

Brain Music System : Standardized Brain Music Therapy

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Abstract

The paper discusses a standardized therapeutic treatment using the Brain Music System, a system that uses Sonified Neurofeedback accurately and cost effectively to convert brainwaves into musical sound using Digital Signal Processing algorithms. A standard course of sonified neurofeedback therapy (for example 15 sessions), tailored specifically to individual patients, is a realistic possibility due to the inexpensive and portable nature of the system, and could be used both inside or even outside of a traditional clinical setting for subjects suffering from a wide array of mental and neurological conditions including Autism Spectrum Disorder. In a pilot study to test the algorithms and output of the Brain Music System, the distribution of the Alpha, Beta and Theta waves in normal subjects corresponds closely to that in published studies using standard high-end equipment (confined to expensive clinical setups). These results allows the Brain Music System to align its protocol to practice standards, and to better associate standard algorithmic tasks to each of the three mentioned brainwave types.

1 Introduction

Listening to music is a personal experience which is influenced by a variety of factors. Music and other mental activities share the same cognitive functions as well as operations. These other mental activities include among others language as a means of expression and communication. However, listening to music for the majority of people is mostly of a receptive nature. The arousing feeling by music and the appreciation of music are essentially the interaction of the musical piece with the emotional and mental status of the listener. Without the expression of this receptive process, exploration of its neuroanatomical substrate is difficult. Nevertheless, the interaction of music with the brain may be reflected in alterations in brain electrical activity, recorded by the electroencephalogram (EEG) as demonstrated by Satoshi et al. A brief exposure to music can lead to an instant improvement in spatial duty performance, correlating with alterations in the EEG power spectrum.

2 Sonification of Neural Signals

There are various distinct processes involved in converting neural signals to sound signals or sonification of neural signals. It is a fact that “analyzing multichannel EEG signals using sounds seems a natural method: using a sonification of EEG signals... perceive simultaneously every channel, and analyze more tractably the time dynamics of the signals – hoping to gain new insights about the brain signals.” (Vialatte and Cichocki). The sonification of neural signals is done in various steps having separate set of procedures. This process will consist of the following stages:

1. **Data acquisition**
2. **Data pre-processing**
3. **The creation of visual and sonic map**
4. **Visualization and sonification**

Usually, Data acquisition process is defined as the phase of data handling that begins with the sensing of variables and ends with a magnetic recording or other record of raw data.

The data recorded then undergoes preprocessing during data preprocessing stage. Data preprocessing describes any type of processing performed on raw data to prepare it for another processing procedure. In sonification activity, data preprocessing is done to get relevant input to represent data before creating the actual visual and sonification output. Visualization can be defined as a tool or method for interpreting image data fed into a computer and for generating images from complex multi-dimensional data sets which is responsible for representing recorded data into visual patterns. Visualization is accompanied by sonification which “is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation” where in our application music is produced at the end. (Hermann).

Various experiments were carried out for deducing some efficient approach for sonification process. Researchers from Georgia Institute of Technology in Atlanta were among those. They were in search of “aesthetically satisfying and educationally useful representation of complex datasets of neural activity through hands-on interaction” sonification procedures. They succeeded in it by their reach to introduce the triumph project on “framework of the “Fish and Chips” project (in collaboration with the Symbiotic Research Group, Perth ,Australia), where they sonified low resolution audio signal from an in-vitro culture of fish neural cells.” (Weinberg and Thatcher 246).

3 Impacts of Neuro feedback Music

“Neuro feedback training is brainwave biofeedback.” (Hammond). The brain waves are fed back to brain cells so that it helps in attaining a pleasant frequency of brain activity. This method can be viewed as “exercising or doing physical therapy with the brain, enhancing cognitive flexibility and control.” (Hammond). By doing this, variations to brain waves can be achieved. But, it is a fact that brain waves are responsible for various activities and moods of an individual. So, through keen analysis and investigation, it becomes possible to change a mood to another by employing neuro feedback. There is extensive experimentation carried out to analyse impacts of Neuro feedback Music. Department of Cognitive Neuroscience and Behaviour within the Faculty of Medicine at Imperial College in London , is an association that explored on the matter through their experiments. They mainly relied on two separate experiments they conducted. “In experiment 1, a group of students was trained on the SMR, Beta1, and a/t protocols and performance changes were compared to a no-training control group and a group receiving additional interventions.” (Egner and Gruzelier 1221). The variations in performance brought about by three different neuro feedback protocols were evaluated. “In experiment 2, different neuro feedback protocols were trained in separate groups and performance changes were contrasted with comparison groups undergoing alternative interventions.” (Egner and Gruzelier 1221-1222). Both the experiments dug out the positive impacts of neuro feedback.

