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Analysis of Brain Wave Activity Realtime Using NeuroSky Sensors With LabVIEW

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Abstract – **The brain is the part of the body that gives us the ability to live, react to all external stimuli, and coordinate our entire body. The human brain constantly generates electrical impulses. These electric currents are often referred to as brain waves. EEG (electroencephalography) is a bioelectrical measurement used in the biomedical field to study the human brain. Through this research, a sensor system will be developed that can detect brain waves non-invasively and transmit signals wirelessly via a Bluetooth connection. The detected EEG signal will be displayed in graphical form using signal parameters. To obtain brain wave signals, sensor electrodes are placed directly on reference points on the surface of the scalp in the front and left ears. The captured brainwave signal will be wirelessly transmitted via USB Bluetooth BLE 4.0. Next, the brainwave signal data will be converted and processed via USB Bluetooth BLE 4.0, which is connected to the USB port on the laptop. Then, the brain wave signal will be displayed in graphical form in real-time and analyzed using LabVIEW software. The results of this study indicate that the monitoring system that works on LabVIEW can display real-time data from the NeuroSky sensor wirelessly, and the type of brain waves and the frequency of the resulting brain waves can vary depending on the condition of the brain at the time.**

Keywords: Brain Waves, NeuroSky Sensor, USB Bluetooth BLE 4.0, LabVIEW.

I. INTRODUCTION

Humans are complex living systems made up of billions that work together to form a network. The neural network that has been built has an information transmission system based on the body's electricity, or bioelectricity. Everything that is on the surface of the skin and all parts of the human body has electrical properties and electric currents that can be detected to indicate a condition [1], [2]. In the biomedical field, the measurement of bioelectrical signals is a very important part of The bioelectrical measurement to monitor heart conditions is known as an EEG (electrocardiography) or EMG (electroneurography) to monitor nerve activity. While signals from the brain are detected from the EEG signal parameters (electroenchepalography) [3].

The EEG signal is the most complex waveform compared to other biomedical signals. Especially in data collection, the place where EEG data is taken is in the head area, which is mostly covered with hair. The placement of the sensor must be in the right position and use the right electrode. Dry, non-invasive electrodes are widely used in EEG data collection because they are comfortable and painless to the skin. Sensors that have interfaces connected directly to the electricity network run the risk of being exposed to current leakage. Interfaces using a cable are also less flexible in use [4], [5].

In this research, a sensor system will be developed that is capable of detecting brain waves in a non-invasive way and can transmit signals wirelessly via Bluetooth. The detected signal will then be processed electronically so that it can be easily adjusted according to user needs. This research integrates NeuroSky sensors with LabVIEW software to monitor and analyze human brain wave activity in real-time [6].

Using this system, users can understand their brain activity under different conditions. Therefore, this system can help users better understand their mental and physiological state when they are in certain situations and can also be used as a tool to monitor and manage mental and physical conditions related to brain activity [7]. The expected benefits of this research are to support understanding of the characteristics of EEG signals, to help facilitate monitoring of brain bioelectrical signals, and as an intervention method in the development of medical electronics technology and neuroscience [8], [9].

II. BASIC OF THEORY

The human brain is the control center of the human body. Various types of scientific research have proven that there is a part of the brain that can regulate emotions, intelligence, feelings, behavior, and reactions to the environment. The brain can also receive and interpret various signals sent by various parts of the body and its environment. The brain is a complex part of the human body. The brain consists of the frontal lobe, occipital lobe, temporal lobe, and parietal lobe. These four parts have different positions and functions that facilitate the acceptance and movement of the human body [10], [11].

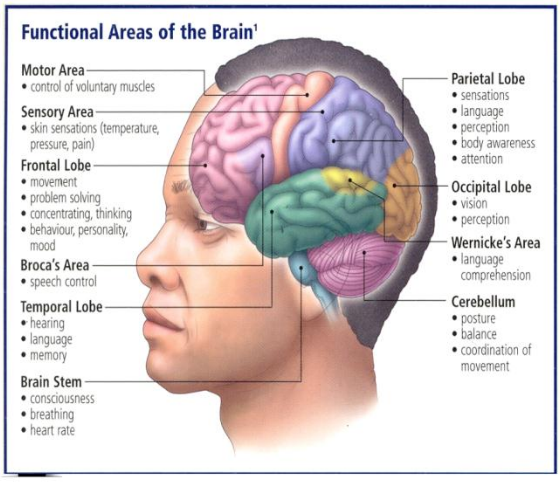

Figure 1. Differences in Parts of the Brain with Their Characteristics

Based on Figure 1, electroencephalography, or EEG, is a device that visualizes human brain waves in graphical form. Brain waves are measured based on the difference in frequency potential between electrodes connected to the human head [12, 13]. The human brain emits waves according to its mood. Because brain waves have their own pattern with different messages. There are four types of brain waves: alpha, beta, theta, and delta [14].

