Hybrid oddball - SSVEP BCI

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Abstract

Objectives: blablabla blalabbla Steady-State Visually Evoked Potential (SSVEP)-based BCIs.

Results: blablabla blablabla SSVEP responses.

Conclusion:

1 Introduction

Brain-Computer Interfaces (BCIs) aim at decoding the brain activity in order to provide a direct communication channel between the brain and an external device. In this study, the brain activity is recorded using electroencephalography (EEG), which offer the advantage over other method (*e.g.* micro electrodes, fMRI ...) to be non-invasive and easy to set up.

Some of the earliest EEG-BCI systems were based on the P3 component of the Event Related Potential (ERP) (Donchin et al. 2000; Farwell and Donchin 1988). The P3 is a positive deflection in the EEG time-locked to salient stimuli presented in an oddball paradigm, typically evoked over the parietal cortex, and occurs between 200 and 500 ms after stimulus onset Sutton et al. 1965. Although those BCIs rely mostly on the P3 component, other components (*e.g.*, occipital N1 and/or N200) may also be used for ERP detection Bianchi et al. 2010; Kaufmann et al. 2011, for this reason we prefer here to use the term *oddball-based BCIs*.

Other systems of interest are BCIs based on Steady-State Visually Evoked Potentials (SSVEPs). They rely on the psychophysiological properties of the EEG brain responses recorded from the occipital cortex during the periodic presentation of identical visual stimuli (*i.e.* flickering stimuli). When the periodic presentation is at a sufficiently high rate (> 6 Hz), stable and synchronized neural oscillations at the stimulus frequency and its harmonics are evoked over the visual cortex Herrmann 2001; Luck 2005; Regan 1966. Such BCIs are particularly attractive because SSVEPs have high signal-to-noise ratios and are less susceptible to eye movement and blink artifacts Perlstein et al. 2003 as well as electromyographic artifacts Gray et al. 2003. Several SSVEP-based BCIs have been successfully tested with healthy subjects (see Vialatte et al. 2010 for a review).

2 Materials and Methods

2.1 Material

The EEG signals were recorded using a BioSemi Active Two system with 32 channels (following the 10-20 international system) at a sampling rate of 1024 Hz. Two additional electrodes were positioned on the right and left mastoids and the mean of the signals recorded at those two sites was used to reference the activity measured by the 32 EEG electrodes.

All stimulation employed MATLAB®, the stimuli were visually presented on a laptop's LCD screen (60 Hz refresh rate) and their display and timing used the *Psychophysics Toolbox Extensions* (Brainard 1997; Pelli 1997).

2.2 Experiment 1: studying the oddball ERPs

2.2.1 Experimental protocol

The aim of this first experiment was to study the effect of a flickering background on the typical ERP response associated to an oddball paradigm. N subjects participated in the experiment (age, gender).

As shown in Fig. 1, a typical *stimulation cycle*, starts with a 2000 ms cue, indicating the participant his/her target item, followed by a 1000 ms pause during which the cue disappears and all icons remained gray. The background rectangle starts then to flicker and the oddball stimulation begins 500 ms later. The oddball stimulation consisted of 10 *flashing sequences* during which each of the 6 icons was flashed one after another in random order for a duration randomly set between 200 and 300 ms. As usually done for oddball experiments, the participants were instructed to focus on their target symbol and count the number of time it flashes. A 1000 ms pause followed the oddball stimulation and preceded the next cue. An *experimental run* lasted approximately 4 minutes and consisted of 12 consecutive stimulation cycles, so that each of the 6 icons was cued twice (in random order).

As we aimed here at studying the effect of the flickering background on the oddball ERP response, we considered 5 experimental conditions. The first one (baseline) consisted of a run as described in the previous paragraph but in which no flickering background was displayed. The 4 other conditions differed only by the frequency of the flickering background; the frequencies used were 8.57, 10, 12 and 15 Hz, corresponding to the division of the refreshing rate of the screen by 7, 6, 5 and 4, respectively.

For each of the 5 conditions, all subjects performed 3 runs, therefore the whole experiment consisted of 15 runs of approximately 4 minutes each. The order of the run was randomized for each subject and a 5 to 10 minutes pause was set up every 5 runs.

