Design of a Mobile Brain-Computer Interface System with Personalized Emotional Feedback

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Abstract. This study design was based on the emotional evaluation training and instant feedback system on mobile devices linked to brainwave measurement instruments. Through the handheld device software, the evaluation framework for content playback, such as music, videos, photos, etc., was built, and the algorithms for evaluating personalized emotions were developed. The users wore the brainwave measurement instruments to measure the parameters of the brainwaves during the guidance of emotions and to calculate the rates of their emotional influences and trigger keys stored in the database. The evaluation results can be used as the voice or prompt text of the system to provide an immediate personalized emotional feedback response to users.

Keywords: Brain-Computer Interfaces, Mobile Devices, Emotion Identification, Brainwave Feedback

1 Introduction

The stress of work, schoolwork, family, economic pressures, and other various factors faced by modern people can easily lead to physical and mental fatigue, panic, insomnia, etc., and can even lead to mental illness in the long term. Listening to music can effectively achieve relaxation and reduce the psychological stress. In the past, traditional research on emotions had no customized services or feedback mechanism for a particular emotion. Relevant studies indicate that music may be effective healing method to influence the music through listening alpha or beta waves [1-2], however, there is no effective way to know exactly the result of music feedback, so the music feedback will be a research.

Parts of the brain that control the activities have been defined [3] by experts in the field of science of the nervous system. For example, the top of the brain controls the limbs; the rear of the brain is responsible for the control of force, human emotions, mental state, and state of concentration. Different neural activities will produce different brainwave patterns, thus demonstrating a different brain state. Different brainwave patterns make brainwaves of different amplitude and frequency. Beta waves, which are brainwaves between 12 to 30 Hz, mean the brain is in a focused state. Alpha waves, which are brainwaves between 8 to 12 Hz, mean the brain is in a calm, relaxed state.

Regarding human physiological signals and cognitive analysis research, in the 1920s, German neurologist Berger (1920) et al. started conducting research on human brainwaves [4]. After decades of research, the results showed that measurement analysis of the brainwaves can show whether or not the user's mental/cognitive status is in a sober state. However, few studies have been able to measure such brainwave signals in real-time. Until recent years, the speed of the computer signal processing technology increased until it could sufficiently process the complex brainwave signals measured in real-time. Information about the mental status thus gradually revealed a research in information science called affective computing.

2 Methods

2.1 Brainwaves

Brainwave training has already reached the state where people can freely enter different brainwave states. The brainwave segments: delta, theta, alpha, beta, and gamma is shown in Table 1.

Because brainwave feedback training is a complex training pattern that aims to let people experience a specific state of consciousness and how to enter these states. For example, a sound or visual message can be used to create a personal feedback mode, and this requires implementing personal tasks many times to achieve the most effective feedback mode.

Table 1. Each brainwave frequency segment.

Brainwave type	Frequency range
Delta δ	1-3 Hz
Theta θ	4-7 Hz
Alpha α	8-9 Hz (low), 10-12 Hz (high)
Beta β	13-17 Hz (low), 18-30 Hz (high)
Gamma γ	31-40 Hz (low), 41-50 Hz (mid)

2.2 Brain-Computer Interface Control

2.2.1 The overview of brainwave sensing device

Usually, brainwaves are measured by trained personnel who place many measuring electrodes, as well as gel, on the head. This traditional measurement method is cumbersome and often leads to incorrect results or interruptions that delay each measurement for a long time. NeuroSky in 2009 released the first Brain-Computer Interfaces (BCI) control. Neurosky MindSet is different from the past BCI devices. It is a single EEG channel comparing with the traditional multi-channels EEG technology and makes wearing easier and more comfortable with no need of people to help you wear it. The NeuroSky product uses its patented ThinkGear chip that can filter out the noise from the EEG to get eSense [5].