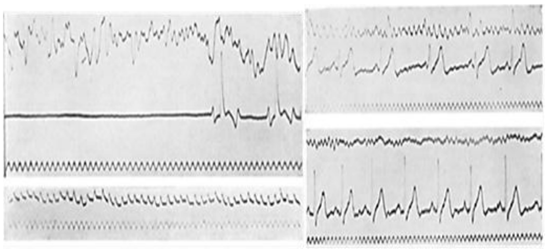

Figure 2. The first recorded EEG sample

Based on Figure 2, brain waves are isolated electrical currents in the brain that are measured in volts. Different brain areas do not show the same brain wave frequency. The EEG signal between the electrodes placed on the head consists of several waves with different characteristics [15], [16]. The sheer volume of data obtained in a single EEG recording makes interpretation difficult. The principles of brain waves are unique to each individual [17].

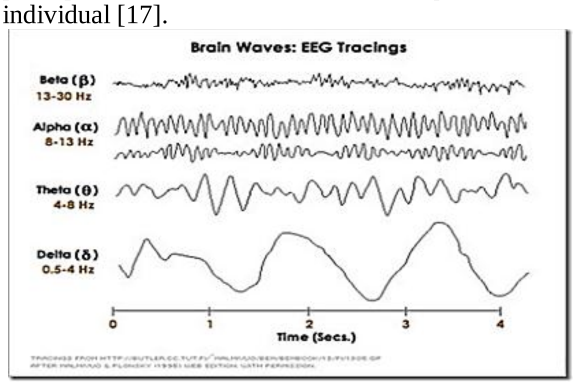

Figure 3. Active Brain Waves in Humans

Based on Figure 3, Neurosky MindWave is one of the EEG devices on the market with a brain-computer interface (BCI). mindWave reports that users can gauge mental state by looking at thoughts, focusing on meditation, or using a meditation algorithm based on a patented core. algorithm, it can display a certain brain wave frequency [18]. MindWave can be used to play video games, conduct research, or enhance certain applications. This image shows the NeuroSky MindWave being used. NeuroSky MindWave uses a dry sensor to capture brain signals. This sensor is located at the front of the headset, so that when worn on the head, it touches the user's forehead. Additionally, there is a video clip connected to the user's earpiece. MindWave integrates with Windows and mobile devices with the Android operating system so that the brain can be recorded in various attention waves and signals. NeuroSky MindWave is a brainwave detector that uses electrodes placed on the front of the fistula by a company called NeuroSky [19]. In general, the features of NeuroSky MindWave are shown in Figure 4.

Figure 4. NeuroSky MindWave

Based on Figure 4, USB Bluetooth is a hardware device that functions as an adapter to connect technology-enabled devices to a computer or laptop via a USB port. USB Bluetooth is often called a Bluetooth USB dongle or adapter. USB Bluetooth BLE 4.0 (Bluetooth Smart) is a low-power Bluetooth (BLE) adapter for connecting devices to computers or laptops via a USB port. Bluetooth Low Energy is a type of Bluetooth specifically designed to meet the needs of communication between devices with low energy. This technology is designed to connect devices with limited battery capacity, such as smartwatches, sensors, or medical devices. The advantage of low-power Bluetooth is its low power consumption, allowing the device to work for a long time without having to change the battery frequently. Besides that,Bluetooth Low Energy also provides faster data transfer speeds and wider network coverage compared to previous Bluetooth versions. A Bluetooth BLE 4.0 cable can be used to connect low-end Bluetooth devices, such as smartwatches, sensors, or medical devices, to a computer or laptop. USB Bluetooth BLE 4.0 devices often have auto-pairing capability, which makes it easier for users to pair low-end Bluetooth devices with computers or laptops automatically [20]. Some USB Bluetooth BLE 4.0 devices have multipoint capability, so users can connect several low-end Bluetooth devices to a single computer or laptop at the same time.

