Optimizing the EEG Electrode Configuration for Signal Acquisition in P300 Speller Systems

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THE P300 speller is a brain-computer interface (BCI) system that restores communication ability to "locked-in" patients by detecting evoked responses to visual stimuli in the user's electroencephalogram (EEG) signal [1]. Choosing the optimal placement and number of electrodes is essential in any EEG system as it balances the amount of available data against the set-up time and the amount of computation work required for signal classification. While several different layouts have been tested [2], no systematic study has been performed to determine the optimal electrode placement. The goal of this project was to optimize EEG electrode placement for P300 studies using an offline Gibbs sampling method.

This study used a data set of 15 healthy subjects who spelled between 8 and 10 five letter words using Donchin's P300 speller with 32 electrodes in an established pattern [3, 4]. Batch Gibbs Sampling was used to find samples from the distribution of electrodes that can best classify EEG signals. Electrode sets were constructed by finding the groups of electrodes that co-occurred most frequently in the samples. Classification with a naïve Bayes classifier [5] was performed offline using data from each of these electrode sets and results were evaluated using information transfer rate (ITR) [6].

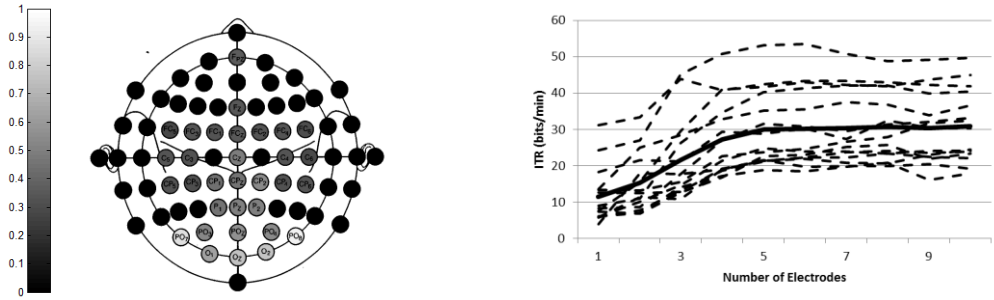

Figure 1: a) Proportion of samples that included each electrode. No data was acquired in locations with black dots. b) ITR for each subject (dashed lines) and average (solid line) plotted against the number of electrodes used in the classification.

Sets of one, two, or three electrodes produced average ITR values (11.54, 15.25, and 21.58, respectively) that were significantly lower than the result when using all 32 electrodes (31.08). Using a set of four posterior electrodes (PO_8, PO_7, PO_Z, O_Z), the average ITR was 27.34, which is still lower than the result when using the full set ($p<0.01$), but could be effective. Data from a set of five electrodes (PO_8, PO_7, PO_Z, O_Z, CP_2) produced an average bit rate of 29.89, which does not significantly differ from the results when using all of the data ($p=0.11$) or when using the six electrode layout from Krusienski et al. [2] ($p=0.46$). This study shows that the number of electrodes used in a P300 speller system can be reduced without significantly affecting system performance. Reducing the number of channels will improve the set-up time as well as reducing the signal bandwidth and computation requirements for classification.

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This work was supported by the NLM Grant T15-LM007356 (WS), the National Institute of Biomedical Imaging and Bioengineering Award Number K23EB014326 (NP), the UCLA Scholars in Translational Medicine Program (NP), and the UCLA Department of Neurosurgery Visionary Ball Fund.

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