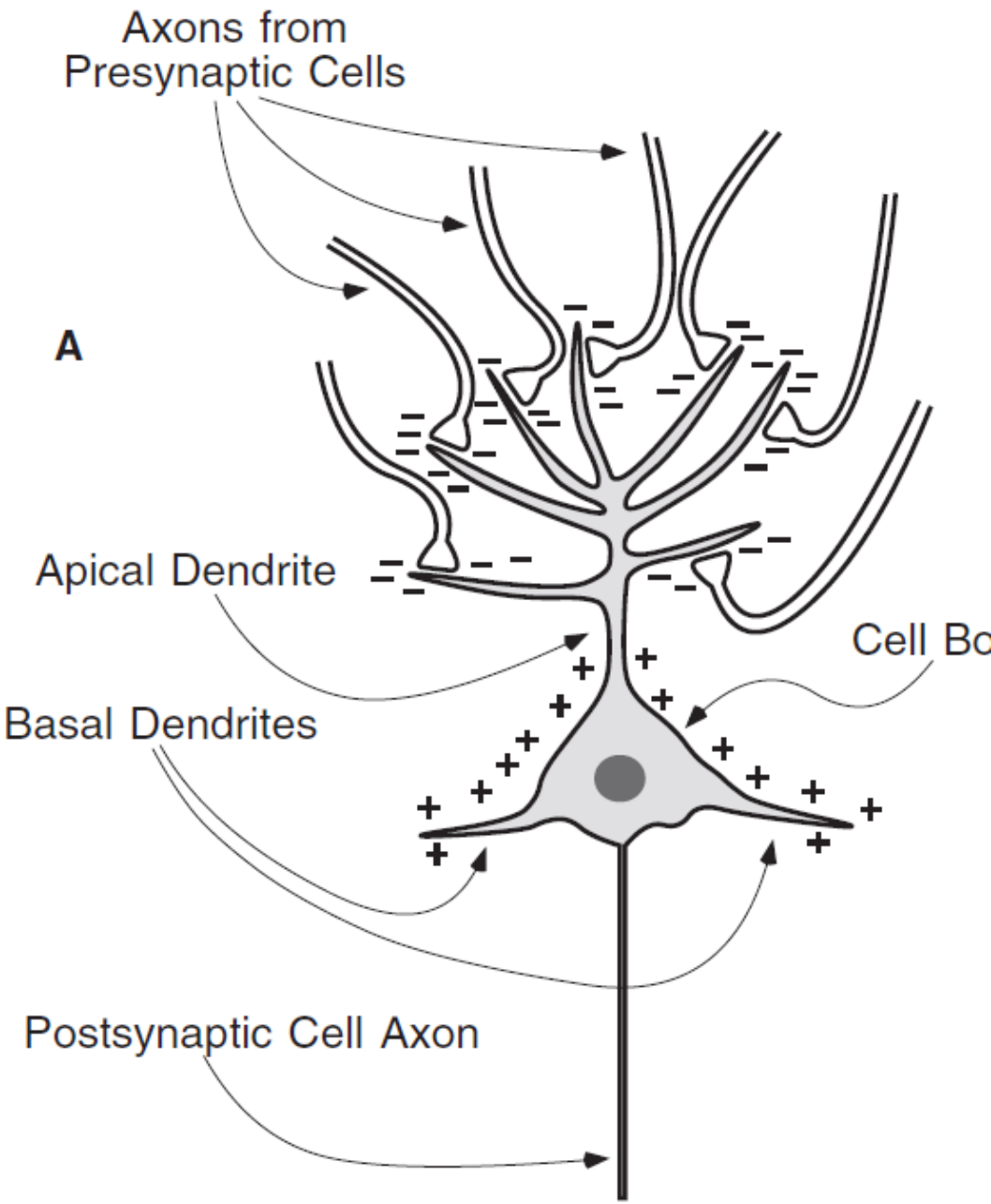
ERPs:

technique and design

- Neuronal communication is essentially electrical activity
- Not big enough to measure one cell
- But when a number of cells ***align*** in the grey matter, enough

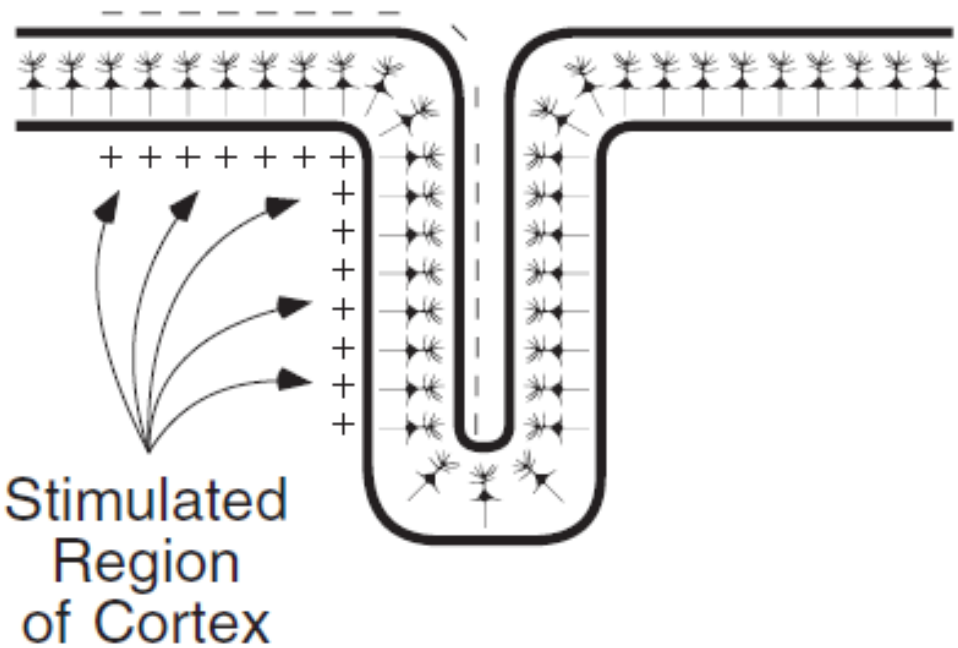


- What we measure at the scalp is summed from large populations of electrodes
- Oriented in the same direction
- Like columns in cortex

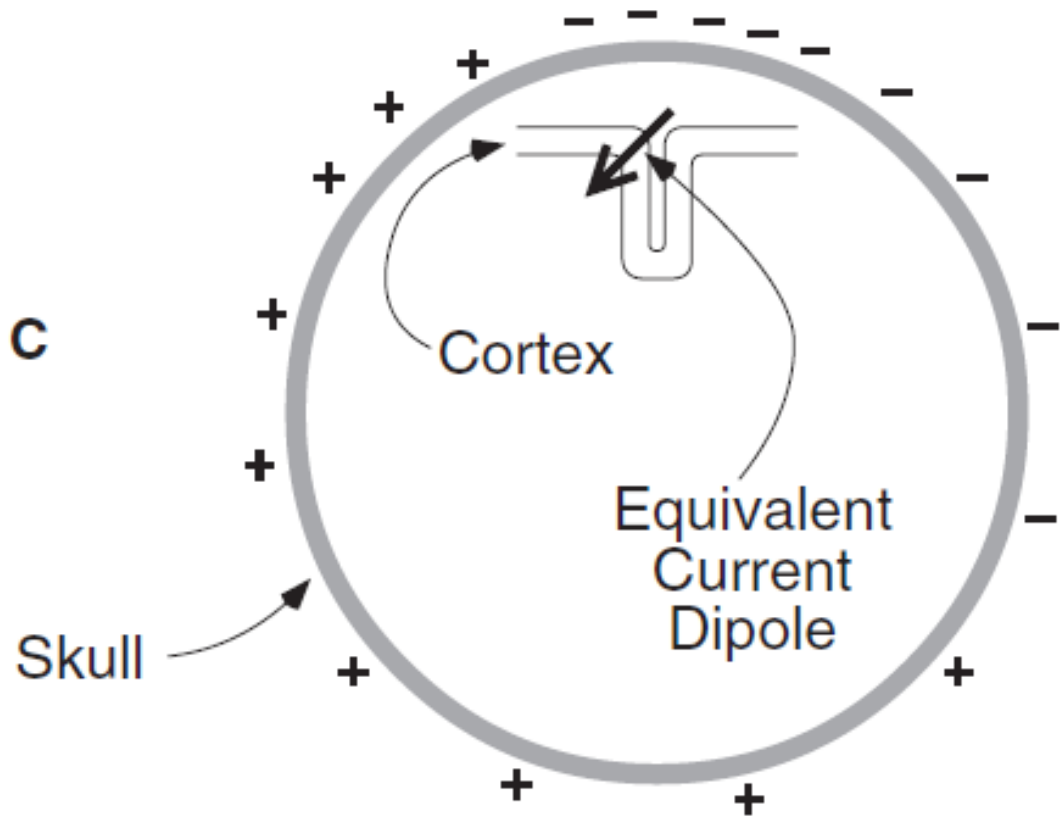
Where do we see activity?

- Not necessarily right above the place where the cells are firing
- Why not?

Aligned cells: usually called equivalent dipole



You will see positivity or negativity depending on the end of the dipole closest to skull

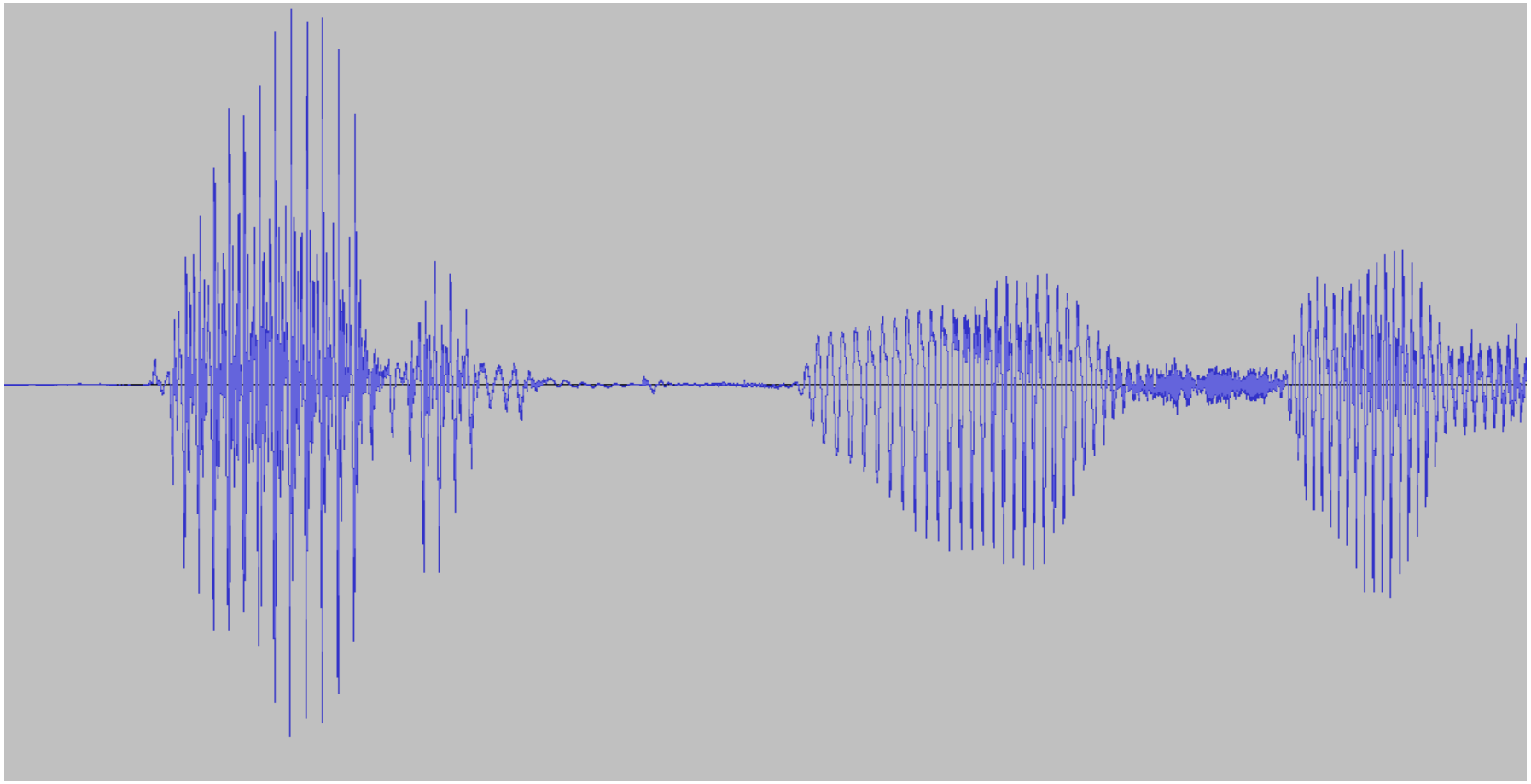


How do we measure ERPs?

Sampling EEG signal

- Sampling period – time between measures (e.g. 4 ms)
- Sampling rate – number of measures taken per s (e.g. 250 Hz)
- Nyquist theorem: analog signal (EEG) can be digitized if SR is as least twice as great as the highest frequency in the signal

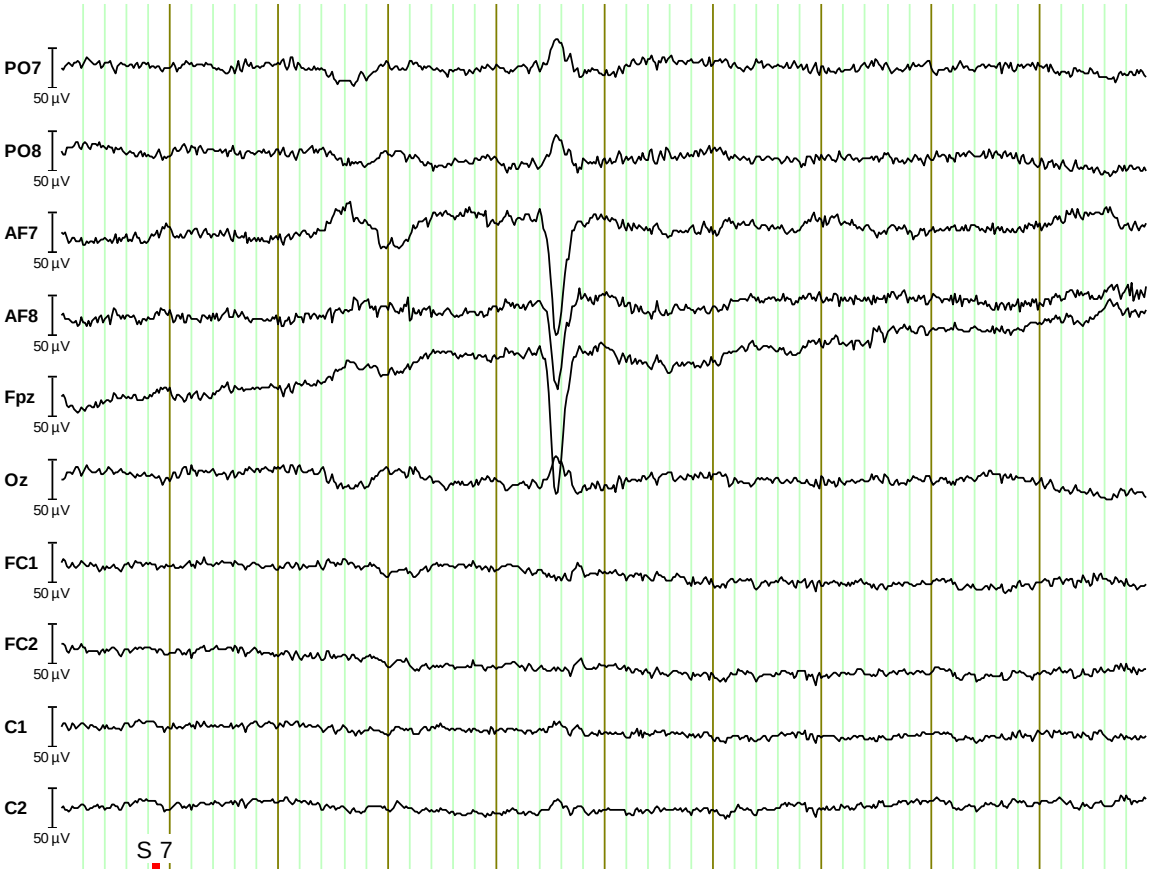
~ осциллограмма



Electroencephalogram (EEG)

