The electroencephalogram (3)

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EEG analysis

Averaging

Single trial analysis

EEG Analysis

- Inspection
- Averaging
  - Segmentation
  - Amplitude and latency
  - Mapping
  - (From ch 11)
    - Nomenclature
    - Effect of ITI ans SOA
- Spontaneous EEG and single trials
  - Evoked / induced activity
  - ERD/S, TSE
  - Time-frequency analysis
- Project related
  - Ch. 12. auditory responses, including steady-state
  - Ch. 13. visual responses, including steady-state
  - Ch. 14. somatosensory responses
  - Ch. 16 motor function
  - Ch. 17 Change detection (CNV, MMN, P300, ErrN, …)

Reference:
Hari and Puce. *MEG-EEG Primer*.
Oxford University Press. 2017

(Mostly from chapter 9)

This is no properly in the exam but the professor advice to read before to do the exam to get deep in the topic.
If the project talk about auditory responses or visual responses prof will ask you that chapter

Off-line data inspection

and mark the channels or the epochs that contain the artifacts

Most of the time artifacts are not spred all over the data so maybe just few channels are affected or a just few time point are affected so you can just cut some time points

- Make sure you review your raw data before processing and analysis
  - garbage in, garbage out

if you have a lot of data, few artifacts are may not affective on your analysis but if you rely on a small dataset more the data are clean more effective is the analysis

- Bad EEG segments or channels must be removed from the data
  - Make sure you understand which artifacts mostly affect the results of your analysis, so that you do not waste data by rejecting too much of it.

Do a sensible choice on what artifacts throw because in base on your analysis some atifacts can not influence your analysis

- From a practical point of view, dealing with bad channels or epochs will depend on the analysis software you are using

Most of the EEG aquisitions are organized in trials so there are several repetitions of some tasks and you may find out that a few trials need to be discard because artifacts happen exactly when you need clean data for your analysis

Even if you do a continuos aquisition or analysis of somebody keeping in size open and close beacause you want to check the fenomeno of the alpha blocking an you want to compare the eyes open condition with the eyes close condition, maybe you need to reject a few second every while because in those seconds artifacts happen

TRIALS: specific segments of EEG that occur at the same time of a stimulus of a specific task that subject has to do

movement artifacts

Blink is very low frequency artifact and when you will analyze the beta you will analyze part of the spectrum that is far away from the where the blinks have their energy so you can decide to not discard blinks becuse they are atifacts but they do not affect the component of the EEG you are intrested on

Averaging

Aquire data during some stimulation

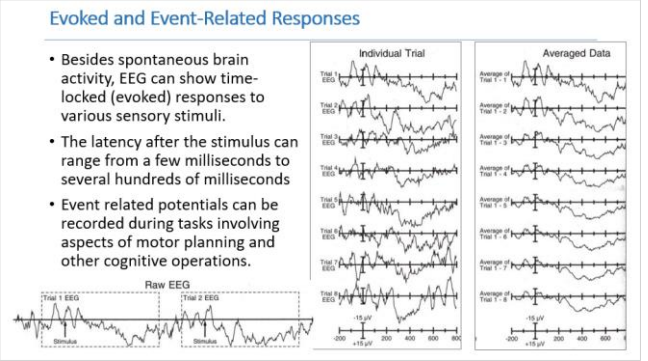
Evoked and Event-related potentials

Electrical brain activity consequent of a stimulation

Activity of the brain related to some events

- EEG data are typically collected in experiments using multiple trials per condition, as the signals of interest may be quite small, but one of the basic assumptions of analysis is that the signal remains the same during the whole experiment although it is masked by noise.

you can collect info from multiple stimulations and merged them. In this way you can reject most of the spontaneous activities



for ex. a flash, image or music

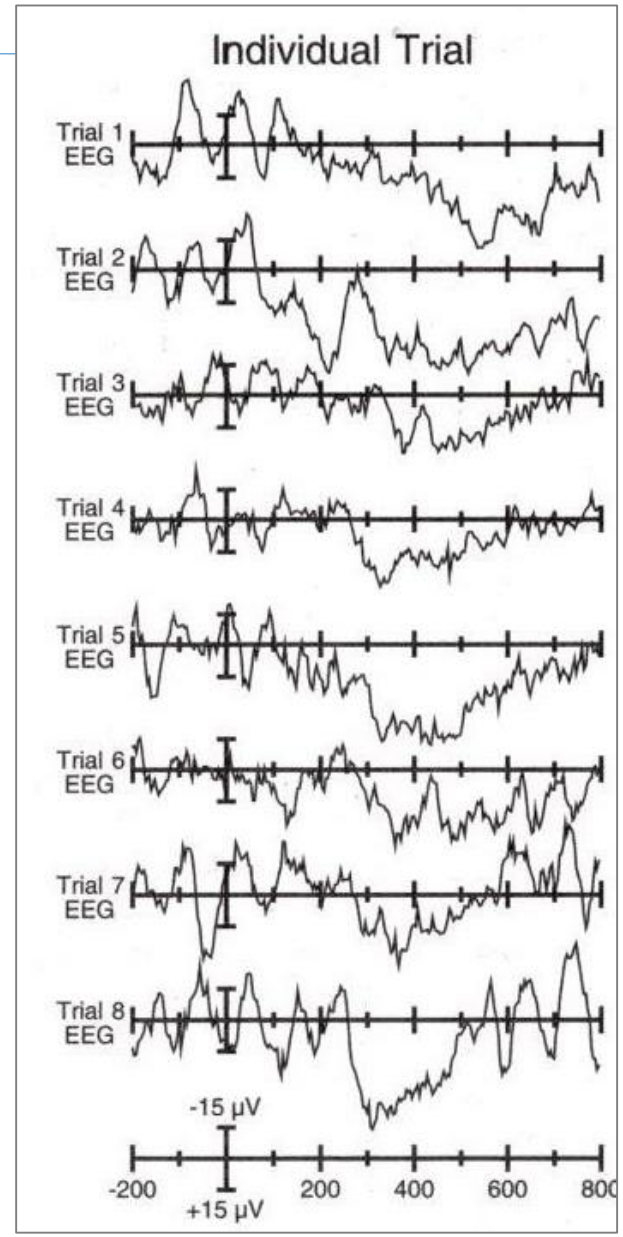
- Stimulus-driven activity has been called an **evoked potential** (EP)
  - In contrast, the terms **event-related potential** (ERP) have been used more generally to describe changes in EEG signals triggered by either external stimuli or related to internal mental or task-related events.

