Designing A Portable Device That Provides At-Home Real-Time Monitoring Of Brainwave Frequencies In Patients With Neurological Disorders, Providing Early Warnings Of Cortical Spreading Depression (CSD), For Prompt Medical Intervention And Ultimately A Better Quality Of Life.

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ABSTRACT

The diagnosis of Cortical Spreading Depression or Spreading Depolarisation occurs with the help of captured EEG signals. Nowadays, individuals suffering from neurological disorders do not have a satisfactory solution. This research aims to enhance an existing feasible device that behaves like an EEG (Electroencephalogram) by incorporating real-time data analysis for patients with CSD and sending reports to doctors. The device will provide continuous monitoring of brain activity, which will allow early detection and intervention for individuals at risk. Moreover, the device will be capable of generating reports based on the collected data, and then sending it to the individual's doctor. Additionally, the device will be integrated with a mobile application that will serve multiple purposes. The application will notify nearby hospitals in case of an emergency, which ensures timely medical assistance. Furthermore, the app will include an exclusive community where individuals with CSD can connect, share their experiences, and seek support. The application will also offer a range of brain exercises and yoga training modules, which are designed to promote mental well-being and lighten the symptoms associated with CSD. Overall, this research aims to significantly improve how CSD is managed by using advanced technology, real-time data analysis, medical reporting, emergency response, community engagement, and mental well-being exercises.

Keywords- Cortical Spreading Depression, Spreading Depolarisation, EEG (Electroencephalogram,)

I. INTRODUCTION

Cortical Spreading depression is a complex neurological phenomenon that is caused by altered electrical activity and changes in ion concentrations between the intracellular and extracellular regions of the nerve cell. Furthermore, a wave is observed to have shorter-lasting events that can occur repetitively and propagate across the brain. It silences the brain's electrical activity for a few minutes [1]. The symptoms related to CSD are migraine aura and some visual illusions. Additionally, Cortical Spreading depression can worsen tissue damage [2]. The process of CSD is as follows: Initiation: The increase of K, Na, Cl and Ca ions outside the neurons rapidly fall, resulting in electrical imbalance. Neural Depolarization: A high extracellular potassium concentration can cause nearby depolarisation. This depolarisation causes voltage-gated channels, particularly Ca channels, to open in the neuron's membrane. Inward Current: When voltage-gated channels (Ca2+) are activated, positive ions, including calcium, can enter the neuron. These channels are activated when the neurons depolarise. In a nutshell, (CSD) and depolarization waves are associated with dramatic failure of brain ion homeostasis, efflux of excitatory amino acids from nerve cells, increased energy metabolism and changes in cerebral blood flow (CBF).

The conventional method to detect CSD is an EEG test . EEG signals can vary significantly between individuals due to differences in skull thickness, brain anatomy, and other factors. This inter-individual variability makes it challenging to establish standardised protocols and comparisons across different individuals or populations. Traditional EEG systems often involve

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cumbersome setups with multiple cables and equipment, which limits their portability. Advancements in wireless and miniaturised EEG systems have been made, but there is still a need for more compact and user-friendly designs for everyday use.EEG signals are complex and require sophisticated analysis techniques to extract meaningful information. Interpretation of EEG data can be challenging, especially when dealing with real-time applications or large-scale data analysis. Hence, our prototype will ensure to overcome most of these challenges. [3]

Our research aims to bring out a low-cost, portable device that allows neurological disorder patients to have an instant observation of brain waves at home, providing early warnings of

II. MATERIALS AND METHODS
2.1 Development of EEG Signal Module
2.1.1 Material Required

The materials required for the formation of EEG modules are numerous. The main component used is from the company Cytron Technology [5], the product MAKER UNO Rev. 1.1 along with a type b to USB cable for it to be connected to a laptop or computer. The Maker UNO is an Arduino-compatible microcontroller board designed to simplify and facilitate the process of creating interactive electronic projects. Next, is the BioAmp.EXG Pill v1.0 SEP 2021 from the upside-down lab [6]. The BioAmp. EXG Pill is an ingestible device that captures and records biological signals from the gastrointestinal tract for diagnostic and monitoring purposes. Moreover, the aforementioned were connected with the help of jumper wires, more precisely it was male to female. Furthermore, a need for BioAmp Cable v2 or v3 [7]. The Bio Amp Cable V3 or V2 is a high-quality cable designed to establish a reliable connection between physiological sensors and data acquisition systems for accurate recording and analysis of biological signals in biomedical applications. Moving on to, gel electrodes which we used from UpsideDown Labs [8], where the electrode can be chosen as per convenience except the repositionable electrodes. A gel electrode is a type of electrode that utilises a gel-filled interface to establish a conductive connection with the skin for accurate measurement of electrical signals in medical and physiological applications. The apps required for EEG signals to be recorded are first the Arduino IDE 2.1.0 where the code is put in the Cytron[9] and SpikeRecorder [10]. The Arduino IDE app [11] is a software application that provides

Cortical Spreading Depression (CSD), with the help of doctors and better patient outcomes [4].

Unlike other devices, it not only monitors the brain waves but also warns the patients about CSD. This device will come with an app that provides the initial take-out steps, real-time data sharing of the patient with their personalised doctor, mandatory brain exercises and an exclusive community of people suffering from CSD from all over the world. This idea will be implemented with more than 9 hours of battery backup which will make it more competitive. This device will be designed with an easier interface with default settings which can be easily used by anyone around at home at an affordable price. The rough sketch of the product will look as follows:- a user-friendly integrated development environment for programming Arduino microcontroller boards. A spike recorder is software used to detect, record, and analyse neural spikes or action potentials in neuroscience research or clinical settings.

2.1.2 Connections

Initially, the connection of the MAKER UNO to the laptop should be done through the type b to USB cable in USB5V. Followed by uploading the code with the help of Arduino IDE 2.1.0. Point to be noted, the wires' nature should not be confused with the colour of the wire. The VCC of BioAmp. Exg Pill should be connected to the 5V of the MAKER UNO. The Ground (GND) should be connected to the ground (GND) of the MAKER UNO. The OUT will be connected to the A0 of the Maker UNO. All these connections are done with the help of jumper wires. On the other side of the BioAmp EXG Pill v1.0 connection of BioAmp. Cable v2 or v3 is connected to the gel electrodes, which are then connected to the gel electrodes. According to the BioAmp. EXG Pill v1.0, the reference wire (REF) left side of the neck is considered as the neutral point. Moreover, the negative potential wire (IN-) is connected to the right side and the positive potential wire (IN+) is connected to the left side.

2.1.3 Visualising the EEG

After the connections are assembled, the opening of the spike recorder can view the EEG signals. At first, the waves will be based on the sound coming from the device's microphone, which can be switched off in the settings. After which, the selection of the port is to be done in which the MAKER UNO is connected. The set band-pass

filter cutoff frequencies are used to select a fixed range of frequencies you want the electrodes to measure and which will be shown in the EEG.

2.2 NeuroAlert

A Maker Uno board with an integrated speaker (buzzer) was used to generate the beeping sound. The Maker Uno was connected to a Bioamp EXG Pill, which measured raw analogue voltage values representing EEG signals. The analogue voltage values were read from the Bioamp EXG Pill using the analogRead() function in the Arduino IDE. A threshold range for brain wave detection was defined, with ALERT_THRESHOLD_LOW set to 100 and ALERT_THRESHOLD_HIGH set to 1000. (This was done to check if the machine acts normally when the brain wave value is inside the threshold range, the average brain wave value of Ritvick Pandey, the person whose scan was used varied between 400-600). Then the threshold range was redefined, with ALERT_THRESHOLD_LOW set to 450 and ALERT_THRESHOLD_HIGH set to 550. The beeping sound was triggered when the analogue voltage value fell outside the specified threshold range (450-550). A boolean variable was used to control the beeping state and ensure that the buzzer was activated only when required.