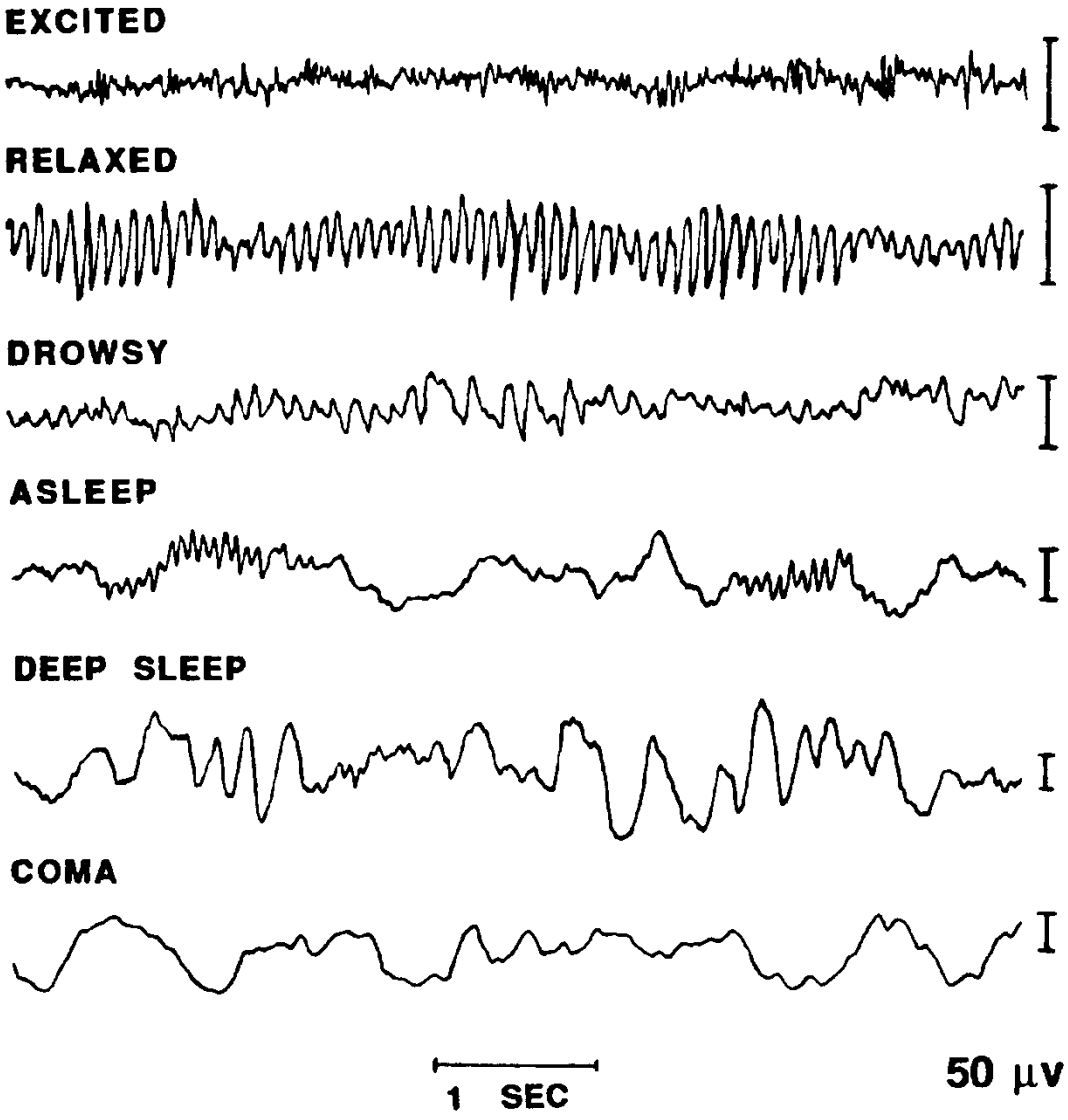
- A record of electrical oscillations of the brain

- Excellent temporal resolution (ms)



Analyzing frequency

- What you see in the signal is an oscillation
- Hz = Hertz (oscillations per second)
- Depending on various factors the oscillation is faster or slower
  - Terminology in terms of frequency bands



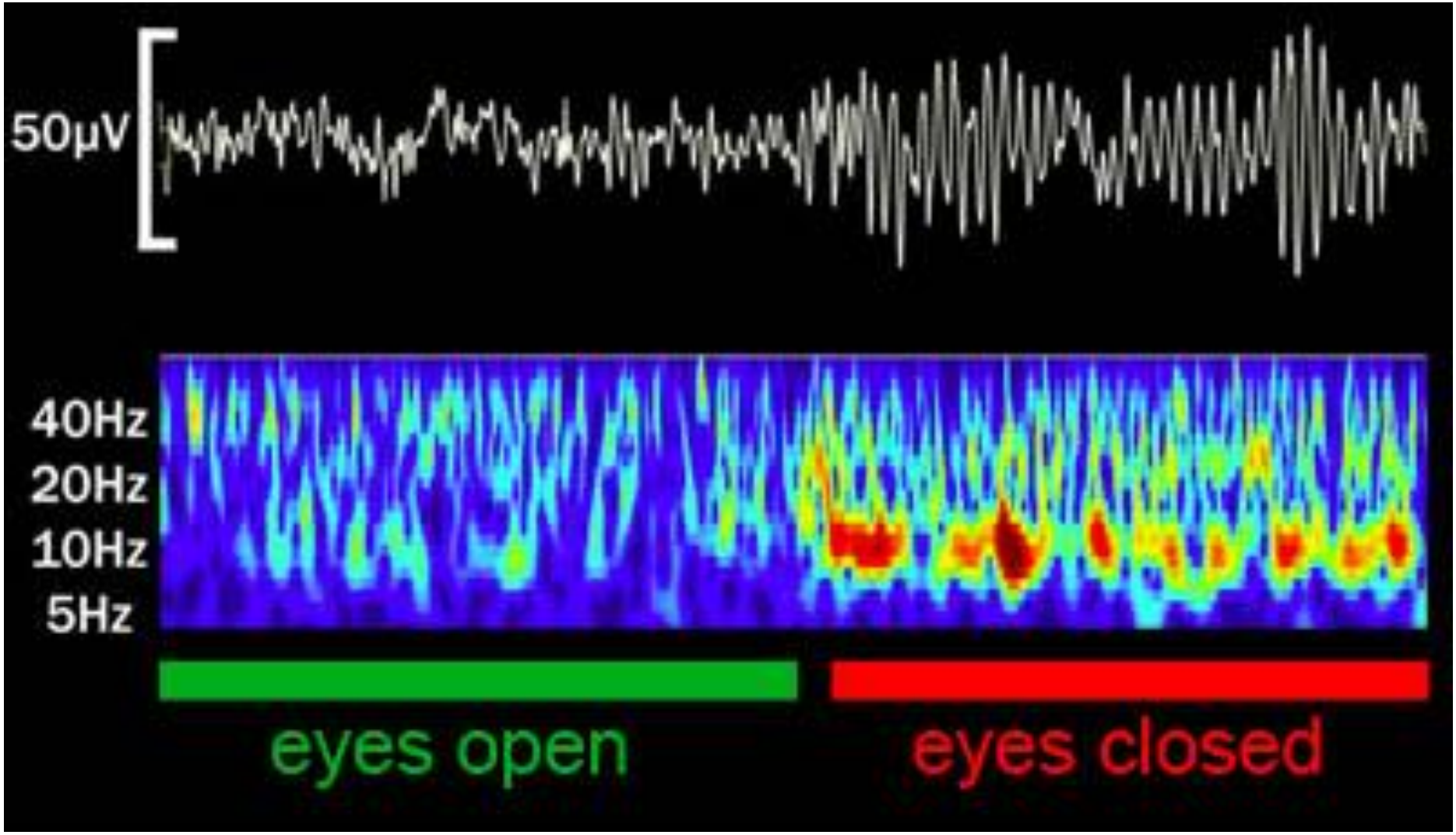
Beta (> 13 Hz)

Alfa (8-13 Hz)

Theta (4-8 Hz)

Sleep Stage 2
Sleep Spindles
(12-14 Hz)

Delta (< 4 Hz)
Sleep stage 3-4
Slow wave sleep


50µV
40Hz
20Hz
10Hz
5Hz
eyes open
eyes closed

EEG coherence

- Brain regions activated by cognitive operations show increased coherence
- Within certain frequency bands
- High coherence in EEGs recorded at different sites
  → increased functional interplay
- Each mental operation relates to a coherence pattern

Weiss & Mueller (2003). Brain & Language

Event-related potentials (ERPs)

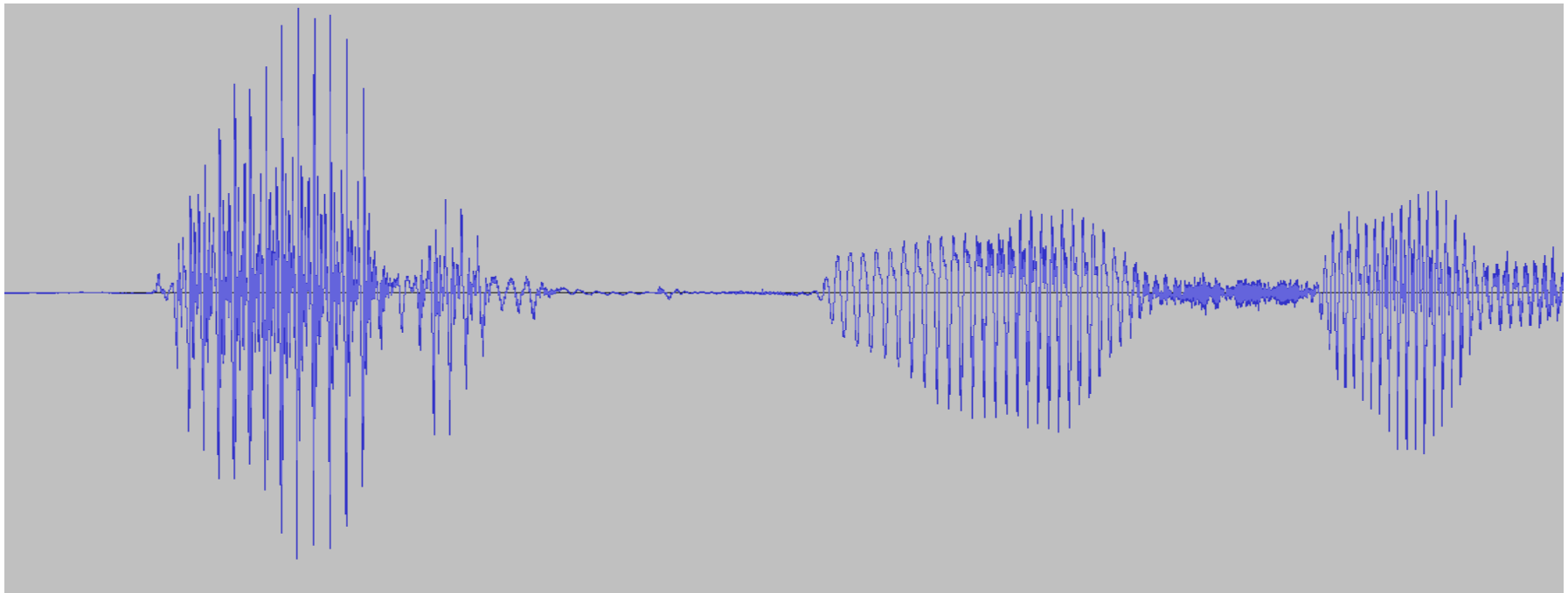
- Reflect basic sensory processing:
  - Physical stimulus parameters

- Reflect psychological processes/task demands:
  - Selective attention
  - Memory
  - Language processing, etc.

Stimuli

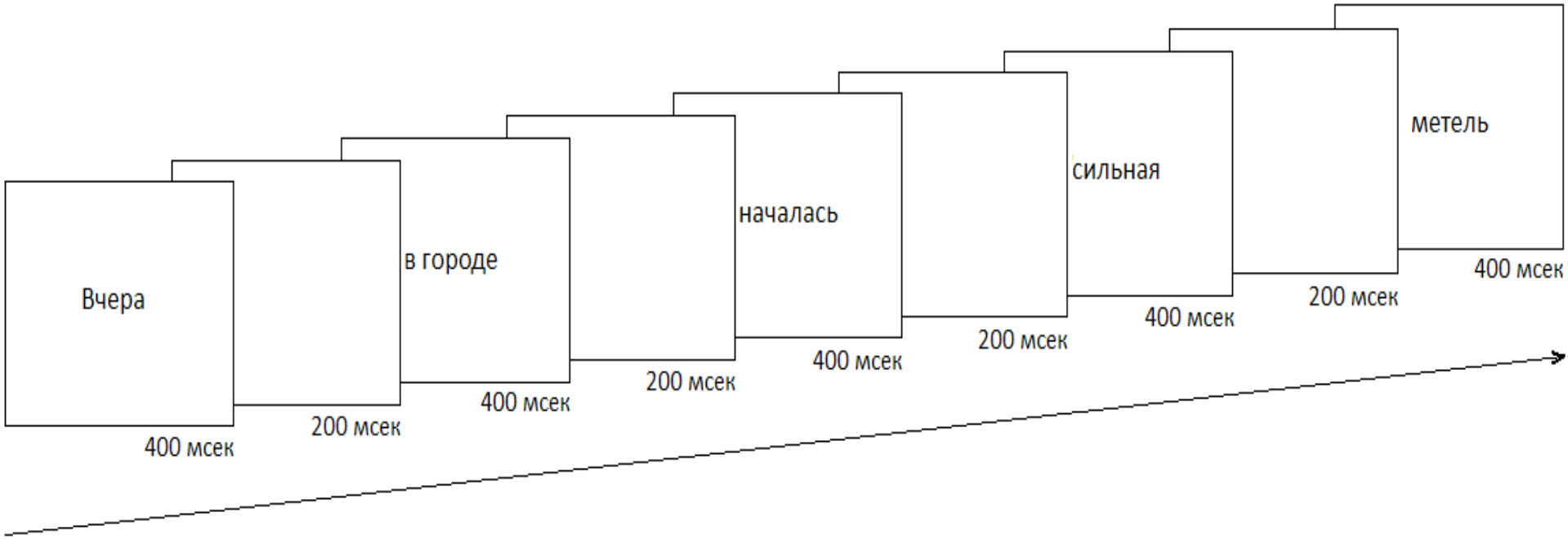
- non-linguistic
- linguistic

- auditory



Stimuli

- visual (***rapid serial visual presentation (RSVP)*** **– why?**)



Eye movements

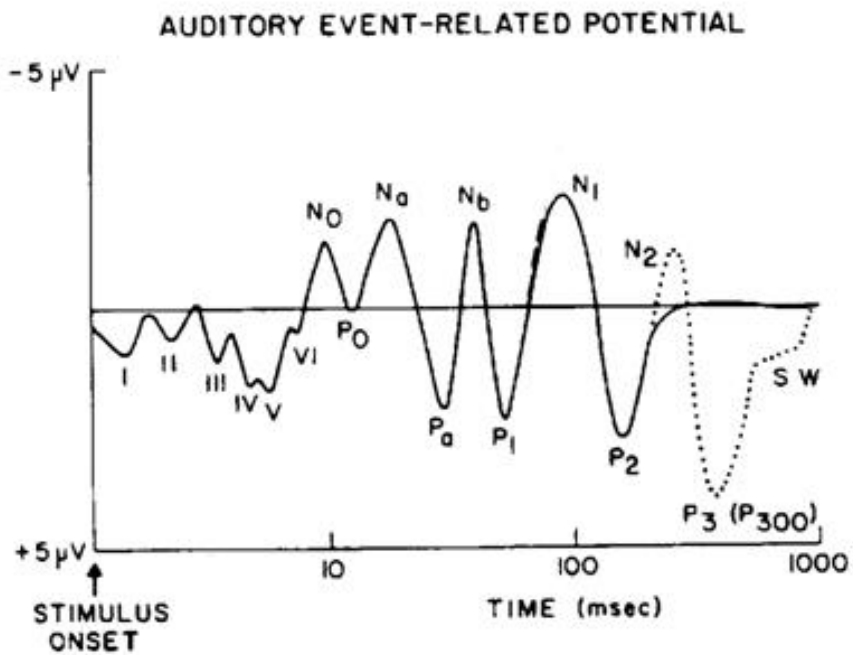
Analyzing Changes over Time

- Create a number of comparable events
- Lock the time to the event
- Average measurements

Evoked potentials (EPs)
Event-related potentials (ERPs)

Naming conventions

- Polarity
  - P= positive
  - N= negative
- Order: 1=first, 2= second
- Latency:
  - 400 = 400 msec after stimulus presentation
- Scalp distribution
  - AN = anterior negativity