Figure 5. USB Bluetooth BLE 4.0

Based on Figure 5, LabVIEW, short for Laboratory Virtual Instrumentation Engineering, Workbench is a powerful programming language that can be used to achieve specific goals, especially in the development of graphical control and measurement systems. LabVIEW is a graphical programming environment developed by National Instruments (NI), which allows high-level programming or short-term programming. LabVIEW is an open and flexible program that allows technicians to connect to other devices, such as programmable logic controllers (PLC) and PACs, using a single software package [21], [22]. LabVIEW is a programming language that uses various symbols to represent instructions. While text-based programming languages execute instructions in the written order, LabVIEW uses a data flow programming method where the input of data via various signals determines the order in which each instruction is executed. In LabVIEW, virtual instruments (VI) are programs that simulate real-world applications. [23], [24].

Figure 6. LabVIEW

III. Method and Design

In this study, the development of the NeuroSky sensor was carried out to detect brain signals in the air. To get a good signal, the NeuroSky sensor is attached to the human head. This sensor works using non-invasive electroencephalography (EEG) technology, which means that it does not require the insertion of electrodes in the human brain. The NeuroSky sensor is placed on a person's head, then the sensor records the electrical signals generated by the nerve cells in the person's brain. The NeuroSky sensor contains the ThinkGear Module (TGAM), which records electrical signals in the human brain. Then, the brain signal data will be converted and processed via USB Bluetooth BLE 4.0 which is connected via a USB port to the laptop. Then, brain signals will be displayed in the form of time graphs and analyzed using LabVIEW software. The following figure is a summary of the system block diagram.

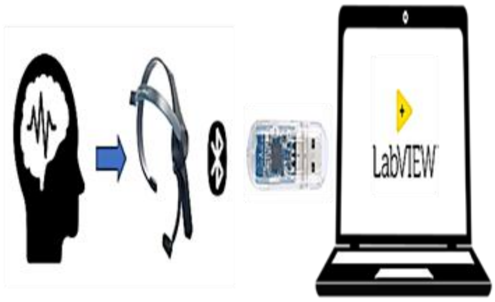

Figure 7. Blok Diagram

Based on Figure 7, the research process uses a systematic approach to determine the performance of the tool described from the beginning to the end of the process. In this presentation, we will explain in detail the dynamics of the NeuroSky sensor system and brain activity recording, from the initial stage to the final stage of the system. The process begins with the introduction of the NeuroSky I/O sensor, which will detect waves or signals in the human brain. The signal is transmitted wirelessly via a Bluetooth connection, with USB Bluetooth BLE 4.0 as the receiver. If the signal is not detected, the signal will be read by the NeuroSky sensor attached to the person's head. If a brain signal or tumor is detected, the brain signal data will be converted and processed via a Bluetooth BLE 4.0 USB cable connected via the USB port to the laptop. Then, brain signals will be displayed in the form of waves and frequency graphs on the LabVIEW software. The following figure is a summary of the system block diagram.

