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A solution to overcome speech disorder of patients using Brain Neuron EEG Signals

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***Abstract*: Speech disorders are neurodevelopmental disorders such as Stuttering, Dysarthria, Dysphonia and Aphasia associated with left inferior frontal structural anomalies that involve repeating or prolonging a word, syllable or phrase, or stopping during speech and making no sound for certain syllables. Most of the people who are suffering from speech disorders encounter difficulties in professional communication. Since people are busy with their day to day life, it is not practical to spend more time in consulting a doctor or do speech therapies for their medical issues. The speech therapist generally charges a significantly much higher rate for a single speech therapy practice, which the patient needs to practice at least twice or more for a week to get a better result. In an economy like Sri Lanka, people with average income cannot afford such an amount of money. Therefore, an innovative desktop application for speech disorder patients to overcome this problem has arisen. The main aim of this application is to reduce the speech imperative percentage of speech disorder patients via capturing the electroencephalogram feed of speech motor (Broca's area) using brain neuron O1, O2, C3, C4, F3, F4, F7, F8 electrodes and analyzing it to identify speech imperative issues. This system identifies the current impact on the left hemisphere of the brain (Broca's area) using EEG neurofeedback. Using speech voice analysis, the system provides the user to measure the articulation interference of the speech process. Self-Learning video tutorials are available for the clinical practices and treatments are available as prolong, relaxing, and humming exercises. Patients can track down the improvements daily or monthly by the rating system which makes the system unique among all other systems and the result can be directly sent to the desired consultant/neurophysiologist by the system itself. Patients can save time and the total cost of a therapy fee by using this system.**

Keywords: *Automated interface, Brain neuron waves, Self-learning video therapies, Speech disorders, Voice analysis algorithm*

I. INTRODUCTION

The purpose of creating this concept is to improve people's speech disorder issues by using EEG brain wave signals. The algorithm basis audio recognition pattern contains self-learning video therapy tutorials. It is a challenging task, as it requires accurate EEG measuring electrode positions and algorithm patterns which can analyze the input voice and predict the outcome impact. Self-learning therapy-based video clips will help the patients to gain their skills. Many researchers have experienced speech/voice analyzing scenarios to measure the outcome of the voice, but none focused on analyzing the real effect of the speech motor function known as Broca's area [1] which controls and functions the speech activities in the brain [2]. Since there are various types of disorders such as aphasia, dysarthria and dysphonia, there is a need for a system to identify the impact of these types of stages of the patients having speech disorders.

This system helps patients who are suffering from speech disorder problems to develop their vocal skills. The system should be operated by a patient or any third-party person. Using the system, it is possible to generate emails to doctors reminding the current activities of the patient. Between algorithm mechanisms in the system, one algorithm pattern analyses the changes of the brain's encephalography waves. The remaining speech-based algorithms help to identify the speech imperative, gaps between voices. The system provides self-learning videos for all the treatments, so patients can do treatments by themselves and, they can watch their improvements daily or monthly by the rating system which makes the system unique among all other systems. Besides, there is an algorithm-based voice pattern analyzing system to calculate the gap between the sentences and ensure the users' success using the system.

Due to the lack of such a system in the market place and based on the current studies, implementing a desktop application for people suffering from speech disorders can bring treatment to overcome their issues. This system is basically about a medical issue. Currently, many people are suffering from aphasia, dysarthria and dyslexia. This can be occurred due to many reasons such as normal speech development, inherited brain abnormalities, stroke or brain injury and mental health problems. Stammering is a speech disorder that associates repeating or prolonging a word, syllable or phrase or delaying during speech and making no sound for certain syllables. People who stammer know what they want to say/express, but have difficulty saying it. Children and adults who suffer from speech disorders get relevant medications or medications such as speech therapy and psychological consultancy to improve speech patterns.

Many researchers have gone through speech/voice analyzing scenarios to measure the outcome of the voice but none focused on analyzing the real effect of Broca's area which controls and functions the speech activities in the brain. In addition, using the video therapy tutorials, there is a chance of curing oral motor delay, tongue thrust and apraxia in children. Since there are various types of disorders such as aphasia, dysarthria, dysphonia there's a need for a system to identify such stages. [3] The main purpose of the research is to provide the most effective and efficient Information Technology based solution for people with speech disorders.

