Application of music listening and EEG analysis for sustained attention training

Ying-Fang Lai, Chien-Yuan Lai and Hsiu-Sen Chiang[3*]

***Abstract*—**There is a very close relationship between the attention and learning in cognitive psychology. Due to the technological advancements, many of web-based and mobile application (such as browsing the website, and addicted to the mobile games etc.) often attracts users' attention. A common problem associated with these phenomena is difficulty with the ability to maintain attention or concentration in the working or learning process. Many previous studies had found music listening can improve concentration and extend the duration of attention. However, the inappropriate music also influences the users focus their attention. Therefore, this study develops an attention training system based on music listening by analyzing EEG features. The experimental results show that the system can improve concentration and sustained attention in the working or learning process by providing users a personalized list of songs.

***Keywords*—**Electroencephalograph, Brain-computer interface, Attention, Musical therapy

I. Introduction

In recent years, the advanced information technology has made the work convenient and productivity enhanced, but the increasing heavy workload results in bad effects. Under the influence of long-term stress, it will unable to make attention-focused. Such effects would lead to memory loss, decline in the ability to learn and understand, and generate learning disabilities and other problems.

Research had indicated that listening to music could be used to improve attention level through the changes of energy intensity in α and θ waves [1]. The changes of brain wave signal under different music have found significant changes in α wave and θ waves [2]. Music therapy can make α wave energy rises, distraction can be improved [3]. From the statements above, besides being as an art performance, by listening to music or create a musical background atmosphere, it can provide not only the effects of treatment, but also the improvements of concentration.

From the observation of reading habits, it is easy to find that whether in the library or other suitable occasions, most people are still used to listening to music while reading. Because of digital music are easy to get, a number of different music are placed in music player. If it has no recommendation for personal preference, people may stop working to adjust music while playing an inappropriate music. Therefore, when people are unable to be focus on reading or other tasks, it may cause a decline the scholastic ability, or low working efficiency and other negative effects. As a result, how to find an appropriate music will become a big issue.

In the past, people often choose the music from top hits or others' recommendation, but they do ignore the better music fitting in. The found that the preference in music would affect the strength of the α wave during the difference of brainwaves and heart rate while listening to different music [4]. Therefore, this study will propose a musical play system to help users to selecting appropriate music based on the brainwave state. NeuroSky's MindWave brainwave device is used to analyze users' brainwave status. A personalized list of songs is constructed for each individual by EEG analysis.

Y. F. Lai is with the Department of Industrial Education, National Taiwan Normal University, Taiwan (e-mail: maymayparadise@dwvs.cy.edu.tw).

C. Y. Lai is with Dong Wu Vocational High School, Taiwan. (e-mail: a292755@dwvs.cy.edu.tw).

H. S. Chiang is with the Department of Information Management, National Taichung University of Science and Technology, Taiwan (corresponding author to provide e-mail: maymayparadise@dwvs.cy.edu.tw).

II. Literature Review

2.1 Electroencephalogram

Electrical activity of the brain reflects a person's mental and physical status. It can be measured and observed by electrical activity of the cerebral cortex. The current of cerebral cortex occurs outside of cells, formed the differences among cell population and others. However, these changes in electrical activity become very weak. It needs to be processed by the amplifier and presented by the waveform. Electrical activity represented above is called brain waves, also known as electroencephalography (EEG), an important physiological parameter of brain. Many studies have confirmed that the course of the operation and mental and physical may be tested through the electrical activity in each electrode points of the brain, including thoughts, emotions, desires, etc. [5]. Those are all potential difference responded among brain cells. With high degree of temporal resolution in EEG and immediately recorded and directly represent the process of brain can be used as a testing and training of concentration, also a common and non-invasive way. Classification based on EEG and International Federation of Societies for Electroencephalography and Clinical Neurophysiology from low to high is divided into: δ wave (0.5 ~ 4Hz), θ wave (4 ~ 7Hz), α-wave (8 ~ 13Hz), β wave (14 ~ 30Hz). The α wave shows person who is in a the most awake, quiet, stable and focused status. The β wave is in a highly brainwaves

representing the emotion involved in working status in a nervous, anxiety or excitement and even uncomfortable. The θ wave then means a person in a light sleep, doze status. Normal adults rarely appear θ wave while awake. The δ wave states a sleeping status representative. Adults usually have no δ wave in awaking. Details are described as Table 1.

