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SPECIAL SECTION ON NEW TRENDS IN BRAIN SIGNAL PROCESSING AND ANALYSIS

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A Review on Electroencephalogram Based Brain Computer Interface for Elderly Disabled

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ABSTRACT Lack of communication causes problems for patients with neurodegenerative diseases, so the need for alternative methods is required to convey their thoughts with caretakers, friends, and family members. Brain–computer interface (BCI) is a device to control external devices by using mental thoughts without any other muscle movements to improve the communication quality for the disabled individual without any other help. The techniques of measuring electrical signal around the scalp during some activities by using electrodes are called electroencephalogram (EEG). By combining these two technologies together to form a brain–computer interaction, this helps the paralyzed individual to communicate with others to share the thoughts. In this paper, we deal with the history of EEG, electrode placements with measurements, and signal ranges, and also further discussed some of the prominent studies completed in designing BCI using EEG. This helps the new researchers to know the EEG measurement and position completely and paved the new way to create EEG-based interface research.

INDEX TERMS Electroencephalogram, spinal cord injury, locked in state, artificial neural network, brain computer interface, support vector machine, linear discriminate analysis, power spectral density.

I. INTRODUCTION

The history of EEG started from 1875 by Richard Canton from Liverpool, he found the electrical activity in animals like dog and rabbit's cerebral position of the brain. In 1890 the scientist named Adolf Beck noted the electrical action of the brain by directly placing the electrodes on the brain surface of the animals. From this study he identified and concluded electrical activity in the brain causes continuous brain waves for all the action performance. Using these waves he classified that different patterns were obtained for different tasks. In 1912 the physiologist named Neminsky identified and published the EEG based evoked potential for dog. Through the continuous study, in 1914 Cybulski and Jelenska photographed the EEG signal with seizure while recording.

During 1924 German Psychiatrist named Hans Berger first record the human EEG signal and paved the way to analyze the brain activity for human beings. Through this new invention remarkable events were took placed in the field of neurology, neuroscience and behaviors. In 1934 the scientists Edgar and Matthews developed the EEG devices for acquiring the EEG signals. In the same year the physiologist Fisher and LowenBack identified spikes in EEG signal and first EEG laboratory was opened at Boston for further study.

During the 1940 the biophysics professor from North Western University named as Franklin Offiner developed an EEG prototype model to detect the brain waves during the action. In 1950 William Grey Walter developed EEG topography to map the electrical activity around the scalp. This technique gave path for Neurologist and researchers to identify the brain signal records. During 1990 EEG signals collected from the brain signals were converted to thoughts with the help of Brain Computer Interface (BCI) and EEG [1]–[7]. By using this method we can able to manage the devices like mouse, wheelchair, keyboard and home appliances etc.

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II. ELECTRODE PLACEMENT AND POSITION

10-20 International electrode standards is followed to position the electrodes for acquiring EEG signals from Nasion to Inion and other measurements from one ear to the end of the other ear (Normally from pre auricular or mastoid) for all different subjects. 10-20 electrode system is nothing but distance among neighboring electrodes are either 10% or 20% of the total front and back or right to left distance of the scalp shown in fig.1.

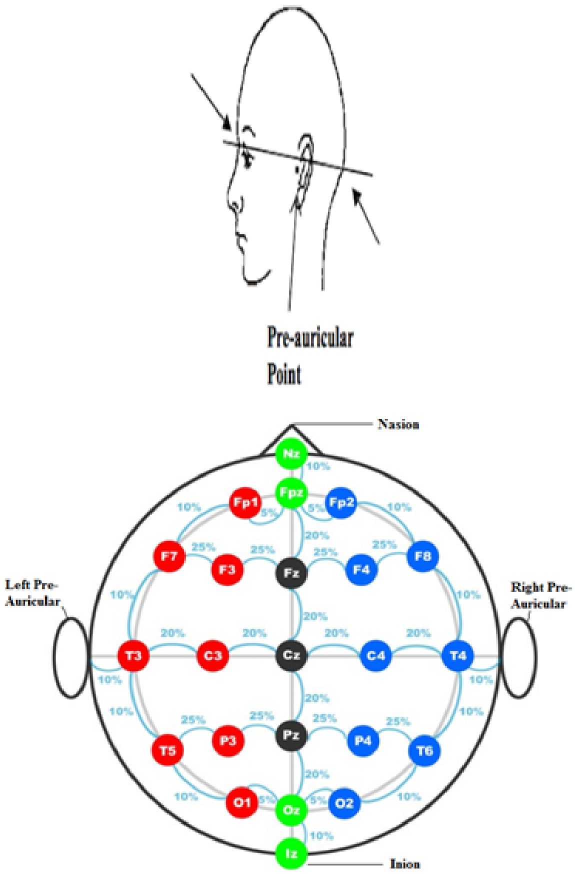

FIGURE 1. 10-20 electrode placements with pre-auricular setup.

