■ RESEARCH ARTICLE

Observing Brainwaves when Playing Games Using a Ruby-based Wireless Brainwave Measurement System

Ri He

Takezono High School, Takezono 3-9-1, Tsukuba, Ibaraki 305-0032, Japan; brooknim@gmail.com

ABSTRACT: Using an electroencephalogram (EEG) headset of Mindflex and a Bluetooth module of HC-06, I developed a wireless brainwave sensing system based on the object-oriented program language of Ruby. With the system, the brainwave data from the EEG headset could be wirelessly transmitted to a computer and could be real-time displayed. Using the wireless brainwave measurement system, I measured the brainwaves when playing games and relaxing, and found low-frequency theta wave (0.5 Hz ~ 2.75 Hz) and high-frequency Mid-gamma wave (41 Hz ~ 49.75 Hz) were both increased when playing games.

KEYWORDS: Ruby; Brainwave; EEG; Bluetooth; Mindflex.

Introduction

Many people like playing video games. Game addiction in young people has also become a social problem. It has been observed that video games have both positive and negative effects.[1,2] Some educational experts think that violent video games affect the structure and activity of the brain and cause the anti-social behavior in young people.[3] However, many scientists and psychologists also find that video games can have many benefits: video games can benefit the mental health of seniors and teach children high-level thinking skills.[4] To know video games' influence on the brain, I wanted to study the activity of the brain when playing games using electroencephalography (EEG).

EEG is a recording of the electrical activity of the brain from the scalp. It is a non-invasive method to detect the activities of the brain. EEG signals are also called brainwaves. According to the signal frequency, there are five patterns of brainwaves: Delta (δ) waves, Theta (θ) waves, Alpha (α) waves, Beta (β) waves, and Gamma (γ) waves.[5,6] The relations between brain activities and brainwaves are studied.[7,8] A review on wireless sensors for non-medical brain activity measurement was made.[9] Brain activity while playing computer games was examined using a complex multi-channel EEG system.[10]

The frequency of Delta waves is less than 3.5 Hz and occurs in deep sleep. Its amplitude increases when the awareness of the physical world decreases. Theta waves have frequencies of 3.5 Hz to 7.5 Hz and are classed as "slow" activity. Theta waves are strong during internal focus, meditation, prayer, and spiritual awareness. Alpha waves have a frequency between 7.5 Hz and 12Hz. When Alpha predominates, most people feel at ease and calm. Alpha appears to bridge the conscious to the subconscious. Beta waves have a wide frequency range of between 12 Hz and 30 Hz. They are divided into low Beta (12 Hz ~ 17 Hz) and high Beta (17Hz ~ 30 Hz). Beta waves are the dominant rhythm in those who are alert or anxious. It is the state that most of the brain is in when we are listening and thinking during analytical problem solving, judgment, decision making, processing information about the world around us. Gamma waves have a frequency above 30 Hz. They are divided into low-Gamma (30 Hz ~ 40 Hz), mid-Gamma (40 Hz ~ 49.75 Hz), and high-Gamma (> 50 Hz). The gamma wave signal is strong when the brain is at the state of solving problems or high concentration.

In this paper, I will report on a wireless brainwave sensing system using Ruby and the results of brainwave measurements. The brainwave data can be real-time transmitted to and displayed on a computer. Average and normalization methods were used to analyze the data. Ruby is a powerful and easy-learning programming language, very close to spoken languages, and it has libraries of Bluetooth communication, 2D display. Using ruby, the application can be developed in a short time.

Methods

The hardware of the Wireless Brainwave Sensing System:

A Bluetooth module HC-6 and an EEG headset of Mindflex were used to construct the wireless brainwave sensing system. The Mindflex is a brainwave toy letting you control the height of a ball with mental concentration. Figure 1(a) shows the brainwave headset. There are three electrodes in the headset. The sensing electrode is aligned on the forehead. The other two electrodes are clipped to the ear lobes as the reference electrodes. Figure 1(b) shows the circuit board in the headset. Figure 1(c) shows the Bluetooth module of HC-06. The connection method between the HC-6 and the circuit board of the headset was also shown in Figure 1. The default baud rate of HC-06 is 9600. To transfer the EEG raw data, the HC-06 Bluetooth module is set at a baud rate of 57600. Styger shows the method to change the baud rate of the Bluetooth module HC-06.[11]

Figure 2 shows the illustration of the wireless brainwave measurement. The voltage between the forehead electrode and ear electrode is amplified and digitalized, then the data is processed by Fast Fourier Transform (FFT) in the headset board to produce the power values of the different brainwave patterns. The digitized raw data and the power values of

DOI: 10.36838/v4i3.15

the brainwave are transmitted to the computer via wireless connection by Bluetooth.