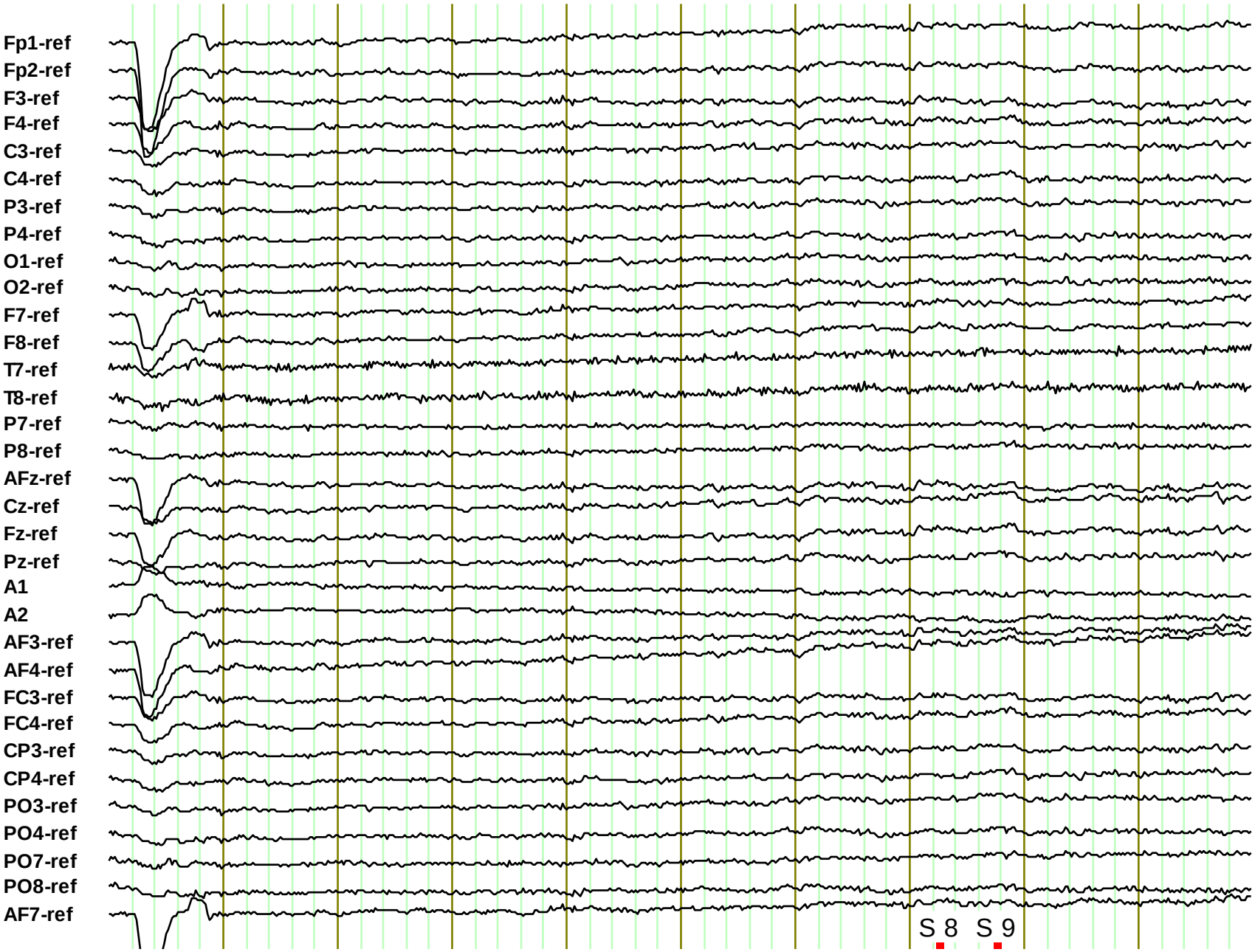


Analyzing Changes over Time

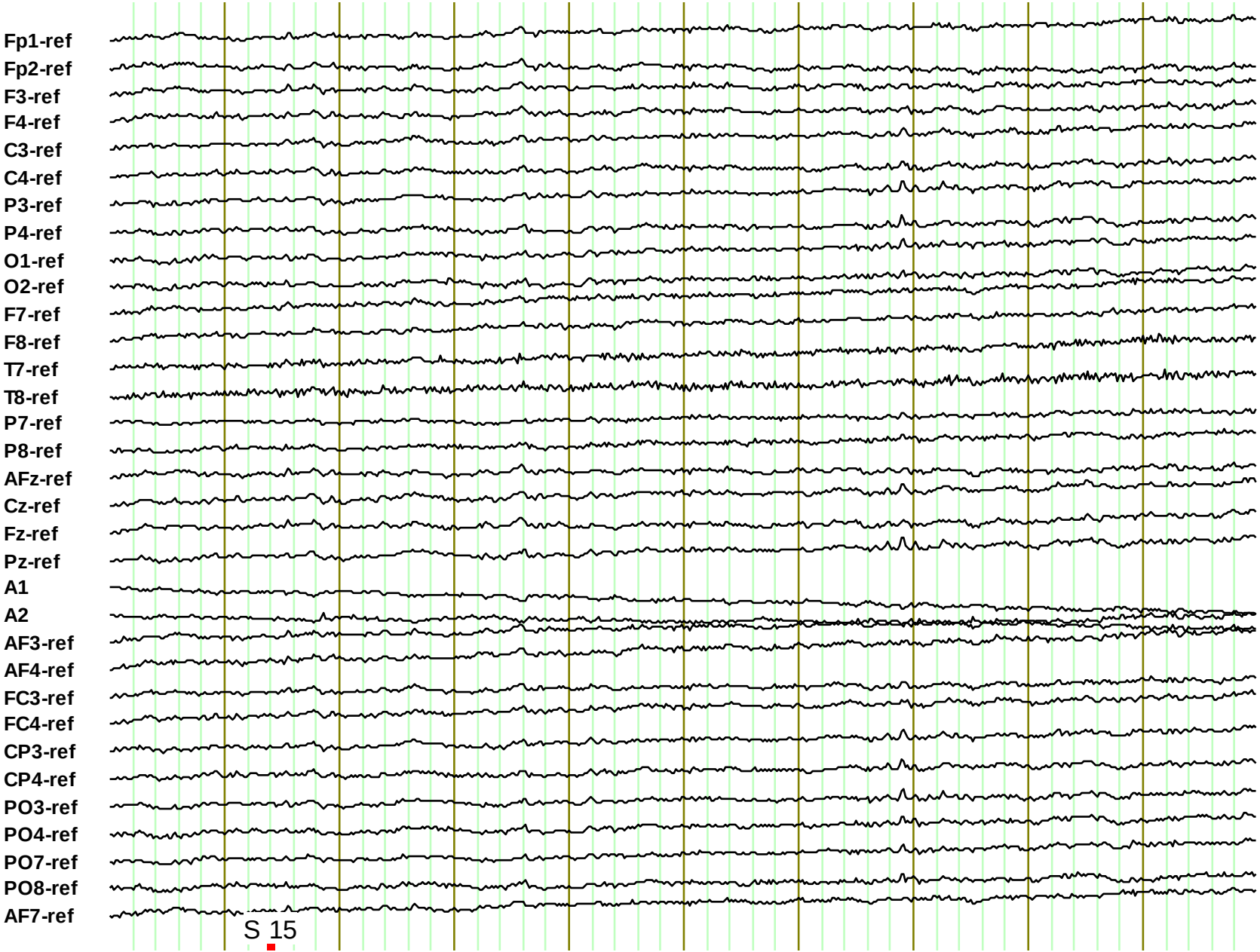
- Rereference if necessary
- Filter
- Segment
- Correct ocular artifacts (or delete)
- Baseline
- Reject other artifacts
  (difference, min/max amplitude, low activity)
- Average
- Compare conditions
- Do statistics

