



Central European Institute of Technology
BRNO | CZECH REPUBLIC

EEG: preprocessing and data analysis

Martin Lamoš

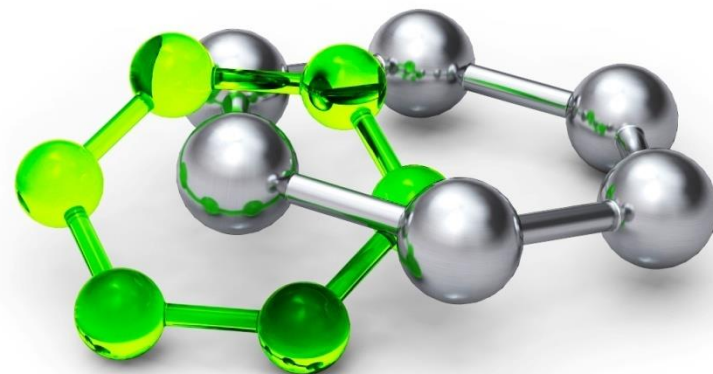
Brno, November 15th 2016



EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
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OP Research and
Development for Innovation



Pipeline

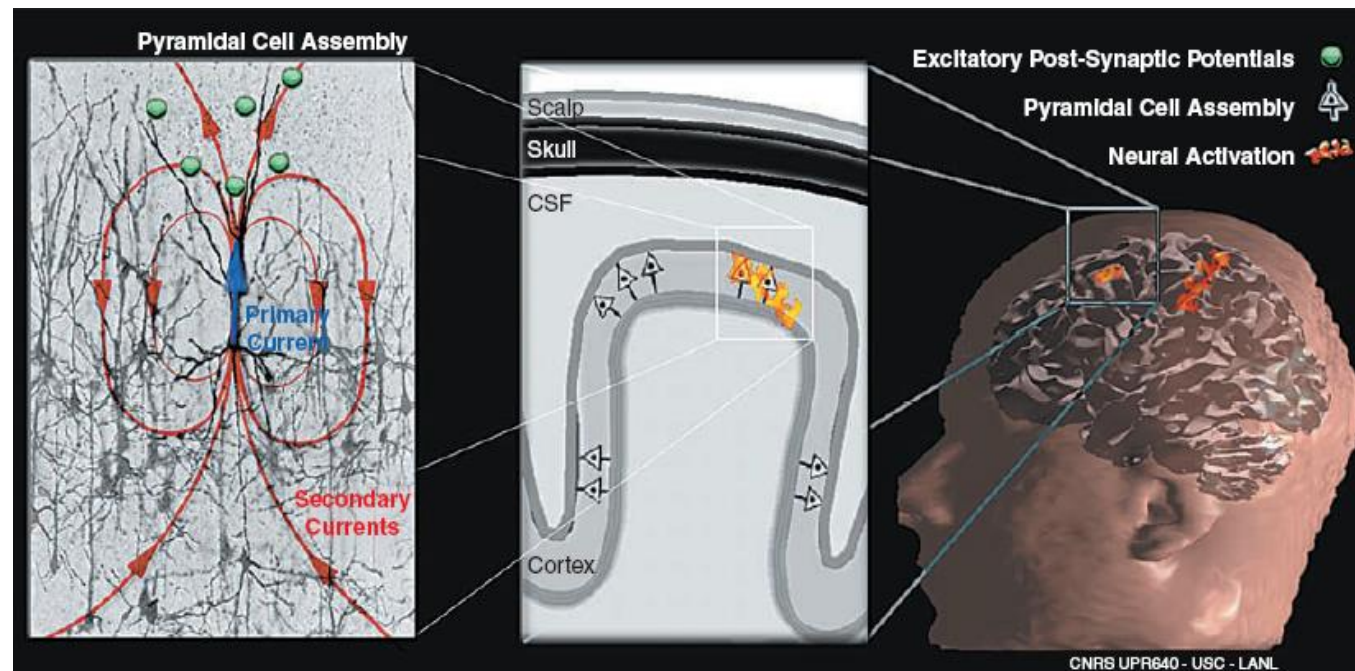
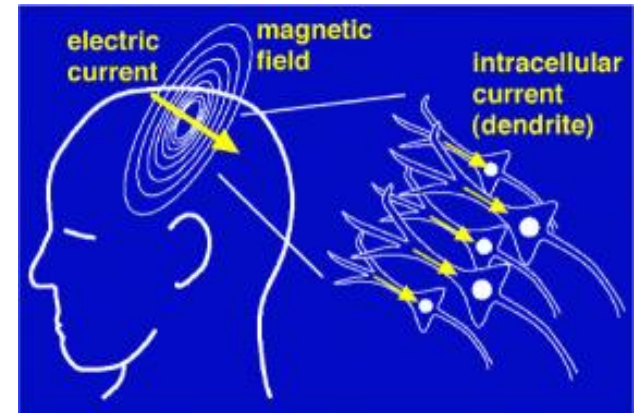
- 1 | **What are we measuring**
- 2 | **EEG study step by step**
- 3 | **Advanced methods of analysis**

Basic idea

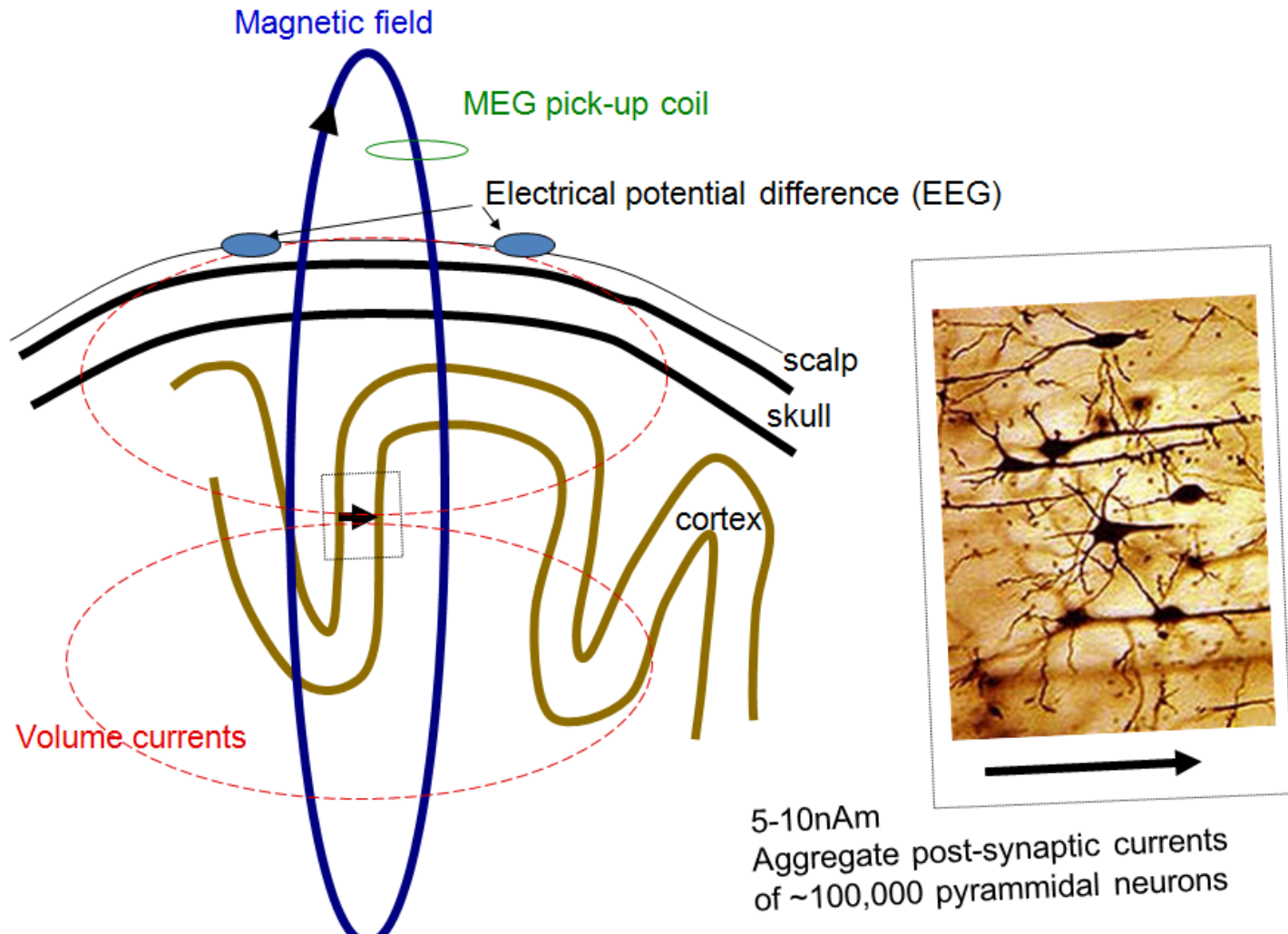
- Electrical activity of neurons – currents spreading over the head
- These currents are propagated on the scalp in the way of voltage changes and magnetic fields – possible to measure both noninvasively
- Measurement of voltage changes on the scalp – electroencephalography (EEG)
- Measurement of magnetic fields on the scalp – magnetoencephalography (MEG)

Electrical activity in the brain

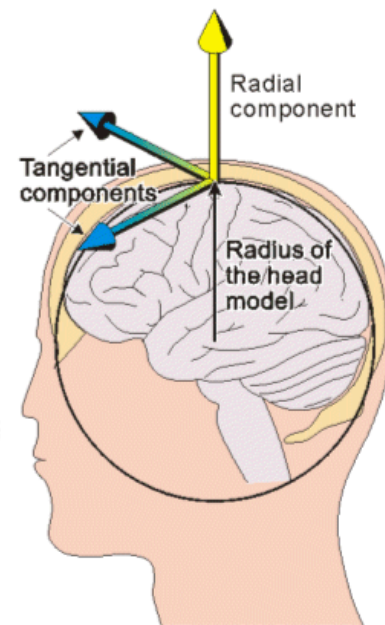
- Neuron x neuronal population
 - Single neuron – insufficient, possible to measure thousands of neurons, which have similar activity pattern
 - Most of the signal is generated by pyramidal cells (parallel, tangentially oriented to surface)
 - EEG measures synaptic currents



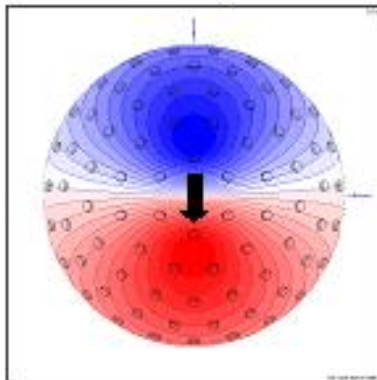
Electrical activity in the brain



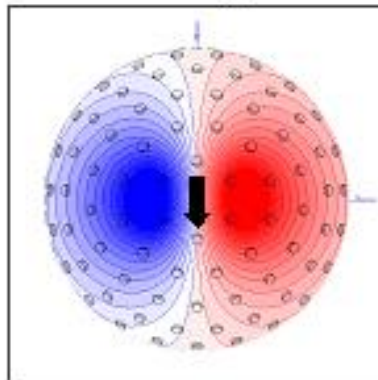
Electrical activity in the brain



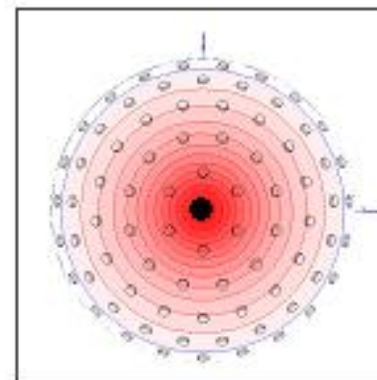
EEG tangential



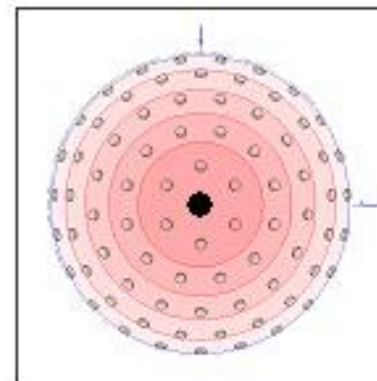
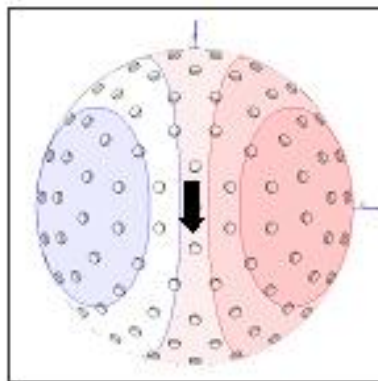
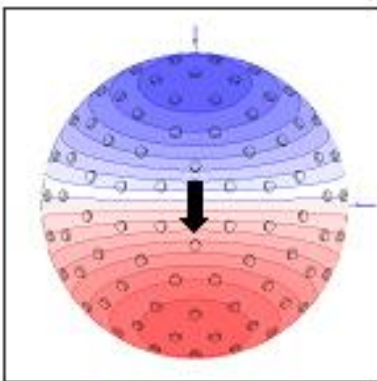
MEG tangential



EEG radial



**8 cm
from
centre**



**4 cm
from
centre**

EEG - parameters

1 | Resolution

Temporal - sampling

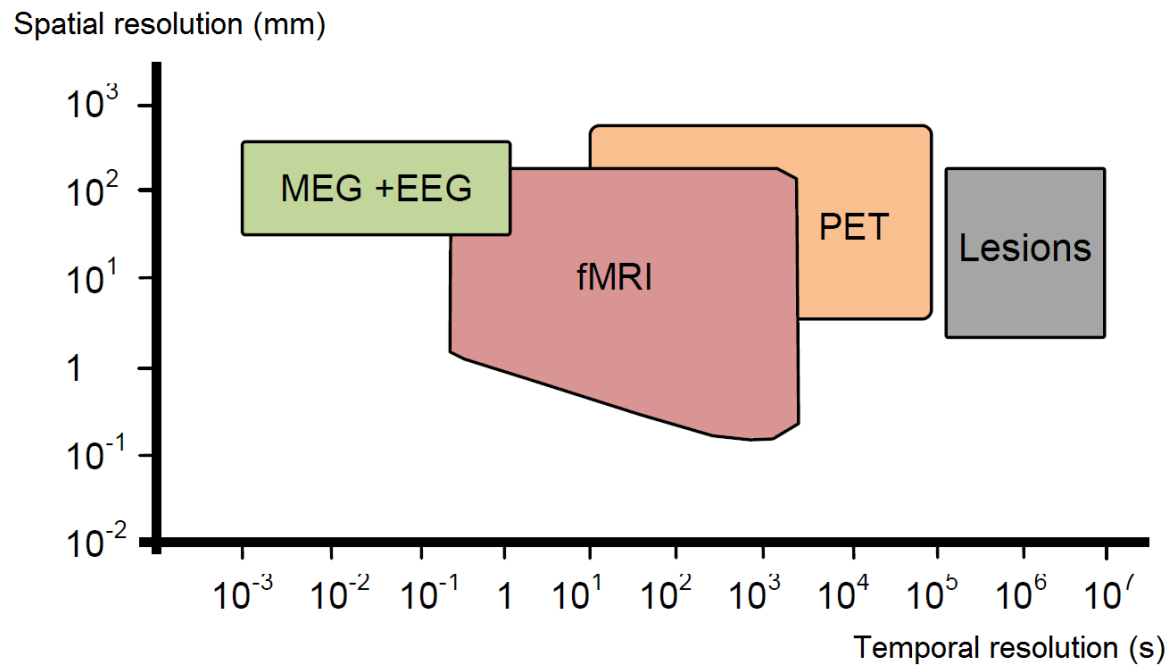
Spatial – number of channels

2 | Input impedance

3 | Frequency bandwidth

4 | AD conversion, etc.