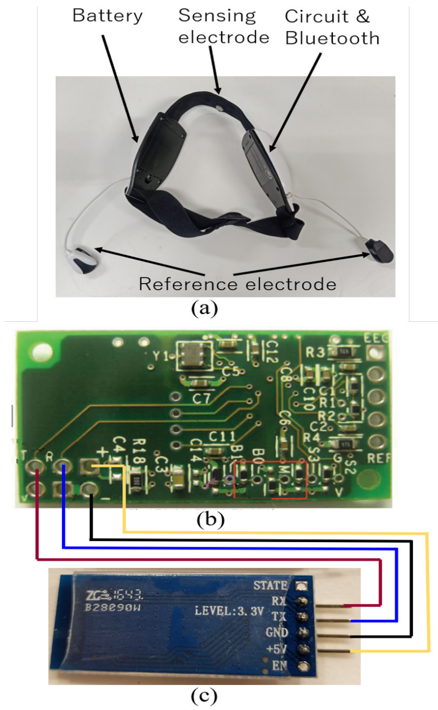

Figure 1: (a). The headset of Mindflex. (b). Circuit board in the headset. (c). Bluetooth module of HC-06 to send the data and the connection method with the circuit board.

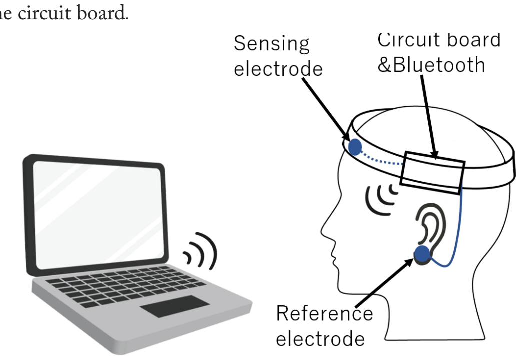

Figure 2: Illustration of the wireless brainwave measurement.

The EEG headset of Mindflex has two modes: mode 0x01 and mode 0x02. In the default mode 0x01, the circuit transmits at a 9600 baud rate and sends processed data every second: Meditation, Attention, and values for various parts of the power spectrum. To get the raw data of the brainwaves, it is necessary to switch the Mindflex headset to mode 0x02 by sending the hex string 0x00, 0xF8, 0x00, 0x00, 0x00, 0xE0 to the circuit board by the Bluetooth at a 57600 baud rate. In the mode 0x02, the EEG headset transmits the raw data of the brainwaves and the processed values of the 8 patterns of brainwaves.

The EEG headset transmits ThinkGear Data Values, encoded within ThinkGear Packets, as a serial stream of bytes over Bluetooth via a standard Bluetooth Serial Port Profile (SPP).[12] The ThinkGear Data Values includes the following values:

POOR_SIGNAL Quality. It describes how poor the EEG signal ranges from 0 to 200. The higher the number, the more noise is detected.

Meters of Attention and Meditation. The meter values are reported on the relative scales of 1 to 100. A value between 40 to 60 is considered "neutral". A value from 60 to 80 is considered "slightly elevated", a value from 80 to 100 is considered "elevated", meaning it is strongly indicative of a heightened level. Similarly, on the other end of the scale, a value between 20 to 40 indicates a "reduced" level, while a value between 1 to 20 indicates a "strongly lowered" level.

Raw Wave Value. It represents a single raw wave sample. Its value is a signed 16-bit integer ranging from -32768 to 32767. In one second, 512 raw wave values are sent.

ASIC_EEG_POWER. This data value represents the magnitude of 8 patterns of brainwaves: delta waves, theta waves, low-alpha waves, high-alpha waves, low-beta waves, high-beta waves, low-gamma waves, and mid-gamma waves. These values range from 0 to 256 and have no units. They are only meaningful compared to each other and to themselves. They are typically output once a second.

The digital data is delivered as an asynchronous serial stream of bytes. The serial stream must be parsed and interpreted as ThinkGear Packets. A ThinkGear Packet consists of 3 parts: Packet Header, Packet Payload, and Payload Checksum.

Ruby Program for Wireless Brainwave Sensing System:

Ruby is an easy learning object-oriented program language. It was created by Yukihiro Matsumoto in Japan in the mid 1990s. It was designed for programmer productivity with the idea that programming should be fun for programmers. It emphasizes the necessity for software to be understood by humans first and computers second. I used Ruby to develop the program for the brainwave measurement. Figure 3 shows the flowchart of the ruby program.