The experiment aimed to simulate a scenario where the Maker Uno monitored brain wave (EEG) signals using the Bioamp EXG Pill and responded with a beeping sound when the brain wave values were beyond the threshold range. The setup allowed for the detection of voltage variations that might indicate unusual brain activity, hypothetically mimicking potential neurological conditions. As Ritvick Pandey scanned himself, the experiment considered personalised EEG data from a single individual.

The Arduino code has been developed by our team [12] which will alert the Neuro patient by a beeping sound through the maker uno board if it goes out of a certain Brain Value. When we refer to "brain wave values" in the context of this code, we are referring to the raw analogue voltage readings obtained from the Bioamp EXG Pill. These values are not directly brain wave frequencies (in Hz) but rather represent the amplitude of the electrical signals measured by the EEG electrodes. To stop the beeping sound the Arduino code [13] was also created by our team, which is to be run while the Maker Uno Board is still connected to the device, for instance, a laptop. A point to be noted, whenever the individual uploads a new code they have to delete the previous code and start fresh. This will prevent any errors from occurring.

2.2.3 Code ForNeuroAlert
Software code for generating auditory output

```
#define ALERT_THRESHOLD_LOW 100
#define ALERT_THRESHOLD_HIGH 1000

void setup() {
Serial.begin(9600);
pinMode(8, OUTPUT);
}

void loop() {
intanalogValue = analogRead(A0);
if (analogValue< ALERT_THRESHOLD_LOW ||
analogValue> ALERT_THRESHOLD_HIGH) {
tone(8, 1000);
delay(500);
noTone(8);
  }
}
```

Software code to stop auditory output

```
#define ALERT_THRESHOLD_LOW 100
#define ALERT_THRESHOLD_HIGH 1000

intbuzzerPin = 8;

void setup() {
Serial.begin(9600);
pinMode(buzzerPin, OUTPUT);
}

void loop() {
intanalogValue = analogRead(A0);

if (analogValue< ALERT_THRESHOLD_LOW ||
analogValue> ALERT_THRESHOLD_HIGH) {
if (!isBeeping()) {
startBeeping();
  }
 } else {
if (isBeeping()) {
stopBeeping();
  }
 }
}

boolisBeeping() {
returndigitalRead(buzzerPin) == HIGH;
}

voidstartBeeping() {
```

```
tone(buzzerPin, 1000);
}

voidstopBeeping() {
noTone(buzzerPin);
}
```

Code for Brainwave Value Measurement

```
void setup() {
Serial.begin(9600);
}

void loop() {
intbrainWaveValue = analogRead(A0);
Serial.print("Brain Wave Value: ");
Serial.println(brainWaveValue);
delay(1000);
}
```

2.3 Neuro-Blitzkrieg App

Initially, a survey is conducted to understand the perspective of the healthcare faculty on the concept of detecting patients having CSD. After which recording will be taken with the help of the EEG Signal module aforementioned. Lastly, these recordings will be sent to an app, which will forward these recordings to a doctor when needed. Moreover, this app also includes various other features.

2.3.1 Ethic Statement

Our medical app utilising EEG signals and delivering warnings to patients is built upon a foundation of unwavering ethical standards. We prioritise patient autonomy, providing comprehensive information about the system's purpose, capabilities, and associated risks. Confidentiality and privacy are paramount, with strict protocols in place to protect personal health information and EEG data. Even after all that, to confirm whether the individual is suffering from CSD or any symptoms of it, they should inquire from a medical professional instead of entirely relying on this app.

2.3.2 The Scenario of the Health Faculty

On the one hand, if the doctors were to collaborate then this app will allow us to send them the real-time data analysis. However, the data will only be sent if something is off in the EEG reading to the nearby hospital. Meaning that, a specific range will be fixed for a normal EEG signal, if it goes above that range the nearby hospital will be notified.

On the other hand, if the doctors are hesitant to collaborate, this app is still capable of being able to give EEG signals and generate a report. However, for confirmation of the diagnosis of CSD seeking a medical professional with the report is significant.

2.3.3 Somatic Mindfulness Practices

The app comes with preloaded videos showing complete guidance over meditation, yoga asanas, mudra and mantras which will effectively increase brain activities. The video section will be divided into three parts. The first part of the section will be the meditation with video and audio support explaining the steps involved in it. The second part of the section will be yoga asanas which will be started with the warmup exercises and then some asanas related to the brain will be taught in the video. Some of the asanas are ArdhaChakrasana, Padahastasana, Padmasana, PrasaritaPadasana, Shashankasana, Ushtrasana, SetubandhSarvangasana, Sarvangasana and many more. The third part of the section will discuss mudra and mantras (which act as sound therapy) such as Ekadanta mudra, Prana mudra, Chinmudra, and Hakini mudra with related mantras will be discussed in the video. Moreover, the related pranayamas will be discussed in the video(14). Last but not least, the presence of a community of individuals suffering from the same thing will help the patients feel less lonely.
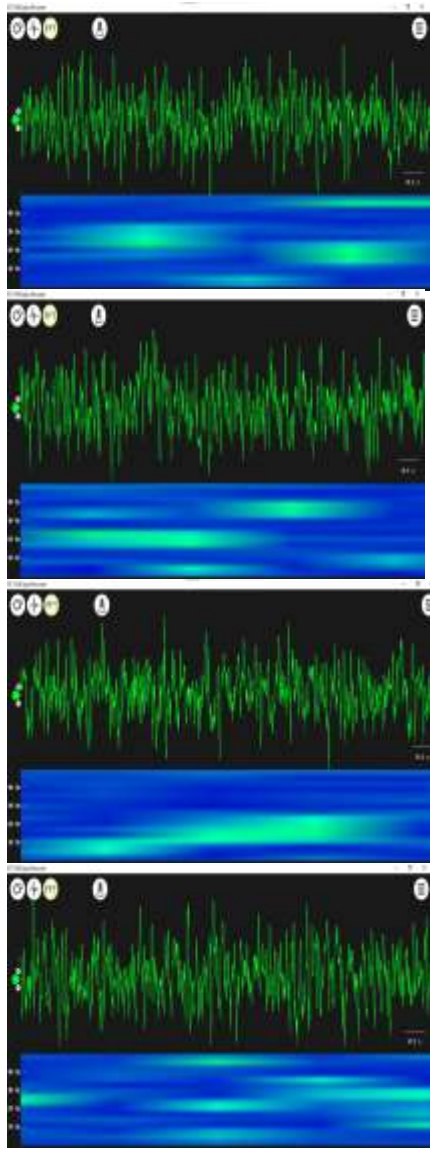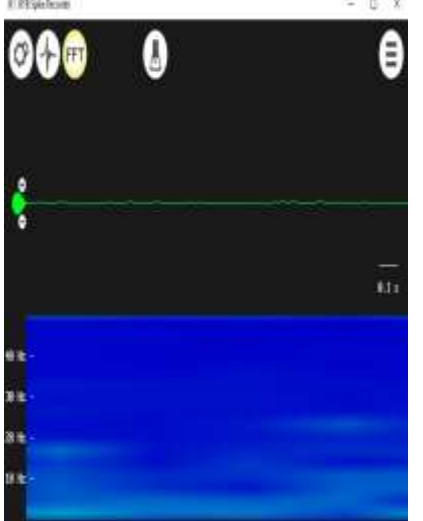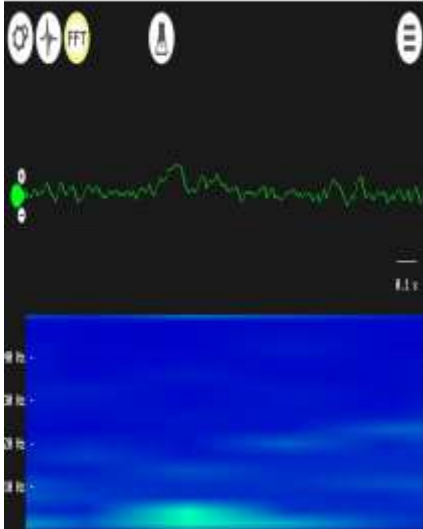
III. RESULTS