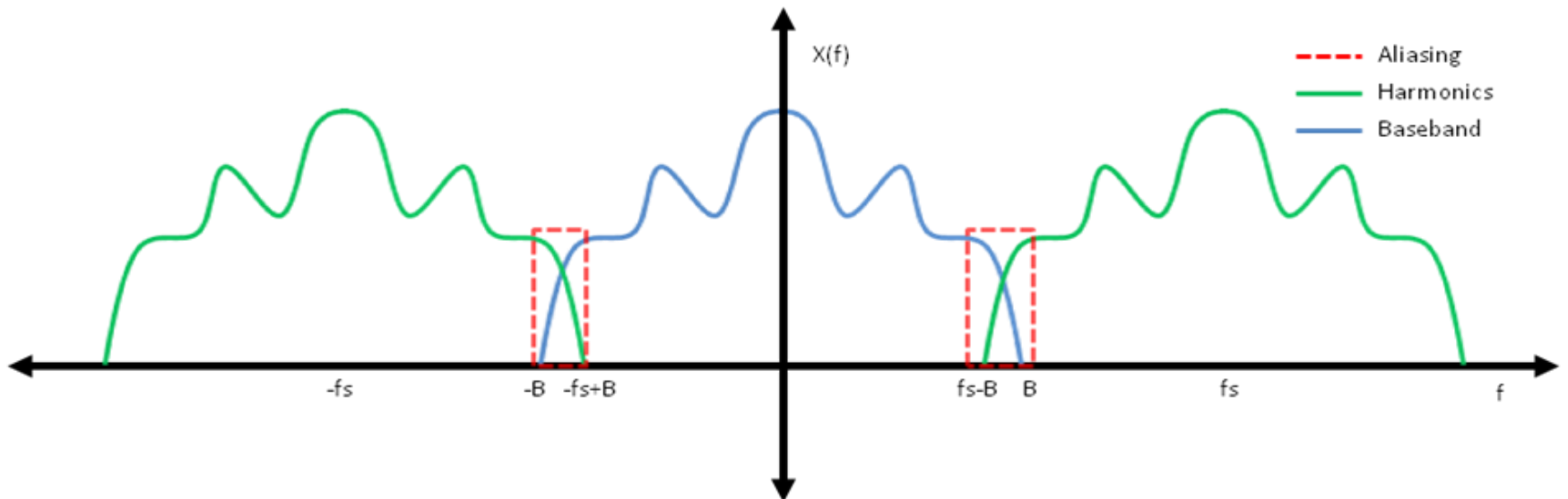
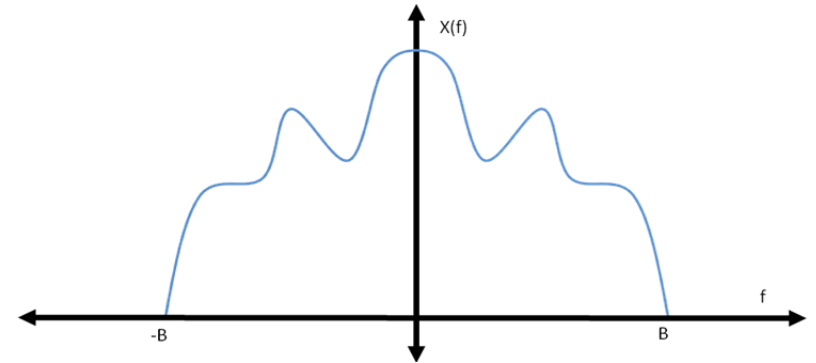
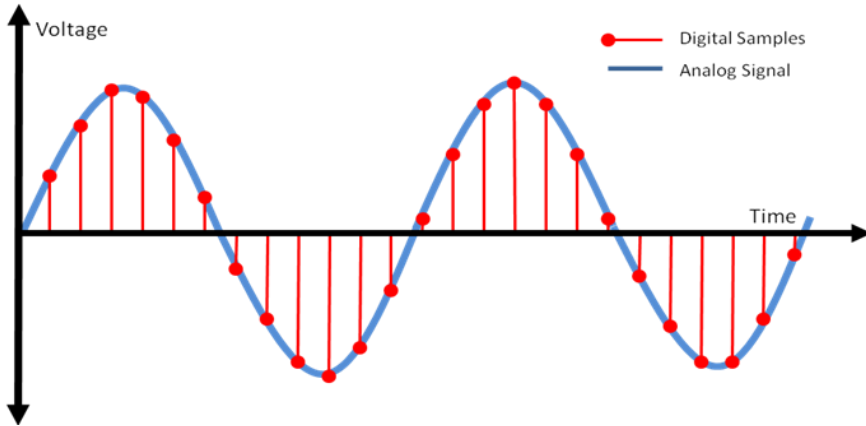
EEG - resolution



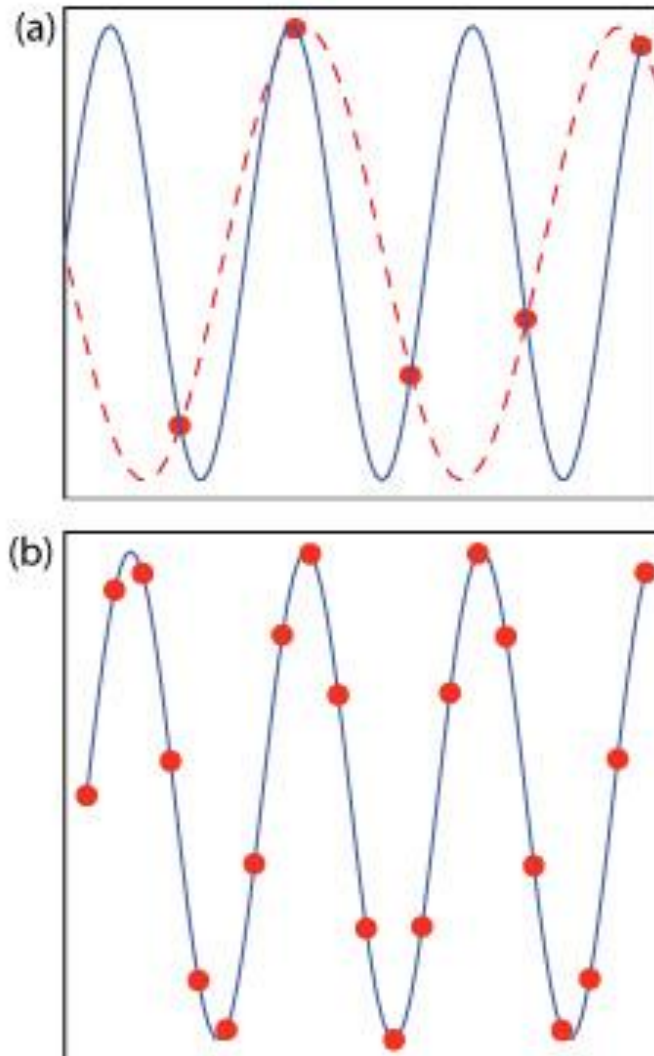
EEG – number of channels



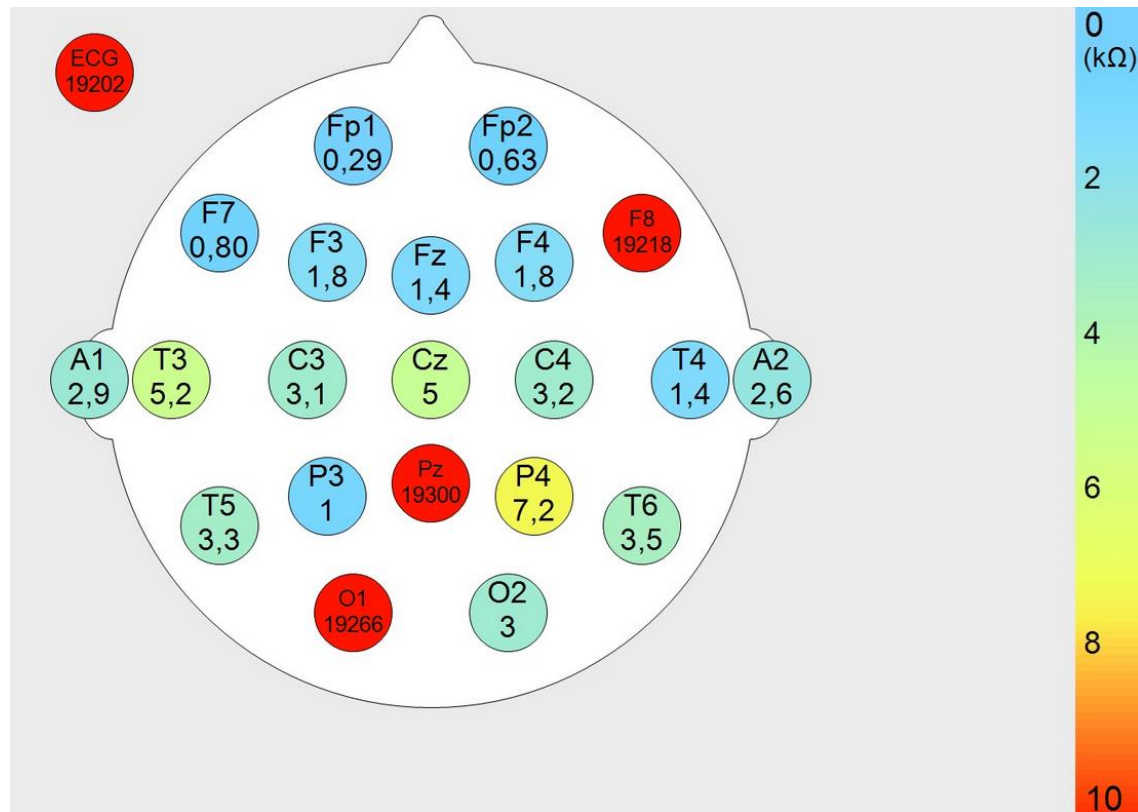
Sampling



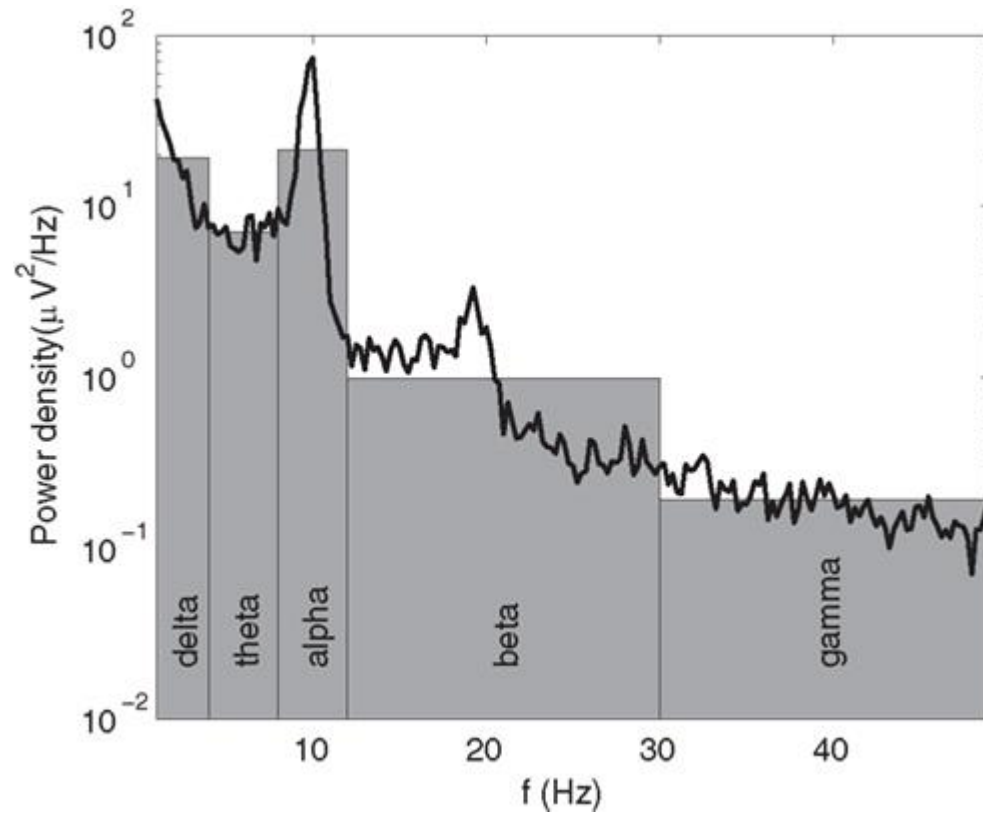
Sampling



EEG - impedances



EEG – frequency bands



EEG – frequency bands

- **Delta** - to 4 Hz, to 100 μ V. Pathological for awake adults, OK in the deep sleep
- **Theta** - 4 to 8 Hz, to 150 μ V, falling asleep in central part of the brain, pathological for awake adults
- **Alpha** - 8 to 13 Hz, to 50 μ V, physical and mental rest with closed eyes. During hyperventilation, higher attention, mental activity and drowsiness is on the decrease.
- **Beta** - 13 to 30 Hz, to 30 μ V, mental activity, higher attention, present in awake healthy adults
- Waves above 30 Hz to 80 Hz are named to **gamma**
- **HFO** – above high gamma

EEG – frequency bands

SINUSOIDAL 8 HERTZ ALPHA



SPINDLES OF BETA



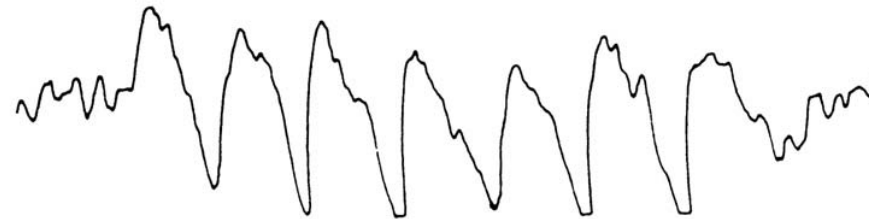
13 HERTZ SPINDLES



MIXED FREQUENCY ACTIVITY
(10 AND 6 HERTZ)



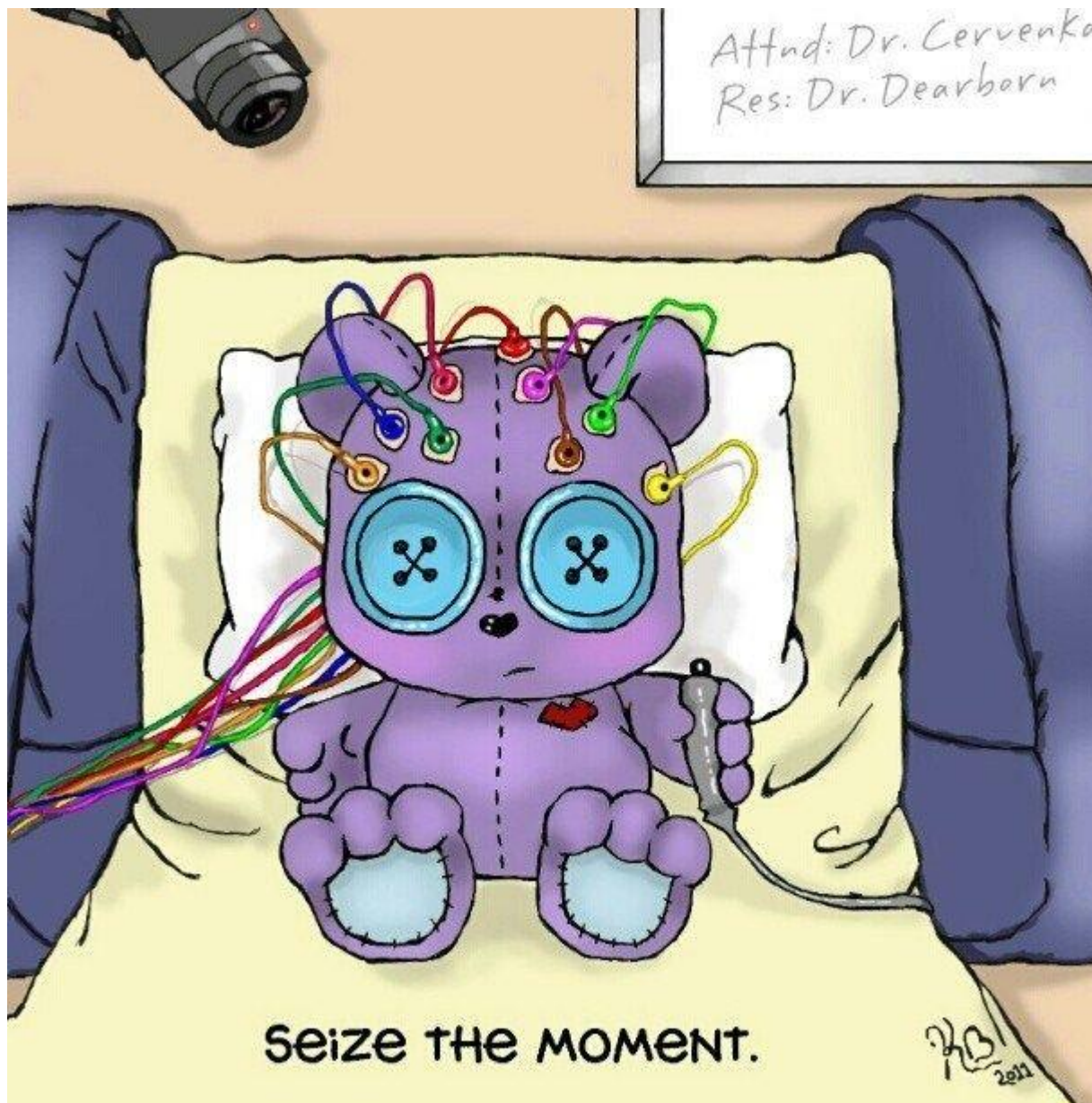
RHYTHMIC DELTA (2 HERTZ)



ARRHYTHMIC DELTA
(2-3 HERTZ)



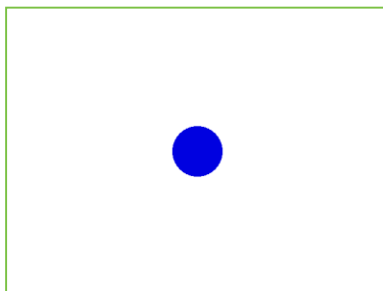
1 SEC



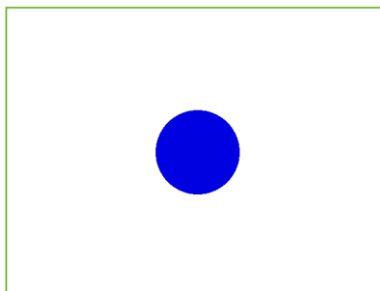
EEG study step by step

- Connectivity in temporal lobe epilepsy patients
 - Patients and healthy controls (age and gender matched) perform Polich visual oddball task (press the button on target stimulus) during EEG recording in shielded room.
 - 70% frequent, 15% target, 15% distractor stimuli
 - ISI = 4 s
 - Stimulus duration 200 ms
 - Random order of 334 stimuli

