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A Study of Frontal Signals in Brain Computer Interfaces: Interpretation of EEG & FNIRS

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ABSTRACT

This paper focuses on electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) comparison to help the rehabilitation patients. Both methods have unique techniques and placement of electrodes. Usage of signals are different in application based on the economic conditions. This study helps in choosing the signal for the betterment of analysis. Ten healthy subject datasets of EEG & FNIRS are taken and applied to plot topography separately. Accuracy, Sensitivity, peaks, integral areas, etc are compared and plotted. The main advantages of this study are to prompt their necessities in the analysis of rehabilitation devices to manage their life as a typical individual.

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Keywords : Brain-computer interfaces, Electroencephalography (EEG), Functional near-infrared spectroscopy (fNIRS), Time- Frequency Analysis, Interpretation accuracy.

I. INTRODUCTION

Brain-computer interface is a well- known study that has played major role for a long time in rehabilitation. Study investigates the electroencephalographic and cerebral hemodynamic responses for disabled patients to restore their motor functions. Event-related desynchronization and blood oxygen response, BCI plays an efficient role in the closed-loop training [1].

Motor learning method carried out by comparing conventional passive and active training. Event-related design is suitable for estimating brain cortical activation in motor functions which provides feedback [2]. The performance of BCI increases by combining Electroencephalography (EEG) and functional Near Infrared Spectroscopy (fNIRS) for classifying Motor functions. Hybrid approach shows the best accuracy for brain computer interface [3].

The data includes measured, demographic and basic analysis results. Time- frequency analysis was achieved for spectral power to discriminate the task-relevant activations. Spatiotemporal characteristics of hemodynamic responses are involved. Hybrid EEG-FNIRS. BCIs was authenticated from classification accuracy. The study helps the performance evaluation and comparison of many neuro analysis methods [4].

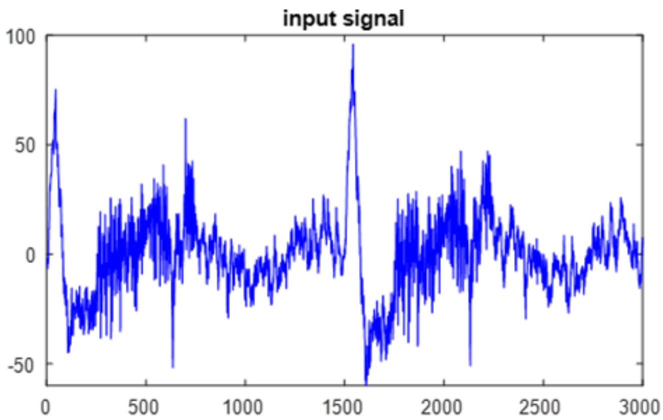
It established the feasibility of the motor functions based on multi-force loads on the limb. The event-related spectral perturbation method used for BCI during multi- force loads on motor functions. This provides a better approach to rehabilitate patients with motor disabilities [5]. To study the different mental states, it can be enhanced by using a hybrid approach. Open access dataset includes motion artifacts and physiological data, it is based on the validation in multiple approaches of BCI research [6].

This paper aims in comparison of EEG and FNIRS to study the Accuracy, Sensitivity, peaks, integral areas, etc. It helps in analysing the rehabilitation devices to manage their life as a typical individual. This study helps in performance evaluation of particular neuro methods based on the evaluation application can be decided and performed.

II. METHODS AND MATERIAL

A. DATASETS

This paper deals with 25 healthy person's datasets for both EEG & FNIRS. Datasets are processed further for the analysis. To improve the accuracy of both signals this study is essential which depends on the wake and anaesthetic conditions. This study helps in rehabilitation research works. Sample input data is displayed in Fig 1.