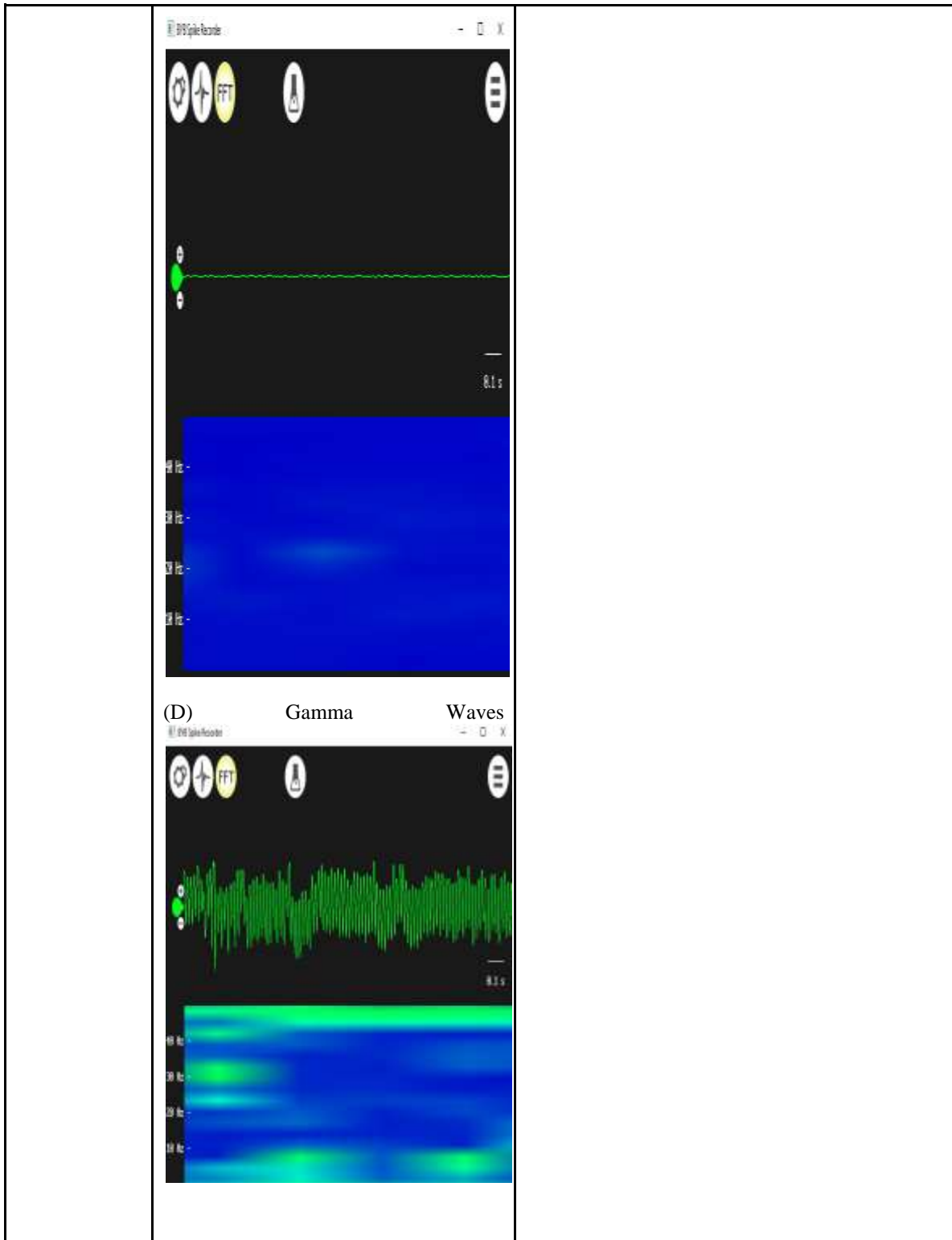### 3.1 Comparison of EEG Signals using Age as the Variable