4 Brain Music System

The Brain Music System delivers electroencephalographic data as modulated MIDI. It is similar to the brain-computer interface (BCI) system created and amply documented by Professor Eduardo Miranda, but runs optimally even on a 2 channel EEG since it does not depend on the collecting end for the processing functions but uses computational methods which can be supported by regular modern office computers (making its uses different and more accessible due to its cheaper running costs).

The brain music system uses the modified LORETA methodology (Attard Trevisan and Jones) which enables the system to obtain and predict information from 2/3 EEG channels. Data is modified before being saved in the European Standard EEG data file format (EDF) thereby simplifying the process of being collected and computed on standard specialized software. The modification enables smaller devices to be less invasive using few electrodes and still be able to monitor clinical standard EEG data.

Data collected from identified areas is augmented using an approximation algorithm in real time so as to obtain virtual channel approximations for use during data computation. Ideally, music being produced will be the representation of

the current level of brainwave activity in the brain music system. This is close to what an expensive 19 channel Clinical EEG produces.

5 Brain Music Therapy

Neurological studies show that temporary co-ordination between different and often distant neural assemblies play a vital role in higher cognitive phenomena. Multiple cortical regions may become co-active during cognitive tasks and also functionally interdependent. For instance, most of information processing most likely takes place in the rear brain regions containing the visual cortex when eyes are open, whereas the principal processing occurs in the frontal brain when eyes are closed (Bhattacharya et al.). It has been shown that listening to music helps to arrange the cortical patterns so that they may not wash out at the expense of other pattern development functions, and particularly, the right hemisphere processes, music is important for excitation and priming of the common repertoire and orderly flow of the cortical patterns responsible for higher brain functions, and helps in the enhancement and facilitation of the cortical symmetry operations among the inherent patterns. “The cortex's response to music can be thought as the 'Rosetta Stone' for the 'code' or internal language of higher brain function”. (Rauscher et al)

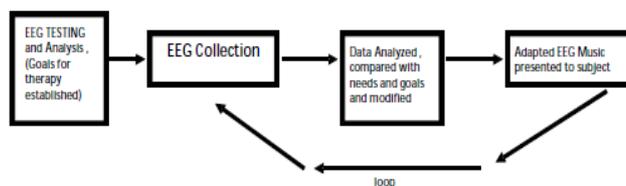


Figure 1 . Brain Music Therapy Diagram

By analyzing the components of an EEG output ; namely alpha, Beta, Delta, and Theta waves, a system can be developed to convert these waves into music by a number of computational methods (modified LORETA in the case of Brain Music System). Various studies show that alteration of this process and presenting to an altered musical representation to the subject in a loop form can help in leveling the brainwaves as a structured type of therapy as shown in “Brain Music Therapy diagram” . This type of therapeutic adaptation can be successfully applied to a range of clinical conditions such as epilepsy, attention deficit hyperactivity disorder and the locked-in syndrome, and to optimise performance in healthy subjects. “In healthy individuals, neurofeedback has been shown to improve artistry in music students and dance performance”.(Egner et al.)

6 Pilot Study

The results for ten subjects undergoing a regular recording of 15 second active blocks using the Brain Music System (as described by Attard Trevisan and Jones) with a Pendent EEG collecting device were collected and presented in the table below. The four different brain waves i.e., Alpha, Beta, Delta, and Theta were color-coded as green, red, yellow, and blue respectively. The table below presents the average values of the four forms of EEG waves for ten subjects undergoing 15 seconds of useful recording blocks.

Objectives of the Study

1. Check if there are common patterns and levels of Brainwave activity in EEG outputs which can be optimally used in the musical process of the Brain Music System
2. Compare Output Brainwave levels by the "modified LORETA" with published literature studies

6.1 Results

EEG	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9	subject 10
Alpha	3.37	3.36	3.29	3.06	3.23	2.88	2.95	2.13	3.52	3.22
Beta	5	4.91	5.21	4.64	4.95	5.03	5.09	5.09	5.02	4.97
Delta	2.89	2.83	2.61	2.42	2.41	2.45	2.93	2.61	2.23	2.88
Theta	3.76	3.34	3.45	3.94	3.59	3.34	3.83	3.97	3.83	4.07