Traditional brainwave measuring instruments are only used to display the results and analysis on the computer and had low portability and device durability. We combined the convenience, durability, and portability of mobile phones with the brain-computer interface (BCI) technology of Neurosky's brainwave headset (Mindset) to carry out real-time acquisition and analysis of EEG data and send the current attention, meditation, and other values [6] to a smartphone with Bluetooth wireless technology, so as to easily interpret the current state of mind.

Our way of focus can cause a measurable shock to brainwaves, which is recorded [7] by EEG. Scientists in the application of EEG confirmed that different forms of focus will form different brainwave frequencies. Brainwave activities are usually recorded in the range of 1 to 50Hz. The so-called brainwave refers to the electrical activity of the brain. Current activities at all times are recorded and converged into an electric current pulse called the brainwave, which can be measured through the forehead (called FP1 area in neuroscience) using brainwave headset sensors.

Therefore, this system measured the users' brainwave state while they were listening to music or watching videos, photos, and so on, and scored their current state. Through the scores, users can understand what kind of music, movie, or photo has the greatest influence on their emotion. In addition, through the manner of real-time voice or text, the relative voice or text is given to the user's emotion, enabling the user to adjust their emotional state through voice. The schematic diagram of the overall system is shown in Fig. 1.

2.3 Brainwave feedback of emotional control system

2.3.1 System Overview

With Android smart phone, we achieved emotional control and adjustment and emotional effect rating. The brainwave sensing headset should be connected to the Android smart phone via Bluetooth to apply this system, including the training mode and real-time mode. Refer to Fig. 1 for the applied schematic diagram of wearing brainwave sensing headsets, and Fig. 2 for the whole screen of the system.

The sequential diagram is used to illustrate the sequential relationship of calls and returns between programs or modules. For example, Fig. 3 and Fig. 4 show the training mode sequential diagram of the brainwave feedback for emotional control system: The content called the brainwave data access unit is followed by the user conducting the entertainment unit and then the mood scores and record storage.

2.3.2 Training Mode

For the screen composed of four units, refer to the training mode interface diagram in Fig. 5(a). The content of each entertainment unit includes a music subsystem, film subsystem, photo subsystem, and database subsystem. The entertainment unit content contrasts the general users' relaxation approaches and at the same time conducted brainwave data acquisition and analysis. After the analysis, the emotional impact score is displayed and stored in the database subsystem. A part of the algorithm is described in Section 2.3.4. The database subsystem is described in Section 2.3.5.

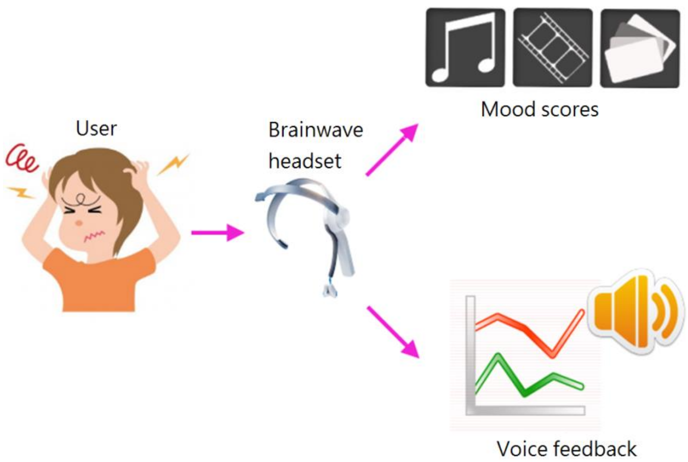


Fig. 1. The applied schematic diagram of wearing EEG measurement headsets.