Frequent



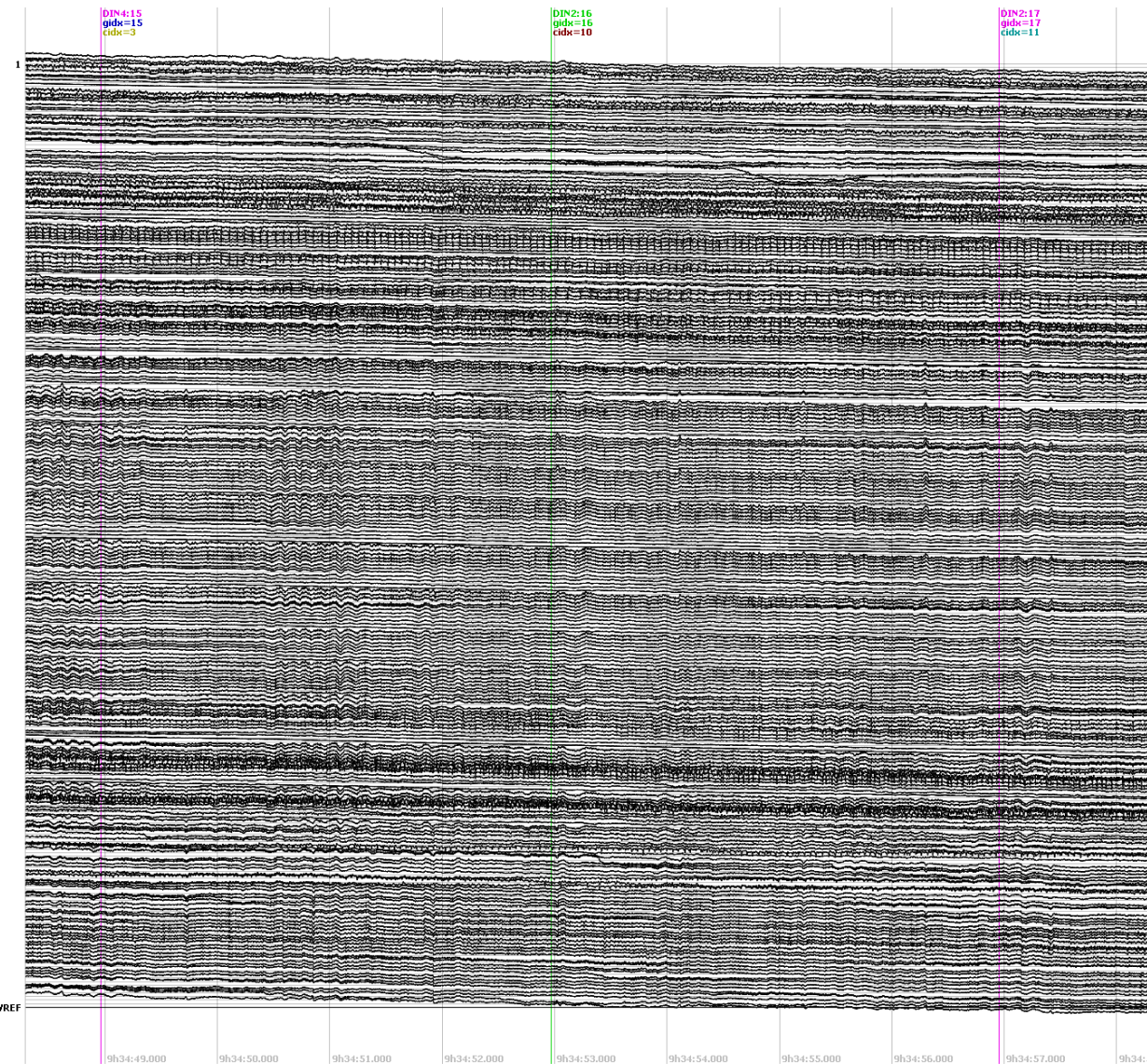
Target



Distractor



EEG data



EGL file format

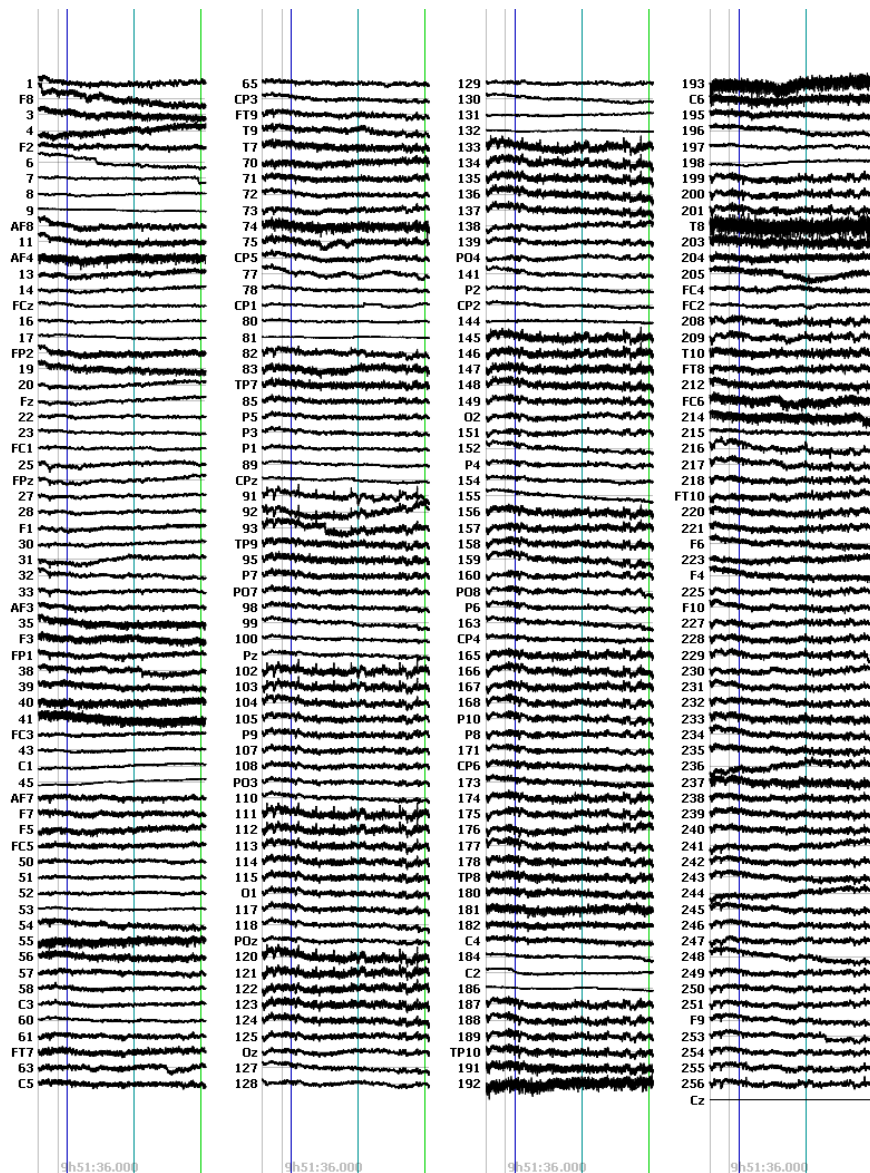
058 20121008 1803

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coordinates.xml	
epochs.xml	
Events_DIN_1.xml	Markers
Events_DIN_2.xml	
info.xml	Xml info
info1.xml	
info2.xml	
notes.xml	
pnsSet.xml	
sensorLayout.xml	
subject.xml	
signal1.bin	Data
signal2.bin	
info.xml.bak	Xml info
Info.plist	

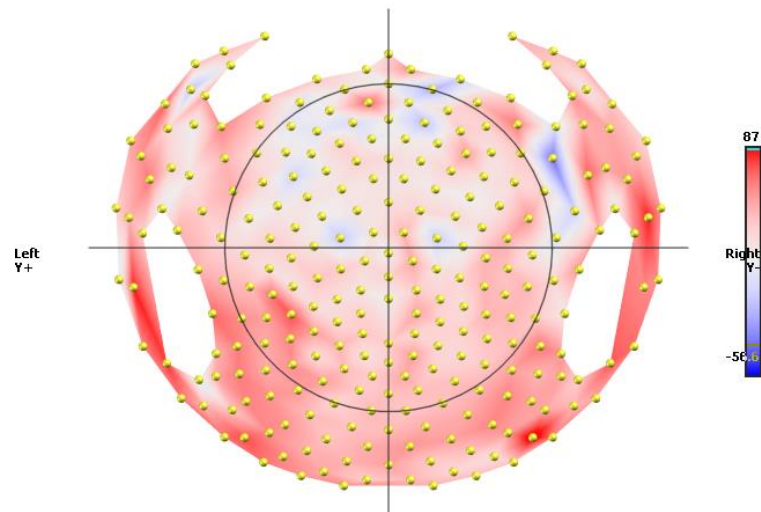
Brain Vision file format

fM01885_Null256.dat	Data
fM01885_Null256.vhdr	Header
fM01885_Null256.vmrk	Markers

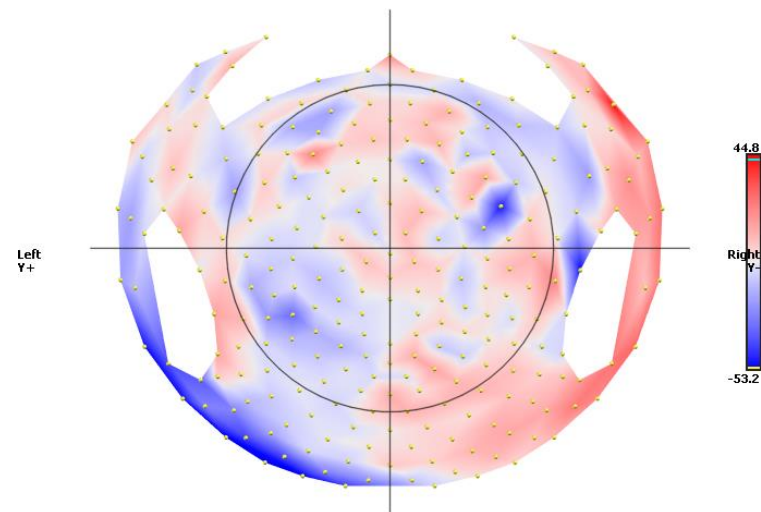
Raw data



EGI257.GenevaAverage13.10-10.xyz
2D Projected



EGI257.GenevaAverage13.10-10.xyz
2D Projected

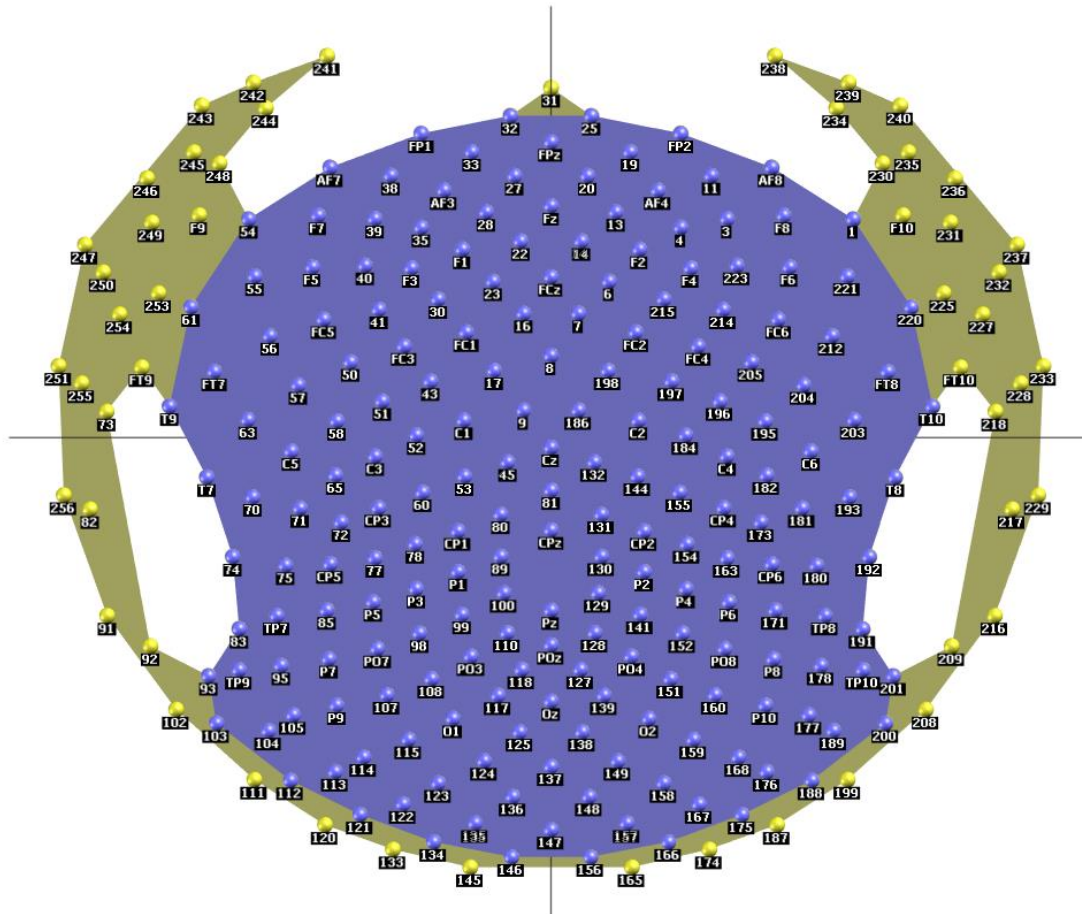


Posterior
X-

Reduction to 204 electrodes

257 electrodes, in 1 cluster(s)
Surface Electrodes
Data are 3D points
2D Projected
Content size: 320.5 389.0 0.0 [mm]

Anterior
X+

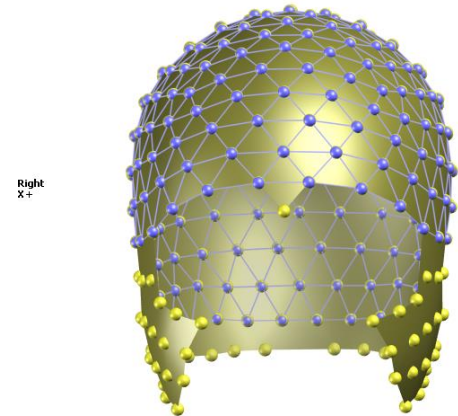


Left
Y+

Posterior
X-

257 electrodes, in 1 cluster(s)
Surface Electrodes
Data are 3D points
3D Space
Content size: 152.6 194.6 192.6 [mm]

Superior
Z+



Right
X+

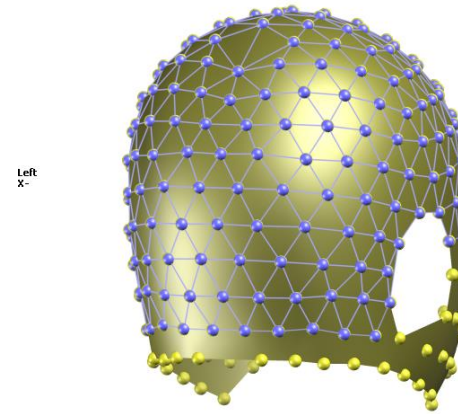
Left
X-

Inferior
Z-

Right
Y-

257 electrodes, in 1 cluster(s)
Surface Electrodes
Data are 3D points
3D Space
Content size: 152.6 194.6 192.6 [mm]