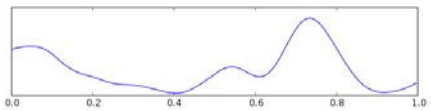
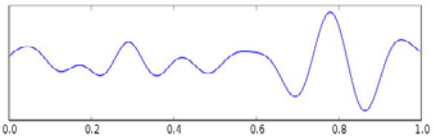
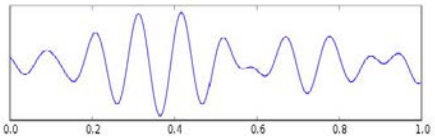
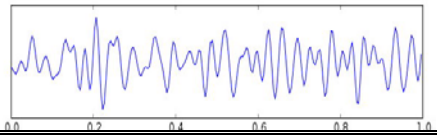
Many studies have found the changes of brainwave characteristics has highly related with the degree of concentration. The amplitude and frequency changes of α wave, β wave, θ wave can directly present different degree of dedication. Prinzel et al. (2001) mentioned that there is a significant correlation among decreasing α wave and increasing θ waves to workload and concentration [6]. Other research indicates when the subjects focus on the mental arithmetic test; the amplitude of α wave is less than usual. And when θ wave and the low frequency waves β, it has significantly improved results to attention-concentrated and memory increasing [7, 8]. Sauseng et al. (2007) mentioned that θ wave related with not only focus, emotional experience, maintain and internalized attention of the outside, but also sustained attention, resource allocation, proprioceptive information processing, and tasks complexity [9]. The amplitude of α wave will be decreased due to the sensory stimulation, independent movement and cognitive activity. However, with lower amplitude and higher frequency of α wave said that it is in an excited brain (focused) state [10, 11].

Based on past studies indicate that brain activities in various districts, the frontal area is the main idea area, which is part of the front of the forehead, including personality, emotional expression, concentration, rationality and creativity. When an individual executes the missions of learning, working or attention-focused, the frontal area and the operation of the neural network plays an important role in the parietal region [12]. With the raised difficulty of the tasks and enhance brain activities, θ wave in the frontal zone becomes active [13, 14]. Meanwhile, the wave in front area of the brain decreased the amplitude of high-frequency [15]. Thus, it infers that the frontal area is the main activities region when the implementation of learning and working memory operations. And neural network operation among regions is an indicator of the implementation of complex tasks and jobs, in which neural networks operation in the frontal and parietal region is the strongest links section.

2.2 Music therapy

Music is just about our lives, listening to a lullaby from the newborn period to the present listening to pop music, classical music, etc. As time goes by, we are accompanied by different music. The music is also often used for the treatment of a therapy. Music Therapy is a treatment, through tone, rhythm, etc. to a method of treatment for patients with physical or mental illness Music therapy, through the department of pitch, rhythm, etc. to the patient for physical or psychological disease. The operation of brain goes through the auditory sense to stimulate them and achieve the effectiveness of the treatment. Lesiuk (2005) discussed the performance of shooting sports while the intervention of music was found listening to music has positive reaction to athletes [3]. It can relieve tension and then improve athletic performance. Davis & Thaut (1989) also mentioned that the responses of music in physiological and psychological could make improvements and relax to the anxiety [17].

Table 1: Brainwave frequencies range

Waveform	Description	Wave chart
Delta (δ wave)	Slow wave and belongs to unconscious level wave, defined as having a frequency between 0.5-4 Hz. Clinical characterization: usually associated with the deep stage 3 of sleep, and may also occur in the depth of anesthesia, hypoxia, infants or patients with severe organ disease	
Theta (θ wave)	Slow wave and belongs to "subconscious level" wave, defined as having a frequency between 4-7 Hz. Clinical characterization: not only focus, emotional experience, maintain and internalized attention of the outside, but also sustained attention, resource allocation, proprioceptive information processing, and tasks complexity [9].	
Alpha (α wave)	When we are in a state of physical and mental relaxation and its frequency are around 8-13 Hz. Clinical characterization: The amplitude of α wave will be decreased due to the sensory stimulation, independent movement and cognitive activity. However, with lower amplitude and higher frequency of α wave said that it is in an excited brain (focused) state [10].	
Beta (β wave)	Emitted when we are consciously alert, or we feel agitated, tense, and afraid with frequencies 14-30 Hz. Clinical characterization: They typically have high amplitude and are linked to the conscious mind. [16].	

