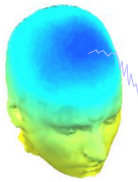
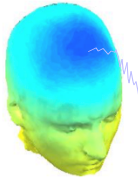


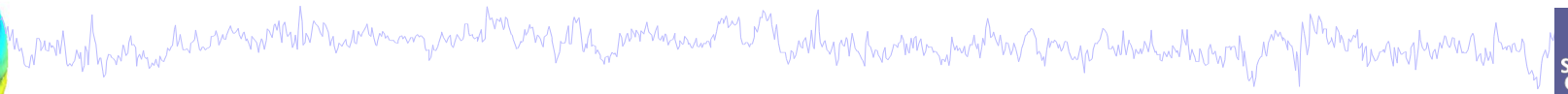
ICA Decomposition of EEG Data

EEGLAB Workshop XXVI
Ben-Gurion University, Be'er-Sheva, Israel
Day 1

John Iversen

Independent Component Analysis



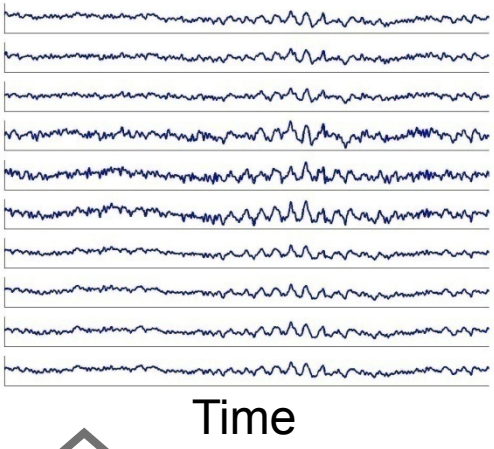


Swartz Center for Computational Neuroscience

x = scalp EEG

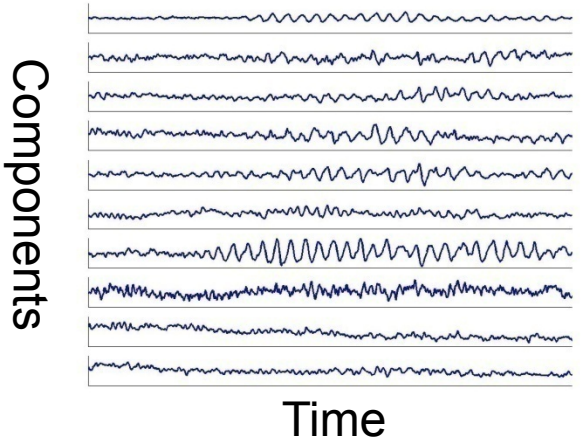
W = unmixing matrix

u = sources



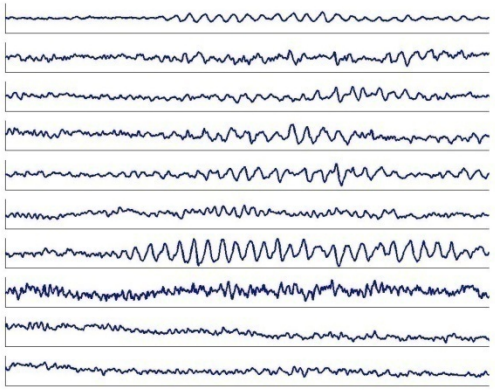
W*x = u

ICA



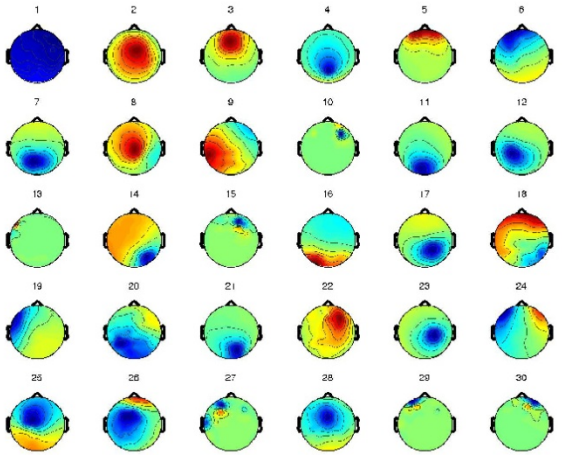
x = W^{-1}*u

u = sources

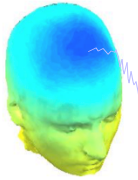


*

W^{-1} (scalp projections)