Superior
Z+

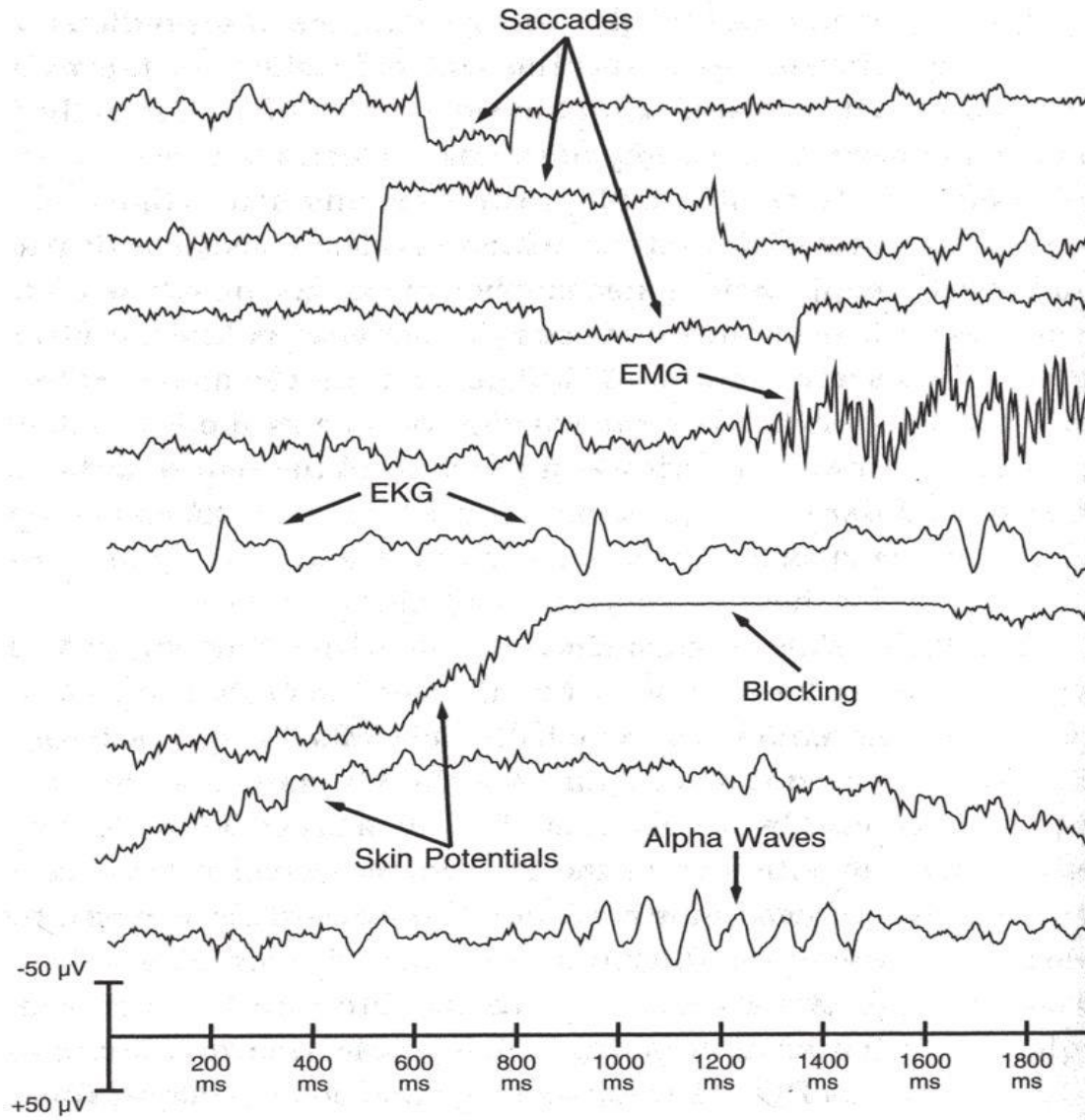


Left
X-

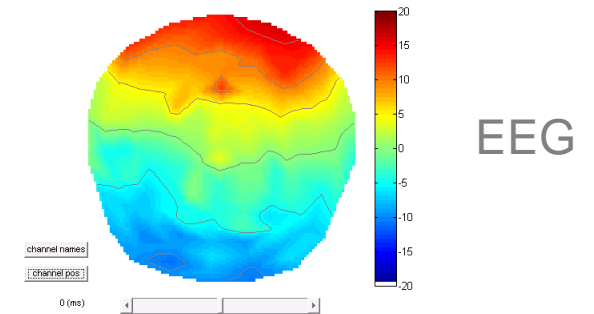
Right
X+

Inferior
Z-

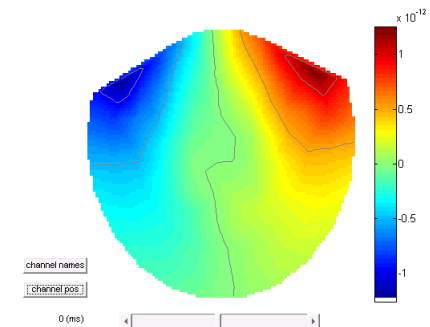
Artefacts - physiological



Eye blink

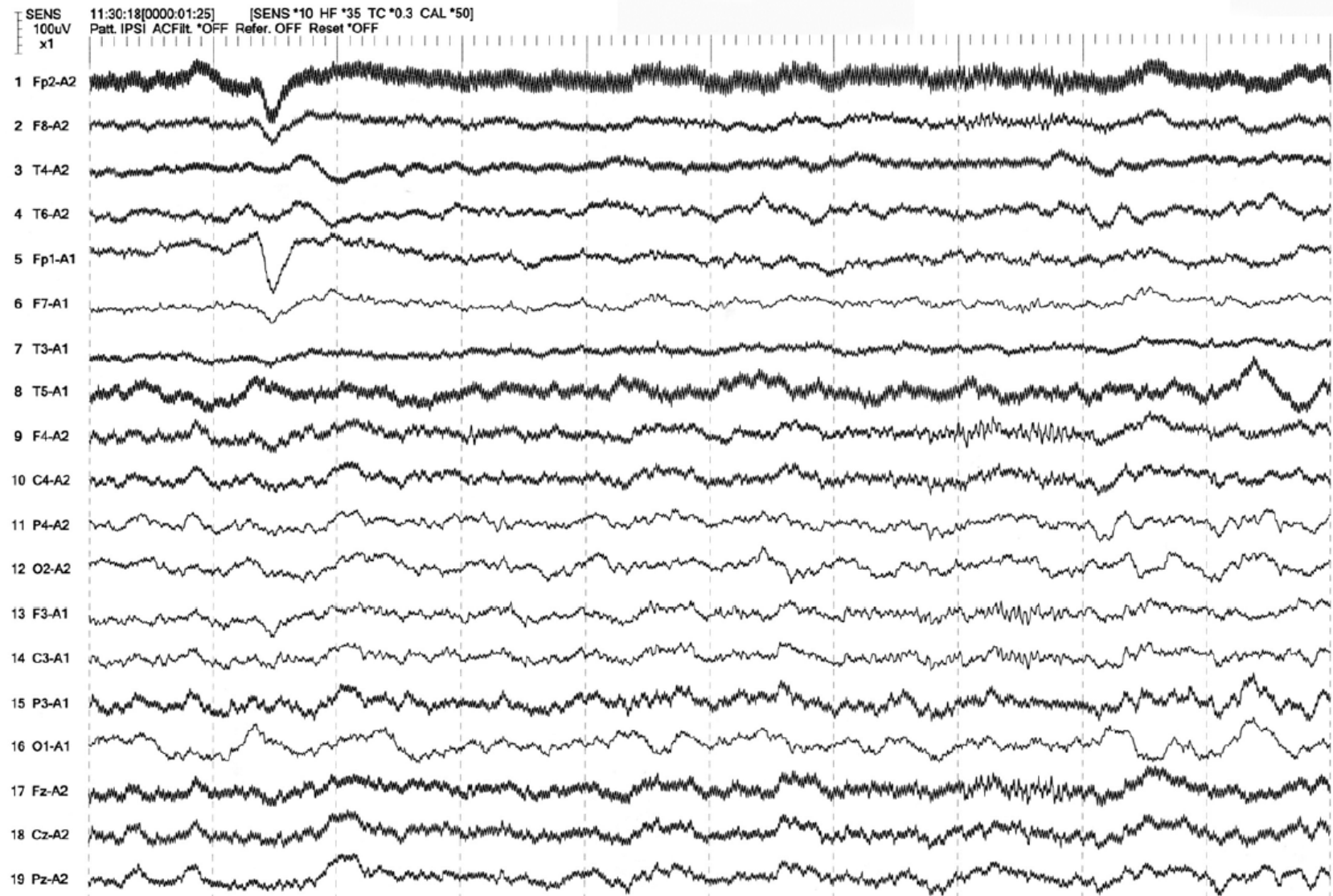


EEG

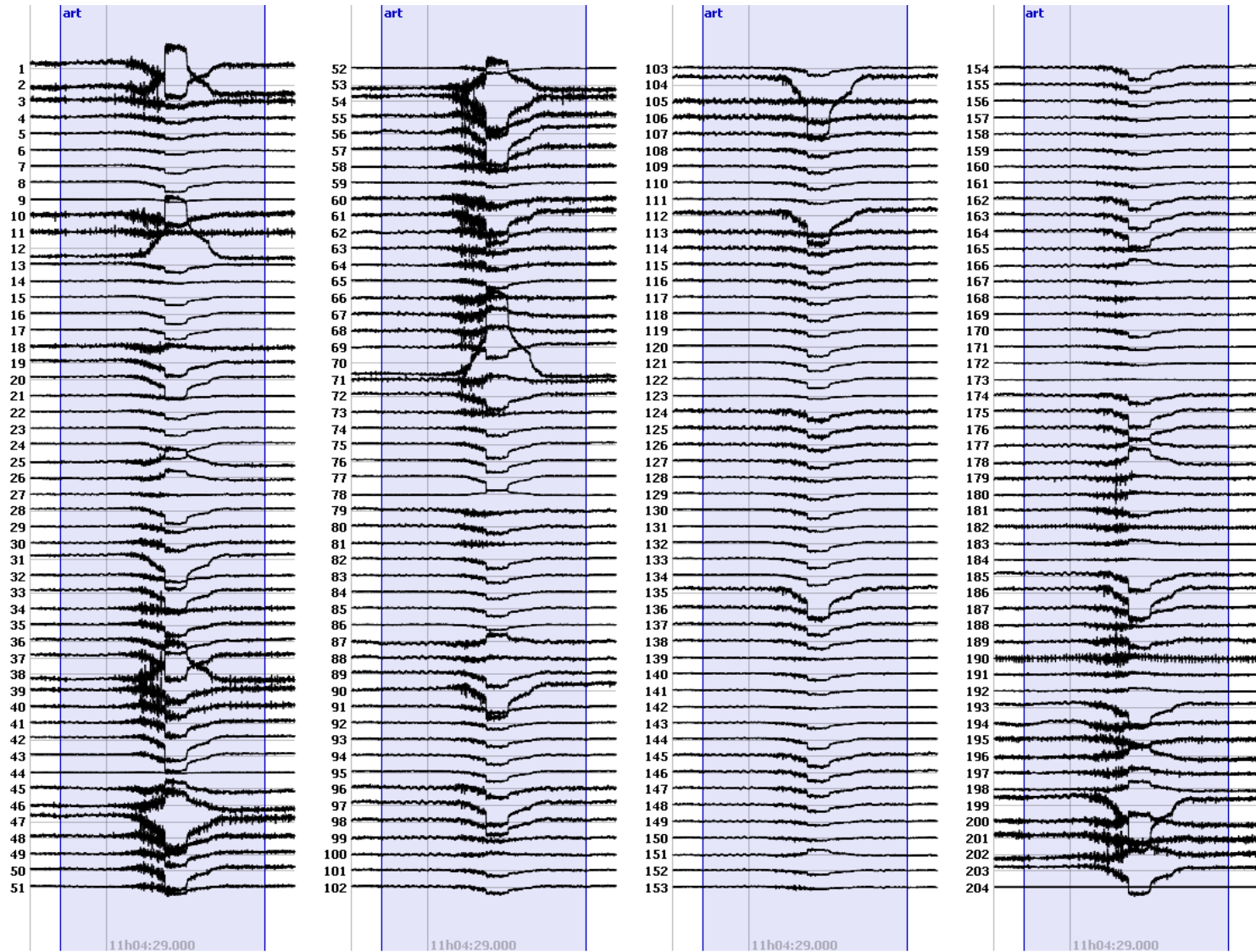


MEG

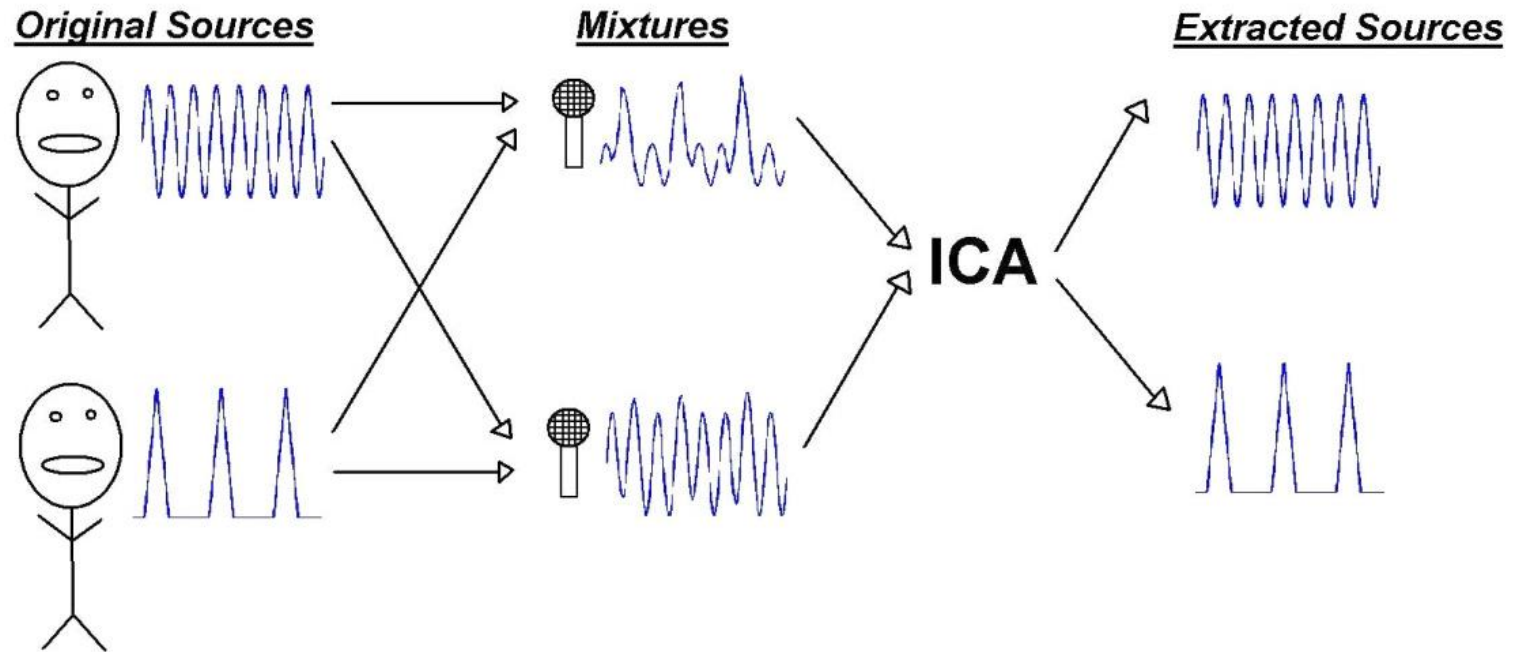
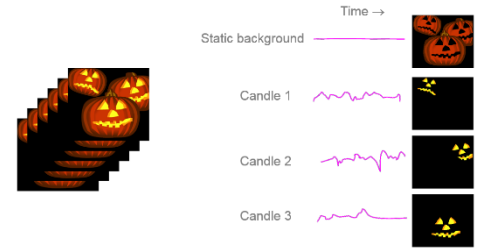
Artefacts – non-physiological



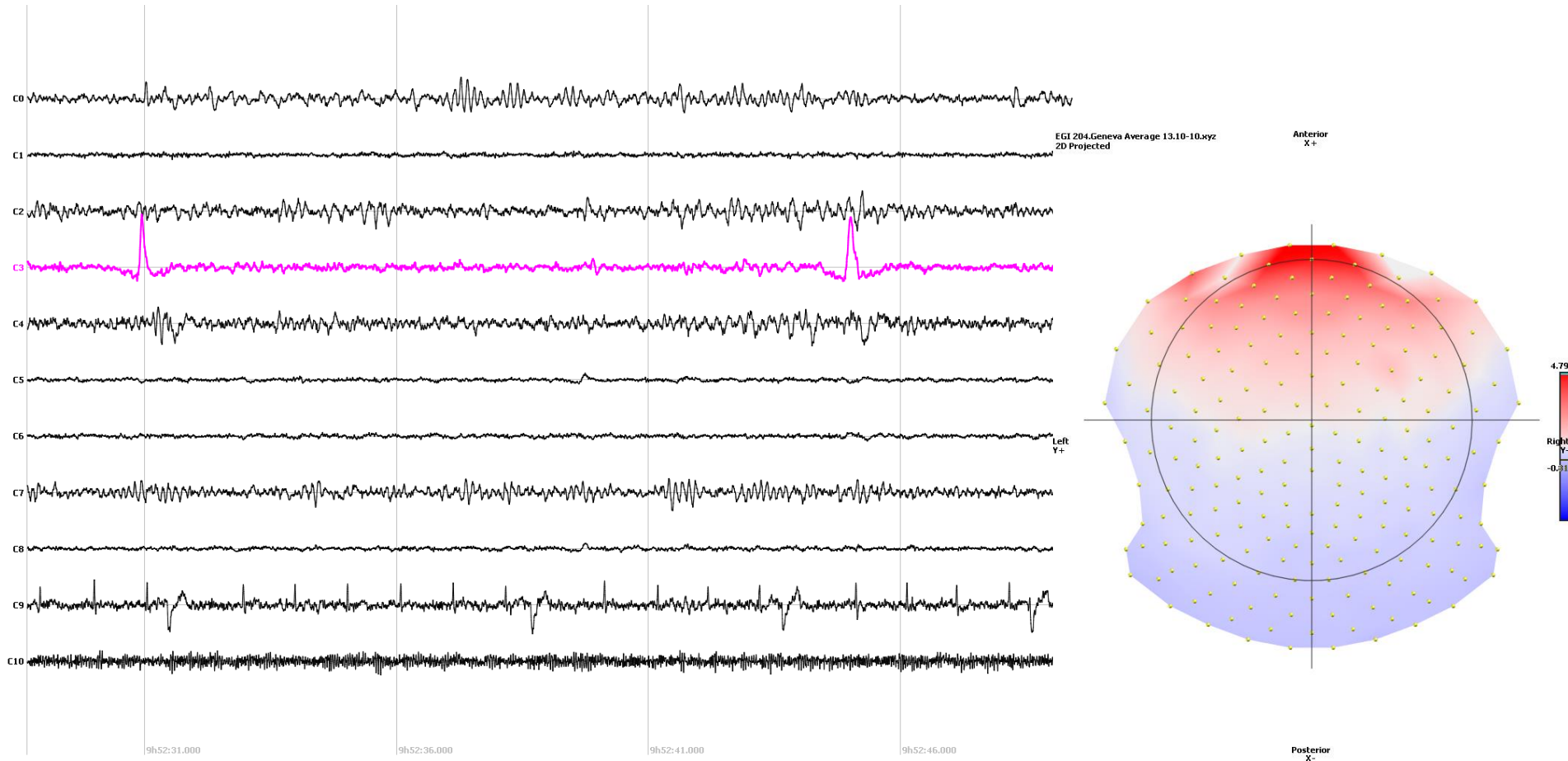
Visual inspection of the data



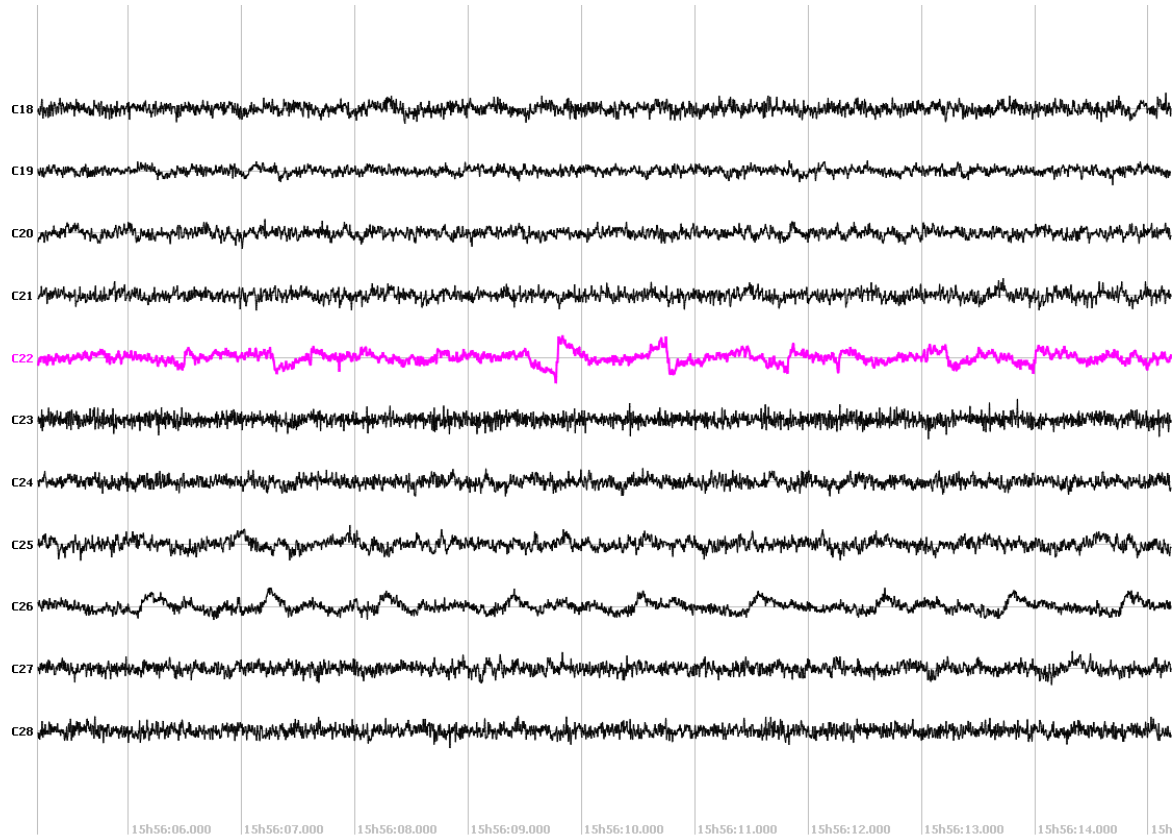
Independent Component Analysis (ICA)



