Micro-state analysis of EEG

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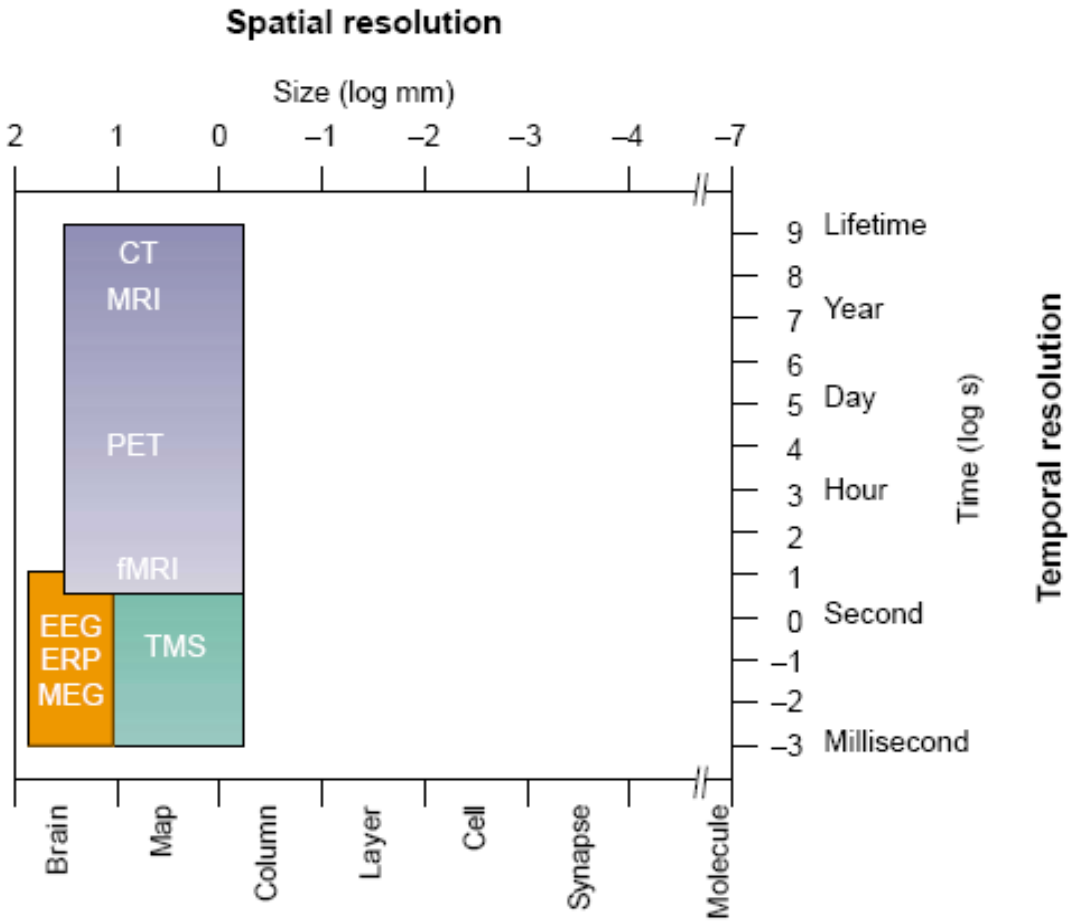
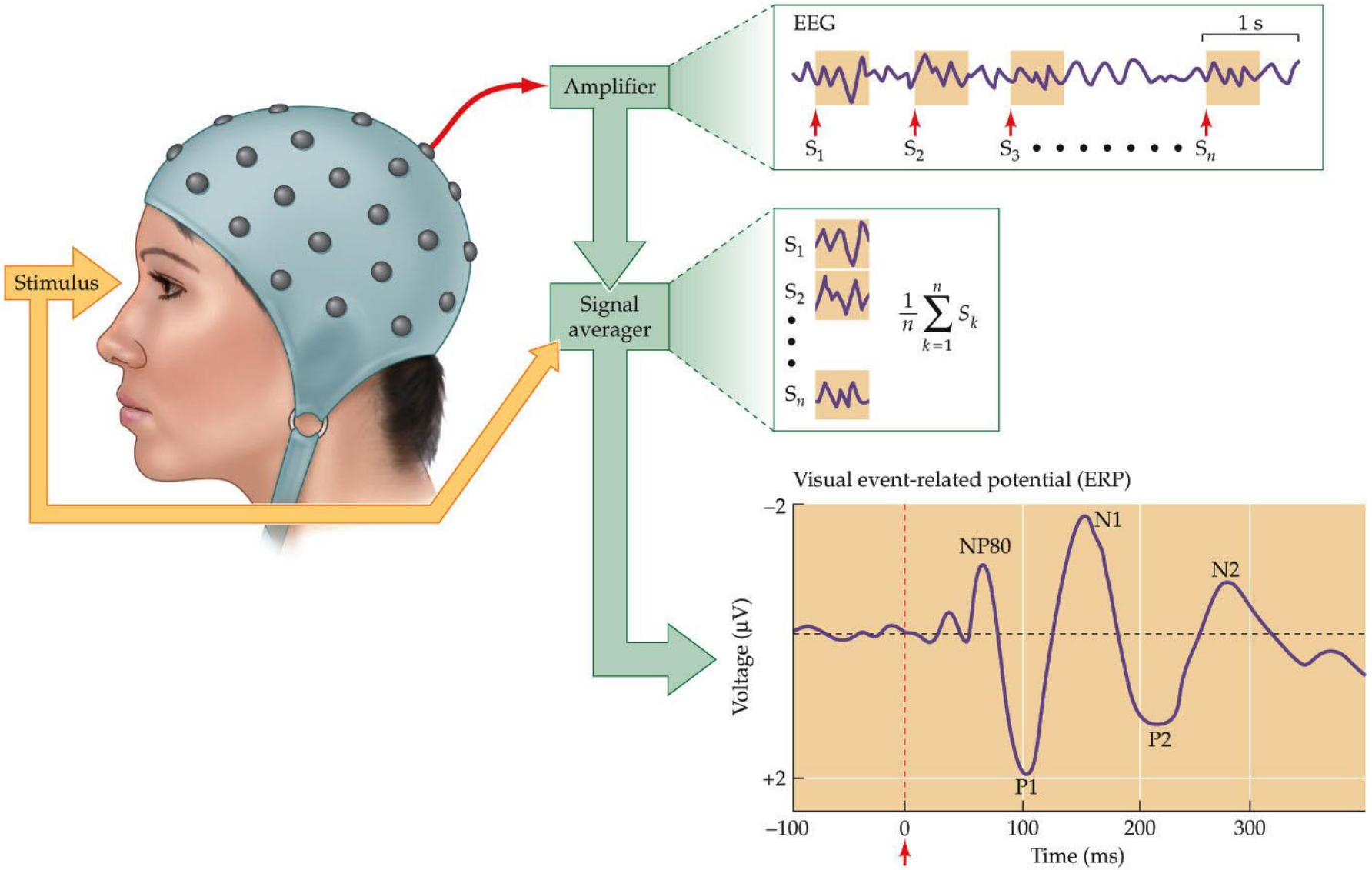
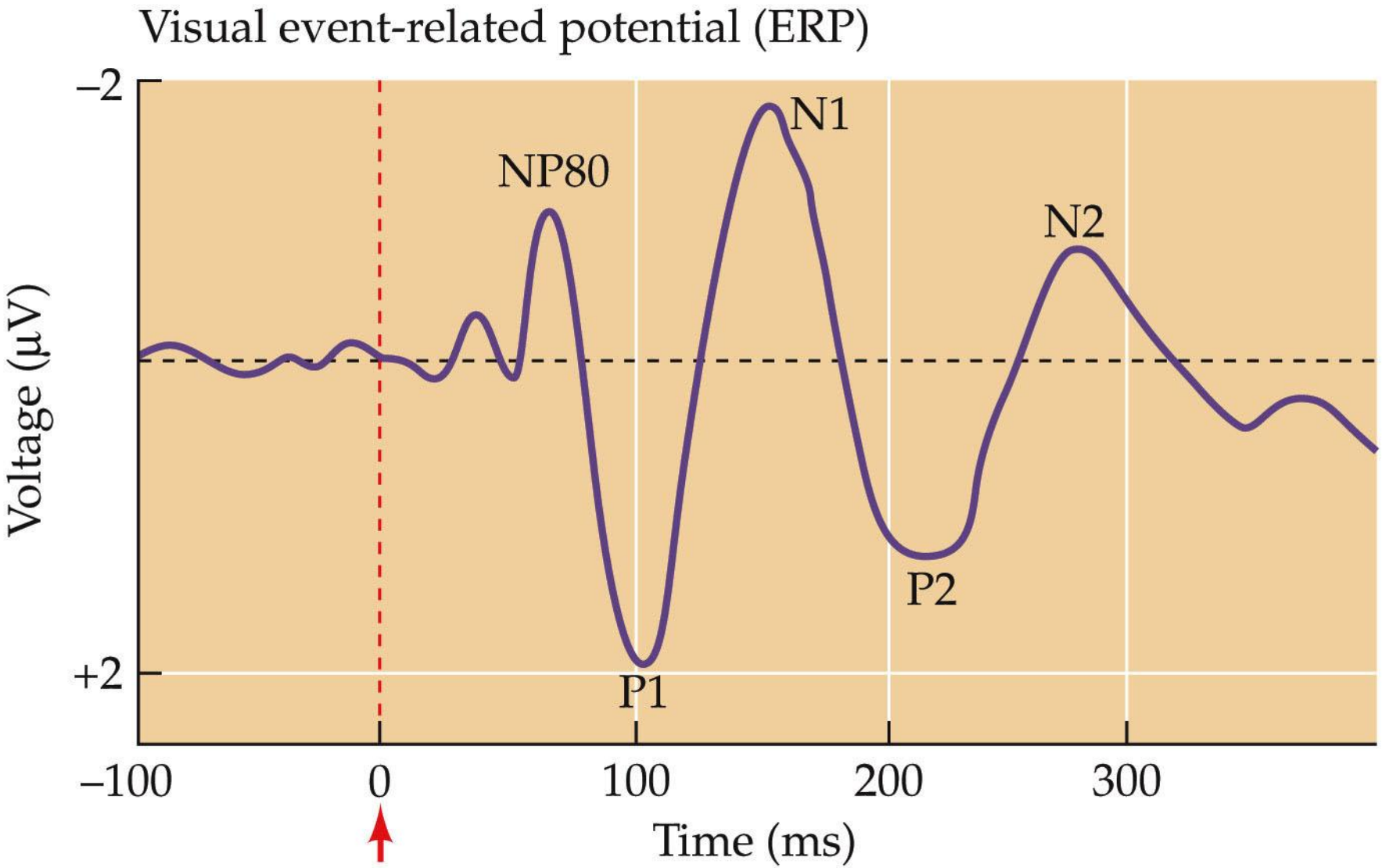


Stewart & Walsh, 2000

A shared opinion on EEG/ERP: excellent temporal resolution (ms time-scale) but poor spatial resolution (scalp recording and inverse solution problem)

ERP = Event Related Potential




Visual event-related potential (ERP)
–2
+2
Voltage (μV)
NP80
N1
N2
P1
P2
–100
0
100
200
300
Time (ms)

