Decoding Intended Movement from Human EEG in the Posterior Parietal Cortex

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Introduction

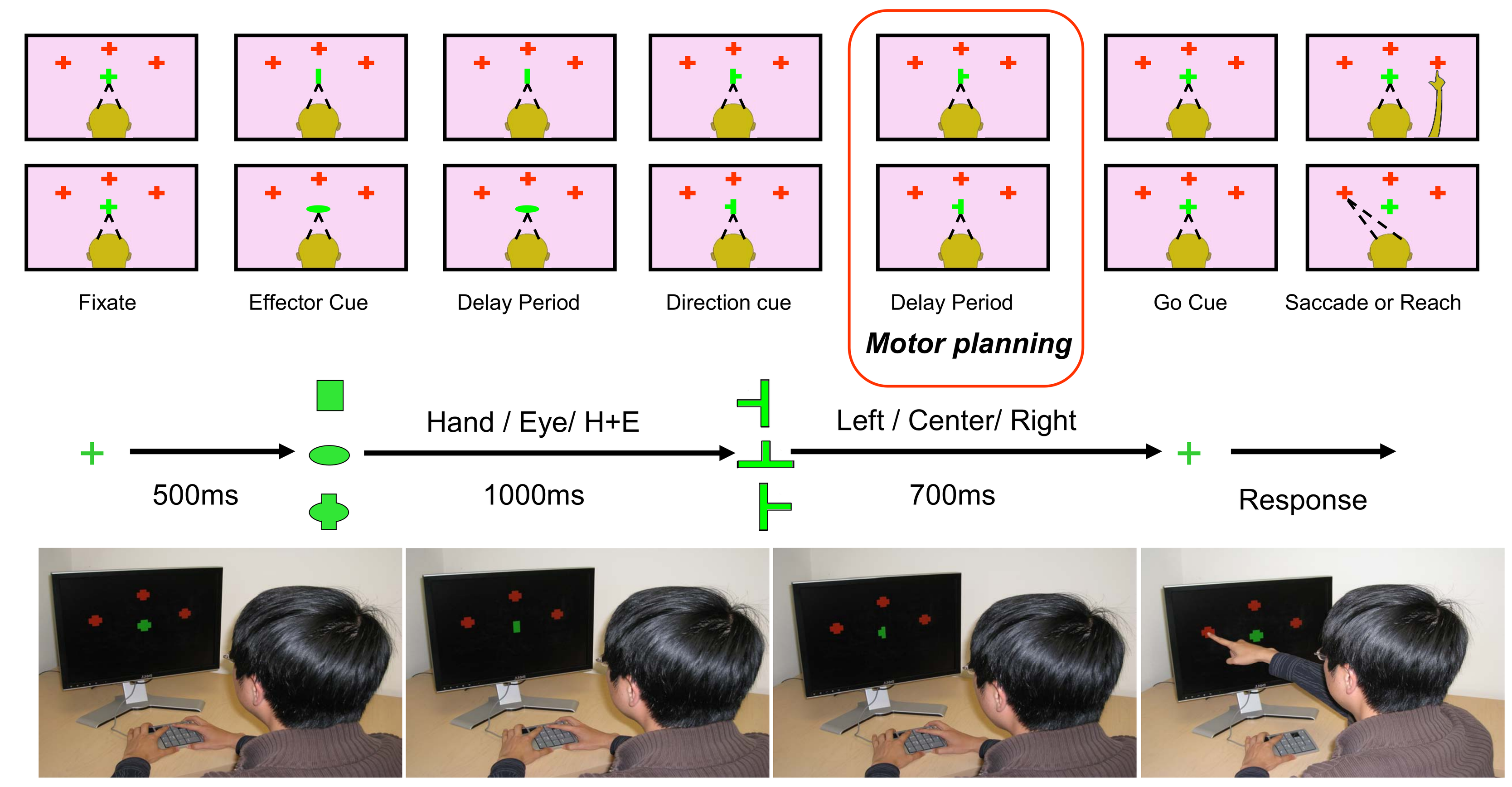
The role of the posterior parietal cortex (PPC) in sensorimotor transformations has been explored by neuronal recording in monkey studies (Quiroga *et al*., 2006; Calton *et al*., 2002). Direction and effector information for an intended movement can be predicted using firing rates of neurons in specific PPC subareas: the lateral intraparietal area (LIP) for saccades and the parietal reach region (PRR) for reaches. In humans, functional magnetic resonance imaging (fMRI) studies on the PPC have identified regions corresponding to the monkey LIP and PRR areas (Sereno *et al*., 2001; Connolly *et al*., 2003). In the present study, we asked whether it is possible to decode intended movement using human EEG recorded in the PPC. To this end, we recorded multi-channel EEGs with a delayed saccade-or-reach task and proposed an approach based on single-trial EEG classification.

