Biomedical Signals
Lab session 5

Synchronized averaging (ERP)

Introduction - ERP

Event related potentials are time-locked EEG activity that helps capture neural activity related to sensory and cognitive processes. So, they are very small voltages generated by postsynaptic potentials when a large number of cortical pyramidal neurones fire an AP as a response to a specific event or stimulus; so while processing information.

The event or stimulus can be: sensory, motor or cognitive. It provides a safe and non-invasive way to study psychophysiological correlates of mental processes

Introduction - ERP

Types:

Sensory or exogenous:
Appear in an early time window (<100ms)
Depend largely on the physical parameters of the stimulus

Cognitive or endogenous
Usually appear in a late time window
Reflect the manner in which the subject evaluates the event and process the information

Nomenclature: Letter + number

Polarity (P/N)

Latency of expected appearance (being 0s the triggering of the stimulus)

Characteristics: amplitude (after baseline correction) + actual latency

Introduction – Examples of ERP

- P200 → visual component between 150-200ms over occipital regions that decreases when load demands increase.
- N200 → negative deflection whose latency increases if alcohol abuse
- P300 → the most studied auditory ERP. Latency is interpreted as the speed of stimulus classification, indicating shorter latencies a superior mental performance. Used in oddball paradigms. P3 amplitude reduces when attentions is directed away from the current target. It is also sensitive to demands placed on working memory. Its changes on amplitude or latency have been associated with Multiple Sclerosis, Schizotypal personality disorder, anxiety disorder or obsessive compulsive disorder, among others

Introduction – ERP

To sum up:

ERP are a millisecond-by-millisecond record of neural information processing, which can be associated with particular operations

It provides a noninvasive means to evaluate brain functioning in patients with cognitive disorders and is of prognostic value in a few cases. It holds great promise for the future of neuropsychiatric research

Introduction – Error correction tasks

Error monitoring and correction are executive functions that serve to adapt to the environment, anticipate, learn, correct and amend the consequences of the actions.

The error-related negativity (ERN) is an ERP observed 60-100ms after the erroneous response. It is maximal when emphasis is placed in accuracy, it might also be present when errors are not consciously detected. It has been interpreted as a physiological correlate of the error detection process itself. It has a frontocentral topography.

Correlation between ERN amplitude and some scale and score of disability and multiple sclerosis have been found

Introduction

Objectives:

1. To study the effect of synchronized averaging on ERPs
2. To study the effect of the number of trials in repetitive stimulation for synchronized averaging
3. To study the effect of poor alignment in synchronized averaging

Materials

- *promedioStimulusLocked(v2)*
- *promedioResponseLocked(v2)*
- *draw_topogram*
- V13PLA.CNT

Exercise – Eriksen Flanker task stimuli

It is a choice reaction time task. Participants have to respond to which centre letter appears of a 5 letter array (S or H). The participants are also instructed to correct all their wrong answers

Stímulus	Stimulus code	Response Code	Definition of stimulus
HHHHH	1	1 (left)	Congruent
SSHSS	2	1 (left)	Incongruent
SSSSS	3	8 (right)	Congruent
HHSHH	4	8 (right)	Incongruent

Stimulus	Response	Correction
1	8	1
2	8	1
3	1	8
4	1	8

Reaction times are supposed to be statistically longer for incongruent stimulus than for congruent ones

To obtain the averages in the incorrect response we only used those that have been subsequently corrected by the volunteer, because ERN is associated mainly with the conscious detection of the error. Incorrect don’t distinguish between congruent or incongruent

Exercise – Eriksen Flanker task stimuli

A fixation cross is presented just below the target letter in the array

The duration of the stimulus is 100 ms with a random stimulus onset between 900 and 1100 ms

Participants were trained with 200 trials to reach reaction time (RT) baseline level.
Training: stimulus were presented in 4 groups of 50 trials with the experimenter monitoring the % of choice errors.
Actual experiment: 6 blocks of 4 minutes and 200 stimuli each + 30s to rest between blocks

To standardize behaviour across subjects: encouraging to respond to the stimuli as fast as possible and to correct the errors likewise.

Exercise – EEG recording

EEG was recorded using 31 gold electrodes: Fp1, Fp2, F7, F3, Fz, F4, F8, FT7, FC3, FC4, FT8, T3, C3, Cz, C4, T4, TP7, CP3, CP4, TP8, T5, P3, Pz, P4, T6, PO3, PO4, O1, O2, LEFT mastoid channel, RIGHT mastoid.
Impedance < 5 kΩ

File of data in ATENEA: EEG, stimuli and corrections with their code and times associated with the visual stimuli and the subject response.