Rereference - before

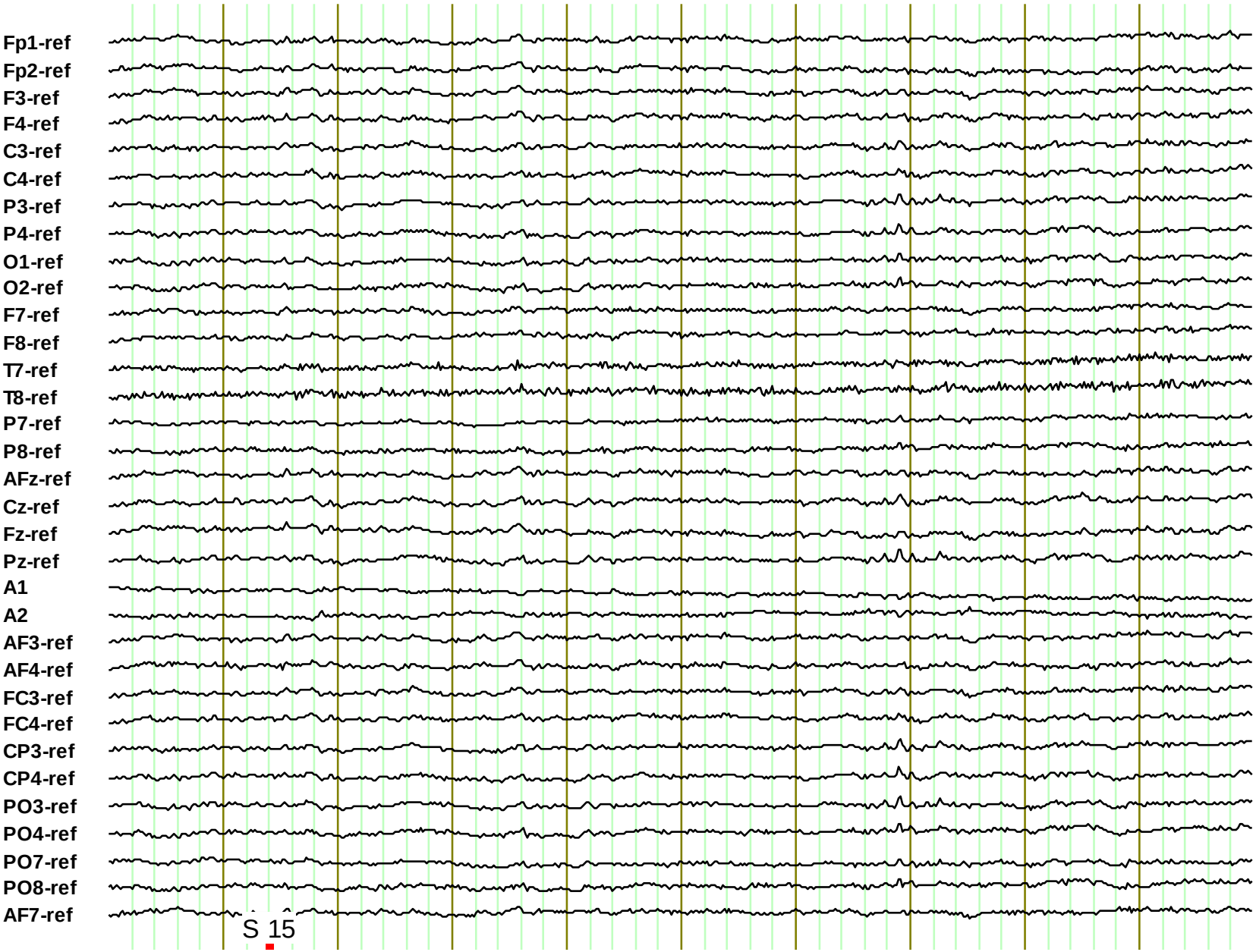
Rereference - after



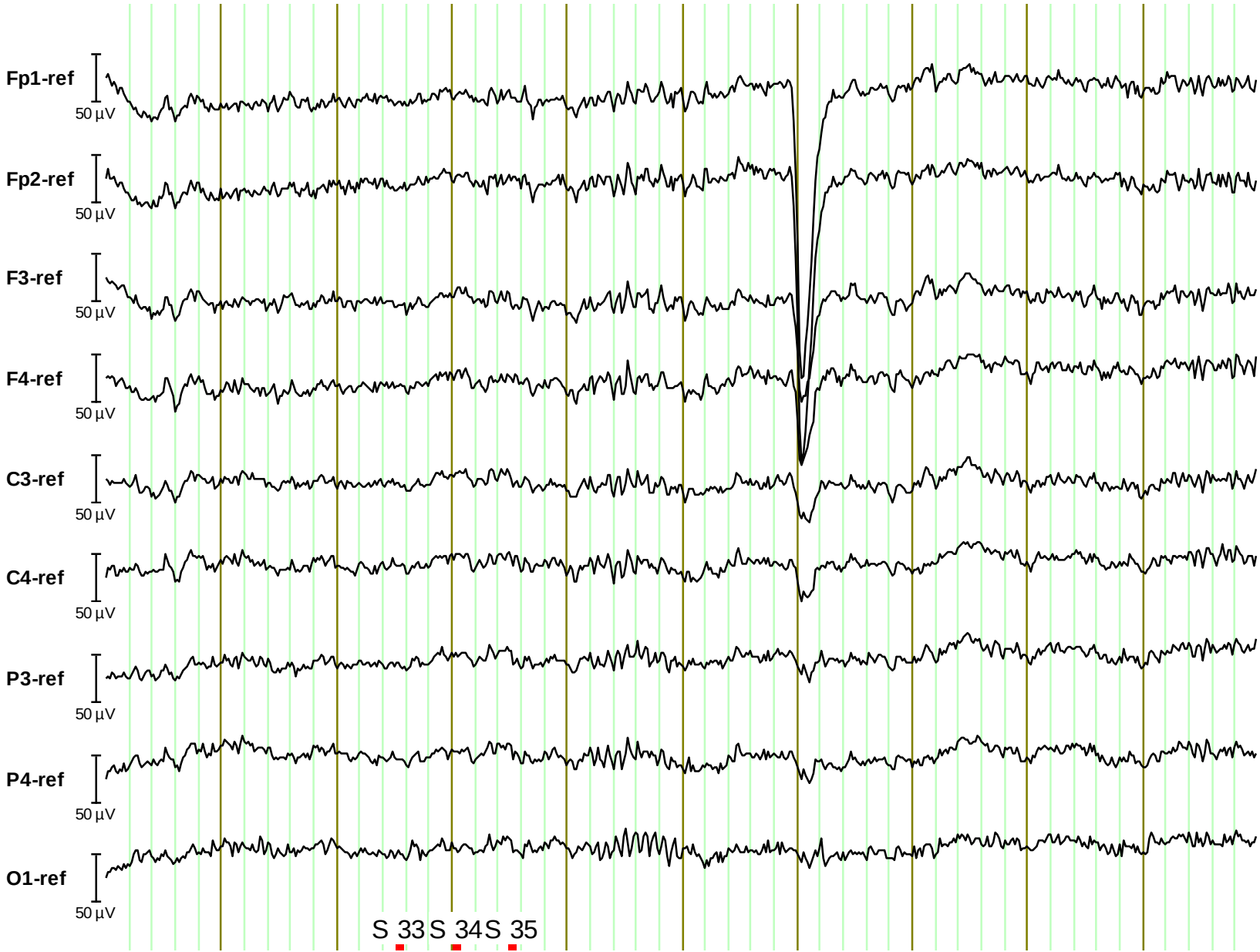
Filter - before



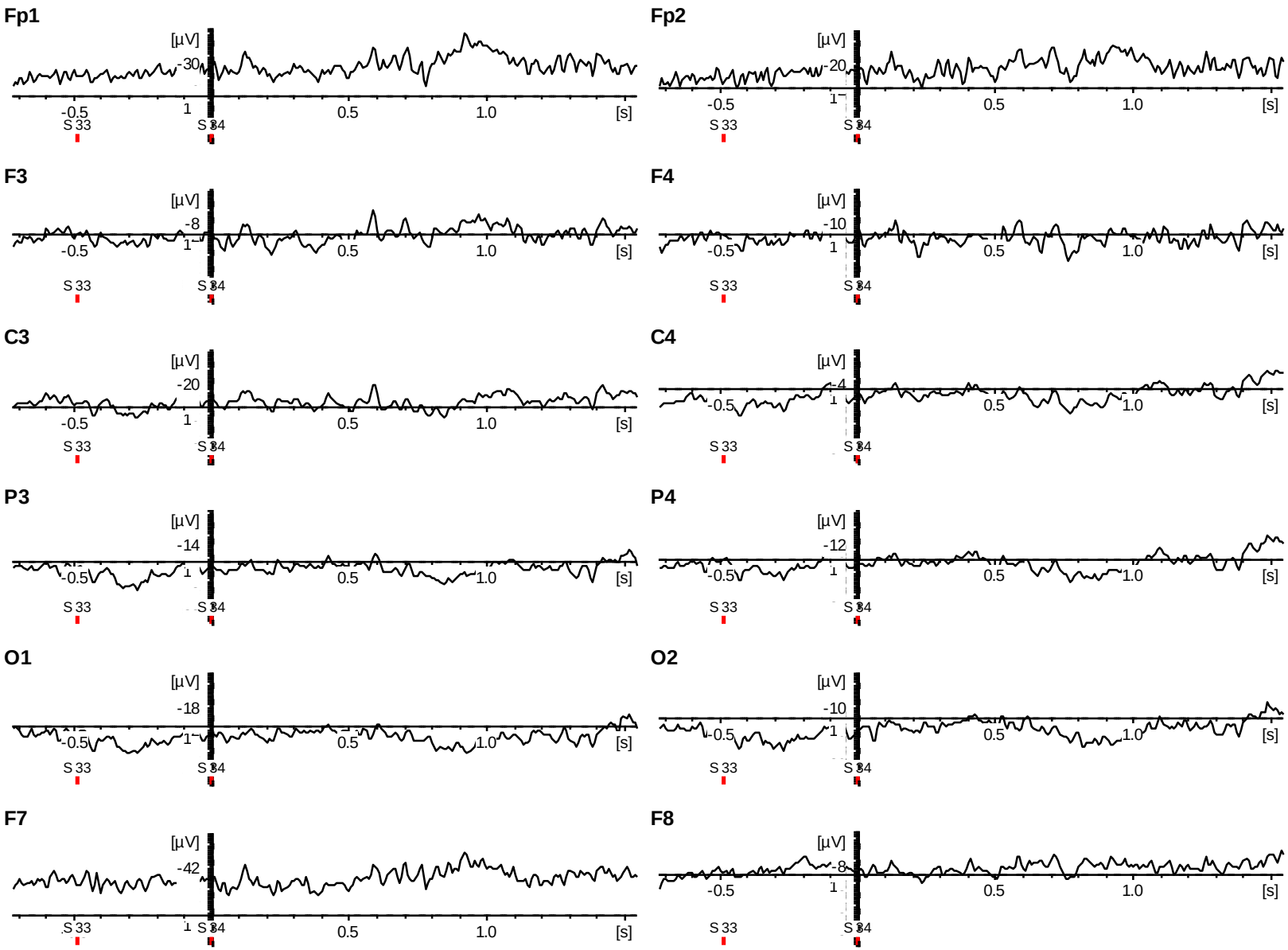
Filter - after



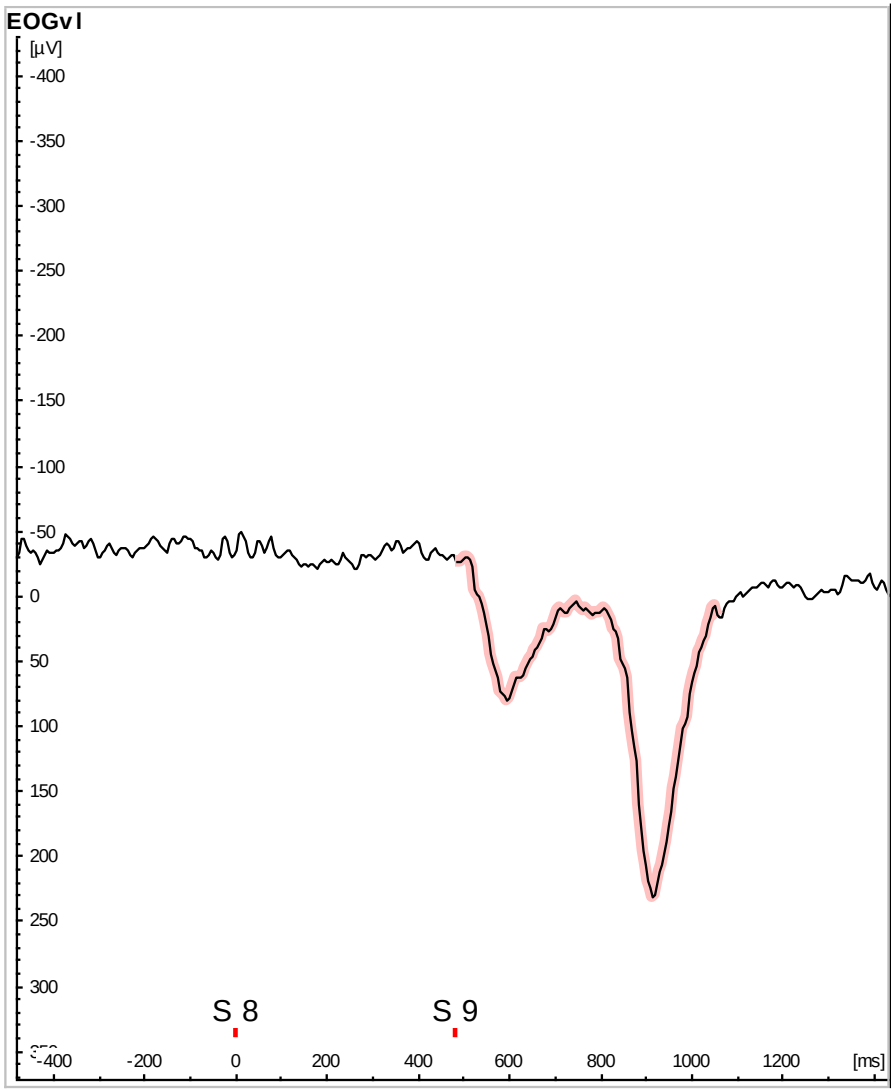
Segment - before



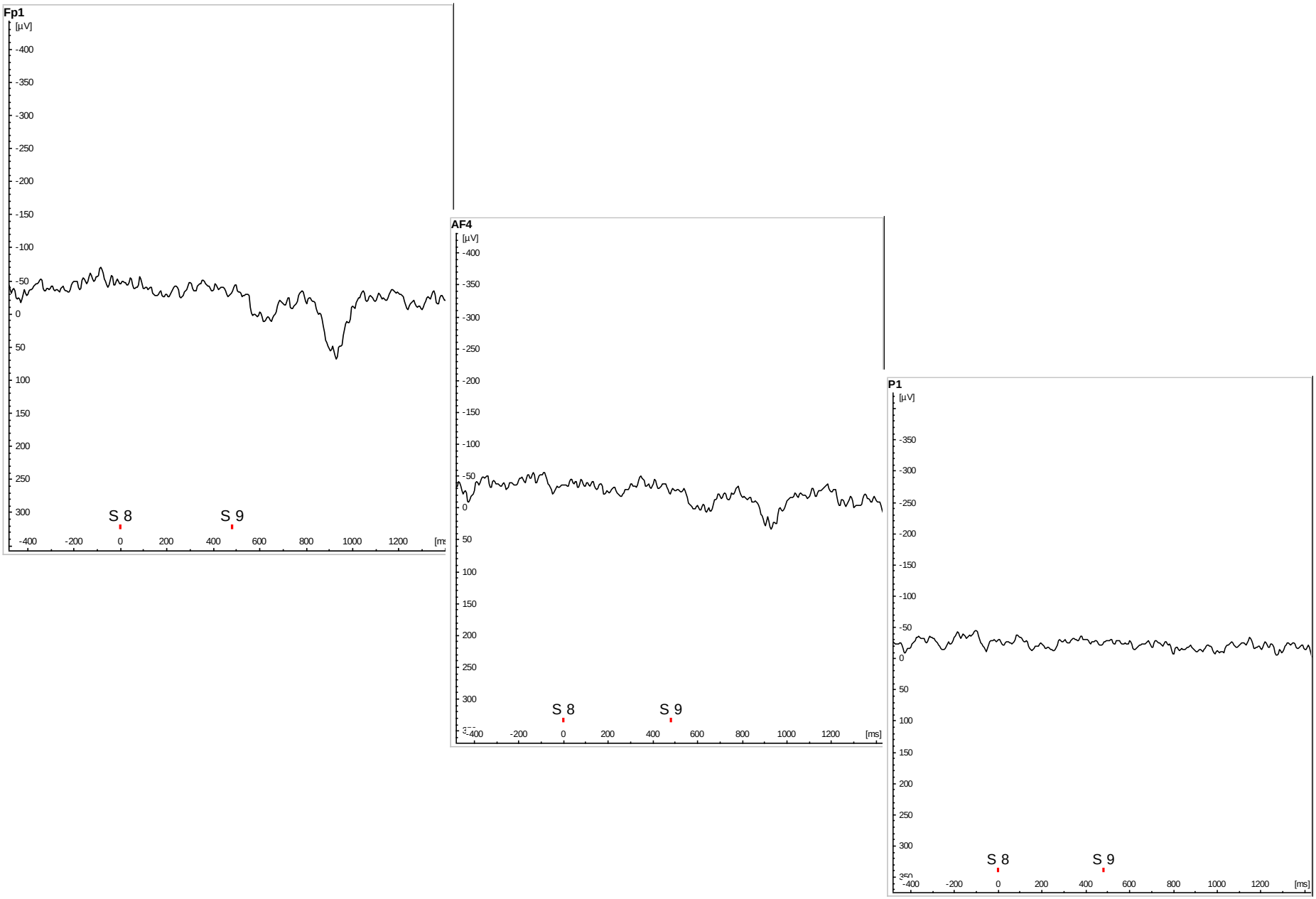
Segment - after



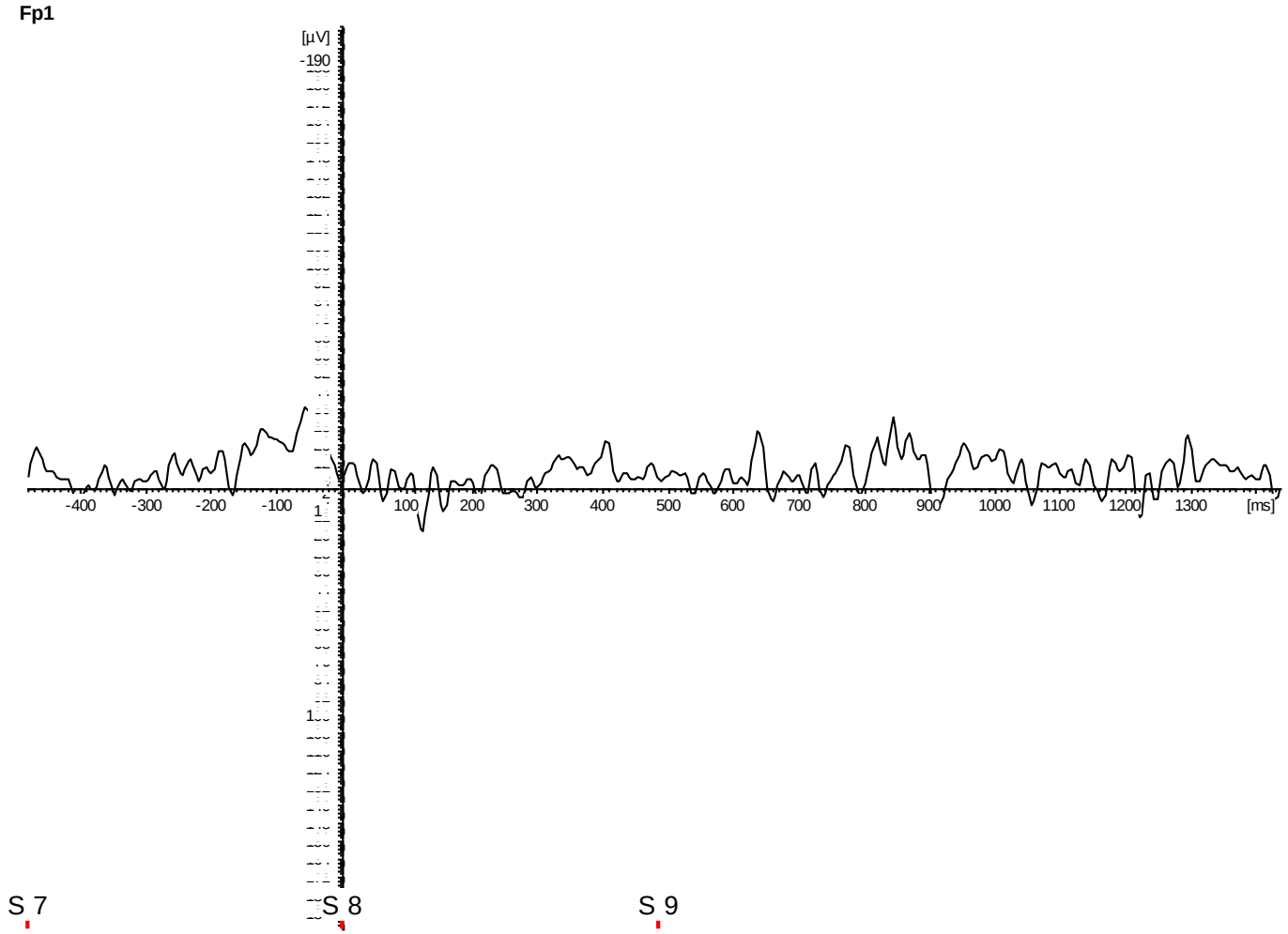
Ocular correction



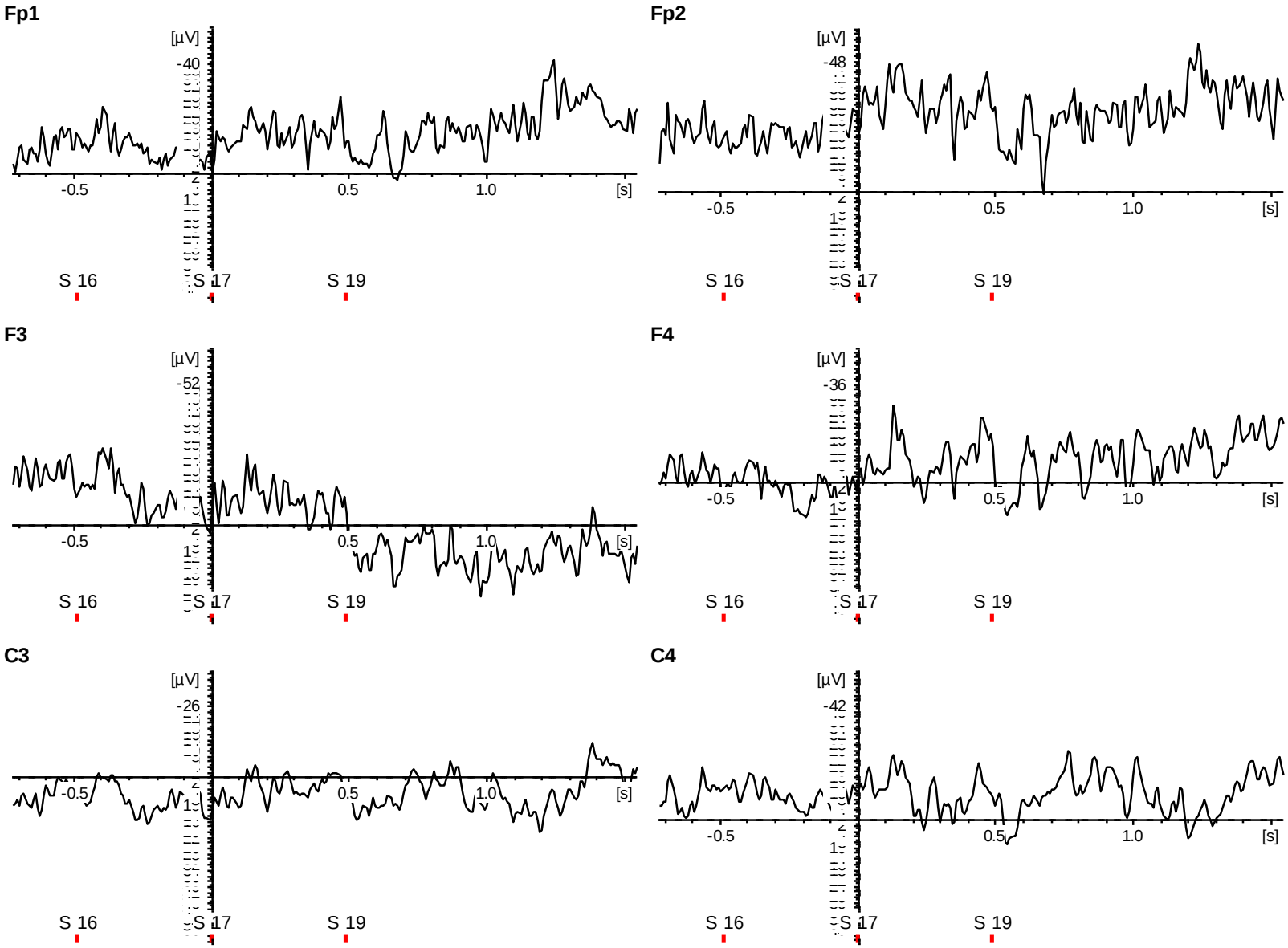
Ocular correction - before



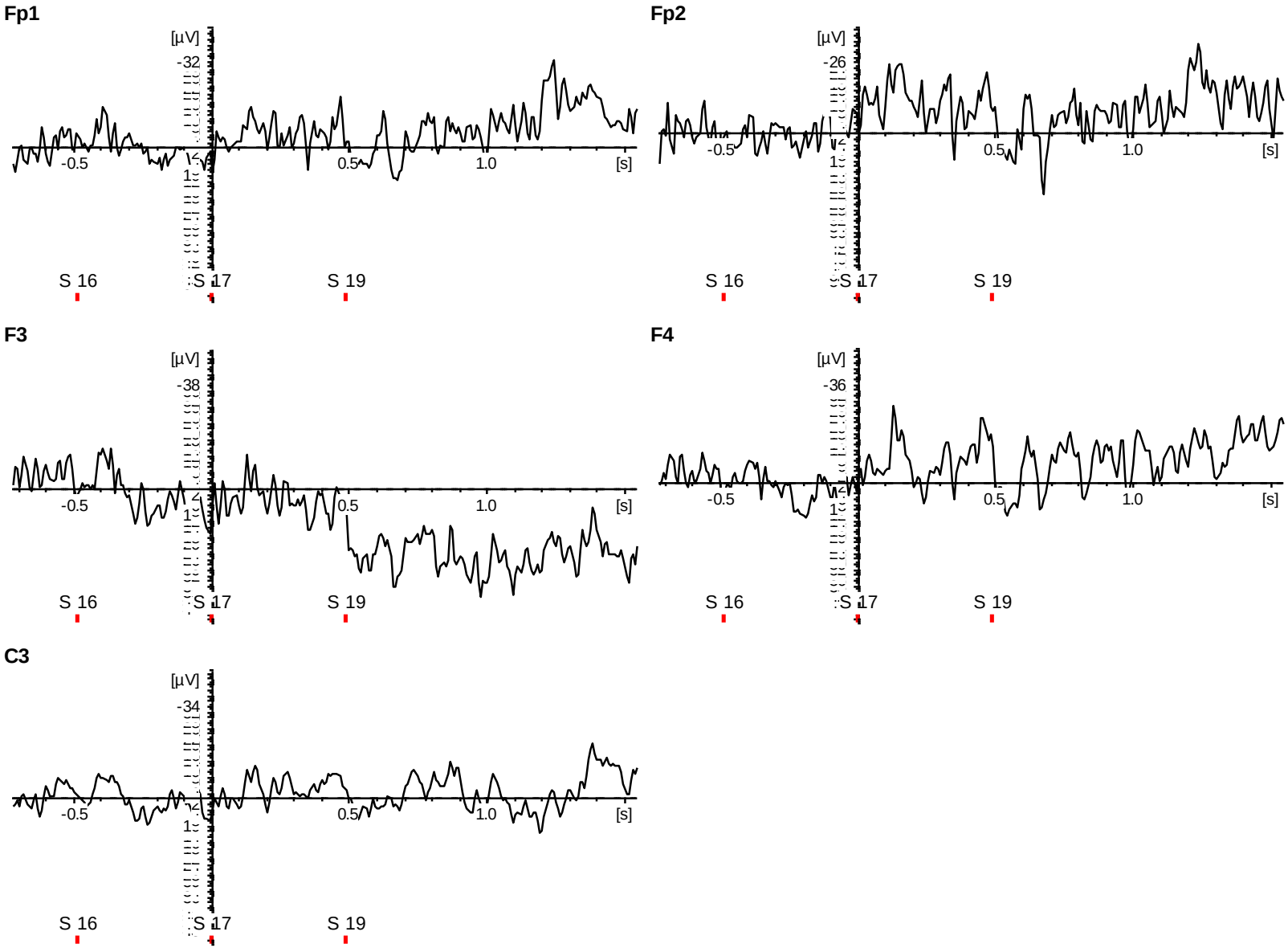
Ocular correction - after



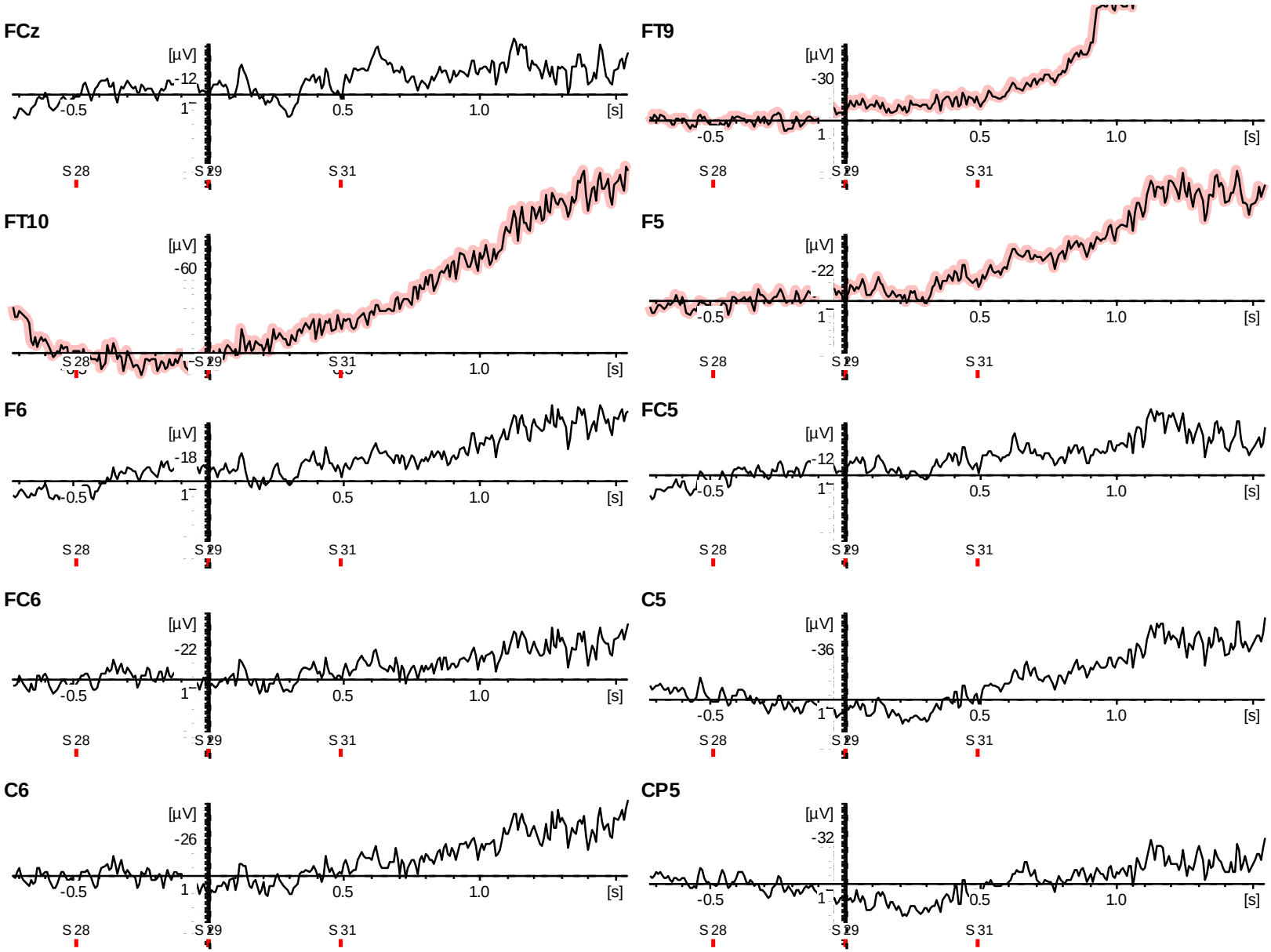
Baselining - before



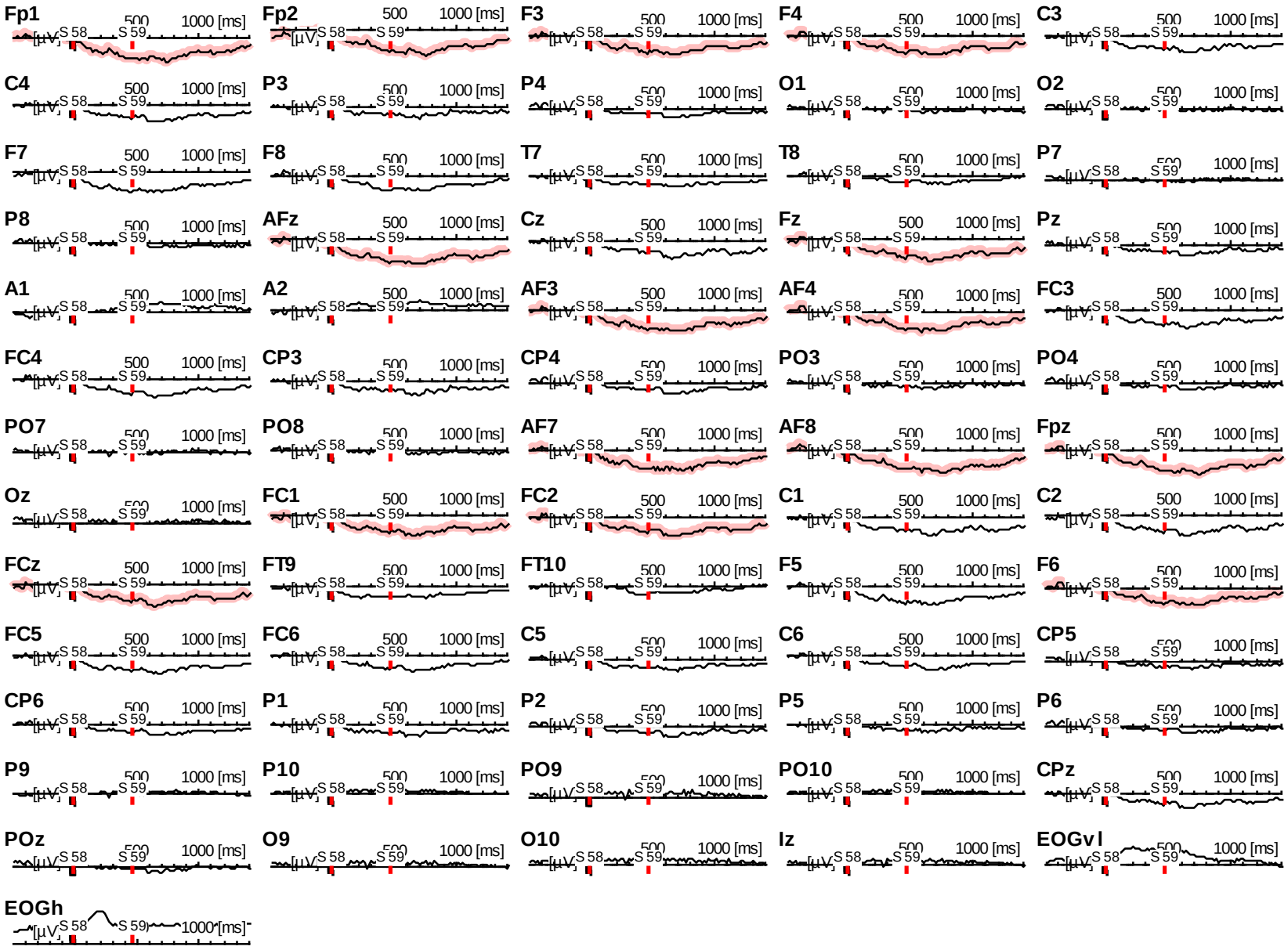
Baselining - after



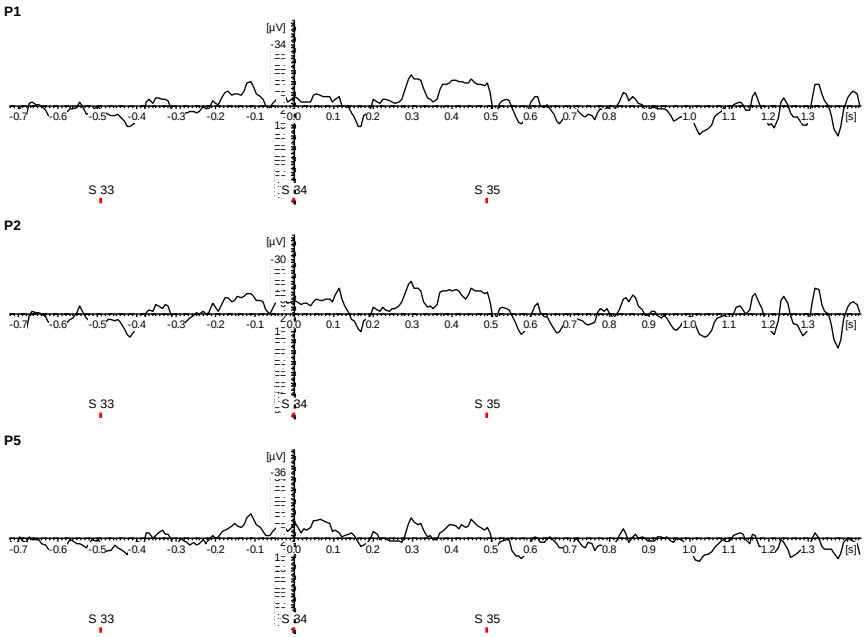
Artifact rejection