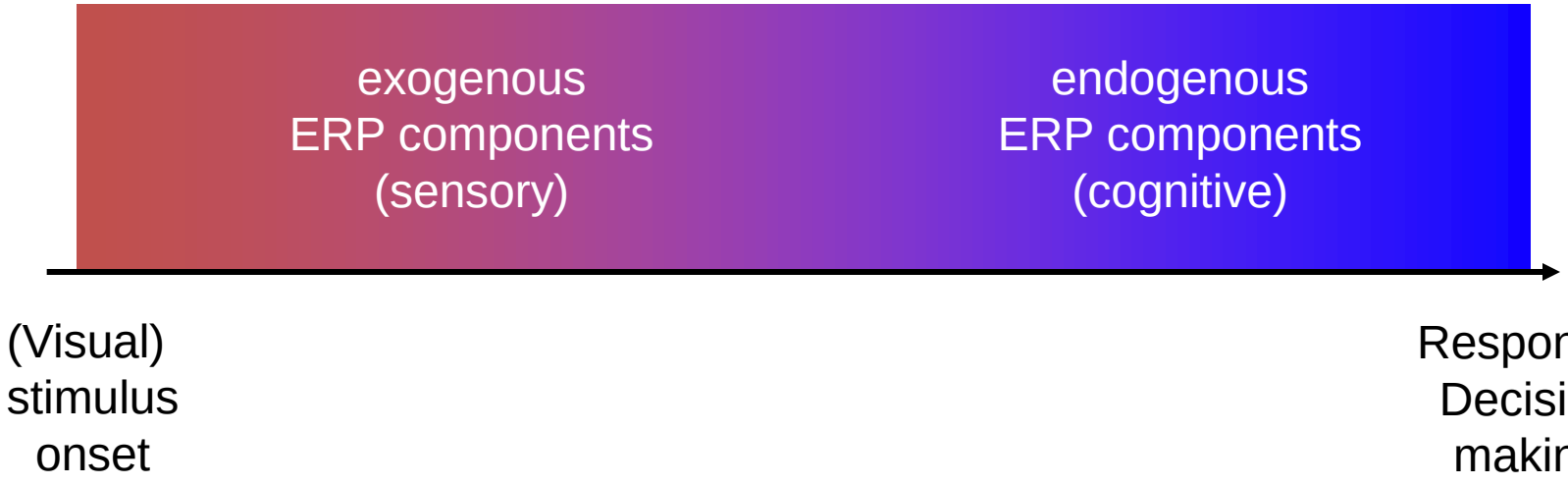
What is a peak?

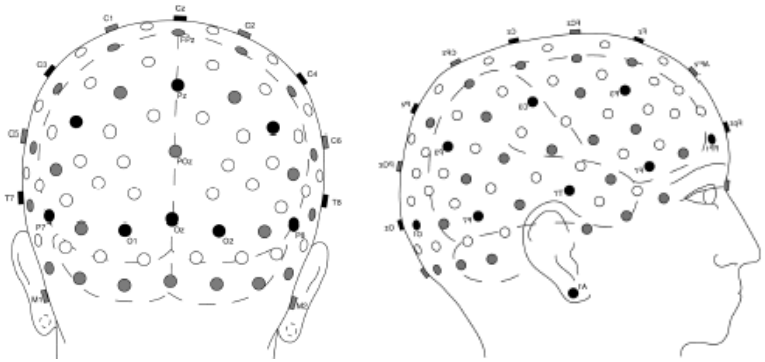
‘‘The simplest approach is to consider the ERP waveform as a set of waves, to pick the peaks (and troughs) of these waves, and to measure the amplitude and latency at these deflections.’’

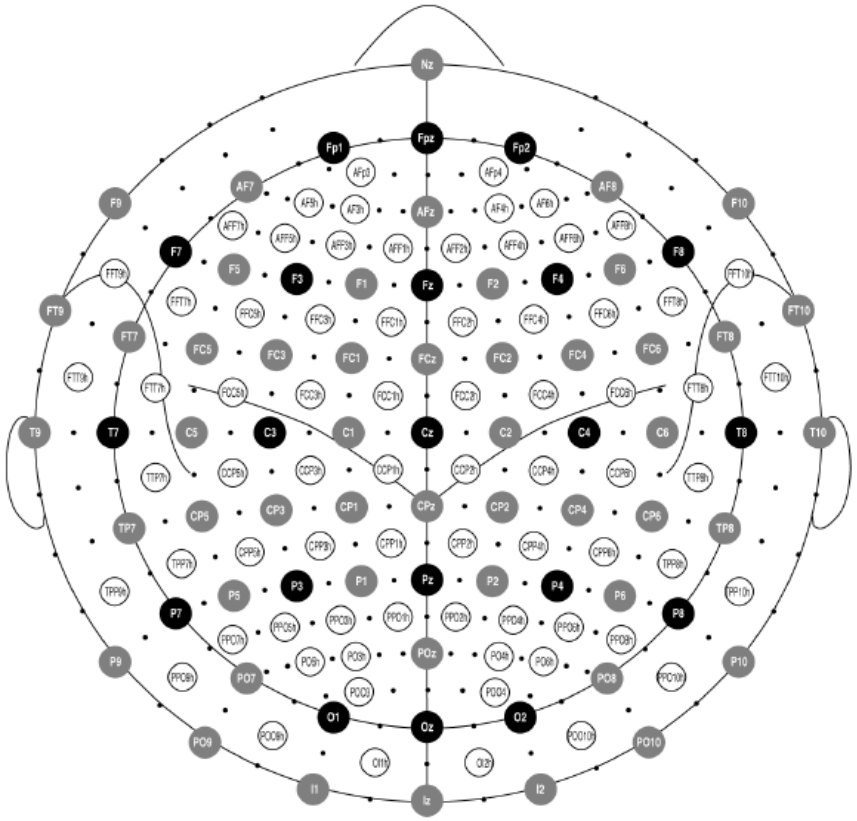
Picton et al., 2000, p.141

Caveat

……C1……P1/N1……..N2……P3……







10-20 EEG system (Jasper, 1958, 20 electrodes)…….up to 128 electrodes (high density ERP mapping)

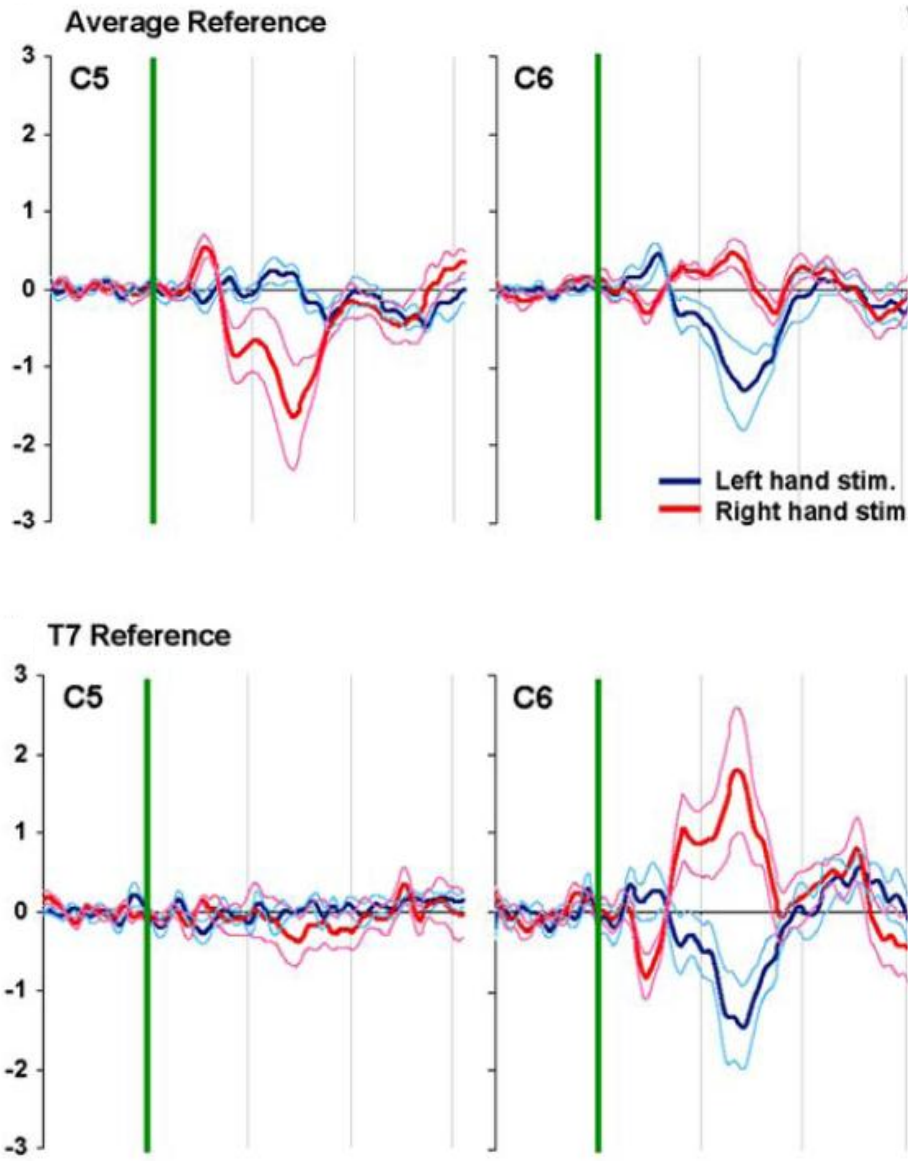
When peaks hurt...

- What does an ERP (peak) actually mean?
  (synchronization, time and phase-locking but…)

- What about inter-peaks electric activity (meaningless)? Really true that only high amplitude (peak) is worth investigating?
- EEG is oscillatory in nature: maxima/peaks alone mean little.
- Worse: what about the landscape? (cf. tree and forest)
- Drawback/problem: reference! ERPs (amplitude) are strongly dependent on the reference!

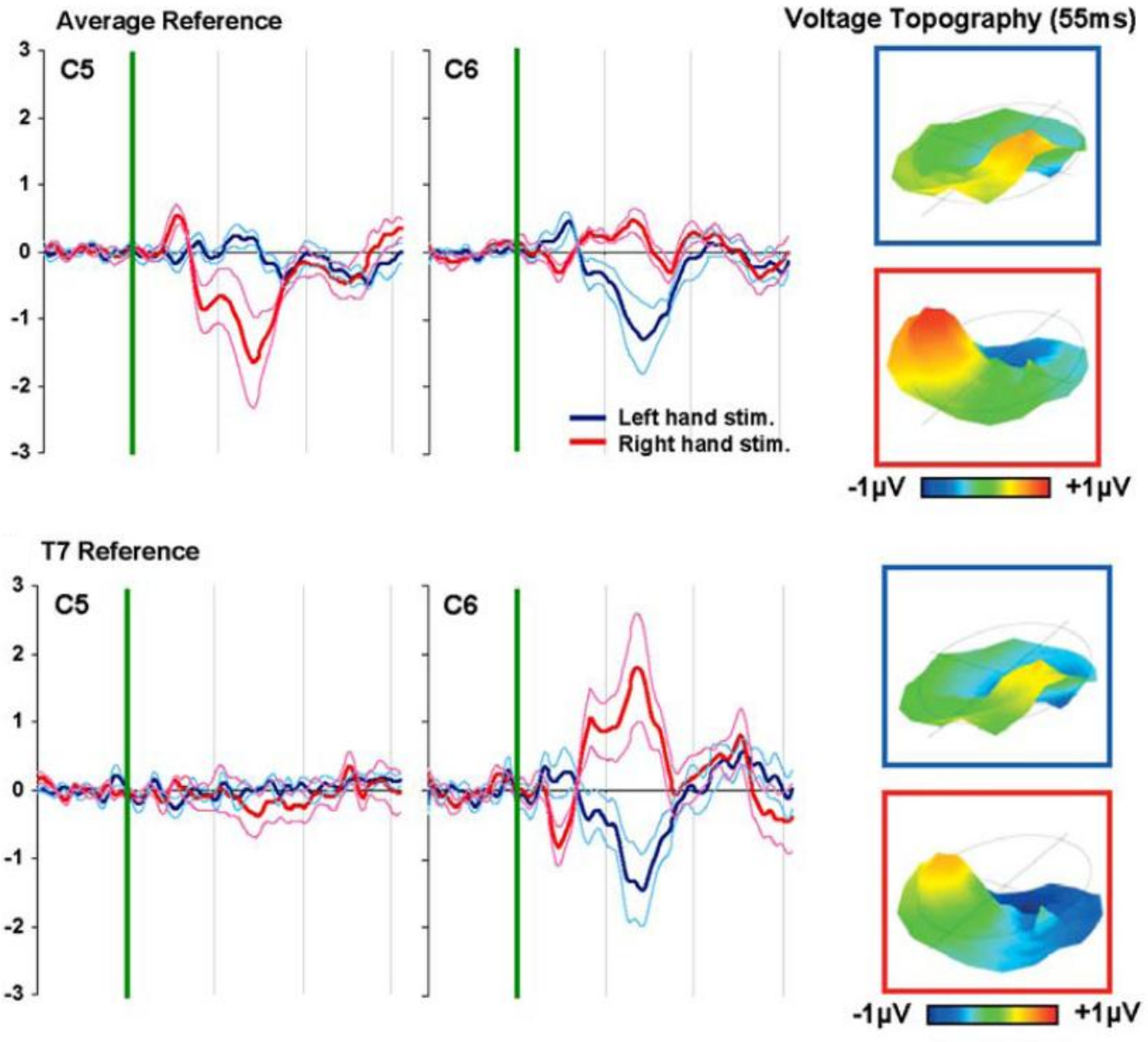
- Wish: to analyze ERP data with less priors (and more power). Time (time-frames) and spatial (electrode positions) domains. + to get rid of the reference problem.