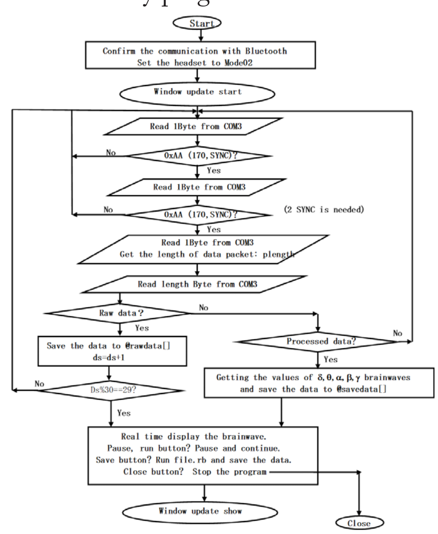

Figure 3: Flowchart of the Ruby program for the Wireless Brainwave Sensing System.

The Bluetooth HC-6 was paired with the computer first, and the port of COM3 was set for the communication between the Bluetooth HC-6 and the computer. In the main Ruby program, the ruby library of "rubyserial.gem"

DOI: 10.36838/v4i3.15

was needed to set up the communication between the Ruby program and COM3.[13] A ruby library of "ruby2d.gem"[14] was used to design the display window and the control panel of the brainwave measurement. Figure 4 shows the design of the display window and the control panel developed by using the Ruby program. The raw data and the processed values of brainwaves could be real-time displayed. The Eye-blink light, the Attention light, or the Meditation light would be turned on when the eye blink signal was detected, the attention value was over 70, or the meditation value was over 70.

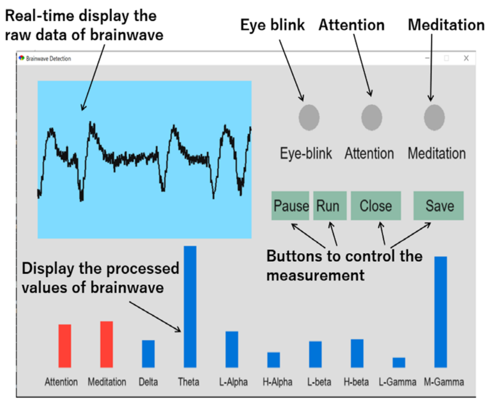

Figure 4: Design of the display window and the control panel for brainwave measurements using Ruby.

The pause-run button and the close button were used to control the measurement of brainwaves. When the save button was pressed, a popup dialog window appeared, and the filename could be chosen. To realize the popup dialog window for filename input, the library of "tk.gem" was needed (Tutorials Point). However, if "tk.gem" was included in the main Ruby program, the speed of the main program became slow, which caused the time-tag of the measurement and brainwave could not be real-time displayed. Figure 5 shows a method to solve this problem. The library "tk.gem" was not included in the main Ruby program <Brainwave.rb>, but included in another program <file.rb>. When the save button was pressed, <file.rb> was then executed and a filename dialog window appeared. The chosen (or inputted) filename was saved in a temp file of <temp.txt>. In the main program and the filename was read from <temp.txt>. Using this method, the speed of the main program was not influenced by the "tk.gem" and the brainwave could be real-time displayed.

```
<Brainwave.rb>
 ・ ・ ・
system("ruby file.rb")
file1 = File.open('temp.txt', &:readline)
name = file1.split(' ')
File.open(name.first,"w") do |f|
     f.puts(@savedata)
end
 ・ ・ ・
<file.rb>
require 'tk'
root = TkRoot.new
root.title = "Window"
  name1 = Tk.getSaveFile
  file = File.open('temp.txt', "w")
  file.puts(name1)
  file.close
  root.destroy
Tk.mainloop
```

Figure 5: Ruby program to pop up the save file dialog window.

Results and Discussion

The image of brainwave measurements is shown as Figure 4. We turned on the power and the EEG headset was worn, and then we ran the Ruby program <Brainwave.rb>, a window appeared shown as Figure 5, and the gathering of brainwave data was achieved via the Bluetooth and was displayed in the window. After measurements, the data was saved by pressing the "save" button. EEG signals were small and susceptible to environmental noise. In order to reduce the influence of this noise, data processing was necessary. Figure 6 shows the data processing method.

First, an unweighted sliding average smooth method was used to reduce the noise of the brainwave data. Second, a normalization method by dividing the value of each EEG pattern by the value of the Low-β wave was used to reduce the measurement error caused by the slight shifts in skin resistance and electrodeposition for each measurement. Then, the average was calculated for each EEG pattern and each person; and finally calculating the average value of each EEG pattern for all the persons.