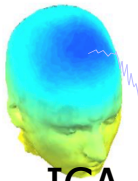
Review: ICA in Plain English



Source activation = unmixing * Channel data

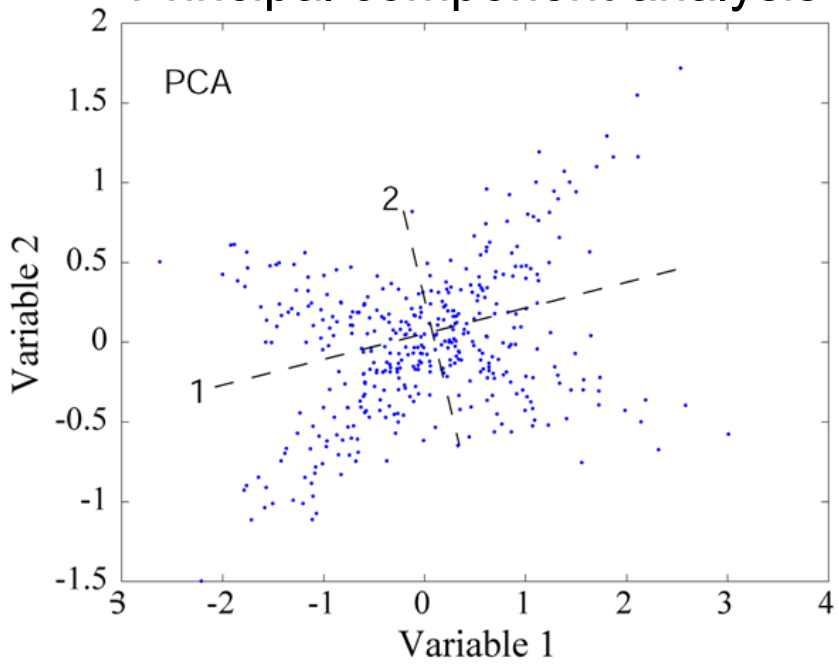
Channel data = mixing (topo) * Source activation

ICA and PCA

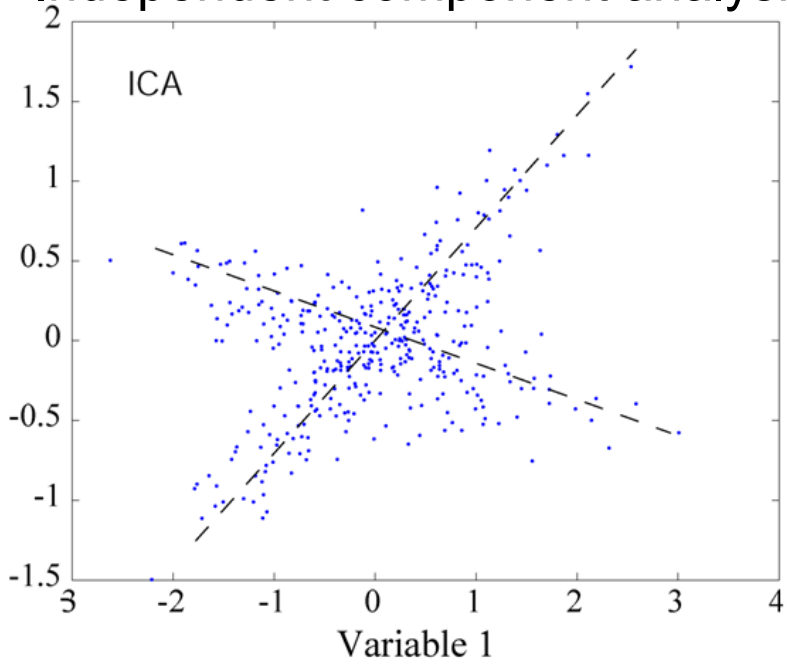


ICA is a method to recover a version of the original sources by multiplying the data by an unmixing matrix,