2.3 Attention

Attention is an important mechanism while learning and also an indispensable behavior. There are so many explanations about attention. Eysenck & Keane (1995) pointed out attention is a concentration on something particular [18]. Pearson et al. (1996) thought that attention is a limited and general cognition to process resources [19]. Coull (1998) knew that attention was stimulated by location, object, or time to cognitively process resource [20]. It was believed that attention is a complex neurological and psychological phenomenon and there are many different forms, brain structures and mechanisms [21]. The explanation of attention was about a focus on the behavior and the process placed on a single or multiple stimulations [22]. Zimbardo (1985) pointed out that the attention a complex and multi-oriented architecture and should be considered widely [23]. Many scholars also have proposed a variety of opinions in different dimensions including directionality, selectivity, dispersion, persistence, focusing, concentration, and alternating [20, 24, 25, 26].

Whether the learning involvement or not is the most critical factor to affect outcomes. It means that the efficiency and effectiveness of learning will be influenced by the level of attention [27]. In the division of attention levels, many scholars have proposed different ways to distinguish. Three different experimental conditions were designed into resting (no attention), playing tennis (high attention) and thinking outside of the test (high attention). Brainwave information extracted from the experiment via statistic divided into three evaluations, including no attention, low and high attention high concentration. Asteriadis (2011) [28] was from head posture and eye gaze angle to calculate the relevant features, and define the range of attention as 3-6, and finally through many types of neural algorithms and fuzzy logic divided evaluations, low, middle, and high. In addition, some scholars also combined with a variety of physical characteristics, such as heartbeat during physiological signals, each brainwave frequency, respiratory rate, blinking rate and duration. Through the experimental design in high attention (observing white circle process) and low attention (observing the changes of white circle) and via a statistical operation, attention was separated into high and low assessment [1]. Xu et al. (2012) used each band in brainwaves and the relaxation (no attention), viewing computer images (low attention), playing simple math subtraction game (middle attention) and complex mathematical multiplication and division games (high attention) to go through the approximate entropy and fuzzy entropy method to divide attention into four level, such as no, low, middle, and high attention [30]. Reif (2008) pointed out that attention was a key role on learning behavior and would affect the depth of information processing and learning effectiveness [31]. According to the research discussed above, to have good learning outcomes needs to maintain sustained attention. Therefore, this study intends to use brainwaves features to be the assistance to detect the attention of evaluation and test while reading.

2.4 Brain-Computer Interface

Recently, NeuroSky has devoted to developing the device of Brain Computer Interface. MindWave is one of the developments as shown in Fig. 1. It is a single dry-electrode sensor and placed at the prefrontal FP1. Adopting biological signals and connecting to the left earlobe referred to the electrode and circuit ground systems and sampled the frequency to 512Hz.

Fig.1 The EEG Headset of NeuroSky MindWave

III. System Overview

People often choose the music from top hits or others' recommendation, but rarely recommended by personalized. However, the preference in music would have different affects with users and responses. Thus, this study proposed a mobile device based on the feedback of brainwaves. Regarding to the results of attention testing determines the impact of music on individuals. Users are advised to have a helpful songs list in attention and are helped to get used to have a better learning environment under musical environments. How we used diagnosis of EEG to have a music recommendation system is about to described in this section. The structure of personalized attention-music recommendation is shown in Fig 2. It is mainly divided into three parts, including EEG parameters capture, personalized attention-aided measurement systems and databases. Users put on the headphone (MindWave) to pass brainwave parameters to Android mobile devices. Users can play pre-set songs one by one and left songs with powerful enough to keep attention to meet personal demands.

3.1 Personalized attention training system

Personalized attention-music recommendation systematic structure includes three parts EEG parameters capture, personalized attention-aided measurement system, and database. Each part contains different sub-modules. Among modules have different functions. The relationship and operation modules will be described in detail as follows:

A. EEG parameters capturing part

This part is divided as two functions: users interface and feedback of personalized attention information. EEG parameters are captured by EEG headset (MindWave). It extracts brainwave parameters to Android mobile devices. Users establish a list of songs on mobile devices in advance and then go through the detection module system to recommended better songs.

