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EXPLORATION OF MULTI-BRAINWAVE SYSTEM MAINFRAME DESIGN

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Abstract. *Synchronized collection of brainwave signals, or electroencephalography (EEG), from a group of people has seldom been conducted. This study focuses on the design of simultaneously collecting EEG generated from many people. People under test will be asked to listen to the same music at the same time. Quantitative measurements of the response from tested people will be used for the verification of the music therapy. This research has the benefits of obtaining the brainwaves from many people at the same time, reducing the duration of research, minimizing temporal and spatial variations, as well as controlling the experimental duration. The results show that exciting α-wave helps people get relaxation more, which is of great help when people are in need of recovering from taking a rest.*
Keywords: Brainwave, EEG, Music therapy, α-wave

1. **Introduction.** According to experts from Laboratory of Brain Recognition and Behavior, Michigan University, long term multitask operation results in the lack of efficiency in filtering out irrelevant signals, which leads to the distraction of paying attention to irrelevant message rather than work-related information. As a result, one would have problems in transition from one job to another [1,2]. However, some people rely on their brains to deal with many things and it may lead to fatigue. Therefore we did this experiment and tried to figure out the most effective way to soothe the spiritual pressure and calm the mind down.

Brainwave reflects the change in electrical potential resulting from the conjunction between the thousands of brain neurons. A neuron can receive signals from other neurons and starts off cyclic discharge reaction when sufficient energy is accumulated. That is also the reason why people persistently emit brainwaves. In 1929, Berger [3], a German doctor, discovered that human's brain can emit four different kinds of basic brainwave forms, i.e., the α-wave, β-wave, θ-wave and δ-wave (Figure 1).

These four brainwaves represent different psychological status of a human. It is reported that when people are in a state of calmness and relaxation, the intensity of α-wave tends to be high. In contrast, under the conditions of tense, thinking and devotion, β-wave raises. In the initial stage of falling asleep, θ-wave starts to appear. During deep sleep, δ-wave emits [4]. The frequency of the α-wave falls in the range between 8Hz and 14Hz. The electroencephalography (EEG) [5] of an example of α-wave is shown in Figure 2.

When brainwave shows strong α-wave signal, normally his or her conscience is clear, but the body is in a relaxed state. It always shows up whenever one is taking rest with eyes closed, while the body is relaxed. The α-wave provides a bridge between conscience and sub-conscience, which is very helpful in relieving stresses for the human body [7,8].

The major contributions of this paper are:

(1) This experiment confirmed this system could receive the multi-human brainwaves of all ages;

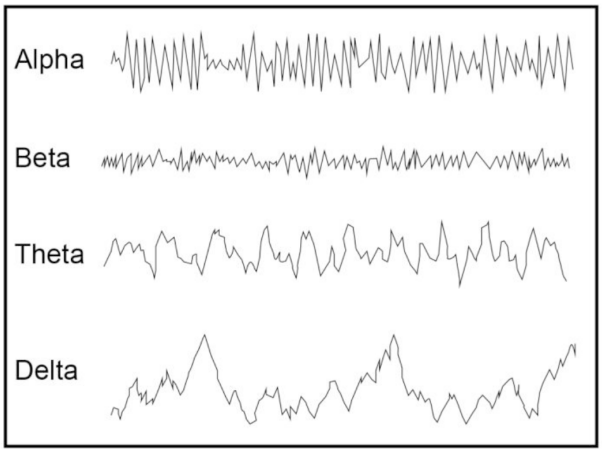

FIGURE 1. Four basic types of brainwaves

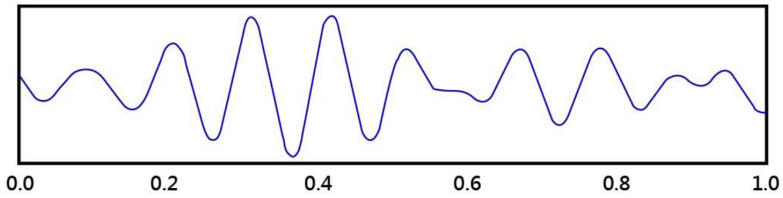

FIGURE 2. The EEG test of frequency change of the α-wave in one second [6]

(2) Receiving multi-human brainwaves could decrease the differentiation over time;
(3) We present a new point of alpha wave;
(4) In this experiment we found low alpha has no significant influence to music;
(5) Brainwave raw data could be exported to excel.csv, and could be set into statistical software as well.