Principal component analysis

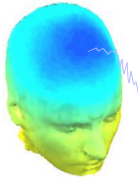


Independent component analysis

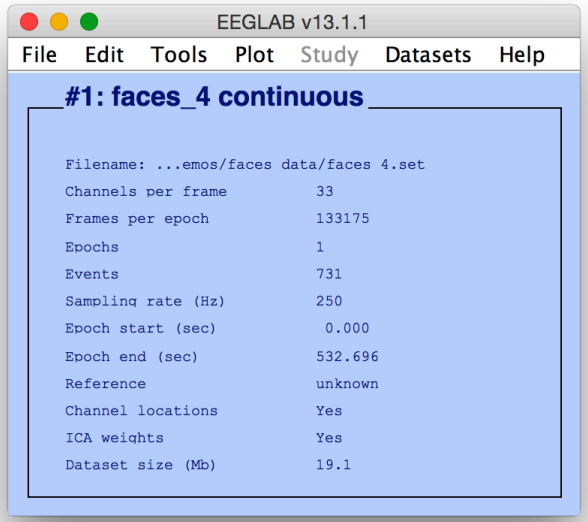


While PCA simply decorrelates the outputs (using an orthogonal mixing matrix), ICA attempts to make the outputs **statistically independent**, while placing no constraints on the mixing matrix.

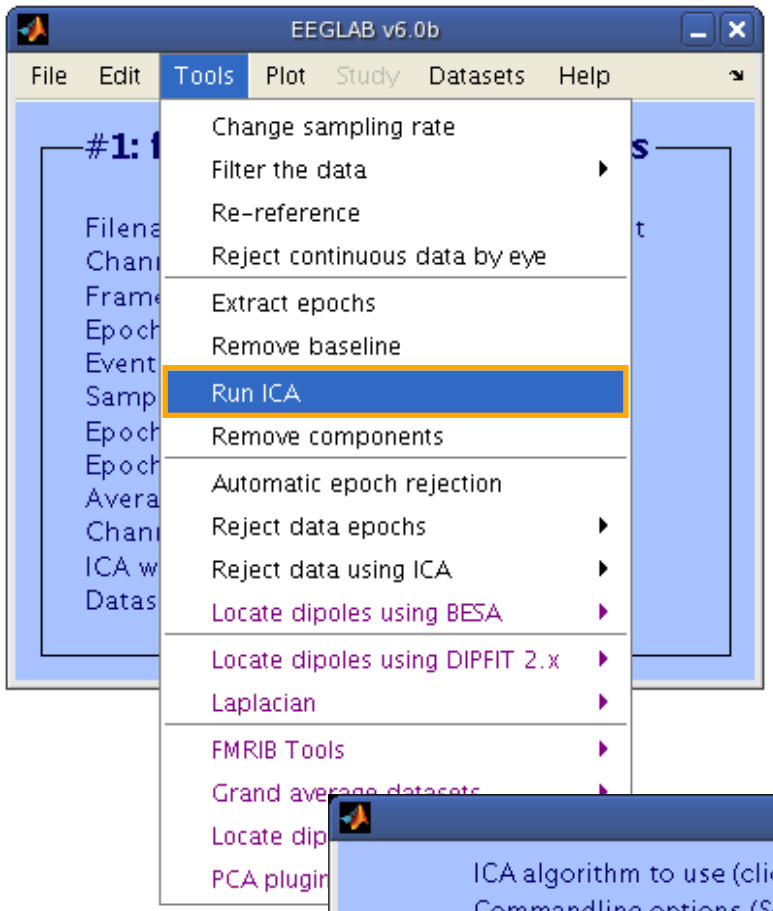
(Example Datasets)



Load: EEG_data/faces_4.set



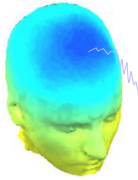
ICA options

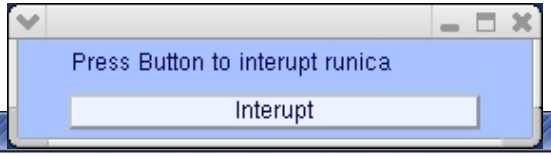


Option	Default	Comments
'extended'	0	1 is recommended to find sub-gaussians
'stop'	1e-7	final weight change → stop
'lrate'	determined from data	too small → too long… too large → wts blow up
'maxsteps'	512	more channels → more steps
'pca'	0 or EEG.nbchan	Decompose only a principal data subspace