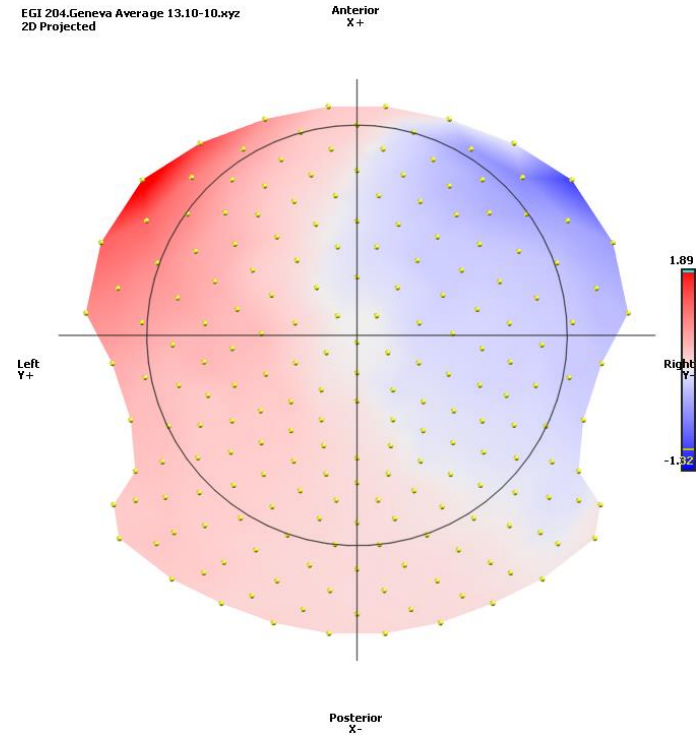
ICA – eye blink artefact



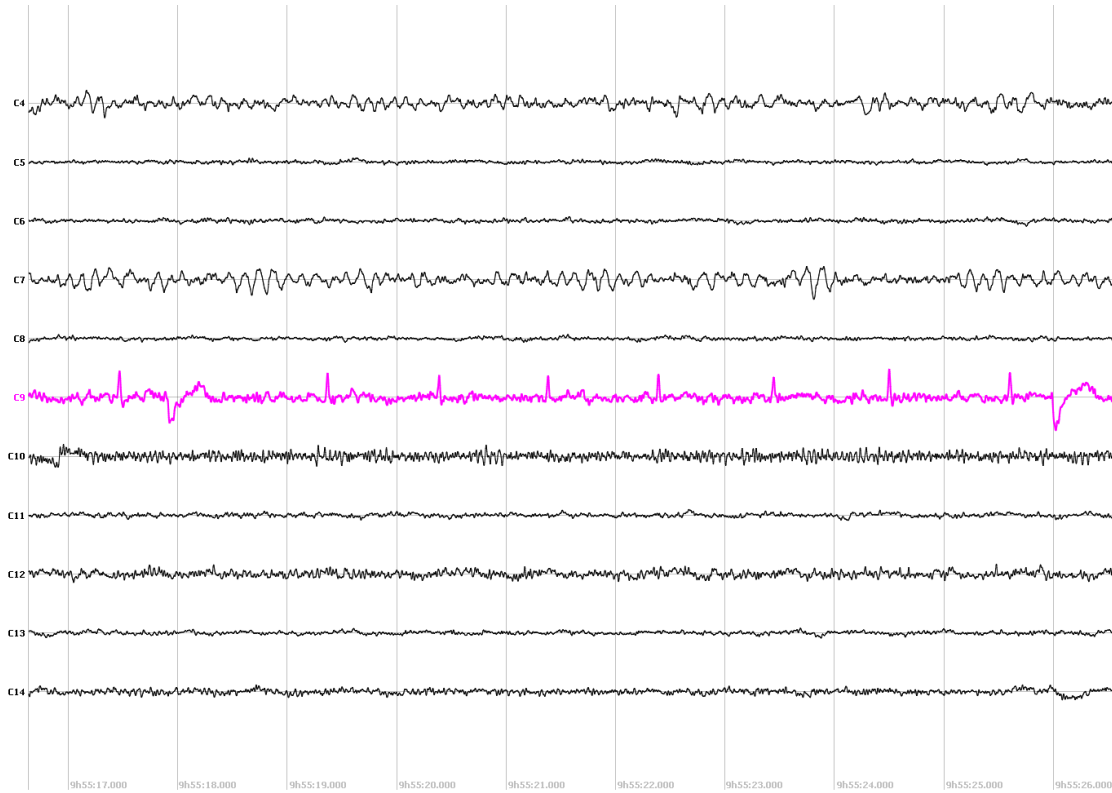
ICA – eye blink artefact



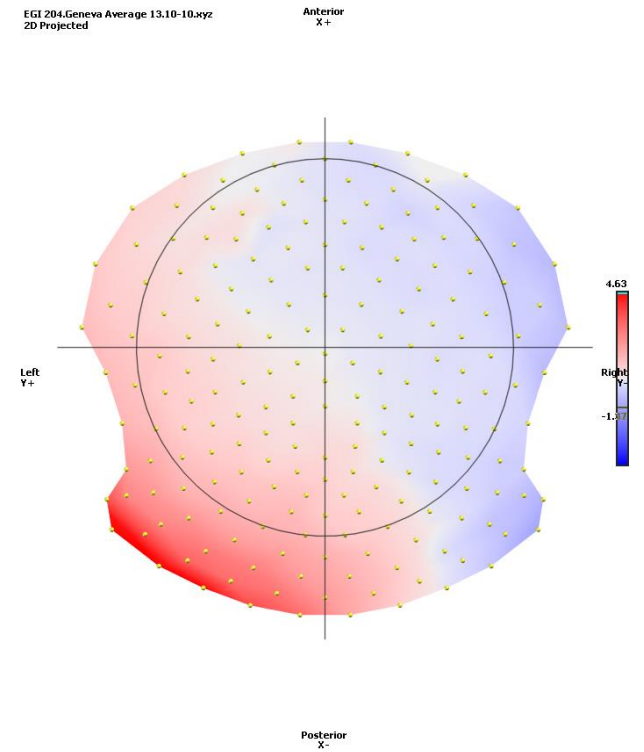
EGI 204.Geneva Average 13.10-10.xyz
2D Projected



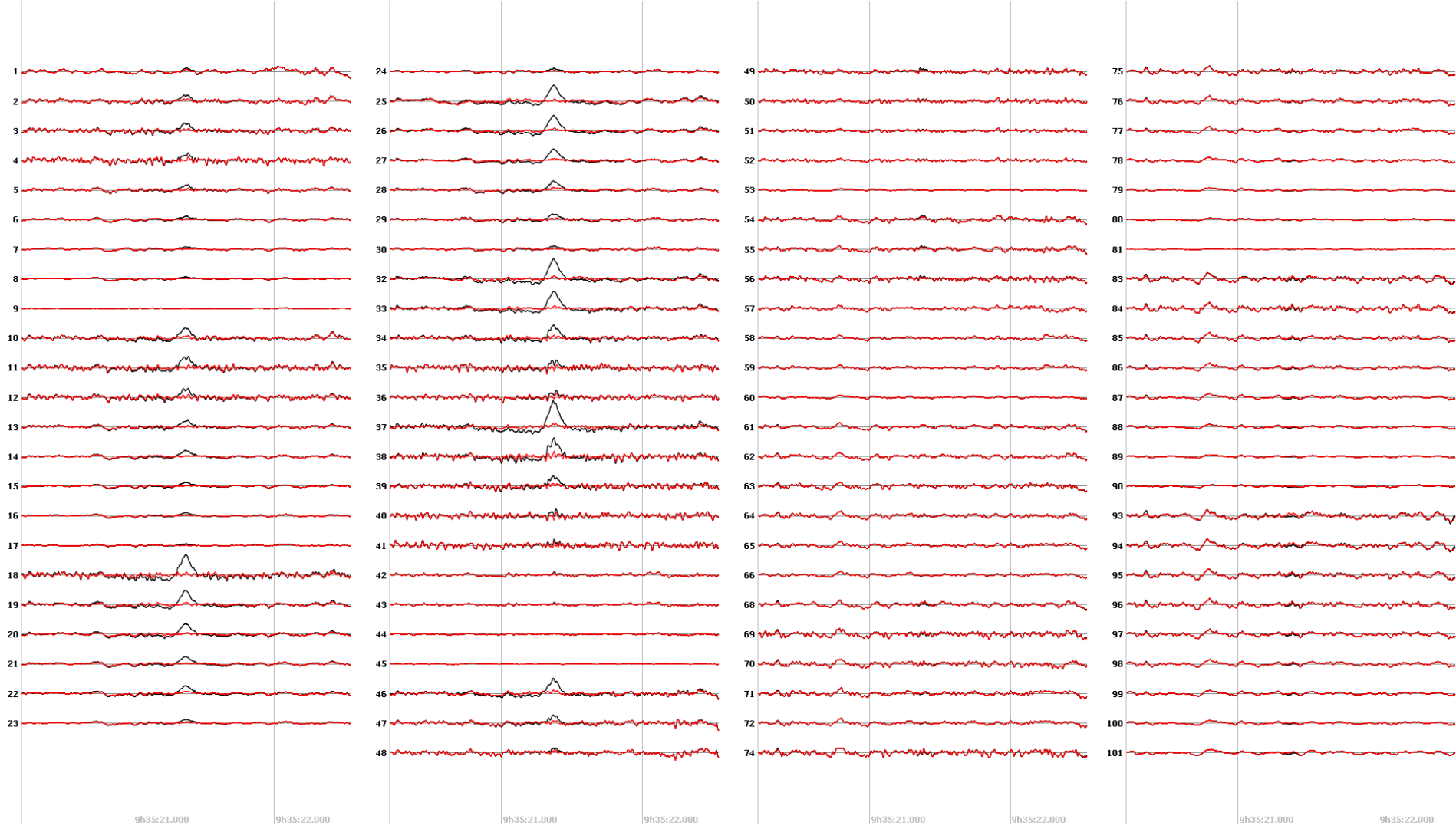
ICA – ECG artefact



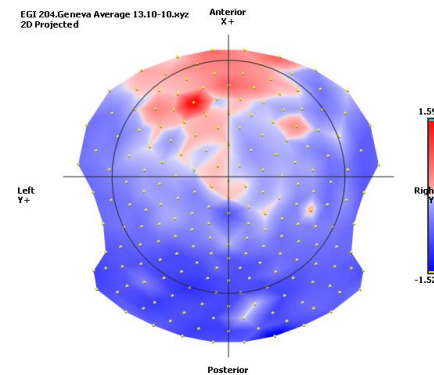
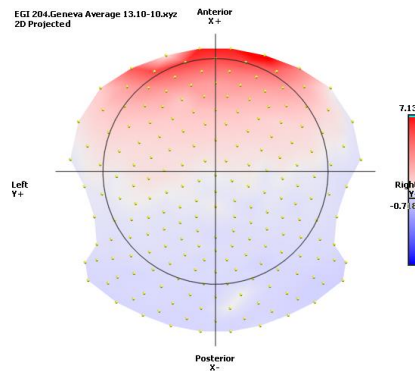
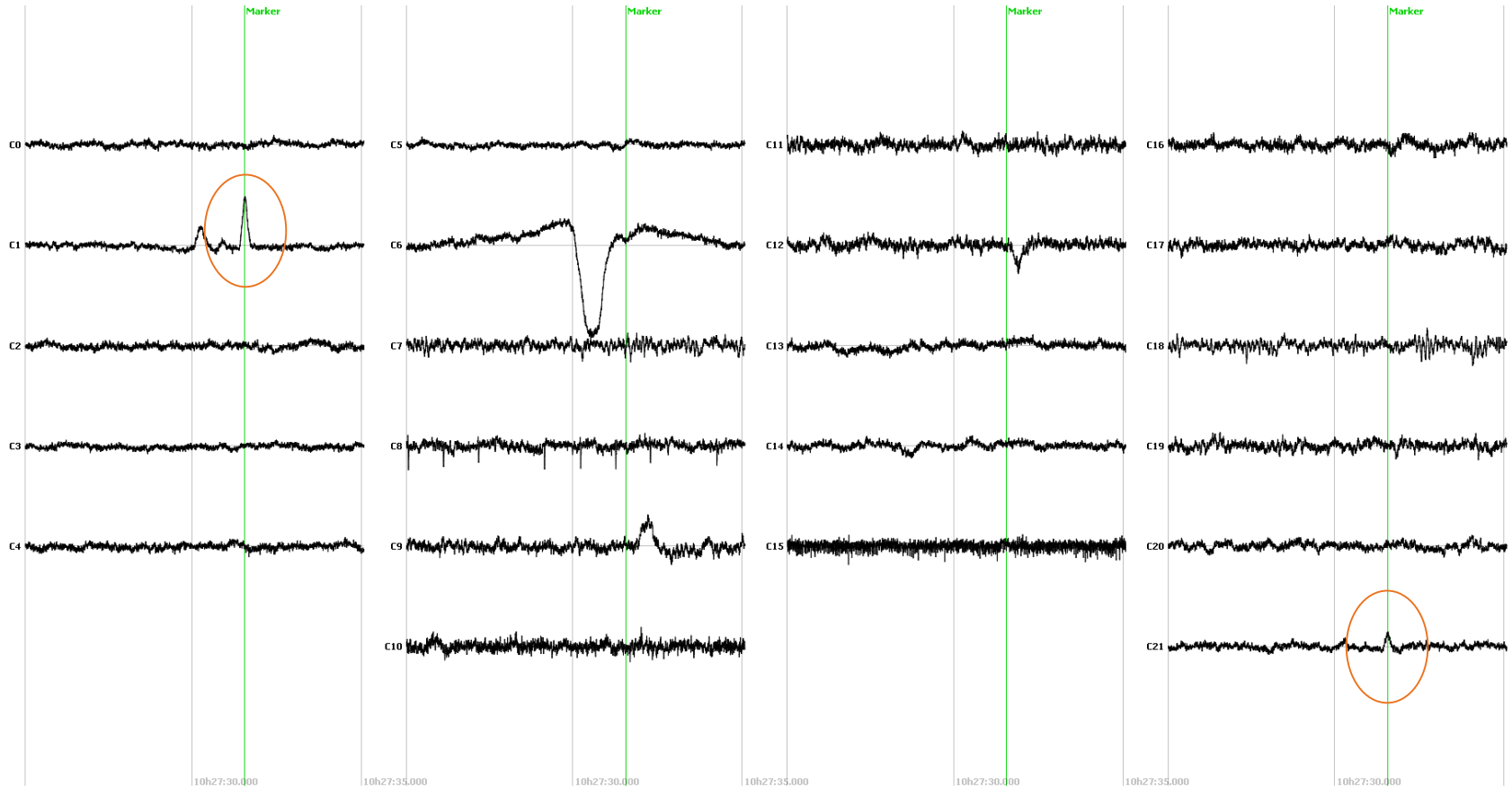
EGI 204.Geneva Average 13.10-10.xyz
2D Projected



ICA – comparison before/after



ICA – small time length of the data



Filtration

- High pass (HP) – suppression of DC and slow trends in the data
- Low pass (LP) – suppression of high frequencies, smoothing
- Notch (narrow-band stop) – suppression of narrow band artefacts like AC 50 Hz noise
- Band pass (BP) – selection of frequency band of interest

Filtration

Filters

Butterworth Filters: [Hz] [Hz]

Filtering causality:

DC / 0Hz / Average removal:

Envelope Filter:

Rectification:

Averaging window: [ms]

Notch(es) Filter(s):