II. LITERATURE REVIEW

Jeffrey L. Fannin has conducted several studies on EEG behaviors and has discovered that the waking apprehension & reasoning wave is associated with normal waking apprehension beta (14-40Hz) [4] and an intensive state of alertness, logic and critical reasoning. Stress, anxiety and restlessness also can be translated by beta brain waves. The waves of deep relaxation are alpha (7.5-14Hz) and present in deep relaxations or during light meditation. It is an excellent time to program the mind for success and imagination, visualization, memory, learning and concentration also heightens by alpha waves. Sleep is detrimental to one's health in more ways than one. The insight wave is the Gamma wave and it is above the frequency of 40Hz. It is the fastest frequency above 40Hz. Most of the initial research shows that waves of Gamma are associated with bursts of insight and capable of high-level information processing. The slowest frequencies as known as the deep sleep wave are delta waves (0.5-4Hz) and are experienced in deep, dreamless sleep and in very deep, transcendental meditation where readiness is fully detached. The Light meditation & sleeping waves are theta waves (4-7.5Hz) all the while during deep meditation and including the all-important REM dream categories. Theta activity from 7Hz to 8Hz, where the optimal range for visualization, mind programming and using the beneficial power of the human mind begins. Children who stutter bear to demonstrate improvement in anomalies of Broca's area, such as less grey matter in the left inferior frontal gyrus, and disorganization of the white matter in the left Rolandic operculum. Researcher Dr. Christian A. Kell and her team [5] analyzed brain morphology like grey and white matter and activations during fluent speech management in PS (before and after a fluency-shaping therapy), RS, and in control, subjects using Magnetic Resonance Imaging (MRI). They have dissociated pathogenesis related anomalies from compensation effects by relating the magnitude of the neural anomaly (grey matter and white matter) to an individual degree of the symptom (off-line stuttering severity). Studies according to the past decade's neuroimaging, catered enough information on the neurophysiological changes paralleling processes like recovery from stuttering, such as treated recovery from stroke or motor learning, therefore, Roger J. Inghama, Janis C. Inghama [6] could not find a relative pattern to analyze brain activities with stuttering as well. However, they have used Deep Brain Stimulation (DBS/DES) a classical conclusion for Deep Brain Stimulation and both of stimulations are hypokinetic and hyperkinetic movement disorders with a primary subcortical origin, including Parkinson's disease, dystonia and essential tremor as well as neuropsychiatric disorders such as treatment resistant depression and obsessive-compulsive disorders, and Tourette Syndrome (TS), which is a neurobehavioral disorder. Common target structures are parts of the basal ganglia, namely the Globus Pallidus internus (GPi) and the SubThalamic Nucleus (STN). The procedure has some shortcomings that may likely decrease its potential application in stuttering.

Correspondingly within the area of deep brain simulation studies over the past twenty years, there has been a boundless boost in the number of published studies regarding the people who stutter, documenting structural and functional differences compared to their fluent peers. Andrew C. Etchella, Oren Civierb, Kirrie J. Ballardd and Paul F. Sowman [7] have found out techniques like positron emission tomography (PET), functional magnetic resonance imaging (fMRI) and near infrared spectroscopy (NIRS) which rely on the flow or the magnetization of differences in blood and are indirect measures of neural activity. Functional Magnetic Resonance Imaging (fMRI) are comparatively better among than spatial resolutions (fMRI having the highest resolution of the three), being able to determine precisely which cortical (PET, fMRI, and NIRS) and subcortical (PET and fMRI) regions of the brain are active during a task. A set of researchers; Soo-Eun Changa, Michael Angstadt a, Ho Ming Chowa, Andrew C. Etchell a, Emily O. Garnett a, Ai Leen Choo b, Daniel Kessler a, Robert C. Welshc and Chandra Sripadaa [8], joined a large longitudinal neuroimaging dataset of the patients which includes the information of who do and do not stutter in children and analysis of whole-brain network in order to examine the changes in the intra- and inter-network connectivity associated with stuttering. The activity of the brain investigated by pediatric image technology during a developmental paradigm in which participants are presented with stimuli (e.g., picture naming, sentence reading, and word generation) and are instructed to provide a response.

