International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET

Attention Level Detection System Based on Brain Computer Interface (BCI)

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Article Info

Publication Issue :
Volume 10, Issue 1
January-February-2023
Page Number : 39-45

Article History
Accepted : 05 Jan 2023
Published: 19 Jan 2023

ABSTRACT

The human brain provides several functions such as expressing emotions, controlling the rate of breathing, etc., and their study has aroused the interest of scientists for many years. In this project, we propose a method to assess and quantify human attention and its impact on learning. In our study, we used a Brain-Computer Interface (BCI) capable of detecting brain state variations, whether distracted or not and displaying corresponding electroencephalograms (EEGs). The BCI headset comprising of surface EEG electrodes is attached to the user's head to acquire the brainwaves. The signal received by the BCI headset is processed to remove external noise. The calculated frequencies are then compared to the threshold frequencies of the brain state and a specific decision like whether a person is in an active or distracted state, and the data is then recorded in the cloud.

Keywords : EEG, BCI, Attention Level, Brain Wave Frequency

I. INTRODUCTION

The human brain is the major organ of the central nervous system that controls all the cognitive and motor functions of the body. The function or malfunction of the brain can be assessed by acquiring the brain signals using different invasive and non-invasive techniques as seen in fig. 1. The electrical activity of the brain is usually acquired and interpreted using electroencephalograph (EEG). The EEG is important because it can record signals that the brain sends out at different frequencies. Different emotions show different properties in the brain wave. For example, when a person is tired or sluggish, their brainwave amplitude may change compared to someone who is more alert and active. There are different classifications for types of EEG waves, such as gamma, beta, alpha, theta, and delta as shown in Fig. 2. Alpha waves are generated when someone is meditating or studying. This type of wave is most prominent in the EEG with a frequency in the 8 to 13 Hz range. Beta waves, on the other hand, have a lower amplitude in the 13 to 22 Hz frequency range. They change when a person is excited or concentrating on something. Theta waves have frequencies between 4 and 8 Hz, which are considered low frequencies. This type of wave is most pronounced when a person is experiencing deep meditation. Conversely, delta waves

have the lowest frequencies, between 1 and 4 Hz. Finally, gamma waves have a very high-frequency range, above 32 Hz. Thus the frequencies of the EEG wave and their amplitudes help to detect the influence of the outside world on the natural neural network.

The Brain-Computer Interface (BCI), also known as the Brain-Machine Interface (BMI), is a hardware and software communication system that enables people to interact with their environment without involving peripheral nerves and muscles by using electroencephalographic control signals. BCI creates a new non-muscle channel to transmit a person's intentions to external devices such as computers, speech synthesizers, assistive devices, and neural prostheses.

BCI is an artificial intelligence system that can recognize a specific set of patterns in brain signals through five sequential steps: signal acquisition, signal pre-processing, feature extraction, classification, and control interface. The signal capture stage acquires the brain signals and the pre-processing stage performs noise reduction and artifact processing. It also prepares the signals in a suitable form for further processing. The feature extraction step identifies discriminatory information in the recorded brain signals. After measurement, the signal is mapped onto a vector containing the true and discriminating features of the observed signals. Extracting this interesting information is a very difficult task. Brain signals are mixed with other signals from a finite set of brain activities that overlap both in time and space. In addition, the signal is usually not stationary and can also be distorted by artifacts such as electromyography (EMG) or electrooculography (EOG). The feature vector should also be low-dimensional to reduce the complexity of the feature extraction step, but without significant loss of information. The classification phase classifies the signals considering the feature vectors. Choosing good classifier is therefore essential to achieve effective pattern recognition and deciphering the user's intent.

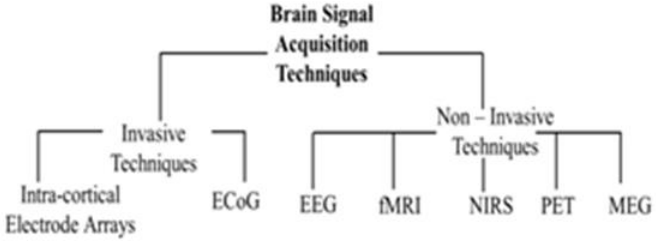

Figure 1. Brain Signal Acquisition Techniques

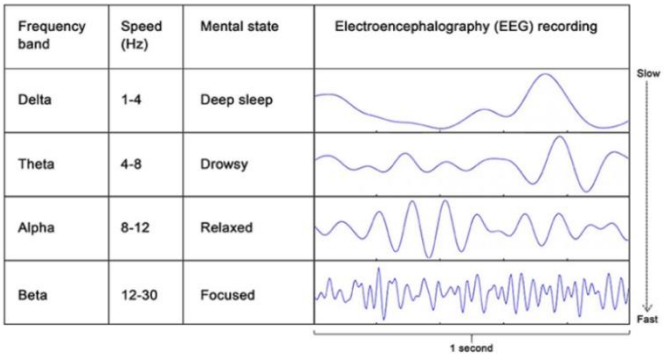

Figure 2. Types of Brain Waves Signal

The following are the objectives of the work.

