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DEPCAP:
A SMART HEALTHCARE FRAMEWORK FOR EEG BASED DEPRESSION DETECTION USING TIME-FREQUENCY RESPONSE AND DEEP NEURAL NETWORK

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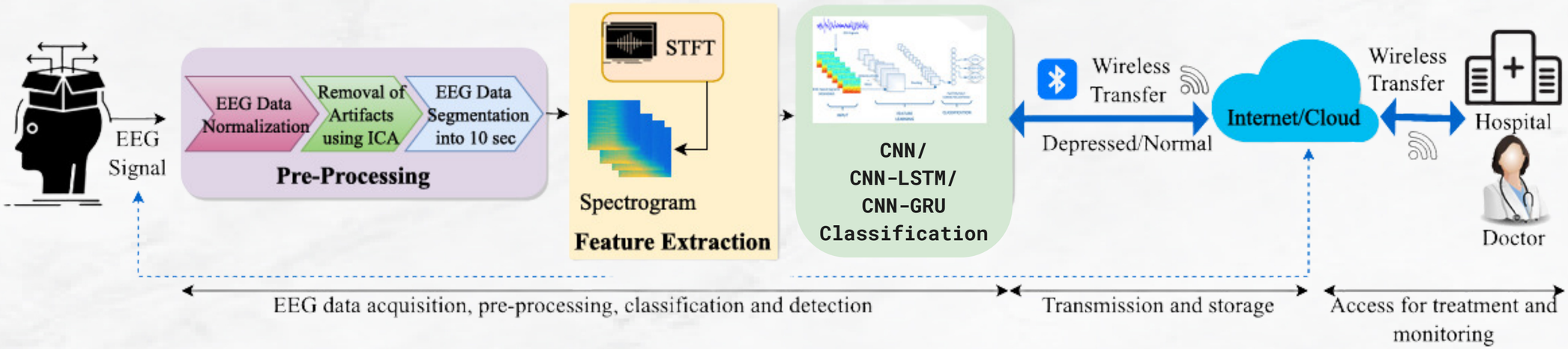
INTRODUCTION

- A novel wearable consumer electronics device for detecting Major Depressive Disorder (MDD) using deep learning techniques for smart healthcare in real-time.
- Depression is a neurological disorder that affects about 280millionindividuals globally.



- It Consists of 4 Major Parts:
  a. **Realtime EGG Data Collection:** EEG data is continuously recorded from the patient with the help of a proposed wearable device known as Dep Cap.
  b. **Data Pre-Processing:** EEG signal is subjected to data pre-processing such as artifact removal, feature extraction, and classification for MDD detection.
  c. **Output:** Based on models output the status of two LEDs attached to Dep Cap will tell if a person is suffering from depression or not.
  d. **Storing Status in Cloud:** The status of the patient is stored on the cloud through IoMT and can be used by doctors and researchers for further treatment.