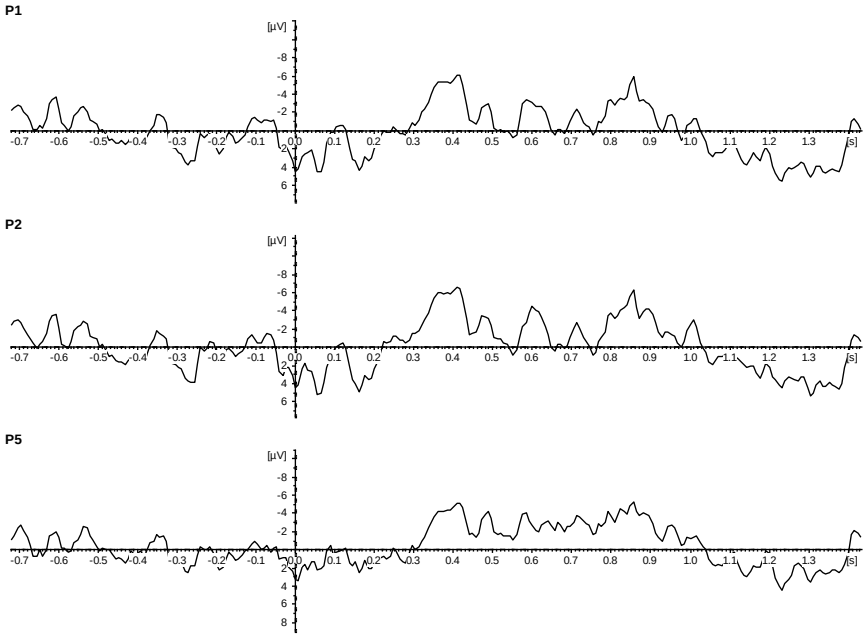
Artifact rejection



Average per Subject



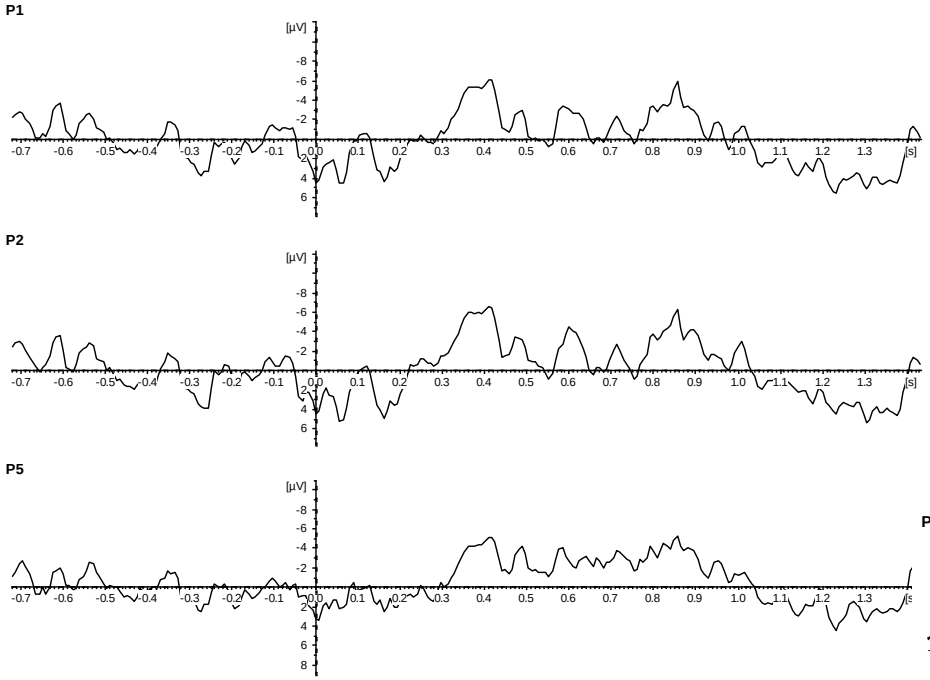
- before



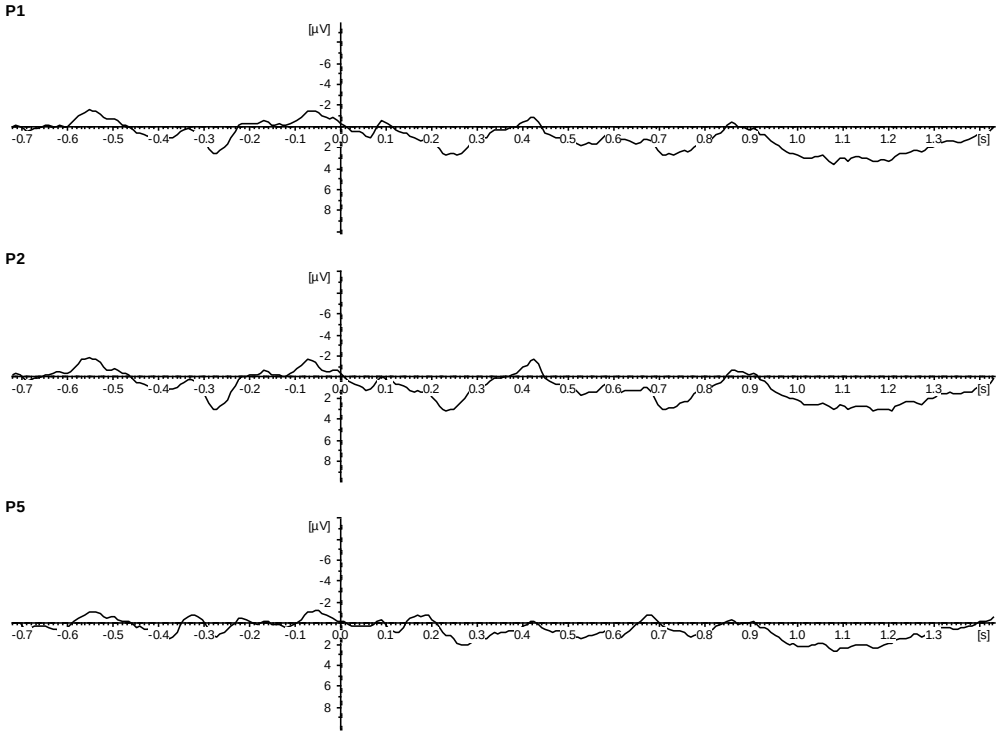
- after

Average across Subjects

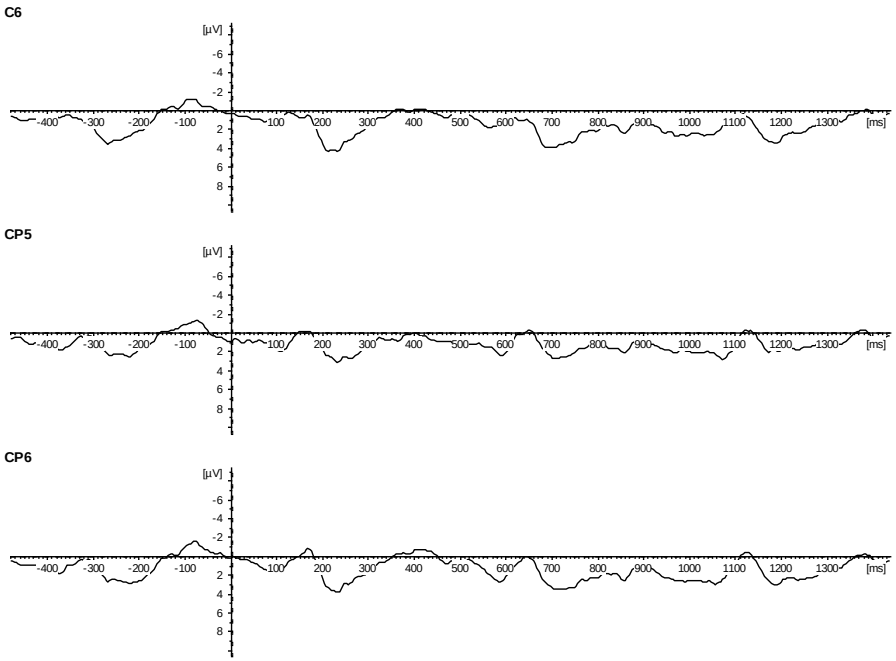
- before

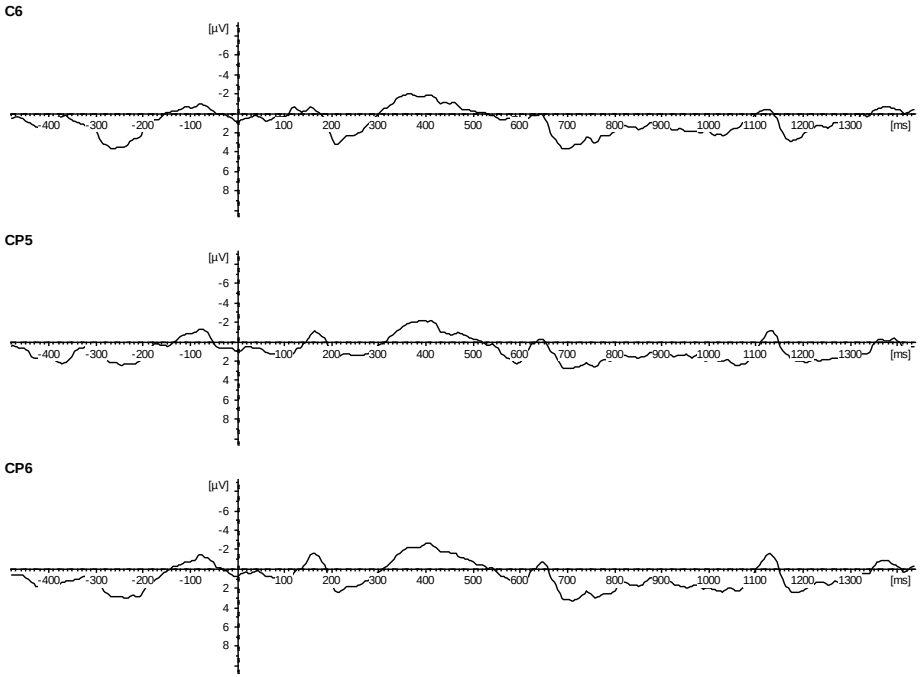


- after



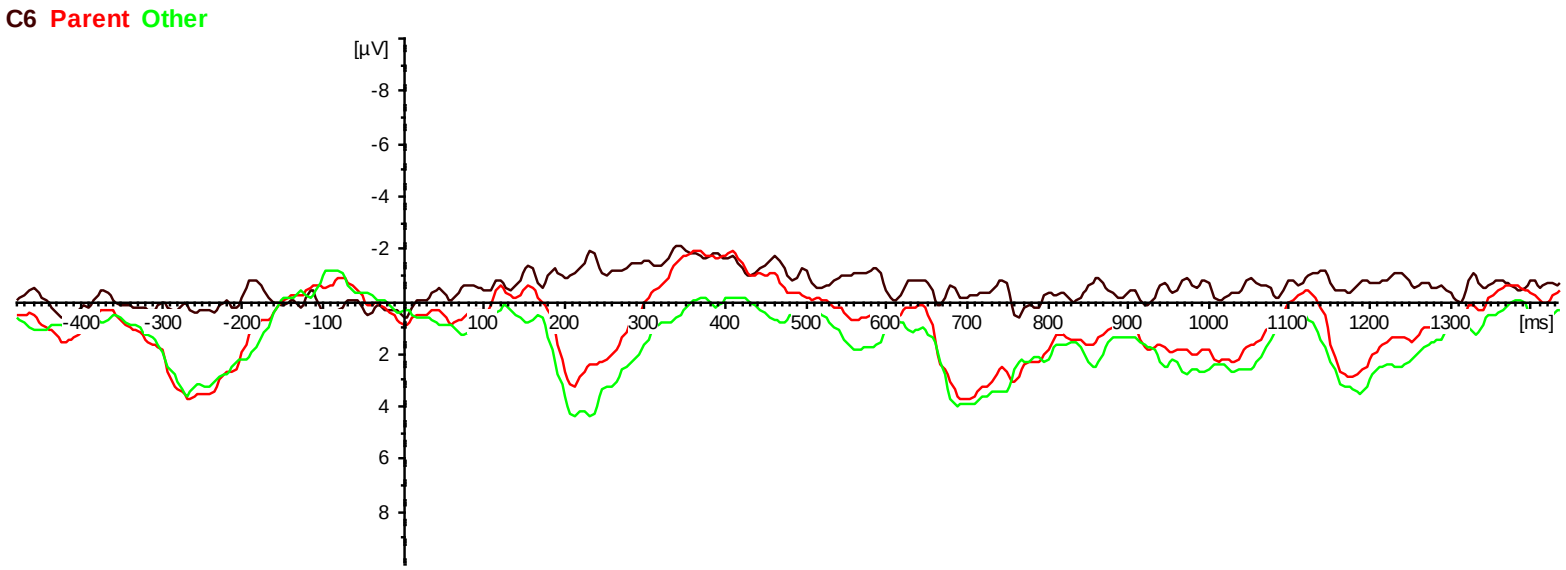
Compare conditions

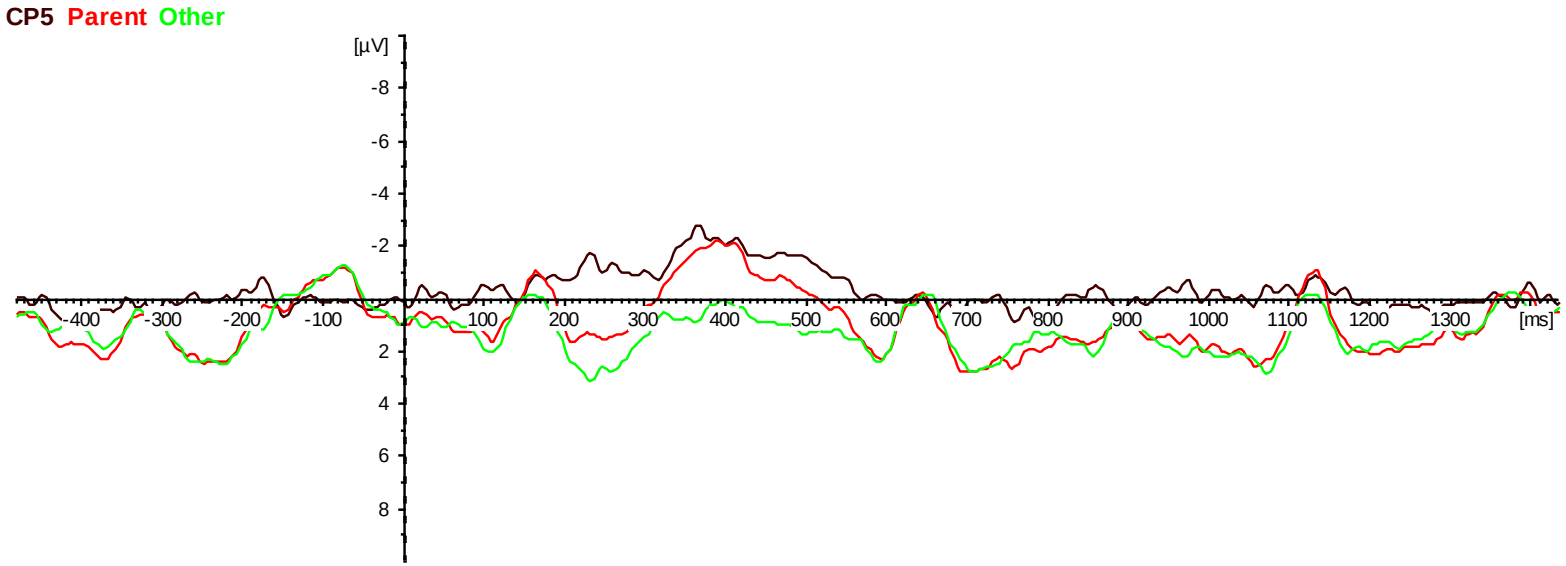




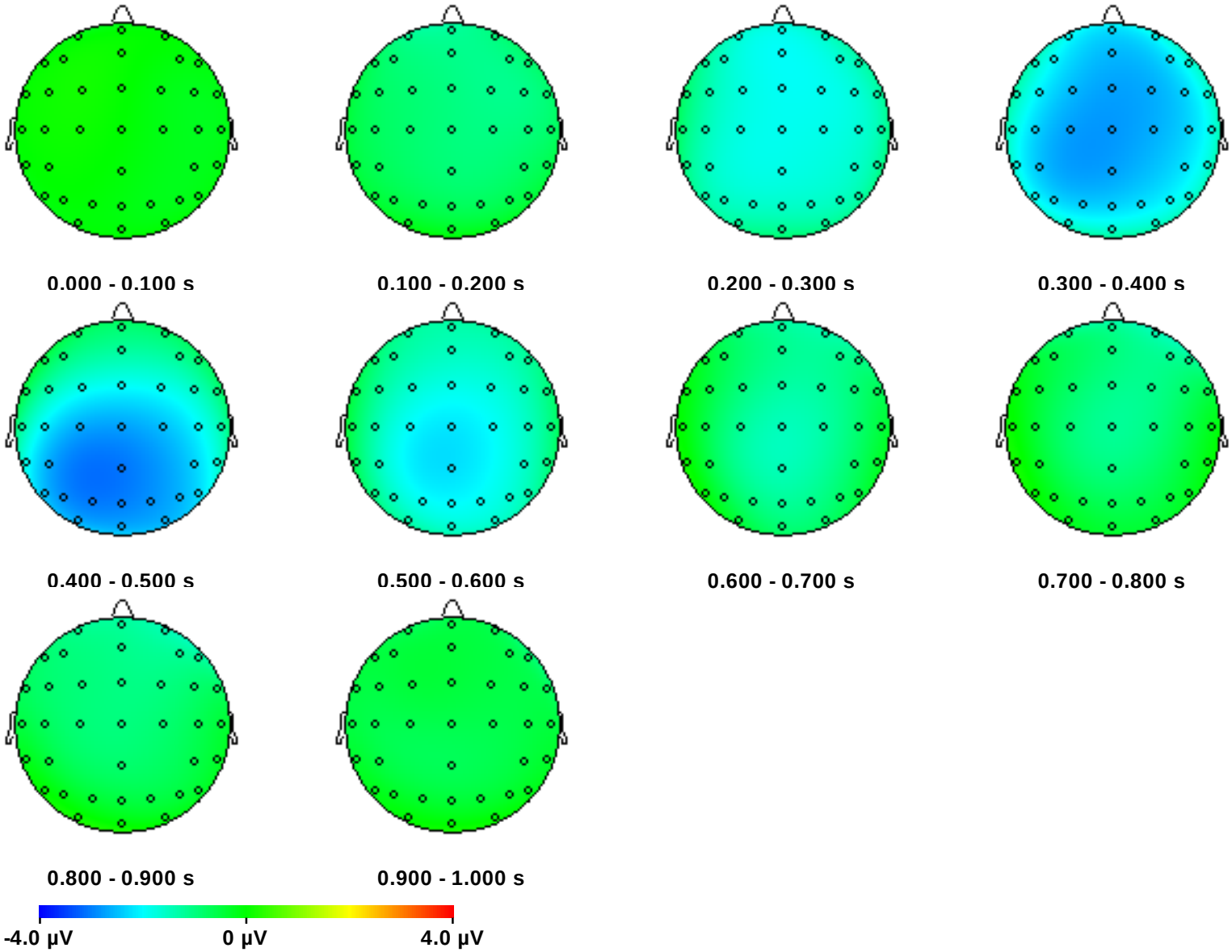
- Cond - ok
- Cond - deviant

Compare conditions

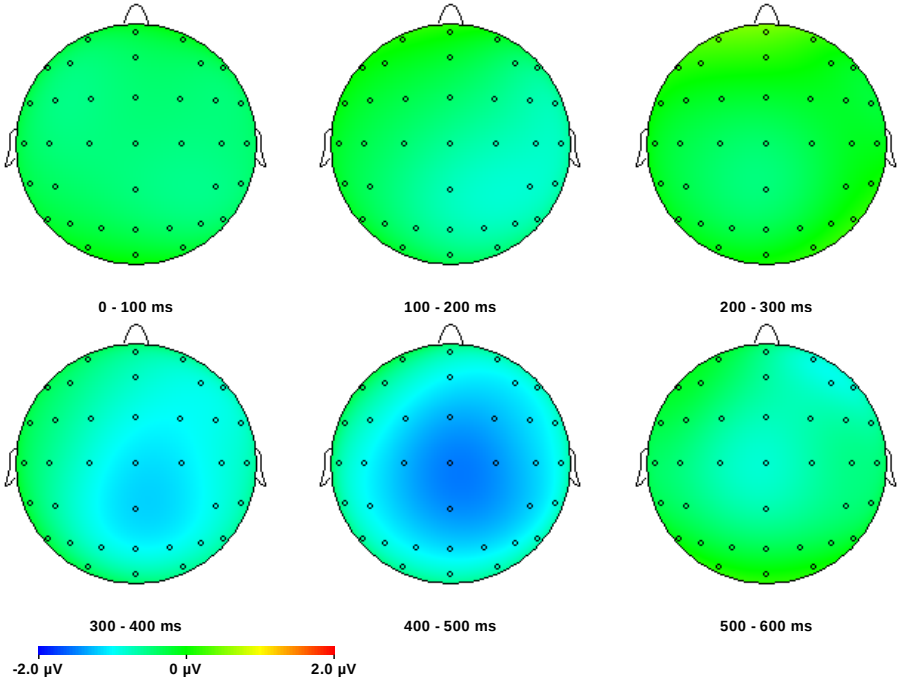


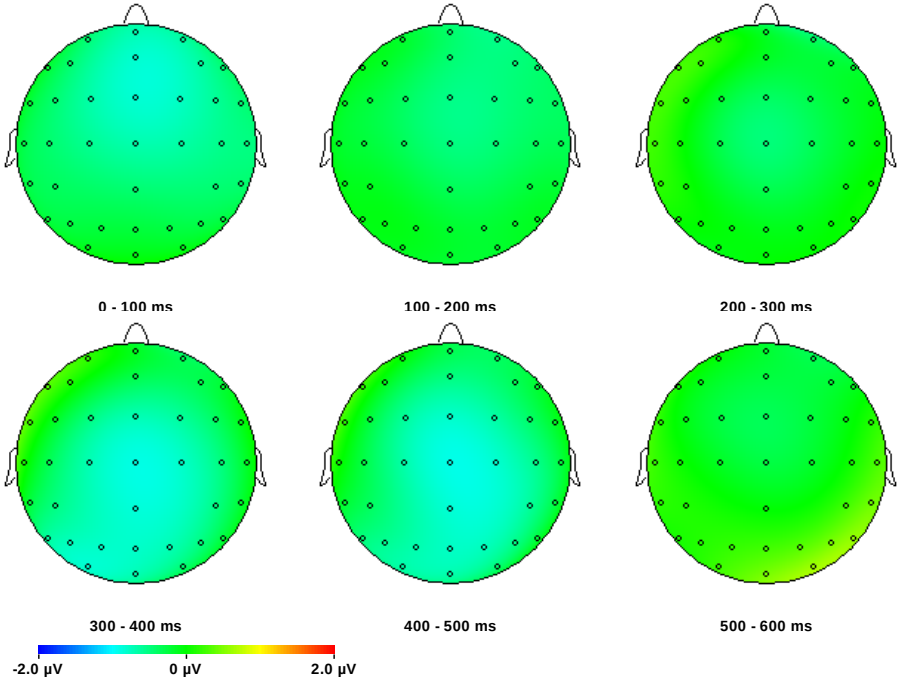


Compare conditions

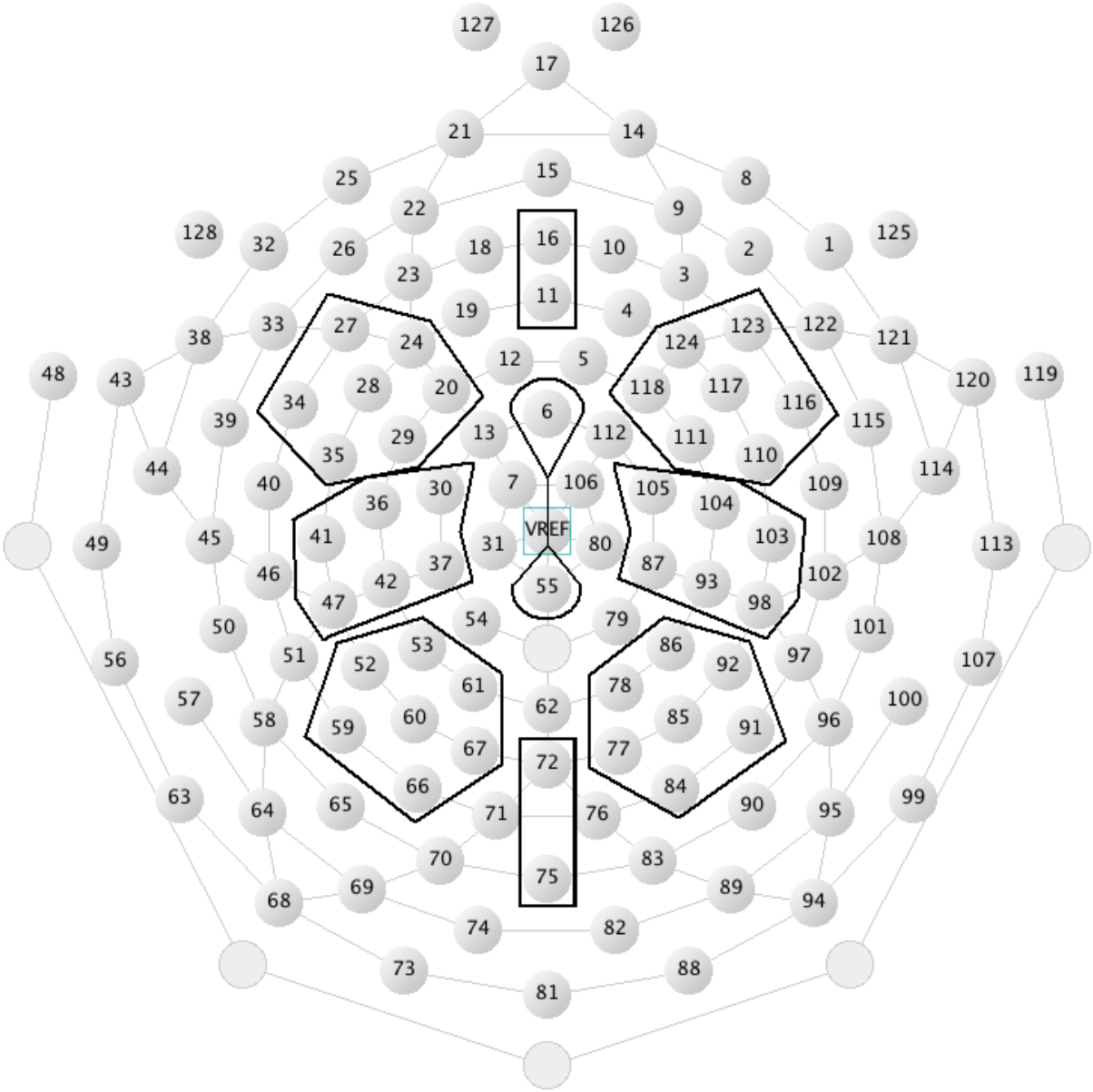


Statistics


0 - 100 ms
100 - 200 ms
200 - 300 ms