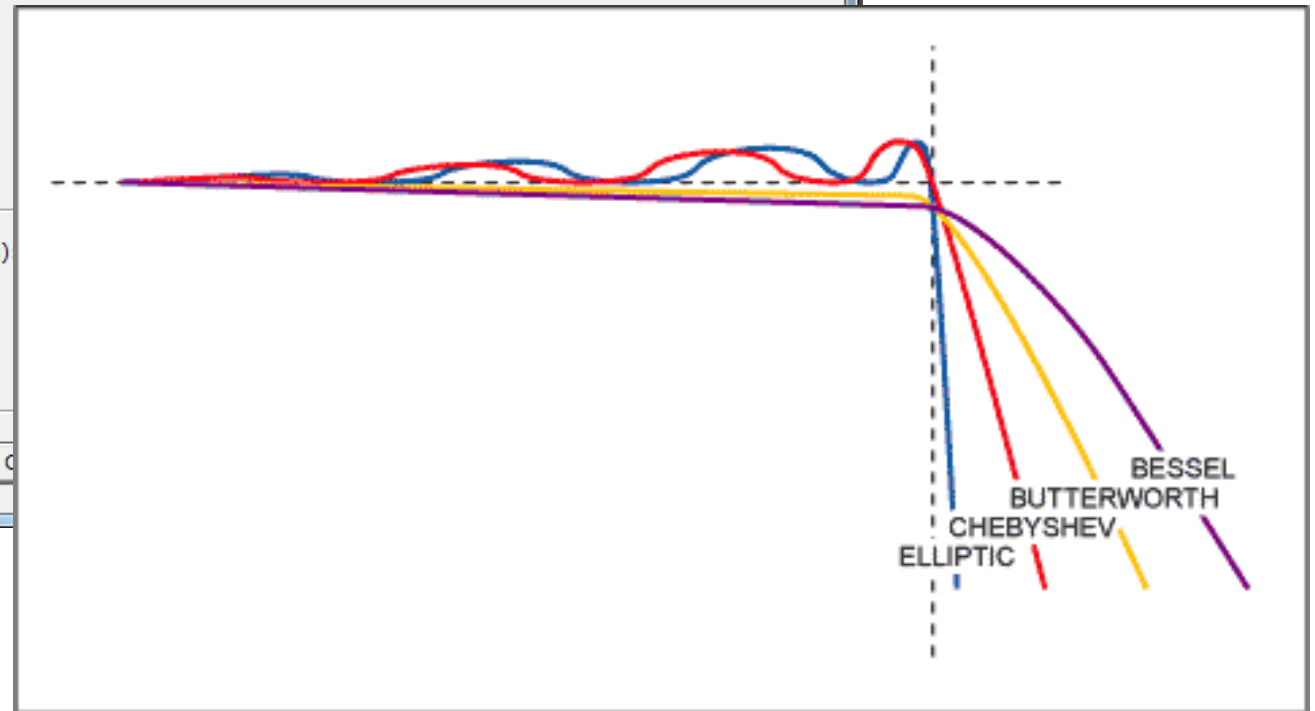
Thresholding:

Options

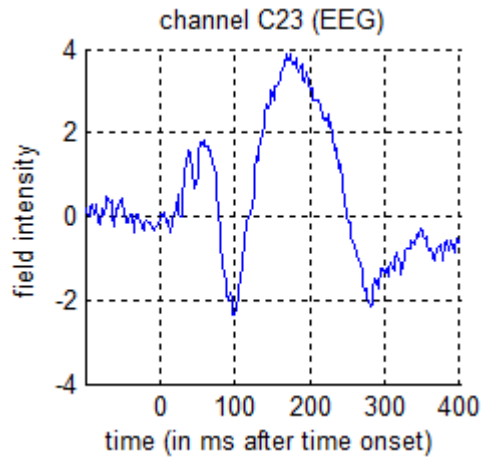
Sampling Frequency (set if missing):

Also apply filters to:

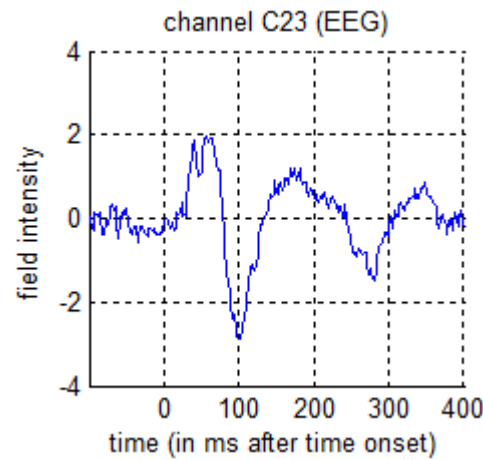
Switch On / Off all filters set:



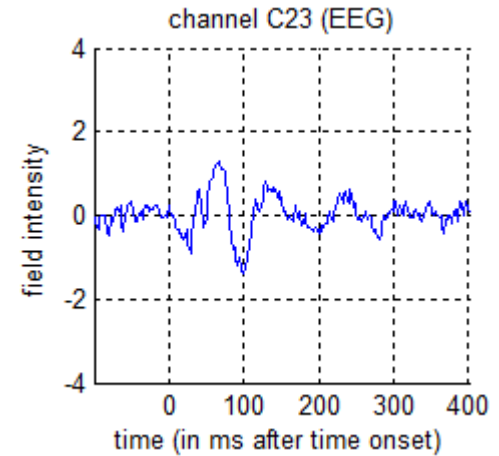
Filtration



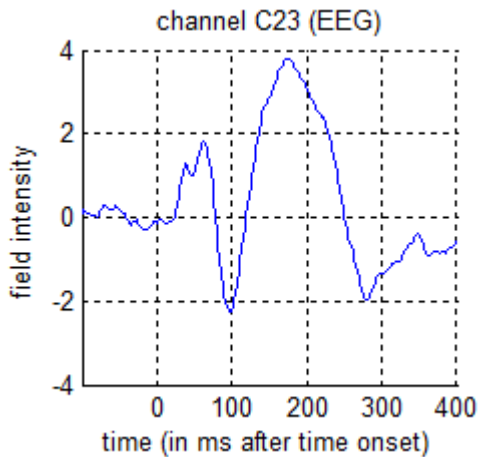
Unfiltered



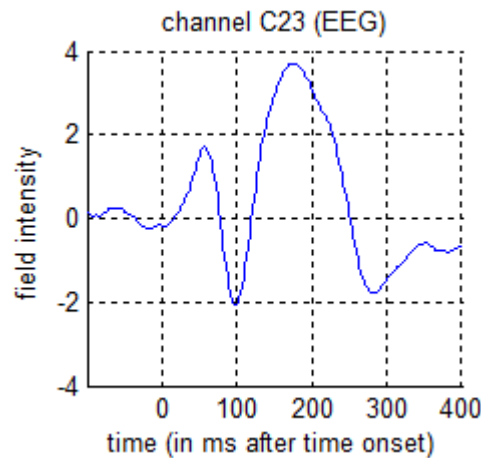
5Hz HP



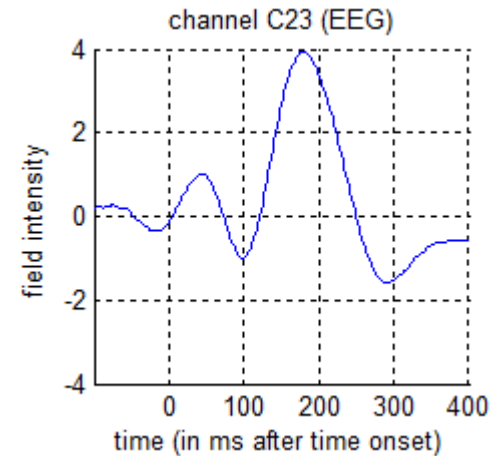
10Hz HP



45Hz LP

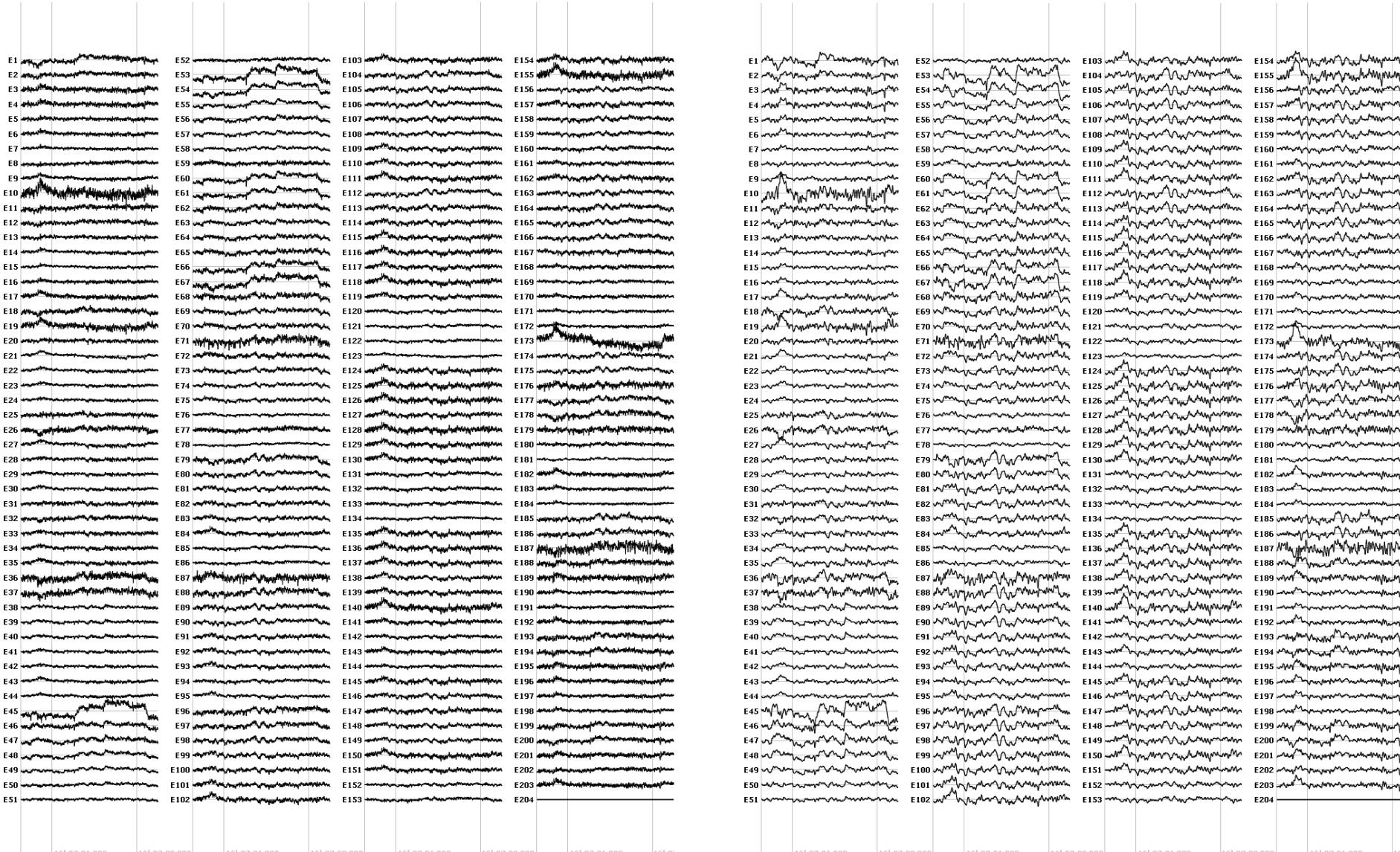


20Hz LP

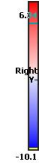
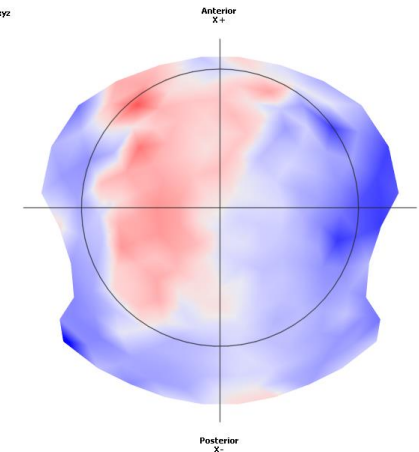
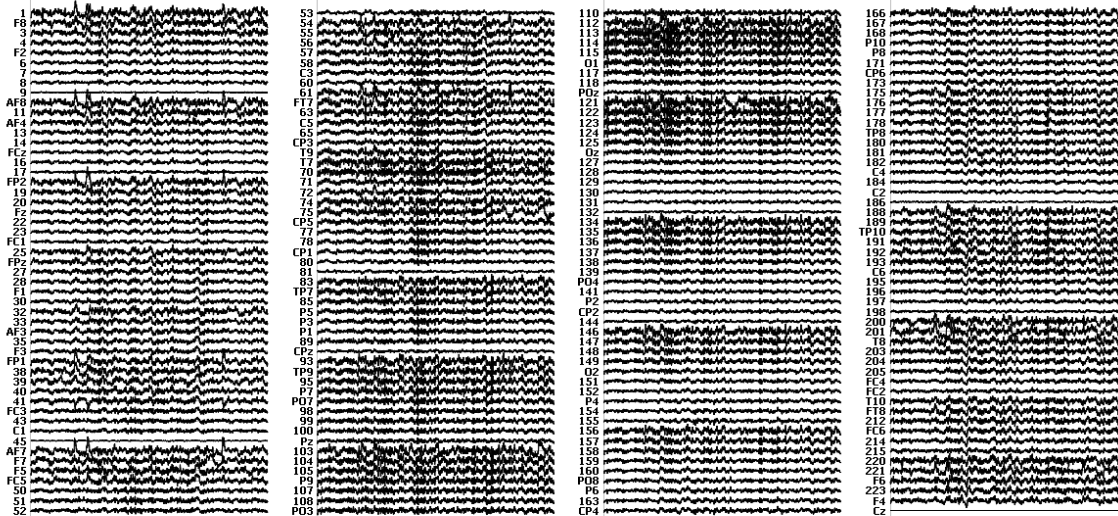
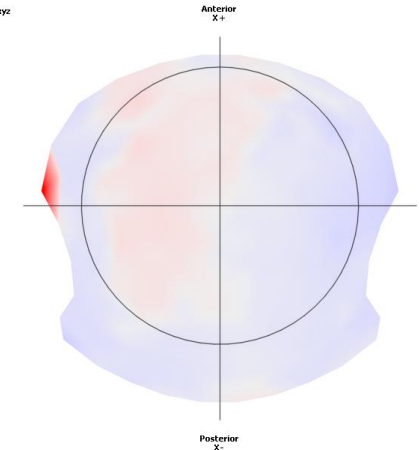
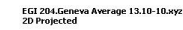
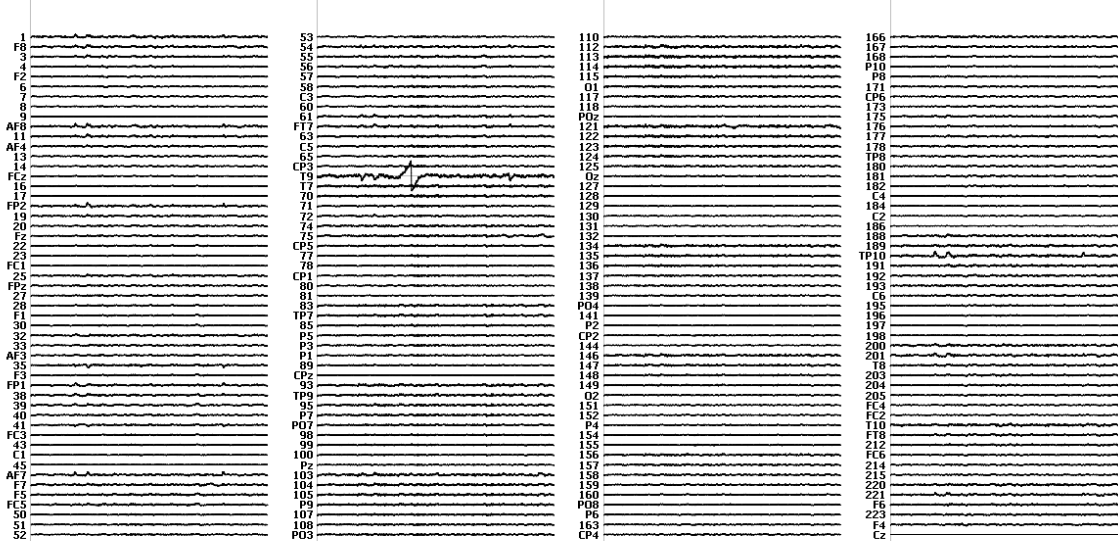