Not all the responses can be extracted from the background using averaging. Some need some other process

Segmentation

- the continuous record must first be “cut up” into epochs (or segments)—consisting of a prestimulus or a pre-event period, followed by a period of time suitably long enough to be able to highlight the particular activity of interest.

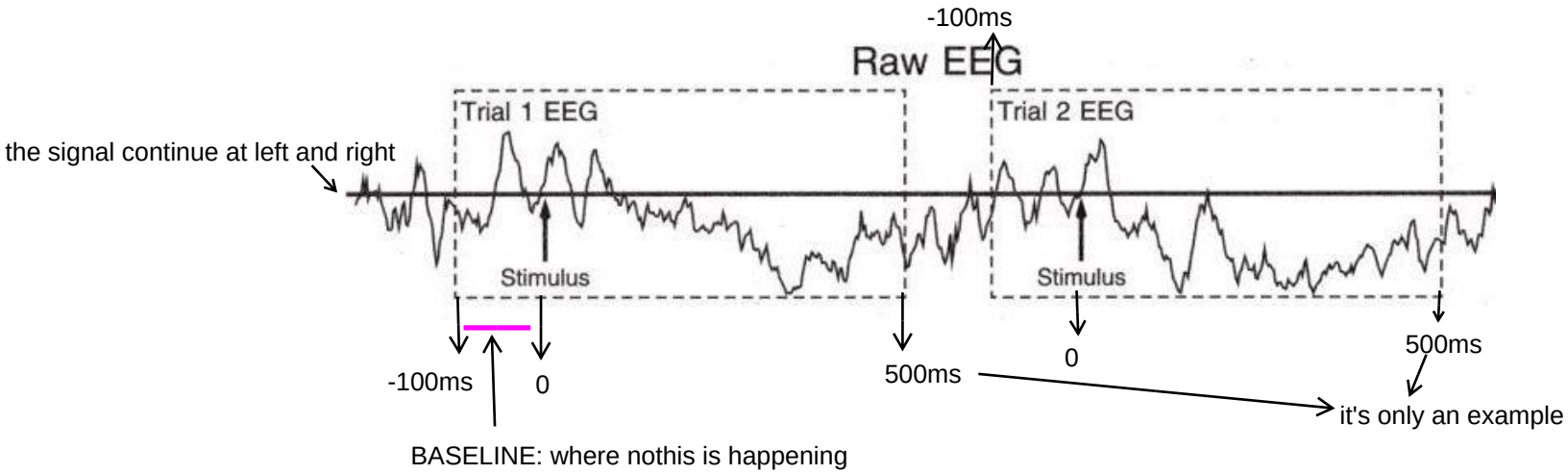
they are spontaneous EEG



TRIAL: part of EEG around some specific event

RUN: from the time start recording to the stop recording(whole record from the beginning to the end (5 or 10 minutes))

SESSION: from the time the subject counts to your recording to the time the subject leaves which maybe broken in different tranche



If you gave a visual stimulation the responses can be in the next few hundreds of ms so you can take 500ms. It's good also to save some part before where nothing happen called BASELINE, in principle the evoke potencial should be 0