300 - 400 ms
400 - 500 ms
500 - 600 ms
-2.0 µV
0 µV
2.0 µV


0 - 100 ms
100 - 200 ms
200 - 300 ms
300 - 400 ms
400 - 500 ms
500 - 600 ms
-2.0 µV
0 µV
2.0 µV

- regions of interest (ROIs)
- time windows
- ANOVA



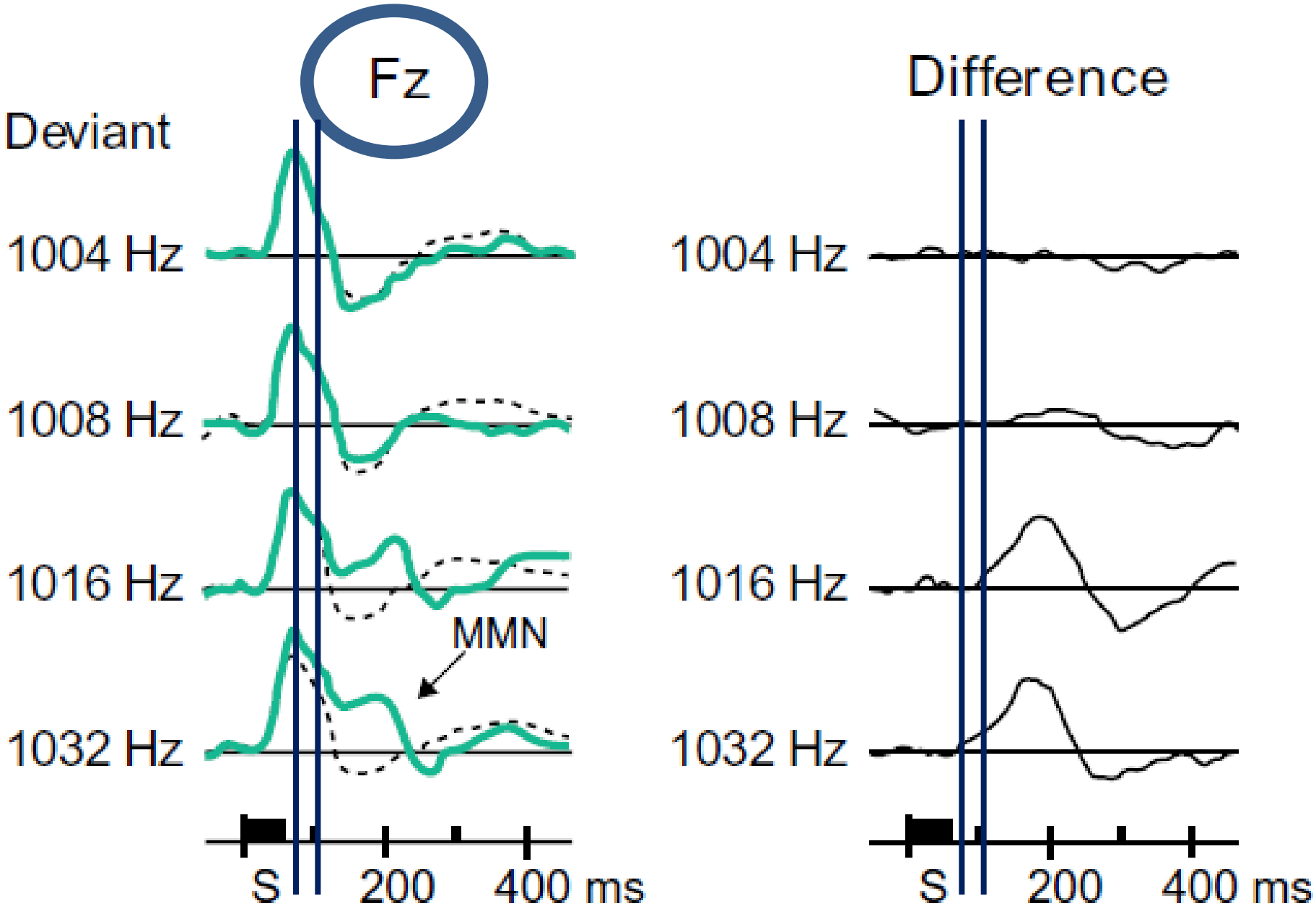
Undertanding spoken language

- Phonology:
  MMN, P3
- Meaning (words, sentences, discourse):
  N400
- Syntax:
  (E)LAN, P600

Mismatch Negativity (MMN)

- Elicited by physically deviant (auditory) stimuli
- Independent of attention
- MMN increases with larger deviance
- Generated in (auditory) cortex
- Applications, e.g.,
  - Early diagnosis of hearing problems
  - Discrimination of speech sounds

MMN as a Function of Frequency Change



P3