Other algorithms:
binica, amica, cudaica, beamica

Runica progress…





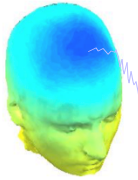
csh

```
Input data size [33,133175] = 33 channels, 133175 frames/nFinding 33 ICA components using extended ICA.
Kurtosis will be calculated initially every 1 blocks using 6000 data points.
Decomposing 122 frames per ICA weight ((1089)^2 = 133175 weights, Initial learning rate will be 0.001, block size
Learning rate will be multiplied by 0.98 whenever angledelta >= 60 deg.
More than 32 channels: default stopping weight change 1E-7
Training will end when wchange < 1e-07 or after 512 steps.
Online bias adjustment will be used.
Removing mean of each channel ...
Final training data range: -171.806 to 179.094
Computing the sphering matrix...
Starting weights are the identity matrix ...
Sphering the data ...
Beginning ICA training ... first training step may be slow ...
step 1 - lrate 0.001000, wchange 16.85061324, angledelta  0.0 deg
step 2 - lrate 0.001000, wchange 0.26760405, angledelta  0.0 deg
step 3 - lrate 0.001000, wchange 0.79058323, angledelta 104.0 deg
step 4 - lrate 0.000980, wchange 0.66700031, angledelta 147.2 deg
step 5 - lrate 0.000960, wchange 0.62849071, angledelta 146.5 deg
step 6 - lrate 0.000941, wchange 0.73967955, angledelta 150.7 deg
step 7 - lrate 0.000922, wchange 0.73727229, angledelta 151.6 deg
step 8 - lrate 0.000904, wchange 0.74051387, angledelta 137.9 deg
step 9 - lrate 0.000886, wchange 0.74536137, angledelta 156.0 deg
step 10 - lrate 0.000868, wchange 0.72101402, angledelta 143.7 deg
step 11 - lrate 0.000851, wchange 0.14690114, angledelta 102.5 deg
step 12 - lrate 0.000834, wchange 0.11822100, angledelta 114.3 deg
step 13 - lrate 0.000817, wchange 0.75552966, angledelta 100.6 deg
step 14 - lrate 0.000801, wchange 0.26739750, angledelta 109.1 deg
step 15 - lrate 0.000785, wchange 0.12123251, angledelta 94.2 deg
step 16 - lrate 0.000769, wchange 0.10285606, angledelta 110.7 deg
step 17 - lrate 0.000754, wchange 0.09770499, angledelta 118.6 deg
step 18 - lrate 0.000739, wchange 0.09544428, angledelta 117.1 deg
```

csh

```
step 241 - lrate 0.000002, wchange 0.00000082, angledelta 101.5 deg
step 242 - lrate 0.000001, wchange 0.00000061, angledelta 96.1 deg
step 243 - lrate 0.000001, wchange 0.00000057, angledelta 97.5 deg
step 244 - lrate 0.000001, wchange 0.00000054, angledelta 93.7 deg
step 245 - lrate 0.000001, wchange 0.00000055, angledelta 100.3 deg
step 246 - lrate 0.000001, wchange 0.00000047, angledelta 96.9 deg
step 247 - lrate 0.000001, wchange 0.00000046, angledelta 91.3 deg
step 248 - lrate 0.000001, wchange 0.00000045, angledelta 101.5 deg
step 249 - lrate 0.000001, wchange 0.00000041, angledelta 103.1 deg
step 250 - lrate 0.000001, wchange 0.00000036, angledelta 95.5 deg
step 251 - lrate 0.000001, wchange 0.00000033, angledelta 92.1 deg
step 252 - lrate 0.000001, wchange 0.00000029, angledelta 97.4 deg
step 253 - lrate 0.000001, wchange 0.00000030, angledelta 95.8 deg
step 254 - lrate 0.000001, wchange 0.00000023, angledelta 94.2 deg
step 255 - lrate 0.000001, wchange 0.00000023, angledelta 97.6 deg
step 256 - lrate 0.000001, wchange 0.00000023, angledelta 97.1 deg
step 257 - lrate 0.000001, wchange 0.00000021, angledelta 92.0 deg
step 258 - lrate 0.000001, wchange 0.00000020, angledelta 99.1 deg
step 259 - lrate 0.000001, wchange 0.00000019, angledelta 95.0 deg
step 260 - lrate 0.000001, wchange 0.00000015, angledelta 98.3 deg
step 261 - lrate 0.000001, wchange 0.00000014, angledelta 99.0 deg
step 262 - lrate 0.000001, wchange 0.00000014, angledelta 94.3 deg
step 263 - lrate 0.000001, wchange 0.00000013, angledelta 95.4 deg
step 264 - lrate 0.000001, wchange 0.00000012, angledelta 94.1 deg
step 265 - lrate 0.000001, wchange 0.00000011, angledelta 96.1 deg
step 266 - lrate 0.000001, wchange 0.00000010, angledelta 94.8 deg
step 267 - lrate 0.000001, wchange 0.00000010, angledelta 94.5 deg
step 268 - lrate 0.000001, wchange 0.00000010, angledelta 97.7 deg
step 269 - lrate 0.000001, wchange 0.00000008, angledelta 95.1 deg
Sorting components in descending order of mean projected variance ...
Permuting the activation wave forms ...
>>
>>
```

