



Power-Sensitive Noise Blocking Enhances EEG-Based Neural Activity Differentiation Between NC and MCI

Ming Gu^{1,5}, Boxin Sun^{1,5}, Tim Martin², Voyko Kavcic^{3,5}, Bruno Giordani^{4,5}, Tongtong Li^{1,5}

¹Department of Electrical and Computer Engineering, Michigan State University, East Lansing, MI, USA

²Kennesaw State University, Kennesaw, GA, USA

³Institute of Gerontology, Wayne State University, Detroit, MI, USA; International Institute of Applied Gerontology, Ljubljana, Slovenia

⁴Departments of Psychiatry, University of Michigan, Ann Arbor, MI, USA

⁵Michigan Alzheimer's Disease Research Center, Ann Arbor, MI, USA



Abstract

Conventional EEG preprocessing often interpolates entire noisy channels, which may remove useful neural signals. This study proposes Power-Sensitive Noise Blocking (PSNB), a segment-level denoising method that removes contaminated channel segments while preserving clean, region-specific EEG information. Task-based EEG data were collected during a motion direction discrimination task. Current source density was computed, and Grubbs' test identified channels with abnormally high power. Compared with non-PSNB preprocessing, PSNB improved classification accuracy from 68.11% to 80.14%, suggesting stronger detection of MCI-related neural features for early Alzheimer's disease screening.

Background

- Early identification of those at risk of developing Alzheimer's disease or a related dementia plays a determinant role for the implementation of timely interventions and improving quality of life.
- Conventional EEG preprocessing often interpolates entire noisy channels, potentially discarding useful neural information.

Experiment Design

- Our research focuses on EEG (64-channel) data acquired at WSU and MADRC, where participants received two 3-minute (eyes-closed) resting-state electroencephalograms (rs-EEG) and between which they were engaged in a visual motion direction discrimination task
- Each trial included multiple periods: stimulus onset, motion detection with Go (need to respond using button-press) or No-Go (no need to respond) indicator, and button press. Inter-trial interval length is uniformly distributed between 1.5 s - 3 s.
- The EEG-based regions-of-interest (ROIs) are shown in Fig. 1b.