Topography enables a reference free measure!



Murray et al., 2008

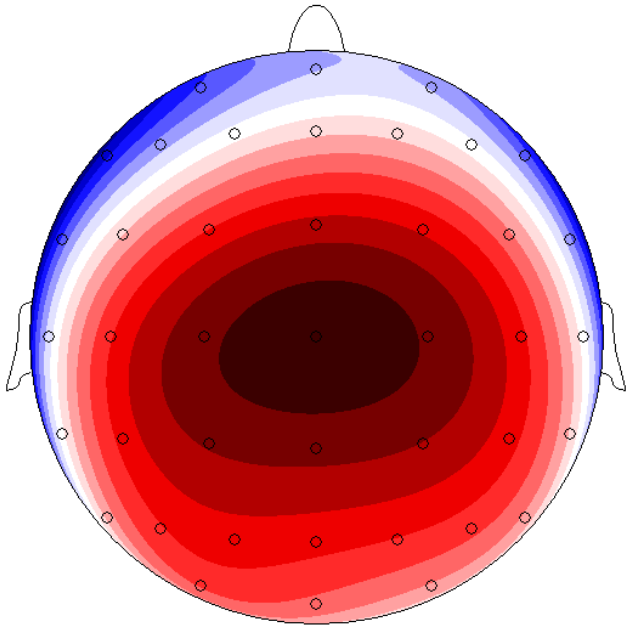
Topography enables a reference free measure!



Murray et al., 2008

Topography matters!

Condition 1



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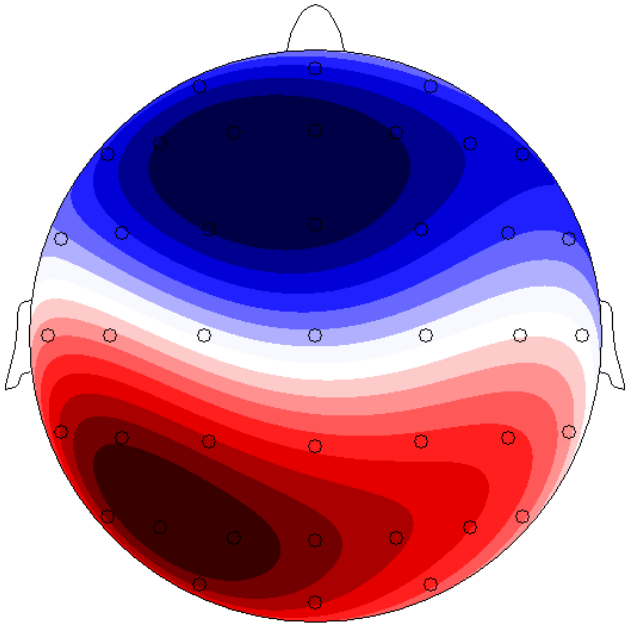
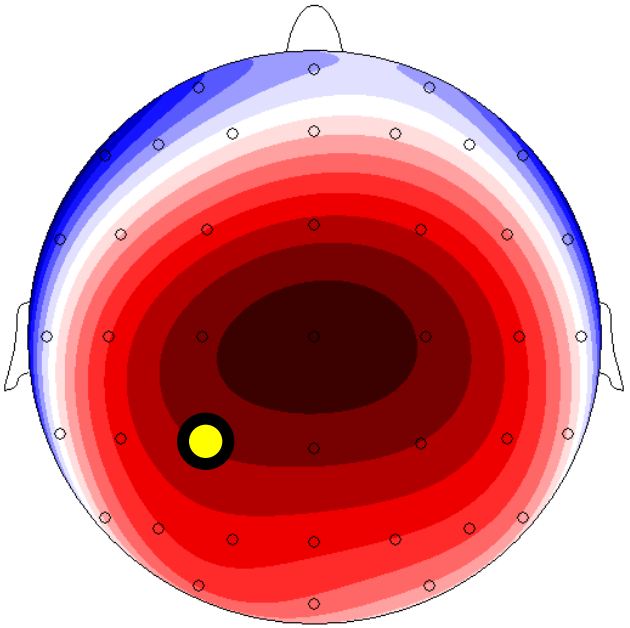
Condition 2



Topography matters!

Condition 1



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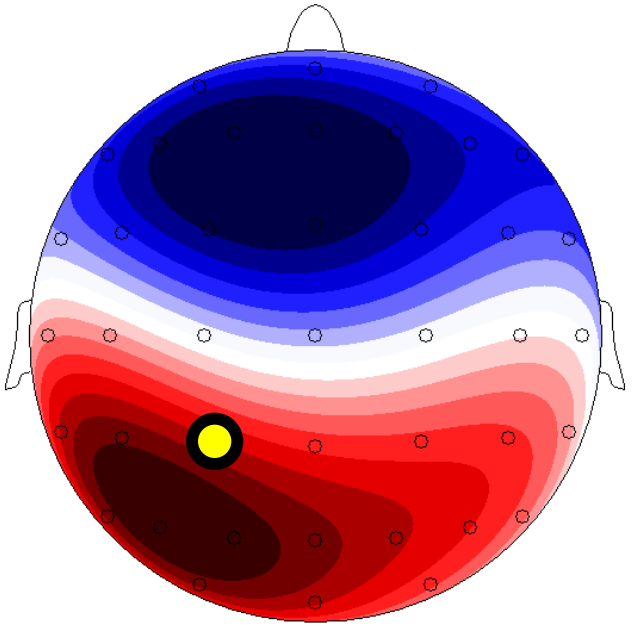
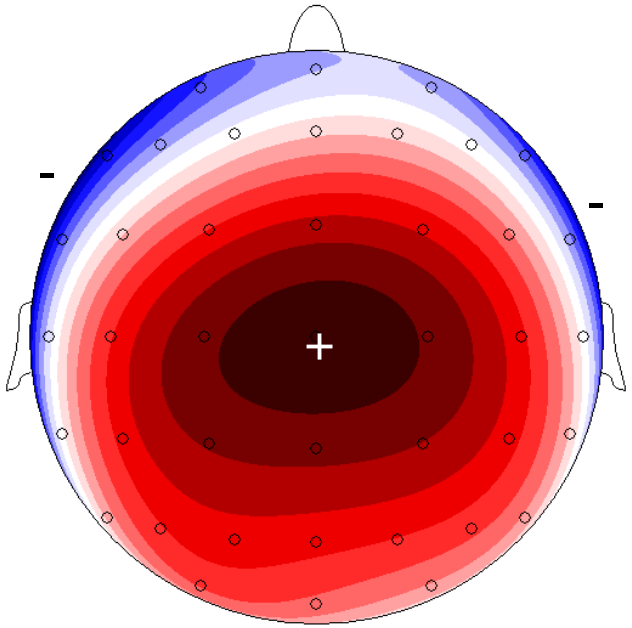
Condition 2



Read methods section (“acquisition: 32 or 64 channels; analyses: 1 or 2 channels”)
For this channel: same effect! At best a significant amplitude difference…
Tree hiding the forest…

Topography matters!

Condition 1



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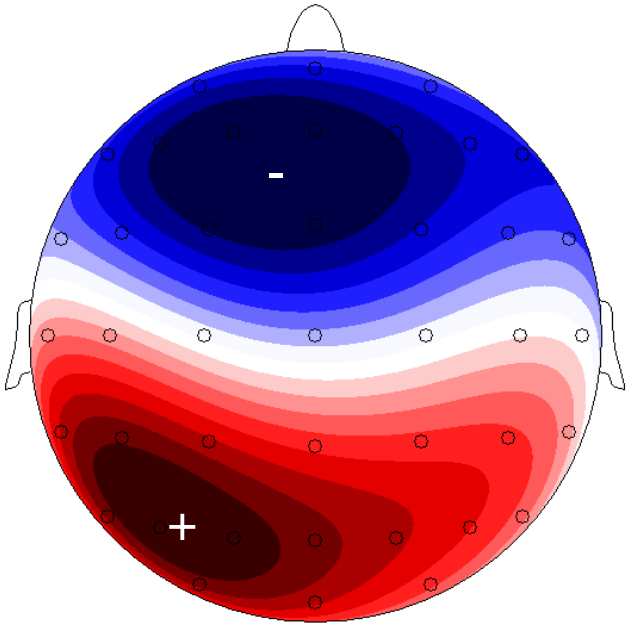
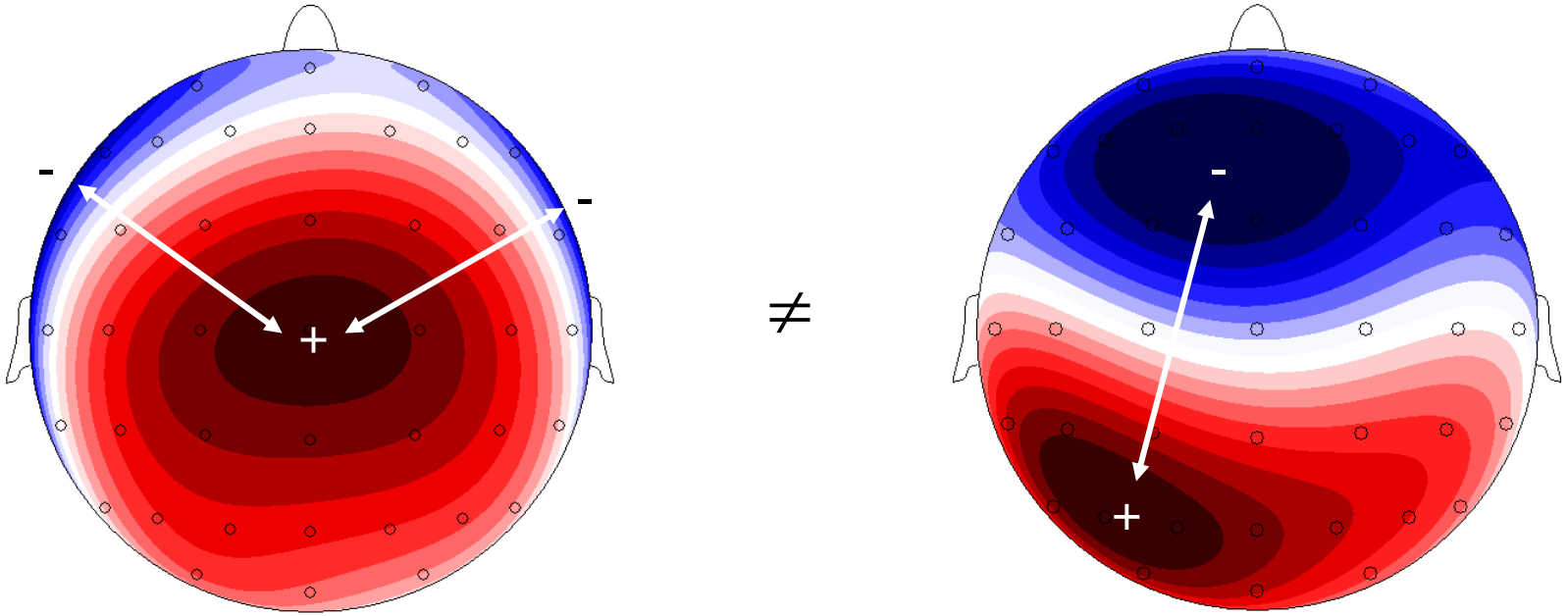
Condition 2



Topography matters!