Averaging

sincronized averaging

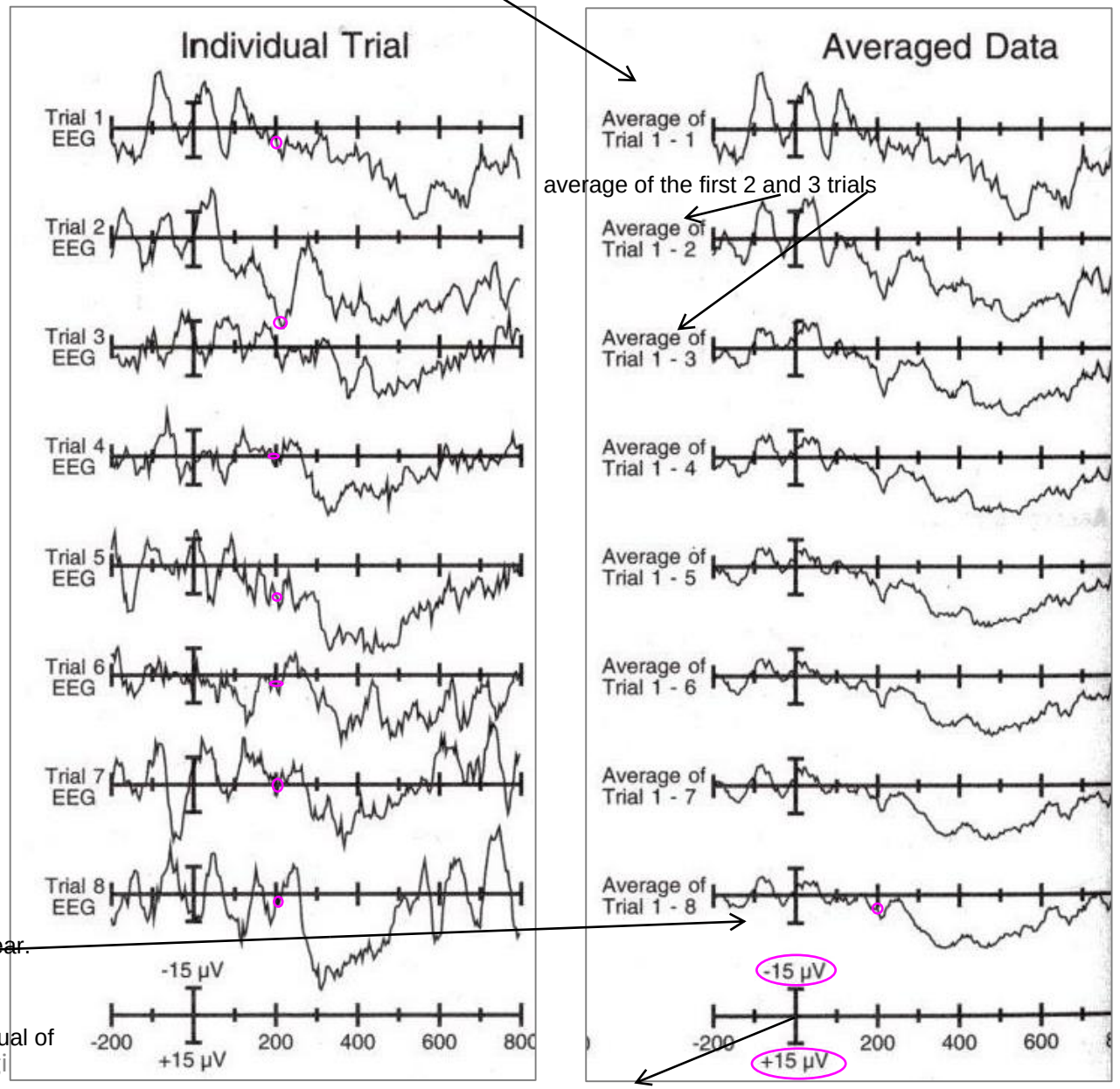
example:if you averaged at 200ms of every trial you have the precise point on the final average line at 200ms ( )

- Signal averaging is based on the assumption that the recorded time-varying signal x(t) comprises a distinct signal embedded in noise
- Averaging N responses would improve the signal-to-noise ratio by $\sqrt{N}$,

EX: If you have 100 trials (N=100) and the amplitude of the noise is like 1, in the averaging, the amplitude of the noise is the amplitude of the single trial divided by sqrt(N)->(1/sqrt(100))
So more trials you have more the spontaneus noise is small

More trial you average, more the pontaneus EEG attenuates

Here we have the combination of more individual trials: second average is formed by trial 1+2; fourth average is trial 1+2+3+4; last avergae is 1+2+3+4+5+6+7+8



average of the first 2 and 3 trials

Once you average all trials you can see a reduction of the spontaneus EEG (noise) and the pattern of the evoke potencials start taking shape. More trials you average, more the shape is clear.

If you do a lot of trials in the final averaging you will see a clear evoke potencial with just a small residual of spontaneus EEG and that will be the best aproximation of the brain response to the stimulus

Here neg is up and pos is down

Amplitude and latency measures

Time interval since the stimulus

Latency is the interval between zero time and when a features occurs (for ex. a peak)

