

# Abnormal functional connectivity in attention networks of post-traumatic stress disorder patients

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**Abstract**— We present a comprehensive machine learning framework to identify EEG features capable of classifying PTSD. We found the model primarily relied on the abnormal functional connectivity in attention networks for the prediction.

**Clinical Relevance**— EEG has good clinical practicality and our machine learning framework can be utilized to discover important features that can potentially serve as biomarkers.

## I. INTRODUCTION

Post-traumatic stress disorder (PTSD) is a serious debilitating psychiatric disorder characterized by long-lasting stress symptoms following exposure to trauma. The first-line treatment is psychotherapy and while psychotherapy is very effective for many patients, there is still approximately two-thirds of patients who retain their diagnosis following psychotherapy [1].

To better understand the pathophysiology of PTSD, many studies have compared electroencephalography (EEG) in patients with PTSD to healthy controls. However, the findings have been inconsistent with no clear consensus. Here, we developed a comprehensive machine learning framework that found features, among commonly used EEG features, that characterizes PTSD and potentially serves as biomarkers.

## II. METHODS

Combat-exposed veterans ( $n = 221$ ) were recruited in the Military Psychology Department in the Danish Defense and both eyes open and eyes closed resting-state EEG were acquired. All participants provided informed consent and the studies were approved by the Danish Data Protection Agency.

Resting-state EEG was preprocessed using MNE-python 0.22.1. Briefly, the data was 1-100 Hz band-pass and 50 Hz notch filtered. Artifacts were removed through visual inspection and independent component analysis (ICA) was utilized to remove the ocular and heart artifacts. A robust common average reference was used and bad channels interpolated with spherical spline interpolation. Subjects with more than 20% bad epochs were excluded from further analysis, resulting in a total sample size of 107 PTSD veterans and 96 combat-exposed healthy controls.

Following preprocessing, commonly used EEG features were estimated, including spectral features, source functional connectivity features and features that capture the temporal dynamics of the EEG. Feature selection followed by three

conventional machine learning classifiers, logistic regression, support vector machines and random forest, was trained to predict PTSD using 10-by-20 two-layer cross-validation across subjects repeated 10 times (Fig. 1).

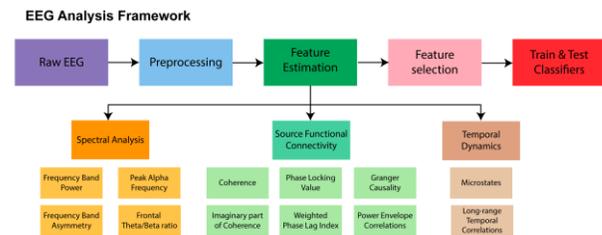


Figure 1. Overview of EEG analysis pipeline.

## III. RESULTS

The best performing classification model was random forest with a test accuracy of 62.7% followed by logistic regression with a test accuracy of 61.3% and support vector machine with a test accuracy of 60.0%. All classifiers performed significantly better than chance (Wilcoxon signed-rank test  $p < 0.01$ ).

To find the more informative features, we evaluated the selected features in our best performing classifier, by computing how often each feature was selected across the 100 final models from the repeated cross-validation runs. Using a threshold of presence in at least 10% of all cross-validation runs, we observed that around 99% of all selected features were connectivity features, with Granger causality being the most commonly selected (29% of all features). Further analysis showed that the predictive performance of using only Granger's causality features was not different from using all feature types (Wilcoxon signed-rank test  $p = 0.895$ ). Investigation of the specific selected Granger's causality features revealed the selected features were primarily from the frontoparietal control network to dorsal and ventral attention networks in the gamma and delta frequency bands.

## IV. DISCUSSION & CONCLUSION

Our results show that the occurrence of PTSD can be classified above chance from Granger causality between EEG source regions, primarily in the attention networks, suggesting that these networks are abnormal in PTSD. Given that we only observed a modest accuracy of the classifier, we speculate that the selected features can only characterize a portion of the PTSD patients, and hence there is not enough evidence that they represent a clinically relevant biomarker.

## REFERENCES

- [1] M. M. Steenkamp, B. T. Litz, C. W. Hoge, and C. R. Marmar, "Psychotherapy for military-related PTSD: A review of randomized clinical trials," *J. Am. Med. Assoc.*, vol. 314, no. 5, pp. 489–500, 2015.

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