Condition 1

Condition 2



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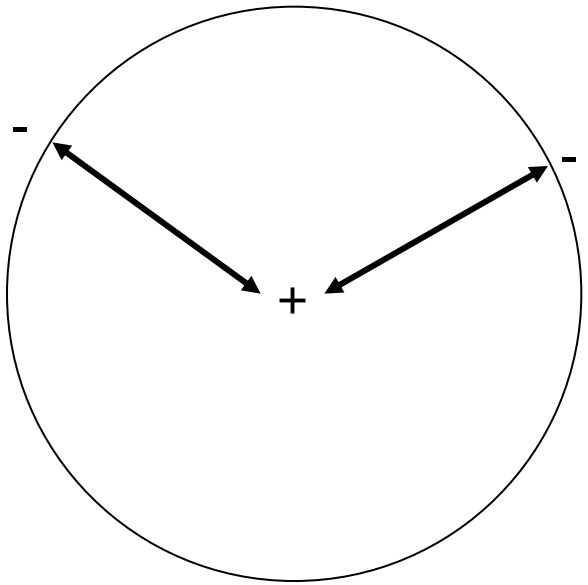

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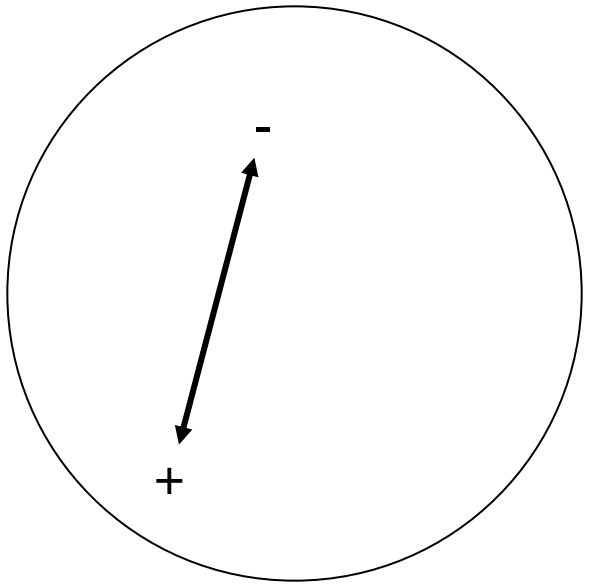
Condition 2



Key assumptions

(Lehmann & Skrandies, 1980)

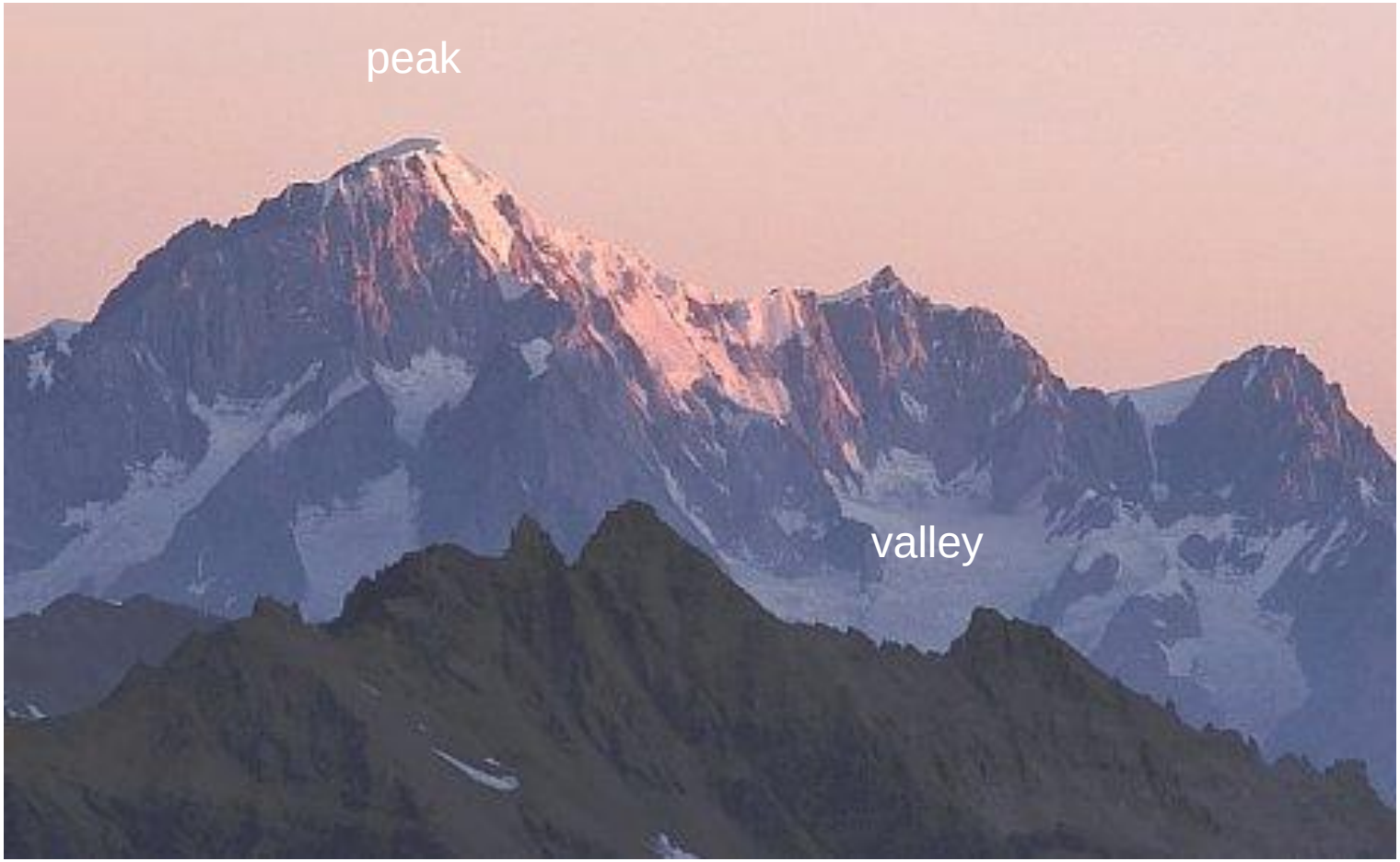
- If two topographic maps are different, one can be sure (demonstrated using maths) that the underlying configuration of intracranial generators is not the same (different brain networks involved!).

- However, the reverse assumption is not true. If the same topographic map is obtained in two conditions, it does not mean that the configuration of intracranial generators is the same (cf. 2 different networks leading to the same scalp map are feasible)!