- sensitive to target probability: P3 amplitude gets larger as target probability gets smaller

- P3 amplitude is larger when subjects devote more effort to a task

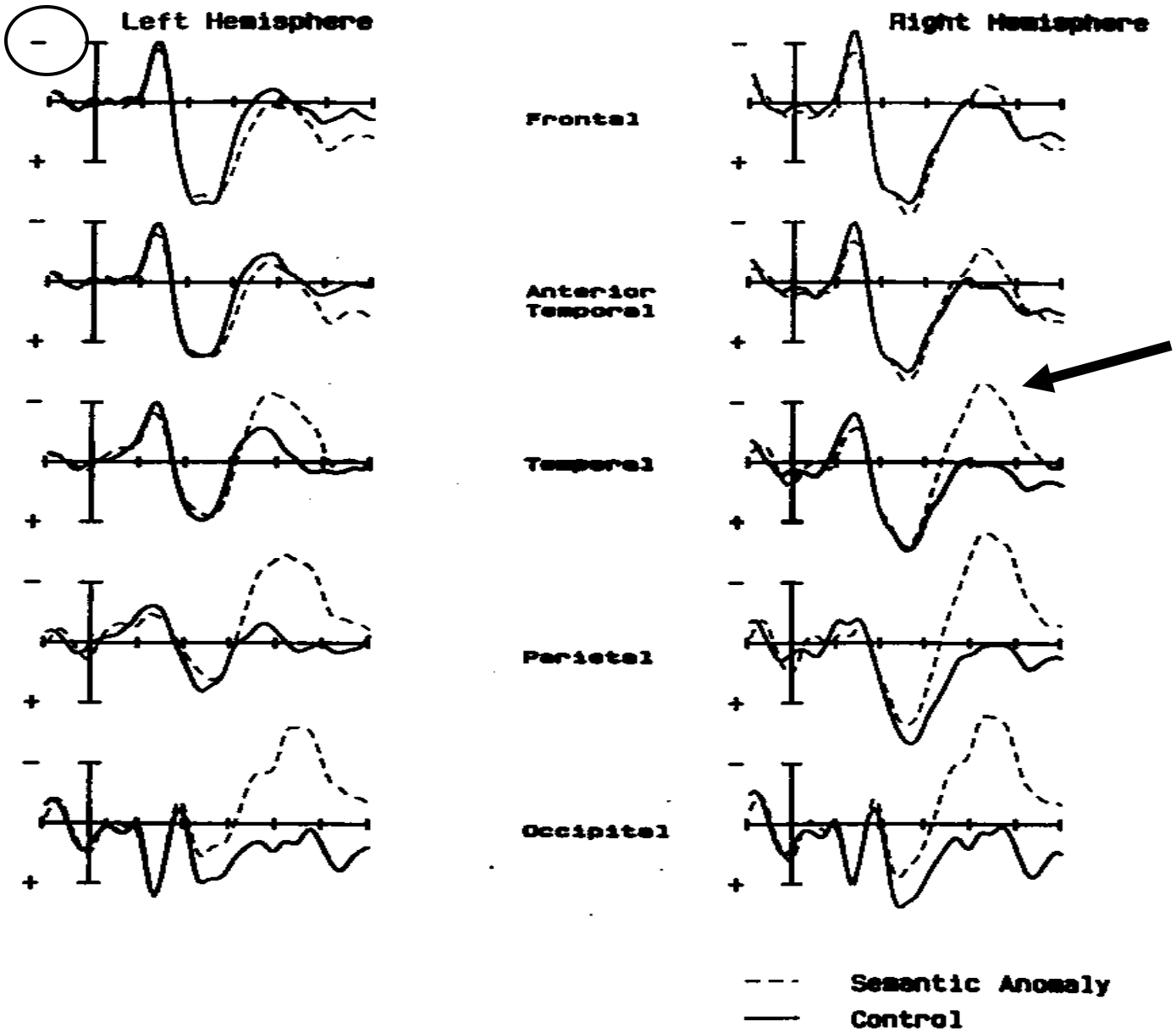
Neville et al., 1991

- semantic contrast:

The scientist criticized Max's ***argument***

* The scientist criticized Max's ***headache***

Semantic Anomaly

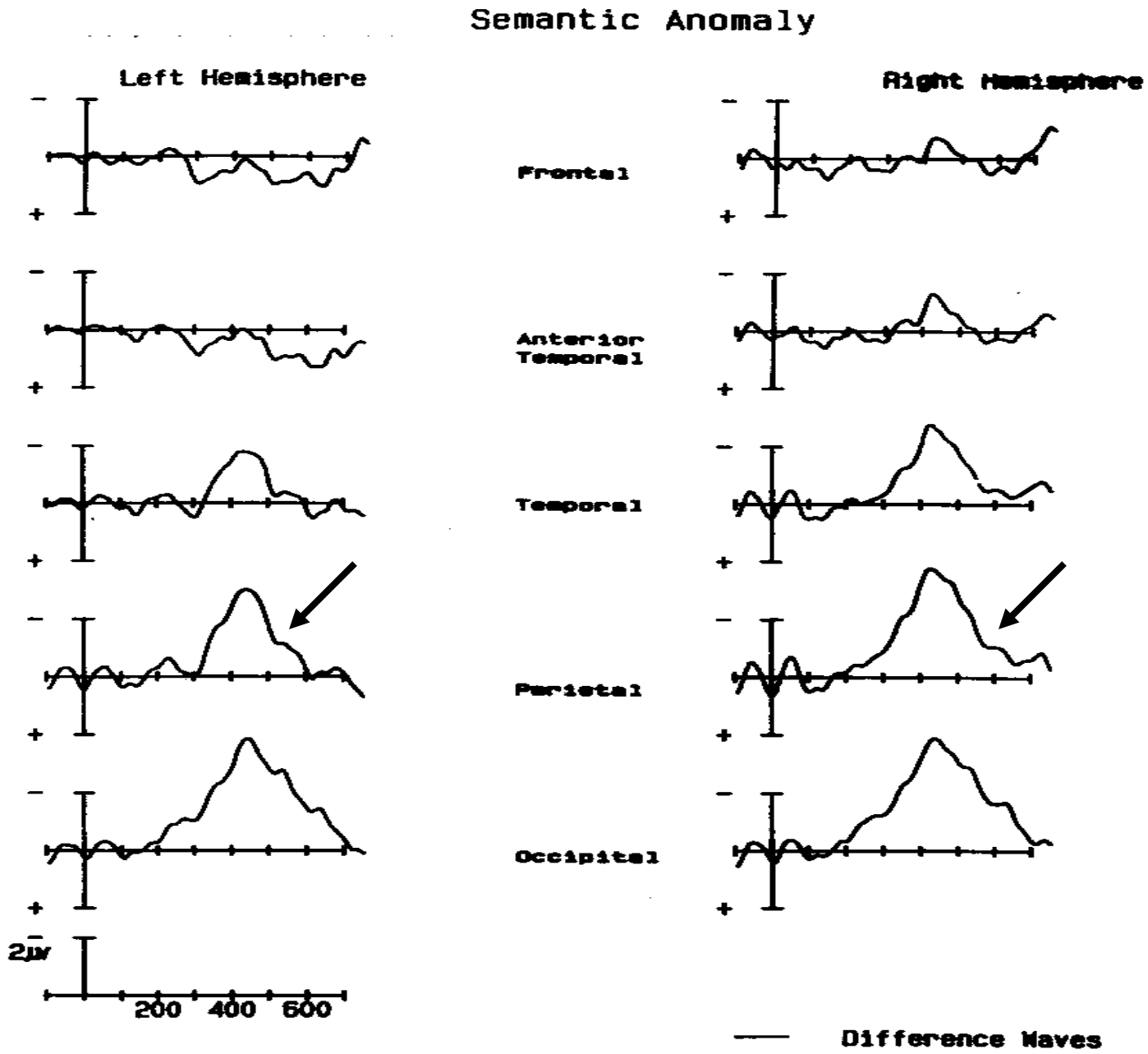


Scalp distribution

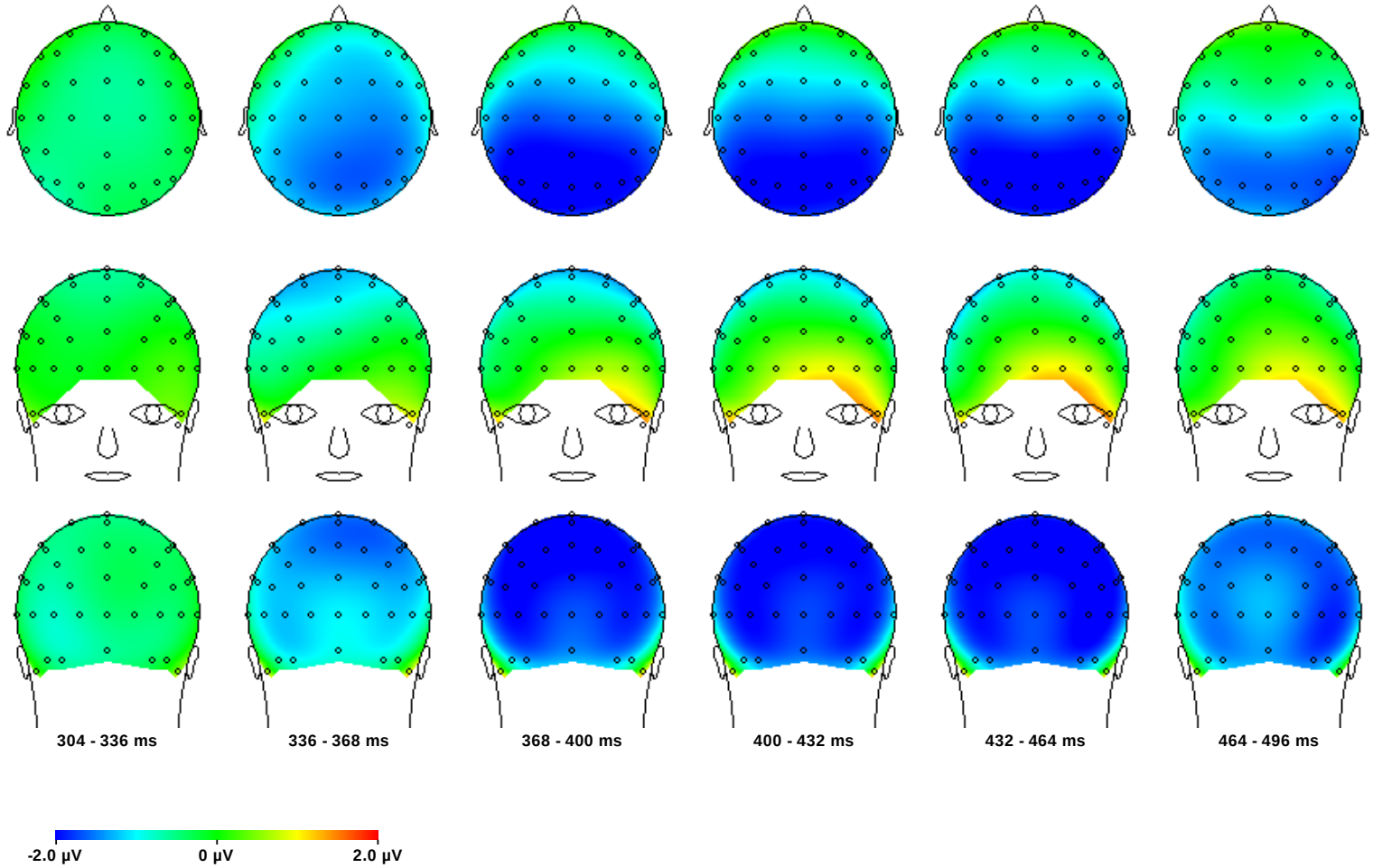
- Can be clearer with difference waves

Difference waves

- Need to know what the original wave form looked like and/or direction of comparison
- Usually hard – easy
  - if hard is more negative, diff = neg (4 – 9)
  - If hard is more positive, diff = pos (9 – 4)


