Both the groups were exposed to white noise prior to the binaural beat stimulation and also between the short burst and continuous beat stimulations. The recorded EEG signals showed increase in cortical mean absolute power after short burst stimulation while continuous stimulation decreased mean absolute power. However, no significant difference or frequency following effect elicited by either continuous or short burst stimulation was observed.

Along with these, there are some other studies about systems generating images and healing music from personal body signals [6], [7]. In addition, the research about Brain Machine Interface(BMI) using electroencephalogram(EEG) is actively performed and the effect of relaxation are proposed by using the location information from the brainwave topography [8], [9], and a lot of researches are also performed on the influence of images and sound waves on the brain [10]-[12].

IV. Proposed Work

In this project, we are going to perform research of various sounds on various states of brain and record them. The brain waves will be mapped using Neurosky’s EEG known as “Neurosky Mindwave Mobile”. The data provided by the EEG is in the form of power of each brainwave, from delta(δ) to gamma(γ). Based on the inferences from these experiments, we will create a product that will take the brain waves input from the user using an EEG, and send the recorded data to the system. The system will then find out the current state of the brain and the nearer brain state using the input received from EEG and selects the appropriate sound from the database and sends the output to the sound processor. The sound processor will process the sound and set the tempo and volume of the sound which will be varied continuously depending on the brainwave power which will help the user reach the desired state using neural networks and supervised learning technique. The application will then send it to the external sound unit. In the background, the profile of the user will be continuously updated and built using neural networks. This sound that will change the brain state will thereby be changing the brain waves which will again be recorded by the EEG and the whole process will be repeated.

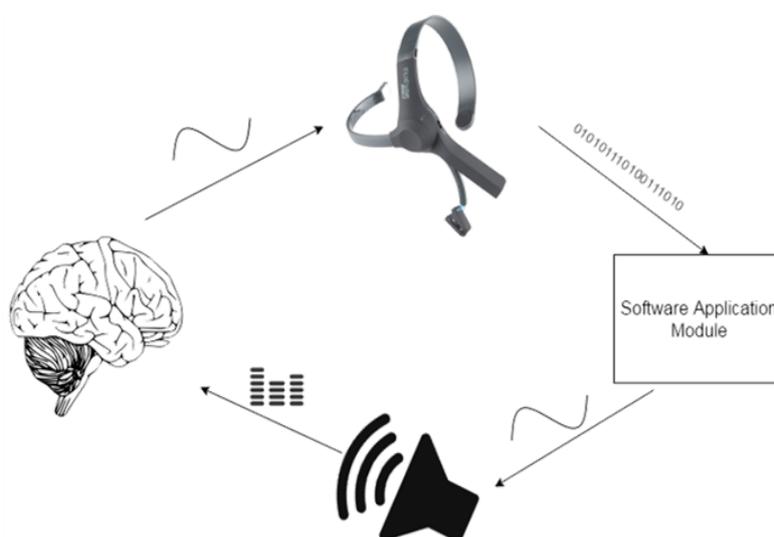


Fig. 1. System Architecture

V. Sound Selection

The data received from the EEG is the power of all the waves, ranging from delta(δ) to theta(θ). Each of these waves are given a rank as 1 to 5 for δ to θ . The mean of data received from the EEG every second will be calculated every 10 seconds as:

$$x = \sum_{i=0}^9 \frac{x[i]}{10} \text{ for each } x = \delta, \theta, \alpha, \beta, \gamma.$$

$\text{rank}_1 = \text{rank}[\max(x[i])] \text{ where } x = 1 \text{ to } 5.$

$\text{rank}_2 = \text{rank}[\text{second_max}(x[i])] \text{ where } x = 1 \text{ to } 5.$

$x_1 = \max(x[i]) \text{ where } x = 1 \text{ to } 5.$

$x_2 = \text{second_max}(x[i]) \text{ where } x = 1 \text{ to } 5.$

The sound related to **rank₁** in the database would thus be selected for processing.

VI. Sound Processing

In the processing phase, the tempo of the sound is set in accordance to the current state of the brain and the required goal state. Even in the current state, how closer or farther the brain is from the goal state will also be taken into account which can be found out by considering the wave with the second highest power. Whenever the brain enters a state close to the goal (change in rank_1), the sound changes and the initial tempo of the sound is set. The database also includes the minimum and maximum allowed tempo for each sound as well as the mean tempo. The initial tempo is thus set as:

$$t_{\text{init}} = t_{\text{mean}} + \text{sign}(\text{rank}_1 - \text{rank}_2) \times (1 - (x_1 - x_2)) \times (t_{\text{max}} - t_{\text{min}})$$

$t = t_{\text{init}}$ where, t is the tempo of the sound.

The formula to set the tempo of the sound uses two techniques depending on the situation. If the goal state has already been reached, the system will slowly but gradually get the tempo from the initial to the mean tempo of the sound. If the brain is not in the goal state, it will use supervised learning technique similar to perceptron learning to set the tempo to get the brain in the goal state.

$\text{net} = \text{rank}_{\text{goal}} - \text{rank}_1$

If $\text{net} = 0$, then

while $t \neq t_{\text{mean}}$, do

$t_{\text{new}} = t_{\text{old}} + \text{sign}(t_{\text{mean}} - t_{\text{old}})$ every 2 seconds.

If $\text{net} \neq 0$, then

$t_{\text{new}} = t_{\text{old}} + \text{sign}(\text{net}) \times k$

where, k is the constant that sets the speed of change (learning constant) and will be updated for every different user as per their usage so as to make the system optimized for every user.

VII. Conclusion

The product thus created from the research will be able to detect the brainwaves of a person and be able to manipulate it using sound that will be first processed by the system in accordance with the input from EEG. It is an attempt to help any of the people belonging to any of the age group who wish to focus, improve sleep, meditate or elevate their mood. Thus it would be helpful in the following ways:

Meditation- If this system is used while meditating; it will help the user to get in a better calm meditative state which can also improve their concentration. Excitation- This system can be used to elevate the mood of the brain by making it alert, attentive, and active. Insomniac- This software can be used by people finding it hard to sleep as we can send the brain closer to a theta state which is the ideal state of mind while sleeping. ADHD patients- If this system is used by people having attention deficit problems and are hyperactive, it can be used to calm them, thereby increasing their concentration while studying and other work.

It will also be able to help us understand the working of the human brain and help us understand various concepts of computational neuroscience and artificial intelligence.

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