Electrode positions are classified in to six landmarks, they are Frontal (F), Pre-frontal (Pf), Parietal (P), Temporal (T), Central (C) and Occipital (O) represented in the fig.1. All the odd number electrodes (FP1, F7, T3, T5, O1, C3, F3, P3) are present in left side of the scalp at the intervals of (5%, 10%, 10%, 10%, 5%, 20%, 25%, 25%) from midline and even number electrodes are present in the right side of the scalp at the intervals of (5%, 10%, 10%,10%, 10%, 25%, 20%, 25%) from the midline. The electrode position in the midline (FPZ, FZ, CZ, PZ, and OZ) with interval of (10%, 20%, 20%, 10%, 10%) [8].

A. EEG POSITION MEASUREMENT STEPS

Step1: Take a measuring tape. Measure over from Nasion to Inion and note down the length. This is shown in the fig.2

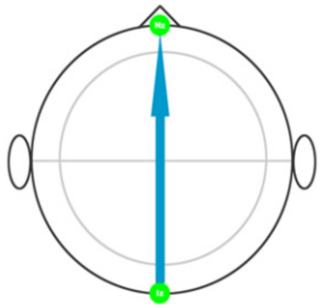

FIGURE 2. Nasion to inion measurement.

Step2: Mark 50% of the total length and named as Cz. This is shown in the fig.3.

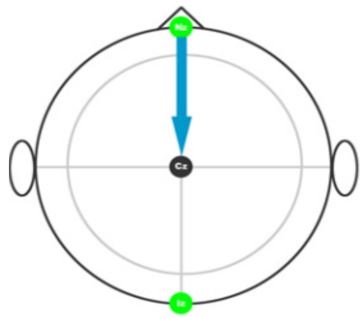

FIGURE 3. Cz placement.

Step3: Mark 10% up from Nasion and 10% from Inion and named as Fpz and Oz. This is shown in the fig.4

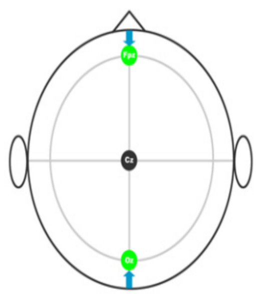

FIGURE 4. Fpz and Oz placement.

Step4: From Fpz and Cz mark 20% on up and downside and named as Fz and Pz. This is shown in the fig.5

Step5: Measure the total distance between left pre auricular and right pre auricular of the ear to identify the total length. This is shown in the fig.6

Step6: From the left pre auricular and right pre auricular mark 10% from left to right and right to left and named as T3 and T4. This is shown in the fig.7.

Step7: From the first track position, T3 to Cz and T4 to Cz measure and mark 20% from left to right and right to left and named as C3 and C4. This is shown in fig.8.

Step8: Mark 5% from Oz on both left and right side and named as O1 and O2 and mark 5% from Fpz on both left and

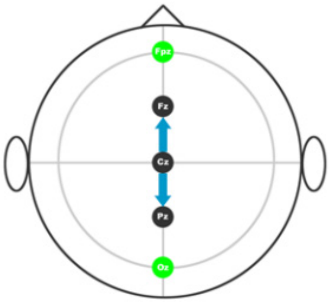

FIGURE 5. Fz and Pz placement.

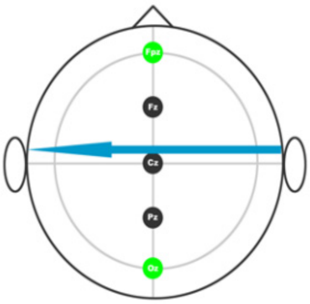

FIGURE 6. Distance between left pre auricular and right pre auricular.

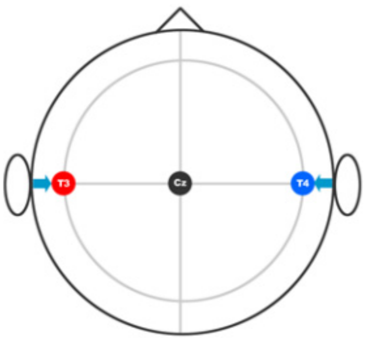

FIGURE 7. T3 and T4 placement.