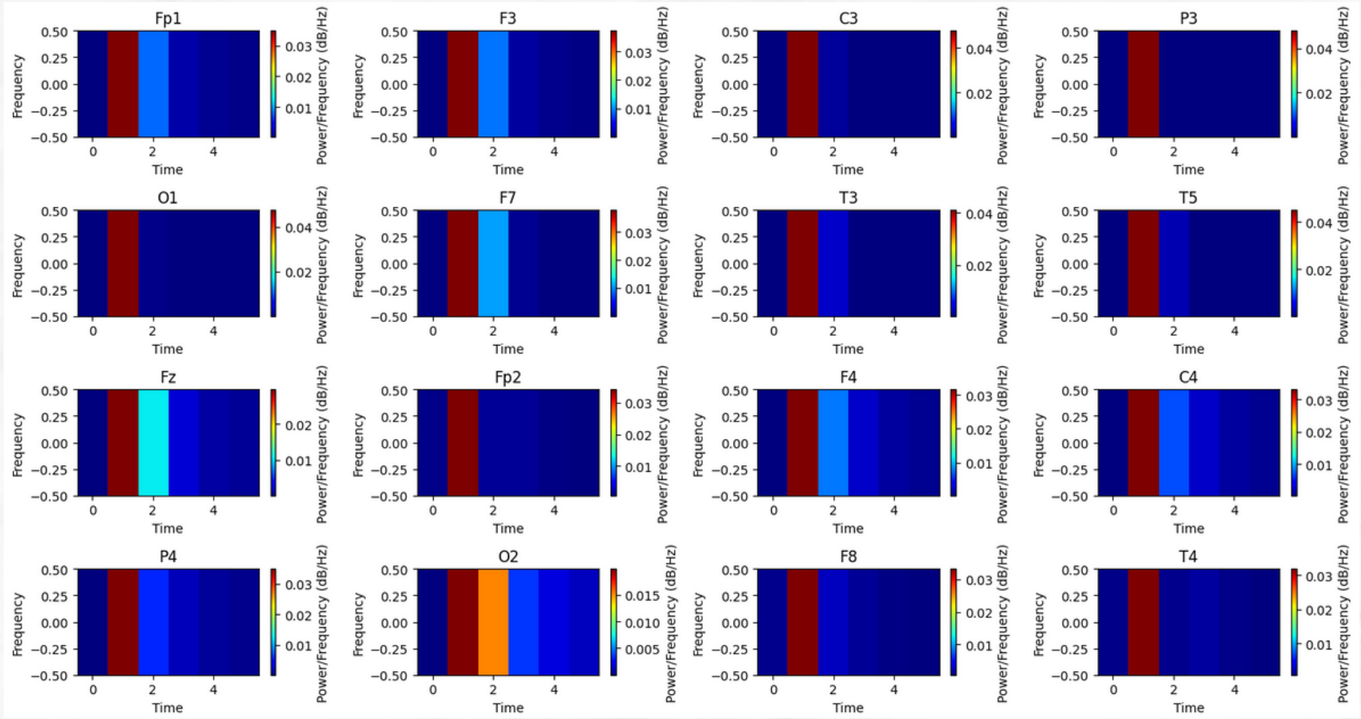
*Image from IEE/10.1109/ACCESS.2023.3275024

DATASET & PRE-PROCESSING

- The dataset was assimilated at the **Hospital Universiti Sains Malaysia (HUSM).**
- **64 participants** (24 Female, 40 Male) were selected from two groups (**30 Healthy, 34 MDD Patients**), with the average age ranging from 12 to 77 years.
- The **International 10-20 electrode** placement standard was used to position the EEG sensors on the scalp.
- EEG was recorded for 10 minutes, comprising 5 minutes with their **Eyes Open (EO)** and 5 minutes with **Eyes Closed (EC)**
- **19 electrodes** comprising placements were Fp1, Fp2, F3, F4, F7, F8, Fz, T3, T4, T5, T6, P3, P4, Pz, O1, O2, C3, C4, and Cz.
- Butterworth band pass filter of cut-off frequency **0.5Hz-70Hz** and a notch filter of **50Hz** is used to remove the power grid effect.
- **Independent Component Analysis (ICA)** is used to reduce artifacts caused by patient movement and eye blinking.
- Signal is segmented into the **interval of 10s**. Finally, the **Z score normalization** technique is used for amplitude scaling.

STFT

- As EEG is a time-varying signal - Fourier Transform (FT) fails to record the variations in amplitude and frequency over time.
- STFT-to generate a feature map from EEG. STFT gives time-frequency graph called a spectrogram.
- EEG Spectrogram Image:



- For our paper we have taken a hamming window of varied window size between 0.2 to 1 second

*Image from IEE/10.1109/ACCESS.2023.3275024

CNN

- Convolutional Neural Network is a type of Deep Neural Network
- CNN consists of three layers -
  1)**Feature Extraction** - Linear and non-linear functions.
  2)**Pooling Layer** - Down sampling process and moderates the dimension of the feature map
  3)**Dense Layer** - Flattens the previous layer's output into a single vector.