The data collected were used to compare the shape of the oddball response (response to the flashing of the target icon) and the ERP classification accuracy (response to target *v.s.* response to non-target flasing) across conditions.

2.2.2 Data Analysis: ERP responses

2.2.3 Data Analysis: ERP classification

We are also interested in studying the effect of the flickering stimulus on the target ERP detection accuracy. As the accuracy of an oddball BCI is known to depend on the number of repetitions of flashing sequences used to average the ERPs; the classification accuracy was measured on ERPs averaged over the n first repetitions of the flashing sequence with n going from 1 to 10. This was done so as to mimic a real use of the system (where the stimulation sequence would stop after n repetitions) and so that the accuracies are always measured on the same number of detection attempts.

For each experimental condition

Data were filtered between 0.3 and 15 Hz (zero-phase 3$^{\text{rd}}$ order Butterworth filter), cut into 800 ms epochs starting from the stimuli onsets and downsampled to 128 Hz.

For each trial (stimulus), we had 8 channels $\times$ 80 data points = 640 features to classify as a response to either a target stimulus or a non-target stimulus. A linear *Support Vector Machine* (SVM; Cristianini and Shawe-Taylor 2000; Suykens et al. 2002) with a 10-fold cross-validation and a linesearch for the optimization of the regularization parameter was built from the normalized training features. Training the linear SVM with the modified finite Newton method proposed by Keerthi and DeCoste (2006) took around one minute.

2.3 Experiment 2: studying the SSVEP responses

2.3.1 Experimental protocol

The aim of this second experiment was to study the effect of an oddball paradigm on the SSVEP responses. N subjects participated in the experiment (age, gender).

The experimental run was the same as described in sec. 2.2.1. Two experimental parameters were manipulated, the first one was the stimulation frequency; the same frequencies as for the first experiment were used (8.57, 10, 12 and 15 Hz). The second experimental parameter was the presence or not of the oddball stimulation sequence. When the oddball stimulation was displayed, the participants were instructed to count the number of flashes of the target icon, while when no oddball stimulation was displayed, their task was simply to focus on their target icon.

The experiment consisted thus of 8 runs of approximately 4 minutes each. The order of the run was randomized for each subject and a 5 to 10 minutes pause was set up after the first 4 runs.

This experimental design allows a comparison of the SSVEP responses of the participants with and without an oddball stimulation superimposed on the SSVEP stimulation for a different set of SSVEP frequencies.

2.3.2 Data Analysis

2.4 Experiment 3: hybrid classification

2.4.1 Experimental protocol

2.4.2 Data Analysis

3 Results

3.1 Experiment 1: studying the oddball ERPs

3.2 Experiment 2: studying the SSVEP responses

3.3 Experiment 3: hybrid classification

4 Discussion

5 Conclusion

Acknowledgments

References

Bianchi, L., Sami, S., Hillebrand, A., Fawcett, I. P., Quitadamo, L. R., and Seri, S., 2010. Which physiological components are more suitable for visual ERP based brain-computer interface? A preliminary MEG/EEG study. Brain topography 23 (2), 180–185.

Brainard, D. H., 1997. The Psychophysics Toolbox. Spatial vision 10 (4), 433–436.

Cristianini, N. and Shawe-Taylor, J., 2000. An Introduction to Support Vector Machines and Other Kernel-based Learning Methods. Cambridge University Press.

Donchin, E., Spencer, K. M., and Wijesinghe, R., 2000. The mental prosthesis: assessing the speed of a P300-based brain-computer interface. IEEE Transactions on Rehabilitation Engineering 8 (2), 174–179.

Farwell, L. A. and Donchin, E., 1988. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. Electroencephalography and Clinical Neurophysiology 70 (6), 510–523.

Gray, M, Kemp, A. H., Silberstein, R. B., and Nathan, P. J., 2003. Cortical neurophysiology of anticipatory anxiety: an investigation utilizing steady state probe topography (SSPT). NeuroImage 20 (2), 975–986.

Herrmann, C. S., 2001. Human EEG responses to 1-100 Hz flicker: resonance phenomena in visual cortex and their potential correlation to cognitive phenomena. Experimental Brain Research 137 (3-4), 346–353.