We develop a system which could collect multi-human's brainwaves at the same time. The system could reduce the variables and research time. Then, we discuss the influences of music to human's spirit, the brainwaves. Especially, we emphasize to discuss the alpha wave, and we separate it into two parts, high alpha and low alpha.

2. Related Work.

2.1. Experimental instrument.

MindWave Mobile [9] is a non-intrusive type of brainwave measurement device developed by NeuroSky Company, USA [10]. It has the capability of detecting the concentrating and relaxing state of human body, with an accuracy comparable to that of Neuroscan. D. Poltavski's paper indicated these two machines have 96% similarity of the brainwave examination results; Figure 3 showed comparison of MindWave Mobile and Neuroscan's FPT1 output [11].

Through the sensor attached on the forehead, the MindWave Mobile is able to measure the modes and frequencies of biological electro-signals given off by brain neurons. The sensor is attached to the prefrontal lobe which helps us comprehend and judge, as well as determine our behavior. Prefrontal lobe becomes particularly important when it comes to the moment that a person's thinking abilities such as attitude, emotion and behavior, are required to be monitored.

The data obtained by the MindWave Mobile is comparable to those of the GSR (Galvanic Skin Reaction) [12] detector, indicating that this brainwave detector is highly reliable. Through the technology of NeuroSky ThinkGear [13], the collected simulated electrical signals, i.e., the brainwave, are converted from analog to digital information which can be transmitted by Bluetooth, from which the information can be processed for

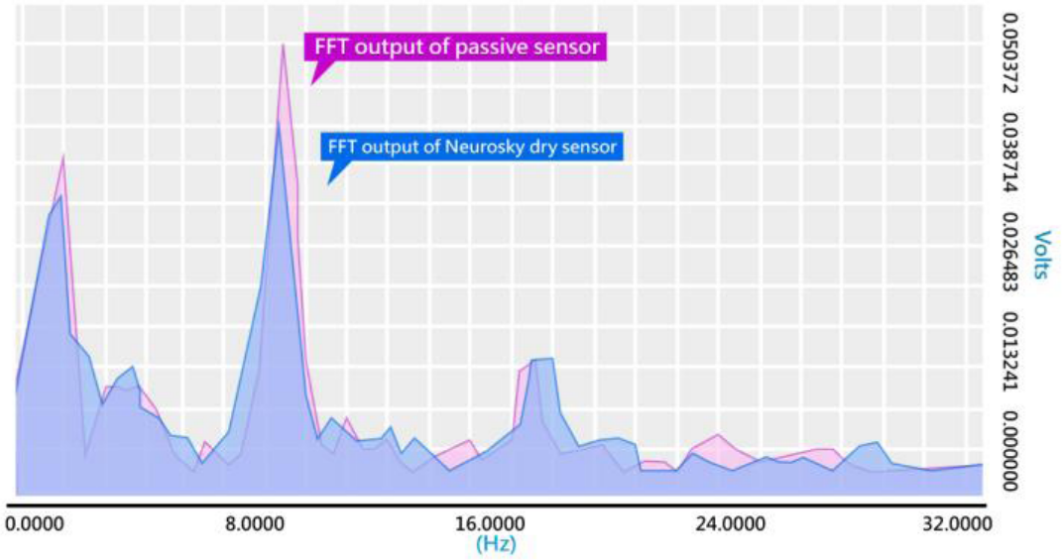

FIGURE 3. Comparison of the results obtained by MindWave Mobile and Neuronscan

TABLE 1. Frequency range of brainwaves and their corresponding spiritual status

Type of Brainwaves	Frequency Range	Spiritual Status
Delta	0.1Hz $\sim$ 3Hz	deep sleep, non-REM sleep, unconscious
Theta	4Hz $\sim$ 7Hz	instinctive, creative, memory, fantasy, imagination, REM sleep
Low Alpha	8Hz $\sim$ 9Hz	feel blank prior to falling asleep, confusion
High Alpha	10Hz $\sim$ 14Hz	inspiration, intuition, wild ideas, relaxed but concentrated
Low Beta	14Hz $\sim$ 17Hz	sport-like rhythm, relaxed and concentrated, coordination
High Beta	18Hz $\sim$ 30Hz	think deeply, clear conscience of oneself and surroundings, alert, excited

further applications. Table 1 depicts the classification of brainwave based on frequency range and the spiritual status of brain represented by each of the various brainwaves [14].

