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# Single trial analysis of SCP for anticipation-BCI

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***Abstract.*** Single trial analysis of SCP faces different challenges than classical EEG such as contamination of Infra Slow Oscillations (ISO) with *f*<0.1Hz and high frequency spatial noise. We present appropriate spectral and spatial filters aimed at improving SNR of anticipation related SCP. We report single trial classification accuracies on average 0.83±0.04 obtained from 11 healthy subjects in 2 different days while performing a variation of CNV Go-Nogo paradigm in an assistive software technology framework for web-browsing.

*Keywords:* Slow Cortical Potentials (SCP); Contingent Negative Variation (CNV); Anticipation;

## 1. Introduction

Since the demonstration of SCP as a control signal for BCI devices [Birbaumer, 1999], there has not been numerous replications as compared to other control signals such as SMR, P300 and SSVEP etc [Bashashati, 2007]. This is probably due the fact that the practice of SCP based BCI faces challenges such as, 1) a reliable full-band EEG (FbEEG) hardware (*fh* << 0.5Hz) [Vanhatalo et al, 2005], 2) tedious training sessions ranging from several months to a few years, and 3) elusive nature of cognitive phenomenon underlying the SCPs. In addition, the SCPs are spatially distributed oscillations covering large scalp areas and are vulnerable to a variety of artifacts (e.g, ISO [Vanhatalo et al, 2005], changes of skin-conductance) leaving the current state-of-the-art BCI techniques at stake.

In the current paper we present an offline study of single trial recognition of anticipation related SCPs recorded from 11 healthy subjects in two different days. The subjects were conditioned in a variation of CNV [Walter et al, 1964; Boxtel and Bocker, 2004; Garipelli et al, 2009] paradigm wherein the reaction time (RT) was optimized over trials. We present appropriate spectral filtering and a novel spatial filtering of SCPs followed by results of single trial recognition wherein the classifiers are trained on day-1 and tested on day-2.

## 2. Material and Methods

The protocol was designed in the framework of assistive software for web browsing by icon selection with scanning mode as shown in Fig. 1.a. Each of the icons was highlighted sequentially every 2s and the subjects were instructed to ***anticipate*** for the target icon to be highlighted (Go) and ***press*** a high precision digital switch (synchronized with EEG) quickly. For a non target icon the subjects were instructed to ***relax*** (No-go). The feedback of accurate RT and a corresponding webpage of the icon were presented to the subjects if the behavioral parameters met a set of criteria (e.g. RT <100 ms for a target icon). For each subject we recorded on average 123.3±27.9 Go trials and 264.0±68.1 Nogo trials on each day.

FbEEG is acquired with 64 EEG electrodes at 2 KHz sampling rate and decimated to 64Hz. We report the presence of widely accepted CNV potential which is an increasing negativity at Cz electrode for the Go condition [Walter at al, 1964] and a flat response for the Nogo condition (see Fig. 1.b). For the single trial analysis, we extracted samples in the window of [-0.25 2.0] s and baseline correction is applied with the sample at 0s (see Fig.1.a). Features are selected as potentials at only Cz electrode at 8 time points (see + marks in Fig. 1. b) in the window of [0 2] s.

## 3. Results

Firstly, we identified a zero-phase narrow band filter that characterizes optimally the discriminability between Go and Nogo conditions by comparing Fisher scores for each subject separately using training samples. This study revealed that for all the subjects the band-pass filter with

[0.1 1] Hz pass band is optimal (see Fig 1.c for dotted-dash-square line for no spatial filter). Secondly, we compared Fisher score obtained for various spatial filters (CAR and Laplacian) with a novel spatial smoothing filter (SSF) in obtained by convolving an approximated Gaussian kernel with scalp distribution after CAR step at each time point in Fig.1.c. The SSF outperformed CAR and Laplacian.