Table 1: Results Table

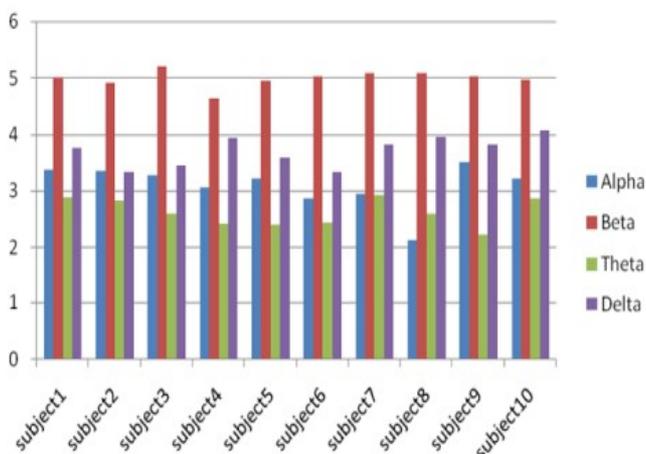


Figure 2 : Band Frequency Graph 1

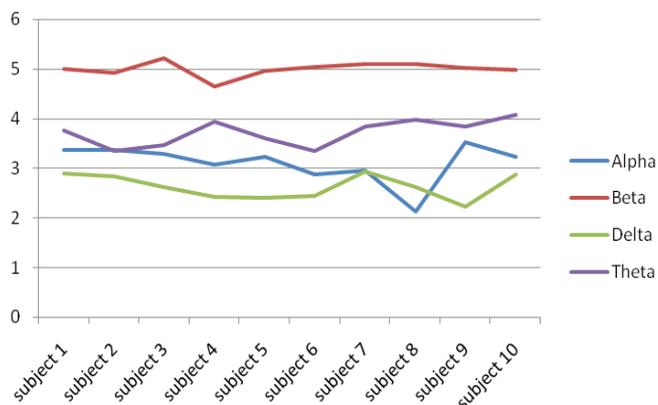


Figure 3 : Band Frequency Graph 2

The linear Band Frequency Graph 2 shows that throughout the analysis of brain waves, the Beta wave presented as the most significant form of brain with the highest mean wave followed by Theta and Alpha waves respectively. The least form of brain

wave was the Delta wave which had consistently lower figures in most of the subjects.

According to the linear graph, Delta is statistically insignificant in this study in awake subjects and is thus deemed not relevant to include it. The means of the relevant bands recorded in the table above were analyzed and the results presented as Band Frequency Graph 1 and Band Frequency Graph 2. They clearly indicate which of the bands had the most stable output, in order to further confirm which bands should be given priority for its role in the system. The results show that the Beta waves have the most stable output, followed by the Alpha and the Theta waves.

Throughout the analysis of brain waves, the Beta wave presented as the most significant form of wave with the highest mean wave followed by Theta and Alpha waves respectively. The least form of brain wave was the Delta wave which since the experiment needed subjects to remain assertive had consistently lower figures in each of the ten subjects .

In this study, the Beta wave provides the best avenue for the study of the interaction between a musical piece and the brain. The results indicate that the left frontal regions of the brain are more involved in processing as shown by the higher mean of the Beta range. The right hemisphere may also be increasingly engaged with higher frequencies of the Beta wave. The Beta range can be used to indicate the part of brain that is involved in processing a particular kind of music. The Theta band showed coherence in pattern in the ten subjects and that coherence increased symmetrically, except in just few cases. The Alpha band was characterized by more coherence decreases and extending over longer distances than other bands.

The interpretation of increases in coherence advances the theory of increasing cooperation between two regions of the brain. Decreases on the other hand indicate that mental process under investigation requires lower collaboration between the two regions in order to perform optimally.

Changes in gravity centers of coherence clearly indicate particular significance of the regions involved for processing information and how other cortical regions are involved. In the case of decreases, the region concerned may decouple from other cortical regions. Visual data processing studies have substantiated this view and can be applied to the alpha band as is the case in this study. In other words, attentive listening needs increased attention and suspends the freely floating thinking that could be assumed to take place upon EEG at rest; the two processes lead to parcellation of the cortex in that frequency band that is concerned in general attention processes. Moreover, it could also be that cortical coherence is reduced for an increased information exchange with subcortical sites. "As far as the behaviour in the Theta band is concerned, it was found to be fairly characteristic in processes where memory takes a momentous part (in this case, the violoncellist knew the piece by heart and thus, mentally anticipated every single phrase)" (Hellmuth et al.). Conversely, emotion is also reflected by coherence. Machleidt et al shows that different bands may be adjacent to different domains of sensory signal processing. It is worthy noting that the extensive twisting of the cortex and the electrical conductivities of tissue layers may cause the electric features of the surface EEG not to be displayed fully. However, characteristic coherence patterns can be found.

7 Conclusion

From this study, common patterns and levels of Brainwave activity in EEG outputs can be optimally used in the musical process of the Brain Music System. The stratification of the different elements of the EEG can help to find out which band is most significant in the musical process of the Brain Music System. The ability of having a standard protocol for a "Brain Music Therapy" program developed on the patient's individual needs while rehabilitating from a number of Neurological conditions has been eased and is now possible without incurring excessive clinical expenses. Another area of utilization of such a structured therapy is rehabilitation. People suffering from paralysis and diseases of the degenerative nervous system and who cannot effectively communicate with the outside world without the help of prosthetic devices can benefit from these findings.

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