Method

We recorded 128-channel EEG from four healthy subjects. The task comprised nine conditions differing by movement type (saccade, reach to touch without eye movement, and visually guided reach to touch) and movement direction (left, center, and right). Each task was indicated to the subject by an effector cue, followed by a direction cue and then an action (go) cue. EEG data between the direction and action cues were extracted for further analysis.

Independent component analysis (ICA) was applied to decompose the scalp EEG into functionally specific component processes using the EEGLAB toolbox (Delorme and Makeig, 2004). Parietal ICs were selected and then back projected onto the scalp. Normalized single-trial amplitudes of these ICs were concatenated and input into a support vector machine (SVM) classifier. Cross validation was run to estimate classification performance. For simplicity, we included four tasks: *saccade left*, *saccade right*, *reach left*, and *reach right*.

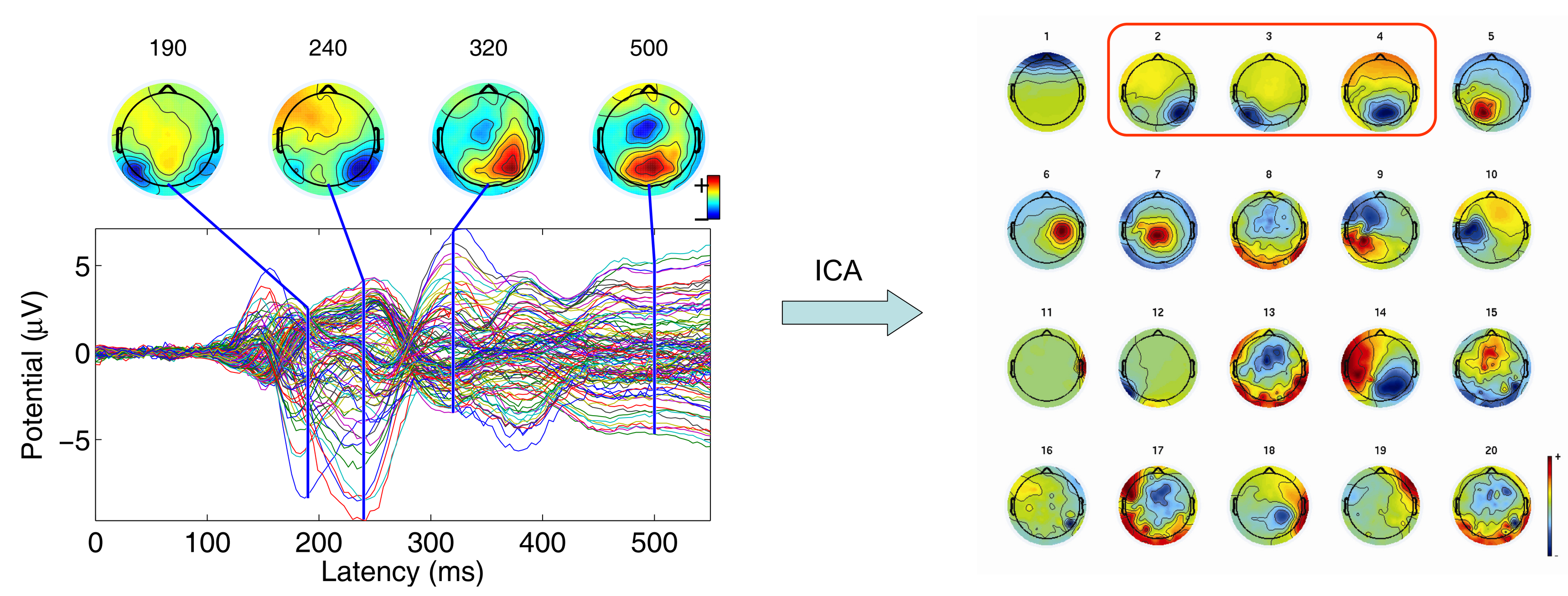
Experiment

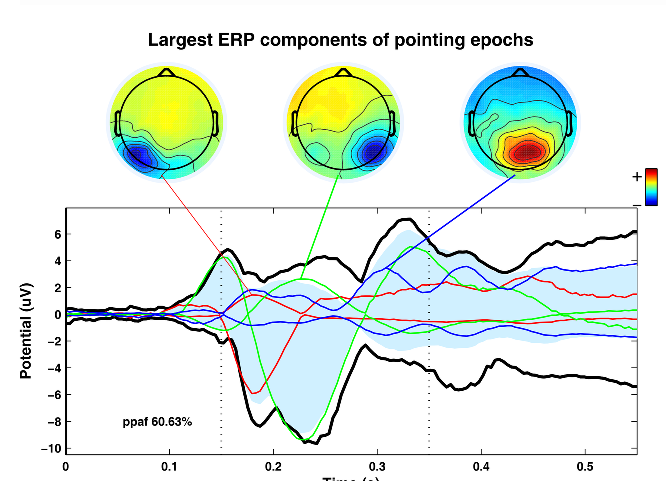


Effectors: (1) Hand (2) Eye (3)Eye&Hand   Directions: (1) Left (2) Center (3) Right

Results

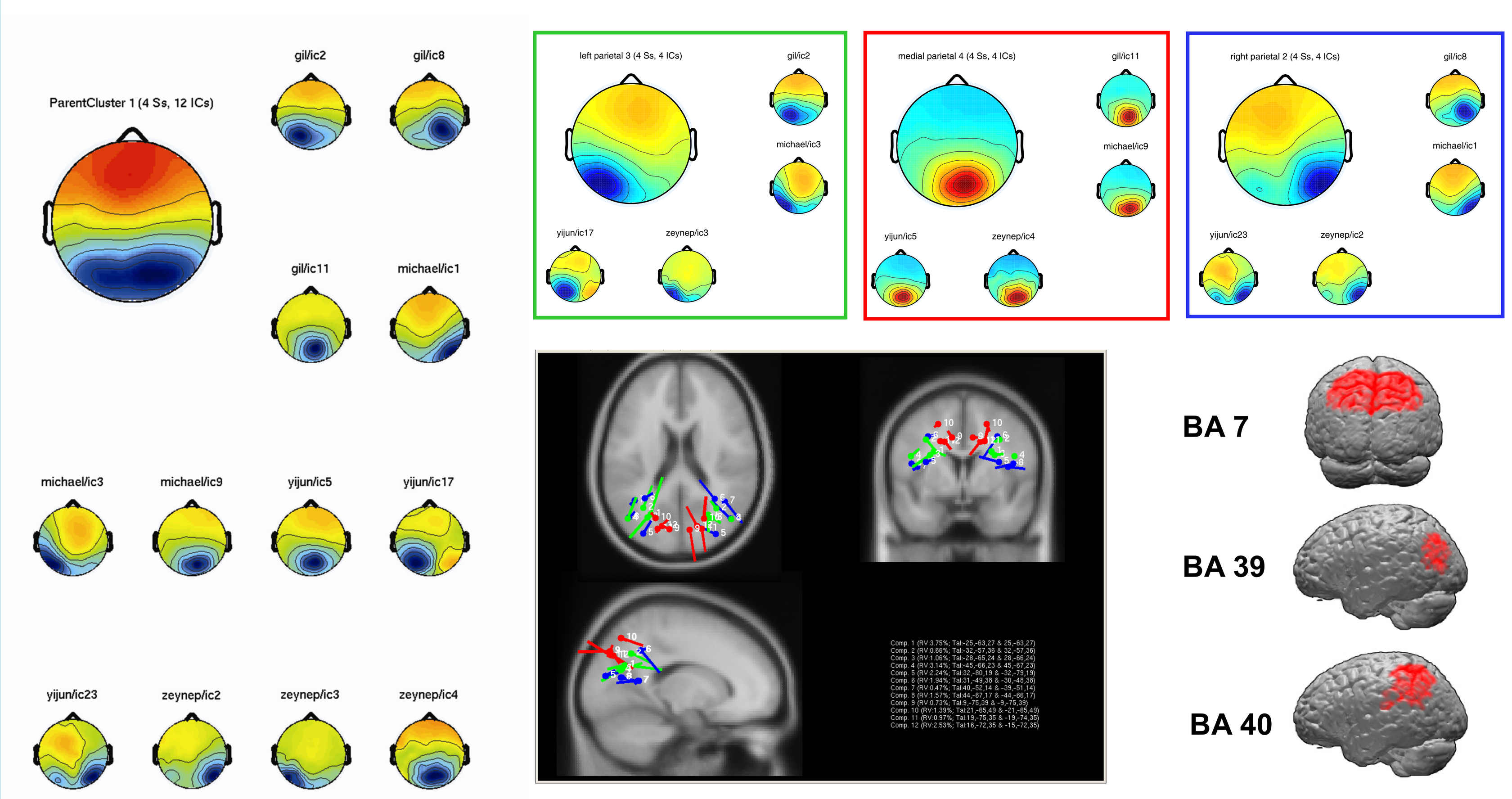
(1) Independent Component Analysis (ICA)