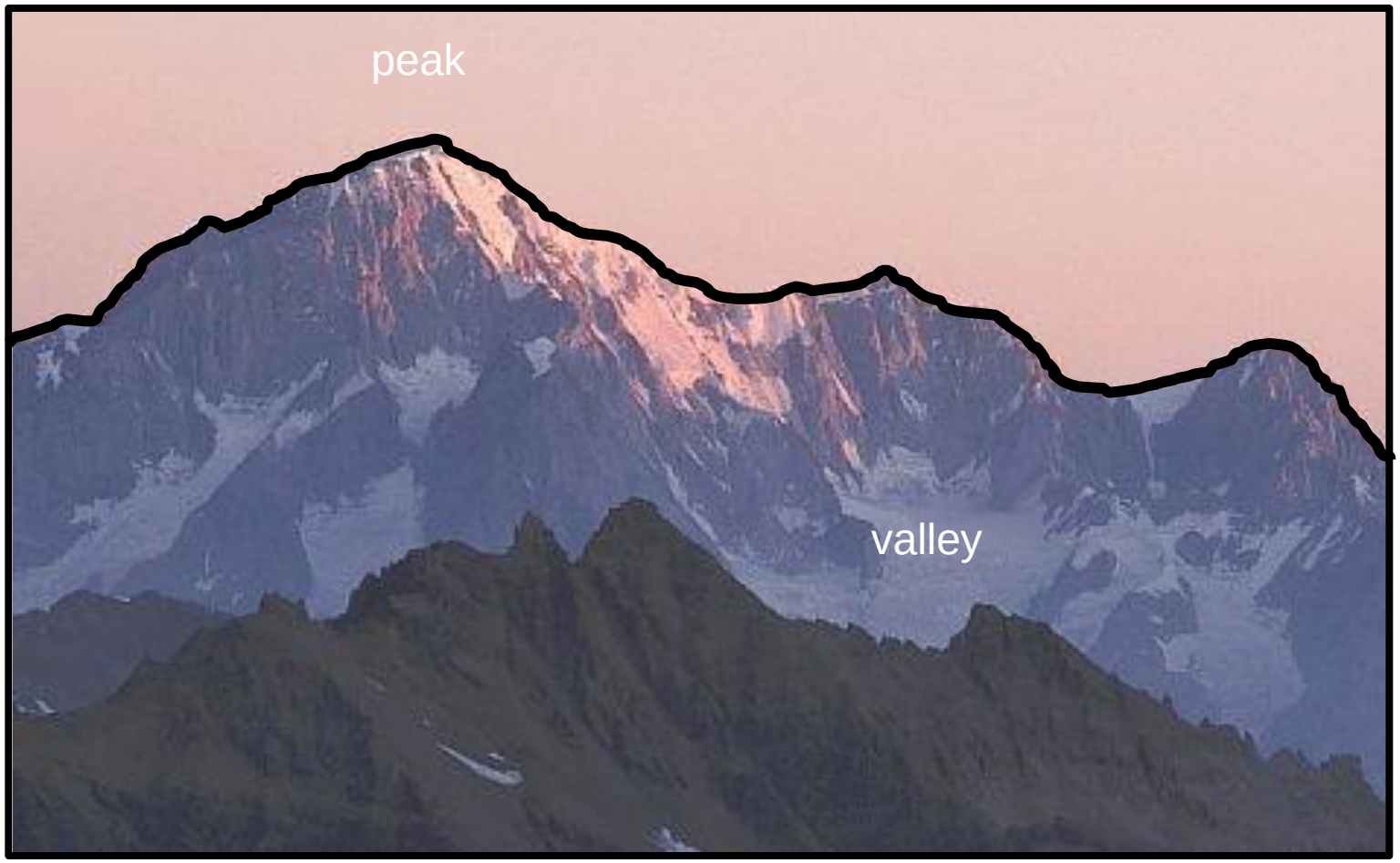
Conventional analysis

Conventional analysis

“Pattern” analysis



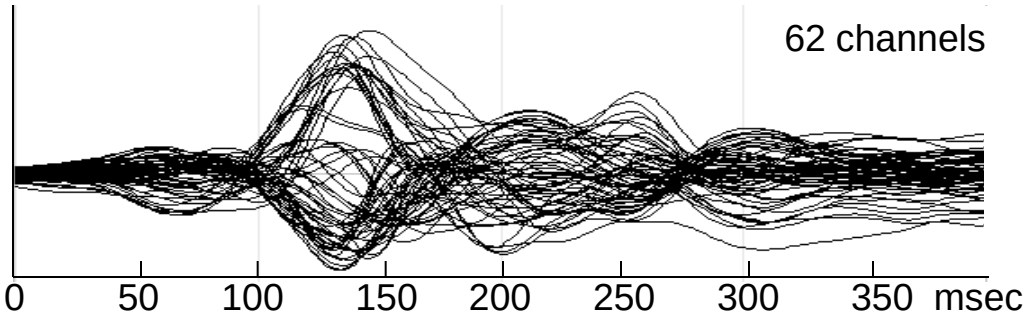
“Pattern” analysis

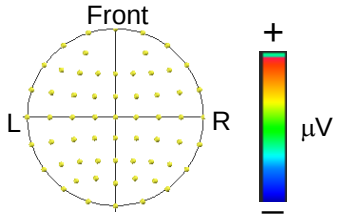


“Pattern” analysis

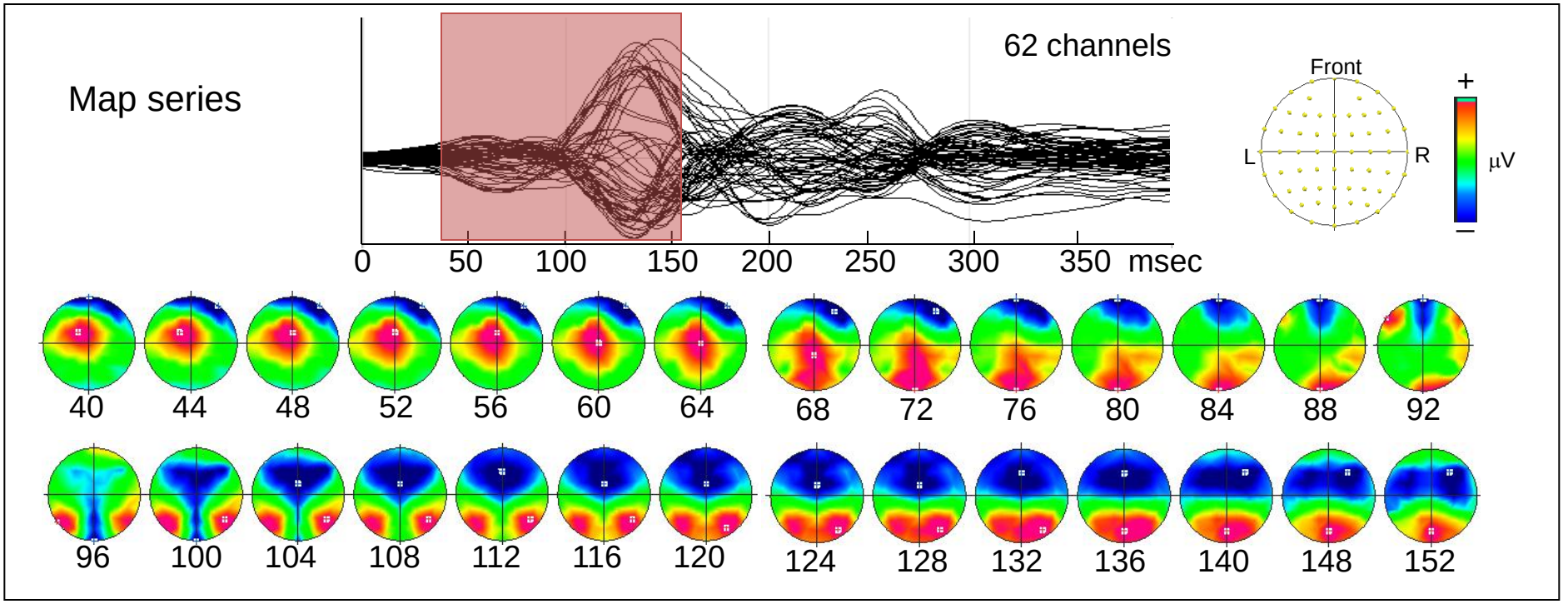
How to define/identify a topographic map?

Spatial cluster analysis *(Michel et al., 1999, 2001)*

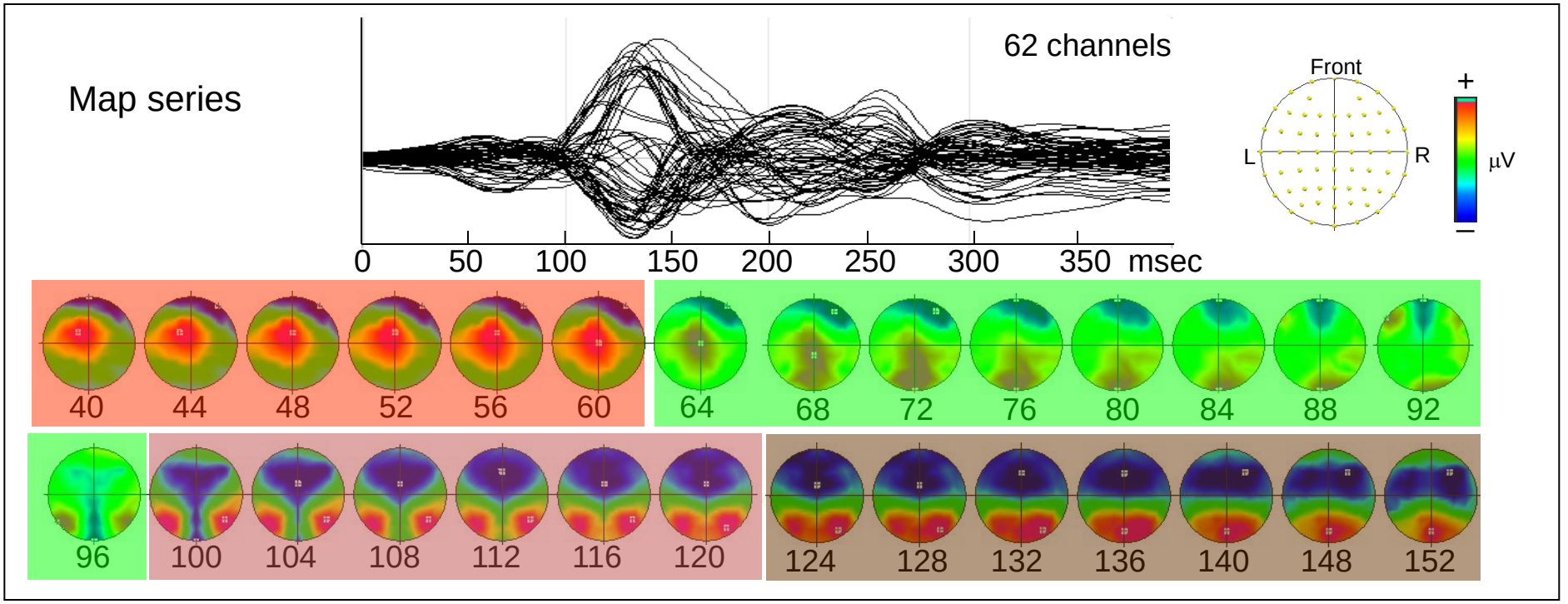




Spatial cluster analysis *(Michel et al., 1999, 2001)*

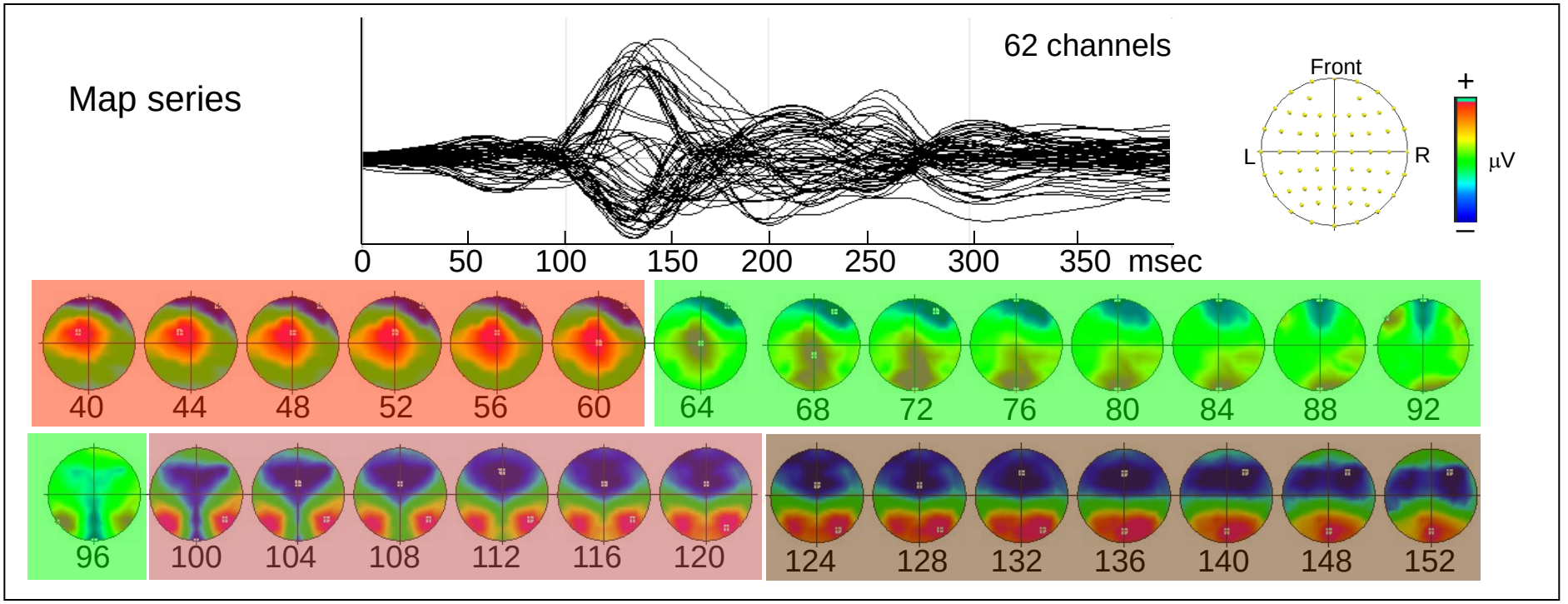


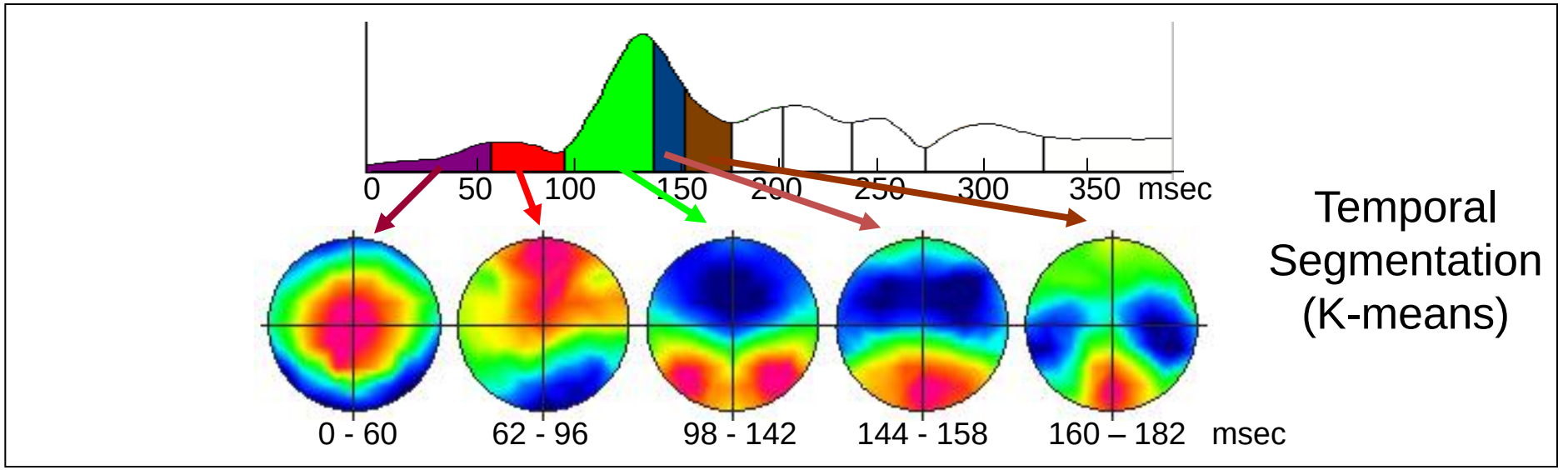
Spatial cluster analysis *(Michel et al., 1999, 2001)*



