A Neurocognitive Study of SIMKAP Multitasking Workload with EEG

Team ON2 : Fantastic 5

Project 7

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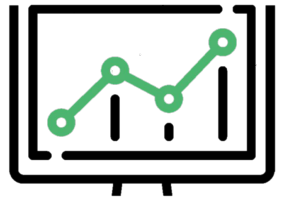
❑ What are the objectives of this project?

❑ Why did we choose this project?

Ecological cognition	cognitive workload relevant to everyday cognition
Reliability and validity of task	robust validity and reliability, objective measure of multitasking and stress tolerance.
Relevance in clinical and non-clinical populations	ADHD, Autism, Depression, Anxiety
EEG testing allows for **temporal accuracy**	and building on existing literature about corresponding spatial neural research, this study can provide deeper insights into understanding the mechanisms of action with **precision.**
Application	HCI research, fields with high cognitive demand like aviation, sport and military, neuromarketing among others.



❑ Introduction to Dataset

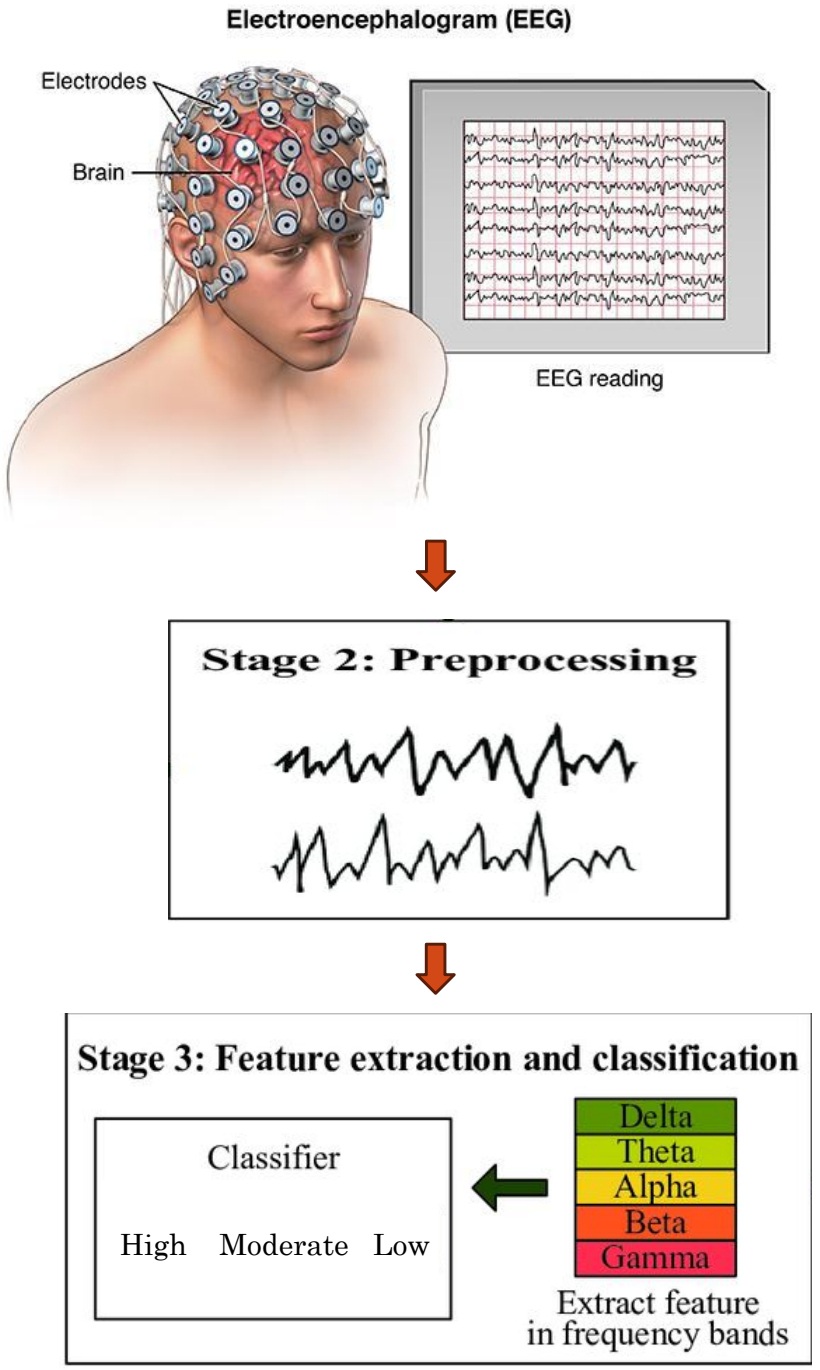
- The EEG data was collected with Emotiv EPOC EEG headset, Sampling frequency> 128Hz, 16 bit A/D resolution