Semantic Anomaly
Left Hemisphere
Right Hemisphere
Frontal
Anterior Temporal
Temporal
Parietal
Occipital
2µV
200
400
600
Difference Waves

Pictures are clearer



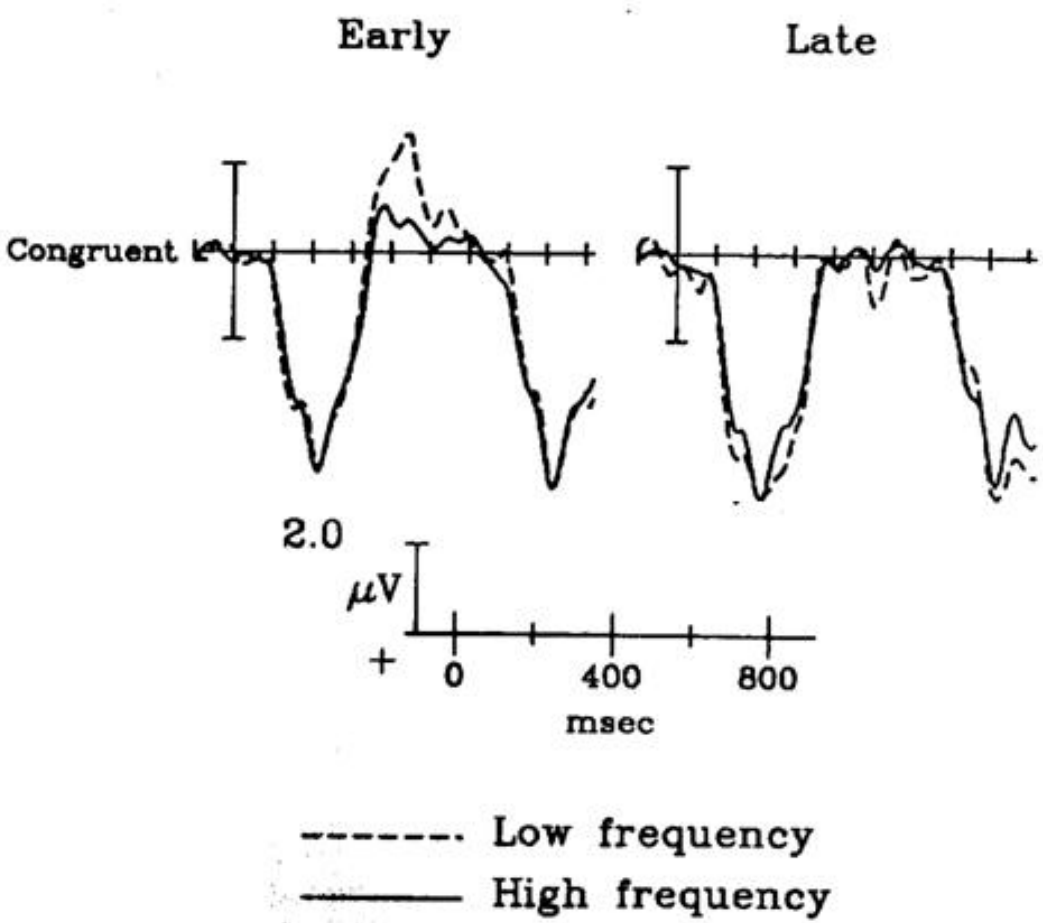
Semantic Processing

- Associated with the N400
  - ***Negative*** deflection of the waveform
  - ***Maximal*** at 400 msec after presentation of word

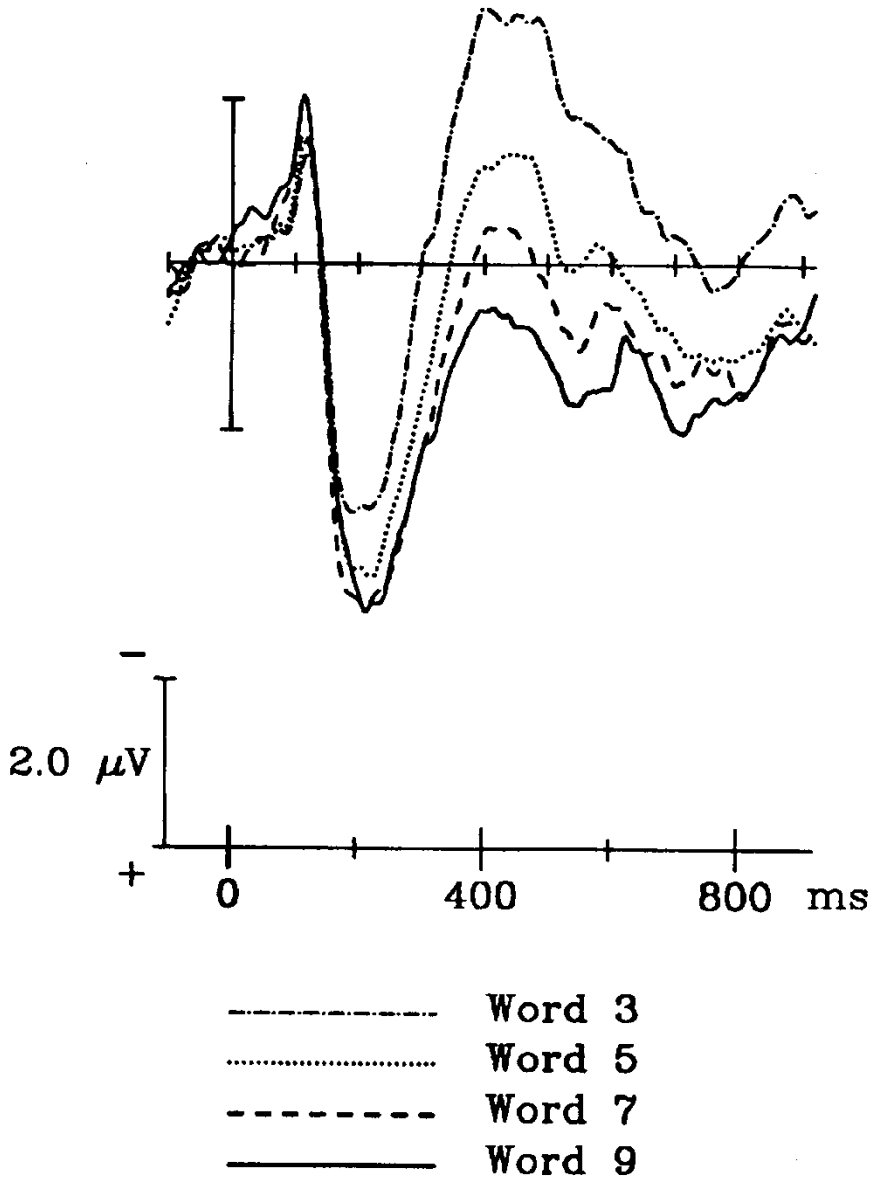
N400 factors:

- word frequency effect
- position in the sentence
- influence of discourse-level context

Frequency


Early
Late
Congruent
2.0
μV
+
0
400
800
msec
Low frequency
High frequency

Position in the sentence



Discourse-level context

van Berkum et al. (1999)

Zoals afgesproken zou Jane om vijf uur ‘s ochtends haar zus en haar broertje wakker maken. Maar de zus had zich al gewassen, en het broertje had zich reeds aangekleed.

Как договорились, Джейн должна была разбудить своих сестру и брата в пять часов утра. Но ее сестра уже умылась, а брат даже оделся.

Jane vertelde het broertje dat hij bijzonder **vlot** / * **traag** was.

Джейн сказала своему брату, что тот был особенно ***быстрым*** / * ***медленным***.

Common Errors

- Words that do not fit elicit an N400 component

Components or *Effects?*

- Both words are relatively negative:

→ N400 component

- They differ in amplitude

→N400 effect

→Not all effects coincide with a component because

→What we see as components may reflect more covert components

Neville et al., 1991

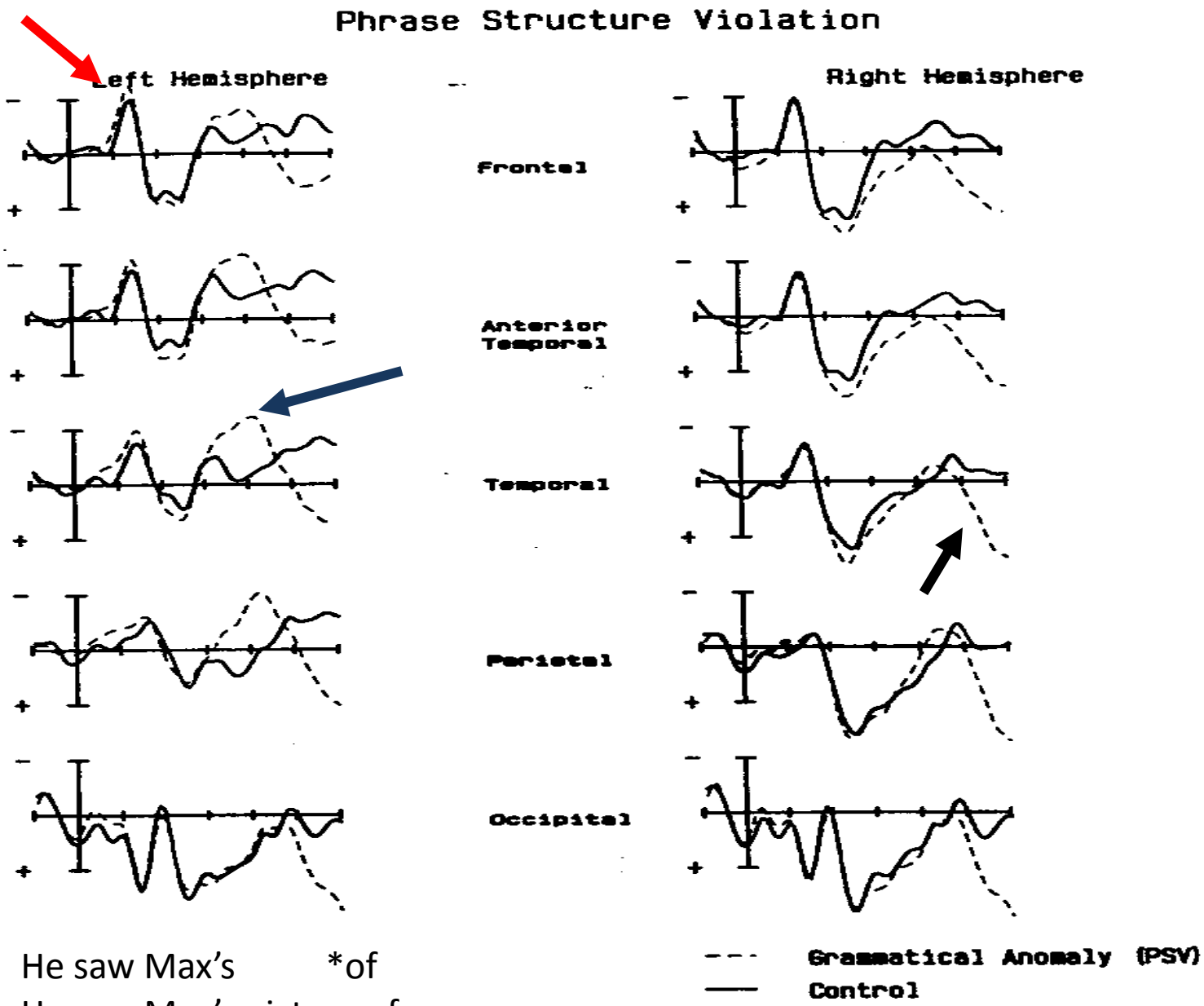
- syntactic processing

The scientist criticized Max's

- ***proof of*** → grammatical
- ***of*** → ungrammatical

Grammatical effects

- ELAN: early left anterior negativity c. 159 msec after presentation
- LAN: left anterior negativity c. 300-500 msec after presentation
- P600: posterior positivity c. 600 msec after presentation



He saw Max's *of

He saw Max's picture of

Semantic vs. Syntactic Effects

Semantics

- N400 (400 msec)

Syntax

- ELAN (150 msec)
- LAN (400 msec)
- P600 (600 msec)

Semantic vs. Syntactic Effects

Semantics

- N400 (400 msec)

Syntax

- ELAN (150 msec)
- LAN (400 msec)
- P600 (600 msec)

Semantics

- negativity
- peak 400
- right/central parietal

- Semantic mismatch and syntactic mismatch elicit different responses within the brain

Syntax

- negativity 2
- peak 400
- left

- Therefore they are two distinct sorts of information which are processed separately

Conclusion

- Semantic processing difficulties appear to produce different effects than syntactic processing difficulties

- Suggests that syntax is normally processed quickly and automatically (< 299 msec)

BUT see Steinhauer & Drury (2011)

Inverse problem
Scalp Distribution and Source

- Some effect is biggest over the right parietal & occipital electrodes

- Does that mean that it was generated there?

Forward calculations

- Given the source and the volume conductor
- Compute potential distribution
  UNIQUE SOLUTION
- Can be used to confirm hypothesized source(s)

Backward calculations

- Given the potential distribution

- Compute the active sources

  NON-UNIQUE SOLUTIONS

Dependent on model of the head and sources

Basic assumptions for dipole modeling

- Model of the head
  - conductivity of tissues
  - realistically shaped head or spherical approximation?
- Model of the source
  - equivalent current dipole
  - number of dipoles
  - distributed sources
  - relative timing of dipoles as well

Conclusion

- Localization not good, too many assumptions necessary

- But, ***if scalp distribution differs***, the effect is not generated by the same source or set of sources (at least one is different)

Using Scalp Distribution to Distinguish Functions

- If scalp distribution differs, the effect is not generated by the same source
- Possibly by the same set of sources but if so one differs greatly in intensity

Experiments on Russian - 1

a) Хирург вправил **сустав** футболисту.

b) * Хирург вправил **фонтан** футболисту.

c) Смотритель выключил **фонтан** у дворца.

d) * Смотритель выключил **сустав** у дворца.

Experiments on Russian – 2

a) Пенсионерка пользуется **плитой** во дворе.

b) * Пенсионерка пользуется **плиту** во дворе.

c) Кухарка чистит **плиту** от налёта.

d) * Кухарка чистит **плитой** от налёта.

Experiments on Russian – 3

a) Покупатель умоляет **доставить** товар в срок.

b) * Покупатель умоляет **доставку** товар в срок.

c) Курьер осуществляет **доставку** в течение дня.

d) * Курьер осуществляет **доставить** в течение дня.

Experiments on Russian –4

a) Завязавши знакомство с миловидной особой, **юрист** парил в облаках.

b) * Завязавши знакомство с миловидной особой, **дохляк** парил в облаках.

c) Круто замутив с отпадной герлой, **дохляк** смачно кайфовал.

d) * Круто замутив с отпадной герлой, **юрист** смачно кайфовал.

Thank you!