A preparatory investigation on the neural oscillatory aspects of speech motor arrangement prior to dysfluent and fluent utterances in adults who stutter has been carried by Anna Mersova et at. in [9]. The capability of the speech in adults who stutter has begun to characterize speech-motor based preparation prior to study speech onset the neural mechanisms. Compelling evidence has suggested that stuttering is associated with atypical processing within cortical and sub-cortical motor networks, exceptionally in the range of beta frequency, that is effective before speech production even begins. Due to the low frequency of experimental in settings of stuttering, be that as it may, the literature has so far reported predominantly on fluent speech production in adults who stutters. Individually there are issues that arise when identifying damaged brain areas of stuttering patients. Therefore, Paul F. Sowman a, et Margaret., mentioned the differences of grey matter volume [10] of left caudate nucleus in stuttering patients by asking from the participants who suffers from stuttering to self-rate their current stuttering severity and the range of severities over which their stuttering could vary on a 10-point scale (1 = no stuttering, 10 = extremely severe). Age of stuttering onset, duration of stuttering, and information about any stuttering treatment were also recorded, along with any other relevant information offered by participants.

TABLE I. EXISTING SYSTEMS

Systems	***Dysarthria***	***Apraxia***	***Oral Motor delay***	***Aphasia***	***EEG Based***	***Video Learning***
Gemm Learning	Yes	Yes	No	No	No	No
Talk time with tucker	No	No	No	No	No	No
Articulation Pro	No	Yes	Yes	No	No	No
Webber hear it	No	No	Yes	No	No	No
Proposed Solution	Yes	Yes	Yes	Yes	Yes	Yes

III. METHODOLOGY

This solution is a practical world system rather than a system that solves theories. Using a prototyping methodology is the ideal solution to fulfill this requirement. Prototyping will test the system from time to time and will provide feedback on the accuracy of the system. In general, there are many types of speech disorders such as dysarthria, stuttering, aphasia and dysphonia. All of them are interconnected to the speech motor area called 'Broca'. Using the Encephalography signals, it will be much easier to capture the impact and the weight of the disorder which damaged the brain or its functions. There are brain waves called delta, theta, alpha, beta, and gamma which can be identified as Encephalography signals. By analyzing these signals which are captured by the device called "NeuroSky Mindwave" it will show the current state or the level of the patients which they are at. Using verbal sounds(speech) level will help to analyze the impact on the speech imperatives. The Encephalography sensor module will automatically start to read the outcoming signals from the brain. Using the voice inputs by the user, the system itself will analyze the piece of voice track and shows a result set the current progress of the user compared to a pre-recorded voice clip (it will always be kept as the default and will be only used for comparisons). Simultaneously, the electronic magnetic device (NeuroSky Mindwave Headset) will capture the outcoming brain waves receiving from the speech motor area from the brain. EEG signals will be categorized into parts and filtered using an algorithm. The system will forward the captured data of brain waves to a framework that analyzes the current impact on the brain. At the end of a session, a user can send a complete report to the desired consultant a copy of the analysis report generated by the system itself.

A. Planning

Based on many literature review findings, EEG brain neuron signals were found as one of the best methods to analyze the impact on brain among human voice frequency pattern analysis. Getting the report via interviewing the patient has been proven ineffective. The therapist should be board at giving the treatments. In this research, the current situation of the patient must be identified via the algorithm. This will allow the system to provide the best solutions and medical treatments through systematic ratings, tutorial videos and voice clips. This system will use EEG brain neuron wave analyzing patterns, speech recognition algorithms. The research will be carried out continuously to find out whether there is a better way to improve the accuracy of analyzing EEG brain waves. The main research tools of this research are EEG brain wave analyzing, vocal impact tests and self-learning medical treatment videos. As to established practicality of the research, it is mandatory to use delta, theta, alpha, beta, gamma electrodes to analyze the EEG signals. Analyzing vocal impact can be considered as a little bit impractical, but to make it most appropriate the researcher has found some methods which are Frenchay dysarthria assessment, Stuttering Hexogen and voice signal sampling that can be used as exercises as well.