There are various wave signals in our brain in the form of frequencies and measured in Hertz. A common one is known as the InfraSlowActivity (ISA) which represents brain activity but slowed down synaptic impulses. The ISA ranges between 0.5Hz to 30Hz in an average person. In addition, to get a deeper understanding of diseases Acute Ischemic Stroke and Severe Traumatic Brain Injury doctors utilise EEG scans and read between certain waves lying in the range ISA; [15] these include delta waves, theta waves, alpha waves, and beta waves. The range of delta waves is 1 - 4 Hz. These are Predominant during deep sleep or certain neurological disorders. The range for theta waves is 5 - 7 Hz. These are associated with drowsiness, meditation, and certain cognitive processes. The range of alpha waves lies between 8 - 12 Hz. They are often observed when the eyes are closed and the person is relaxed or
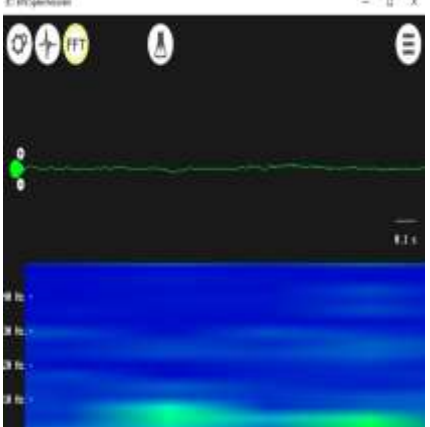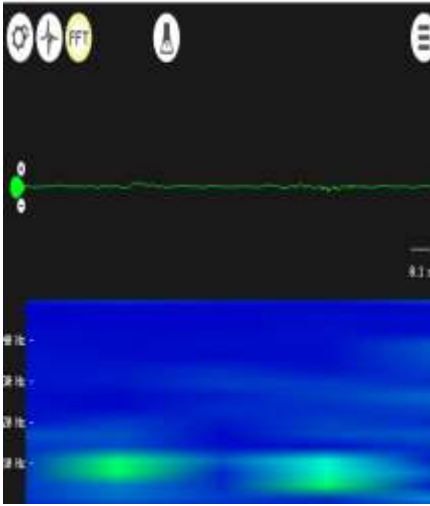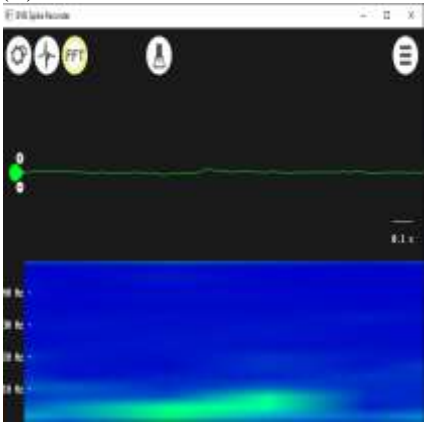
idle. Lastly, the range for beta waves lies between 13 - 30 Hz. They are common during wakefulness and cognitive activities. Moreover, the range of gamma 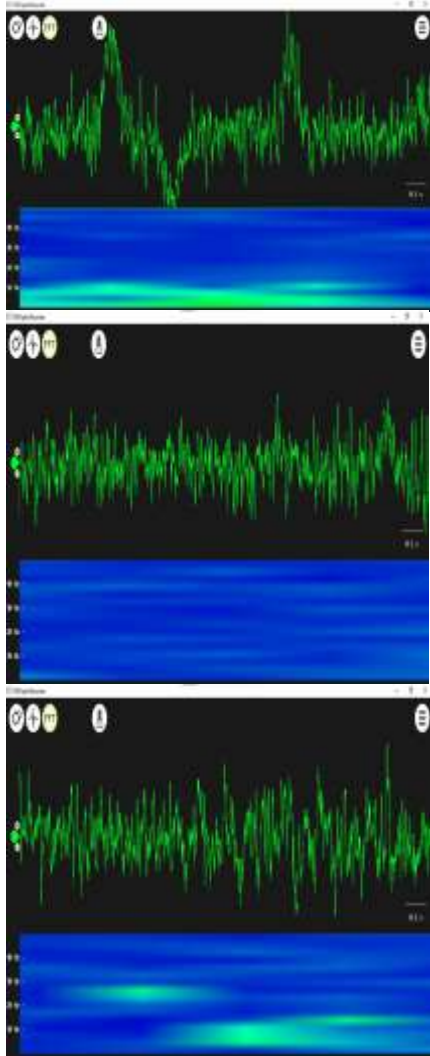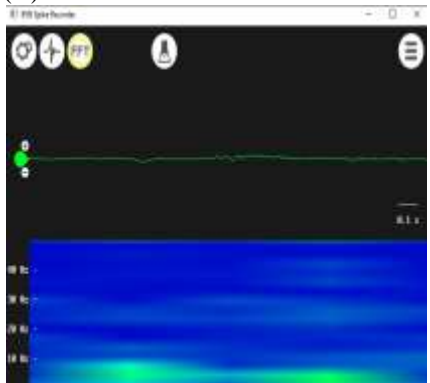waves falls between 30 - 100 Hz or even higher. They are linked to high-level cognitive processing and consciousness. The following is the illustration of the EEG Scans observed:
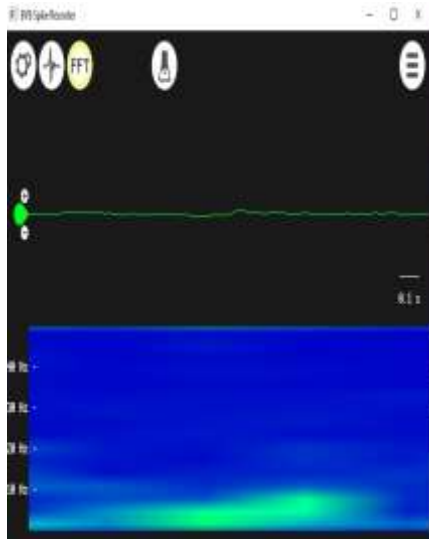
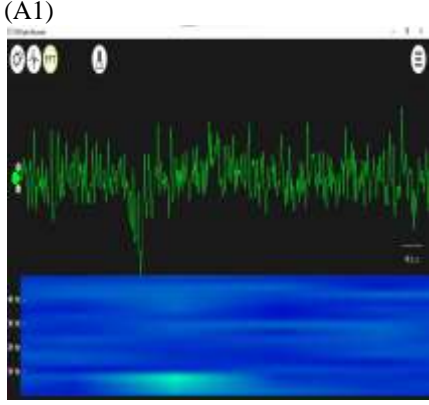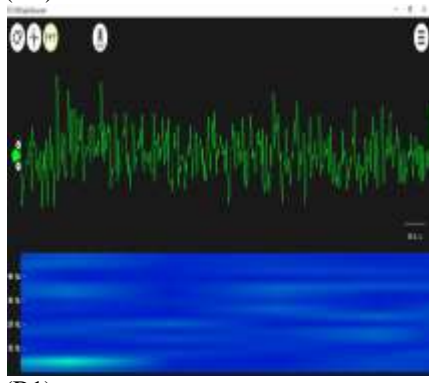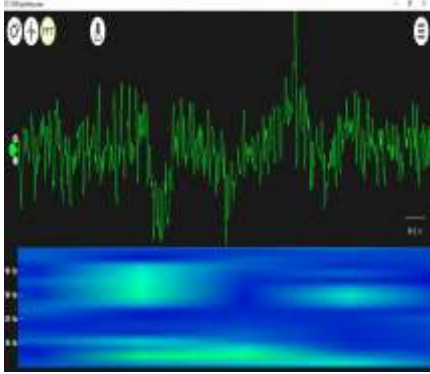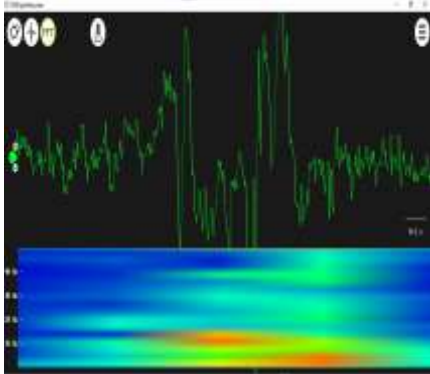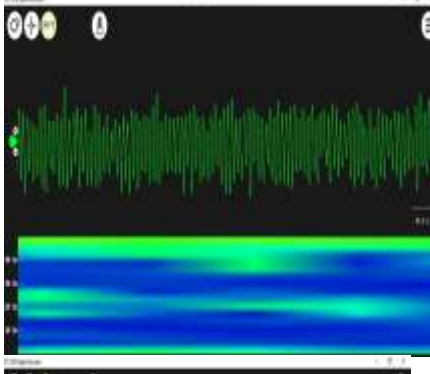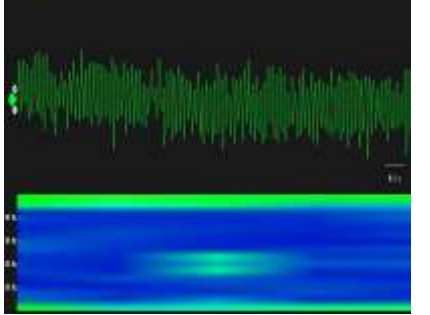| Age in Years	EEG Scans (from Spike Recorder)	Inferences
11		The following readings of EEG signals are from an 11-year-old girl. The greenish blue pattern in the Fast Fourier Transform (FFT) in the range of frequency between 13-30 Hz is considered to be Beta waves. Along with Beta waves Gamma waves were also observed. Also, the Delta, Theta, and Alpha waves were observed in less amount compared to Beta and Gamma. As the recording was taken during the day and not in sleep the presence of alpha, theta, and delta is less. The presence of more Beta waves signifies that her brain was more active. The presence of Gamma waves signifies that her brain might be concentrating.