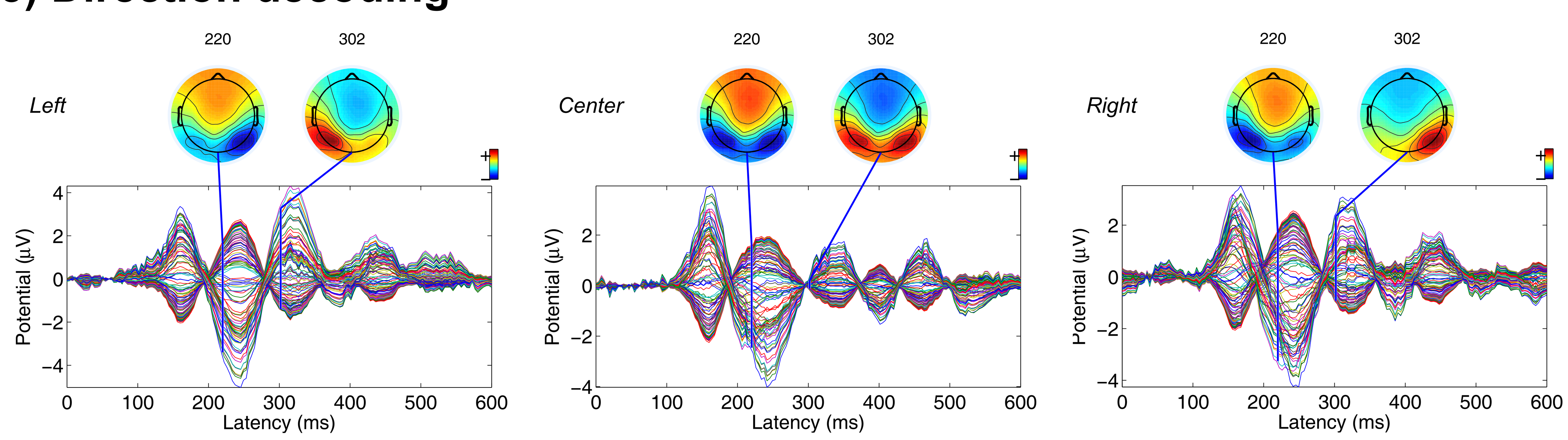
Independent component analysis (ICA) has been widely used in EEG analysis. It can decompose the overlapping source activities constituting the scalp EEG into functionally specific component processes. Here, we used ICA as an unsupervised spatial filtering technique to extract parietal EEG independent component (IC) activities that excluded noise from eye and muscle components as well as brain activities from other functional processes (e.g., in motor, visual, and frontal areas). For each subject, all trials were band-pass filtered (1-30 Hz), concatenated, and then decomposed using the extended infomax ICA algorithm.

(2) Clustering parietal components



Two lateralized temporal-parietal and one medial parietal components were identified in each subject's decomposition based on their spatial distributions and prominent contributions to the average event-related potential (ERP) waveforms. Equivalent dipole localization fitting two symmetric bilateral model dipoles to each IC scalp map indicated that these lateralized IC processes originated from the bilateral PPC (Brodmann Area 39/40).