Structure of Convolution Neural Network used in paper :

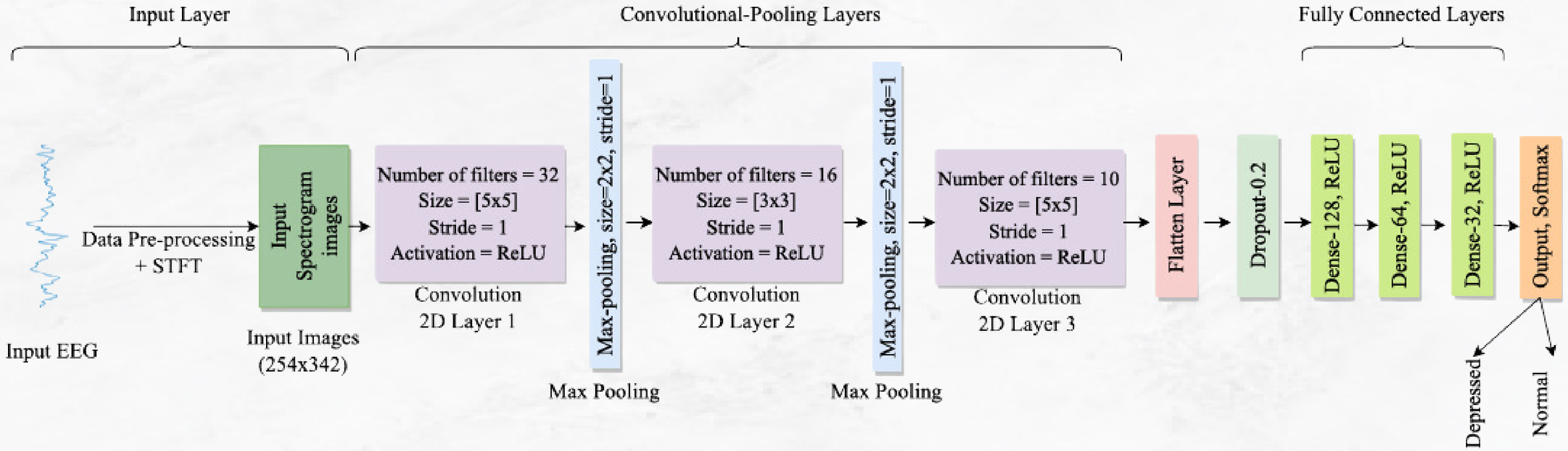


*Image from IEE/10.1109/ACCESS.2023.3275024

RNN

- Recurrent Neural Network is also a type of Deep Neural Network
- RNNs help to achieve Sequential learning of signals.
- This paper has used two types of RNNs namely:

LSTM

- LSTM has mainly three gates (input, output, and forget)
- It contains following functions, hyperbolic tangent (tanh), sigmoid (σ), multiplication (x), and sum (+) to update the weight during the backpropagation process.
- LSTM has more gates and more parameters than GRU, which gives it more flexibility and expressiveness, but also more computational cost and risk of overfitting.

GRU

- GRU has only reset and update gates, no output gates.
- It contains following functions, hyperbolic tangent (tanh), sigmoid (σ), multiplication (x), and sum (+) to update the weight during the backpropagation process.
- GRU has fewer gates and fewer parameters than LSTM, which makes it simpler and faster, but also less powerful and adaptable.

DEPCAP

- DepCap is a portable consumer electronics wearable device concept proposed in this study for the rapid diagnosis of depression.
- It is in the form of a hood that includes electrodes, a display unit consisting of Red and Green LED, an Edge Processing Unit (EPU), and communication components.
- The EEG data are persistently stored in the cloud for the future patient examination.