EEG already filtered with a bandpass 0.1-35 Hz and digitized at rate of 250 Hz

Exercise – Routines

`promedioStimulusLocked(name,pair,channel)`

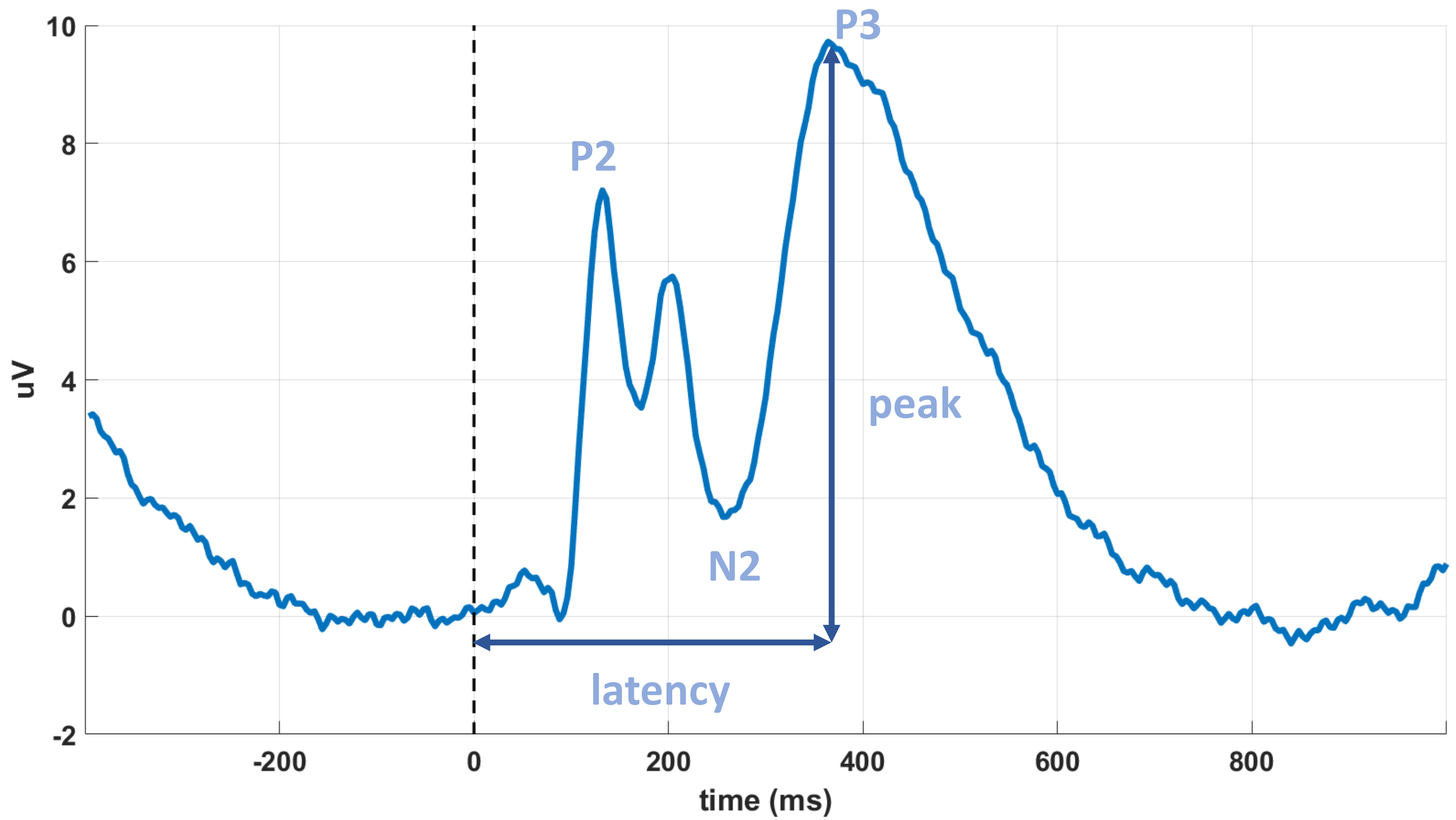
Stimulus-locked ERPs for a channel (trials x samples). The signals has been epoched from -400 ms to 1000ms regarding stimulus onset. Baseline correction was performed using a time window of 100 ms before stimulus onset. Artifcatual epochs have been detected and removed using an amplitude threshold. The reference channel was one located next to the right eye, however the common reference are the mastoids. So, the data was re-referenced to the average of the right and left mastoids channels ((R_mast+L_mast)/2)

Name = file name with the complete path; Channel = the channel you want to assess.