10Hz LP

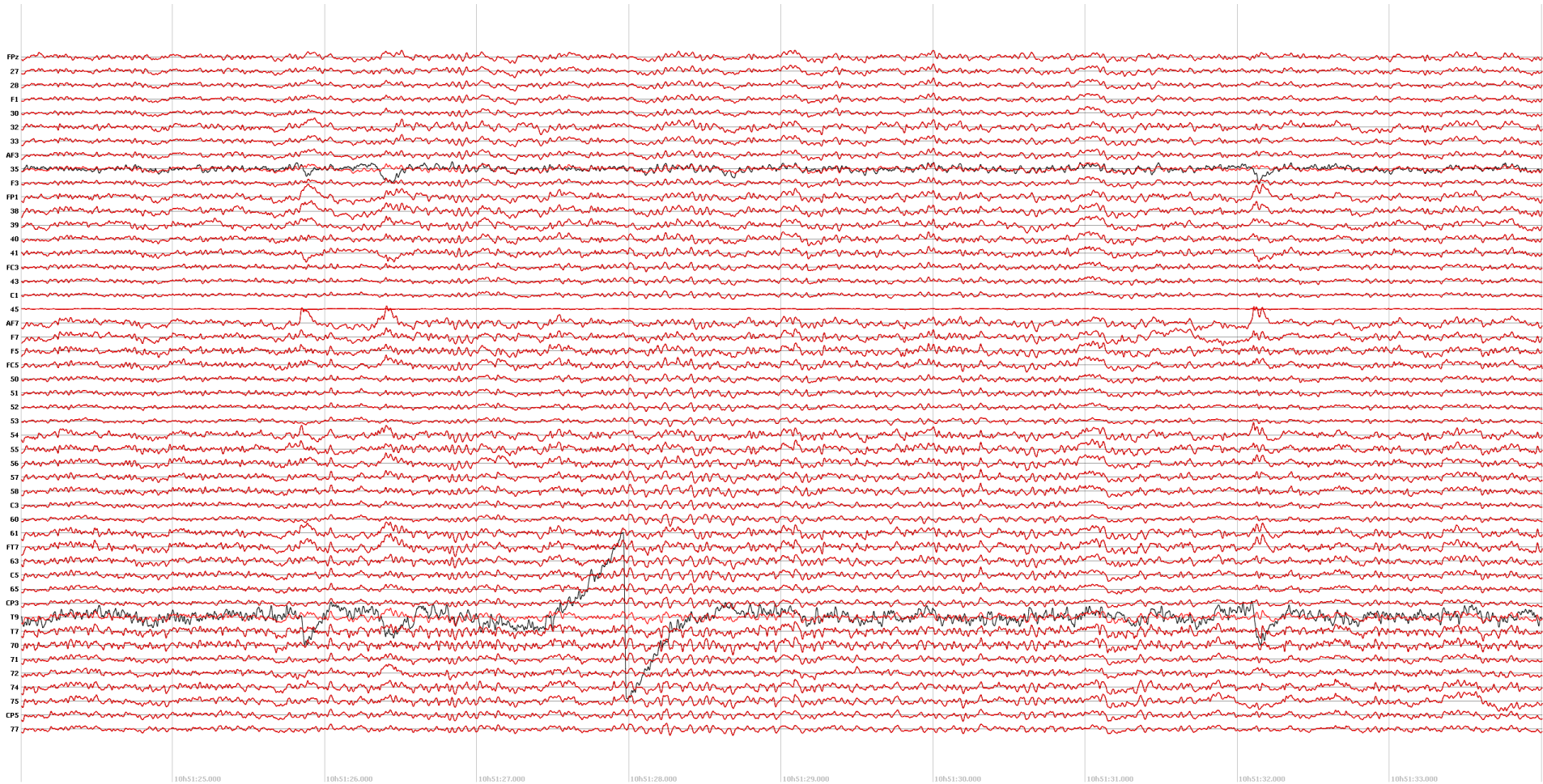
Filtration



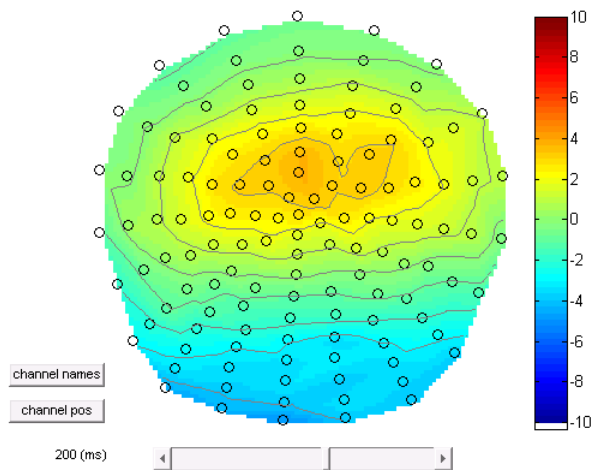
Interpolation



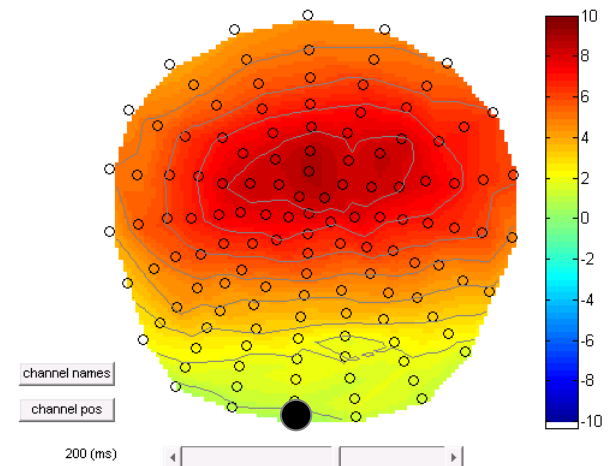
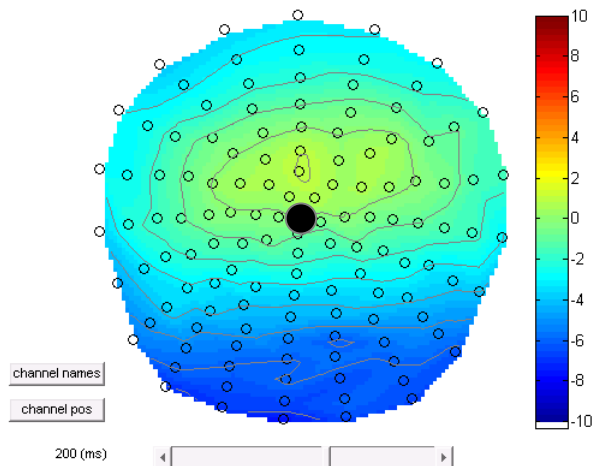
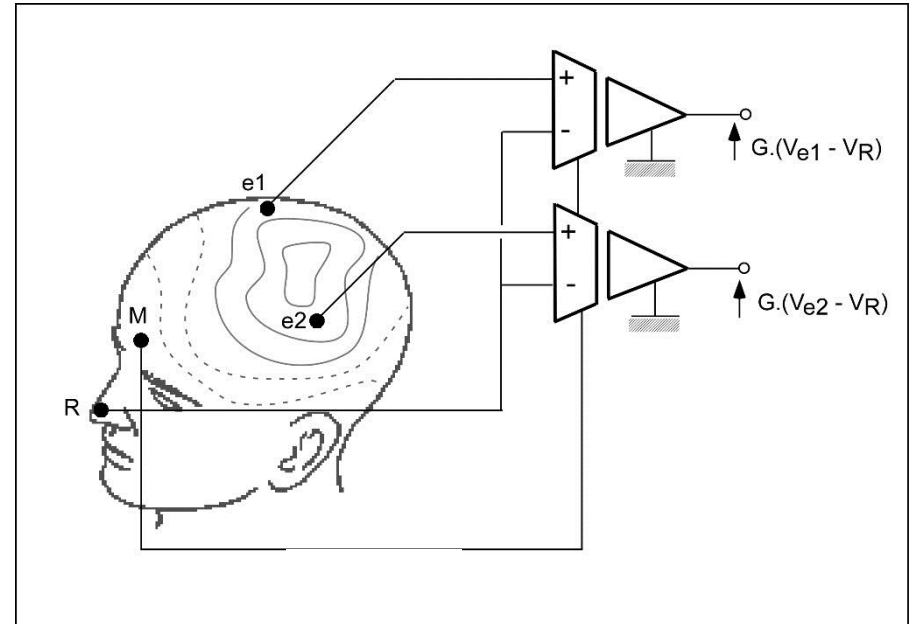
Interpolation



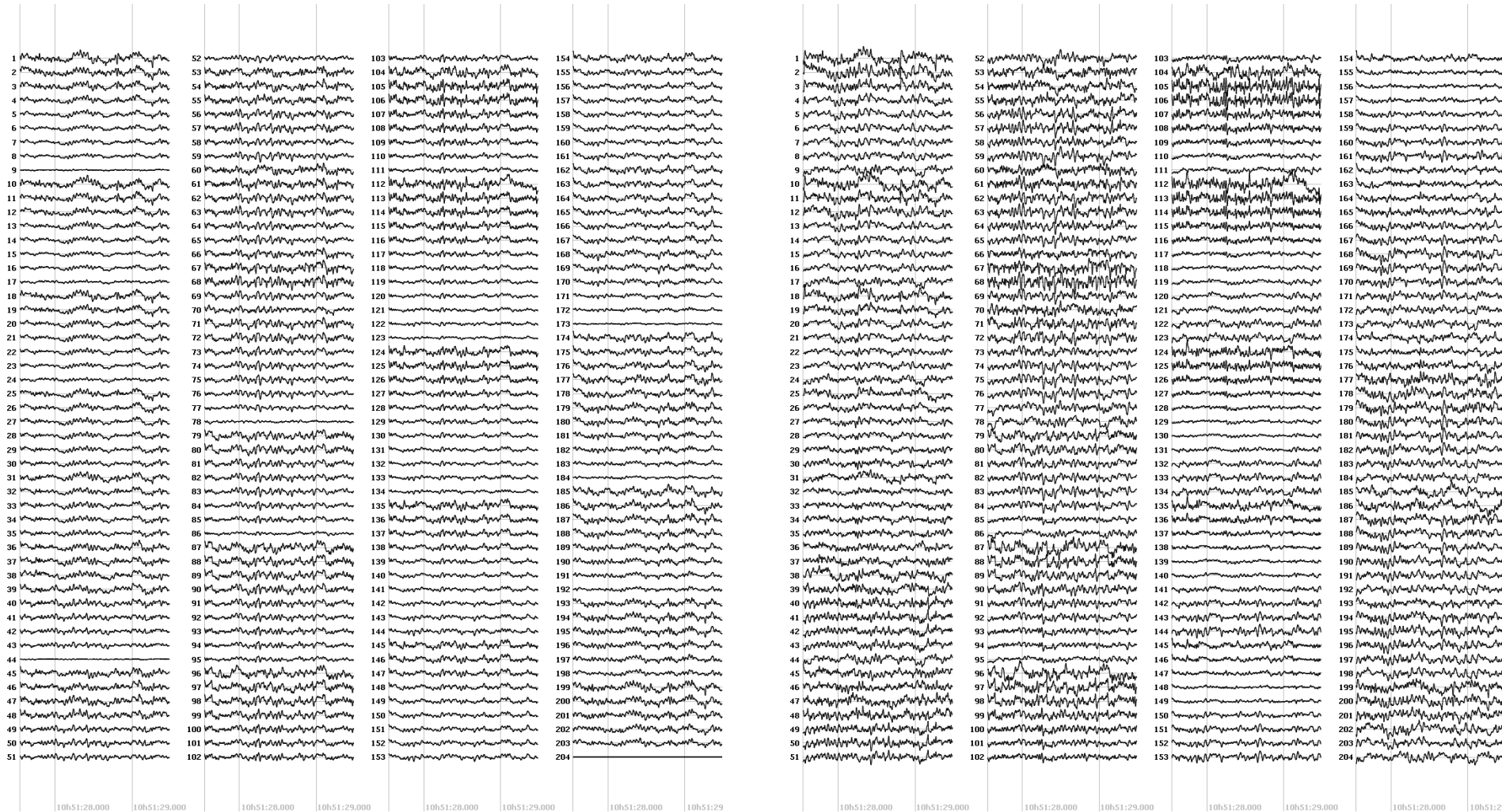
Reference, montages



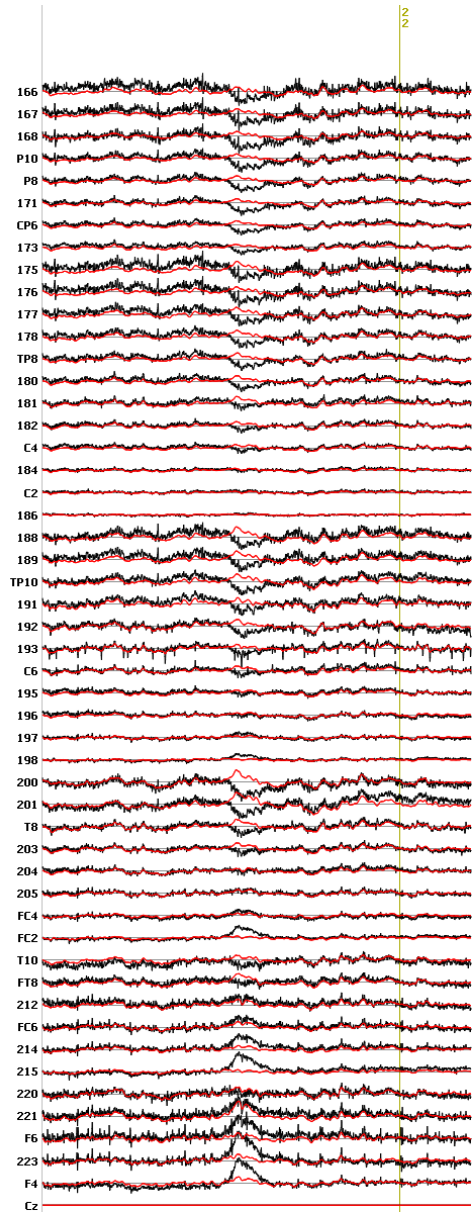
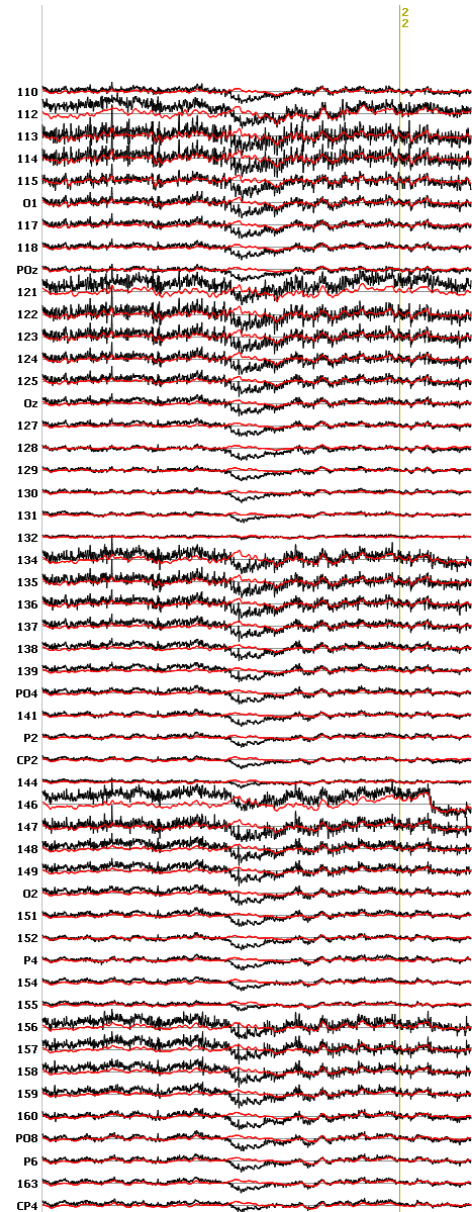
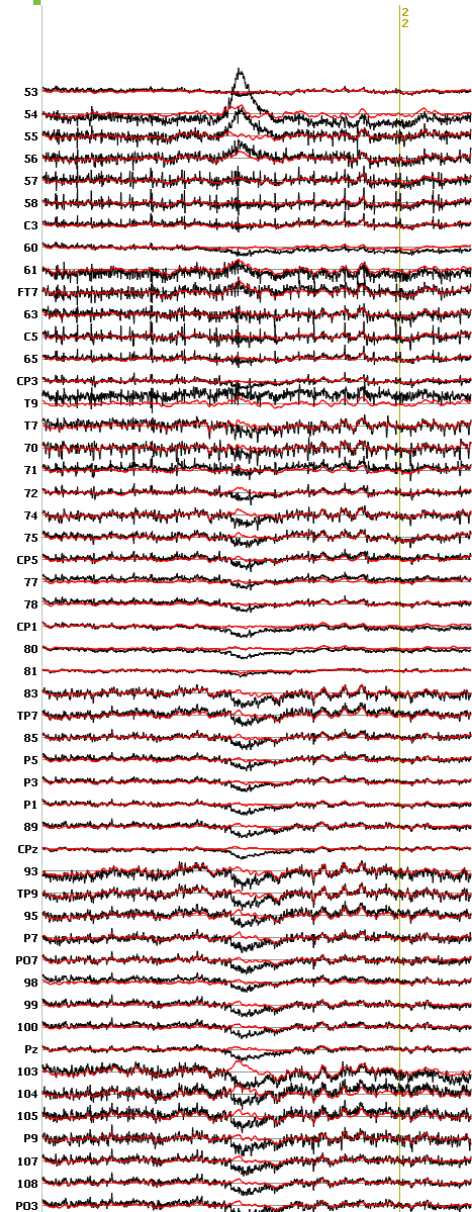
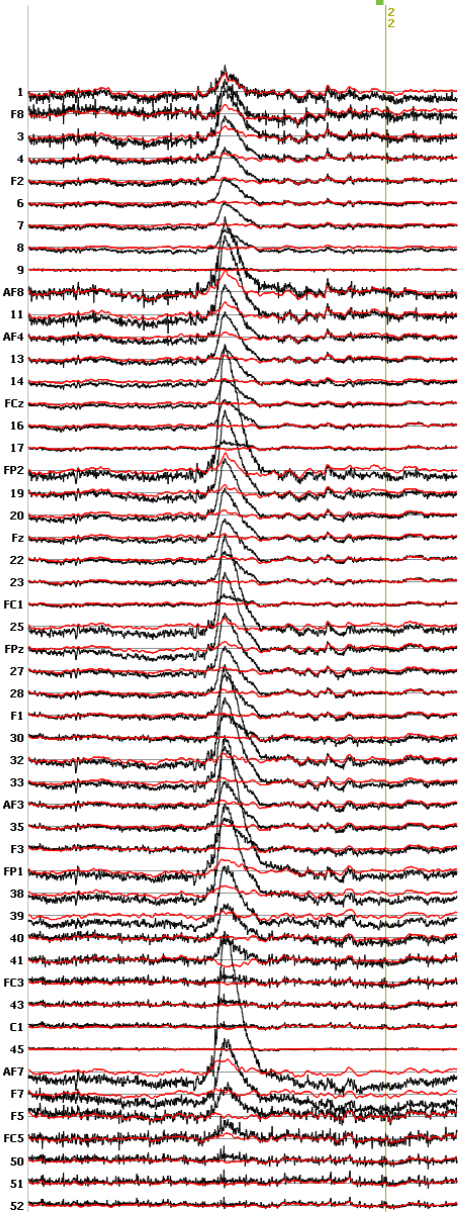
Average reference