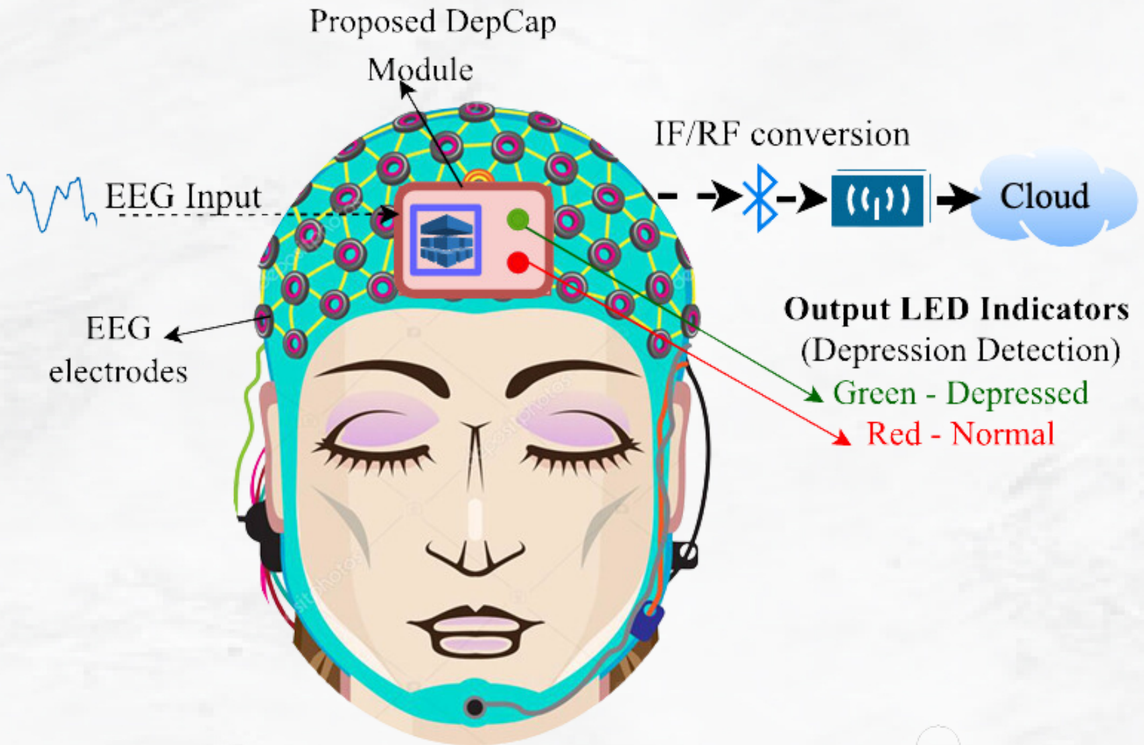


*Image from IEE/10.1109/ACCESS.2023.3275024

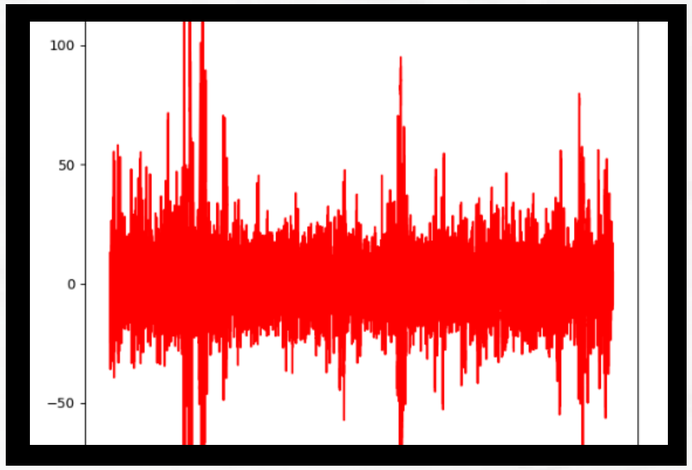
RESULT AND PAST WORKS

Parameters	VGG16	AlexNet	Inception	ResNet50	CNN	CNN-LSTM	CNN-GRU
Accuracy(%)	96.22	94.98	97.00	97.32	99.10	99.9	99.84
Sensitivity(%)	95.00	92.89	98.1	97.93	98.73	100	100
Specificity(%)	96.98	94.90	97.32	98.50	99.36	99.81	99.57
Precision(%)	94.69	95.10	96.55	96.79	98.98	99.47	99.23