2.2. **Algorism and experimental environment.** eRI (eSense Relaxation Index or meditation index) indicates the degree of "calmness" or "relaxation" in the spirit of a user. The numerical range of eRI is 0 to 100. The most efficient way of promoting relaxation index is to close your eyes. When one's spirit is in the state of distracted mind, absentminded, anxiety and excitement, or under excess sensory simulation, eRI value will be lower [15]. It is to be noted that eRI reflects a user's spiritual state instead of physical condition. Therefore, if one simply stretching whole body muscle, the relaxation will not rapidly raise eRI level. However, for most of people in normal situation, relax body usually helps relax spiritual state. The enhancement of eRI is clearly associated with the reduction of brain activities.

Long term observation reveals that closing one's eyes renders brain without processing sensory stimulation through eyes, which could reduce the spiritual activity level of brain. Therefore, keeping eyes close is usually an efficient way to increase the eRI value. Distracted mind, absentminded, anxiety, excitement and unsteady spiritual state, or sensory simulation will yield a low eRI value.

MindWave Mobile is capable of taking 512 sets of brainwave raw data. Through the algorism designed in this system, the whole experimental procedure can be simplified by integrating the information obtained, so that the output speed is one set of data per second. Hence, each time after the measurement is done, the numerical variation in the brainwaves of the subject can be calculated by taking the average of the Alpha, Beta, Delta and Theta-wave recorded each and every second during the experiment.

3. **Methods.** Every MindWave Mobile machine has a unique set of MAC (Media Access Control) codes. The whole system needs to hook up to 7 machines by matching their MAC codes. After the initialization process is set up, the basic information of the 7 brainwave machines are checked and paired to the system, and the system interface is shown in Figure 4.

