Narcolepsy Disorders Explainability in EEG via Spectral Band Cluster Prevalence

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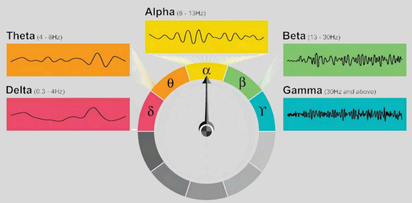
Introduction

AI models have previously demonstrated clinically promising performance for detecting Narcolepsy Type-1 (NT1) versus clinical control patients in overnight polysomnography (PSG), while explainability of AI detection for complex disorders remains an unsolved challenge. Seeking to increase explanatory power of AI results, we introduce a novel analysis method, Spectral-Band Cluster-Prevalence (SBCP), for clustering and categorizing PSG without AI/ML techniques or sleep scoring measures. We demonstrate the method for explainability of EEG comparisons evaluating Narcolepsy versus clinical control groups.

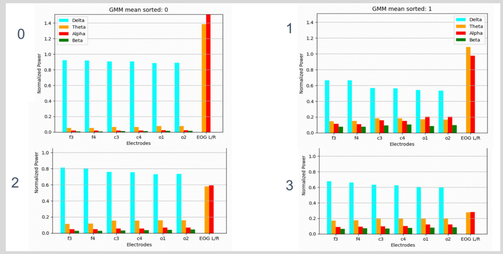
Methodology

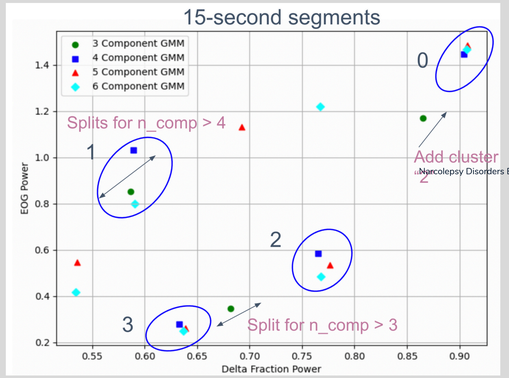
Our data source was retrospective EEG/EOG recordings from N=78 PSG participants including n=54 Narcolepsy Type-1 diagnosed patients (based on MSLT findings and patient-reported Cataplexy) with n=24 clinical controls. EEG channels were excluded based on artifact, normalized then extracted into 10-second segments. Signal features were extracted for each segment: EEG delta (1-4), theta (4-8), alpha (8-12), beta (12-30) spectral band-powers and EOG broadband-powers.

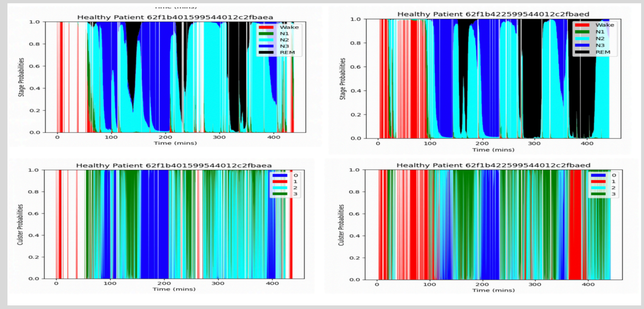


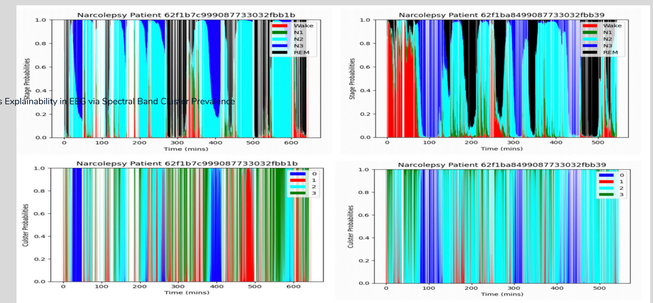
Feature EEG band-powers were projected into 3-dimensional subspace, where optimal parameters for Gaussian Mixture Model (GMM) were identified to allow overlapping EEG states. Cluster quality measures Silhouette, Davies-Bouldin, Akaike-Information-Criterion were evaluated to determine the optimal number of components (i.e. unique EEG states) required by the GMM to maximize explainability based on global optima in cluster quality values. Dwell Fraction was estimated by assigning components to 10-second EEG segments, and reported for comparison between NT1 versus clinical controls.

