Developing Educational Game Software Which Measures Attention and Meditation with Brainwaves: Matching Mind Math

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Abstract

An educational game is computer software that enables students to learn course topics or to develop their problem-solving skills by taking advantage of their desire and enthusiasm to play. Today, educational software and educational games software are increasing rapidly and their development has improved. Brainwaves produce weak electrical signals that can be measured from the skull. Electroencephalography is a system that measures the activity of brainwaves using an electrical method. The Brain Computer Interface is a system that converts electrophysiological actions or metabolic rate to signals to be interpreted by a device. This study aims to develop an educational game that measures attention and meditation rates using the EEG Device. In this study, an educational application named "Matching Mind Math" is developed using Flash software. The application will appeal to elementary school students and fundamental mathematical problems will be provided to students. In order to measure the attention and meditation values of students they will wear a electroencephalograph device provided by "Matching Mind Math". NeuroSky MindwaveMobile will be used as an electroencephalography device. The attention, meditation and correct answers are seen with Matching Mind Math when students play the game.

Keywords: *Education, Game, EEG, Brain Computer Interaction, Attention, Meditation*

1. Introduction

The game world is now very advanced and new methods are also being investigated from different sources such as using the mouse, keyboard, joystick, which are mainly used for input device by game developers. Gaming technology is unstoppable as a result of the enormous numbers of gamers who introduce new technologies in games [1].

Because there are cost-effective electroencephalography (EEG) devices that can be developed for anyone, Brain Computer Interface (BCI) is more important than ever for the game industry. For example, game developers can move a character with brainwaves or they can use the mouse, keyboard, joystick and EEG devices together and gaming can be more entertaining.

Educational games are designed to teach fundamentals about a certain topic or to provide consolidation and repeat previously learned knowledge in a more comfortable environment. Brainwaves have a great importance for educational games. Teachers and parents can see the attention and motivation rates of the student when a student plays educational games using an EEG device. Thus, they can understand where and when the student's attention is decreasing or increasing and the appropriate time for student's learning.

Given all the developments in the world of gaming, there is a great lack of educational game software with integrated BCI. In the scope of this study, an educational game named Matching Mind Math has

been developed with Flash software and students' attention and meditation rates can be seen with an EEG device.

2. Overview of the Literature

2.1. Educational Games and Educational Game Design

Educational learning games enable students to reach the objectives of their learning topics and gain educational experiences. General elements in educational games are unity, exploration, competition and challenge, because challenge and competition motivate students and make them learn [2].

Although computer games are activities that include rules, objectives, feedbacks, interaction and results, they also offer learning potential to students due to their natural characteristics [3]. The studies done on 236 students in Malaysia revealed that the average amount of time spent playing computer games was 8.47 hours per week and the average playing game frequency among students was 75.8%. (91.3% of male students, 54.1% of female students) [4]**.** With this result, the utilization of educational games for learning can be deduced from their perception as popular activities for children. Educational game design is difficult but designing an educational system is more difficult [5]. Although the focus of the game is teaching, the teachers and students provide real contributions to the game in the designing game process, by sharing their ideas about the game's scenario and game's entertainment [6].

Some factors are important for educational game design; to understand the gamers according to age, gender and experience of previous games; preparing appropriate content for the game; appropriate methods and techniques of learning must be determined; Appropriate sound effects, graphics, user control, feedback should be determined as the game elements [7]. Educational game design principles need to be taken into consideration for a game's success.

2.2. EEG Signals

As a result of the electrical activity of the cells, the body of organism consists of many electrical signals, and one of the electrical signals is electroencephalogram (EEG) which is the measurement of electrical activity that occurs in the brain [8]. The EEG was developed in 1929 by the German psychiatrist Hans Berger.
Without complex techniques, brainwaves can be measured and analysed by using a non-invasive EEG with a dry electrode on the forehead [9]. Today, affordable EEG devices are available for users.
The EEG spectrum has separate bands with special names based on their dominant frequency contain waves as follows [10]:

- Delta (δ) waves: Frequencies are: 0.5–4 Hz, amplitudes are: 20–400 μV. They are encountered in deep sleep, very low activity in the brain, such as general anaesthesia.
- Theta (θ) waves: Frequencies are: 4–8 Hz, amplitudes are: 5–100 μV. It is encountered in dreaming sleep, medium depth of anaesthesia, low activity in brain such as stress in normal individuals.
- Alfa (α) waves: Frequencies are: 8–13 Hz, amplitudes are: 2–10μV. They are encountered when awake individuals have a complete physical and mental rest in a place where there is no external warnings, eyes are closed. They are seen in healthy individuals in comfortable cases. The meditation value in our application occurs with these waves.
- Beta (β) waves: Frequencies are: higher than d13 Hz, amplitudes are: 1–5 μV. They are encountered in focused attention, mental work, sensory information processing. Beta waves correspond with the highest level activity of the brain. The attention value in our application occurs with these waves.

