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Mitigating EEG Non-Stationarity in Multi-Session MI BCI with Autoencoder Denoisers

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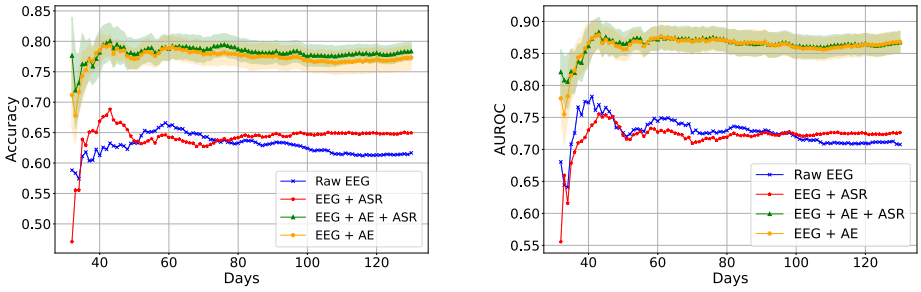
Introduction:
A fundamental challenge in motor imagery (MI) brain-computer interfaces (BCIs) is related to the non-stationary nature of brain signals. This inherent variability undermines the performance of classifiers, as models trained on data from one session often fail to generalize effectively to subsequent sessions. Traditionally, addressing this issue requires recalibrating the model for each session, a labor-intensive process that limits the scalability and practical deployment of BCIs in real-world applications.

Material, Methods and Results:
We propose a preprocessing method to enhance EEG signals using an autoencoder (AE) based on a convolutional neural network (CNN) architecture. The AE captures a low-dimensional latent representation of EEG signals from the initial N days, effectively filtering out noise while preserving essential features. The decoding step reconstructs EEG signals with an enhanced signal-to-noise ratio (SNR), providing stable signals across sessions without the need for recalibration [1]. The reconstructed signals represent a stable, invariant representation of the subject's intent, while the residual signals capture session-specific information. These reconstructed signals are then utilized for feature extraction and classification. When applied to longitudinal motor imagery (MI) data from a stroke patient, the proposed method demonstrates a substantial improvement in performance, as measured by accuracy and the area under the ROC curve (AUC), compared to the same classifier without the AE preprocessing as depicted in Fig 1. Additionally, the application of Artifact Subspace Reconstruction (ASR) does not significantly alter the performance, indicating that the observed improvement arises primarily from addressing non-stationarity rather than artifact removal.



(a) *Comparison of test accuracy across days.* (b) *Comparison of test AU-ROC across days.*

Figure 1: *Performance analysis across* 131 *daily sessions from a stroke patient, trained on the first* 30 *days and tested on the rest.*

Conclusion:
The proposed AE effectively captures a low-dimensional invariant representation of the subject's intent, eliminating the need for recalibration in subsequent sessions. The residual signals, which encapsulate session-specific variations, may offer valuable insights into the underlying sources of EEG non-stationarity.

References:
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