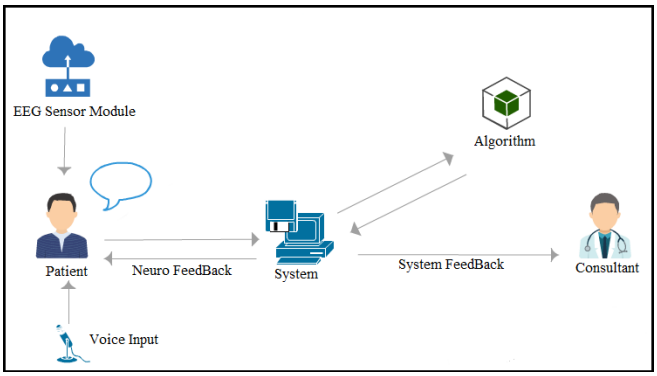

Fig. 1. System Design Diagram

B. Information gathering

Systems that assist speech disorder patients are increasingly used in web and mobile platforms. There are various types of desktop and mobile applications, but this innovation has already made way to a lot of comfort and convenience to several people having speech disorder issues. To gather primary data, meetings are arranged with the Head in Charge of Mental & Psychology department of General Hospital Colombo and Lady Ridgeway Hospital for Children, and interviews were conducted as a qualitative method of data gathering. Formal interviews have been carried out with doctors and consultants and informal interviews with patients. Interviews with neurophysiologists were conducted to gather information regarding the functioning of EEG signals and how O1, O2, C3, C4, F3, F4, F7, F8 electrodes are important to identify speech imperative issues with patients having voice disorders and what immediate reactions were made to overcome those issues by neurophysiologists.

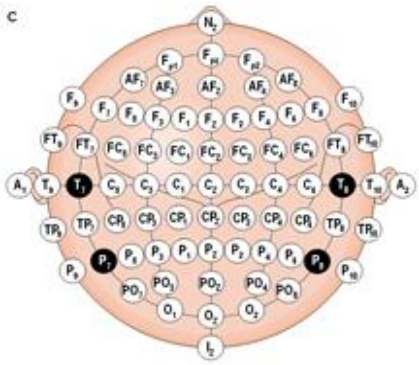

Fig. 2. EEG – Electroencephalography of Brain

Also, several meeting sessions were arranged with the physiatrist who does speech therapy such as fast track speech therapies and prolong therapies for stuttering patients. The findings from the interviews indicate that there are about 60 patients in Colombo General Hospital and collected data regarding all the symptoms and the history of their speech disorder issues. About 20 people have experienced speech disorders since birth. Some patients were stammering from time to time while some others were made by strokes. As primary data gathering, studies have been carried out for currently available voice recognition systems, identifying their methods. As for the secondary data gathering, a number of research papers were analyzed and that can be useful as a technological aspect of secondary data gathering.

C. Data Analyzing

In the present time, there is no system that analyzes speech disorders based on EEG brain signal electrodes, so developing this proposed system can be considered as a novel approach to compromise and align with the pre-designed process as its requirement analysis has been done by reviewing multiple research journals and interviews. The fundamental objective of the analysis phase is to figure out and document the needs of the business and the processing requirements of the new system. In the analysis phase of the project, requirement gatherings were carried out about the research and prioritized the requirements to achieve to desired goal step by step. Based on the studies, EEG signal analysis has been identified as the main requirement and voice recognition algorithms and self-learning video therapy tutorials as sub-requirements.

D. Designing

This will be the first phase in designing since the patient is interacting with the interface which has been already provided. The main interface contains registration, settings, view reports, video category, skills development, patient's info, encephalography analysis and voice algorithm analysis sub interfaces to allow the user to access the application in a more convenient way. The interface must be user-friendly and must fulfill all the needs of the patient and be easy to access.