FUNCTIONAL MICROSTATES
(obtained regardless of local amplitude changes)

Spatial cluster analysis *(Michel et al., 1999, 2001)*





Spatial correlation (C)

$$C_{u,v} = \frac{\sum_{i=1}^{n} u_i \cdot v_i}{\|u\| \cdot \|v\|}$$

$$\|u\| = \sqrt{\sum_{i=1}^{n} u_i^2}, \|v\| = \sqrt{\sum_{i=1}^{n} v_i^2}$$

(C is equivalent to the Pearson coefficient)

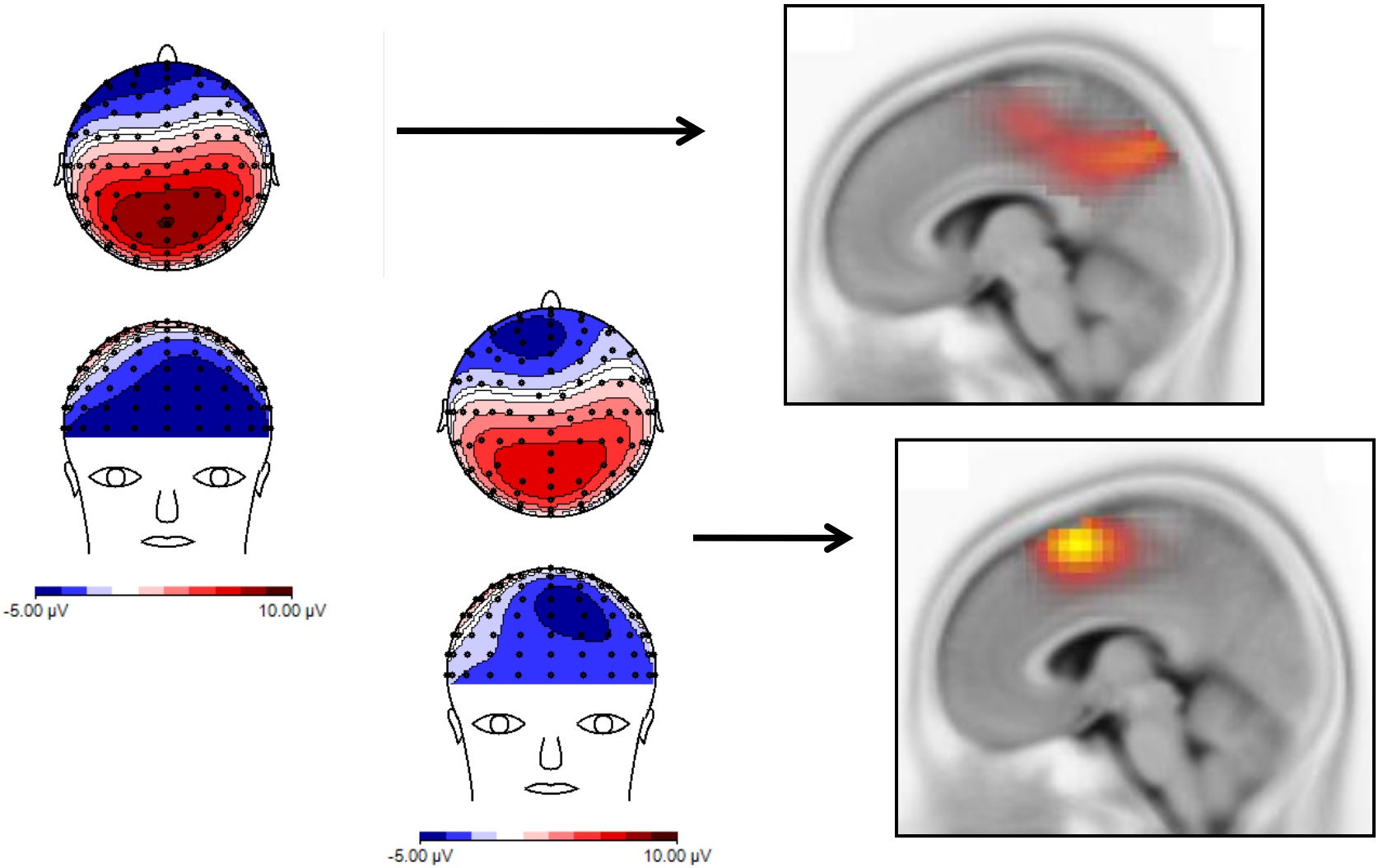
For each dominant map, one obtains then (after fitting) important indices not available with a peak analysis:

***Explained variance**
***Duration**
***Onset/Offset**
***Strength (GFP)**
***Best Correlation**

Use these indices to perform brain-behavior correlations!
Perform the tracking of a topographic map into raw (EEG) or epoched (ERP) data

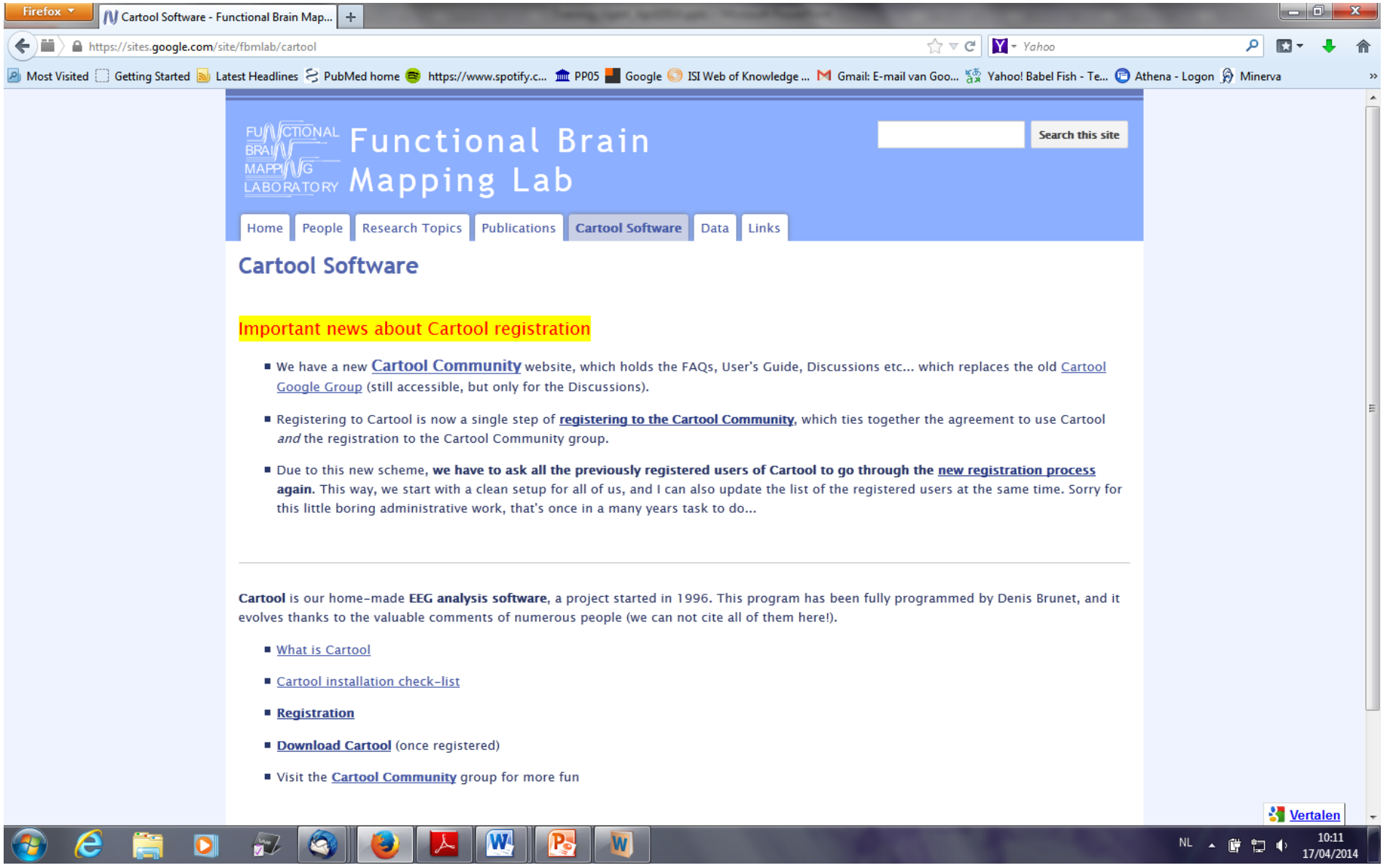
One of the advantages of topographic mapping over peak analysis:

Reduction of priors (time and space), and topographic maps can be used directly for Source Localization (inverse problem).