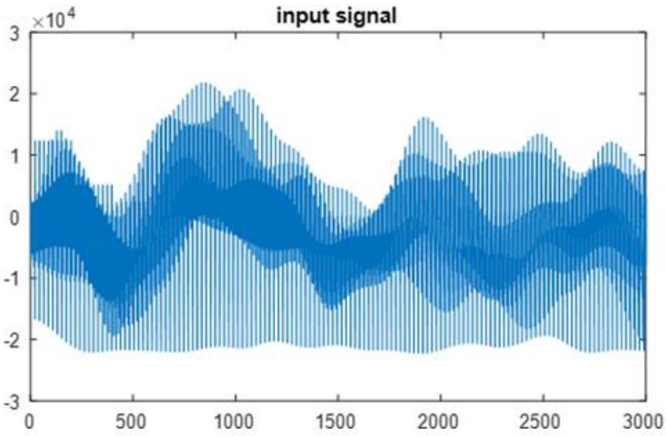


Fig.1. Input signal of EEG & FNIRS

B. SPECTRUM ANALYSIS

The analysis for spectrum in signals are basis of broader frequency. Spectral analysis is the quantification of both EEG & FNIRS. Frequency bands are based on the alpha, beta, theta, delta, gamma frequencies. Alpha signal frequency is 8-13 Hz, Beta signal frequency is 14-30 Hz, Theta signal frequency is 4-7 Hz, Delta signal frequency is <3.5 Hz and Gamma signal frequency is 30-100+ Hz.

According to this frequency, the frequency band is limited to 300 Hz. Processed signal is given in Fig 2.

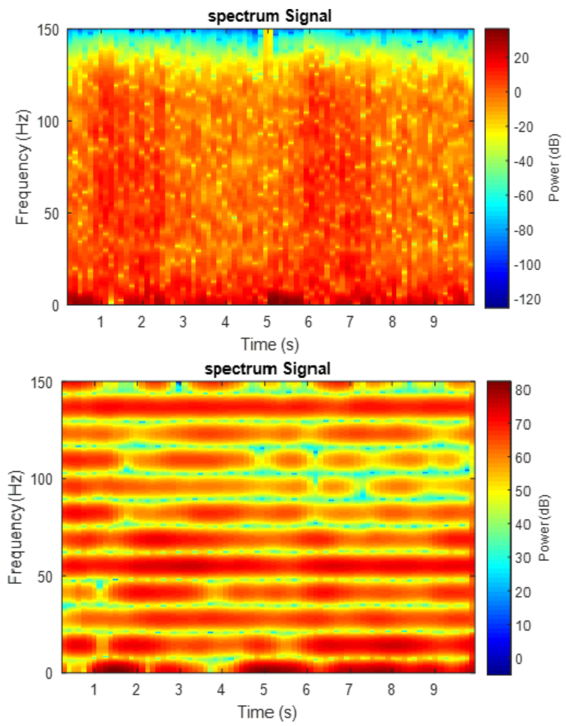


Fig.2. Spectrum Signal of EEG & FNIRS

C. WAVELET TRANSFORM

The wavelet transform is a representation of time-frequency domain. The Continuous Wavelet Transformation of a signal is then defined as:

$$CWT_{\psi} X(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{+\infty} X(t)\psi^{*}\left(\frac{t-b}{a}\right) dt \quad (1)$$

According to Parseval's theorem, the signal can be subdivided at different levels. It is presented as:

$$CD_i = \sum_{j=1}^{N} |Dij|^2,\ i = 1, \ldots\ldots, l \quad (2)$$

$$CA_l = \sum_{j=1}^{N} |Alj|^2 \quad (3)$$

where 1 i ,......, 1= is the wavelet decomposition level from level 1 to level l. N is the number of the coefficients of detail or approximate at each decomposition level.

i CD is the energy of the detail at decomposition level i and l CA is the energy of the approximate at decomposition level l. The Fig 3 shows the classification of signals.

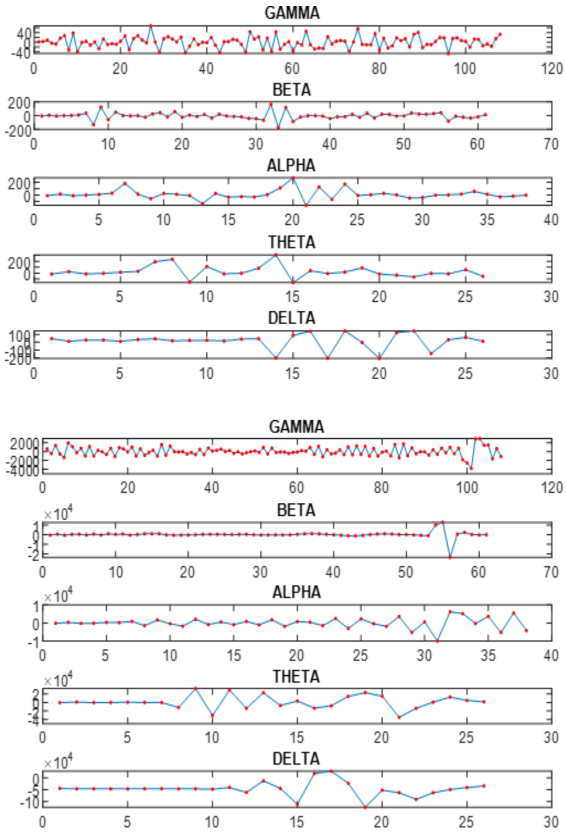


Fig.3. Classification of Signal

D. FREQUENCY DOMAIN

Discrete fourier transform is applied for obtaining frequency domain from time domain. D1, D2, D3, D4 is the noises detected and D5, D6, D7, D8, A8 is the detail and approximation decomposition levels. Feature extraction is explained in Fig 4.