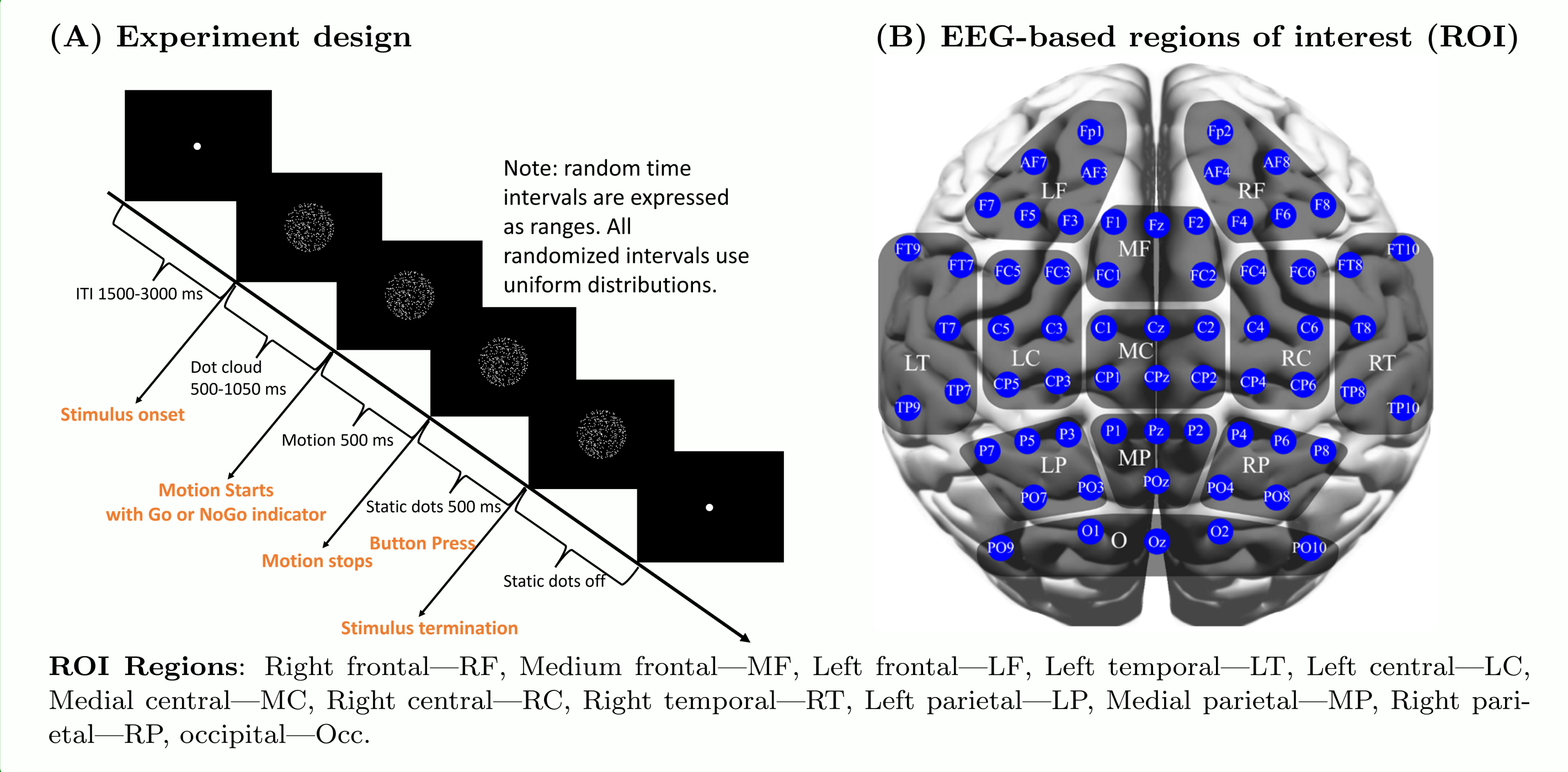


Figure 1: Experiment design and EEG-based regions of interest (ROI). (A) The motion direction discrimination task experiment design; (B) The EEG-based ROIs.

Data Acquisition and Preprocessing

- **EEG Data acquisition**
 - This dataset includes 56 consensus-diagnosed, community-dwelling American seniors with subjective cognitive complaints (ages 60-90 years, 28 NC and 28 MCI) recruited through the Wayne State Institute of Gerontology and the Michigan Alzheimer's Disease Research Center with subjective cognitive complaints.
- **EEG Data preprocessing**
 - The data was filtered with Analyzer 2 (Brain Vision, Inc.).
 - Before further analysis, the current source density (CSD) or the Laplacian (second spatial derivative) of the scalp voltage was calculated from the EEG signal using the CSD Toolbox in Matlab.

Power-Sensitive Noise Blocking (PSNB)

- For each channel and task segment, root mean square (RMS) power is computed.
- PSNB detects abnormal noise by examining CSD power in each EEG segment using Grubbs' test.
- Grubbs' test with a significance level of $\alpha = 0.05$ was used to identify outliers, meaning that observations were classified as outliers if they significantly deviated from the remaining data at the 5% significance level.
- Channels in each task segments with abnormally high power (outliers) are removed before further analysis.
- Regional CSD signals were calculated by averaging valid channels within each region. A segment was rejected only when more than one bad channel was detected within the same region.