B. Personalized attention measurement part:

This part includes three modules: feature transformation module, detection and instant remind module, and attention/meditation training module. These modules are as following:

1) Feature transformation module: in this module, after capturing parameter, brainwave signals filters noise. Through the Fourier transforms method, the time domain characteristics of brainwave are transformed into frequency domain and finally retrieves the brainwave frequency characteristics (α, β, θ, δ wave).

2) Detection and instant remind module: transforming brainwaves signals into attention and meditation value, and then analyses the degree of dedication by reasoning module.

3) Reasoning module: After obtaining the initial the attention and meditation value, the values calculated by Education distance method determine the effects of music on dedication.

4) Music list recommend module: Based on the value calculated by reasoning module, the more the level of attention increased, the higher the weight gets. When the music weights are lower than threshold, the song will be automatically removed from the list.

C. Database:

In this study, the attention/meditation training module is used to construct a personalized song list of attention. Users establishes list of songs in advance and storages songs in storage system and then gives weight index in the repository in every song. During music playing, the system tests and determines the impact of brainwaves to adjust the weights of songs. These modules are as following.

5) Attention/meditation training module: EEG signal is converted into characteristic band. The different bands of characteristics were converted to attention and meditation value through NeusoSky's eSense™.

6) Music list storage module: This part stores users' song list, personalized attention computer-aided measurement system calculates the weights of songs, and user's personal brainwaves information.

3.2 Systematic operational process

The MindWave headset turns your computer into a brain activity monitor. Before entering the system, song list established first. Click on a single song into the main program, when the main program starts began to accept brainwave physiological parameters. Then according to the user's current attention level makes the initial state. After the initialization is completed and then starts to play music, playing music in the process continuously measures users' attention level. The more the level of attention increased, the higher the weight gets. The weights of music lower than the threshold, the music will be removed off the list.

The log-in screen of system is shown as in Fig. 3. To ensure the song list used by an individual, this system uses the account management to avoid to recording brainwaves information. We can set up and editing a personal song list through music+ button as in Fig. 4 and 5. While done with the editing, push the save button then complete the establishment of music list. Fig. 6 is music player interface. The icon on the top-left side is reference value of attention level. The icon on the left means the level of attention.

IV. Experiment

This section including experiment design, results and discussion are as follows:

