Optimal Electrode Configurations of Wearable EEG Devices for the Computer-Aided Diagnosis of Mild Cognitive Impairment

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Introduction

Mild Cognitive Impairment

- Mild cognitive impairment (MCI) is a syndrome characterized as cognitive decline greater than expected for an individual's age and education level.
- The fact that MCI does not interfere with daily life and individual heterogeneity of the symptoms that can vary depending on etiology and cognitive reserve can delay the patient's visit to the hospital for the diagnosis.

Wearable EEG Device

- The prominent characteristics of EEG in MCI patients compared to the normal elderly are power spectrum shifts from high-frequency components towards low-frequency components, reduced complexity, and decrease in synchronization.
- A huge amount of progress in wearable EEG device was made in terms of potability and cost-effectiveness, providing the opportunity for early detection of neurological diseases in daily life.

In this study

- We presented a procedure to investigate the optimal electrode configurations of wearable EEG devices for the computer-aided diagnosis (CAD) of MCI.
- Furthermore, we demonstrated that the proposed optimal electrode configurations exhibited statistically higher performances than those of consumer wearable EEG devices.

Methods

Participants

- 21 MCI patients / 21 healthy controls (HC)
- There were no significant differences statistically between the two groups in terms of demographic characteristics, including sex, age, and education.

Signal acquisition and pre-processing

- Resting-state EEG was recorded for 4 minutes with eye closed
- The EEG signal was acquired from 32 channels according to the modified 10-20 system.
- The EEG data was baseline-corrected and band-pass filtered at cut-off frequencies of 0.5 and 50.
- The preprocessed EEG data were segmented into 5 s epochs without an overlap.
- After rejecting epochs whose maximal absolute value exceed the threshold of 75 µV, 20 epochs were randomly selected for each participant.

Feature extraction

- Absolute power spectrum density (APSD), relative power spectrum density (RPSD), differential asymmetry (DASM), rational asymmetry (RASM), phase-amplitude coupling (PAC), Shannon entropy (SE), Hjorth parameters (HP), Lyapunov exponent (LE), Hurst exponent (HE), Kolmogorov complexity (KC) were extracted as the candidate features for the diagnosis of MCI.

Feature selection & classification

- An SVM classifier was employed.
- Leave-pair-out (LPO) cross-validation (CV) was conducted to evaluate the classification performance of the model.
- In each iteration of LPO CV, z-score normalization was applied to each feature of training set.
- Then, we selected the feature subset from the training set according to Fisher's score

Determination of optimal electrode configuration

- The investigated electrode configurations consisted of 2, 4, 6, or 8 electrodes by following the rule: (1) midline of the montage (2) configurated in pairs
- The classification accuracy of the proposed optimal electrode configurations was compared with that of the consumer wearable EEG devices including Focusband™ (T2 Green Pty Ltd., Carrara, QLD, Australia), Insight™ (Emotiv Inc., San Francisco, CA, USA), DSI-7™ (Wearable Sensing LLC), Imec™ (Imec Inc., Leuven, FB, Belgium), and EPOC™ (Emotiv Inc., San Francisco, CA, USA).