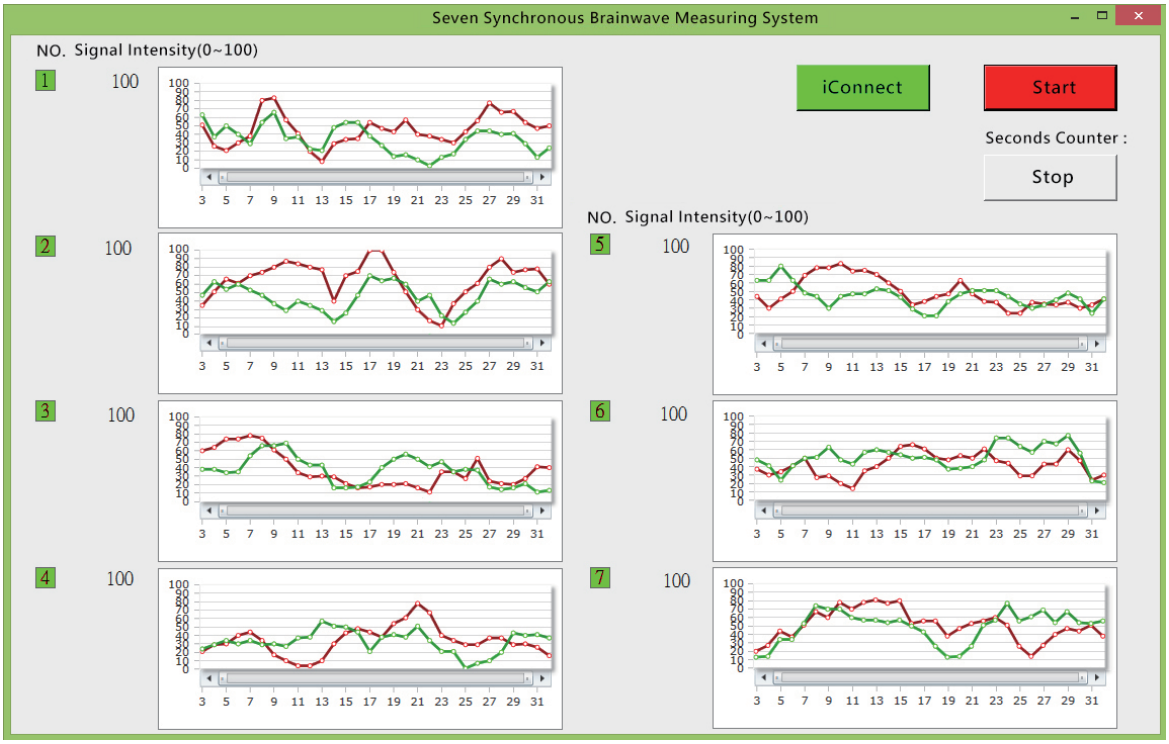

FIGURE 4. System interface

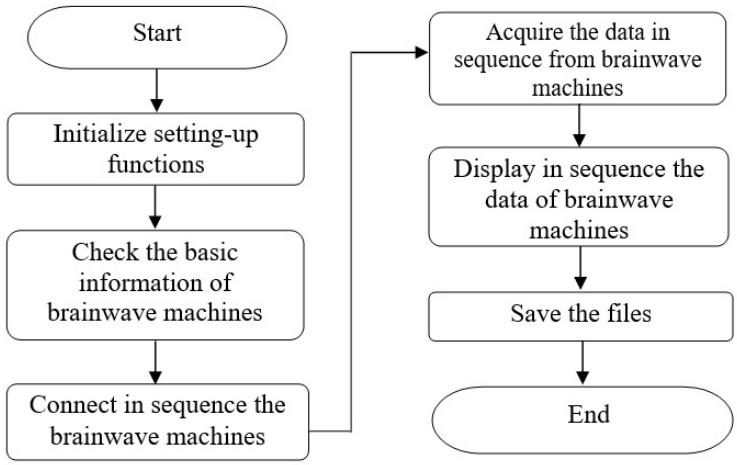

FIGURE 5. Flow chart of system mainframe

Then connect the brainwave machines one by one to the system. The system is ready to collect raw data sending from brains following the sequence of the lined up brainwave machines. The flowchart of the system framework is shown in Figure 5.

Once all the Mobiles were ready to connect to the system, then we could start to run system. The whole test required 10 minutes, and all the subjects were in the same environment and listened to music. The first and the last 1 minutes would not be used in the experiment. Our team adopted the remaining 8 minutes' raw data as effective information and data to analyze the influence of music to human's brainwave.

4. **Experiments and Discussion.** Up to now, research and technology development on the tests and evaluation of brainwaves have been documented [16]. However, few attempts have been made on the simultaneous exploration of brainwave behaviors of many people. In this study, we explore the feasibility of synchronized collection of brainwave signals from a group of people. Users are asked to put on Mindwave Mobile earphone, the brainwave signals of each individual user are collected and sent to a fixed computer for further analysis. The system contains two parts: hardware devices and software requirement.

Hardware Devices:

Mindwave Mobile, Laptop computer (notebook), (processor: Intel® Core™ i5-7200U, 2.5GHz, memory: LPDDR3 8G (On board)), Bluetooth transmitter.

Server: (Dual-Core Intel® Core™ 2E4600 processor, RAM 8G*1, hard disc: 500GB*2), Fire wall (ZyWALL 2 plus).

Software Requirement:

Windows 10 (64 bits), Visual Studio 2010, Microsoft Excel 2012.

4.1. **Experimental data.** The tested specimens (called "users" in the following context) were 7 people including males and females, of different ages. The users were asked to listen to music that is so called "help to relax when listening". The brainwave data were collected by "synchronized brainwave measuring system" designed in this study. The music that users are asked to listen is D-Major piano concerto by Mozart. The total recording time during which brainwave test was given was 10 minutes. Subtracting initial and final minute, the remaining 8 minutes of recording time was taken as valid information. The data were plotted on the X-Y coordinate diagram, taking X-axis as the experimental time and Y-axis as brainwave intensity. Through patented algorism, the user's degree of devotion and degree of relaxation are denoted as non-unit number ranging from 1 to 100. The degree of devotion demonstrates to what extent a user concentrates or pays attention to a particular issue. The degree of relaxation represents the user's spiritual steadiness or extent of relaxation.

The selection of suitable statistical method is very important. We found that after listening to the music, people's brainwave changes with the style of the music. Therefore, to make comparison between before and after the same stimulation was given.