- To detect the attention distraction in people.
- To record the neural patterns using BCI and store them in the cloud.
- To analyze the data of distraction rate and study of their behavior.

II. LITERATURE REVIEW

The distinct frequency bands of EEG waves have been studied extensively for its potential to detect different states of concentration of the human mind [1-3]. The development of sensor technology and computing systems has led to the field of Brain Computer Interfacing, which acquires, digitizes and processes the brain waves for automatic detection of attention levels [4],[5].

BCI has been studied extensively for evaluation of Brain Attention levels across gender and age, to

distinguish levels of stroke [6],[7] , the ability to discriminate and attend one specific sound source in a complex auditory environment[8] , to determine locus of auditory attention [9] etc., Also optimization of power consumption [10] and wireless transmission [11] involved in BCI systems are being reported in literature.

III. SYSTEM OVERVIEW

Attention is a fundamental cognitive skill in everyone's life, regardless of age. It is a mental process that tends to increase the academic and professional performance of an individual. This promotes the development of other skills such as imagination and creativity. It also creates more self-confidence and improves interpersonal relationships. Problems with concentration are increasing in today's society; however this deficit can be overcome with appropriate training and motivation.

Exercising our attention span helps us increase and improve our focus, which makes us much more productive people. The purpose of this study is to measure the attention level of the person using the proposed system. The collected data is stored in a spreadsheet and based on the concentration values, a real-time line graph is created to obtain models based on each profile. The block diagram of the proposed BCI system is shown in fig. 3.

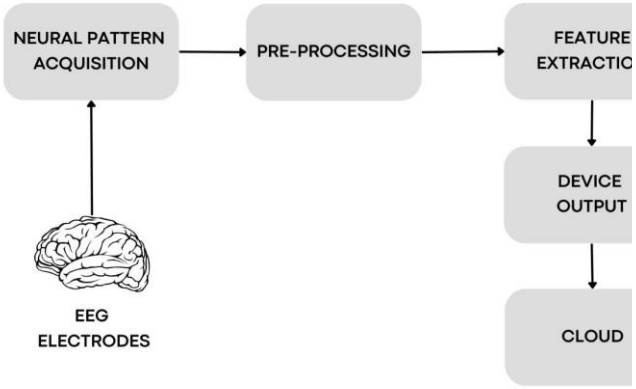

Figure 3. Block diagram of BCI Based Attention level detection system.

The brain signals are sensed by electrodes are then processed, digitized and sent to a computer as follows.

(1) Signal acquisition

Signal acquisition is the measurement of brain signals with a specific sensor. The electrical activity of neurons in the brain produces currents that reach the surface of the scalp, with the voltage differences between these scalp potentials being signals on the order of microvolts. The probes used in this experiment were disposable surface electrodes.

(2) Preprocessing

The pre-processing phase includes the amplification of microvolt signals to levels suitable for electronics processing, filtering to remove noise and other unwanted signal frequencies. Finally the analog-digital conversion, i.e. digitization of analog EEG signal is performed. The LM324 OP - AMP integrated circuit is used for the construction of instrumentation amplifier with a voltage gain of 50 as shown in fig.4.

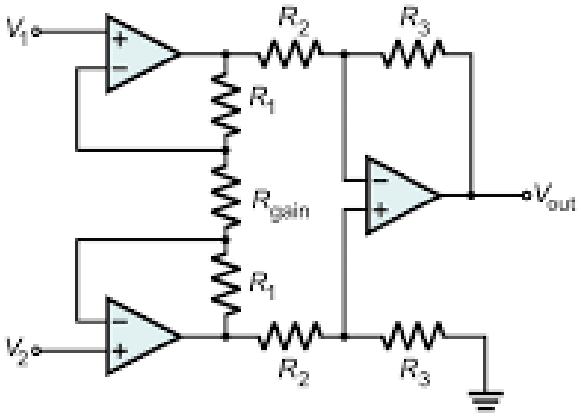

Figure 4. Circuit diagram of Instrumentation Amplifier

The two active electrodes of the sensor attached to the user's forehead are connected to the instrumentation amplifier. The instrumentation amplifier is unique and ideal for measures like this because it has very low noise and very high input Impedance.