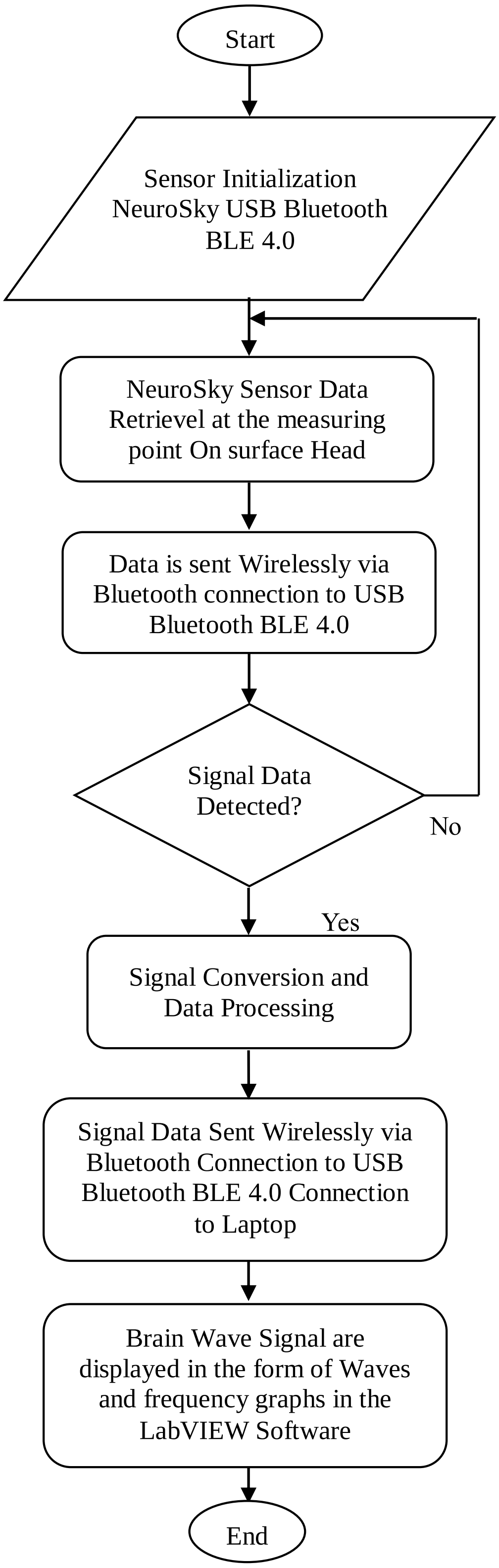

Figure 8. Flowchart

Based on Figure 8, the planning stages for making a monitoring system using the software LabVIEW From the display design made, we can see several important indicators, including the serial port name of the USB Bluetooth BLE 4.O, the signal quality from the NeuroSky sensor bluetooth connection, as well as brain wave data displayed in graphical form along with wave graphs and frequency wave graphs. First, there is a serial port name indicator from USB Bluetooth BLE 4.0, which is used as a signal receiver. This ensures that the wireless connection between the NeuroSky sensor and the monitoring system is established properly, and secondly, there is a signal quality indicator that shows the stability of the NeuroSky sensor's Bluetooth connection. This information is critical to ensuring accurate and consistent data delivery from sensors to monitoring systems. Next, the brainwave data is displayed in graphical form, which provides an immediate visualization of the detected brainwave activity. These graphs allow monitors to see changes and patterns in brain wave activity in real-time. In addition to brain wave graphs, there is also a frequency wave graph that displays the frequency distribution of the observed brain waves. This provides information about the composition of the frequencies present in brain wave activity, such as delta, theta, alpha, and beta. With these elements in the monitoring system design, users can easily view and analyze brain wave activity in real time. The design of the brain wave activity monitoring system can be seen in Figure 9.

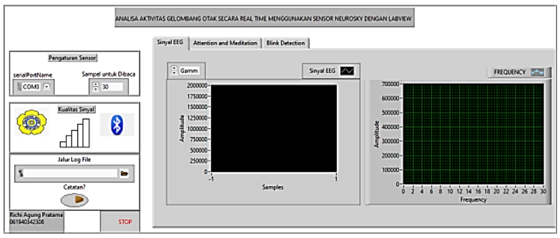

Figure 9. Brain Wave Signal Monitoring Display

IV. Results and Discussion

This chapter describes the results of tests conducted by the author to evaluate the level of success in analyzing brain wave activity in real-time using NeuroSky sensors with LabVIEW.

The test was carried out to observe the detected brain wave signals for four different brain wave conditions in human subjects, and this test involved both adult and child subjects to gain a more comprehensive understanding. During the test, the results of the brain wave signal are displayed and evaluated in real time using the LabVIEW software. The display includes a graph of the brain wave signal that describes changes in brain activity as well as a frequency spectrum that shows the distribution of energy in various frequency ranges. This allows for a more in-depth analysis of the subject's brain activity in each of the conditions tested. In this stage, system testing is carried out using the NeuroSky sensor, which is equipped with the ability to use Bluetooth communication. A USB Bluetooth BLE 4.0 device is connected to the computer. The goal is to ensure that the computer can receive serial data from the NeuroSky sensors. The NeuroSky sensor used is equipped with Bluetooth, so it can be used immediately after the switch is turned on and the two Bluetooth devices are connected (paired). An example of the use and placement of the NeuroSky sensor can be seen in Figure 10.

Figure 10. Use of NeuroSky sensors

Based on Figure 10. The first tests were carried out on brain wave signals in adult subjects. This test aims to observe brain wave signals detected in four brain conditions from adult subjects.

Figure 11. The First Test on Adult Subjects

Based on Figure 11, the NeuroSky sensors were tested while the brains of adult subjects were asleep. From the displayed results in real time on the software LabVIEW, the data graph of detected adult brainwave signals shows frequency graphs in the range of 2-4 Hz. These results indicate that in experiments with adult subjects, they show delta brain waves, which are the waves with the lowest frequency and are close to zero. Delta waves generally have a working frequency range between 0.5 and 4 Hz.