4.2. **Experimental results.** As indicated by experimental results in this study, we were able to carry out brainwave measurement of 7 people at the same time and collected 7 different sets of data. It provides the possibility in conducting research on collecting a large amount of brainwave data simultaneously. The users' brainwave can be compared on site, which promotes the reliability and validity of the data. Moreover, the research procedure can be carried out smoothly without being delayed by the time and energy wasted in collecting data individually.

The paired t-test statistical examination method was used for data analysis in this study. In numerical analysis, the difference between two sets of data is based on the expected value, p. In statistical analysis, $p < 0.05$ denotes that the difference between two sets of data reaches the standard of "obvious difference", while $p < 0.001$ indicates that two sets of data reach the standard of "very obvious difference".

When listening to music in harmonic resonance with the α-wave, the soft and beautiful melody of the music will lead human body into a calm and relaxed state. In the statistical analysis of the experimental results, we found that when users were stimulated by music, the intensity of their high alpha brainwave changed with the state and situation of the music, as shown in Table 2. In listening to Mozart's D-Major piano concerto, the intensity of α-wave was obviously enhanced. The soft and beautiful melody would lead the activity of brain to a calm and relaxed state which caused the increase in α-wave intensity. Therefore, it is concluded that by means of listening to Mozart's D-Major piano concerto or music with frequency close to α-wave, the α-wave in the brainwave may be raised by harmonic resonance. The tense in the nerve and the anxiety in emotion can be relieved; therefore the human body can be relaxed through the help of music.

Table 2. A comparison of high alpha in response to music

User	**Music**	**No music**	***p* value of paired t-test**
1	6275.43	15265.78	***.046**
2	9767.53	17172.84	
3	12993.44	19695.15	
4	5055.73	61427.48	
5	5648.19	8989.12	
6	4643.48	25961.22	
7	5462.37	22684.09	
mean	7120.88	24456.53	
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$			

Table 3. The effect of music to meditation (eRI)

User	**Music**	**No music**	***p* value of paired t-test**
1	57.86	53.37	****.010**
2	58.46	53.26	
3	53.95	48.55	
4	67.65	45.33	
5	57.33	48.86	
6	61.55	51.22	
7	55.46	49.75	
mean	58.90	50.05	
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$			

Table 4. The effect of music to low alpha wave

User	**Music**	**No music**	***p* value of paired t-test**
1	21777.78	59128.09	**.757**
2	10641.43	24179.66	
3	30136.38	27348.04	
4	20364.97	30403.44	
5	66354.98	10413.87	
6	24439.97	33862.03	
7	14311.41	27440.39	
mean	26860.99	30396.50	
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$			

t-test examination reveals users' high alpha wave and eRI (or meditation index) show obvious difference before and after listening to the music as shown in Table 2 and Table 3, while low alpha wave does not show obvious difference as indicated in Table 4.

In this experiment, we use the paired t-test to analyze the brainwave data. The p-value showed that the music is affected by high alpha wave and meditation, but there was no obvious influence to low alpha wave.

5. **Conclusion.** The study indicated that listening to music helps human to relieve their tension, stress and improve the sleeping quality [17]. Music affects the intensity of α-wave and θ-wave. To increase the intensity of α-wave and θ-wave will help people to improve their spiritual status. In the book "This Is Your Brain on Music", Levitin [18], a neurologist and musician, mentioned how music affects a human's brain and the capability of music in stimulating brain. "Music activity almost contains all the region of brain, and almost all neural sub-systems," he said.

In this experiment, our group confirmed this system could work and receive multi-human's brainwave of all ages at the same time successfully. It helps us to collect a larger number of accurate brainwave raw data. Through this experiment we also found music has no significant influence to low alpha.

In the future, with more and more research and development, knowledge regarding to brain will be expected to grow rapidly. Therefore, brainwave measurements will be widely applied to education and daily lives, which may bring much benefit in the future. It will definitely provide important effects and contribution to human's life.

Preliminary results obtained in this study indicate that listening to music in harmonic resonance with α-wave will prominently increase the intensity of high alpha wave and the energy of eRI, or the degree of meditation. The question whether listening to other types of music can also promote meditation effect will be testified by further long term clinical experiment tests.

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