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Visual Perceptual-based Spatial Location Discrimination Using Single-trial EEG Analysis

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Introduction: Decoding a person's brain activity to infer the current perceptual state of that person has recently drawn great interest among researchers (see [1] for a review). Despite much recent progress, the spatiotemporal activations that encode perceptual information have not yet been reliably identified. Research on this field is not only important to neuroscience but resulting knowledge could also be used for practical applications, such as reactive brain-computer interface (rBCI). Furthermore, decoding perceptual information for single trials in a cheap, non-invasive way from recorded brain signals is not a trivial task. In this study, the aim is to demonstrate that it is possible to determine different spatial location cues which covertly appear to the left or right visual field using scalp electroencephalography (EEG) signals within milliseconds.

Material Methods: A custom-made visual stimulus presentation device with one central visual reference marker (fixation) LED and four target light LEDs was used to present experimental stimuli, resulting in four stimulus locations (see Fig. 1). EEG data was collected from ten healthy subjects while performing the delayed memory-guided saccade task to visual stimuli located in their straight-ahead visual field, i.e., subjects need to focus on the fixation LED even the stimulus presents. By using SPM12 artifact detection functionality, the artifact-free 30-channel EEG segments of length 400ms were selected. A sliding window of length 200ms and a step size of 20ms is used to search the active window. The proposed method uses best basis-based wavelet packet entropy [2] as feature extraction, fuzzy entropy [3] as feature reduction, and naive Bayes classifier (NBC) as a classifier. To obtain an idea of the distribution of the attainable accuracies, 10-fold cross-validation was performed on a four-class classifier and two-class classifiers for reliable estimation.

Results: Average cross-validation results are summarized in Table 1. It shows that (1) the four-class classifier dividing the target into four different locations is with well above chance (2-class is 50% and 4-class is 25%); (2) comparison pair <L2 vs. R2> yields the higher discrimination accuracy than pair <L1 vs. R1>. Subject S3 and S9 showed the higher discrimination accuracy in pair <L1 vs. R1> than pair <L2 vs. R2> due to using different active windows and different channel sets.

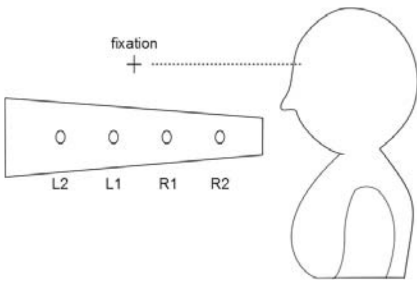

Figure 1. *Schematic of visual perceptual light stimuli. The fixation LED was positioned 5 cm above the center of the stimuli. Four visual targets were at 60cm viewing distance and were at 2.5 and 7.5 degree visual angle to the left and right of body midline / straight ahead.*

Table 1. Discrimination accuracy for each subject (%).

Subject	4-class	2-class	
	L2 vs. L1 vs. R1 vs. R2	L1 vs. R1	L2 vs. R2
S1	45.561	80.832	82.538
S2	42.085	75.743	77.455
S3	40.886	78.898	75.735
S4	44.655	76.467	80.154
S5	49.058	77.833	83.320
S6	41.657	76.379	76.561
S7	45.375	80.359	84.091
S8	47.011	76.055	82.267
S9	44.702	81.576	80.806
S10	43.994	79.554	81.847
Ave	44.498	78.370	80.477

Significance: The result demonstrates that a short time segment EEG activity pattern before eye movement is a useful tool for covert visual perception location discrimination. The proposed method can help design an actual reactive BCI system for detecting perceptual-spatial location.

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