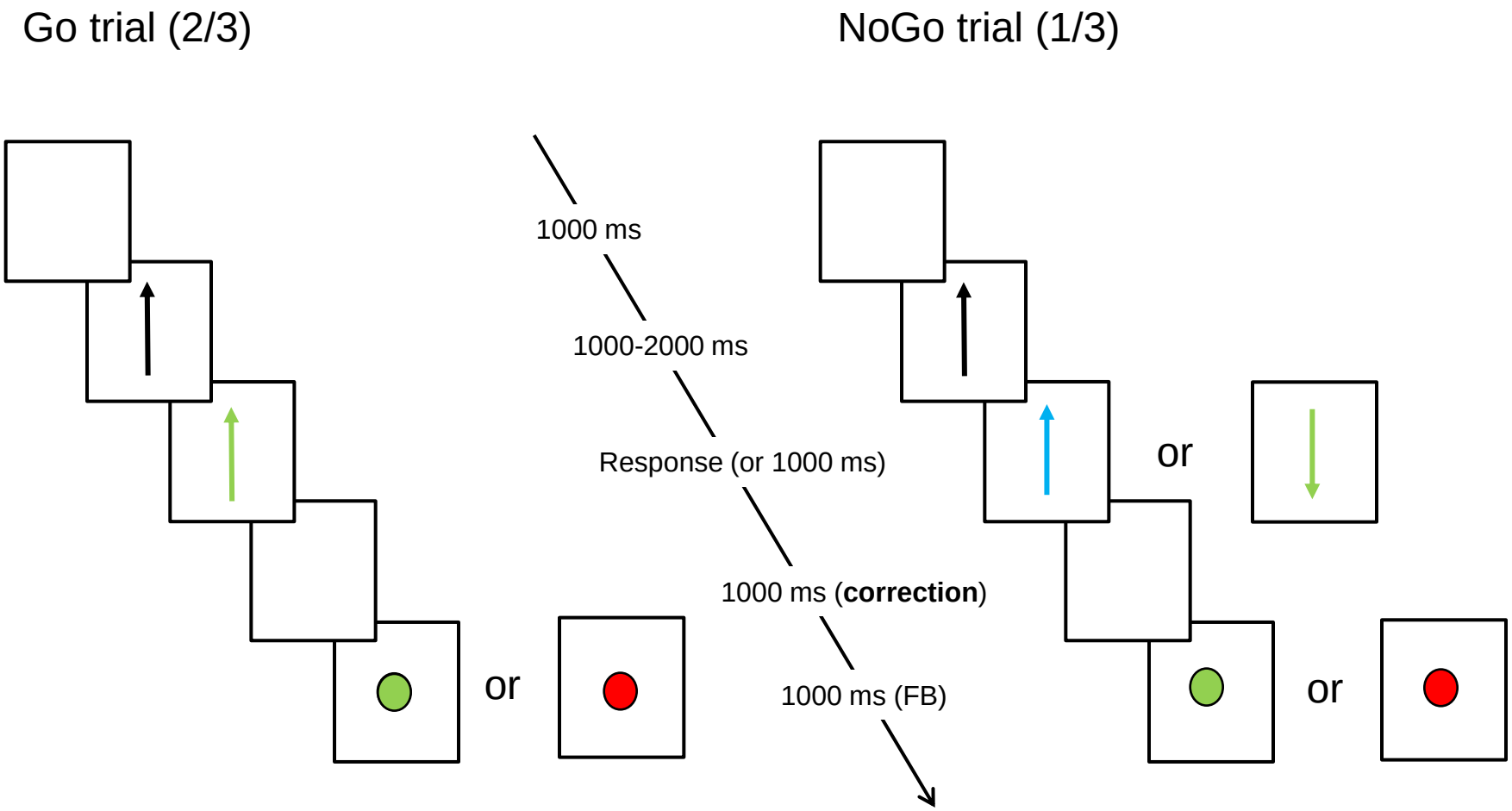
Easy solution: CARTOOL©

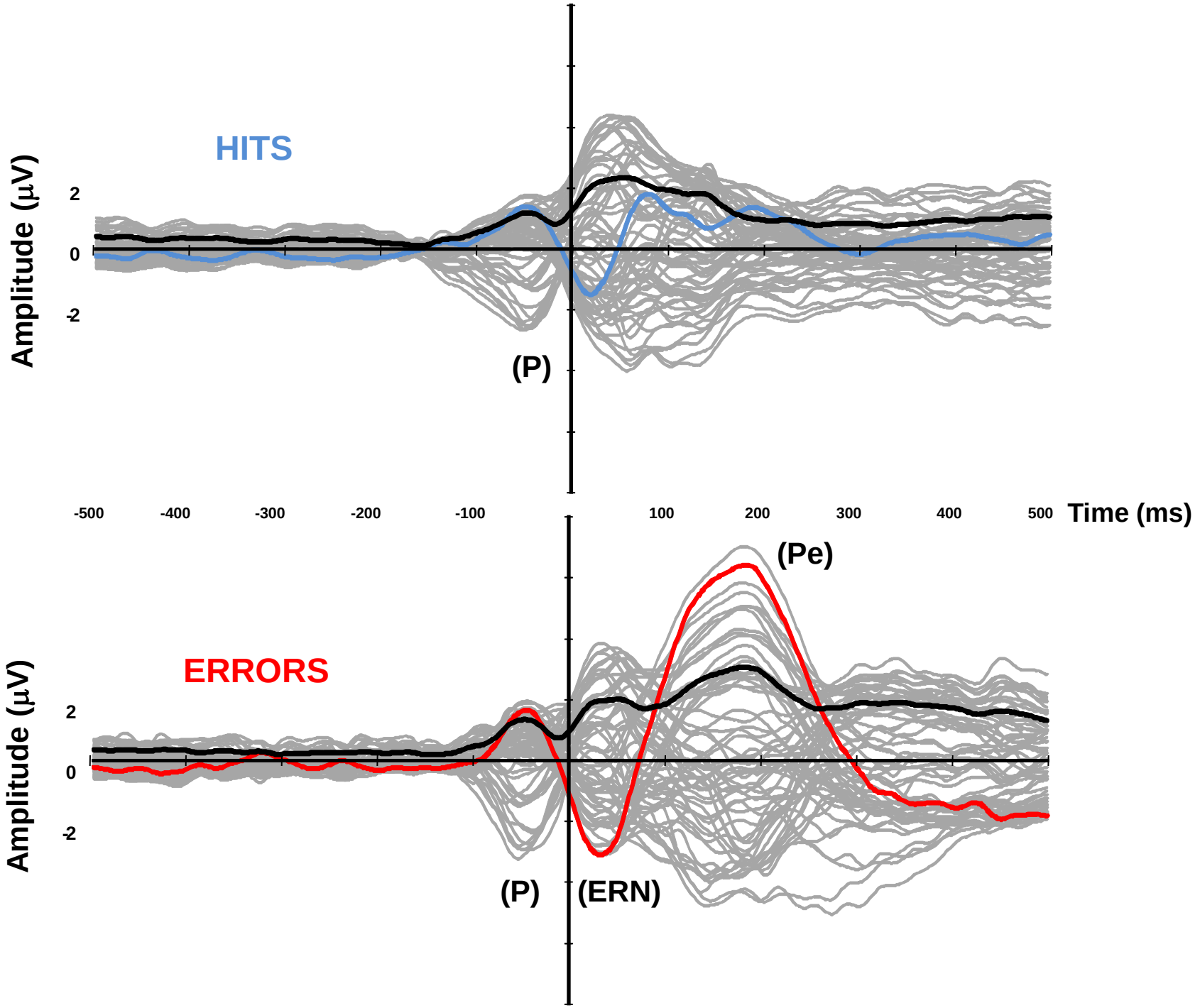
https://sites.google.com/site/fbmlab/cartool

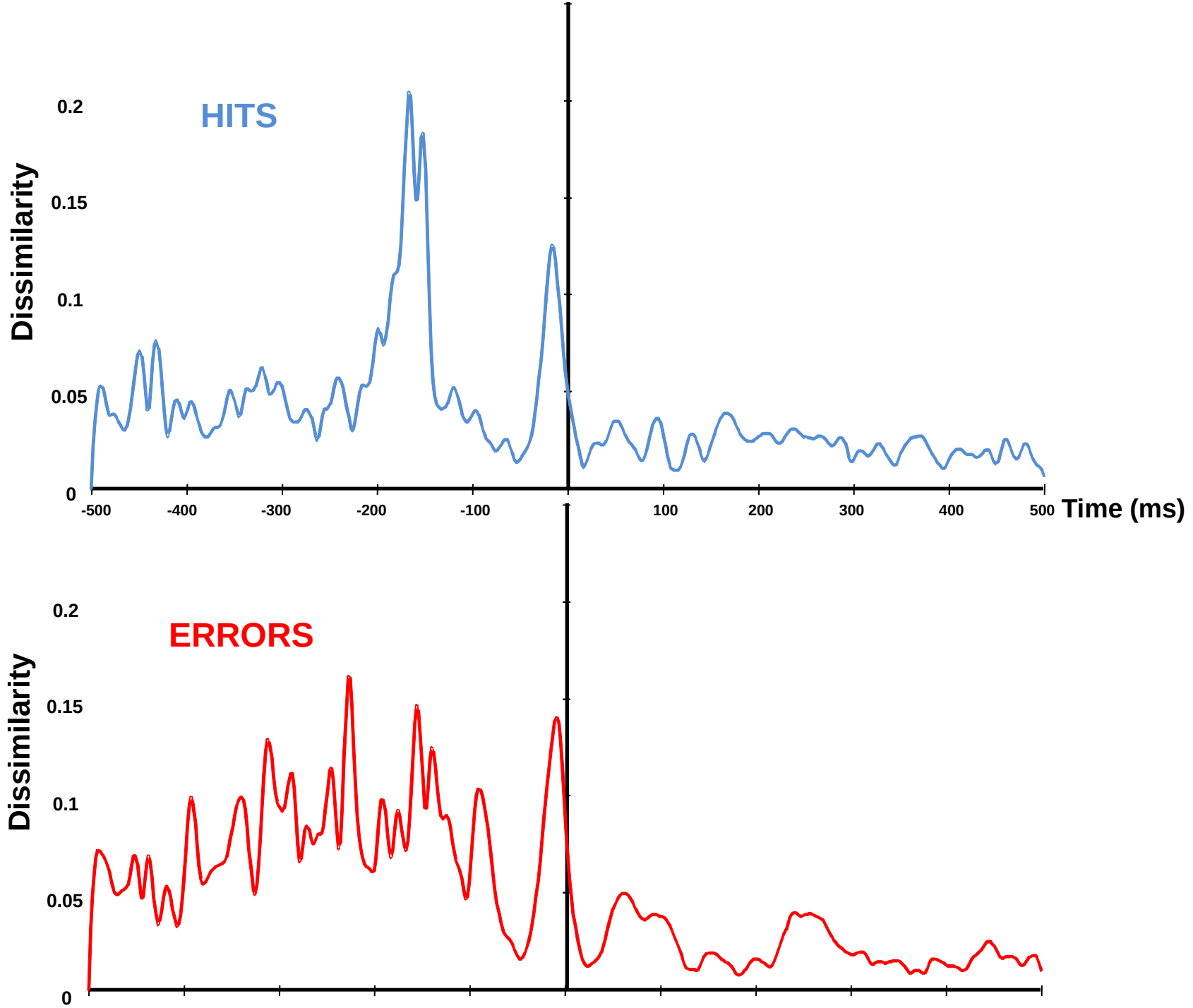


One example/application

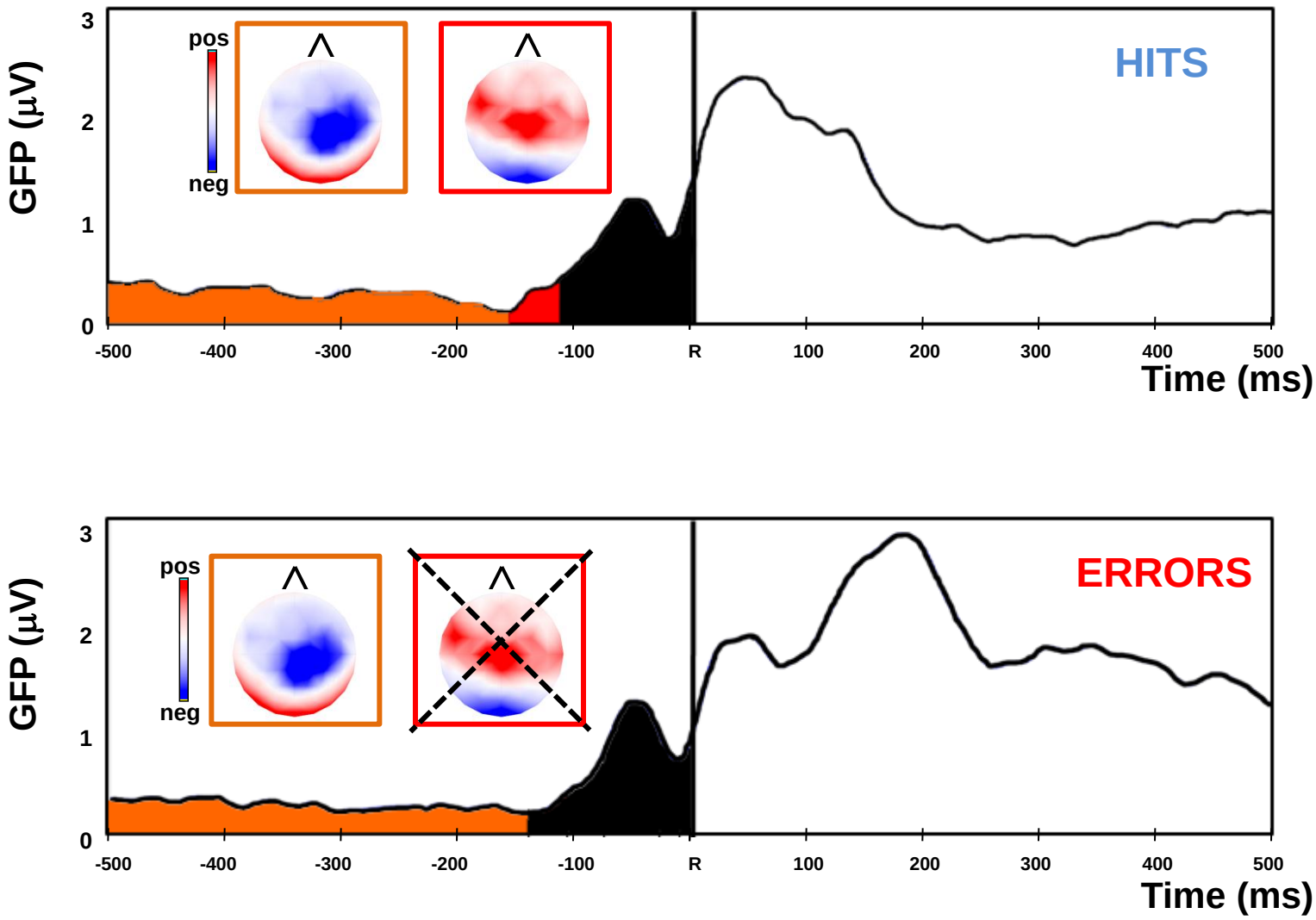
Go-NoGo task (color + orientation discrimination)