The Table 1 shows the levels of classified signals in both EEG & FNIRS.

TABLE 1. Levels and Classified Signal

LEVELS	SIGNAL
D1, D2, D3, D4	Noises
D5	Gamma
D6	Beta
D7	Alpha
D8	Theta
A8	Delta

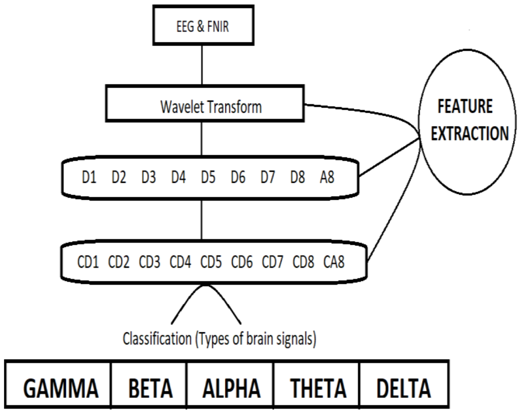
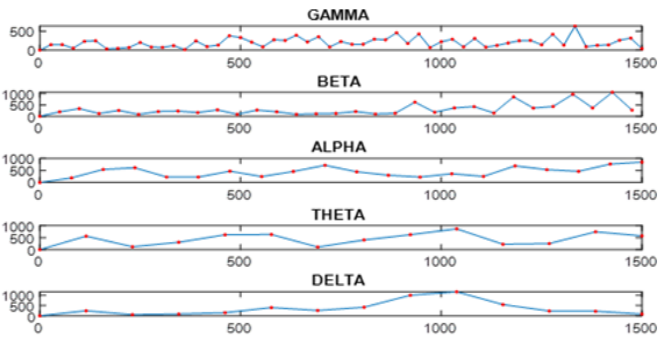


Fig.4. Feature Extraction of Signal

The Fig 5 shows the Frequency domain of classified signals in EEG & FNIRS.



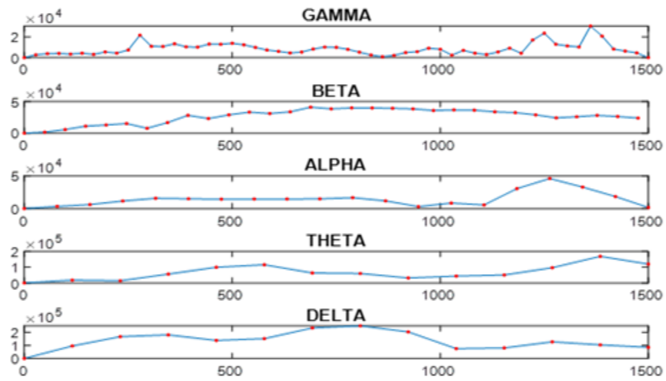


Fig.5. Frequency Domain of Classified Signals in EEG & FNIRS

E. TOPOGRAPHY

Topographical distributions are based on 10-20 systems. 'Fpz','Fz','Cz','Pz','Oz' are the positions taken for observation and distributed in topography. By finding four K nearest values of 'Fpz','Fz','Cz','Pz','Oz' positions this study finds the peaks of signal. Colours indicated is referred for the attention and relax state is shown in Fig 6.