- Electrodes: 10-20 system, AF3/4. F7/8, F3/4, FC5/6 relevant out of the 14 channels as per lit review

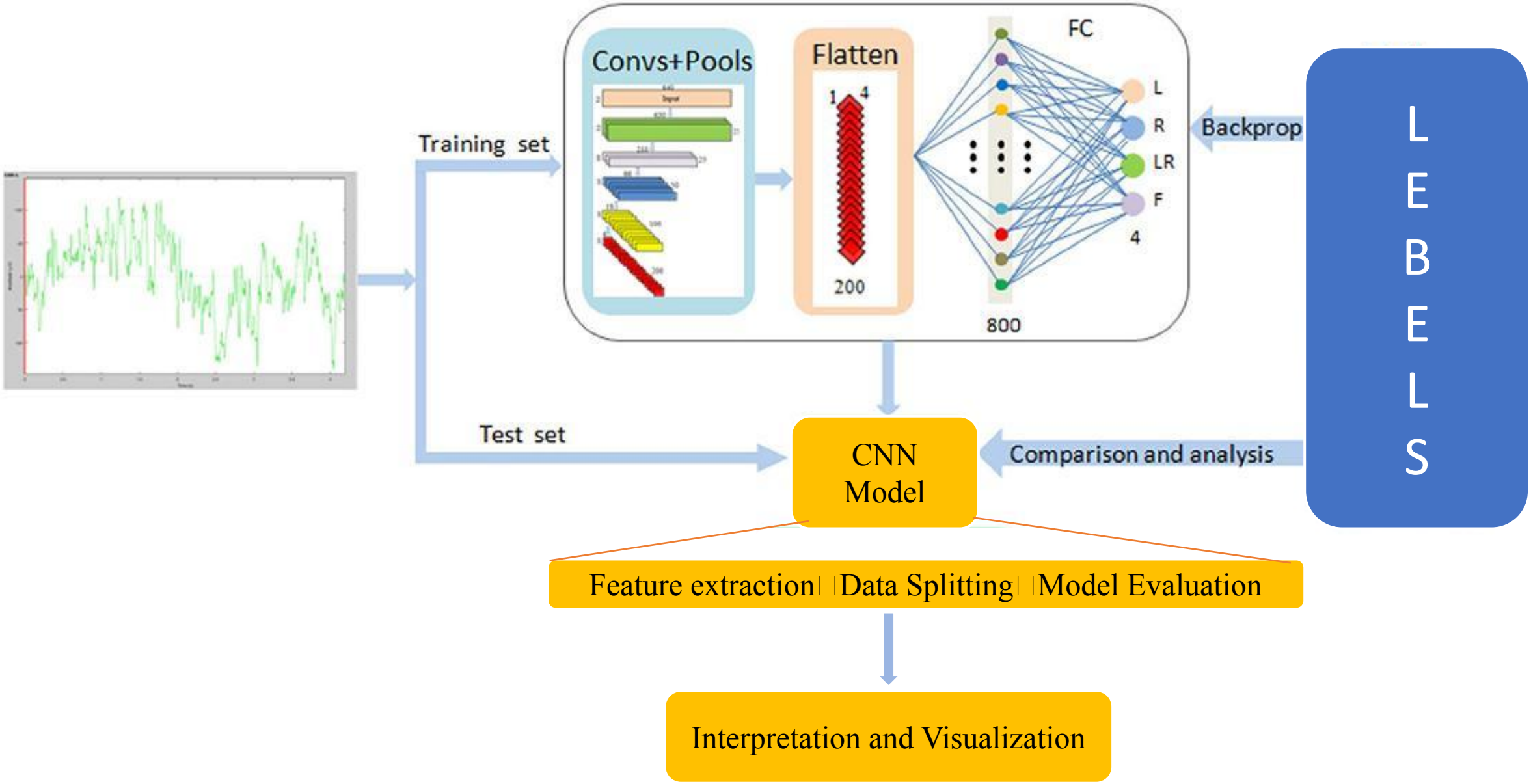
- N(48), (t)=2.5 min

- Data divided into high vs low MWL conditions (subjective Likert rating scale)

- Dataset preprocessed for line noise and large amplitude artifacts, high pass filtered at 1Hz, and re-referenced to average