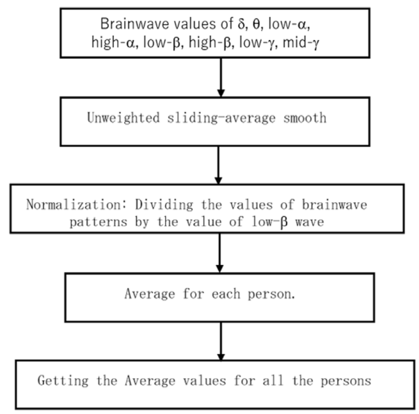

Figure 6: Data processing method.

For the experimental method, a game of First-Person Shooter (FPS) was used. Since playing games with inexperienced gamers might cause extra tension and stress, the EEGs of 11 experienced gamers between the ages of 16 and 50 years old were measured while they were playing games and while they were in a relaxed state with their eyes closed. Figure 7 shows the normalized average values of each EEG pattern for all 11 persons. From Figure 7, both the high-frequency Mid-γ wave and low-frequency δ wave had bigger values when playing the game than those when relaxing.

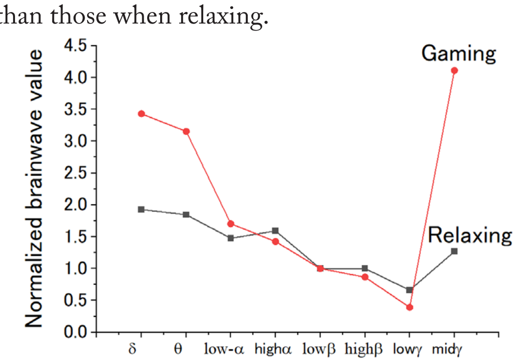

Figure 7: Normalized average of each EEG pattern. Both the high-frequency Mid-γ wave and low-frequency δ wave had larger values when participants were playing the game than those when they were relaxing.

Figure 8 shows the values of Mid-γ waves of the left and right sides of the brain changing with time when playing games. The black line represented the right side of the brain, and the red line represented the left side of the brain. The value of the Mid-γ wave of the right side of the brain was clearly larger than that of the left side of the brain.

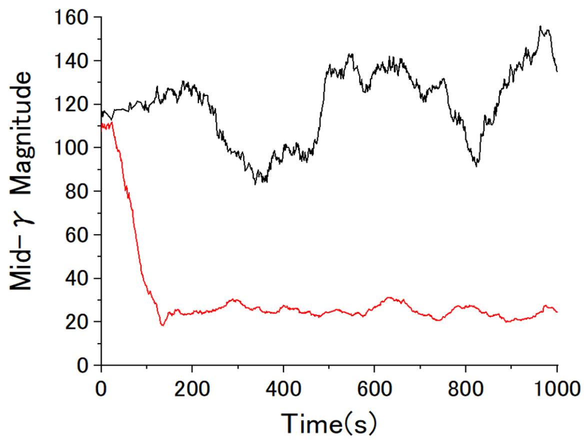

Figure 8: Magnitudes of Mid-γ waves of the left and right brain changed with time when playing the game. The left side of the brain was less active during the game (lower magnitude of Mid-γ wave), while the right side of the brain was very active (higher magnitude of Mid-γ wave).

Conclusion

A wireless brainwave sensing system was constructed using the Ruby program, the Bluetooth module HC-06, and the EEG headset of Mindflex; and brainwave signals were measured when playing games and relaxing.

From Figure 7, both the high-frequency Mid-γ wave and low-frequency δ wave had higher values when playing games than those when participants were relaxing. This result indicated that some parts of the brain were extremely active during playing games that caused the higher value of the Mid-γ wave. In the meantime, the high concentration when playing games might also cause the inactivity of some parts of the brain and the high value of low frequency δ waves.

From Figure 8, the value of the mid-γ waves of the right side of the brain was clearly larger than that of the left side of the brain. This result suggested that the left side of the brain was less active during the game, while the right side of the brain was very active. In fact, the right side of the brain is responsible for abilities related to games, such as advanced calculations and spatial awareness, while the left side of the brain is responsible for slower thinking, such as comprehension, language, and memory. Thus, we can conclude that during game playing, the brain regions related to the game (especially the right side of the brain) become very active, while the brain regions not related to the game (especially the left side of the brain) become extremely inactive.

Acknowledgements

I appreciate the help and support of Mr. Ryosuke Araki, Mr. Kanade Matsuo, Mr. Mitsuhide Sakurai, and Mr. Tom Black, and I also appreciate the measurement support of my classmates.

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Author

Ri He is a senior student at the Takemoto High School in Tsukuba, Ibaraki, Japan. He likes science, programming, and music. His research on brainwave measurements started from 2019.

DOI: 10.36838/v4i3.15