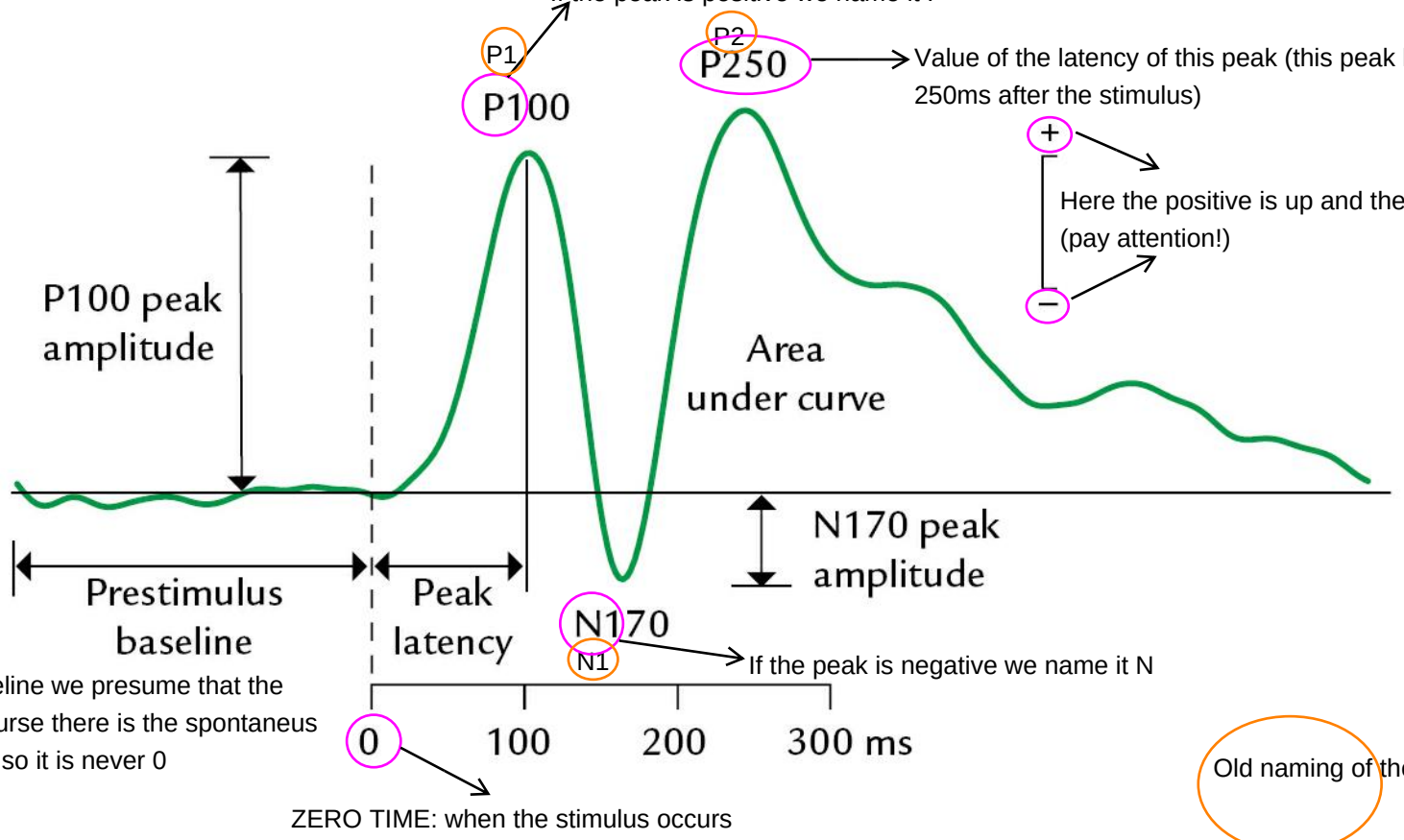
- The peak amplitudes (with respect to prestimulus baseline) and latency (with respect to stimulus onset, or relative to a motor event) are commonly measured.

time when the stimulus occurs(100-250...)

If the peak is positive we name it P

In the baseline period can happen that you have a potencial that is different from 0 so we used to change the axes

So when you measure the ampitude of a peak you measure it from the pre-stimulus baseline



ZERO potencial is the potencial around the baseline is

On pre-stimus baseline we presume that the value is 0 but of course there is the spontaneus activity of the brain so it is never 0

Old naming of the peak

Nomenclature of ERP components

(From ch 11)

- In the vast EEG and MEG literature, the nomenclature of evoked responses is diverse and confusing.
- An old naming convention numbered successive deflections separately for scalp-positive (P) and scalp-negative (N) EPs—where the polarities refer to the "active electrode"—resulting in notations such as P1, N1, P2, N2, P3. To make matters worse, letters are sometimes added to these labels, such as P3a and P3b. Sometimes you can find the old way to describe peak and side to P an N (Pos or Neg) you have progressive numbers indicating
  In the previous slide you have the new way but you'll find also the old
- A less ambiguous way is to combine the polarity (N or P) of the response peak or trough with the nominal peak latency in milliseconds, for example, P60, N100, and P200 New way to describe the peak-> side to P or N (Pos or Neg) we have the latency of that peak
- Note that in most cases it is clear enough to use in the response name the approximate (or nominal) latency (and not the measured individual latency). For example, the mean peak latency of the N100 deflection may vary between, say, 90 or 110 ms without causing any confusion in the nomenclature

When someone give you the value of some peak related to a specific impulse, you have to figure out that that value is based on a study but it can be little bit diffrent from person to person. So the value is a population average (time 1:01:33)

Effect of stimulus timing

(From ch 11)

If you have more stimulus in a trial ISI refers to the distance from one stimulus to the next event in the same trials, ITI from the end of the first stimulus of the first trial to the onset of the stimulus of second trial

- Stimulus onset asynchrony (**SOA**) refers to the time between two successive stimulus onsets, This can be a fixed value or it can change from trial to trial to introduce some variability
- interstimulus interval (**ISI**) refers to the time between the offset of one stimulus and the onset of another If you have only one stimulus in the trial ISI=ITI
- intertrial interval (**ITI**) refers to the time between successive trials (during which multiple stimuli may be presented).
  - SOA and ISI/ITI can be quite different from each other if the stimulus duration is long