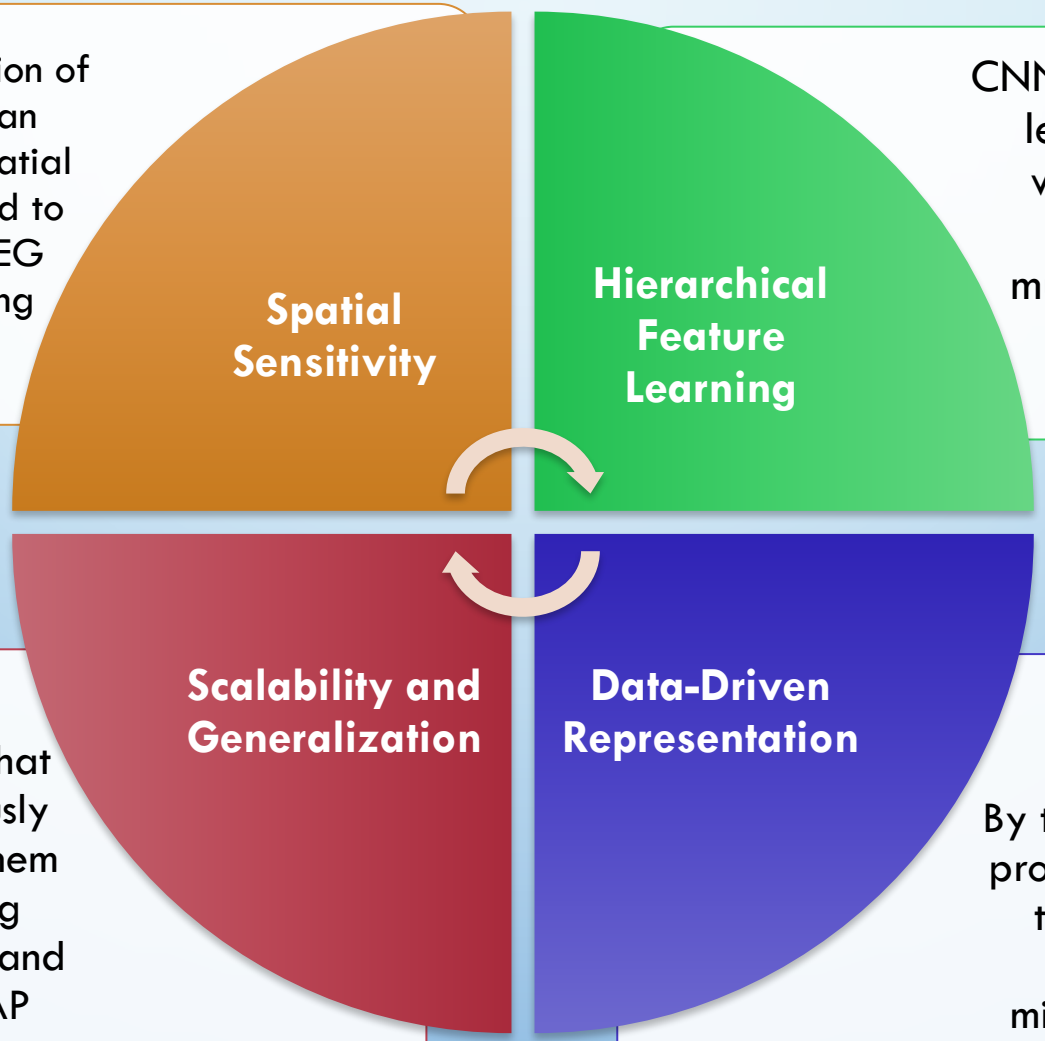


❑ Project Methodology



CNNs excel in this context for several reasons:

EEG data, with its spatial distribution of electrodes across the scalp, can benefit from CNN's inherent spatial sensitivity. CNNs are well-suited to detect localized patterns in EEG signals associated with varying cognitive workloads.