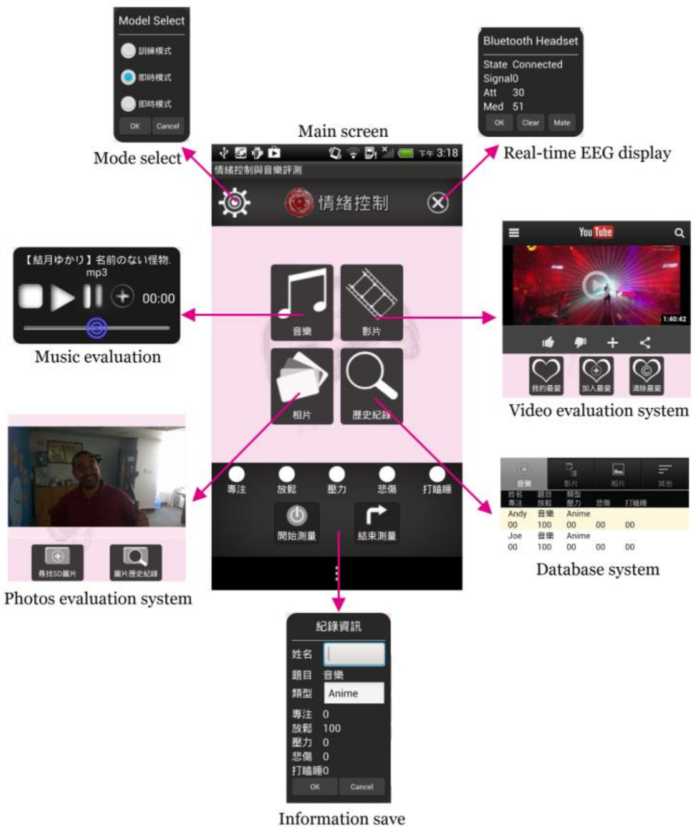


Fig. 2. System operation interface diagram.

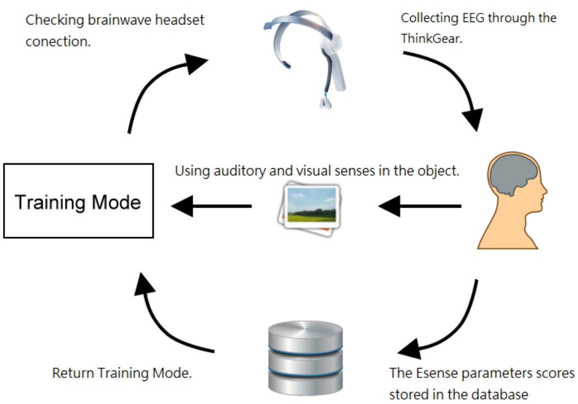


Fig. 3. Training mode sequential diagram.

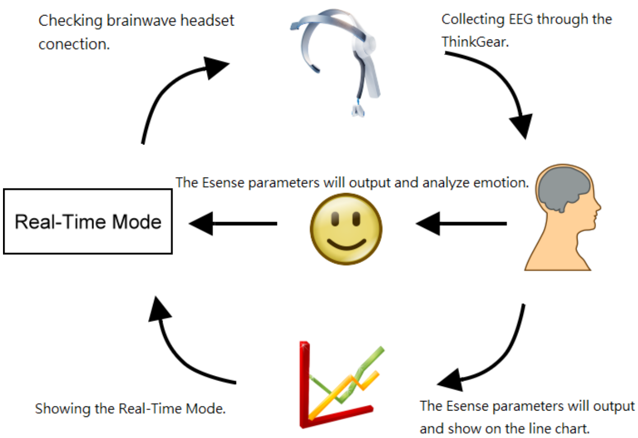
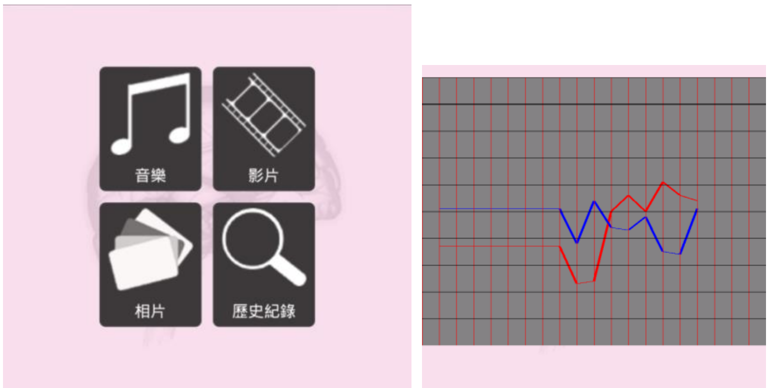


Fig. 4. Real-time mode sequential diagram.