It is observed that when the wave frequency increases, amplitudes decrease.

2.3. Brain Computer Interface (BCI)

Technological advances for the measurement of brain activity, stimulation of nerve tissue, advances in computer technology and the science of robotics allow creating interfaces between human brain and artificial devices, these interfaces are called the Brain Computer Interface (BCI) [8]. BCI is a type of communication system that outputs and commands not to transmit out to the world with normal ways but that system recognize and analyse brain activity [11] .

The mode of operation of the BCI is shown in Figure 1.

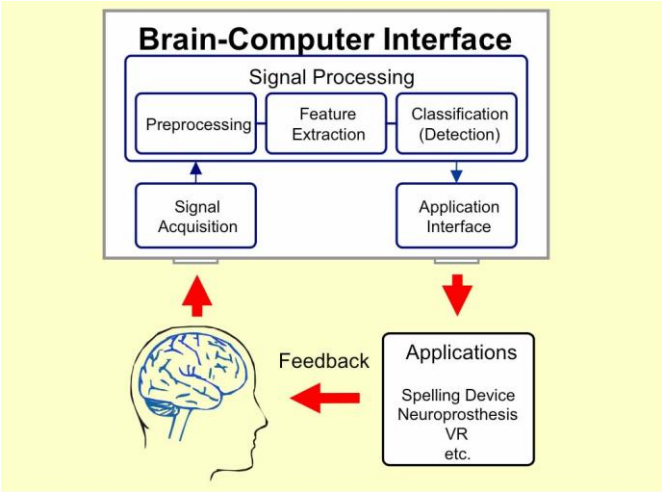

Figure 1. Brain Computer Interface [12]

The basic components of BCI systems can be listed as follows [11];

- Signal acquisition
- Signal processing: feature extraction
- Signal processing: conversion algorithm
- Output device
- Management protocol

Previous years' BCI applications were made for patient users but nowadays BCI applications have been developed for healthy people [13] such as for games, meditational applications, educational applications etc. Therefore, many BCI applications are now available and more developers are working on BCI applications.

2.3.1. Importance of Brainwaves in Education

Training is done without taking consideration of students' meditation, stress and attention levels in schools. That problem concerns every student. These questions are important; How do I pay attention, listen, concentrate and remember; much less relax [14]?

Yoshitsugu Yashi [9] conducted a study on real life brainwave measurement. The study was conducted on a 22-year-old male student. The measurements were performed on a normal college day. In the morning class, the student concentrated and at lunch time the student was relaxed. The student was sleepy at the beginning of the afternoon class, then the student concentrated in the later class. After school, the student was relaxed again. The student's readiness for learning can be understood by measuring brainwaves.

Teachers can empirically determine whether the student is paying attention with brainwave measurement [15]. Educators and parents estimate a student's achievement with correct answers and attention rates.

There is a strong correlation between correct answers and attention waves [15]. Thus, brainwaves have an importance for education.

2.3.2. Importance of Brainwaves in Games

When BCI is thought of in terms of game play, it seems to use three methods the game industry. Playing games is possible with brainwaves without using joystick, keyboard or mouse devices, which are well-known game input devices, and game manufacturers produce games which are played with brainwaves by EEG devices. Alternatively, game developers can measure some states of games such as boredom and excitement by using brainwaves for evaluating the efficiency of games. Since 2004, EmSense has been using biofeedback to help game designers evaluated new products [16]. Finally, users can view their meditation and attention levels when playing a digital game.

Some constraints are faced when using brainwaves as an input device. Because the technology is still limiting and only concentration and meditation is not enough for games, some players think that they don't have total control like playing with a joystick [17]. Thus, the game's entertainment may be reduced. That can be a disadvantage for using brainwaves in games.