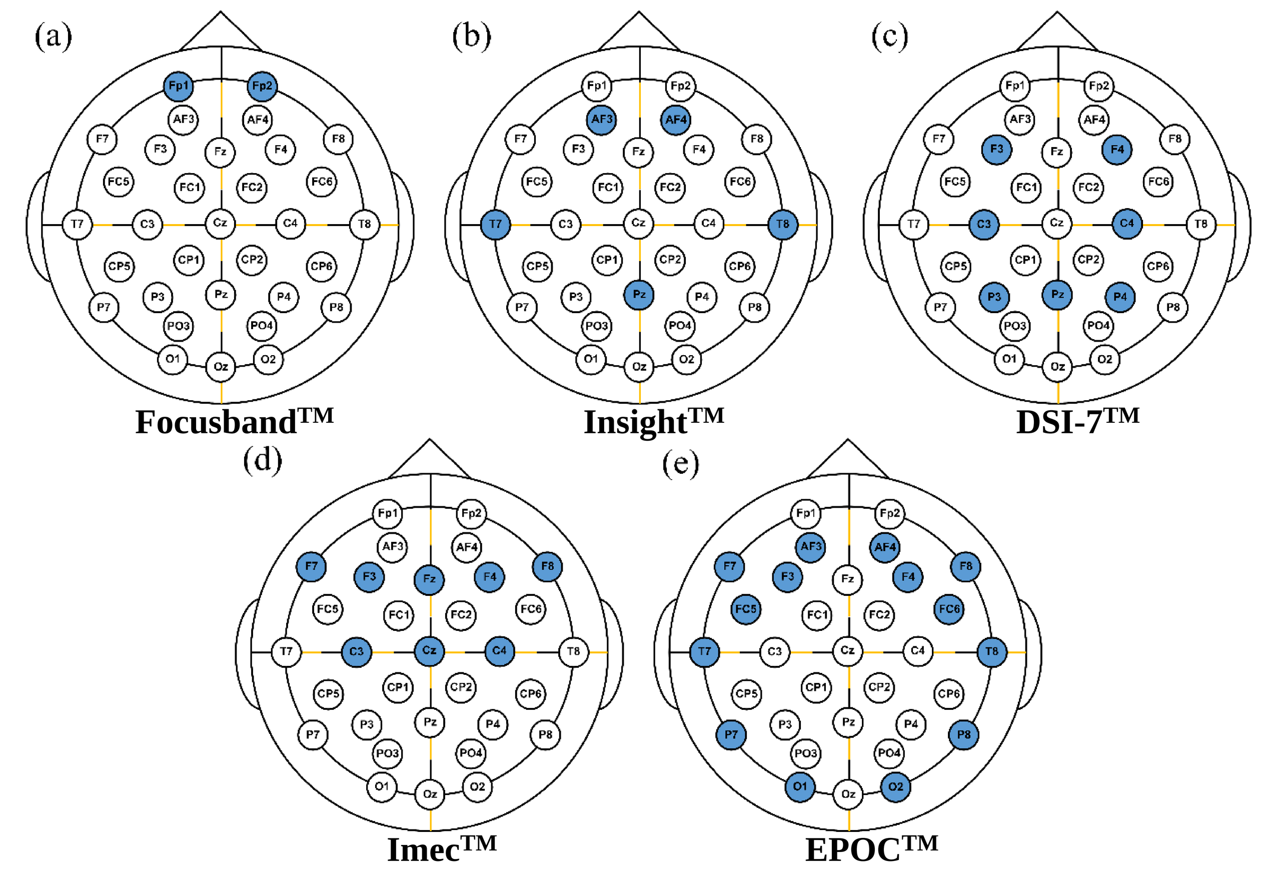

Figure 1. Electrode configuration of the consumer wearable EEG device

Results

Performance of optimal electrode configuration (Opt-Nch)

	Accuracy	Sensitivity	Specificity	Channel combination
Opt-2ch	74.06%	63.95%	84.13%	F3-F4
Opt-4ch	82.43%	70.75%	94.10%	AF3-AF4-FC5-FC6
Opt-6ch	86.28%	86.17%	86.39%	FC5-FC6-C3-C4-P7-P8
Opt-8ch	86.85%	86.85%	86.85%	F3-F4-FC5-FC6-C3-C4-P7-P8

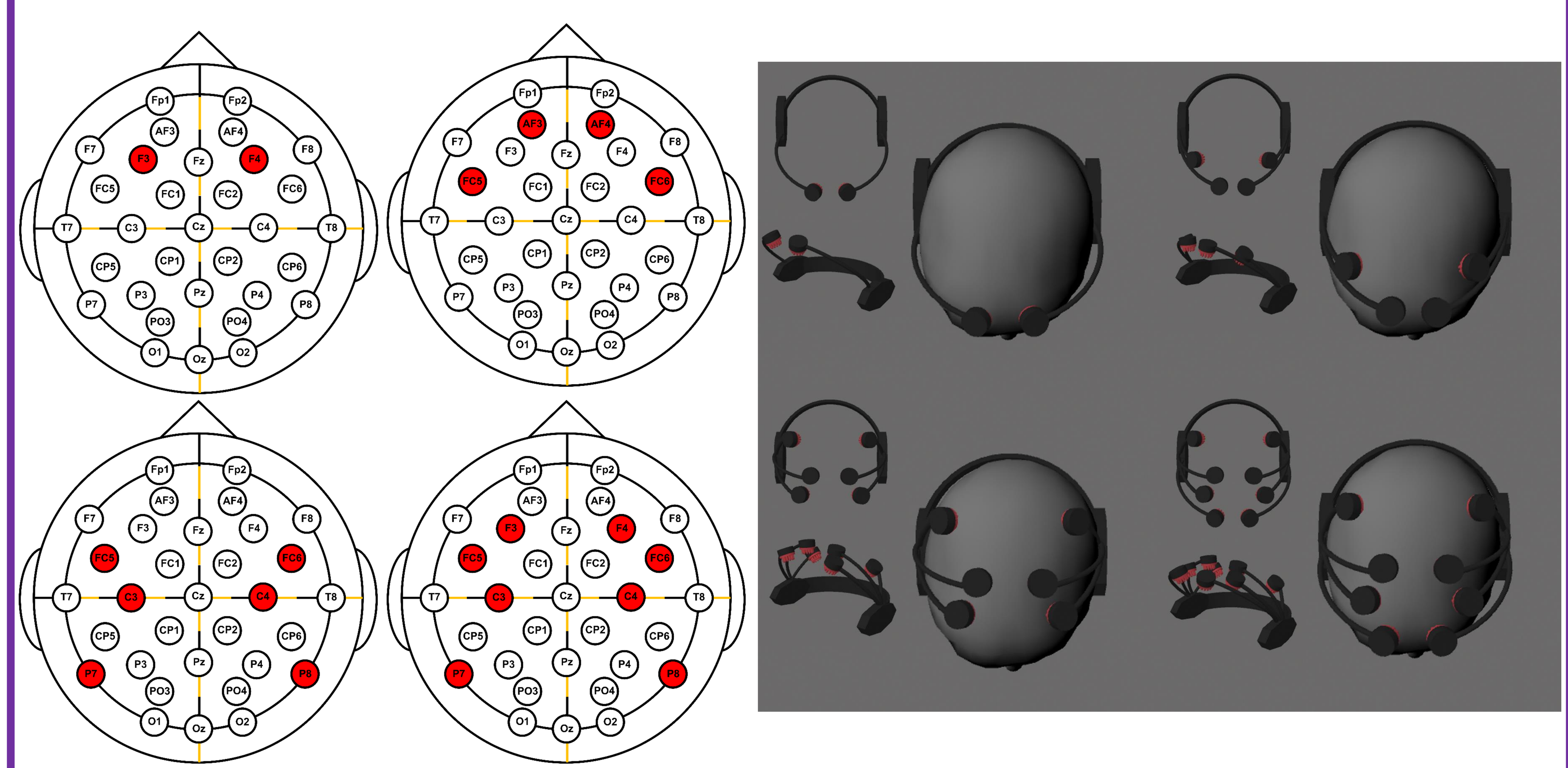
Figure 2. Optimal electrode configuration & 3D rendered images of custom-designed wearable EEG devices