The output can be created separately for correctly-responded congruent stimuli (*pair* = [1, 1;3, 8]) and correctly-responded incongruent stimuli (*pair* = [2, 1;4, 8]).

After averaging across epochs → P2, N2 and P3 components

Exercise – ERP identification: stimulus-locked



P2

Most positive deflection between 150-250 ms after stimulus onset

P3

Most positive deflection between 250-600 ms after stimulus onset

Exercise – Routines

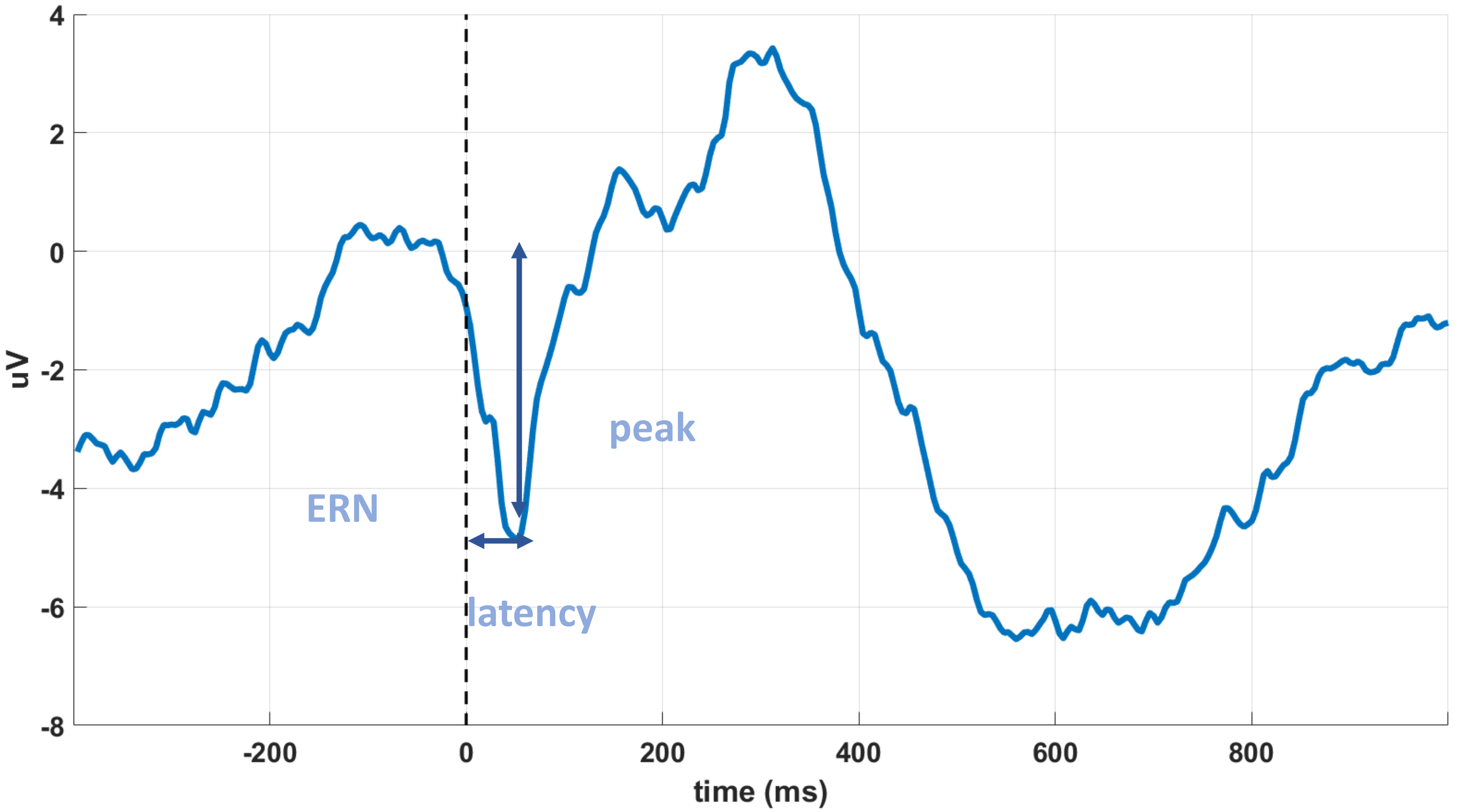
`promedioResponseLocked(name,triplet,channel)`

Response-locked ERPs for a channel (trials x samples) to evaluate the ERN component. Epochs were centred around the response (when the participant press the button) from -400ms to 1000ms of response onset. Baseline corrected using a 100ms time window before the response. Same artifcat rejection than before.