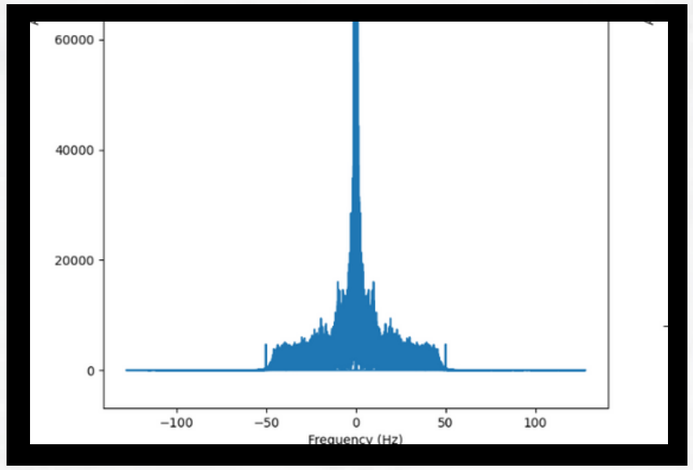
Author/Year	Method used	Number of participants	Accuracy (%)	Sensitivity (%)	Specificity (%)	Precision (%)
Mumtaz et al. [22], 2017	Power and symmetry features+SVM	30 Normal, 34 Depressed	98.4	96.66	100	-
Mahato et al. [53], 2019	Alpha power+RWE+MLPNN	30 Normal, 34 Depressed	93.33	94.44	87.78	-
Kang et al. [54], 2020	Asymmetry image+2D-CNN	30 Normal, 34 Depressed	98.8	99.1	98.5	-
Aydemir et al. [55], 2021	Melamine pattern+SVM	30 Normal, 34 Depressed	99.1	98.4	99.8	99.8
Sharma et al. [56], 2022	Non-linear features+RBFSVM	30 Normal, 34 Depressed	98.9	99.2	99.7	-
Khan et al. [57], 2022	Wavelet coherence	30 Normal, 34 Depressed	98.1	98.0	99.82	-
Loh et al. [32], 2022	CNN	30 Normal, 34 Depressed	99.58	99.70	99.48	99.40