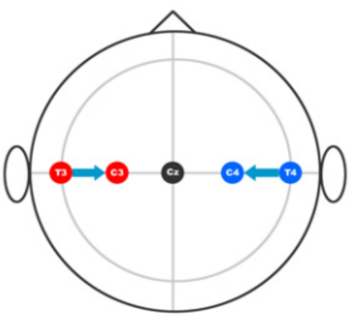

FIGURE 8. C3 and C4 placement.

right side and named as Fp1 and Fp2. This is shown in the fig.9

Step9: From the position Fp1 and Fp2 mark down 10% and named as F7 and F8 and measure the total distance between F7 to F8. This is shown in the fig.10.

FIGURE 9. O1,O2, Fp1 and Fp2 placement.

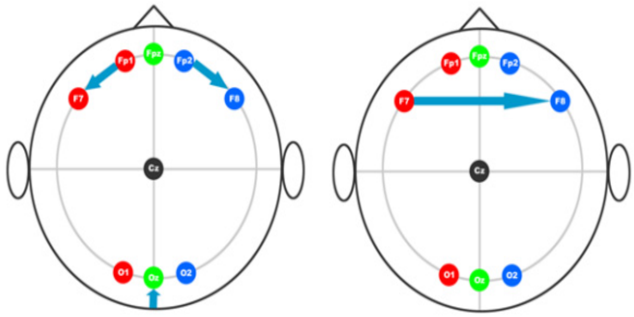

FIGURE 10. F7 and F8 placement.

Step10: From the step9 measure the half of the total distance between F7 and F8 and named as Fz. This measurement is shown in fig.11.

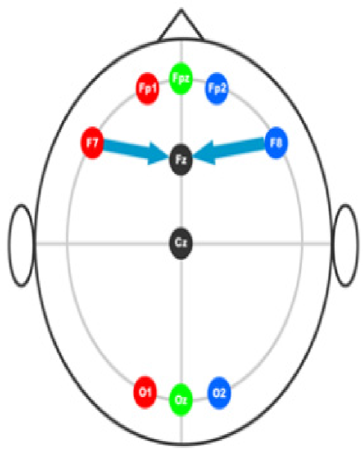

FIGURE 11. Fz placement.

Step11: Next measure the distance between F7 to Fz and F8 to Fz and mark half of the distance and named as F3 and F4.To confirm the F3 and F4 position mark down 20% from Fp1and Fp3, the intersected point F3 and F4 are present. This cross measurements shows that marked positions are true which is shown in the fig.12.

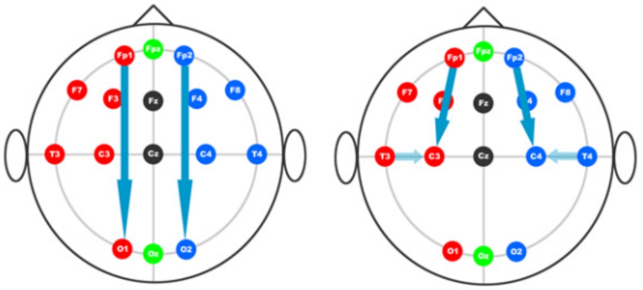

FIGURE 12. F3, F4 placement.

Step12: To confirm the marked position mark half distance from total distance between Fp1 to O1 and Fp2 to O2, C3 and C4 are present. This is shown in the fig.13.

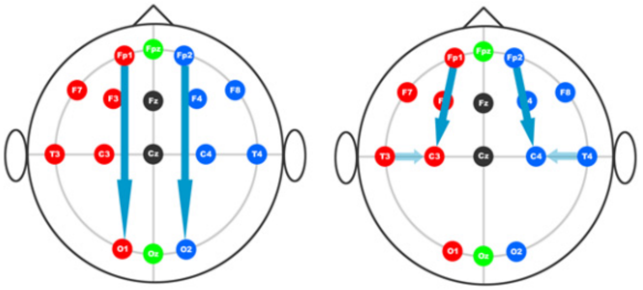

FIGURE 13. C3, C4 placement confirmation.

Step13: From the position T3 and T4 mark down 10% and named as T5 and T6 which is shown in fig.14.