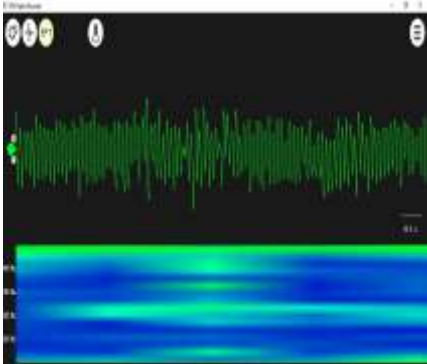| 12 | (A)Beta   waves (B)   Alpha   Waves (C)   Delta   and   Theta   Waves | The following EEG scans are of a 12-year-old girl.
(A) It is evident that the light blue strokes are Beta Waves which means that every 3 seconds there was an observation of Beta waves from the electrodes. Hence the girl's brain was active slightly.

(B)   Alpha   Waves
It can be seen that Alpha waves are slightly visible, despite the fact they were not periodic. Hence, reflecting that the young girl isn't restful during the EEG process.

(C) No signs of Delta and Theta waves were seen. Thus, signifying the fact that the patient was feeling little to no tiredness or sleepiness.

(D) Multiple gamma waves were observed through the FFT. |

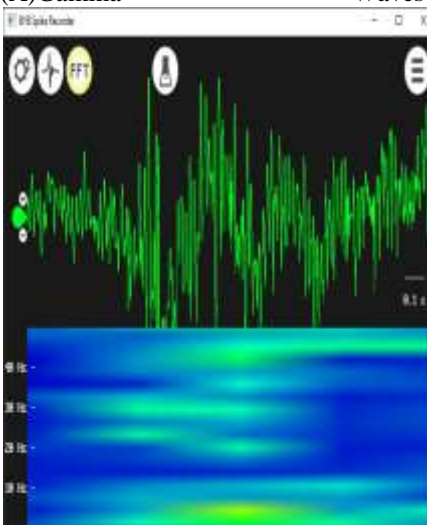(D)   Gamma   Waves

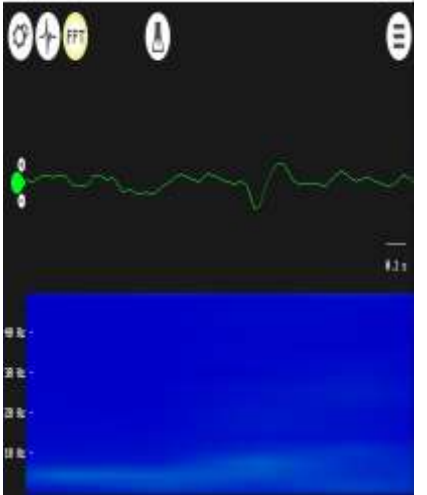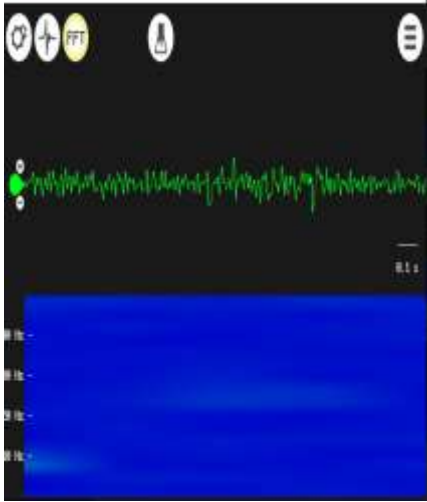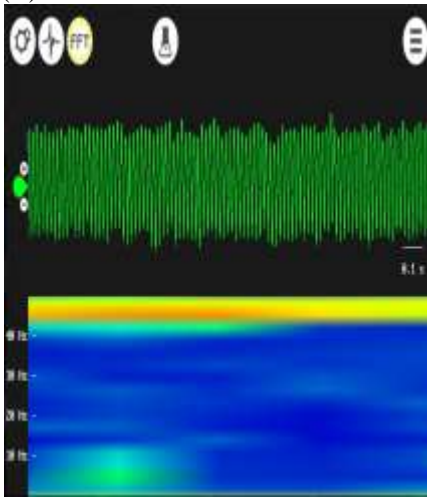| 15 | (A)Alpha   waves (B)Beta   Waves (C)Delta   Waves | The following EEG scans are of a 15-year-old teenager. (A)It is evident that the Alpha waves are recorded every 3 seconds. Therefore, her mind was quite active during the EEG recording. (B) The EEG scan reflects the presence of Beta waves; the waves were periodic every 3 seconds. Hence, during the EEG scan the individual's brain was calm and relaxed quite often. It can be seen that (A) shows that the individual's mind is relaxed as opposed to (B) scan. Both of these waves have opposing effects on an individual's mind. When your brain's alpha waves are dominating, you're likely in a state of wakeful relaxation. [16] High beta waves (18–40 Hz): known as "beta three" waves and associated with significant stress, anxiety, paranoia, high energy, and high arousal. [17] (C) Although FFT recorded the presence of a delta wave, they were not as prominent in the EEG wave signal. |

| 17 | | The following readings of EEG signal are from a 17-year-old teenager. From the readings displayed it was observed that a dark greenish pattern of waves in FFT was present below 20Hz. Delta waves were present in a dark greenish pattern resembling a calm and sleepy mind. Also, the Theta waves were found in a dark green pattern. This represents that the person is in internal focus, meditation.[18] .The majority of Alpha waves were observed in the teenager which is considered to be common. The frequency reaches the highest values at around 20 years of age and slowly declines [19]. Beta and Gamma waves were less visible than Delta, Theta, and Alpha, so the brain seemed calm and restful. |
| 23 (Deaf) | (A)Beta waves

(B)Alpha waves | The following EEG signals are of a 23-year-old young adult who is deaf.

(A) The beta waves were visible constantly, there were no observations made by the waves that are periodic. Stress, strong emotions, and tension can cause this beta power. [20] |

		(B) Alpha Waves were visible at 20 seconds periodically. Decreased Alpha peak frequency may reflect disease or brain injury such as TBI, dementia, medication effects, and age-related cognitive decline. Alpha peak frequency below about 8.5 Hz at PZ in the Adult waking record is considered slow. [21] Furthermore, no signs of theta or delta waves were observed. This could be due to the fact of them being disabled.
41	(A1) (A2) (B1)	The following readings of the EEG signal are from a 41-year-old Adult. The EEG scans here are recorded during the normal and thinking phase which shows a major difference in the case of brain waves. (A)From the EEG recordings , It is observed that the brain waves below 20Hz were more active. Delta waves were barely visible compared to Theta and Alpha waves. Alpha waves are seen more frequently than any other wave. It is the major rhythm seen in normal relaxed adults. Beta and Gamma waves are very rare .Thus it shows that the recordings were taken during the person's mind is in a calm and restful situation. (B)When the person was told to think despite the Delta, Theta, and Alpha waves the Beta and Gamma waves were seen more often. Considering the brain wavesbelow 20 Hz , we can observe that the reddish colour pattern in FFT signifies a high power value. The Delta, Theta, and Alpha waves were having high power levels than Beta and Gamma waves. This shows that the person might be busy or have an active mind while recording the signals.