The amplified signals are converted to digital form and read into the Arduino Controller. Bandpass filters and Notch filter algorithms are implemented to separate the required frequency band of EEG signals and to eliminate 50Hz power line noise respectively.

(3) Feature extraction

Feature extraction is the process of analyzing digital signals to distinguish the significant features of the signal from external content and present them in a compact form suitable for translation. These characteristics must be highly correlated with user intentions. Because much of the relevant brain activity is transient or oscillating, the signal characteristics most commonly extracted in current BCI systems are the timed EEG response amplitudes and delays, the power in the specific EEG frequencies of the bands, or frequency activation from individual cortical neurons. Environmental artifacts and physiological artifacts such as EMG signals are avoided or suppressed to ensure accurate measurement of brain signal properties.

(4) Attention detection

The level of attentiveness of the subject may be recognized from the extracted feature signals using suitable classification algorithms.

IV. COMPONENTS REQUIRED

A. Arduino UNO

Arduino is an open-source hardware. Arduino microcontrollers are pre-programmed with a boot loader that can be simplified by uploading the programs to the on-chip flash memory. The default bootloader of the Arduino Uno is called the Opti-boot bootloader. Boards are loaded with program coding via a periodic connection to another computer. Fig 5 shows the Arduino Uno board.

Figure 5. Arduino UNO

B. Surface Electrode

Surface electrodes are those which are placed in contact with the skin of the subject in order to gain bioelectric potentials from the surface. Body surface electrodes are of numerous sizes and. types. In spite of the type, any surface electrodes can be used to sense ECG, EEG, EMG. Fig 6 shows the surface electrodes.

Figure 6. Surface Electrodes

C. IC LM324

The operational amplifier LM324 IC works like a normal comparator, and it consists of four independent op-amps internally. This IC has been designed with low-power, bandwidth and high stability for operating with a single power supply over extensive voltage ranges. The range of operating voltages of this ICLM324 includes 3 Volts for low and 32 Volts for high. The range of output voltage also consists of the negative voltage supply. Fig 7 shows the IC LM324.

Figure 7. IC LM324

D. Resistor

A resistor is an electrical element that limits or regulates the inflow of electrical current in an electronic circuit. Resistors can also be used to give a specific voltage for an active device such as a transistor. These are used in designing the amplifier and filter for required gain and cutoff frequencies.

E. LED

Light Emitting Diode (LED) are lighting products that can produce light upto 90% more efficiently than incandescent light bulbs. An electrical current passes through a microchip, which illuminates these tiny light sources and the result is visible light. LEDs are used to indicate different levels of attention in subjects under study.

V. SOFTWARE REQUIRED

The Arduino Integrated Development Environment or Arduino Software (IDE) includes a text editor for writing code, a communication area, a text console, a toolbar with buttons for common functions, and a set of menus. It connects to Arduino hardware to tackle, to load and communicate with programs. The editor has functions for cut/paste and find/replace text. The message pane provides feedback on saving and exporting, and also displays errors. The console displays text output from the Arduino software (IDE), including full error messages and other information. The lower right corner of the window shows the configured card and serial port. The toolbar buttons allow you to review and load programs, create, open and save sketches, and open the serial monitor.

VI. SYSTEM DESIGN

The main focus of this project is to define the perception Index of people's attention over a long time. The proposed system using the brain-computer interface helps to recognize how distracted a person is. The purpose of BCI is to recognize and quantify the characteristics of brain signals.

Brain activity is analysed from the electrical signals detected by the recording electrodes placed on the scalp or on the cortical surface. Brain signals are amplified and digitized. Noise are suppressed in the amplified signal and filtered into various freuency bands. Hence the average attention span of a human can be recognized by the extracted frequency signals. The connections of the Attention detection system using Brain Computer Interfacing are shown in fig. 8. The surface electrodes acquire the brain signals, which are processed using suitable analog electronics. The signals are digitized and filtered using Arduino Controller. The system is designed to indicate whether or not a subject is distracted and

also to determine how often the subject is distracted by flashing LED.