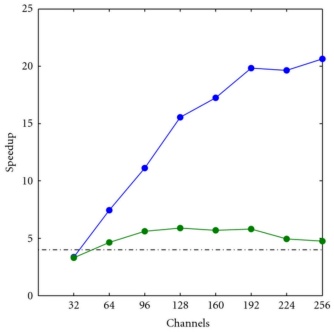
Alternatives to runica



Infomax ICA

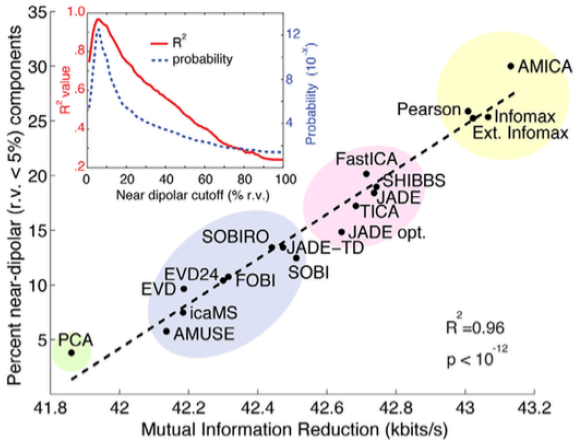
- `runica` matlab implementation
- `binica` compiled version; fast
- `cudaica` GPU version

