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A Unified Data-Driven EEG Framework for Multiclass Dementia Classification Using Spectral, Microstate, and Connectivity Features

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Abstract:

differential screening of Alzheimer's disease (AD) and frontotemporal dementia (FTD) remains difficult. EEG-based screening is therefore a promising scalable option; however, prior work often benchmarks spectral, microstate, and connectivity features separately and uses heuristic dimensionality reduction. Using a public OpenNeuro eyes-closed resting-state EEG dataset (N=88; 10–20 montage; 500 Hz), we built a standardized pipeline including EEGLAB preprocessing (filtering, ICA artifact removal), temporal standardization (60–360 s), multi-domain feature extraction (spectral band power, theta–alpha ratio, aperiodic 1/f exponent, alpha peak frequency; wPLI-based connectivity with graph metrics; four-class microstate parameters), and leakage-controlled dimensionality reduction via PCA with parallel analysis to automatically determine retained components within each training fold. We compared Elastic Net, RBF-SVM, and Random Forest (500 trees) using repeated 5-fold cross-validation over 100 cycles, evaluating classwise precision, recall and F1 as well as an integrated radar-area index capturing balanced multi-class performance across AD, FTD and controls. Across models, FTD was frequently misclassified as AD, indicating limited separability from resting EEG alone. Feature representation had a stronger impact on performance than classifier choice: microstate features yielded the most balanced radar areas, spectral features were intermediate, and connectivity features were weakest. The workflow provides a reproducible baseline for EEG/BCI-oriented dementia screening systems.

Keywords:

Alzheimer's disease, Frontotemporal dementia, EEG, Resting-state, Machine learning.