Comparison with the electrode configurations of consumer wearable EEG devices

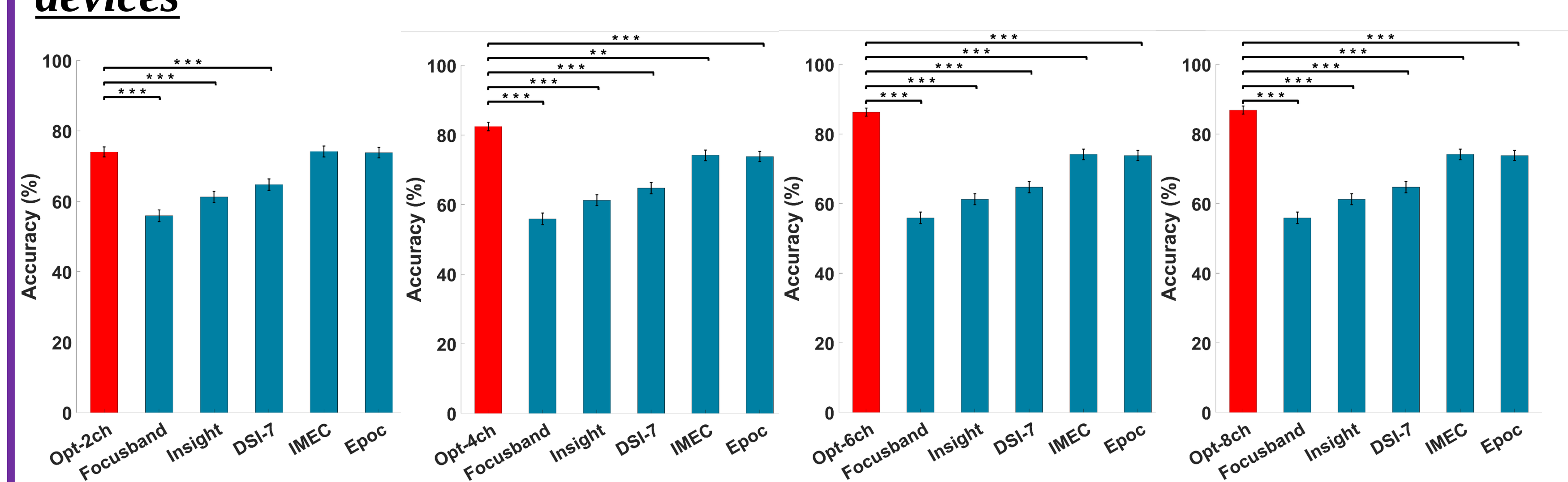

Figure 3. The performance comparison between the proposed optimal electrode configuration and the electrode configuration of the consumer wearable EEG devices.

- Bonferroni-corrected Wilcoxon signed-rank test was conducted to identify the significant difference between the accuracies of the proposed electrode configurations and those of the electrode configurations of the consumer wearable EEG device.

Conclusion

- We suggested the optimal EEG electrode configurations with 2, 4, 6, and 8 electrodes for the CAD of MCI.
- The proposed optimal electrode configurations showed significantly better performance than the electrode configurations of the consumer wearable EEG devices, albeit with a smaller number of electrodes.

Acknowledgment

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