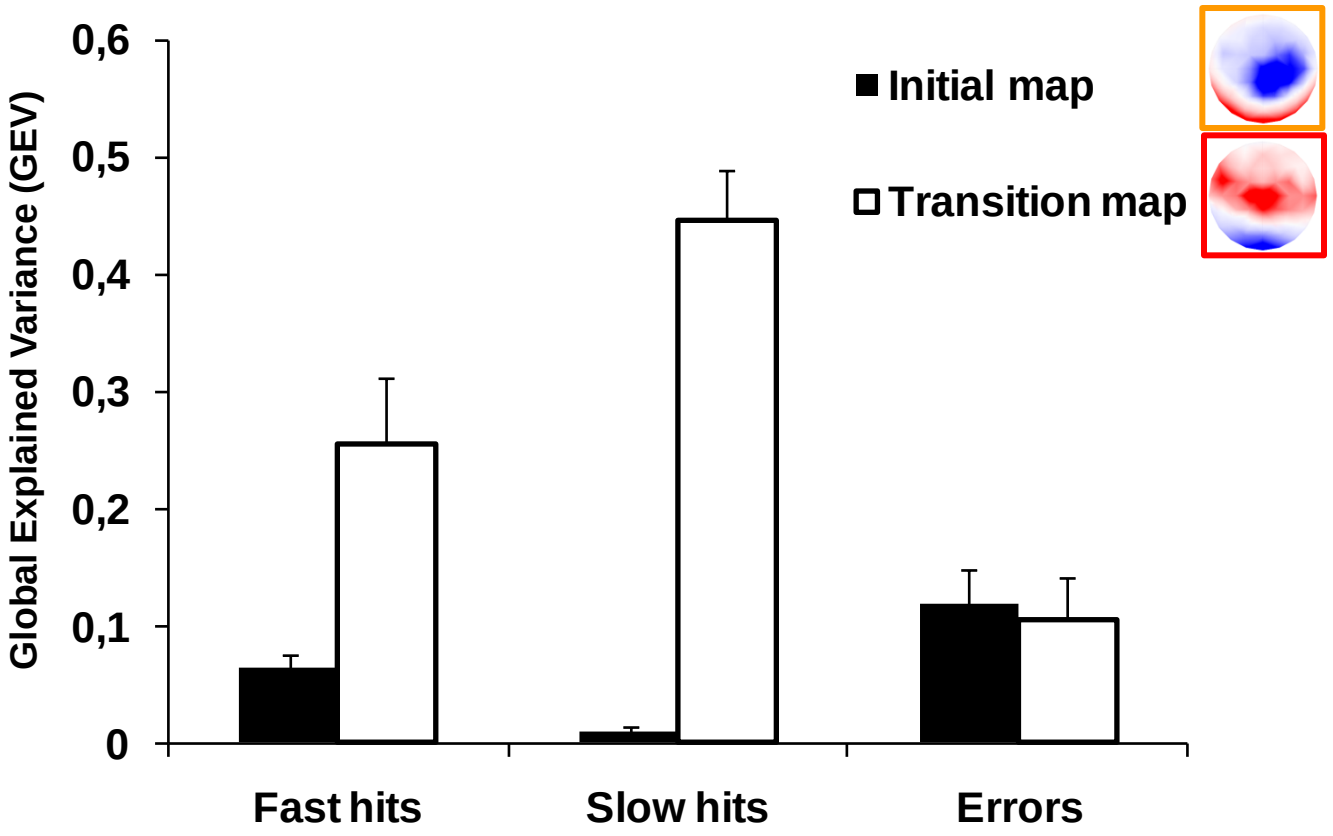



HITS
Amplitude (μV)
2
0
-2
(P)
-500
-400
-300
-200
-100
100
200
300
400
500
Time (ms)
ERRORS
Amplitude (μV)
2
0
-2
(Pe)
(P)
(ERN)

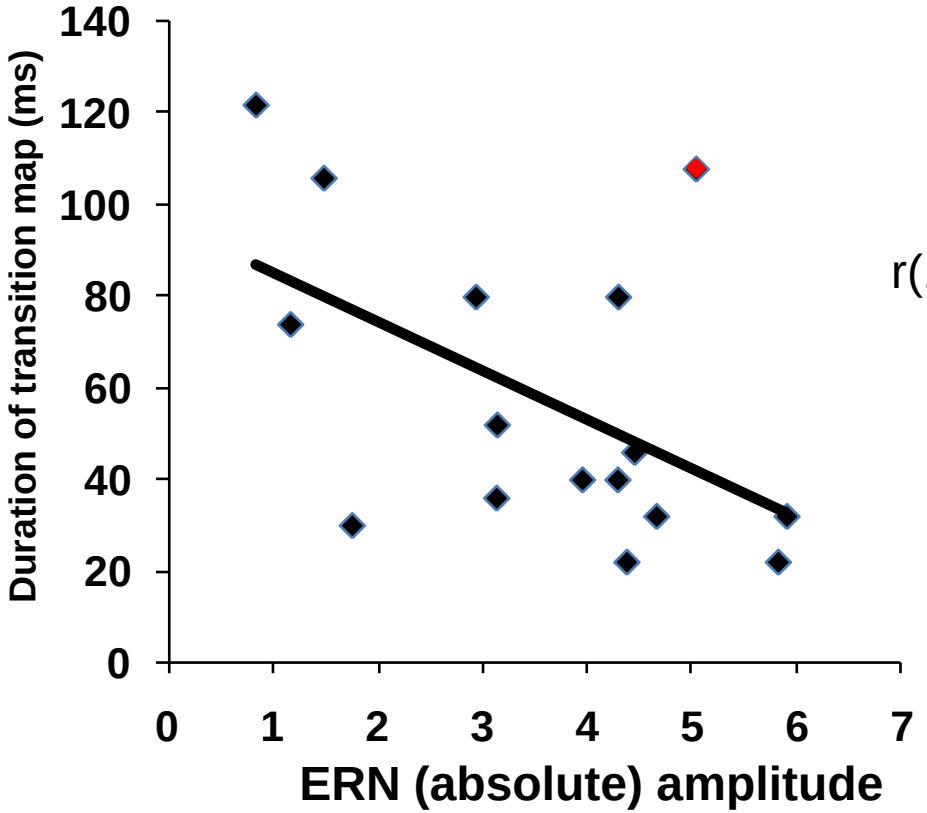

HITS
Dissimilarity
0.2
0.15
0.1
0.05
0
-500
-400
-300
-200
-100
100
200
300
400
500
Time (ms)
ERRORS
Dissimilarity
0.2
0.15
0.1
0.05
0

Topographic pattern analysis

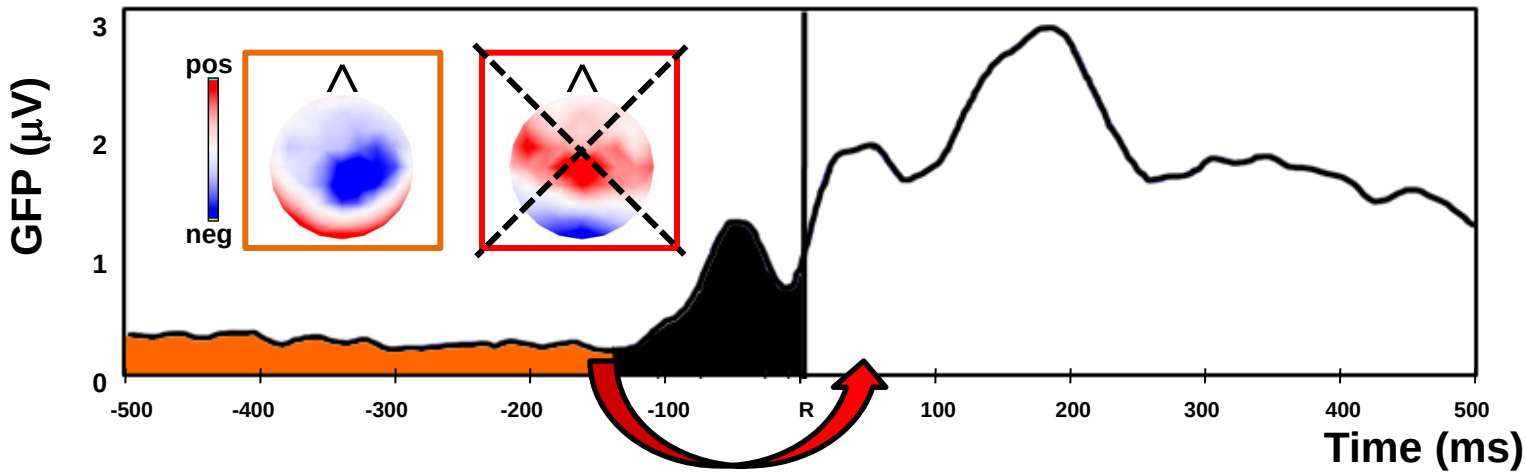




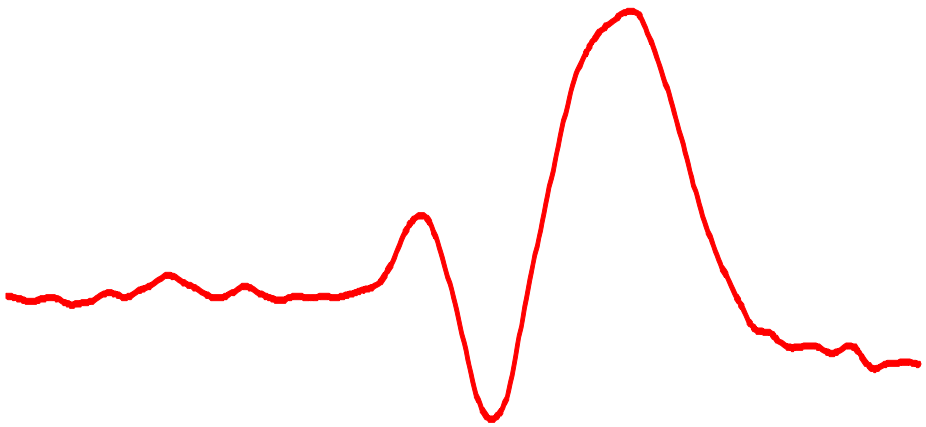
Map x Condition interaction; F(2,30) = 27.58, p<.001


Duration of transition map (ms)
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
ERN (absolute) amplitude

r(15) = -.70
p=.004


GFP (μV)
3
2
1
0
pos
neg
-500
-400
-300
-200
-100
R
100
200
300
400
500
Time (ms)

Conclusions



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Thank you for your attention!

Question?
=> Email me: gilles.pourtois@ugent.be