To obtain the trials of all corrections (both congruents and incongruents), triplet = [1 8 1;2 8 1;3 1 8;4 1 8].

Averaging across epochs → ERN.

Exercise – ERP identification: response-locked



ERN

Negative deflection in the ERP appearing between 0-100 ms

Exercise – Number of trials

1. Plot in the same figure the first 5 stimulus-locked EEG epochs overlapped for congruents and incongruents trials separately of channels Fz, Cz and Pz. Are you able to distinguish the ERPs clearly?

2. Plot in the same figure 5 response-locked EEG epochs overlapped of channels Fz, Cz and Pz. Are you able to distinguish the ERN clearly?

3. Computed the average stimulus-locked EEG across epochs, considering the first: 10, 20, 30 and 40 trials. Plot all these averages in the same figure (overlapped) of channels Fz, Cz and Pz; considereing congruents and incongruents trials separately. Evaluate the effect of averaging.

4. Repeat the computation but averaging the response-locked EEG epochs.

Exercise – Number of trials

1. Compute the amplitude and the latency of the ERPs (P3 and ERN). To do so, average the epochs considering different number of epochs: 1-5, 1-10, 1-15,… 1-N. You'll have the same number of ampltiudes and latencys as averages performed. Compute it for channels Fz, Cz and Pz
2. Build a figure with 4 subplots:
    1. P3 amplitude as a function of number of repetitions averaged, opveralpping traces for Fz, Cz and Pz
    2. ERN amplitude as a function of number of repetitions averaged, opveralpping traces for Fz, Cz and Pz
    3. P3 latency as a function of number of repetitions averaged, opveralpping traces for Fz, Cz and Pz
    4. P3 latency as a function of number of repetitions averaged, opveralpping traces for Fz, Cz and Pz
3. Analyze the results and find the minimum number of epochs that should be considered to achieve a "stable feature value"

Exercise – Epochs alignment

`promedioStimulusLockedv2` and `promedioResponseLockedv2` → same functions as before with an extra input parameter: sigma (defined in samples)

The output is the same as before, but the epochs are not created from the exact stimulus or response onset. Now, the time = 0s of the trial has changed a little bit by adding a random value following a normal gaussian distribution with $\mu = 0$ and sd = σ

1. Calculate the output of both functions with a misalingment of $\sigma = 10$ and $\sigma = 20$.
2. Overlap in the same figure 3 average epochs: one with perfect alignment and the other two with both misalignmnets. Consider only incongruents trials for the stimulus-locked average. Do it for channels Fz, Cz and Pz.
3. Conclude if the effect of the misalignment is significant to modify the ERPs

Exercise – Topography study

1. Using the function `draw_topogram` obtain the topographical distribtuon of P3 and ERN, calculated from the average of all available epoches in the 19 EEG channels of this function. For ERN, consider absolute values.

2. Plot in the same figure;
    1. P3 peak distribution for congruent stimuli
    2. P3 peak distribtuion for incongruent stimuli
    3. ERN peak distribtuion for corrected responses

3. Discuss the results

Exercise – EEG recorded in lab 2

Materials

- Student2:
  - Eemgu2: EEG matrix (samples x 14 channels)
  - Fs: sampling frequency
  - Marks: events that has occurred
    - 9: fixation cross
    - 3: first image
    - 4: second image congruent (figures are the same than in the previous figure)
    - 5: second image incongruent
    - 0: incorrect response of the subject
  - Marksamples: samples when the event from the vector ‘marks’ appear

Exercise – EEG recorded in lab 2

Procedure

1. Compute and plot the average of the stimulus-locked EEG in Fz, Cz and Pz for
   1. Congruent
   2. Incongruent
   3. Both (together)
2. Consider:
   1. Epoch : -100ms to 1000ms being at 0s the appearance of stimulus of the second image
   2. Baseline correction in each trial: subtracting the mean activity between -100ms to 0s prior stimulus-onset
   3. Smooth the average EEG by low pass filtering at 7 Hz
   4. Only trials with a correct answer

Exercise – EEG recorded in lab 2

Procedure

1. Extract the P3 amplitude for congruent, incongruent and joint in the 14 EEG channels as the maximum of the average EEG between 250ms and 400ms

2. Plot the topographical distribution of P3 using `draw_topogram2` as presented in the lab session 2

3. EEG non-related features (for all students)
    1. Response time (mean and sd)
    2. % of correct responses in congruent and in incongruent cases