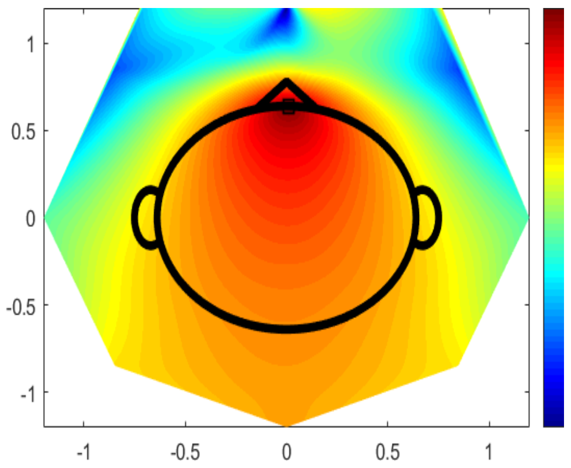
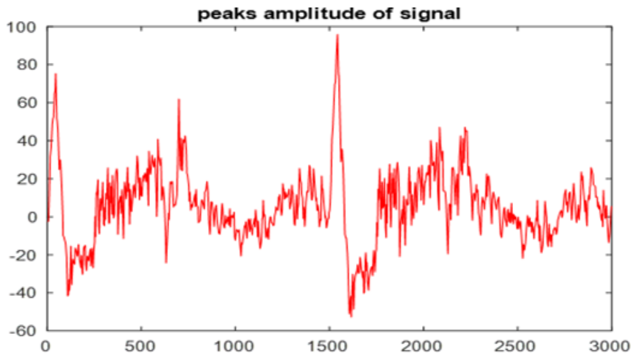


Fig.6. Topographical Distribution

The Fig 7 shows the Peak amplitude of signal both in EEG & FNIRS.



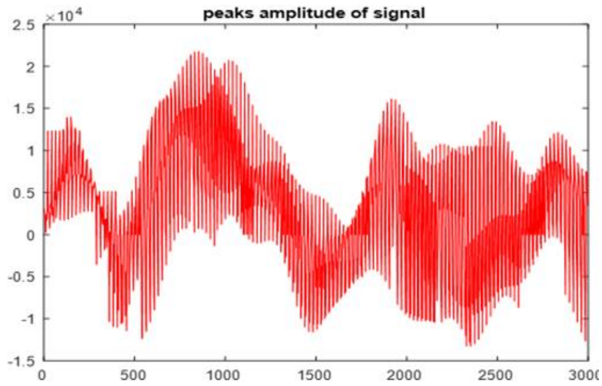


Fig.8. Peaks of Integral Area

F. POWER SPECTRUM ANALYSIS

By Analysing the power spectrum of Delta, Theta, Alpha and Beta signals, the average power spectrum is analysed. Peak amplitudes and band frequency of particular signals are shown in below Fig 9 and Fig 10. Average power spectrums of different signals are used for defining the wake and anaesthetic state. Conditions are defined according to the specified theory,

(avg1>4.0000e-06) (4)

(avg2>5.1790e-06) (5)

(avg3>10.4152e-06) (6)

(avg4>1.46134e-06) (7)

This is the four conditions applied for finding the wake and anaesthetic states.

If above conditions satisfy then the subject is in wake condition or else the subject is in anaesthetic state. Both conditions are shown as wake and anesthetized state.