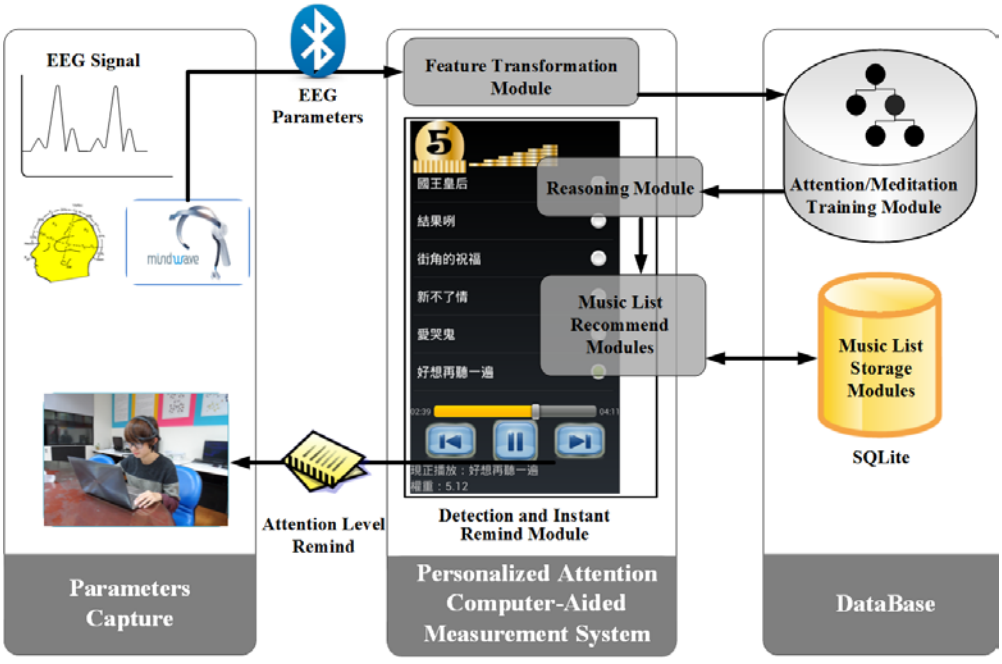


Fig. 2 Architecture of the proposed attention training system

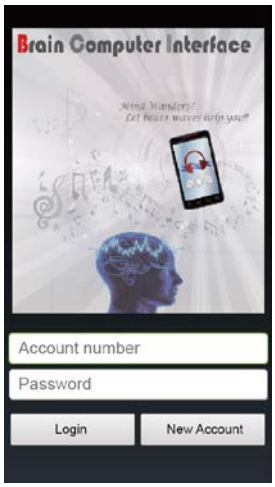


Fig. 3 The Log-in screen

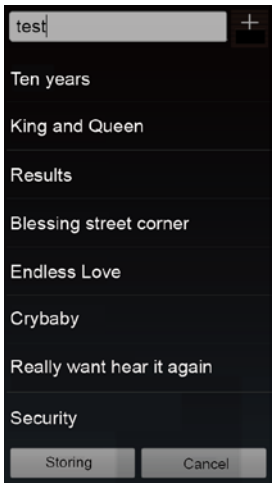


Fig. 4 Default music list

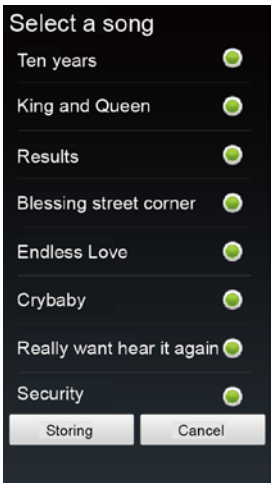


Fig. 5 Music list selected

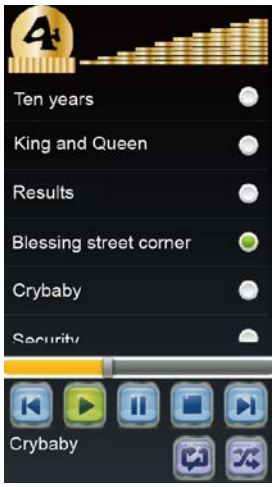


Fig. 6 Music player interface

4.1 Experiment design

In the experiment, the subjects were six university students, three boys and three girls. The average age is 21.33 and a standard deviation of 1.11. Measured subjects usually have reading habit and get used to listen to music in the process of reading.

Experiments were divided into three days and separated by 3 steps. The Pre-test is in the Step 1. Step 2 is the reading task phase, subjects read "Let's Talk in English" in the library with music playing. The step 3 is post-test. The related instructions below:

Step 1 Pre-test: On the first day of testing, the subjects fill out a letter of authorization and personal information. Subjects then rest calmly for 5 minutes to concentrate on finishing Reading Attention Scale.

Step 2 Reading task: the subjects were divided to two groups (Control and Experimental group). Control group: On the first day to third day of testing, subjects were reading while music playing during the testing, once a day and 40 minutes at once. The brainwave state would be recorded during testing also. Experimental group: On the first day to third day of testing, subjects were reading while music playing during the testing, once a day and 40 minutes at once. The brainwave state would be recorded during testing.

Step 3 Post-test: On the third day of testing, Subjects rest calmly for 5 minutes in the last experimental record fill out Reading Attention Scale and questionnaire in the system.

4.2 Reasoning model

After the initialization is completed, it firstly obtains users' brainwave state and sets it as the reference value. During music playing, based on value of attention and meditation projected in a two-dimensional space, such as Fig, 7. Next, taking the detected value and reference value obtains d from Euclidean distance, as shown in Eq. (1):

$$d(A,M)=\sqrt{\sum_{i=2}^{n}(A_i-M_i)^2} \quad (1)$$

Starting the reference value divides into four quadrants, and then determines the quadrant where the detected value is. Depending on different quadrant music weight precede adjustment, formula is as follows:

The first quadrant: $W= w + (1.0 + d)$ (2)
The second quadrant: $W= w - (0.5 + d)$ (3)
The third quadrant: $W= w - (1.0 + d)$ (4)
The forth quadrant: $W= w + (0.5 + d)$ (5)

Assume that the system has made the initial value (A_0= 0.52, M_0=0.48) and reference value (A_1=0.72, M_1=0.88). Based on the Eq. (1) gets d=0.45. From the origin, the comparison value is in the first quadrant, and then the music weight rises 1.45.