Raimondo, et al, 2012, `https://liaa.dc.uba.ar/node/13`

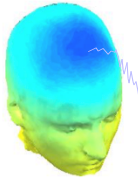


AMICA

- Best at extracting dipolar ICs
- Multiple-model support



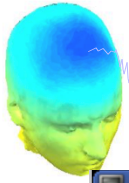
Review: ICA in Plain English

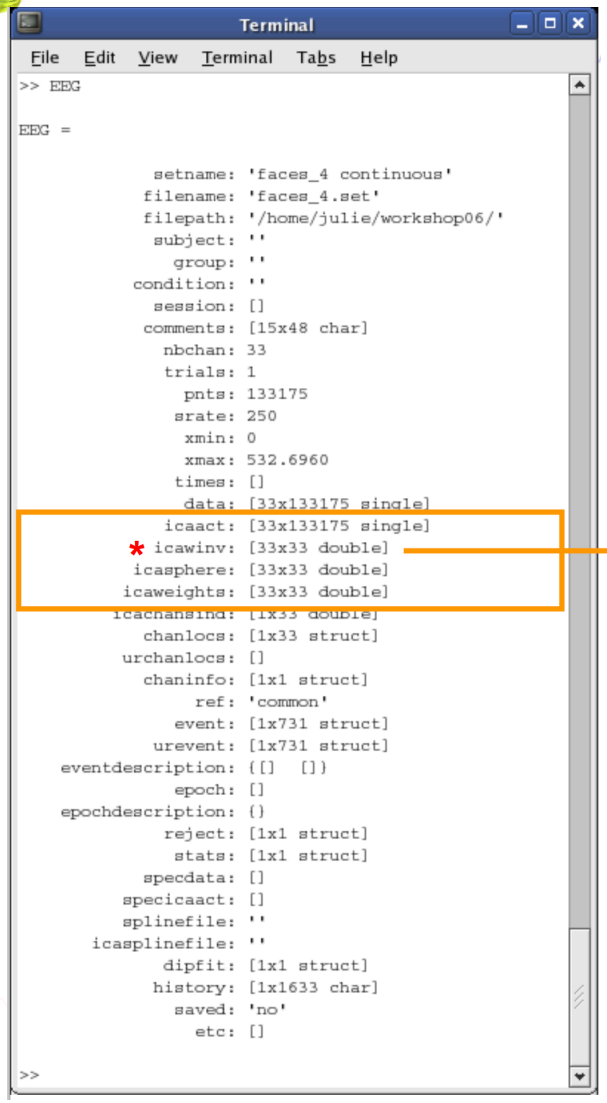


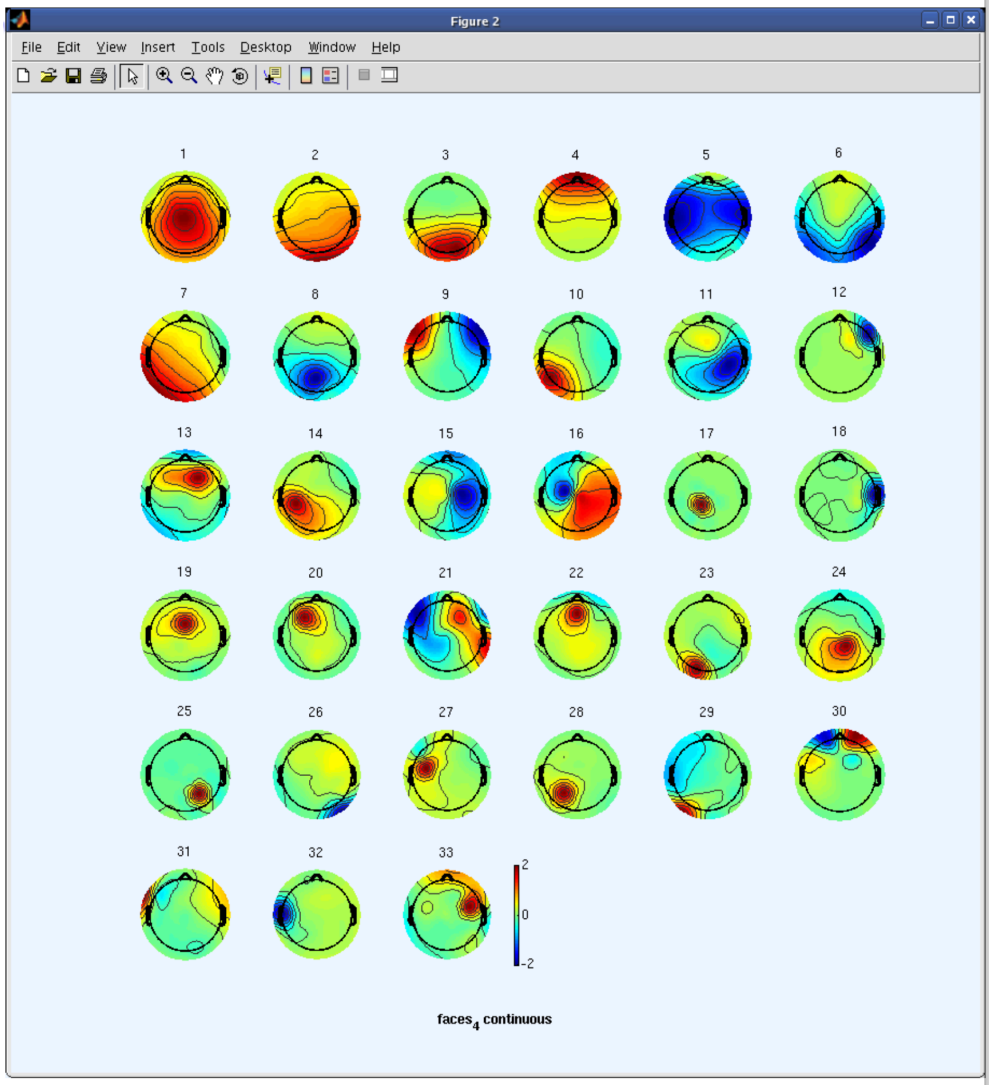
Source activation = unmixing * Channel data

Channel data = mixing (topo) * Source activation

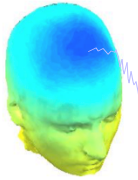
Results of ICA Decomposition in EEG struct







English → MATLAB



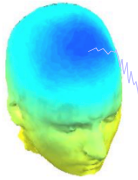
Source activation = unmixing * Channel data

Channel data = mixing (topo) * Source activation

```
EEG.icaact = (EEG.icaweights*EEG.icasphere) * EEG.data

EEG.data = EEG.icawinv * EEG.icaact
```

Now what…?