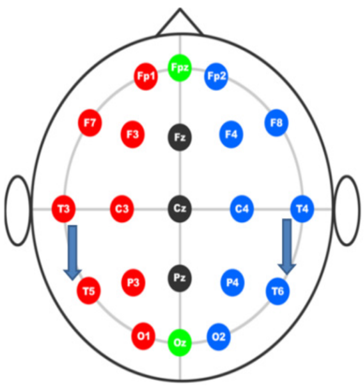

FIGURE 14. T5, T6 placement.

Step14: From the Inion to Nasion measure and mark 10% above and named as Oz. From Oz measure and mark 25% above and named as Pz. To confirm the exact Pz position measure the distance between T5 to T6 and mark the half of the total distance. This cross measurements shows that marked positions are true which is shown in the fig.15.

Step15: From the position T5 to Pz and T6 to Pz measure and mark 25% and named as P3 and P4 position. This is shown in fig.16.

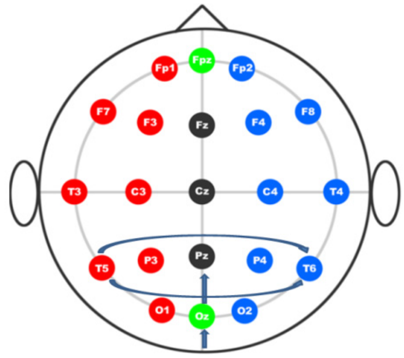

FIGURE 15. Pz placement.

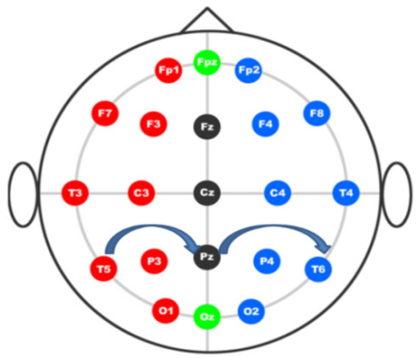

FIGURE 16. P3, P4 placement.

III. EEG RECORDING

During the EEG recording electrodes were placed separately in the scalp by 10-20% international standards of the human head using conductive gel or sometimes subjects were asked to wear the electrode cap, its depend up on the research shown in fig.17. Each and every electrode connected to a bio amplifier for EEG recording. Now an activity performed by the human was converted to electrical signal and pass through the electrode and reaches the bio amplifier or differential amplifier.

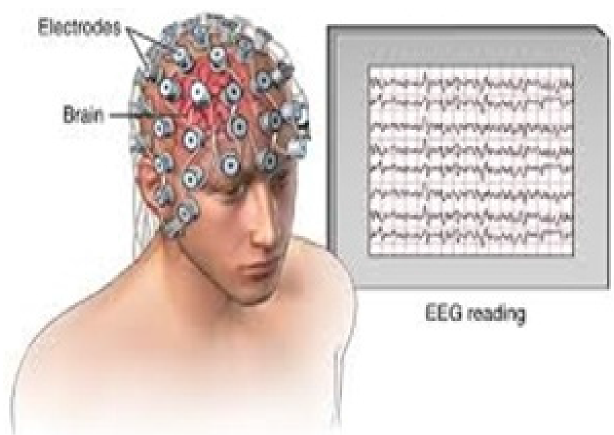

FIGURE 17. Electrode cap.

Filters were designed inside the amplifier to filter both high pass as well as low pass signals. Filtered amplified Signals were enter in to the personal computer through serial port. Signals from the brain activity were converted in to wave forms on screen with the help of chart (eg.ADILabchart) which is displayed in the personal computer or laptop. During the signal acquisition EEG need sound proof room for its recordings [8].

A. EEG SIGNAL RANGES AND BEHAVIORS

Normally EEG signals were differentiated into six categories depends upon the frequency levels shown in the Table.1 [9]–[15] and fig.18. EEG analyzes the activities in the form of waves. Using this wave pattern we can able to analyze the brain disorder associated with the human beings. By analyzing the signal variance, we can able to find some of the brain oriented disorders like epilepsy, Strokes, neurodegenerative diseases, Sleep disorders, brain dysfunction etc.

TABLE 1. EEG signal ranges and behaviors.