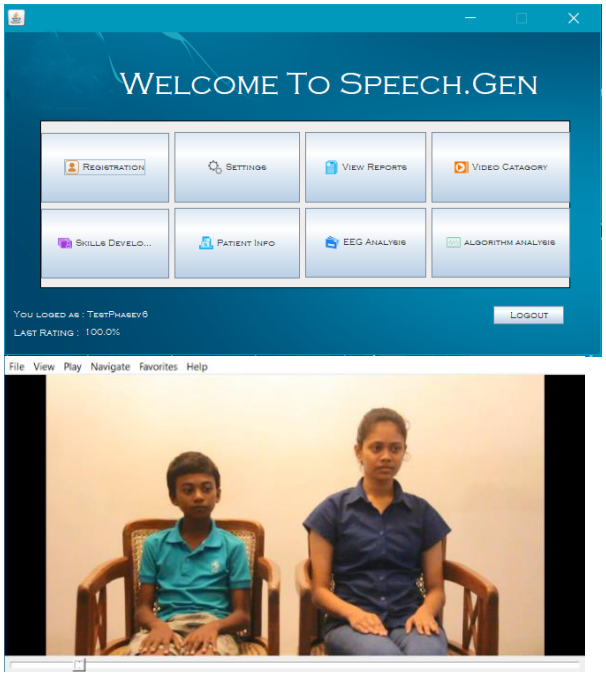

Fig. 3. Main Interface and Meditation Level signal

IV. IMPLEMENTATION

According to the information gathered, a prototype of the system was developed and shown to the responsible persons. In the EEG analysis phase, the system provides adjustable input fields for the delta, theta, alpha, beta, and gamma EEG waves. The main reason is not to set up with a static value to each signal leave because there will be various types of patients who use the system, so that frequency values depend on each patient's disorder conditions. The patient needs to be wearing the NeuroSky Mindwave Headset when running the analysis. At first, it will read and save the data to an excel sheet when only the connect was made between the device and the human brain scalp. When the process is done, it will be shown as multi-type graphs displaying the frequency compared to the expected level and it will be sent to the neurologist as an email via the system.

TABLE II. EEG FEED ANALYSIS DIAGRAM

Signal Frequency							
Delta	***Theta***	***Low alpha***	***High alpha***	***Low beta***	***High beta***	***Low gamma***	***Mid gamma***
5180	248	44	47	72	81	11	11
880113	166214	4550	10565	9681	9366	3278	1447
301403	25462	4583	3550	689	951	457	167
233022	13483	4367	1251	2444	2610	883	213
454202	253160	24639	15882	27102	7756	4334	9711
2228099	123839	55359	53930	27389	8816	8734	7712

The speech analysis can be in divided into three sections. As for the first algorithm, it inputs the patient's voice via default microphone and it will be sent to a pattern analyzing method to identify the issues and the impact on the disorders of their speeches. As for the algorithm, it was constructed and filtered by the Department of Physiotherapy and Occupational Therapy under National Hospital Sri Lanka and will predict the output via calculating voice.

Voice Pattern calculation is one of the key calculations in the system. It calculates the reading time of a given paragraph by a healthy person and a stammering patient who are facing the test. According to the results of the patient, the current improvements of the patient are determined and ratings are provided using the following equation.

TPA 1 = Reading time of healthy person – Reading time of stammering Patient

- IF TPA 1 is between 1-5 – rating = 100%.
- IF TPA 2 is between 5-10 – rating = 90%
- IF TPA 3 is between 10-15 – rating = 80%
- IF TPA 4 is between 15-20 – rating = 70%
- IF TPA 5 is between 20-25 – rating = 60%
- IF TPA 6 is between 25-30 – rating = 50%
- IF TPA 7 is below 30 = "Display to improve"

The second speech analysis uses the Frenchay dysarthria assessment (FDA) which is an international treatment standard on speech disorders. Voice clips will be recorded according to the process. the patient must read out loud the shown sentences within the given time and then it will be sent to the desired speech therapist for further analysis of the verbally sound pronunciations.

For the third speech analysis, the patient's voice will be recorded and be instantly given an image output of a frequency [11] of the input voice file. Self-learning video therapy treatments will guide the patient to improve his/her speaking patterns.