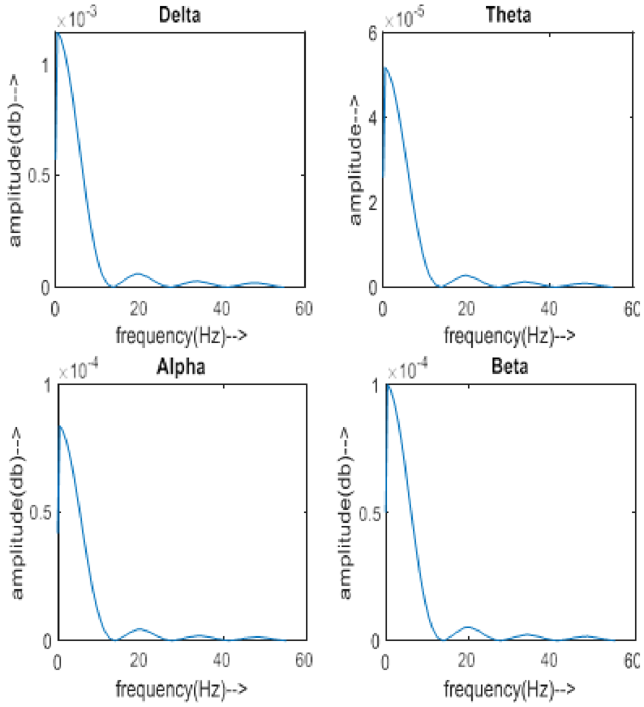


Fig.9. Power Spectrum Analysis of EEG

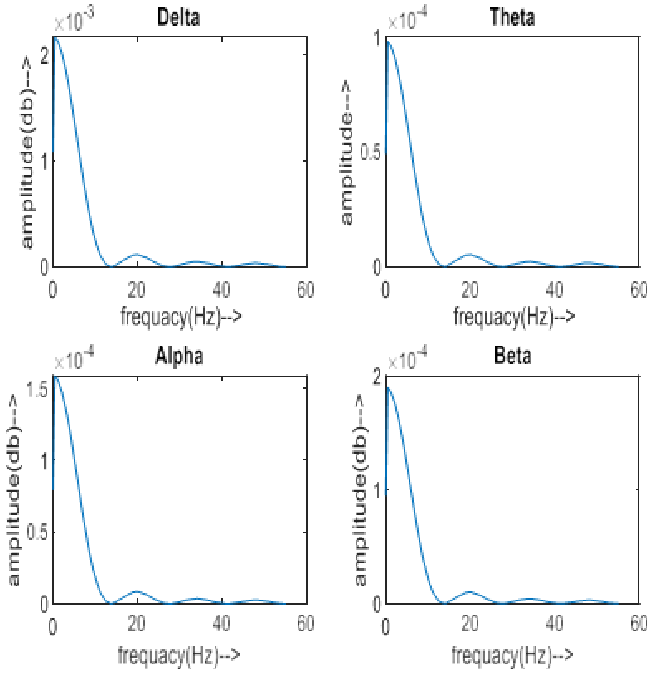


Fig.10. Power Spectrum Analysis of FNIRS

The Fig 11 shows the Sample result of wake state by satisfying the conditions. The Fig 12 shows the Sample result of rest state by satisfying the conditions.

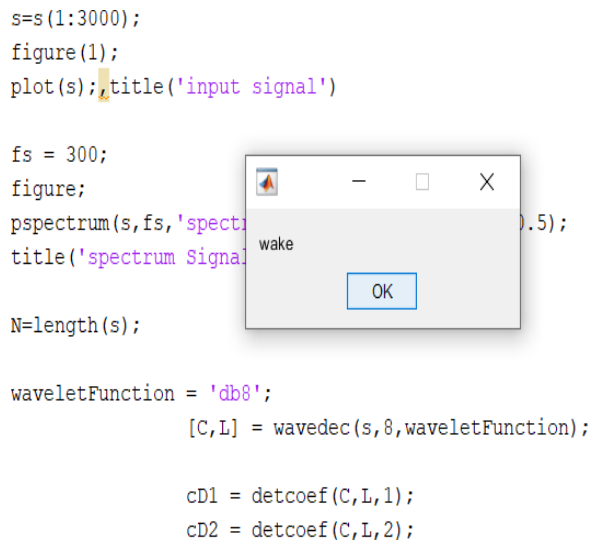


Fig.11. Sample Result of Wake State

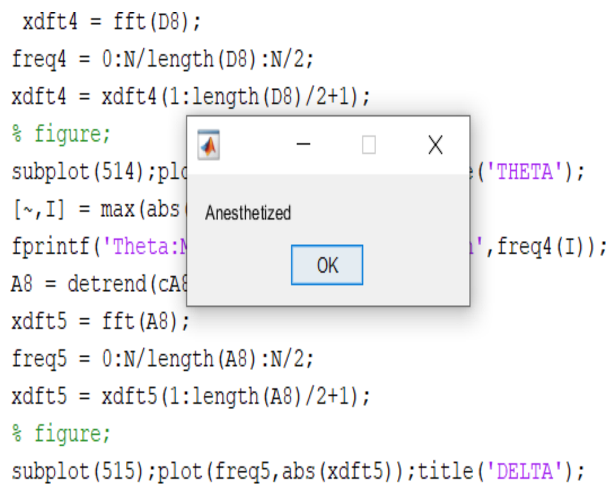
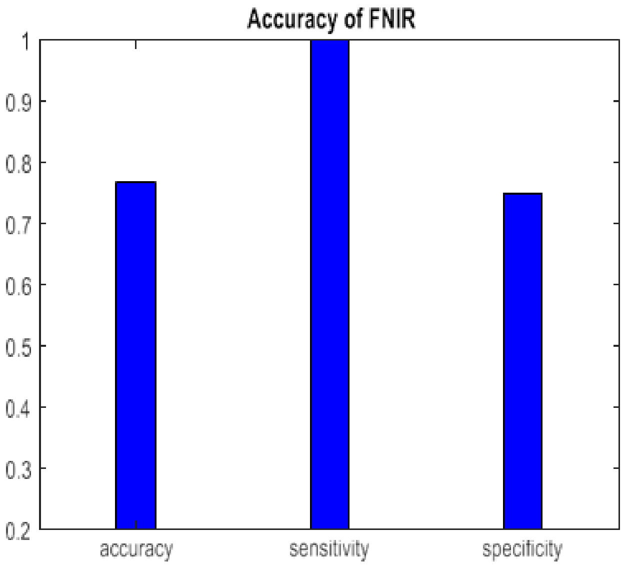


