Brainwave Entrainment using Visual-Auditory Stimulation as Therapy for Sleep Disorders

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ABSTRACT
Sleep disorder is one of the problems faced as a side effect to many disease like depression, epilepsy, cardiac problems., It is generally treated either by means of sleeping pills or through psychotherapy which when taken for long time leads to health problems. In this work, attempted is to develop a device which provides a combination of audio visual entrainment therapy to induce sleep. This device provides drug-free treatment through a user friendly environment that enables relaxation of brain and muscles. Two audio signals at two different frequencies were given to left and right ears. This results in binaural beat signal in delta band. Visual input (Red LED) is also given to two eyes through eye-mask to block the entry of external light. These two which when applied simultaneously suppresses alpha band frequency and increases delta band of brain signal and thus induces sleep. When this procedure tried on controls and test subjects, subjects with sleep disorder took 10 to 15 extra to enter into sleep state. Thus this device provides no discomfort to the user and also very cost effective.

KEYWORDS: Binaural beat, EEG, Entrainment, Insomnia, Sleep

I. INTRODUCTION

Sleep is one important factor that keeps a person active and healthy. Insomnia is a condition that makes disorderliness in the sleep. It plays a significant role in normal, pathological and psychiatric subjects (Mathew R et al., 2012). Many pathological conditions like cardiac problems, thyroid, blood pressure and stress, anxiety also contributes to the disorders of sleep. Most of the times inducing sleep either through hypnotics or through sedative medicines are commonly adopted for treating sleeplessness (Mathew R et al., 2012). This however have side effects includes Diarrhea, Dizziness and Headache and day time drowsiness (Daniel F et al., 2013).

Brainwave Entrainment is an alternative procedure that modulates neural activities by synchronizing brainwave frequency with that of stimuli (Shusheng et al., 2016). Human conscious state is dictated by the kind of brainwave generated by the brain. High mental activity is associated to the frequency of 13-30 Hz (beta), alert state to 9-13 Hz (alpha), drowsy state to 5-8 Hz (theta) and deep sleep state to 0.5-4 Hz (delta) (Hsin- Yi Tang et al., 2015). Audio or visual stimulus is one way of influencing neural activity. By selecting the right stimulating frequency, Delta wave can be generated and hence inducing sleep.

Various photic effects on brain are a point of discussion for the past six to seven decades. John & Barlow, (1959) have demonstrated the relation between rhythmic brain waves and photic flash rates. They have also demonstrated the responses of the difference between the two hemispheres of the brain for the subject with cerebral hemorrhage. Whereas a great degree of similarity between hemispheres were observed on visual stimulation.

Donker et al, (1988) have studied inter hemispheric response to visual stimulation on normal and pathological subjects and conducted that inter hemispheric communication is distributed on pathological condition from EEG results. Apart from diagnosis, photic stimulation is used in therapeutic application. Hiroaki et al., (1996) have increased the alpha activity through photic stimulation for a subject suffering with depression and insomnia.

Audio is one another stimulating factor that activates brain function. Specifically Binaural beat, arising from two different frequencies when presented separately to left and right ears (James D et al., 1998). Hillel et al., (2009) investigated the brain activity on different auditory frequencies and was able to obtain better response for lower frequencies than higher.

Audio-Visual Entrainment (AVE) is yet another method of stimulating the brain activity. This entrainment at low frequencies promotes deep relaxation. From the above discussion it is clear that audio and visual stimulation at specific frequency is useful in relaxing stress and also for inducing sleep. On this background attempted here is to develop delta frequency in the brain through AVE in normal and control subjects. (Hsin-Yi et al., 2015) have concluded that when AVE is applied over chronic Insomnia subjects, quality of sleep found to increase. They have also observed this kind of test, in addition to improve sleep, it reduces the body pain and anxiety.

II. METHODOLOGY

A. System Overview

AVE experiment is performed on CONTROL subjects and subjects with sleep disorderliness. Audio and Visual stimulus are given simultaneously in silent environment and brainwave is recorded across P4 and O2 using BIOPAC 4.0 with 125 Hz as sampling frequency. In addition to this, Controls are also subjected to audio and visual stimulation separately. Response from the brain is recorded in the same procedure as mentioned above for AVE. The Figure 1 shows the recording setup of AVE therapy for inducing sleep for the insomnia patients.
B. Audio Unit

One of the stimulating factors for brain is audio. Two different audio signals at 60 Hz and 64 Hz are given to Left and Right ears. Due to the superposition of neuronal activity arising from these two frequencies Binaural beats are formed in the brain (Hillel et. al., 2009). The audio signals are checked for its frequency components using Audacity software. (Courtesy: An open source audio frequency signal generator. www.wavetones.com/functiongenerator.php).

C. Visual Unit

Apart from light being used for diagnostic purposes, photic stimulation is also used to treat sleep disorders and migraine (Michael L. et. al., 2001; Anderson D. J. et. al., 1989). Visual unit is constructed using Black colored eye mask over which Red LEDs (one for each eye) are place and covered in such a way that no external light influences either the LED or eyes. Due to the direct relationship between wavelength of red light and melatonin (Deanna Alicia et. al., 2007), the visual stimulation also aids in inducing sleep.

Combination of Audio and Visual units and applying these two stimulations simultaneously forms the AVE unit.