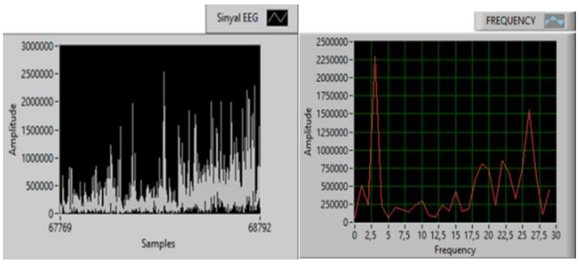

Figure 12. Brain Waves in Adult Subjects While Sleeping

Based on Figure 12, the subject is tested while in a sleepy state. From the displayed results in real time on the software LabVIEW, data graphs of detected adult brain wave signals show frequency graphs in the 4–7 Hz range. These results indicate that this experiment displays theta brain waves, which have a working frequency range of 4–7 Hz and generally appear when the brain is resting but has not yet fallen asleep. It can be seen that the waves shown in LabVIEW are as follows:

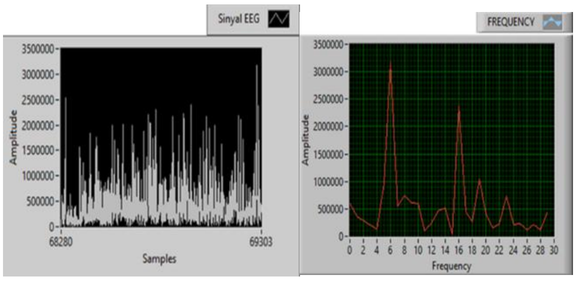

Figure 13. Brain Waves in Drowsy Adult Subjects

Based on Figure 13, this test was performed when the adult subject was relaxed. The results displayed on the software LabVIEW detected brain wave signals with frequencies in the range of 10–12 Hz. This range is included in the category according to alpha brain waves, where alpha waves have a working frequency range ranging from 7 to 13 Hz and appear when the brain is relaxed.

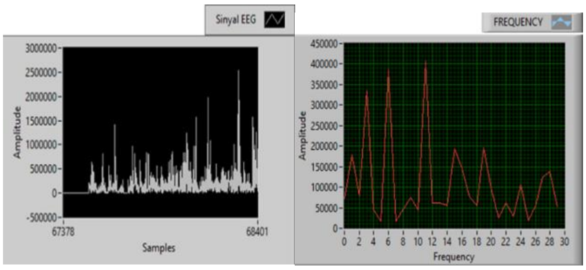

Figure 14. Brain Waves in Relaxed Adult Subjects

Based on Figure 14, adult subjects are tested while in a state of concentration or when the brain is working hard. In this experiment, the subject performed the activity of typing a final project report, which required a high level of concentration. From the results shown on the software LabVIEW, we detected brain wave signals with frequencies in the range of 26–29 Hz. Thus, it can be concluded that in this experiment, the subject's brain works on beta waves, which have a working frequency range of 13–30 Hz.

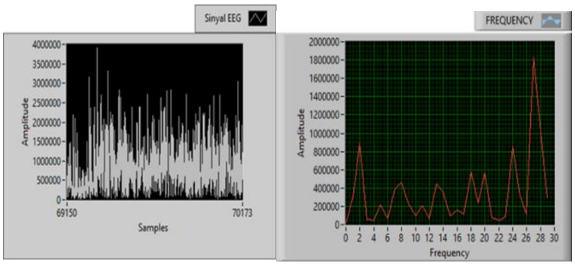

Figure 15. Brain Waves in Adult Subjects When in a State of Concentration

Based on Figure 15. the second test was carried out on brain wave signals in children aged 10 years with the aim of observing the brain wave signals detected in four different brain conditions. This was done as an analysis of the first test performed on adult subjects.

Figure 16. Second Testing on Children Subjects

Based on Figure 16. the NeuroSky sensors were tested while the brains of the children's subjects were asleep. From the displayed results real time on software LabVIEW, data graphs of the detected brain wave signals of children subjects show a graph of frequencies in the range 1-4 Hz. These results indicate that this experimental waveform represents a delta brain wave, which is the wave with the lowest frequency close to zero. Delta waves generally have a working frequency range between 0.5-4 Hz.

