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BASIC SCIENCE AND PATHOGENESIS

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POSTER PRESENTATION

HUMAN NEUROPATHOLOGY

EEG low conventional bands non-linear machine learning-based analysis for Classifying MCI and sleep quality as a function of brain complexity

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Abstract

Background: Good sleep quality is essential for both physiological and mental health. It helps in clearing TAU and beta-amyloid aggregates and consolidating memory, key processes in delaying dementia. Poor sleep is linked to reduced cognitive flexibility in daily life, likely due to decreased brain complexity, reflecting a reduced range of adaptive spatiotemporal brain dynamics. This study introduces a novel approach using non-linear EEG analysis focused on low conventional bands to classify sleep quality in individuals with mild cognitive impairment (MCI), based on brain complexity.

Method: Resting-state EEG was collected from 22 participants with MCI aged 60+, grouped by sleep quality (Pittsburgh Sleep Quality Index): 11 MCI with good sleep, and 11 MCI with poor sleep (Table 1). EEG data (128 channels, 5-minute recordings) were normalized and decomposed using the Discrete Wavelet Transform to reach delta (1–4 Hz) and theta (4–8 Hz) bands. Ten non-linear complexity features, namely approximate entropy, correlation dimension, detrended fluctuation analysis, energy, Higuchi fractal dimension, Hurst exponent, Katz fractal dimension, Boltzmann Gibbs entropy, Lyapunov exponent and Shannon entropy, were extracted from 5 second segments. Statistical measures (mean, standard deviation, 95th percentile, variance, median, kurtosis) were computed from these time-distribution features. These statistics were then used for training and testing a set of classic machine learning classifiers, employing leave-one-out cross-validation (Figure 2).

Results: Brain complexity successfully classified sleep quality in MCI, achieving an accuracy and area under the curve (AUC) of 1 in channel D13 (delta subband) using

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Quadratic Discriminant Analysis (QDA), and an accuracy of 0.94 and an AUC of 0.95 in channel B17 (theta subband) using the Extra Trees Classifier (ETC) (Figure 3).

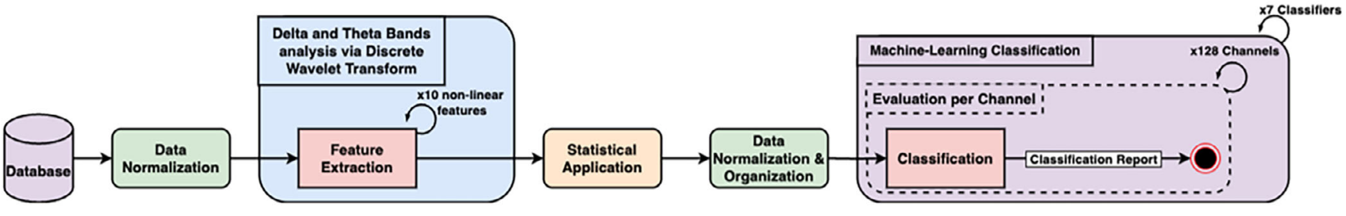
Conclusion: Specific machine learning classifiers distinguish excellently sleep quality in MCI using spatiotemporal complexity features from slow EEG subbands. The most relevant channels for group discrimination were primarily located in bilateral temporal regions of the neocortex known to be among the first affected in amnestic MCI, as previously shown in neuroimaging studies. Future longitudinal studies could investigate whether changes in brain complexity within these slow-frequency temporal regions, influenced by sleep quality, are associated with an earlier or faster onset of dementia.

Table 1. Participants

Group	MCI good sleep	MCI poor sleep
Sample (women)	11(5)	11(5)
Age	75.91 ± 4.59	79.00± 8.38
PSQI	<5	>5

Note. Table 1 displays information related to the participants included in this study: group (MCI with self-reported good sleep quality and MCI with self-reported poor sleep quality), sample size, age and cut off in the Pittsburgh Scale Quality Index.

Figure 1. Overview of the method



Note. This diagram outlines the steps followed in the present study. EEG data were first normalized, followed by multiband analysis using the Discrete Wavelet Transform. Ten non-linear complexity features were then extracted from each subband. The data were segmented into 5-second windows, and statistical metrics i.e., average, standard deviation, 95th percentile, variance, median, and kurtosis, were computed and compressed. These processed features were used as input for various machine learning classifiers. The classifier that achieved the highest classification performance between group pairs in at least one EEG channel was selected for analysis.

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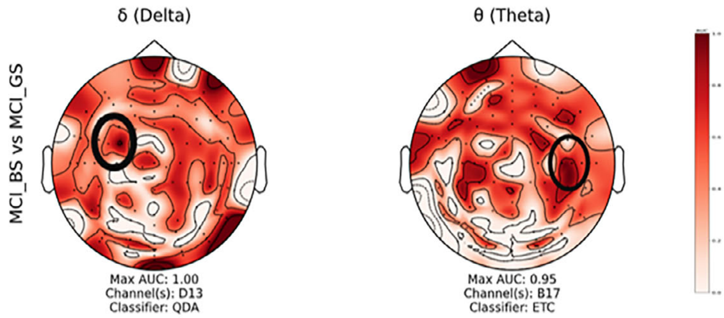
Figure 2. Topographic map classification results at scalp level



These topographical plots show the classification performance of the best-performing classifiers (based on the Area Under the Curve, AUC. Darkest red reflects higher prediction) in at least one EEG channel. The plot on the left presents results from the delta subband, comparing the MCI group with good sleep quality (MCI_GS) to those with poor sleep quality (MCI_BS). The plot on the right displays results from the theta subband for the same comparison. QDA = Quadratic Discriminant Analysis; ETC = Extra Trees Classifier; Max AUC = Maximum Area Under the Curve.