Since it is the best clinical solution available, the researcher decided to record it as video clips and divide into

the seven categories such as breathing [12], fast prolong, prolong, humming, relaxation and shadowing exercises. All these videos were recorded under the direct supervision of a speech therapy specialist. Implementation of the system has been done using NetBeans IDE 8.0. Running the system requires MySQL Server, JDK 6 (minimum) platforms. The system database has been developed in a MySQL environment. Use of these languages and database environment were based on cost-effectiveness as all of them are open source resources. Integration with an SMTP server will be required to send email reports. Predicting the patient's voice-based rating system was done based on the voice pattern analysis algorithm.

V. Results & Discussion

The results of the analysis of EEG signals in the brain neuron signals are captured and displayed in charts. According to the system feedings, there are x & y-axis charts for Delta, Theta, Low alpha, High alpha, Low beta, High beta, Low gamma, Mid gamma. Assumptions levels of a sample neuro feedback raw data of a normal person were added as follows.

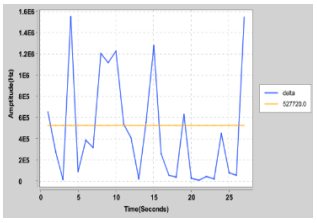

Fig. 4. Delta signal

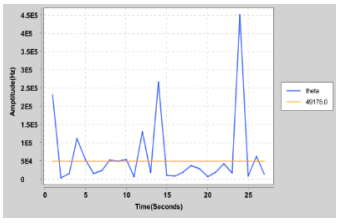

Fig. 5 Theta Signal

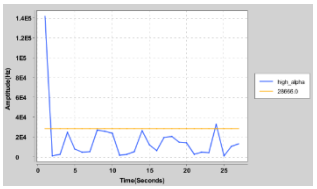

Fig. 6. High Alpha signal

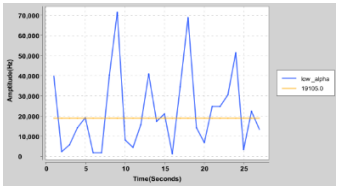

Fig. 7. Low Alpha signal

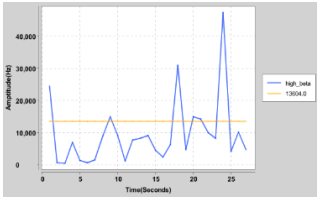

Fig. 8. High Beta signal

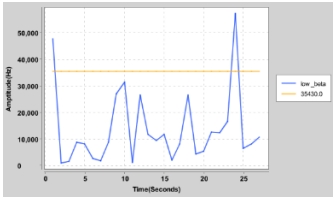

Fig. 9. Low Beta signal

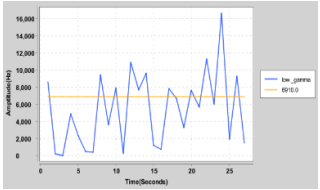

Fig. 10. Low Gamma signal

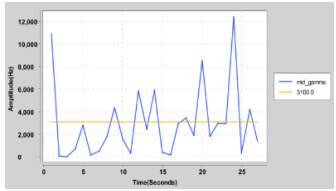

Fig. 11. Mid Gamma signal

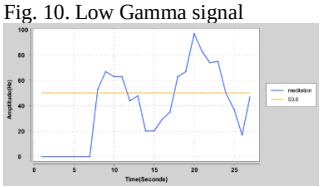

Fig. 12. Meditation Level signal

Table III. Electrode Frequency Listing

Graph Figure	Electroencephalography	
	Signal	***Frequency***
Figure 4. Delta signal	Delta	527720
Figure 5. Theta signal	Theta	49175
Figure 6. High Alpha signal	High alpha	28666
Figure 7. Low Alpha signal	Low alpha	19105
Figure 8. High Beta signal	High beta	13604
Figure 9. Low Beta signal	Low beta	35430
Figure 10. Low Gamma signal	Low gamma	6910
Figure 11. Mid Gamma signal	Mid gamma	3100
Figure 12. Meditation Level signal	Meditation Level	50

Based on the shown data on the graphs, a neurophysiologist can measure the impact of the speech motor area of a speech disorder patient. Depending on the type of speech disorders, these input values may change according to the actions taken by a neurophysiologist.