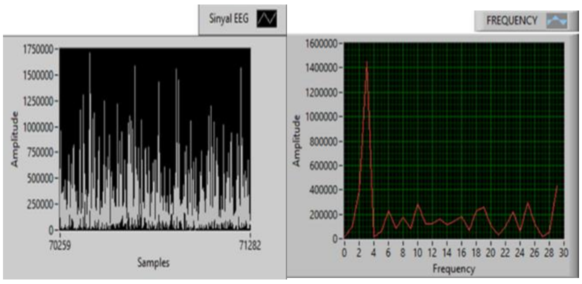

Figure 17. Brain Waves in Children Subjects While Sleeping

Based on Figure 17. children are tested when they are sleepy. From the displayed results real time on software LabVIEW data graph of the brainwave signal of a child subject shows a graph of frequencies in the 4-6 Hz range. These results indicate that these experiments displayed theta brain waves. Theta brain waves have a working frequency range between 4-7 Hz and generally appear when the brain is resting but not yet asleep.

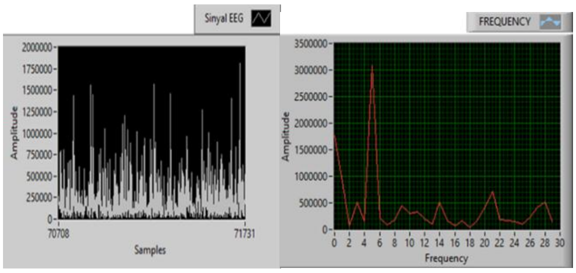

Figure 18. Brain Waves in Children's Subjects in a Drowsy State

Based on Figure 18. children are tested while in a relaxed state. Of the results displayed on software LabVIEW, detected brain wave signals with frequencies in the range of 9-11 Hz. This range is included in the category according to Alpha brain waves, where Alpha waves have a working frequency range ranging from 7-13 Hz and generally appear when the brain is relaxed.

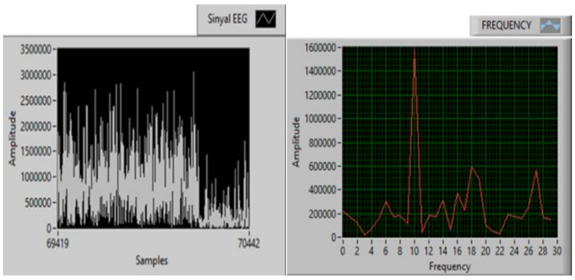

Figure 19. Brain Waves in Child Subjects in a Relaxed State

Based on Figure 19. children are tested while in a state of concentration or when the brain is working hard. In this experiment, the subject carried out the activity of working on questions that required a high level of concentration. From the results shown on software LabVIEW, detected brain wave signals with frequencies in the range of 27-29 Hz. Thus, it can be concluded that in this experiment the subject's brain works on beta waves, where beta waves have a working frequency range ranging from 13-30 Hz.

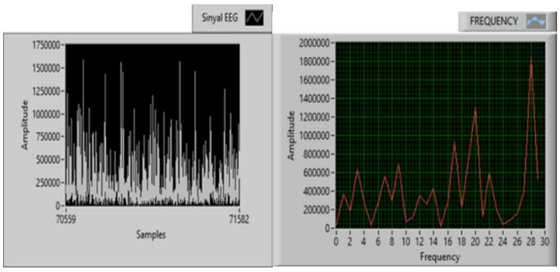

Figure 20. Brain Waves in Children Subjects When in a State of Concentration

V. CONCLUSION

Based on the results of testing and discussion of brain waves in adult and child subjects, it can be concluded that there are significant differences in the brain wave frequency range between adult and child subjects under the same conditions. Delta, Theta, Alpha, and Beta waves show characteristic differences between the two groups. In delta waves, children have a lower frequency range than adults, with a frequency range of 1-4 Hz for children and 2-4 Hz for adults. This suggests differences in brain activity that may be related to development and growth. Theta waves also showed slight differences between the two groups. The theta frequency range for children is 4-6 Hz, while for adult subjects it is 4–7 Hz. This difference indicates that the theta waves in children have a slightly lower frequency compared to adults. Alpha wave frequency ranges in children (9–11 Hz) and adults (10–12 Hz) also show small differences, although they are relatively similar. This indicates a difference in brain activity in the alpha frequency range between the two age groups. Lastly, the beta wave shows little difference between children and adult subjects. The beta frequency range in children is 27–29 Hz, while in adults it is 26–29 Hz. Thus, the differences in brain wave frequency ranges between adult and child subjects suggest slightly different characteristics in their brain activity under the same conditions. This could possibly be attributed to differences in brain development between the two age groups.

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