4.3 Results and Discussion

In first section, it goes experimental data analysis. The first part is attention analysis based on EEG data obtained in a three day experimental scenario. In the second part is the reading attention scale analysis, which explores the difference of reading attention between two groups.

4.3.1 EEG-based attention analysis

The Independent samples t-test was used to explore if there are significant differences on the attention mean value of EEG, when users adopt our system in reading process. On the first day, there is a not great difference between two groups. On the second day, the mean of attention value in the experimental group is better than control group and also greater than the result on the first day. On the last day of experiment, mean of attention value in experimental group is not only higher than control group, but also reach significant level ($p < 0.05$), as shown in Table 2. According to the result, it shows that the music is filtered by the system can help users to pay attention to reading.

Also, the impact of music on reading attention is increased with time.

4.3.2 Reading attention scale

From the results of questionnaire, reading attention in the control group during the reading is easily to be affected by the dislike songs, as shown in Table 3. Another, the attention values of all subjects were also found there was no significant difference on the hard part in the reading. Whether the system is used or not, it may not have a great help for the users' attention in the reading process. Although it is not statistically significant, the overall mean values of the experimental group is still relatively high compared to the control group. Therefore, it can be seen that music can provide users with a concentrated mind and relaxed atmosphere in reading. Especially the filtered song list will help users to have the relatively better performances.

4.3.3 System usability analysis

The post-study system usability questionnaire is revised to assess user satisfaction with system usability, as shown in Table 4. Questionnaires were collected from the subjects in the experimental group. The satisfaction questionnaires were adopted to evaluate the users' feeling after using our system. The result shows that the system has positive assistances on the reading attention for users. It can effectively raise the performances of attention during reading. However, users generally reflect the system is unable to quickly filter out their dislike songs. In the future, we will improve effectiveness on removing the users' dislike songs by enhancing the weight algorithm. In the functional part of system, users have a positive response on the performance of operational fluency. Overall, users' satisfaction to this system is good and willingness to try this system in reading process.

4.3.4 Discussion

The experimental results were explored in three parts. In the EEG-based attention analysis part, the result shows that the personalized song list can help to sustain in a focused attentional state. When the users use this system over a period of time, the effect of sustained attention would be better. Since the songs screened over a period of time, personalized song list will be more suitable for the user's own situation. From reading attention measurement, we find the users can not feel focusing their attention, when they listen to music in the reading process.