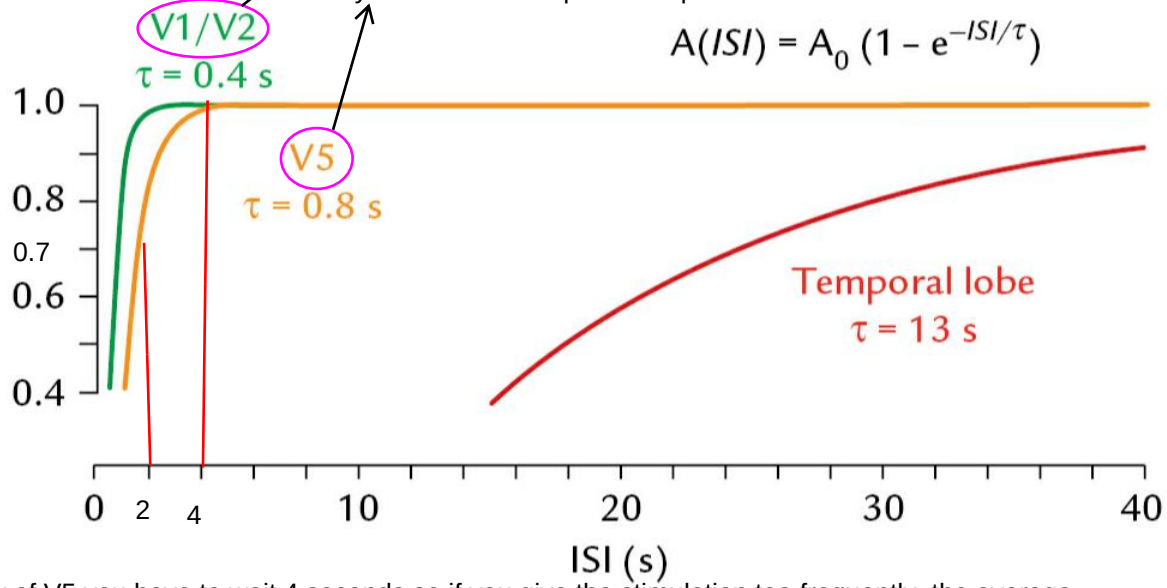
    ISI = (SOA – stimulus duration)

depends on the SOA

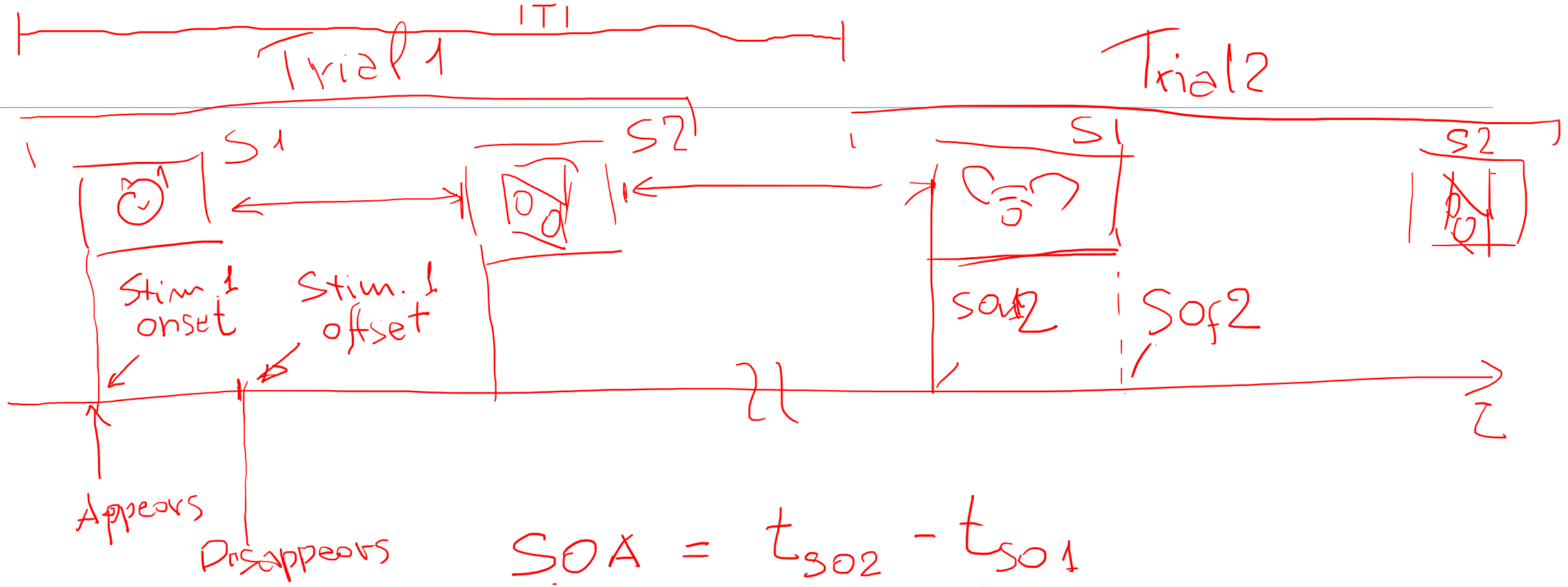
- The shape and amplitude of the ERP may strongly depend on the timing of stimuli
- In general, the longer the latency of the response, the more sensitive the response is to stimulus repetition rate,
- Tradeoff between number of stimuli (noise=$\sqrt{N}$) and SOA (total time = $N \cdot SOA$)

