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Project N° 2
ACTIVE VISUAL ODDBALL STIMULI:
Standard Vs Oddball Visual Stimuli

# Latency and CWT analysis on EEG signals: how P300 occurs in visual stimuli

GROUP 28

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## Abstract

Whereas much of the EEG signal occurs spontaneously, a subset can be related to external stimulus sources: these are referred to as event related potentials (ERPs). Different types of control signals can be used, such as P300. P300 evoked potentials are positive peaks in the EEG due to infrequent auditory, visual, or somatosensory stimuli. These endogenous P300 responses are elicited about 300 ms after attending to an oddball stimulus among several frequent stimuli. Different studies have shown that characteristics of P300 wave, such as amplitude and latency could be affected by several factors, such as age, gender, frequency of oddball stimuli. P300 signals are currently object of investigation for BCI applications to obtain clearer control signals.


## 1. Introduction

This study focuses on the evaluation of activation of frontal and central/parietal areas of the cortex through continuous wavelet transform (CWT) analysis in order to highlight significant features between oddball and frequent single EEG[1], important for BCI's application and detection of pathologies. A point is made also about the latency, to shows some possible outliers for the study and to emphasize different timing between oddball and standard stimuli.

## 2. Methods

### 2.1. Data acquisition

The experiment consisted of one session of visual stimuli. The letters A, B, C, D, and E were presented in random order, each letter with the same probability (p=0.2). One of the letters was chosen to be the target for a given block of trials in order to elicit the P300 component, while the other 4 letters were non-targets. So, the probability of the target category was 0.2. EEG signal was recorded from 40 subject, aged between 18-30: 25 females and 15 males, 38 right-handed and 2 left-handed.

The experiment consisted of a session comprised 5-10 min of brain activity recording during which visual stimuli (duration 200 ms) were delivered with a random inter stimulus interval (range: 1450 - 1500 ms). Data are provided after being filtered and down sampled at 256 Hz for computational reasons. EEG signals were recorded Biosemi ActiveTwo recording system with active electrodes (Biosemi B.V., Amsterdam, the Netherlands) used with 30 scalp electrodes mounted in it and placed according to the International 10/20 System (FP1, F3, F7, FC3, C3, C5, P3, P7, P9, PO7, PO3, O1, Oz, Pz, CPz, FP2, Fz, F4, F8, FC4, FCz, Cz, C4, C6, P4, P8, P10, PO8, PO4, O2).

### 2.2. Data pre-processing and preparation

*2.2.1. EOG artifact*

The MATLAB code allows us to analyze all the EEG signals in succession. When we talk about electroencephalogram (EEG) recorded from frontal channels, it's important the evaluation of ocular artifacts. Eye blinks are one of the most influential artifacts and thereby detecting and rejecting eye blink artifacts is an essential procedure for improving the quality of EEG data. Being involved in thinking about the task and not to blink, the instruction to inhibit eye movements or blinks may seriously distort brain activity and significantly affect the P300 wave [2]. Omitting the instruction and using off-line blink subtraction procedures seems a viable alternative[3]. For this reason, the intent was to implement the eyeblink function to detect peaks at very low frequencies in the VEOG (vertical electro-oculogram) signal not considering the HEOG signal because by plotting it was evident how there was a lot of noise and not so much of the information we need. Basically, the signal was filtered and epochs with signal amplitude greater than a selected threshold were omitted. At the end, the decision of not using this function was made because the interpolation didn't work as the expectations: in fact, a lot of the information was lost, and the study of the EEG would've been distorted.

*2.2.2. Signal filtering*

Since the largest response is obtained from electrode positioned on fronto-central areas approximating the channel 1 (Fp1) in the 10-5 system, channel 1 and later channel 17 (Fz) are chosen for the analysis. Raw signals are offline referenced to the mastoid sites P9-P10 as recommended. After that, a qualitative evaluation of these signals showed the presence of high frequency noise. The signals have been filtered firstly with a high pass anticausal Chebyshev filter (cut-off at 0.5 Hz); a low pass anticausal Chebyshev filter (40 Hz) is then applied to the filtered signals to obtain a bandpass filter.