Kaufmann, T, Hammer, E. M., and Kübler, A., 2011. ERPs contributing to classification in the P300 BCI. 5th International Brain-Computer Interface Conference, 49–52.

Keerthi, S. S. and DeCoste, D., 2006. A modified finite Newton method for fast solution of large scale linear SVMs. Journal of Machine Learning Research 6 (1), 341–361.

Luck, S. J., 2005. An Introduction to the Event-Related Potential Technique. MIT Press.

Pelli, D. G., 1997. The VideoToolbox software for visual psychophysics: transforming numbers into movies. Spatial vision 10 (4), 437–442.

Perlstein, W. M., Cole, M. A., Larson, M., Kelly, K., Seignourel, P., and Keil, A., 2003. Steady-state visual evoked potentials reveal frontally-mediated working memory activity in humans. Neuroscience Letters 342 (3), 191–195.

Regan, D, 1966. Some characteristics of average steady-state and transient responses evoked by modulated light. Electroencephalography and Clinical Neurophysiology 20 (3), 238–248.

Sutton, S., Braren, M., John, E. R., and Zubin, J., 1965. Evoked-Potential Correlates of Stimulus Uncertainty. Science 150 (3700), 1187–1188.

Suykens, J. A. K., Van Gestel, T., De Brabanter, J., De Moor, B., and Vandewalle, J., 2002. Least squares support vector machines. World Scientific.

Vialatte, F.-B., Maurice, M., Dauwels, J., and Cichocki, A., 2010. Steady-state visually evoked potentials: focus on essential paradigms and future perspectives. Progress in neurobiology 90 (4), 418–38.

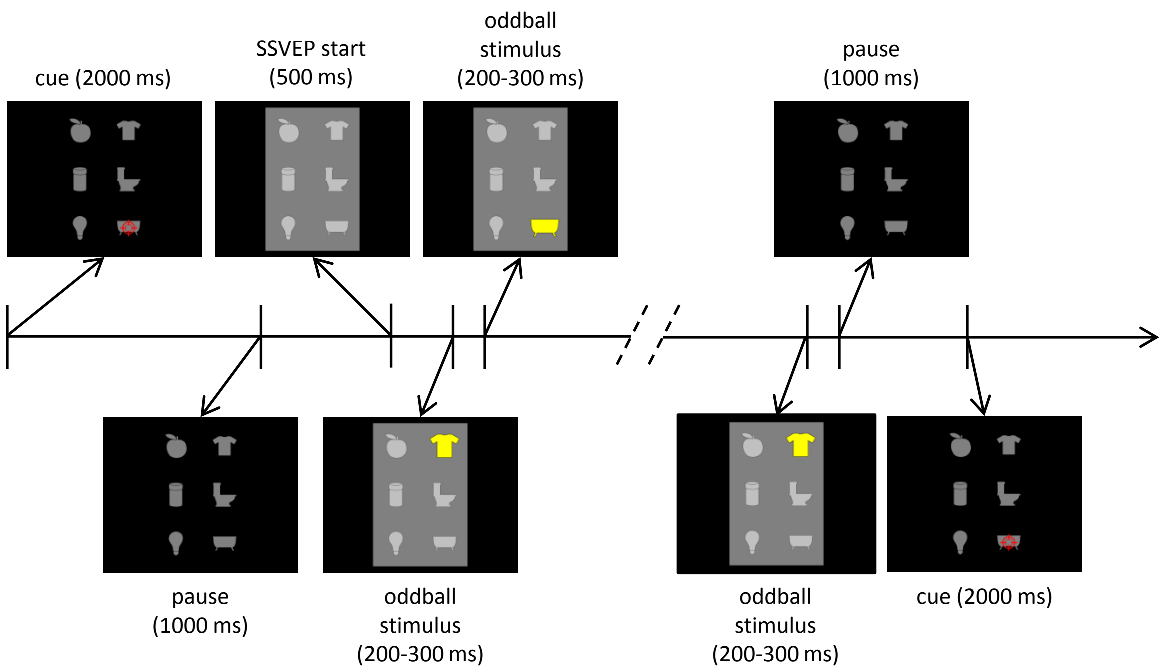

Figure 1: stimulation sequence