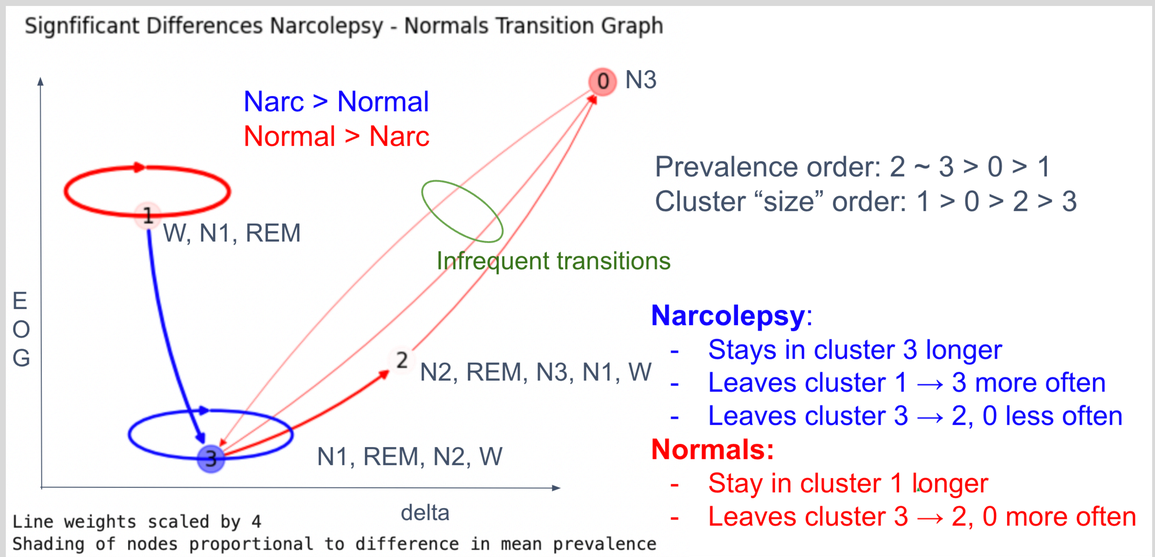
Experimental Results: GMM Clusters show significant Prevalence & Transition differences in Narcolepsy



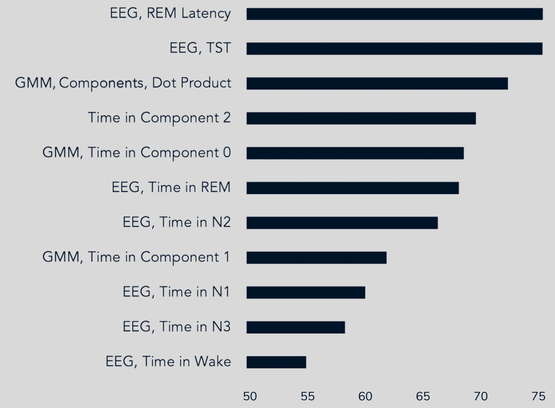








Performance Results: Sleep Stage Comparison



The global optima GMM identified n=3 unique components as the optimal number of components for describing 10-second segments of EEG/EOG in terms of explainability and predictability of between-group differences for NT1-vs-controls.

The n=3 components GMM showed the highest cluster quality scores in Silhouette (0.23), DB (2.30), and AIC (-7,318,399). Components were characterized by differences in spectral and broadband-power distributions.

Dwell Fraction, the percent of sleep-time in each component, revealed statistically significant differences associated with Narcolepsy (Component-1: NT1< Normals, Component-2: NT1> Normals) in Mann-Whitney-U and t-test results. ROC-AUCs were calculated for classifying NT1-vs Normals, based only on percentage of time spent in each component (Component-1: 0.71, Component-2: 0.78).

Conclusions

We demonstrate novel analytic methods for explainability, SBCP, with potential applications to Narcolepsy disorder-specific EEG biomarkers and AI understandability.