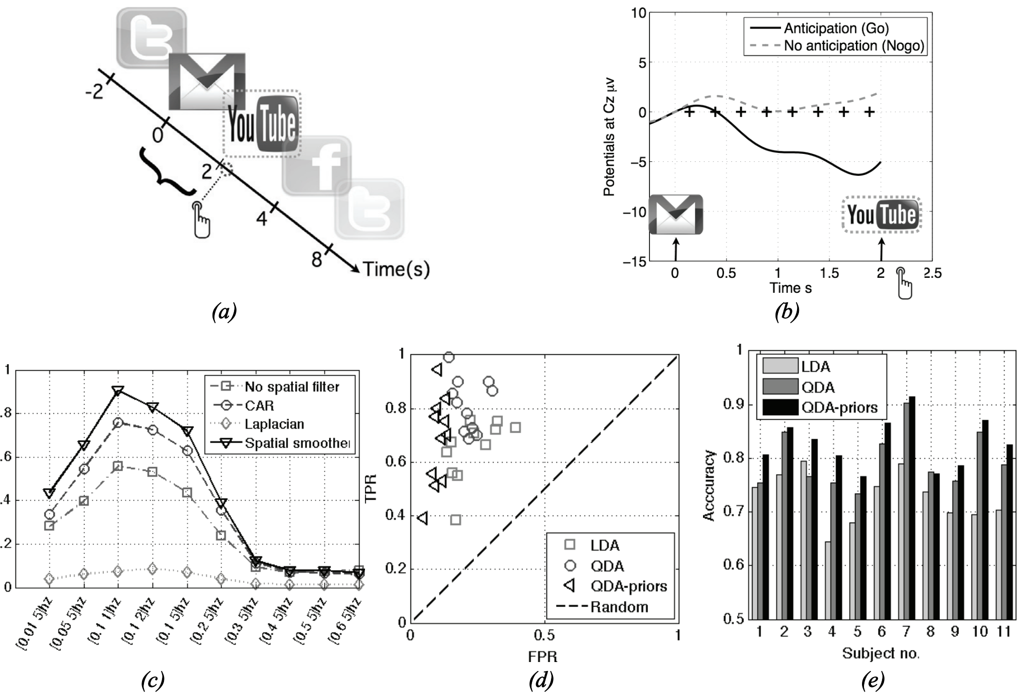


*Figure 1. (a) Timeline of events in the protocol. Four icons were used in the variation of CNV paradigm. (b) ERP grand averages of anticipation and No-anticipation conditions for a subject. (c-e) Results using features computed from Cz only (c) comparison of Fisher-scores for various spatial and spectral filters, (d) Single trial accuracy of LDA and QDA classifiers with and without priors for test data(e) ROC analysis for each subject ($p_{th}$=0.5) for all the classifiers.*

The single trial accuracy for each subject for the best spatial (i.e. SSF) and best spectral filtering (i.e. [0.1 1] Hz) methods is compared in Fig.1.d for LDA and QDA classifiers that are trained on day-1 and tested on day-2. The mean accuracy for LDA classifiers across 11 subjects is 0.73±0.04 and for QDA classifier is 0.80±0.05 with an improvement of 7%. Further improvement of 3% in classification accuracy (0.83±0.04) is obtained by incorporating priors into QDA classifier proportional to the number of Go and Nogo trials in training samples. It can be observed from Fig.1.e that, in general the QDA classifiers with priors increased accuracy by reducing the False Positive Rate (FPR).

## 4. Discussion

We presented a potential BCI framework based on single trial recognition of SCP potentials related to anticipatory behavior. Offline analysis revealed that traditional spectral and spatial filters used in the classical EEG analysis are not optimal for SCPs. We presented appropriate narrow band-pass filters that reduce the ISO and spatial smoothers that diminish high frequency spatial noise (e.g. local changes in skin-conduction). We report classification accuracies for QDA-priors method with a minimum of 0.76 and maximum of 0.91 just using one training session of approximately an hour.

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