CNNs are adept at automatically learning hierarchical features, which is particularly valuable when dealing with the multi-scale nature of EEG data.

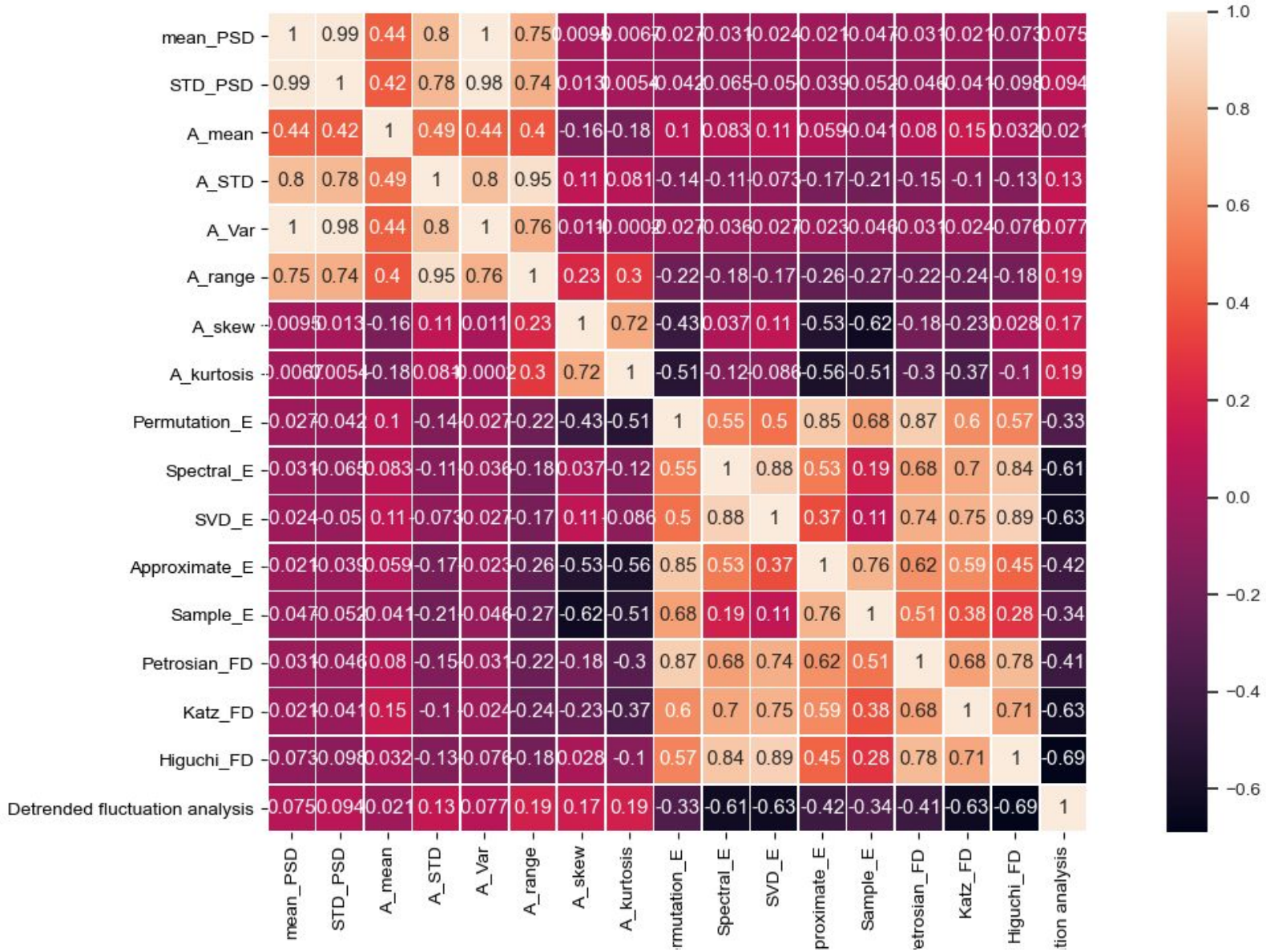
CNNs offer a scalable solution that can generalize well to previously unseen EEG samples, making them an ideal choice for classifying mental workload in a dynamic and diverse setting like the SIMKAP multitasking test.