For increase the number of trial you can make it shorter but if the trial are too close, the brain can not completely rest before you give the next impulse

Information from the visual cortex (part of the brain in the back of the head that analyze how visual impulse are processed



For a full recovery of V5 you have to wait 4 seconds so if you give the stimulation too frequently, the average potencial will be shorter (for 2 seconds, it will be 0,7)



$$SOA = t_{SO2} - t_{SO1}$$

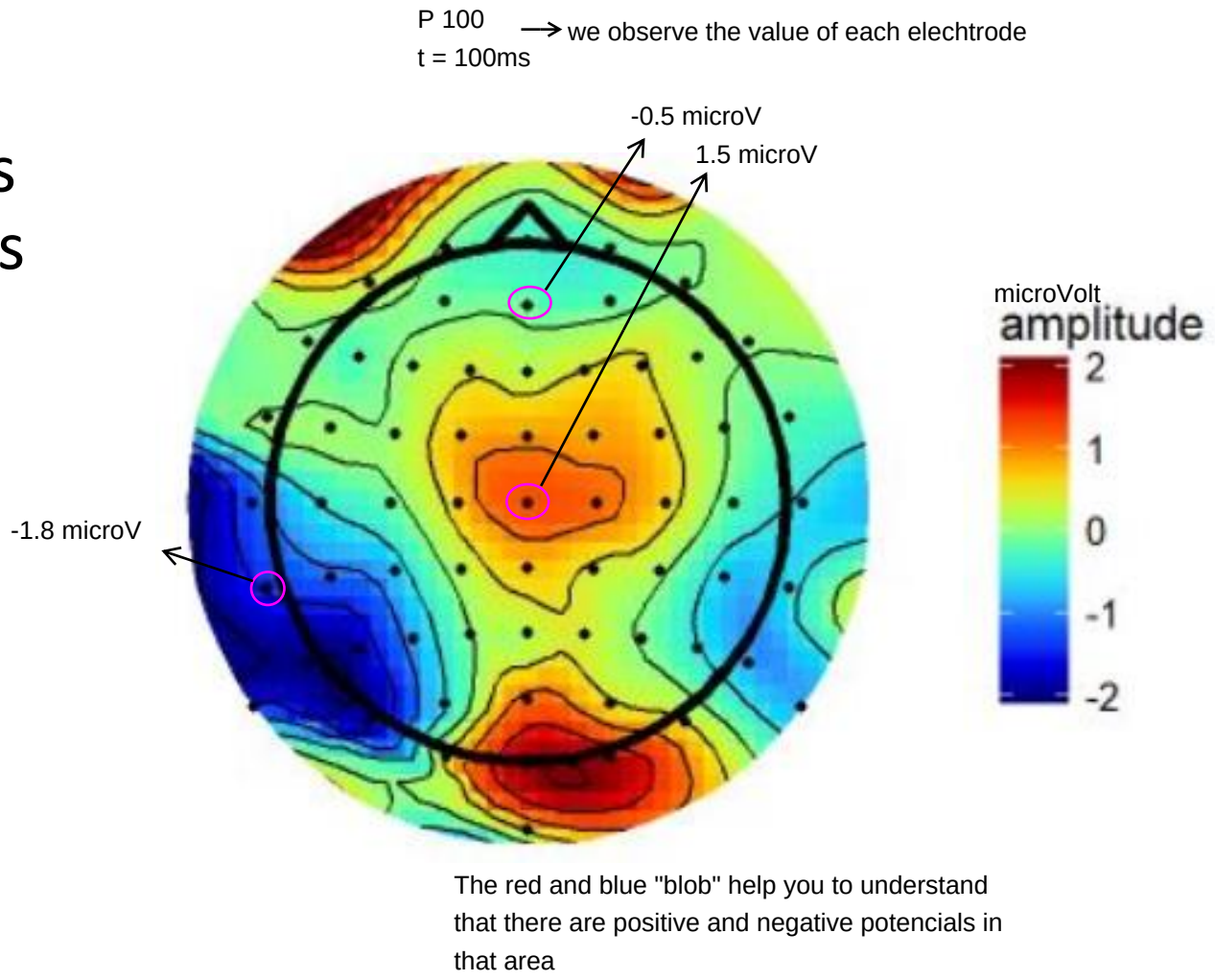
$$ISI = t_{SO2} - t_{SOF1}$$ → questo è ISI

$|S_1|$ se abbiamo un solo stimolo

$|ITI|$

Mapping

- In a 2D display of EEG data, topographic scalp voltage maps can depict interpolated voltages between the electrode locations at any time point.
- Most typically, such maps are displayed at times of response peaks and troughs.