*2.2.3. Division in epochs*

In order to evaluate oddball and standard stimuli separately, we divided the signals in epochs. Epochs were chosen and separately averaged, considering 1200 ms after and 200 ms before the trigger. In Fig. 1, a random epoch represented in all the channels. It is important to notice the different y-axis scales.

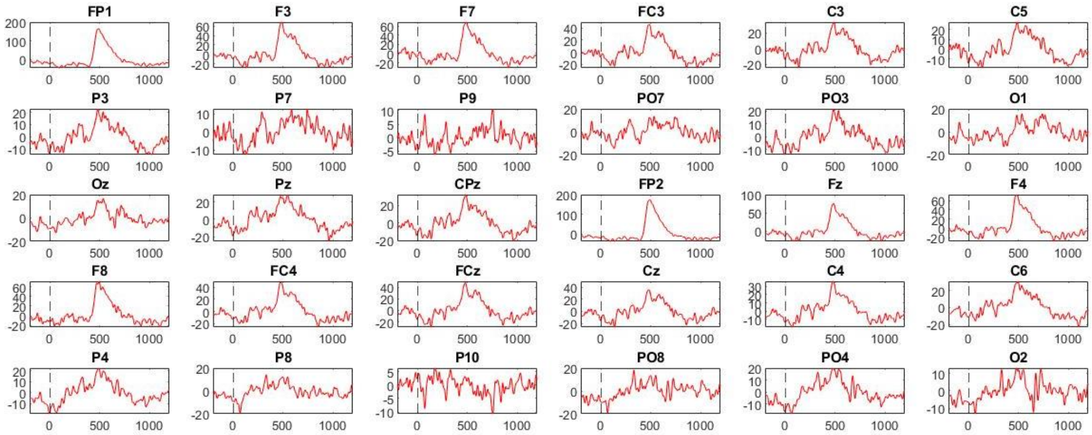



*Fig. 1: All channels of an oddball stimulus trial by a random subject in a random epoch.*

## 2.3. Latency

For the latency analysis, channel Fp1 was chosen as reference because the amplitude peaks, that we are interested of, are more noticeable. We decided to remove epochs in which signals exceed 400 µV due to possible artefacts. For each subject, after the evaluation of the average between the epochs left, only for oddball stimuli, cross-correlation is calculated between the averaged signal and each epoch; we only took the maximum values from each cross-correlation, normalized them and epochs under a certain threshold (0.2) were discarded because too different from the others. At this point, we computed the average for each patients taking into account only the remaining epochs. For standard stimuli, only the threshold at 400 µV was imposed.

At the end, we calculated the instant in which peaks occur in a time window we expect the P300 to happen (150-1000 ms). This evaluation was done for both oddball and standard stimuli epochs.

## 2.3. Continuous wavelet transform

The continuous wavelet transforms (CWT) it's a good parameter for analyzing signals, using wavelet properties. The CWT involves the analysis of a signal at a very high number of frequencies using multiple dilations and shifting of the mother wavelet. The advantage of this analysis over classic methods arises from the special properties of the wavelet, suitable for transient signal analysis, in which the spectral properties of the signal vary over time[4], in fact it allows to analyze non-periodic signals.

We applied CWT to Fz channel epochs of signals and results are shown in paragraph 3.3.

## 3. Results

### 3.1. Topography and signals representation

As we can see in the topography in the Fig. 2, when an oddball stimulus occurs, there is a pre-frontal perceptible activation of the cortex even before the peak (Fig 2.a) (yellow: high activation, blue: low activation); the activation grows during the peak (Fig. 2.b) and shows some activation after the peak (Fig 2.c) in the occipital area. For the standard stimulus instead, we cannot appreciate as much as before the elicited peak (Fig 2.d), an expected (lower) activation during activation peak (Fig 2.e) and a residue activation after it in the occipital area (Fig 2.f).