Result before and after PSNB

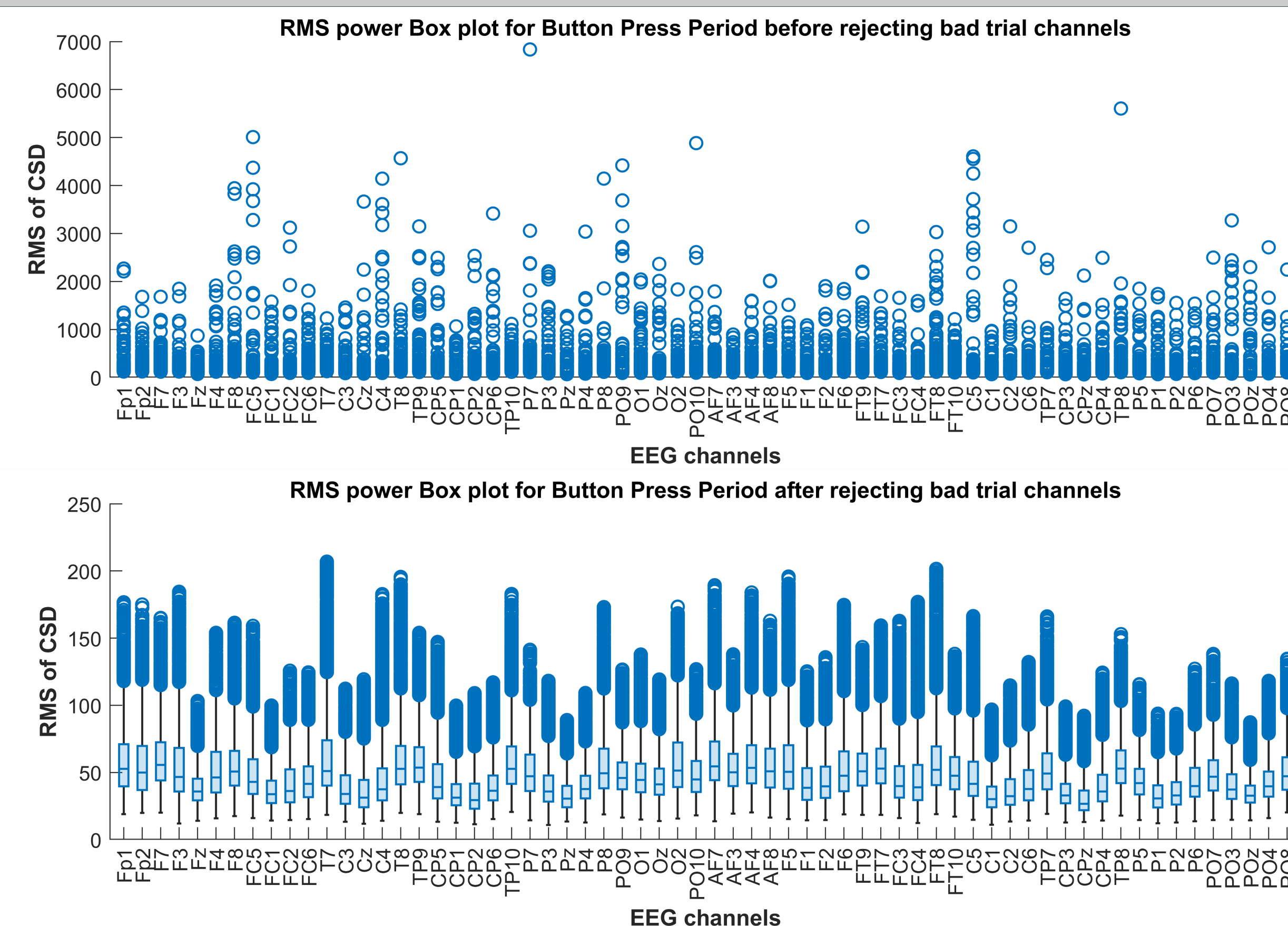


Figure 2: RMS power box plots for the Button Press period before and after rejection of high-noise channel segments. The results demonstrate that PSNB can identify and exclude contaminated channel segments.

Temporal Feature Selection

- Point-wise two-sample t-tests were used to compare HC and MCI CSD signals at each event segment, ROI, and time point.