	(B2)	
65		The following readings of the EEG signal are from a 65-year-old Adult. From the EEG scan recording a constant greenish pattern is observed having a frequency greater than 30Hz. These range of brain waves are considered to be Gamma waves which are found majorly throughout the whole recording. After Gamma waves, Beta waves were found almost frequently but not as Gamma waves. The presence of alpha waves was found very least. Theta waves were rarely observed but the Delta waves were almost constant with a bit of power differences which can be observed through the fading of the greenish pattern. Thus it shows that the person might be having an active or deeply concentrated calm brain while recording the EEG Scans.

|		
69	(A)Gamma Waves (B)Delta waves 	The following EEG signals of a 69-year-old. (A) There is a large fluctuation of gamma waves in the individual. Gamma brain waves have the highest frequency among all brain waves. They are associated with high levels of thought and focus. They can have different effects depending on their levels in the person's brain: If the individual's brain produces high levels of gamma waves, you tend to be happier and more receptive. [22] (B) The delta waves were less prominent, as opposed to earlier age groups. Ageing is associated with many changes with one of the most prominent being a reduction in slow-wave sleep. Hence, delta waves decrease with age. [23] (C)Although there are waves present in the EEG signal nothing much is visible in the FFT. According to NeuroHealth Associates, "Theta waves are strong during internal focus, meditation, prayer, and spiritual awareness. It reflects the state between wakefulness and sleep and relates to the subconscious mind. It is abnormal in awake adults." [24]

	(C)Theta waves 	
75 (Brain Issues)	(A)Gamma Waves (B)Delta Waves	The following EEG scans are of a 75-year-old containing some brain problems, which are unclear and the doctors aren't sure about them. (A) At first glance, a long streak of yellow and red is visible in FFT ranging above 40 Hz. The yellow colour generally signifies moderate power or activity in specific frequency bands. However, it is essential to note that the colour schemes used in EEG visualisation can vary between different EEG analysis software or researchers, and there might not be a universal standard for colour representation. (B) Contrasting to the earlier mentioned subject, this individual is suffering from a certain neurological disorder (it is not CSD and the Doctors are unclear of what it is). According to Tryhealium, Delta waves are most commonly associated with sleep and meditation. However, delta activity can also signify head trauma, exposure to toxins, or cognitive impairment if abnormally active.[25]
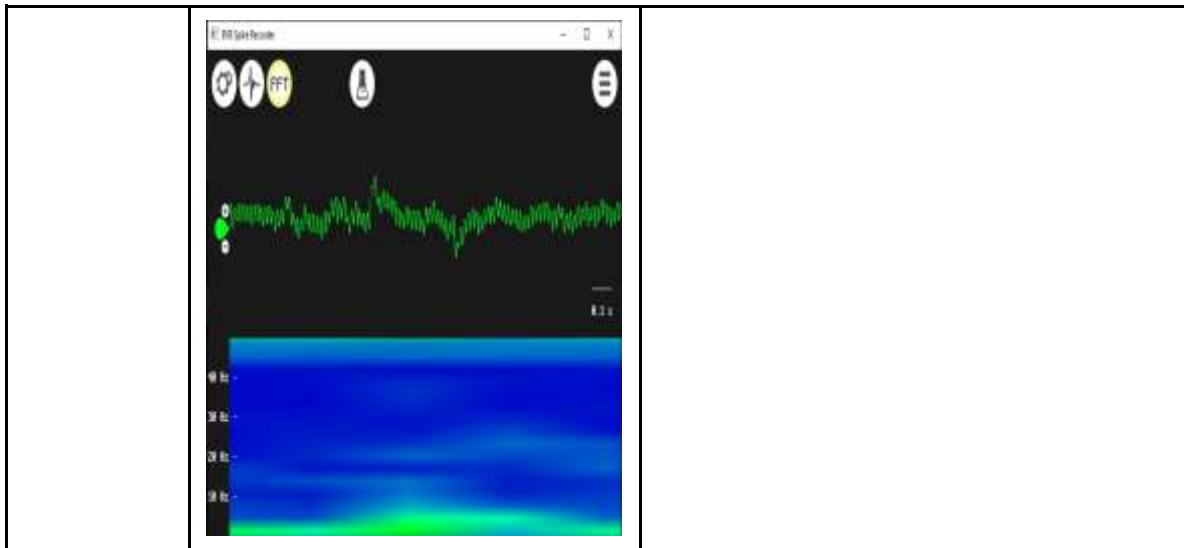
3.2 NeuroAlert on the go

The experimental setup successfully monitored brain wave signals using the Maker Uno integrated with the Bioamp EXG Pill. The graph below shows the brain wave values (y-axis) plotted against time (x-axis) during the experiment. A threshold range for brain wave detection was defined, with the low threshold set to 450 and the high threshold set to 550.
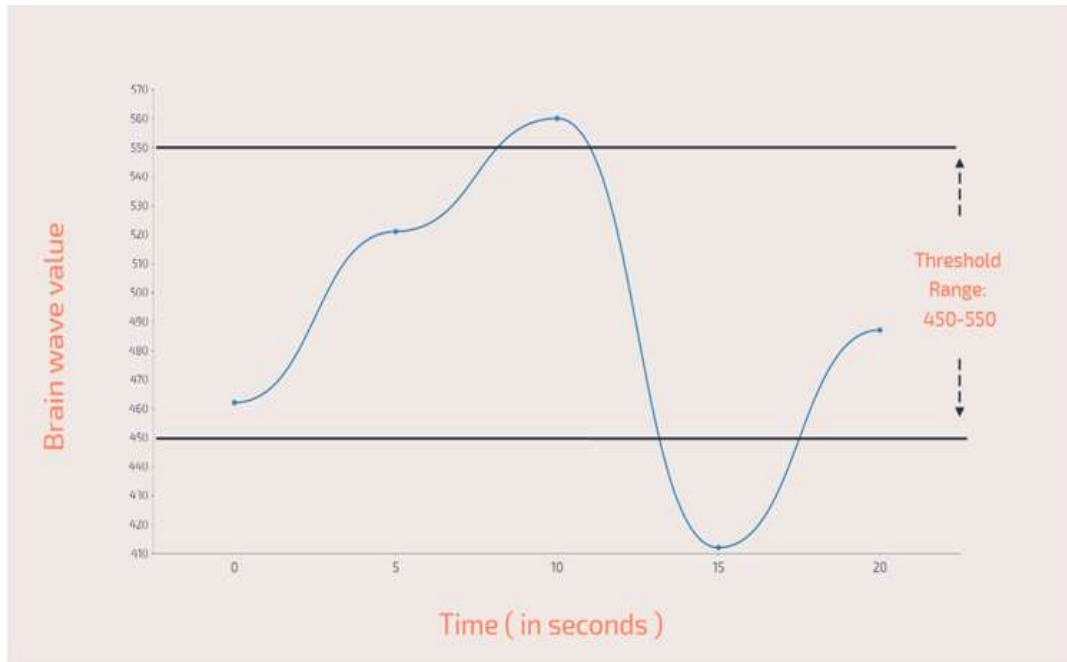
The beeping sound occurred precisely when the brain wave values fell outside the specified threshold range. These instances indicated potential abnormalities in brain activity, hypothetically resembling neurological conditions. The beeping sound effectively served as an alert mechanism, successfully identifying deviations from normal brain wave patterns. Conversely, when the brain wave values remained within the threshold range of 450 to 550, the beeping sound was not activated, indicating the machine's accurate discrimination of normal brain wave patterns within the defined range.

The experiment showed that the Maker Uno and Bioamp EXG Pill effectively monitored brain wave signals and quickly detected unusual patterns that needed attention. The fact that the beeping sound activated when there were abnormal brain wave values confirms that the setup works well as an EEG monitoring system.

The findings show the system's capability to effectively identify unusual brain activity and trigger appropriate alerts, enhancing the potential for early detection of neurological irregularities and timely medical intervention. These results highlight the significance of the proposed technology in advancing brain health monitoring and fostering a proactive approach to neurological care.