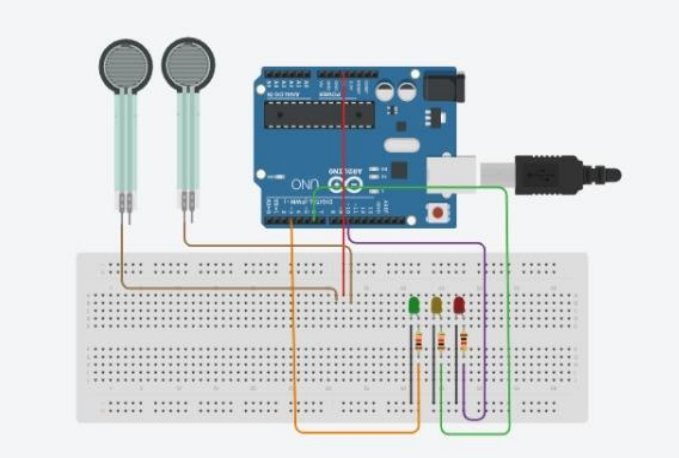

Figure 8. Circuit diagram of Attention Detection System

VII. .RESULTS AND DISCUSSION

The study is to be performed on a sample of 30 volunteers under controlled attention levels. The experimental set up and signal acquisition process from a sample volunteer while concentrating on various states of mind is shown in Fig.9.

Fig. 10 represents the neural pattern acquired when the subject is in a relaxed state. Fig. 11 represents the pattern acquired when the person is highly focused. It can be observed that the patterns obtained are visually distinct. Thus, the attention level of the subject can be successfully detected using the proposed system. The data acquired with respect to time are stored in the cloud for further analysis and interpretations.

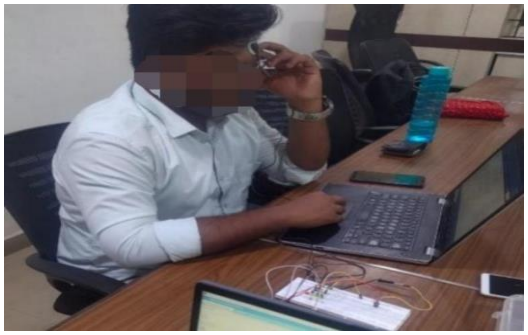

Figure 9 Experimental Set up for Signal Acquisition from a Volunteer

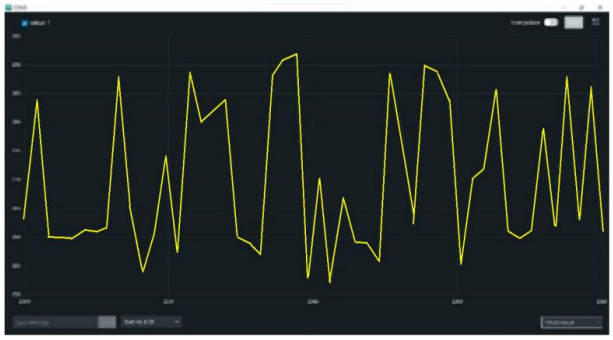

Figure 10 Neural pattern while relaxed

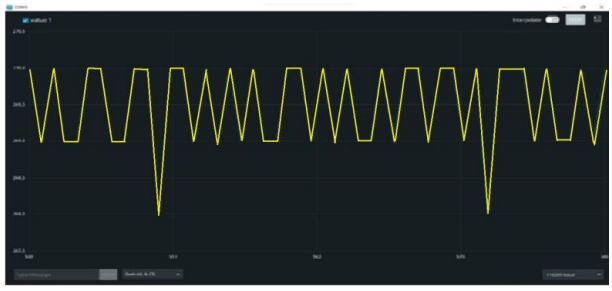

Figure 11 Neural pattern while focused

VIII. CONCLUSION AND FUTURE SCOPE

The BCI based system for attention level detection has been implemented and tested on sample volunteers. It is found that the neural patterns observed are distinct for different levels of focus and attention.

The patterns stored may be processed further by extracting features and classifying the attention states of a subject automatically using classification algorithms. The study can be extended to study attention levels across gender and age groups. The proposed system may be designed for other monitoring applications such as, mental health in rehabilitation centres, attention span of students during lecture sessions, Mental state before and after excessive involvement in video games, alertness of drivers etc.

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Cite this article as :

Dr. Sheeja V Francis, Arun Boaz D, Dharshini C, Emalda preethi L, Nithyalakshmi P, "Attention Level Detection System Based on Brain Computer Interface (BCI)", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 10 Issue 1, pp. 39-45, January-February 2023.
Journal URL : https://ijsrset.com/IJSRSET231016 |