By training the CNN model on the provided pre-processed EEG data, the network can autonomously learn discriminative features, mitigating the need for manually crafted feature engineering.

❑ Discussion

From the pre-processed EEG signal 17 statistical, entropy, and energy features were extracted. For performing the identification task Random Forest, SVM, XGboost and CNN was used.

Features extracted are :- **STD_PSD, A_mean, A_STD, A_Var, A_range, A_skew, A_kurtosis, Permutation_E, Spectral_E, SVD_E, Approximate_E, Sample_E, Petrosian_FD, Katz_FD, Higuchi_FD, Detrended fluctuation analysis**


mean_PSD 1 0.99 0.44 0.8 1 0.75 0.009 0.006 -0.027 0.031 0.024 0.021 0.047 0.031 0.021 0.073 0.075
STD_PSD 0.99 1 0.42 0.78 0.98 0.74 0.013 0.005 -0.042 0.065 -0.05 0.039 0.052 0.046 0.041 0.098 0.094
A_mean 0.44 0.42 1 0.49 0.44 0.4 -0.16 -0.18 0.1 0.083 0.11 0.059 0.041 0.08 0.15 0.032 0.021
A_STD 0.8 0.78 0.49 1 0.8 0.95 0.11 0.081 -0.14 -0.11 -0.073 -0.17 -0.21 -0.15 -0.1 -0.13 0.13
A_Var 1 0.98 0.44 0.8 1 0.76 0.011 0.0002 -0.027 0.036 0.027 0.023 0.046 0.031 0.024 0.076 0.077
A_range 0.75 0.74 0.4 0.95 0.76 1 0.23 0.3 -0.22 -0.18 -0.17 -0.26 -0.27 -0.22 -0.24 -0.18 0.19
A_skew 0.009 0.013 -0.16 0.11 0.011 0.23 1 0.72 -0.43 0.037 0.11 -0.53 -0.62 -0.18 -0.23 0.028 0.17
A_kurtosis 0.006 0.005 -0.18 0.081 0.0002 0.3 0.72 1 -0.51 -0.12 -0.086 -0.56 -0.51 -0.3 -0.37 -0.1 0.19
Permutation_E 0.027 0.042 0.1 -0.14 0.027 -0.22 -0.43 -0.51 1 0.55 0.5 0.85 0.68 0.87 0.6 0.57 -0.33
Spectral_E 0.031 0.065 0.083 -0.11 0.036 -0.18 0.037 -0.12 0.55 1 0.88 0.53 0.19 0.68 0.7 0.84 -0.61
SVD_E 0.024 -0.05 0.11 -0.073 0.027 -0.17 0.11 -0.086 0.5 0.88 1 0.37 0.11 0.74 0.75 0.89 -0.63
Approximate_E 0.021 0.039 0.059 -0.17 0.023 -0.26 -0.53 -0.56 0.85 0.53 0.37 1 0.76 0.62 0.59 0.45 -0.42
Sample_E 0.047 0.052 0.041 -0.21 0.046 -0.27 -0.62 -0.51 0.68 0.19 0.11 0.76 1 0.51 0.38 0.28 -0.34
Petrosian_FD 0.031 0.046 0.08 -0.15 0.031 -0.22 -0.18 -0.3 0.87 0.68 0.74 0.62 0.51 1 0.68 0.78 -0.41
Katz_FD 0.021 0.041 0.15 -0.1 0.024 -0.24 -0.23 -0.37 0.6 0.7 0.75 0.59 0.38 0.68 1 0.71 -0.63