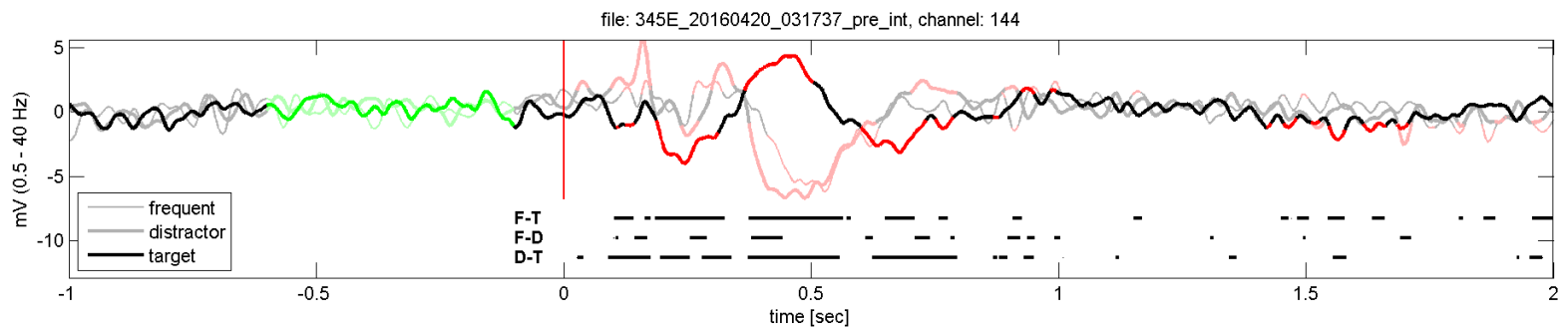
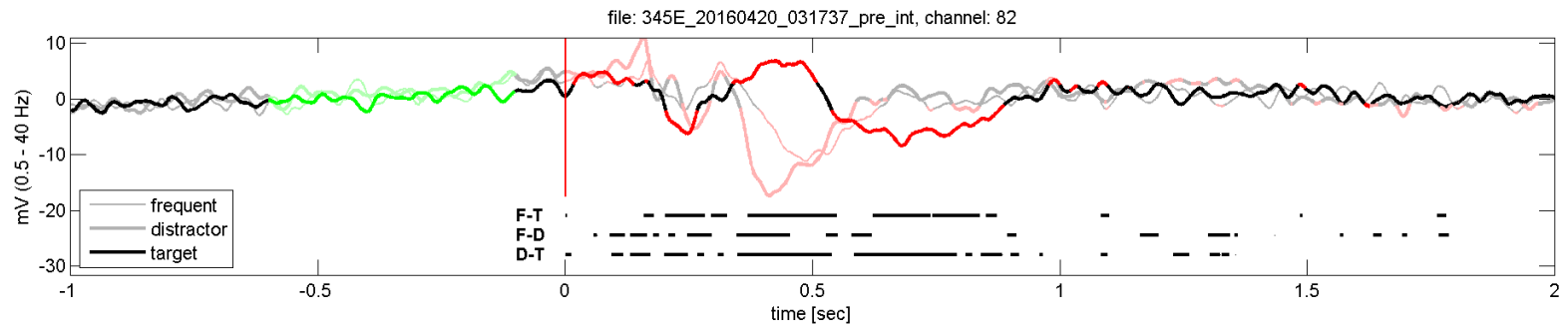
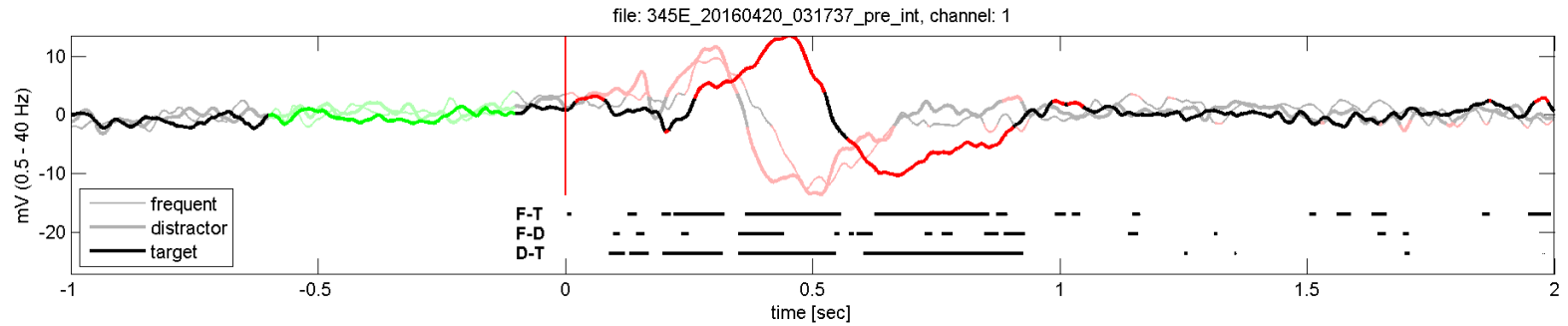
Reference Cz vs Average



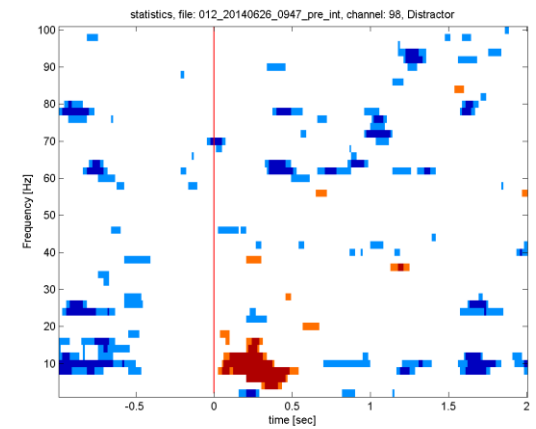
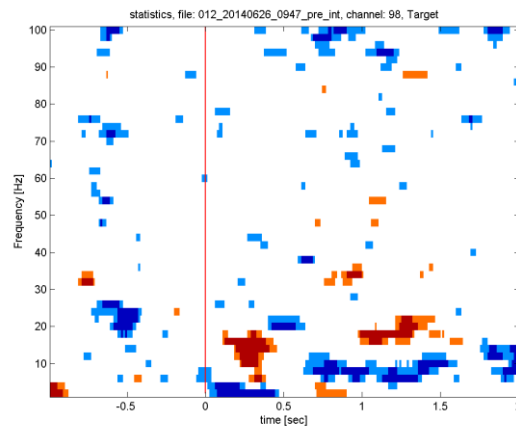
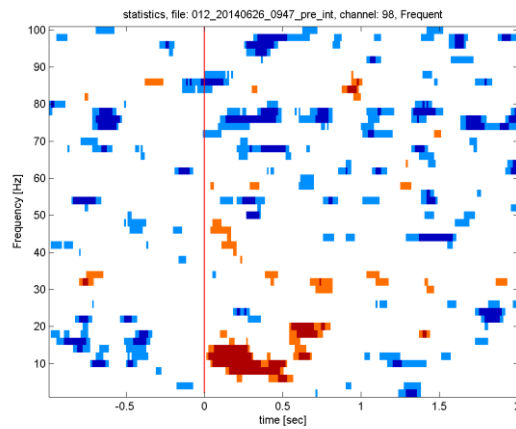
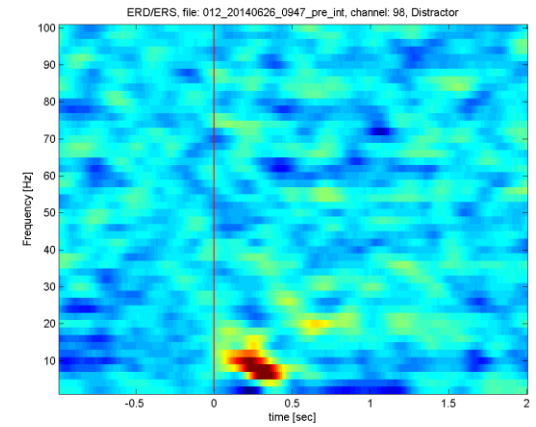
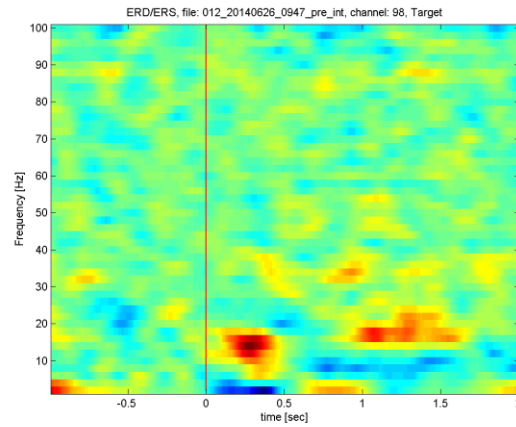
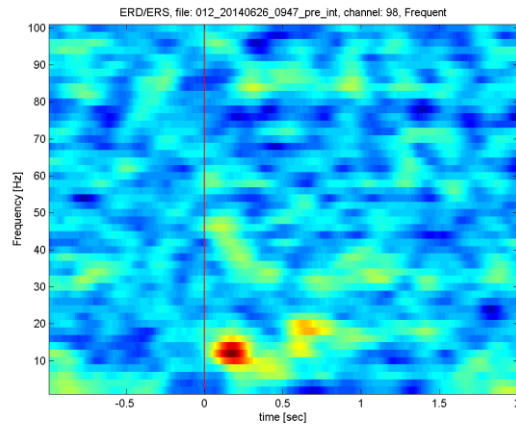
Raw vs preprocessed data



Event-related potentials (ERP)

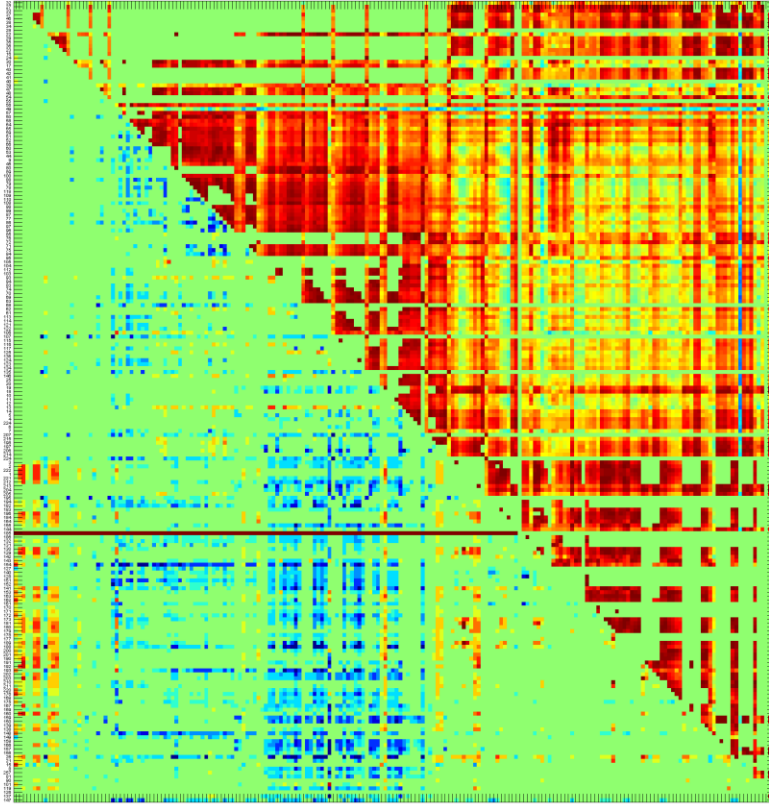


Time-frequency analysis

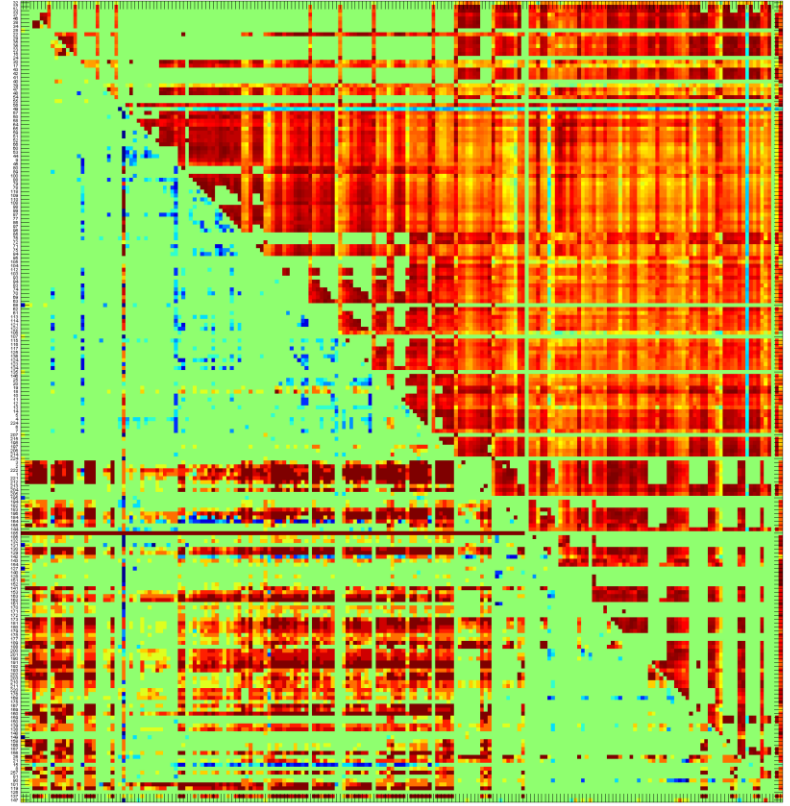


Functional connectivity on scalp

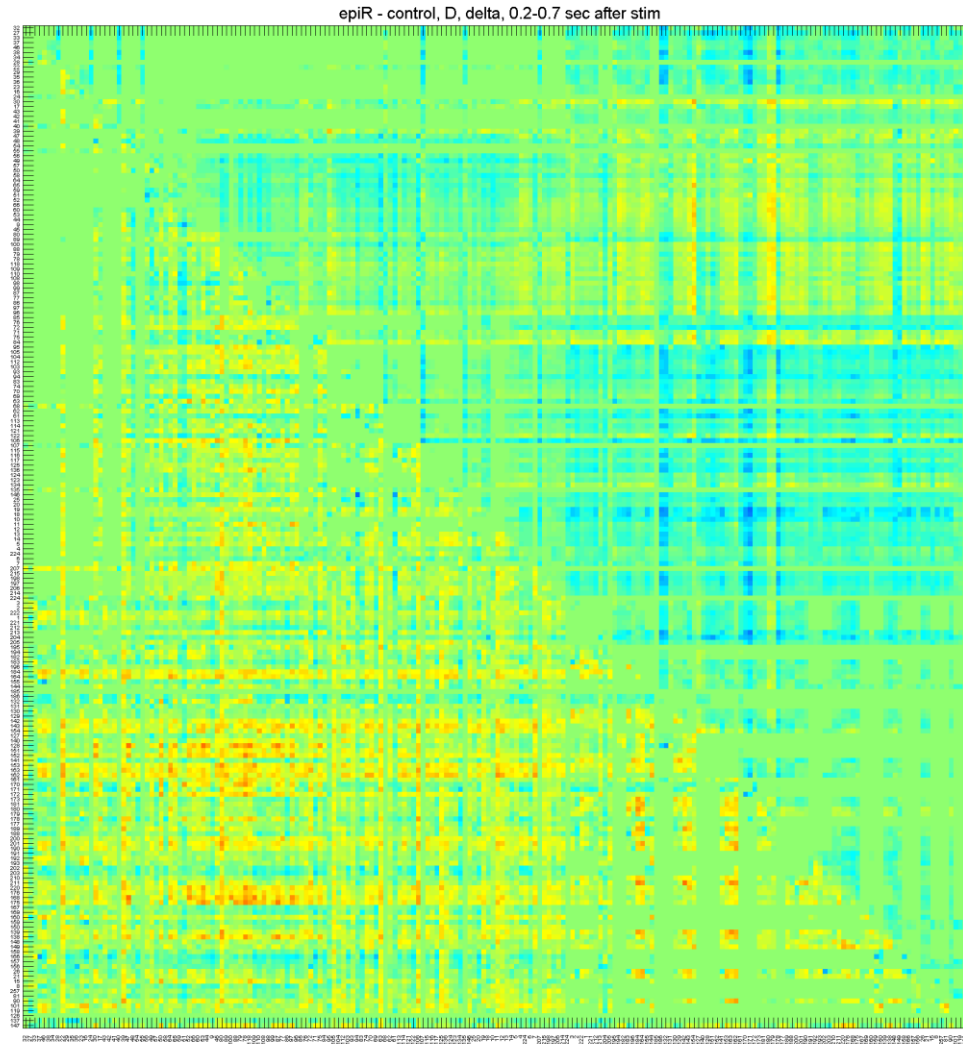
301E_20160310_121840_pre_int_alpha, Frequent, time: 0.2-0.7 sec after stim



301E_20160310_121840_pre_int_alpha, Target, time: 0.2-0.7 sec after stim



Functional connectivity on scalp



Thank you for your attention



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