The red and blue "blob" help you to understand that there are positive and negative potencials in that area

Spontaneous EEG and single trials

Evoked / induced activity

Synonymus of time-locked

- If the evoked activity is time-locked ("phase-locked") to the stimulus, it can be uncovered by stimulus-locked averaging
- It is also possible that each stimulus will induce EEG/MEG activity, which, despite being each time of the same frequency, is not exactly phase-locked to the stimulus

TSE: poiché l'evoked response è espresso in ampiezza mentre ERD e ERS in potenza, il TSE permette di rettificare il segnale (ERD e ERS) per confrontarlo con gli evoked response

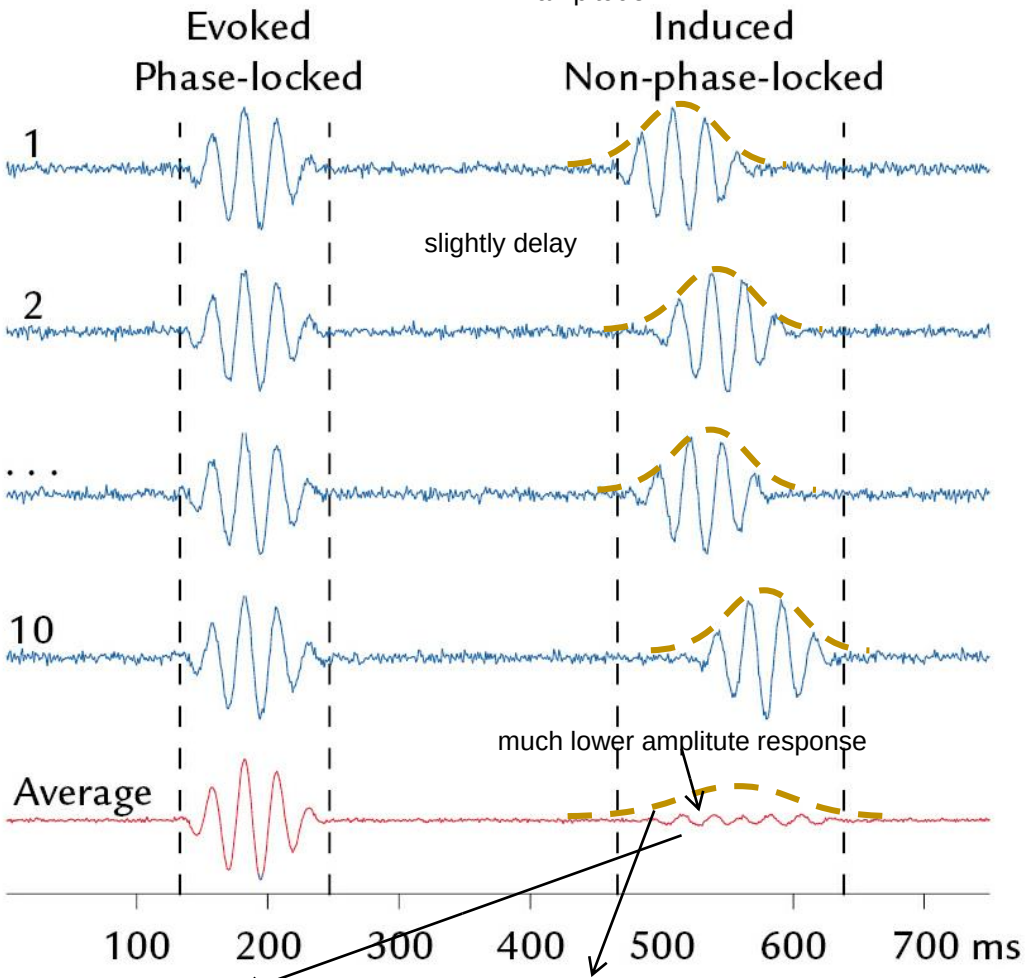
- Induced activity could be seen by first either rectifying (to examine amplitude) or squaring (to examine power) the signals in the frequency band of interest and thereafter averaging them with respect to the event.

TEMPORAL SPECTRAL EVOLUTION

- Spontaneous or ongoing brain activity is always present irrespective of whether or not a subject performs a task, and it can influence how evoked and induced responses evolve and how they are related to perception and cognition

The Evoke activity with the same stimulus are equal, so pos and neg peak are the same in all trial (latency is the same in every trial)

They are related to the evoked activity but they have slightly diffent delay every time so the peak are not lined and the final average have a lower ampitude



The short latency responses are usually phase-locked, the long latency responces are less phase-locked

Basically in non-phase you extract some features and average them

With induced activity I average not the peak but the anvelow

Event Related Desynchronization (ERD) or Synchronization (ERS)

It means reduction of amplitude that is linked with the power with a quadratic relation

It means increasing of amplitude

- Event-related desynchronization (ERD) and synchronization (ERS) is used to quantify changes in the power of EEG rhythms at one time relative to a “baseline” period at another time.
- In this analysis, the MEG/EEG signals are

  Device or algorithm to remove every part of the EEG that are not included in the band you are intrested in

  - first bandpass-filtered to the frequency band of interest and
  - their amplitudes are squared across all epochs,
  - then a moving window is used to calculate the average power as a function of time.