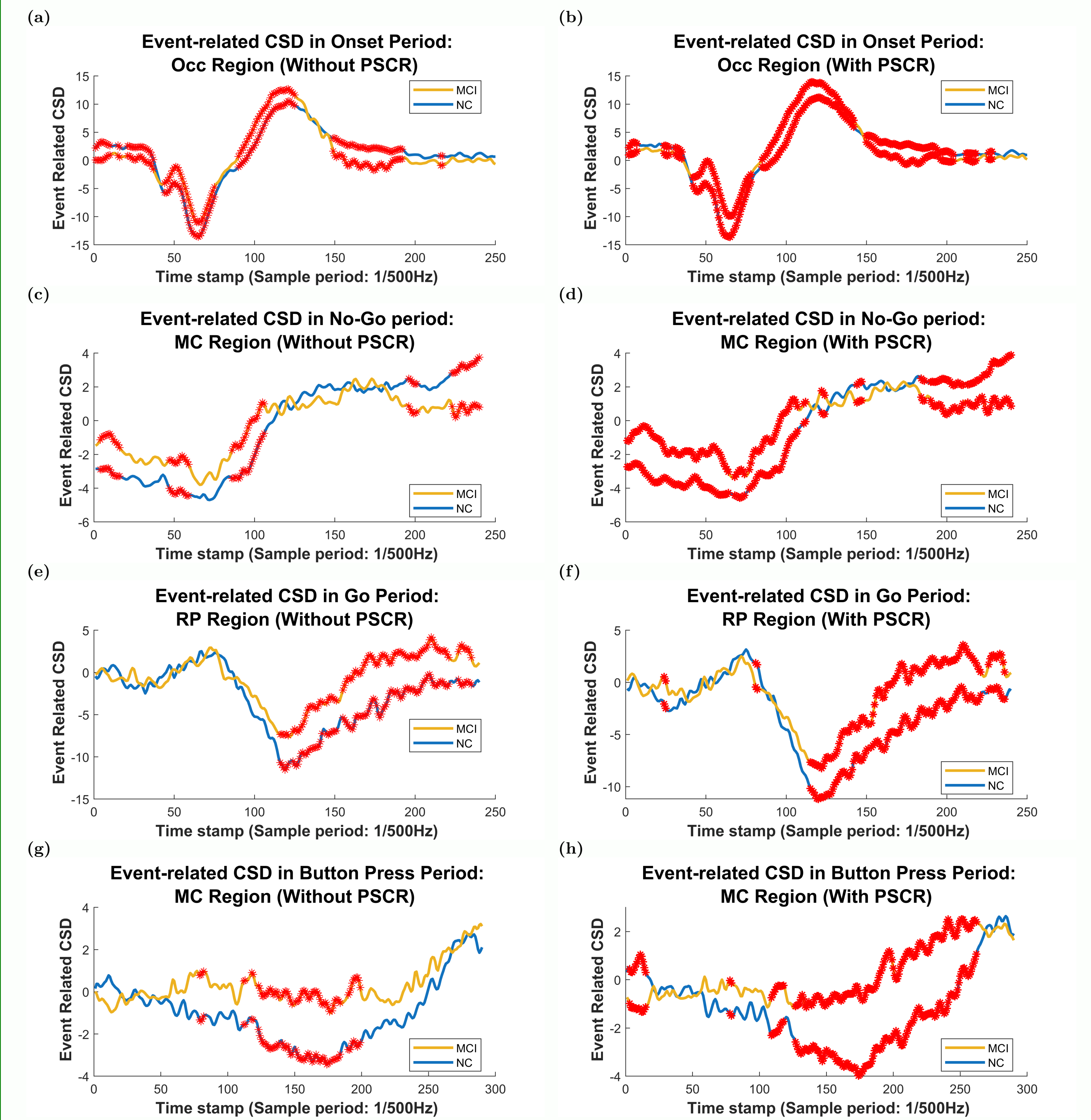


Figure 3: Comparison of time points with significant HC-MCI differences before and after PSNB

- Five most significant temporal windows, each containing more than 20 consecutive time points, were selected using two-sample t-tests. For each window, the averaged regional CSD signal was then used as features for model training and performance evaluation.
- The same feature selection criteria were applied to both denoised and non-denoised pipelines, enabling a fair comparison of whether PSNB improves the quality of extracted EEG features.

Conclusions

- PSNB improved localized EEG analysis by preserving regional specificity while reducing interregional interference, enhancing detection of MCI-related neural features for early Alzheimer's disease screening.
- Applying PSNB increased the average classification accuracy to 80.14% across 50 repeated 10-fold cross-validations, compared with 68.11% without PSNB.