3. Aim of the Study

The aim of this study is to develop an educational game that measures attention and meditation values that are important for learning by brainwaves when students play the game. An educational game software named Matching Mind Math (MMM) has been developed for the scope of the study. The student matches the maths operations with correct answers while measuring brainwaves with MMM. NeuroSky MindWave Mobile is used as an EEG device to measure brainwaves and MMM developed by Adobe Flash Software. The attention and meditation output ranges from 1 to 100, and higher values indicates more attention. In MMM, the student races with time and aim to give more attention and meditation.

Today, many varieties of educational games and many games, and applications with integrated BCI are available. BCI applications are also important in many other fields such as education as mentioned in the literature. The relationship between attention, meditation and number of correct answers can be understood by educational games with integrated BCI. High meditation and attention is important for learning. When a person becomes upset, cortisol levels are elevated in the part of brain in which learning and memory reside, which can have a negative effect on learning [18]. The study will be an example for developing educational games that use EEG devices.

4. MMM Development

In this section, the MMM game's development stages will be handled.

4.1. Software and Hardware Devices Used in MMM

In this application, Flash is used as the software and NeuroSky MindWave Mobile is used as the EEG device.

4.1.1. Flash Software

Adobe Flash CS 5.5 software has been used for developing games and the programming language used is ActionScript 3.0. The educational game engine that is centre of designing various games is needed to increase the student's learning interest is important for education and it can be said that Action Script design is the core of the game engine [19]. Reasons for using Flash Software are:

- Can use rich visual effects, which affect students
- Action Script language is a rich language.
- Preparing applications with Flash brings advantages in terms of cost and time

4.1.2. NeuroSky MindWave Mobile

NeuroSky MindWave mobile translates brainwaves into digital information and beams it wirelessly to computers or mobile devices [17]. Figure 2 shows MindWave Mobile. About 1,700 software developers are working with NeuroSky's technology and they make mind-controlled computer games for their works or NeuroSky [17].

We use NeuroSky MindWave Mobile for our application. MindWave Mobile uses the TGAM1 module, and has automatic wireless pairing, takes a single AAA battery, Bluetooth v2.1 Class 2 (10-metre range), static headset ID (headsets have a unique ID for pairing purposes) [20]. MindWave Mobile measures raw-brainwaves, processing and output of EEG power spectrums (Alpha, Beta, etc.). Processing and output of NeuroSky proprietary eSense meter for attention, meditation, and other future meters, EEG/ECG signal quality analysis (can be used to detect poor contact and whether the device is off the head) [20].

Figure 2. NeuroSky MindWave Mobile [20]

4.2. Progress Of MMM

At first, the student wears the EEG device and connects the device with the computer to play the game. Attention, meditation and poor signal levels can be seen on the first screen of MMM. When the student presses the start button, the timer and average attention and meditation levels are reset, than the average attention and meditation rates start to be calculated. The student matches mathematical operations with true answers using a drag and drop game. The finishing time and average attention and meditation rates are seen when the student presses the finish button. The green check marks are seen on the left side of the correct answers.

The flow chart of the progress of the game can be seen in Figure 3.

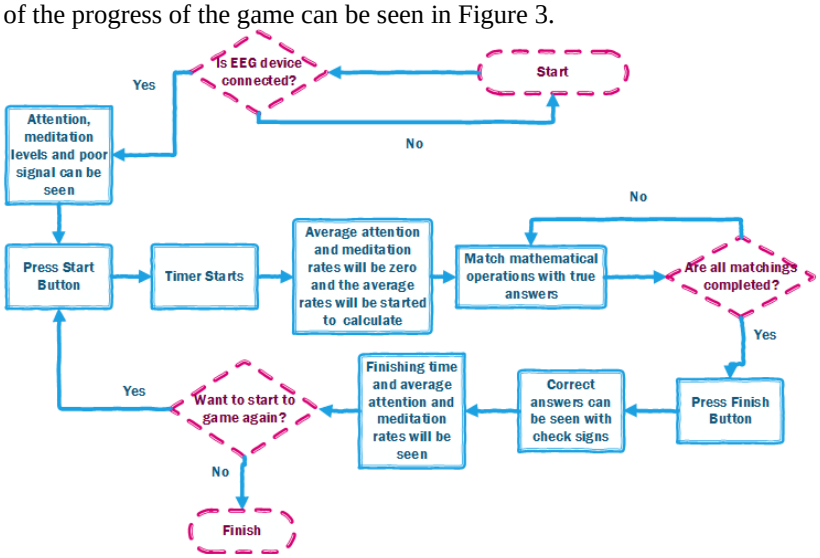

Figure 3. Flowchart of Progress of MMM

A screenshot from MMM is shown in Figure 4.