(a) (b)

Fig. 5. **(a)** Training mode interface diagram. **(b)** Real-time mode interface diagram.

2.3.3 Real-Time Mode

The content uses a line chart to show the user's current attention (in red) and Meditation (in blue). Refer to Fig. 5(b) for the real-time mode interface diagram. In addition to the brainwave line chart, this mode can also produce a voice every ten seconds to remind users to adjust their emotional state. A part of the algorithm is described in Section 2.3.4.

2.3.4 Algorithm Design

The phenomenon with electrical shock characteristics and electrical wave generated in general human brain cell activity is called a brainwave. Recent medical studies have proven that various activities in the human brain, including thoughts, emotions, desires, etc., are revealed by the current and chemical reactions, and waveforms of different vibration frequencies can be measured by brainwave instruments. In studies by Crowley, K., et al.[8], the intensities of Meditation degree and attention degree were calculated. Refer to Fig. 7 for the emotional interval determination conditions.Therefore, this study refers to the design of emotional scoring algorithm, converted into a score from 0 to 100, as shown in equation (1)-(2).

2.3.5 Database Subsystem

As a result of storing user scorings, which will help further analysis, the database field design is as shown in Table 2.

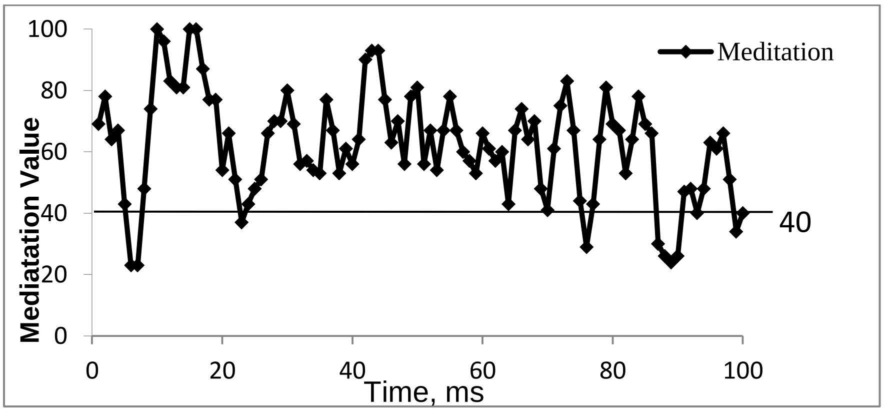


Fig. 5. Cumulative line chart with Meditation degree below 40.

$$\text{Meditation degree X} = 100 - \frac{\text{Meditation time below 40}}{overalltime} * 100 \qquad (1)$$

$$\text{Attention degree X} = 100 - \frac{\text{Attention time below 40}}{overalltime} * 100 \qquad (2)$$

Table 2. Database field design.

Field name	Example
_id(PK)	1
name(not null)	Ting-Jhao Jheng
object(not null)	Music Subsystem
object_name(not null)	Andy Lau-Desensitizing water
attention_score	98
Meditation_score	64

3 Conclusions

The ultimate goal of this study is to recommend to each user a personalization system, which can help adjust emotions according to the different needs and also adjust the current mood through the real-time mode. The system development can be used as a framework, to introduce the essential oil case to adjust the emotional state in the future. The brainwave sensing headphone was used to combine application for the development of the emotional control system, in order to feedback emotion to the user in a way different from the past. This research will continue to conduct the experiments and analysis of focus and relaxation and to achieve personal emotional adjustment.

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