Frequency Band	Frequency (Hz)	Signal Occurrence
Delta	Less than 4	Slow waves occurred in infant
Theta	4–7	Higher than delta, higher waves in young children and sleepiness in teenagers and adults
Alpha	8–15	Relaxed, closing the eyes
Beta	16–31	Energetic thinking, Attention, high alert, anxious
Gamma	More than 32	Combining two different sense like reading while writing
Mu	8–13	Motor neurons in rest state

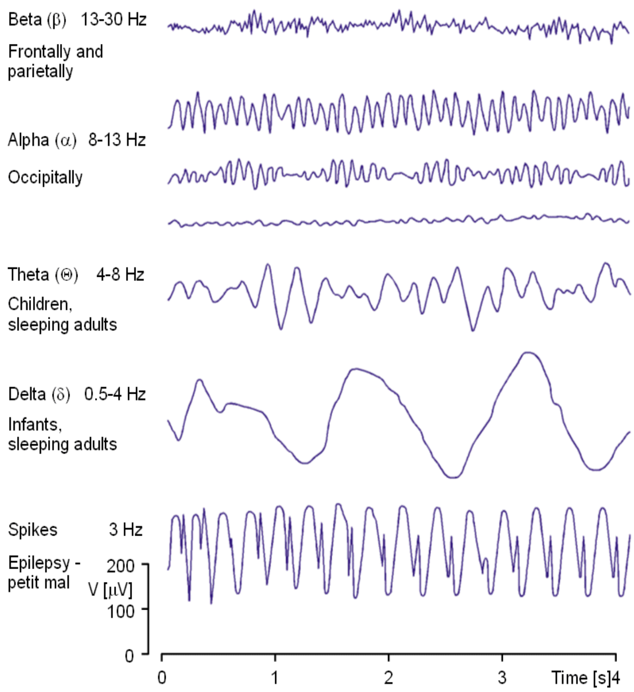

FIGURE 18. Different types of EEG waves.

IV. ARTIFACTS

Artifacts are nothing but unwanted activities during signal acquisition and make the noisy signal or the signal acquisition is not from the cerebral origin of the scalp area is called artifact. Generally artifacts were classified into two major categories termed as physiologic and extra-physiologic artifacts. Physiologic artifacts were raised from human body excluding the brain and Extra-physiologic artifacts were raised from outer surface of the body [16]–[21]. Some of the common physiologic and extra-physiologic artifacts were added with EEG signal during the acquisition, they are:

i. Bad electrode Position,
ii. Poor Ground Electrode
iii. Not clean properly
iv. Eye blink
v. Electrode impedance
vi. Equipment Problem
vii. Power Line Interference
viii. Ocular Artifacts
ix. Cardiac Artifacts
x. The Muscle Disturbances

V. BACKGROUND STUDY

There were several studies related to EEG based BCI had been developed to overcome the problem for disabled individuals. Some of them work carried out in this area were listed below. Pascual *et al.* [42] designed BCI to operate the upper-limb neuroprosthesis using non-invasive motor imagery tasks. To identify the performance of the system, single trail analysis was conducted for two tasks and obtained the accuracy of 80% for the following tasks [22]. Reshmi and Amal [41] established wheelchair controller using EEG signals for five motor imagery states using SVM classifier with wavelet technique. The control signals are passed towards ATMEGA 328 microcontroller to govern the wheelchair movements [23]. Aznan and Yang [39] developed BCI controller using common spatial pattern with Radial Basis Function classifier. Obtained result was compared with Fisher Linear Discriminant Analysis to analyze the better classifier for motor imagery tasks to move the external devices [24]. Kim *et al.* [40] created EEG controlled wheelchair for five motor imagery tasks using common spatial pattern with linear discriminant analysis to move the wheelchair on the multi pathway [25]. Sarmiento *et al.* [38] created EEG based automatic vowel recognition system for amputated individuals using Support Vector Machine (SVM) and Power Spectral Density (PSD) and acquired the classification precision of 84% to 94% [26].

Tan *et al.* [35] modeled BCI controller to determine the familiar and unfamiliar Images using band power method and Support Vector Machine (SVM) from seven subjects and obtained the average accuracy of 70.71% [27]. Aydemir [37] developed wheelchair system using modern feature extraction techniques with different classifiers and obtained the classification accuracy of 69.08%. Compared with previous experiment results, this study showed encouraged performance with good accuracy [28]. Fan *et al.* [36] created EEG based BCI for neuro-developmental disorder to determine the Autism Spectrum Disorder using 14-channel EEG neuroheadset. Seven different classifiers and obtained the 75% accuracy for classifying emotional states and 80% accuracy for mental tasks [29].