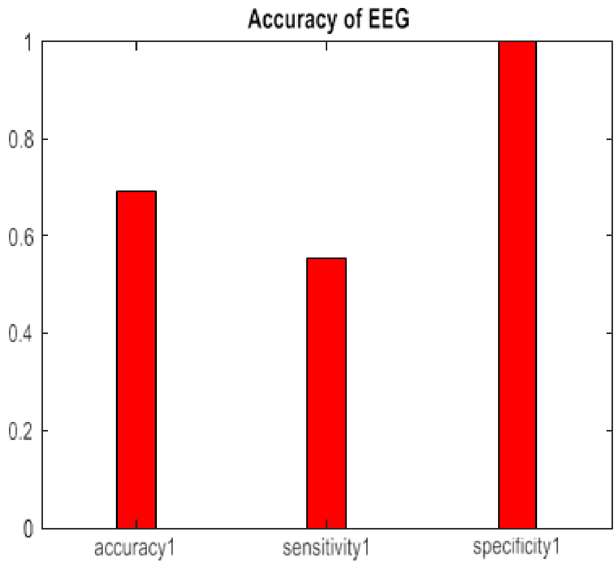
Fig.12. Sample Result of Rest State

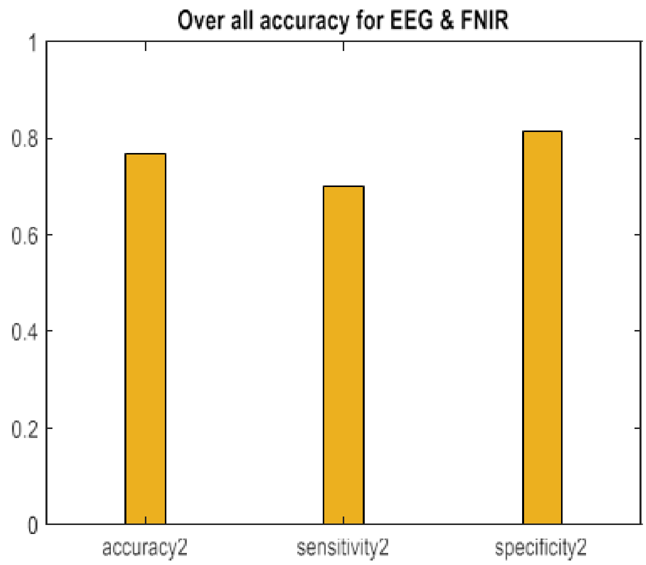
Most of the studies are based on combined modalities or hybrid BCI. In this study, both EEG and FNIRS played an individual role to find the feasibility, accuracy, sensitivity and specificity. It is mainly focused on the interpretation of FNIRS and EEG. Parameters for both FNIRS and EEG methods are discussed in this study. According to the application decision of using methods differ.

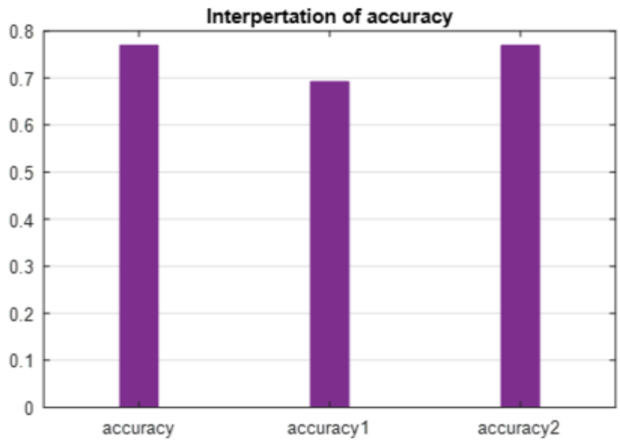
The main disadvantages using hybrid BCI is the long time it takes to set up both modalities. Trial duration is also longer, since it is difficult to make the subject concentrated for long time. This study differs on uses preferences.

Accuracy for EEG & FNIRS and the Interpretation of EEG & FNIRS are estimated in the below figures.









III. ACKNOWLEDGMENTS

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