High alpha signals are the sinusoidal signals of relatively high voltage/amplitude and develop from the human's brain at about 10 waves per second. High beta signals are formless waves of low volatility/amplitude and develop from the brain at a rate of 20 waves or more per second. Between these signals, the activity of the beta signal is seen as a disruption of the activity of alpha waves. An increase in the amplitude of alpha waves is an indication of reduced consciousness. A disruption of the alpha rhythms into formless beta activity is an indication of a focus of mental activity. The more alike any two brain areas left hemisphere and right hemisphere are in alpha patterns, the more indication of the lack of mental activity. This type of indication of the mental activity can be declared as reduced consciousness.

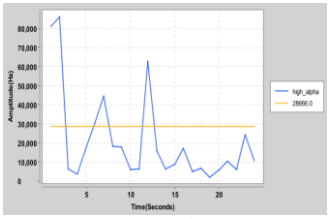

Fig. 13. High alpha of a Patient

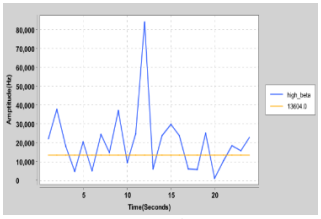

Fig. 14. High beta of a Patient

In regard to the size of the waves of speech disorder patient, it was found to have larger high alpha and high beta waves than normal person Fig.13, Fig.14. Following the criterion that larger waves, means a loss of mental specificity. Four of speech disorder patients [13] were used in order to test these scenarios. All the raw data was captured before and after the speech therapy, practical videos were watched by the patient. After attempting on several relaxations, breathing and humming exercise therapy videos with speech disorder patients, there was a slight incensement of the encephalography waves with speech disorder patients [14]. When the encephalography waves of speech disorder patient and the waves of normal person were compared, the normal person was discovered to have a stabilized amplitude and the speech disorder patient [15] was found with larger waves with high amplitudes and failed to maintain attention level as well. This was done only on the left hemisphere of the brain area.

As per the voice spectrum analysis, the finding indicates that there are differences in the normal person's voice

spectrum [16] against the patient's voice spectrum. It cannot be identified by the patient himself, but those spectrums will be sent as an e-mail to the neurologist/consultant via the system, in order to analyse further.

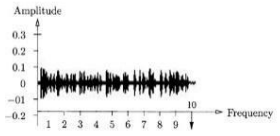

Fig. 15. Original Spectrum Signal

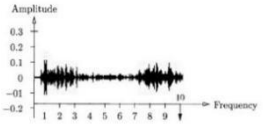

Fig. 16. Sample Spectrum Signal

The system was pre-integrated with a voice spectrum sample of a person [17] who does not have any speech disorders Fig 15, during the use of the system it compares with a voice spectrum sample of a speech disorder [18] patient Fig 16. Later, the test sample spectrum file will be sent to a doctor/neurologist for further analysis of the patient's sound wave condition in order to find defects of the speech.

VI. CONCLUSION

Current studies have found that using the EEG signal helped patients to monitor their level of impact, but not to identify the direct impact because the NeuroSky Mindwave device which I used to identify the EEG signals only covered the T4, A1 and Fp1 electrodes in the brain scalp and the device only had 1 channel to simulate the signals. Most electrode places were not covered by the electrode channels such as O1, F3, F4, F7, F8 electrodes which were only specialized for the speech motor area due to the lack of electrode channels of the device. However, there was a significant improvement in using the EEG signals for neurologists to maintain the patient's anxiety level using the mediation level provided by the system. Also, the Delta, Theta, Low alpha, High alpha, Low beta, High beta, Low gamma, Mid gamma signal levels were useful to monitor and track the brain activity while using the system multiple times. Fluency of speaking of the speech disorder patients has been improved using voice analysis patterns and with the help of self-learning video therapy tutorials as well. Therefore, the effectiveness of the suggested solution to overcome the issue of speech disorder patients using brain neuron EEG signal is clear as per the significant improvements of patients. Based on the studies, several factors and drawbacks were identified and those will be useful to inform the future studies in this type of speech disorder.

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