Pan *et al.* [34] developed EEG based BCI to detect the emotions using SVM and Common Spatial pattern to recognizing the emotional tasks like happiness and sadness from six subjects. Extracted signals were applied using specific frequency bands and fixed frequency bands. The study proves that subject-specific frequency band performance was high with average classification accuracy of 74.17% compared with fixed frequency bands [30]. Smitha *et al.* [33] designed a EEG based BCI to recognize the familiar and unfamiliar voice using continuous wavelet transform and Linear Discriminant Analysis for eight subjects and obtained classification accuracy of 72.2% for familiar and unfamiliar voices[31].

Huang *et al.* [31] developed EEG based wheelchair controller for two states using LABVIEW to enhance the quality of disabled patients and obtained the accuracy of 60% and 70% for motor imagery tasks like right and left [32]. Mohammadi and Mosavi [28] modeled the wheelchair for the disabled person to overcome the communication problem using Filter Bank Common Spatial Pattern with Naive Bayesian classifier and Mutual Information (MI) algorithm to translate the human thoughts to control signals [33]. Rajesh and Mantur [30] proposed automatic controlled wheelchair for quadriplegia and locked in state patients using EEG and EOG methods. Deep learning network method was used to categories the tasks and obtained the accuracy of 99% for one task [34]. AlQattan and Sepulveda [32] developed EEG based BCI to recognize the American Sign Language for speech disabled using SVM and LDA with Entropy method to determine the accuracy of the system and obtained the accuracy of 75% through the assist of the brain signals [35]. Liu *et al.* [29] developed realistic rehabilitative device with EEG technique and motor imagery tasks for ALS and SCI patients using Power Spectral Density and linear discriminate analysis and obtained the classification accuracy of 0.67 ± 0.07 [36].

Nguyen *et.al.* [25] created EEG supported audio speller using energy features and Support Vector Machine for three states and obtained the accuracy of 93.8% with average spelling rate of five letters per minute [37]. Han and Im [22] designed EEG-based brain-computer interface system for real time communication for disabled person and obtained the accuracy of 87.5% for female subjects using support vector machine, linear discriminant analysis and Riemannian geometry[38]. Pelayo *et.al.* [27] created robotic arm for disabled individual using steady state visual evoked potential method to control the servo motors directions to control the device and obtained the classification accuracy of 85.56% to get better the lifestyle[39].

Pinheiro *et al.* [23] modeled intelligent wheelchair using motor imagery tasks for 106 subjects using mean features with recurrent neural network and obtained the accuracy of 74.96% for patients with Cerebrovascular Accident [40]. Dehzangi and Farooq [26] designed Brain Computer Interface for patients in Intensive Care Unit affected with locked in state using Power Spectral Density Analysis and Canonical Correlation Analysis with Steady State Visually Evoked potential and obtained the accuracy 98.7% for ten subjects [41]. Choi *et al.* [24] patterned auditory stimuli-based BCI system to identify the sleepiness using frequency-band optimization algorithms and common spatial pattern and obtain the performance accuracy of 68.07% and 71.8% respectively [42]. Junwei *et al.* [43] proposed wheelchair control for four subjects using Radial Basis Function with band power methods to perform online study and obtained the classification accuracy of 92.50% [43].

VI. CONCLUSION

As per the background study we confirm that EEG was the most excellent tool to measure the brain reflections. By inserting electrodes on the scalp the neurologist and researchers can able to find the brain activity in terms of wave patterns. For measuring the EEG signal it required the following things

i. Electrode leads or electrode cap
ii. Conductive Gel
iii. Sound Proof Room
iv. Bio Amplifier with Filters
v. Personal Computer or Laptop
vi. Lab Chart or some other chart for visualizing the EEG signals during Acquisition
vii. Trained or Untrained Subjects
viii. Other required things depends upon the study

To avoid the unknowing mistakes of the equipment one should connect the equipment by placing electrodes on scalp of the subject and without subject and observe the reading. If both signals for same tasks are different confirm that equipment is working properly. Through this study, we have discussed the electrode position with measurement details, EEG wave patterns and its ranges and some of the works carried out from past five years in the field of EEG based BCI. So this paper will give basic ideas to use the EEG based study for the beginners. From this study we concluded that EEG requires less training and practice. Through the proper training we can able to achieve good result using this technique.

VII. FUTURE PLAN

As per the schedule of funding agency, In future we are planned to design the Brain Computer Interface for disabled individuals using EEG techniques.

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