III. STIMULUS AND PROCEDURE

The investigation was carried out in a group of 5 normal subjects (CONTROL) and 3 subjects with sleep disorder, in the age group between 20 and 70 with mean age being 38 and Standard deviation (SD) 20. All the enrolled subjects were explained about the nature of study and written consent was obtained from them participants. The experiment was carried out in a sound proof room that has the facility to record the brain signal without any disturbance. All the subjects were asked to relax for 60 seconds and then first brainwave signal is recorded. After obtaining first brainwave signal, AV stimulus is begin.

A. Test on CONTROL Subjects

The experimental procedure consists of 3 parts: a pre-AVE test and two tests during AVE phase, where the subjects enters into drowsy state and when the subject enters into deep sleep state. Signals were recorded after 10 and 15 minutes of commencement of AV stimulus. After the end of this therapy (15 minutes) all the CONTROL subjects started sleeping.

B. Test on Subjects with Sleep Disorderness

Three Participants with sleep disorderness were tested for AVE response (Participant 1, aged 70, male; Participant 2, aged 64, female; Participant 3, aged 42, female). They were medically apt to undergo AVE test as suggested by the neuro physician. After relaxed state AV stimulus is applied, signals were recorded after 10 minutes, 20 minutes and 25 minutes. The period here...
extended by 10 minutes because the subjects relatively took longer time to fall asleep.

IV. RESULTS

Brainwave arising due to AV stimulus is recorded on (A1-P3-O1, A2-P4-O2) both the hemispheres for all the subjects undergoing test procedure. Response of brain to audio and visual input is widely observed in parietal and occipital lobes (Adrian E et. al., 1934). In normal condition, the response of two hemispheres will be similar. Whereas, on pathological condition, response arising from two hemispheres could be different.

The brain signal measured is the distribution of electrical voltage with respect to time. However, the focus of this study is to induce sleep i.e., delta wave (0.5-4 Hz) and to suppress active state i.e., alpha wave (8-12 Hz) by AV stimulation. This is achieved by measuring brain signals before and after AV stimulation and analysing it for power distribution on different frequencies. Therefore after finding power spectral density of the signal, average power over a band of frequency is computed and plotted in Figure 2. This kind of analysis is done for both CONTROL and pathological subjects on both the hemispheres.
V. DISCUSSION

Sleep disorder normally arises in patients suffering from neuro related problems, emotional stress, work nature or as a side effect of any other pathological conditions. This leads to poor efficiency in work and fatigue if not treated correctly. The main aim of this study is to induce sleep in subjects with sleep disorder without any drugs. An AVE unit is developed in such a manner that it gives relaxation and comfort to the user. This is tried over 5 CONTROL subjects and 3 TEST subjects.

At first control subjects are tested with Audio and Visual inputs when given respectively with other condition like environment and time remaining the same. All the participants felt that audio stimulation is more effective than visual. This is because of the production of binaural beat that activates neurons in such a phase to produce delta waves. But visual signal input (Red light), though do not aid in the sleep inducing mechanism (production of melatonin) they do not suppress it (Deanna Alicia et. al., 2007). However, when the same Subjects are tried with simultaneous Audio & Visual (AV) stimulus, response in delta band was found to increase, This confirms that both visual and Audio inputs helps sleep induction.

After ascertaining the effectiveness of AV stimulus, test was extended to subjects with sleep disorder. These people took relatively longer time to enter into sleep state when compare with CONTROLs. From this experimental analysis the following are the observations.

i. During relaxed state, though low frequency is present, content of high frequency (8-12 Hz) is dominant.

ii. Time taken for CONTROL subjects to enter into sleep state is less when compared to subjects with sleep disorder.

iii. After AVE is commenced, it can be observed that (Figure 2 a to e), power in low frequency content increases and power in high frequency content decreases. This is a proof for entry into sleep.

iv. As time progresses, there is further increase in low frequency and further decrease in high frequency where the subject went to deep sleep. This state occurred in both the cases (CONTROL and pathological), only

Figure 2. Band power measured during AVE a) on right hemisphere for CONTROLs, b) on right hemisphere for participant 1, c) on left hemisphere for participant 1, d) on right hemisphere for participant 2, e) on right hemisphere for participant3.
difference being time duration i.e, CONTROL subjects take smaller duration when compared to test subjects to enter into sleep.

v. When signals from two hemispheres are compared, CONTROL subject exhibits similar response with magnitude of power being the same. But the pathological subjects shows similar variation in frequency content, however its power value is different. All the three pathological subjects exhibited high power on right side and low power on left side of hemisphere.

From this it can be observed that AVE increases power in delta band and decreases power in alpha band indicating lowering the active state. In addition to this, the test group of subjects are interviewed for their comments on this therapy. All the participants uniformly welcomed this sort of non-invasive therapy without any oral intervention. They also felt more convenient in the audio than video input. Few are of opinion that the drug they consume for sleep gives sort of inconvenience like headache and made them less active, specifically if sedative drugs are consumed in combination with pain killers or drugs related to their physiological condition, sometimes its interaction leads to disturbed sleep. Above all the participants felt an improvement in quality of sleep in the night after this AVE therapy. However still more study is to be done to quantify the quality of sleep. This however being a primitive study would definitely prove to be an alternative for drug based therapy.

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Kindly add

Conflict of interest statement

The author has declared that no competing or conflict of interests exist. The funders had no role in study design, writing of the manuscript and decision to publish.

Author’s Contributions

Kindly add

REFERENCES