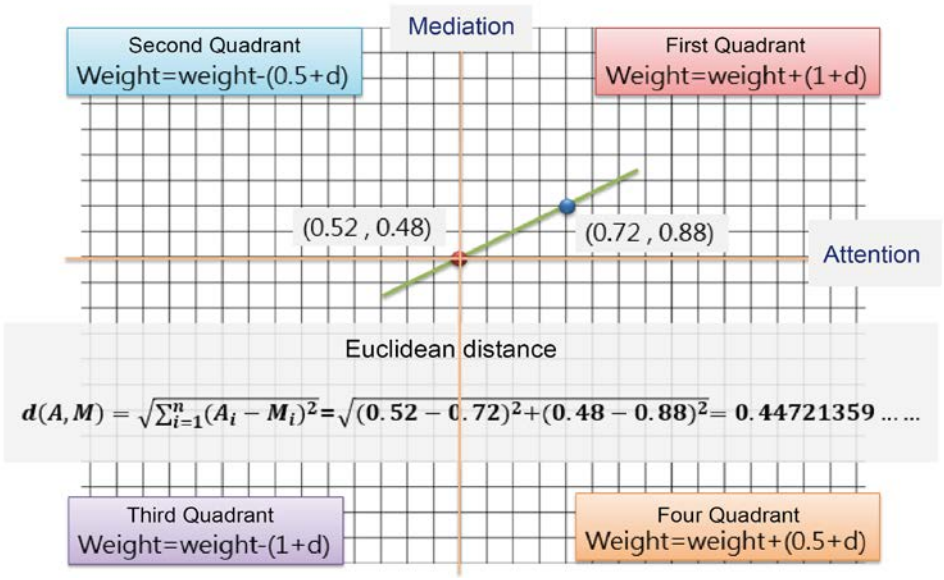


Fig. 7 two-dimensional space schematic in reasoning module

Table 2: The T-test of attention analysis based on EEG

	Group	Count	Mean	S.D.	Mean difference	T	P
Day1	C	3	51.0467	1.50444	2.9633	1.280	.270
	E	3	48.0833	3.71729			
Day2	C	3	49.9567	2.24754	-1.0833	-.655	.548
	E	3	51.0400	1.77502			
Day3	C	3	48.8933	.52539	-6.6300	-5.616	.005**
	E	3	55.5233	1.97627			

Note: C: Control Group; E: Experimental Group (*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$)

Table 3: Reading attention scale

No.	Item	C. group mean	E. group mean
1	Reading, I could not concentrate on boring or difficult content.	2.33	2.00
2	The process of reading, I will not be distracted by extraneous things.	3.33	4.00
3	Reading, some parts of content require special focus, I clearly understand them.	3.00	3.33
4	The process of reading, I am able to fully understand the key concepts.	3.33	3.33
5	Even very tired, I was able to concentrate on reading.	3.67	4.00
6	Regardless of whether the content can understand, I was able to keep reading.	3.67	3.67
7	When reading, I will clearly understand the article's content.	3.33	3.33
8	The process of reading, I would seriously rather than do other things.	3.67	4.00
9	I can forget about all the things, focusing on reading.	3.67	4.00

Table 4: The modified post-study system usability measurement

No.	Item	Mean
1	When I am reading, this system can focus my attention.	4.33
2	This system can provide song list to assist focusing my attention.	4.33
3	I think I could become more focusing my attention in the reading process through using this system.	4.33
4	The system can be quickly removed my dislike songs.	3.00
5	It was simple to use this system.	4.67
6	It was easy to learn to use this system.	4.67
7	I felt fairly fast and smooth using this system.	4.00
8	This system has all the functions and capabilities I expect it to have.	3.00
9	Overall, I am satisfied with this mobile system.	4.33
10	In the future, I would like to use this system.	4.33

However, there is still some performance on sustained and focused attention. In the evaluation of user satisfaction with system usability, subjects are asked about the feeling after using the system and fill out the questionnaire. The result shows the personalized song list could help to sustain attention in the reading process. Also, it was easy to learn to use this system. Users feel dissatisfied with the speed of create a personalized song single and the functions of media player too simple. Overall, users still have a positive evaluation for system usability.

V. Conclusion

This study proposed a reading attention-aided prototyping system based on EEG analysis. When users use our mobile system to listen music, it can gain the level of attention through analysing EEG. According to the changing of brain waves on different music, it decides whether to keep the song and thereby generates a personalized songs list for users. Therefore, this mobile system can help users to sustain their attention in the reading process or other tasks. In addition, the study also used a three-day test. In a library, subjects used our mobile system in reading process and compared with other subjects using general media player. The result shows that our system has a better performance on sustaining user's attention. In the evaluation of system usability, users also feel easy to use our system and are willing to continue to use in the future.

Acknowledgments

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Ying-Fang Lai is Ph. D. student in the Department of Industrial Education, National Taiwan Normal University, Taipei, Taiwan. Her interests include internet community, marketing and information education.

Chien-Yuan Lai received his PhD degree in Information Management from National Yunlin University of Science and Technology, Taiwan. He currently serves as the principal at Dong-Wu senior vocational school, Chiayi, Taiwan. And his interests include virtual community, Internet marketing and user behavior.

Hsiu-Sen Chiang received his PhD degree in Information Management from National Yunlin University of Science and Technology, Taiwan. He is an associate professor in Department of Information Management, National Taichung Institute of Technology, Taiwan. His current interests include e-commerce, internet marketing, data mining, and Petri net.