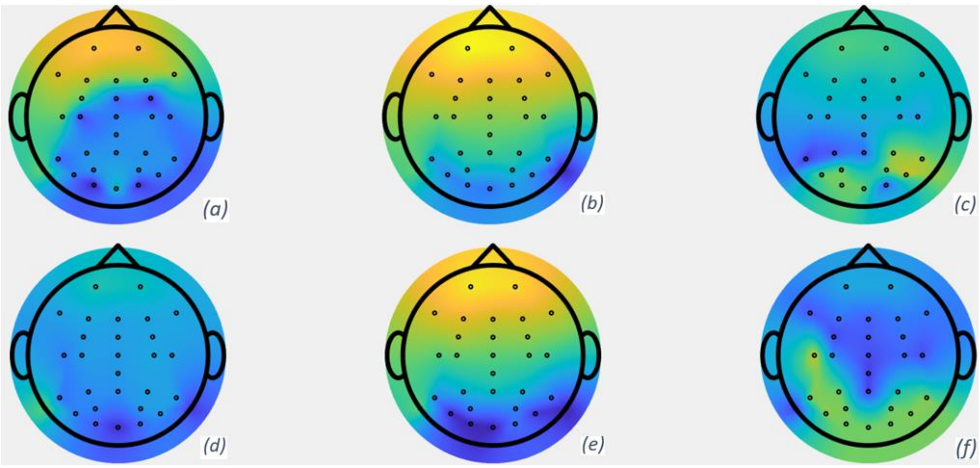



*Fig. 2: Topography averaged of subject in a log amplitude scale: (a) 150 ms before the peak (oddball), (b) instant of the peak (oddball), (c) 150 ms after the peak (oddball); (d) 150 ms before the peak (standard), (e) instant of the peak (standard), (f) 150 ms after the peak (standard).*

Graphic representation of averaged epochs seen from Fz electrode by subject a random subject. Looking at Fig. 3.a and Fig. 3.b we can see how P300 peaks manifest slightly earlier in the oddball elicited potentials (Fig. 3.b). Fig 3.c expresses the difference between the averaged epochs of oddball and averaged epochs of standard stimuli, pointing out where substantial differences between the two signals occur.

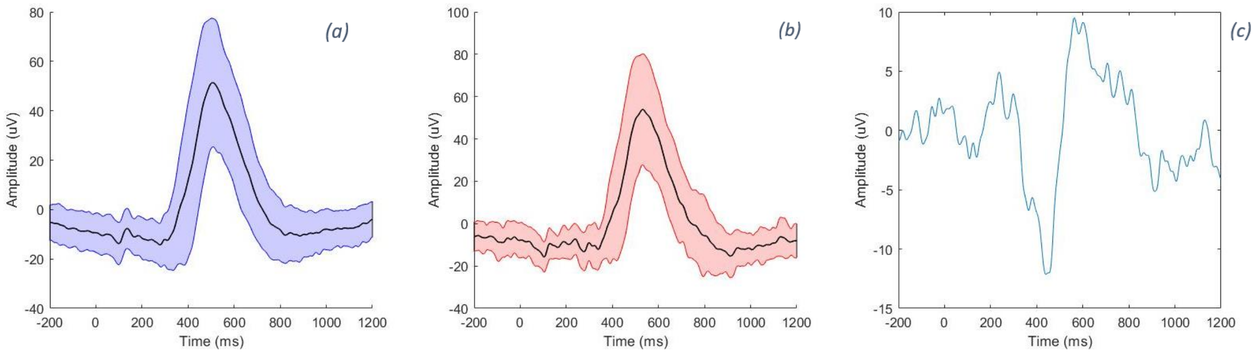



*Fig. 3: (a) Standard averaged signal: mean value ± standard deviation; (b) Oddball averaged signal: mean value ± standard deviation; (c) subtraction between the oddball averaged signal and standard averaged signal.*

### 3.2. Latency and outliers

The boxplot in Fig. 4.b shows the distribution of latency value for the two types of stimuli and allows to detect outliers, so subjects with significant deviation of latency from the others (in this case, subjects 1, 2, 12, 15, 22 and 34).

We can notice by looking at the bar diagram in Fig. 4.a that oddball mean latency is greater than standard mean latency: 596 ms for oddball stimuli and 527 ms for the standard ones (starting from the trigger).