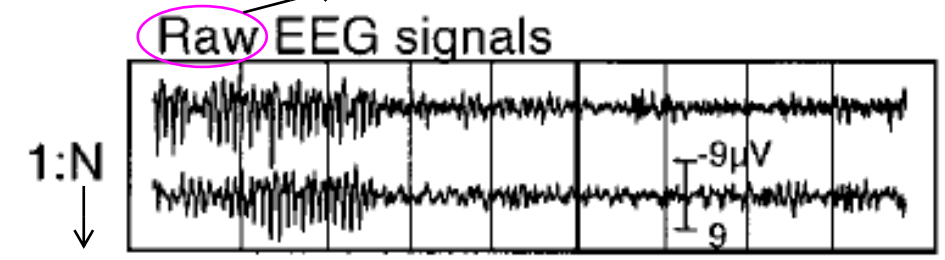
Here we can not consider the baseline potencial 0 because also there there is the Alpha rithm

- ERD and ERS are expressed as percentage power changes relative to a baseline period preceding the event, be the event a sensory stimulus or a motor action.

Alpha (mu) Event Related Desynchronization (ERD)

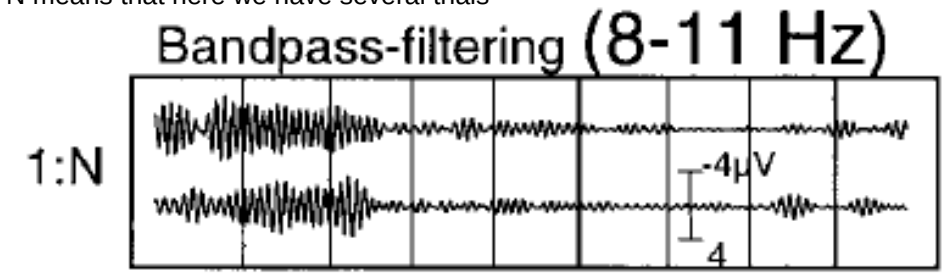
Reduction of power

Unfiltered

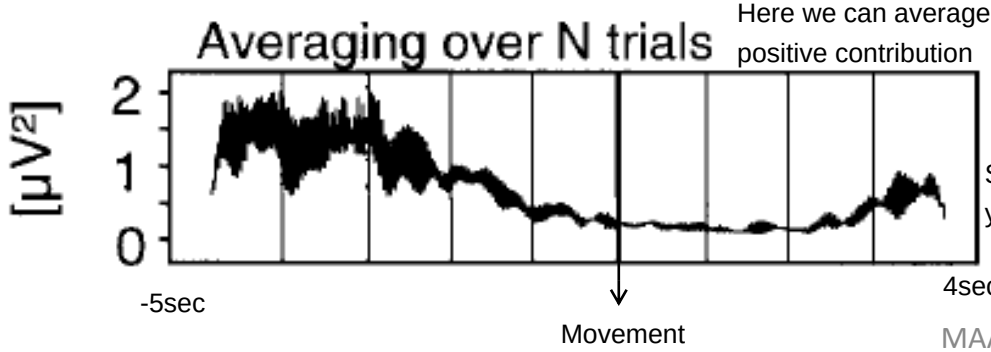


N means that here we have several trials

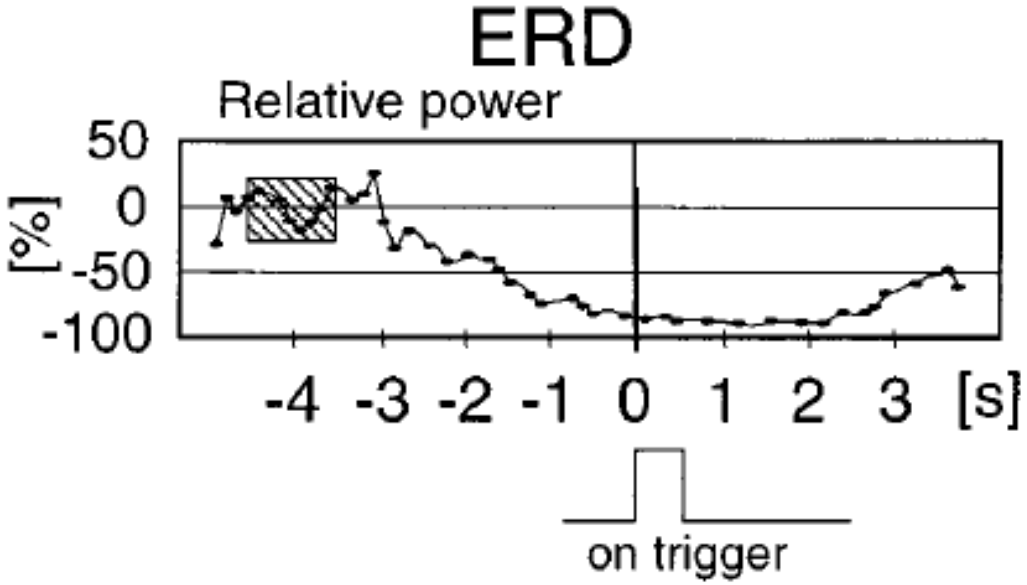
If you are preparing a movement your brain is working before the movement happen so the baseline is even earlier



Here we removed negative waves (they did not disappear but we mirror them to the positive)



Here we can average because all the waves now have a positive contribution



Since the changing amplitude is much slower than the obsoleting changing of the Raw EEG signals, you can take small chunks of this signal and average within them