Higuchi_FD 0.073 0.098 0.032 -0.13 0.076 -0.18 0.028 -0.1 0.57 0.84 0.89 0.45 0.28 0.78 0.71 1 -0.69
Detrended fluctuation analysis 0.075 0.094 0.021 0.13 0.077 0.19 0.17 0.19 -0.33 -0.61 -0.63 -0.42 -0.34 -0.41 -0.63 -0.69 1
mean_PSD
STD_PSD
A_mean
A_STD
A_Var
A_range
A_skew
A_kurtosis
rmutation_E
Spectral_E
SVD_E
proximate_E
Sample_E
etrosian_FD
Katz_FD
Higuchi_FD
tion analysis
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

❑ Discussion

Link to code repo :-
https://github.com/siddharthiitian/A-Neurocognitive-Study-of-SIMKAP-Multitasking-Workload-with-EEG.git

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CNN :-

Accuracy: 0.4409722222222222

Random Forest Metrics:

Accuracy: 0.9097222222222222

Xgboost

Accuracy: 0.8819444444444444

Gradient Boosting Metrics:

Accuracy: 0.8854166666666666

❑ Future Work

- Making our CNN more robust
- Using some prebuilt model like EEGNet and LSTM.
- Analysing model on different frequency bands like alpha, beta, gamma and Sub band exploration.
- Analysis channels and making use of one that are useful for our objective
- Using methods like SelectKBest to extract features that are best suited for our use and dropping one that are not relevant

❑ References

- Kok A. (2022). Cognitive control, motivation and fatigue: A cognitive neuroscience perspective. Brain and cognition, 160, 105880.
- Stenhav, A., Botvinick, M. M., & Cohen, J. D. (2013). The expected value of control: An integrative theory of anterior cingulate cortex function. Neuron, 79(21), 7–240.
- Hockey, G. R. J. (2013). The psychology of fatigue: Work, effort and control. Cambridge University Press
- Botvinick, M., & Braver, T. (2015). Motivation and cognitive control: From behavior to neural mechanism. Annual Review of Psychology, 66, 83–113.
- Wylie, G. R., Yao, B., Genova, H. M., Chen, M. H., & DeLuca, J. (2020). Using functional connectivity changes associated with cognitive fatigue to delineate a fatigue network. Science Reports, 10, 21927.
- Cools, R., Nakamura, K., & Daw, N. D. (2011). Serotonin and dopamine: Unifying affective, activational, and decision functions. Neuropsychopharmacol, 36, 98–113