(3) Direction decoding

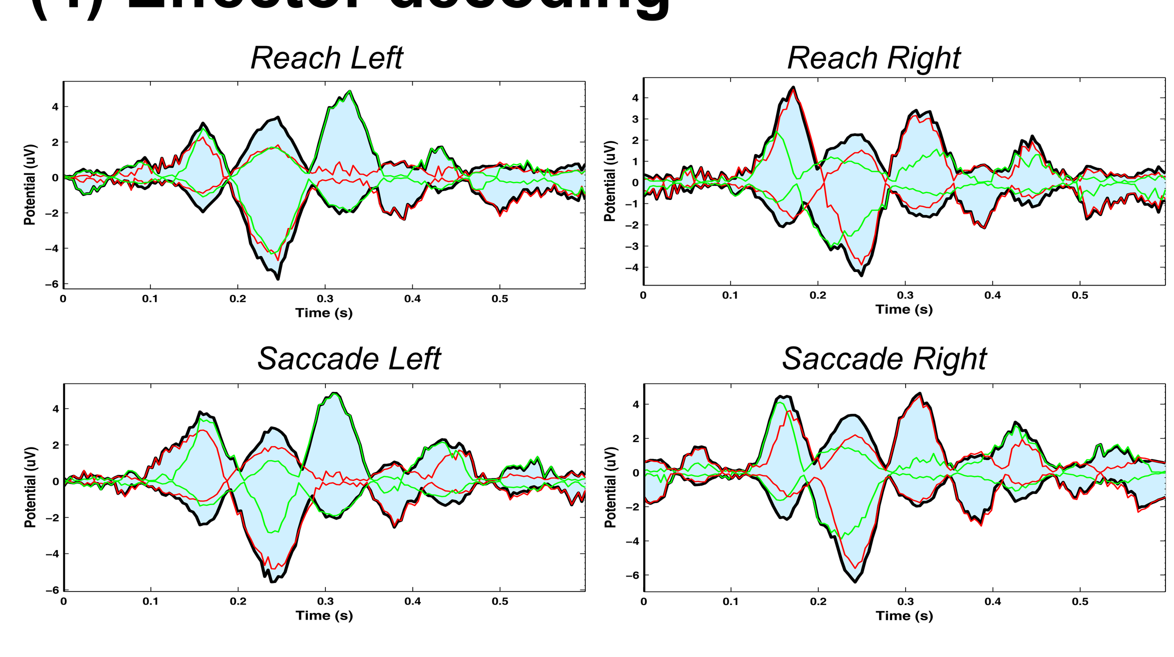


Time-frequency parameters and classification performance (*left* vs. *right*)

Subject	Time Window (ms)	Frequency Window (Hz)	Accuracy (%)
S1	180-500	0-25	79.9±0.45
S2	150-480	0-25	81.9±0.94
S3	180-450	0-20	77.2±0.86
S4	210-510	0-35	81.9±0.81
Mean	——	——	**80.25±2.22**

Binary classification of "*left*" versus "*right*" trials was performed using standard machine learning techniques. Because this study focused on EEG modulation in the parietal cortex, only the parietal IC components were used for feature extraction. After low-pass filtering, normalized amplitudes in the selected time window, normalized at each time point to have a range of [-1 1] across trials, were employed as features. Feature vectors from both parietal components were concatenated and then input to a support vector machine (SVM) classifier using an RBF kernel.

(4) Effector decoding



As shown in the ERP envelops of the lateralized parietal ICs, effector-specific information involved distinct changes in ERP amplitude and latency (*reach* vs. *saccade*), while movement direction information was reflected by hemispheric asymmetry.

For 4-class classification, we obtained an average accuracy of 49.8% (44.8%-55.0% across all subjects; chance level, 25%). Considered separately, direction classification accuracy was 80.3%, effector classification 69.1%. Binary condition classification was performed for all 6 pairwise condition combinations for each subject; the most distinguishable pair (mean, 84.9%; range, 80.0%-90.5%) differed across subjects.

Summary

1. The PPC (BA 7,39,40) plays an important role in intended movement planning.

2. Two lateral tempo-parietal components (BA 39,40) and a medial parietal component (BA 7), which contribute most to scalp ERPs, can be easily identified after ICA.

3. Direction and effector information during intended movement planning can be decoded using features derived from two lateral tempo-parietal (BA 39,40) ICs.

Conclusion: Here we have shown that brain activity in the PPC is modulated by movement planning. We obtained classification accuracy well above chance level for direction and effector estimation. Based on these findings, we find that intended movements can be predicted using EEG recordings, providing a new basis for design of a noninvasive brain-machine interface (BMI).

References

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