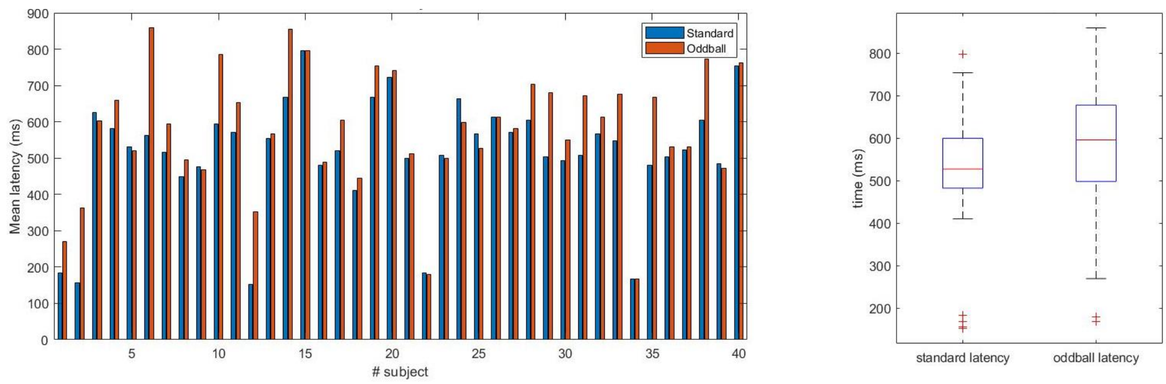
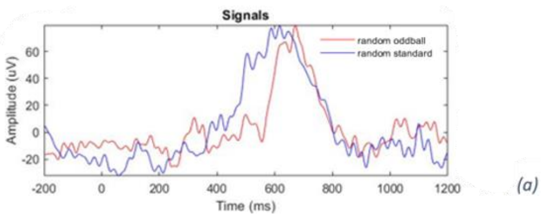



*Fig. 4 (a) Latency in bar diagrams for each subject, related both to standard and oddball stimuli, as showed by the legend. (b) The boxplot of the latency for the oddball and standard stimuli, used for the outliers finding, represented as red crosses*

## 3.3. CWT analysis

The two time series showed in Fig. 5.a demonstrate examples of typical oddball and standard trials from the same random subject seen from Fz electrode (channel 17). Fig. 5.b and Fig. 5.c reveal how the wavelet coefficientes are distributed along scales and the color bars show the amplitude of the wavelet coefficients. It is evident that for the oddball stimulus the P300 occurs at low frequencies around 600-700 ms. The standard trial has dipersed weak wavelet coeffiecients compared to the oddball one.



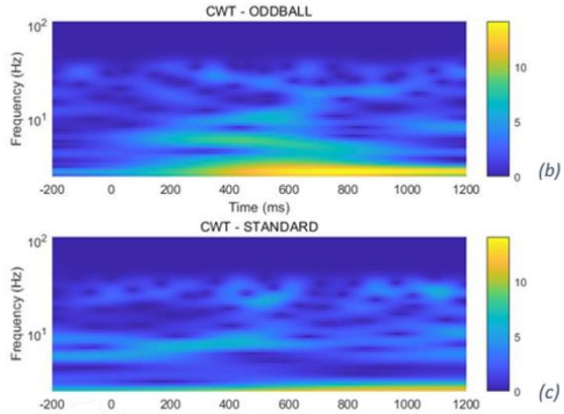




*Fig. 5: (a) The measured 17 channels during single oddball and frequent trials of random subject. (b) and (c) The computed CWT coefficients for oddball and for frequent trials.*

## 4. Discussion and conclusions

In this study, latency was a feature to show that, for most of the subjects, oddball elicited responses happen after a more prolonged time than the standard ones and eventually to find outliers. It can also be used to as a parameter to develop, for example, a classification of attention deficit hyperactivity disorder (ADHD) and find predictors of treatment response[5].

The results in this study underline the potential utility of wavelet transform analysis providing visual representation of one of the features of EEG event-related signals, P300, that could be less evident in the simple time series. Moreover, it was demonstrated how the comparisons across experimental conditions can be facilitated by the wavelet transform analysis[1].

The analysis in frequency domain could be crucial for BCI applications technologies: that is because BCI research on this field is relatively young and brain activity had been seen as strange and remote topic[6]. It is now acknowledged that studies of EEG provides acceptable quality signal with high portability and event related potentials BCIs are by far the most usual modalities.

**Bibliography**

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