*Image from IEE/10.1109/ACCESS.2023.3275024

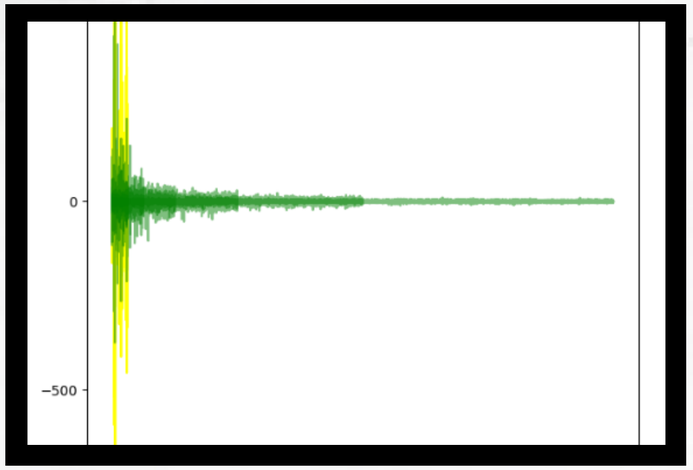
RESULTS



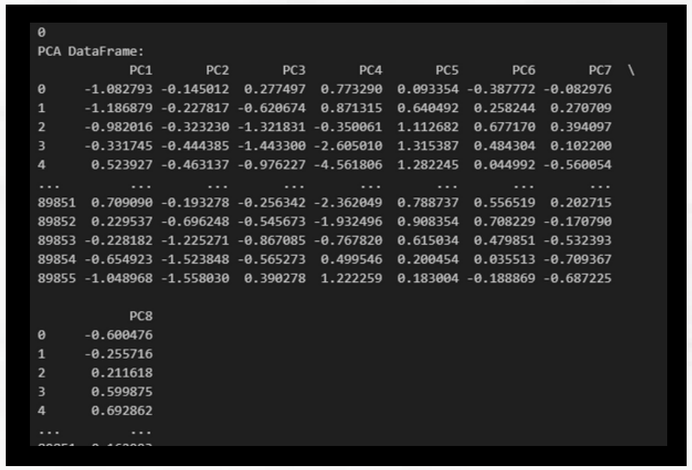
Original Signal



Fourier Transform



Wavelet Transform



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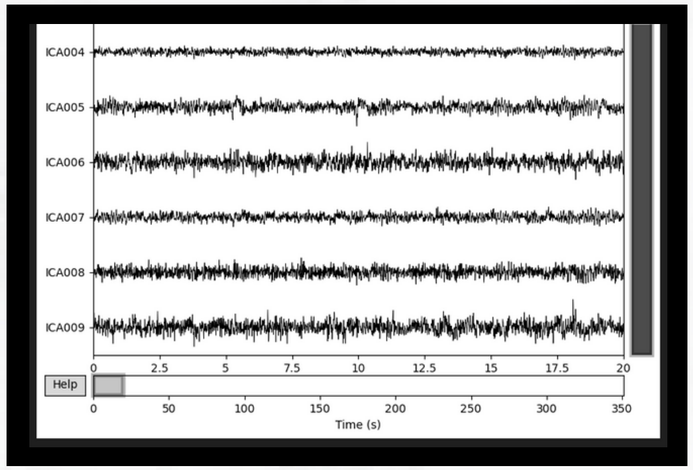
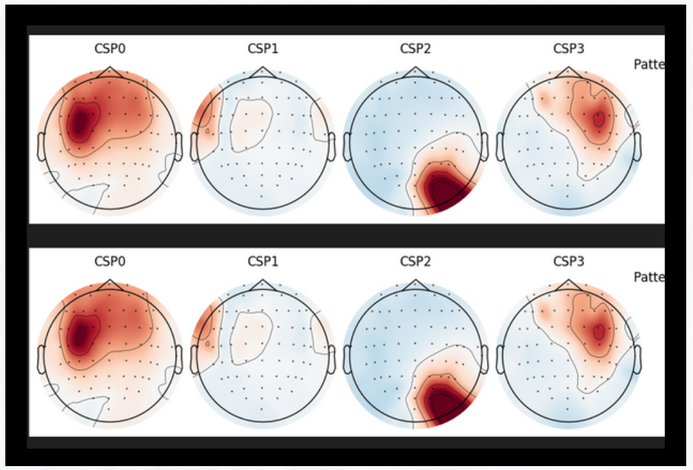
0
PCA DataFrame:
             PC1       PC2       PC3       PC4       PC5       PC6       PC7  \
0      -1.082793 -0.145012  0.277497  0.773290  0.093354 -0.387772 -0.082976
1      -1.186879 -0.227817 -0.620674  0.871315  0.640492  0.258244  0.270709
2      -0.982016 -0.323230 -1.321831 -0.350061  1.112682  0.677170  0.394097
3      -0.331745 -0.444385 -1.443300 -2.605010  1.315387  0.484304  0.102200
4       0.523927 -0.463137 -0.976227 -4.561806  1.282245  0.044992 -0.560054
...          ...       ...       ...       ...       ...       ...       ...
89851   0.709090 -0.193278 -0.256342 -2.362049  0.788737  0.556519  0.202715
89852   0.229537 -0.696248 -0.545673 -1.932496  0.908354  0.708229 -0.170790
89853  -0.228182 -1.225271 -0.867085 -0.767820  0.615034  0.479851 -0.532393
89854  -0.654923 -1.523848 -0.565273  0.499546  0.200454  0.035513 -0.709367
89855  -1.048968 -1.558030  0.390278  1.222259  0.183004 -0.188869 -0.687225

             PC8
0      -0.600476
1      -0.255716
2       0.211618
3       0.599875
4       0.692862
...          ...
```

PCA



ICA



CSP

[Implementation and Detailed Results here](#)

THANK YOU !