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MACHINE LEARNING-BASED EEG CHARACTERIZATION OF COGNITIVE AND MEDITATIVE STATES IN UNIVERSITY STUDENTS

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Abstract

Over the years, people around the world have been exposed to mental illnesses or mental health problems. Researchers and experts have used a variety of techniques and tests to identify the brain state, measure mental stress, and detect it. This study utilized supervised machine learning techniques applied to EEG features to classify mental states specifically stress, meditation, and cognitive tasks among university students. The study compared electroencephalogram (EEG) recordings of 15 meditation-naive individuals (6 males and 9 females; mean age 23.13 years) of the University of Sri Jayewardenepura, recorded during five phases: baseline, arithmetic, meditation, post-meditation, and relaxation. EEG data were collected by OpenBCI Cyton Biosensing Board with eight Ag-AgCl dry electrodes (Fp1, Fpz, Fp2, P7, P8, T7, T8, Oz) according to the 10-20 system, sampled at 250 Hz with impedance maintained below 5 kΩ. Recordings were pre-processed with 0.5-30 Hz band-pass and 50 Hz notch filter, and artefacts were removed by Independent Component Analysis (ICA). The filtered signals were divided into 2-second epochs, and the Power Spectral Density (PSD) features were extracted using Welch's method in Delta (0.5-4 Hz), Theta (4-8 Hz), Alpha (8-12 Hz), and Beta (12-30 Hz) bands. The primary objective of this research was to develop a unified supervised learning framework capable of classifying the above stages with the best accuracy. The secondary goal was a comparative benchmark of various supervised classifiers: Logistic Regression (LR), Random Forest (RF), SVM-Linear, SVM-Radial, and XGBoost, to identify the most informative frequency bands and cortical regions. XGBoost model is seen to offer the highest binary classification accuracies, with above 90 % for stage-wise comparisons. Band-wise comparison demonstrated that Beta-band features offered superior performance, with the frontal electrodes offering the highest accuracies in ensemble models. The findings confirm that EEG combined with supervised learning can effectively distinguish between stress, concentration, and relaxation states, with a foundation for real-time stress detection and meditation-based mental health support.

Keywords*:* *EEG, Machine Learning, Stress, Meditation, Cognitive Tasks*

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