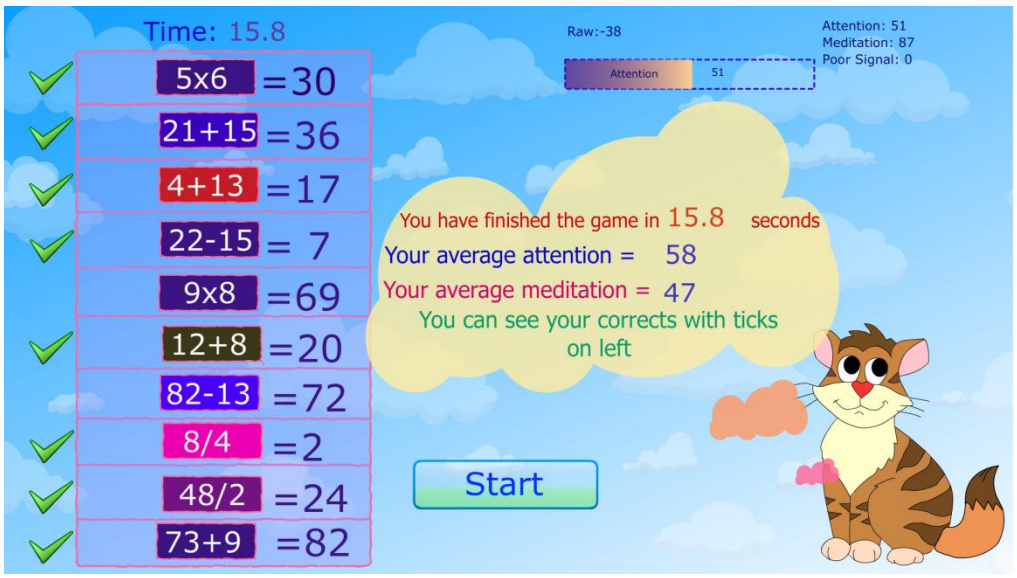

Figure 4. A screenshot from MMM

A student wearing an EEG device and playing MMM is shown in Figure 5**.**

Figure 5. A student wearing EEG device is playing MMM.

4.3. Programming

NeuroSky MindWave uses the Think Gear chipset, which is the core of brainwave sensing technology. Think Gear Socket Protocol (TGSP) is a JSON-based protocol, and it was designed to allow languages without a standard serial port API [21] . Therefore, the ThinkGear socket protocol is used in programming and we adapt it to Flash with API.

ActionScript 3.0 is used for the game's programming. At first the ThinkGear Socket Protocol was coded. The "Hello EEG" application in the NeuroSky developer's page is helpful for our study. Example code from ThinkGear Socket is as follows:

```
configuration["format"] = "Json";
thinkGearSocket = new Socket();
thinkGearSocket.connect("127.0.0.1", 13854);
thinkGearSocket.writeUTFBytes(JSON.encode(configuration));
thinkGearSocket.addEventListener(ProgressEvent.SOCKET_DATA, dataHandler);
```

In MMM, to match the operations with the correct answer, drag and drop codes have been used. For calculating the average attention, the following example of ActionScript code has been used;

```
addEventListener(Event.ENTER_FRAME, attention)
function attention(e:Event):void{
        attentionlevel= attentionlevel+ int(attentiontext.text);
        counter=counter+1
        averageattention=(attentionlevel/counter)}
```

Thus, the average attention level will be calculated.

5. Conclusion and Suggestions

This study only examines an educational game's developing steps that measure attention and meditation rates by the EEG device and brainwaves. Considering the importance of the brainwaves, attention and meditation for education as discussed in the literature, MMM has developed for an example game. The developed MMM game is not tested on students and MMM's effects are not investigated.

Meditation is important because it is known that stress affects learning. Students, parents or teachers can see the average attention and meditation level in MMM. Only a high level of attention may not be sufficient for learning. If attention and meditation levels are high, the student is found to be in an appropriate state for learning. If necessary, students can be provided with a stress-free environment in which to learn.

In the literature, there are inadequate educational games that can be controlled by brainwaves or that measure attention and meditation rates. Developing those types of games is suggested due to handled reasons. Improving and testing MMM with students and obtain and interpret the test results are suggested. This could be the subject for a future study. In this way, the benefits of MMMs can be discussed from every aspect.

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