IV. DISCUSSION
4.1 EEG Scans

The observation was divided into four parts that are a school-aged child (ages 6–12 years), adolescent (ages 12–18 years)Young adulthood (generally defined as 18 to 22 or 18 to 25) later adulthood (generally defined as the mid-20s and older) [26] It is evident that the EEG waves became more prominent as the age increased (in accordance with the resting state of the patient). Spike Recorder utilised FFT (Fast Fourier Transform) which recorded the brain activity in various colours. The colours in an FFT EEG plot are often used to represent different power levels or amplitudes.Yellow or intermediate colours are commonly used to indicate moderate power values, falling between the lower power values represented by cooler colours (like blue) and the higher power values represented by warmer colours (like red). It has been observed that while thinking highly valued power patterns such as Red and orange colour has been found in FFT (Fast Fourier Transform) plots. During the restful state, these colour patterns are rarely seen. In statistical measures, mean and maximum values of EEG signal indicate the largest dispersion and they are chosen as the prominent features for the detection of different colours according to the stimulation of the brain signal. From the FFT and PSD analysis, the maximum frequency and power can be detected for specific colours.

Rhythm	Typical Frequency (Hz)	Location	Reason
Alpha	08-13	Frontal, Occipital	Relaxing, Closed eyes
Beta	13-30	Frontal, Central	Concentration & Thinking
Delta	01-05	Frontal Lobe	Deep sleep
Theta	04-08	Middle temporal	Drowsiness & Meditation

One of the individuals with whom we had done the EEG scans led to the discovery of a larger concept. Delta waves have been shown to decrease across the lifespan, with most of the waves almost invisible by the last 50s. Yet, this individual (aged 75) showed to exhibit high frequencies of Delta Waves in the scan. What does this signify? According to an Oxford Academic Press release in 2021, "High amplitude delta oscillations are frequently observed in states of diminished consciousness, including slow wave sleep, anaesthesia, generalised epileptic seizures, and disorders of consciousness, such as coma and the vegetative state. This strong correlation between loss of consciousness and high amplitude delta oscillations is thought to stem from the widespread cortical deactivation that occurs during the 'down states' or troughs of these slow oscillations."[28] .

However, as more research was done with regards to this correlation there were many other hypotheses formed stating that the delta waves had an association with the complexity or entropy of EEG and magneto encephalographic signals strongly relate to an individual's level of consciousness. Although delta waves remain a possible biomarker for the detection of various neurological disorders, not enough evidence is available to support the delta waves claim for Cortical Spreading Depression or Spreading Depolarization. As opposed to the statement aforementioned regarding the correlation between high amplitudes of delta waves and neurological disorder, there are claims stating suppression of the same can lead to the detection of one such disorder which is CSD. [29] Henceforth, more data and

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research are required to be able to draw a strong correlation between CSD and brain waves.

4.2 EEG Model

Our EEG model was utilised for the observation of variables and used as a control group. This EEG model had quite a few advantages and limitations. The advantages ranged from the effectiveness of consumer surplus to the feasibility of the app. First off, affordability combined with potential cost savings on hospital fees makes our machine an accessible and cost-effective option for patients. The high portability of our device allows patients to use it conveniently from the comfort of their homes, reducing the need for frequent hospital visits, technical expertise is not required as our machine autonomously detects and sends reports of unusual brain activity, eliminating the need for any specialised knowledge or training. Additionally, the incorporation of mental well-being exercises complements the medical treatment, offering patients a valuable tool to manage stress and enhance their overall well-being, which they can access at their convenience in their free time.

On the other hand, extremely precise EEG signals acquired using the BioAmp EXG Pill may not be as reliable as signals recorded with medical-grade EEG equipment. Another notable disadvantage of our solution is the lack of sufficient data on CSD patients, hindering the ability to gather and collect extensive information for further analysis and improvement. As of now, our machine uses brain wave value [30] to set the threshold range, however, we do not have the range of brain wave value of an individual suffering from CSD, we need to test with several CSD patients to find out the average range or figure out a way to correlate/transform brain wave values into the frequency of alpha waves, so we can find a relation between brain wave values and CSD patients. However, it is safe to say that the advantages outweigh the disadvantages.

4.3 CSD Management App
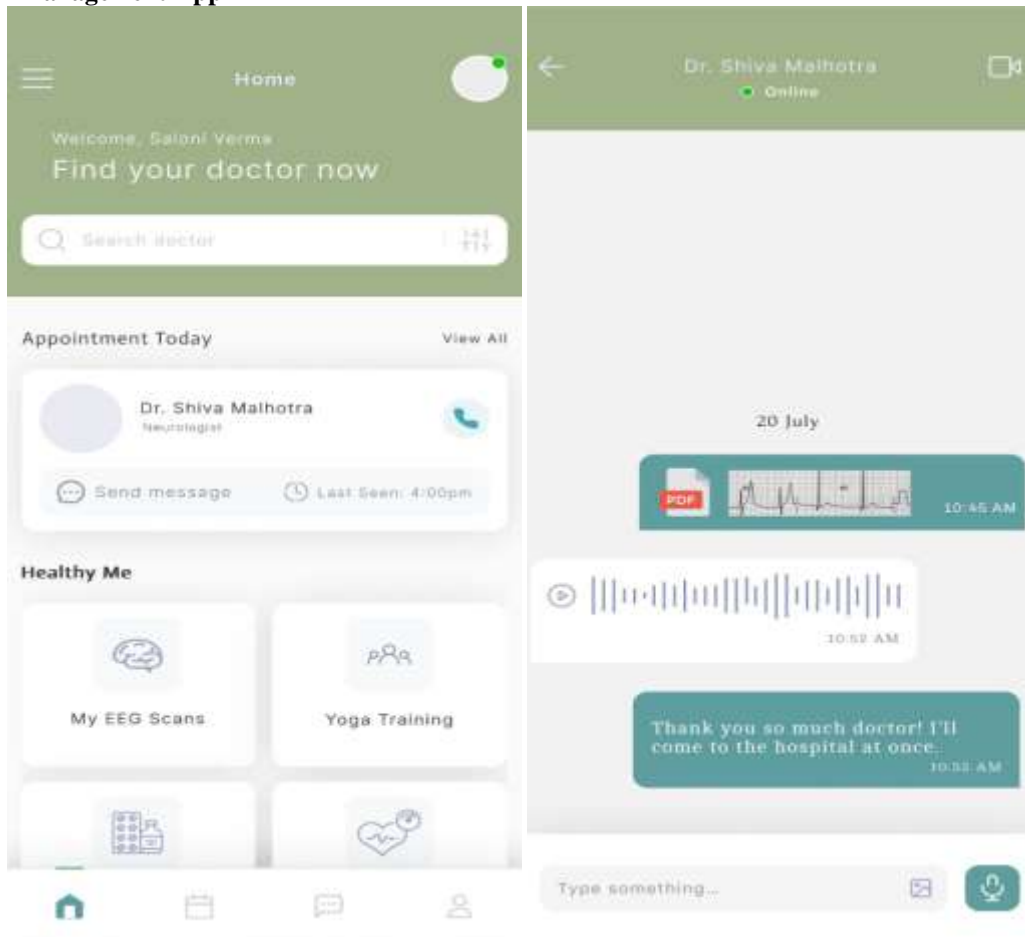
The development of our app has been a crucial step in remodelling the management of Cortical Spreading Depression (CSD) by integrating advanced technologies and holistic well-being practices. The user-friendly interface of the app provides individuals prone to CSD with several essential features, enhancing their overall experience and well-being.

Firstly, the 'Send Message to Doctor' option serves as a vital communication channel between patients and their healthcare providers. Users can conveniently send messages to their doctors regarding any health concerns, symptom updates, or queries. Moreover, the app allows for the seamless transmission of all EEG reports generated by our monitoring system. This integration ensures that patients can maintain continuous contact with their healthcare professionals, facilitating early detection and timely intervention for any potential health issues.

The 'My EEG Scans' feature allows users to access and review their previous EEG scans easily. This functionality fosters patient engagement and encourages self-monitoring, enabling individuals to keep track of their brain wave patterns over time. The ability to view past scans allows users to identify any notable changes or trends, which can be crucial in understanding their condition and assisting doctors in making informed decisions.

Additionally, we have incorporated a 'Yoga Training' module, which provides users with access to a variety of mental well-being and calming yoga exercises. Recognizing the importance of mental health in managing CSD, we curated these exercises to promote relaxation, stress reduction, and overall emotional well-being. By offering this exclusive feature, our app aims to empower users to take proactive steps in maintaining their mental and physical health, complementing the medical aspects of CSD management.

The combination of these features within a single platform enhances patient engagement, attachment to treatment plans, and overall management of CSD. By facilitating communication with healthcare providers, granting access to previous EEG data, and promoting mental well-being exercises, our app aspires to become a valuable tool in the comprehensive care of individuals prone to CSD.

In conclusion, our app represents a novel and comprehensive approach to managing CSD.

The seamless integration of advanced technology, real-time data analysis, medical reporting, emergency response, and holistic well-being practices is a significant step forward in the field of neurological health management. We believe that the utilization of this app has the potential to positively impact the lives of patients with CSD, facilitating better health outcomes and improving their overall quality of life.

V. CONCLUSIONS & FUTURE OUTLOOK

There were many hurdles in this research, but we were able to overcome a few but not many.

5.1 Closure

In conclusion, our current EEG signals module remains in its early stage, requiring a wired connection for data transmission, limiting its portability and convenience. The use of a spike recorder previously proved inefficient as it could only record EEG signals through direct connections. The survey conducted to gather feedback yielded no responses, highlighting the need for further outreach and engagement in future studies. Nevertheless, progress has been made in measuring the EEG signals of various age groups using three electrodes. However, some limitations persist, such as the absence of Bluetooth connectivity, rendering the device non-portable and reliant on continuous wiring. Additionally, the inability to be recharged also reduces its usefulness for everyday use. Our research path has paved the way for the creation of a portable device capable of detecting Cortical Spreading Depression (CSD), even though no direct collaboration with medical practitioners has been formed thus far. Moving forward, addressing these limitations and seeking medical expertise collaboration will be essential to enhance the potential of our portable CSD detection device and contribute to advancements in neurological research and patient care.

5.2 Future Outlook

The model that is currently in use will be developed to send the EEG data to the user's device through Bluetooth module HC-05.[31] The HC-05 is a widely used Bluetooth module that enables wireless communication through UART and can function as either a master or slave device, making it popular for various DIY electronics projects. If the doctors are willing to collaborate, we would prefer to send the EEG data in pdf format, through our app. That is possible only if the doctors have

installed the app, this also assures that the patient's data will be secured through our app rather than depending on third-party communication apps. Instead of using a spike recorder, we will use MATLAB, as MATLAB is a lot more precise in collecting EEG signals.MATLAB is a programming platform designed specifically for engineers and scientists to analyse and design

systems and products that transform our world. The heart of MATLAB is the MATLAB language, a matrix-based language that allows the most natural expression of computational mathematics [32]. Moreover, the EEG model will also be transformed into a finer version containing more electrodes. It will look as follows.
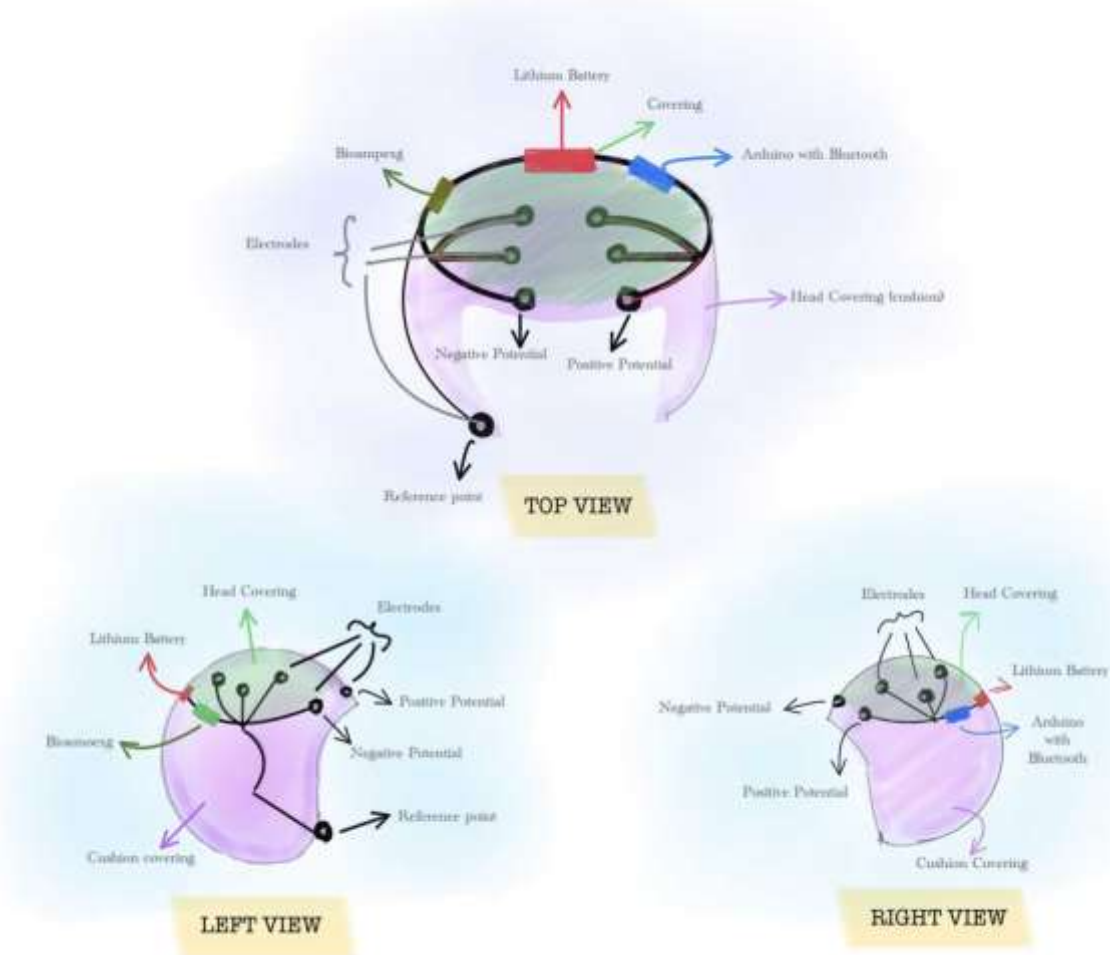
It can be seen that the EEG model will be using a Lithium Battery allowing the model to be charged. Moreover, an increase in the number of electrodes will give more precise results as the electrodes will be recorded from other parts of the cerebral cortex as well. There will be a cushion covering which will be split into two parts by the wires in the middle and the electrodes sticking out which the patient has to put on the scalp. Finally,

the data will be stored and transferred in the app through the Arduino Bluetooth module.
Furthermore, we will make the model more portable by using Arduino with built-in Bluetooth so that it doesn't require extra space for Bluetooth other than Arduino[33] or [34]

VI. ACKNOWLEDGEMENTS

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