Part 1

Getting an overview of your ICs

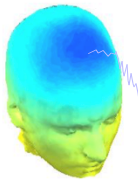
Part 2

Classifying/Evaluating ICs

Part 3

Detailed look at IC properties

- ERP
- Spectrum
- ERP images
- ERSP

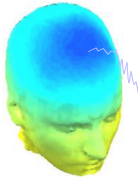


Evaluating ICA Components

EEGLAB Workshop XXVI
Ben-Gurion University, Be'er-Sheva, Israel
Day 1

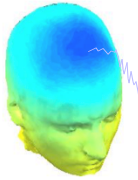
John Iversen

IC Evaluation Practicum (Day 1)

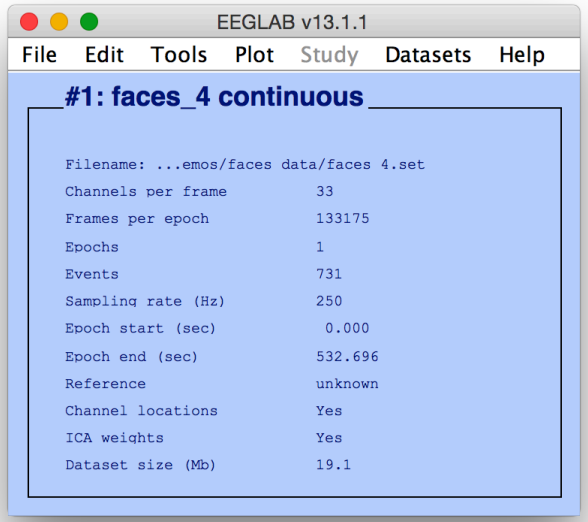


- **ICA Component Classifier Competition**
- **Traditional Practicum using faces_4.set**

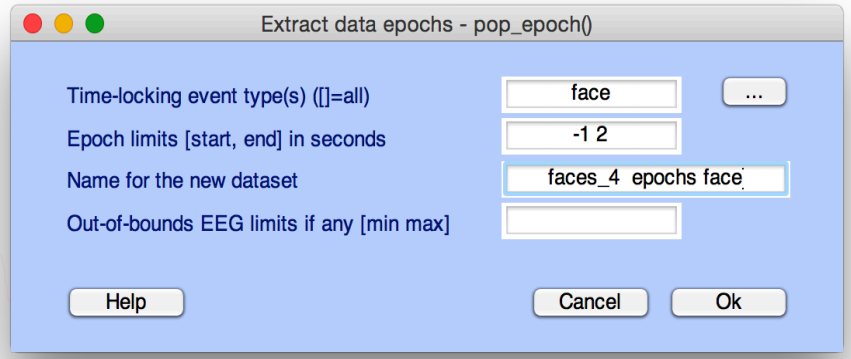
(Example Datasets)

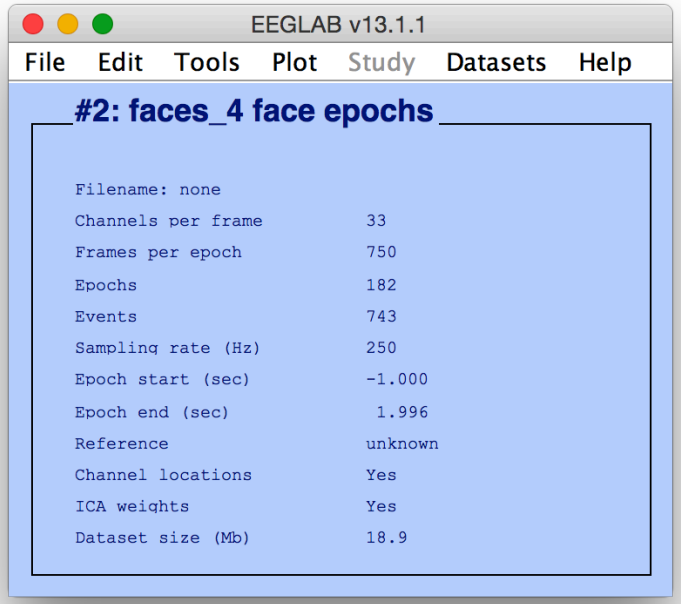


Load: EEG_data/faces_4.set



Tools → Extract Epochs

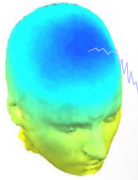


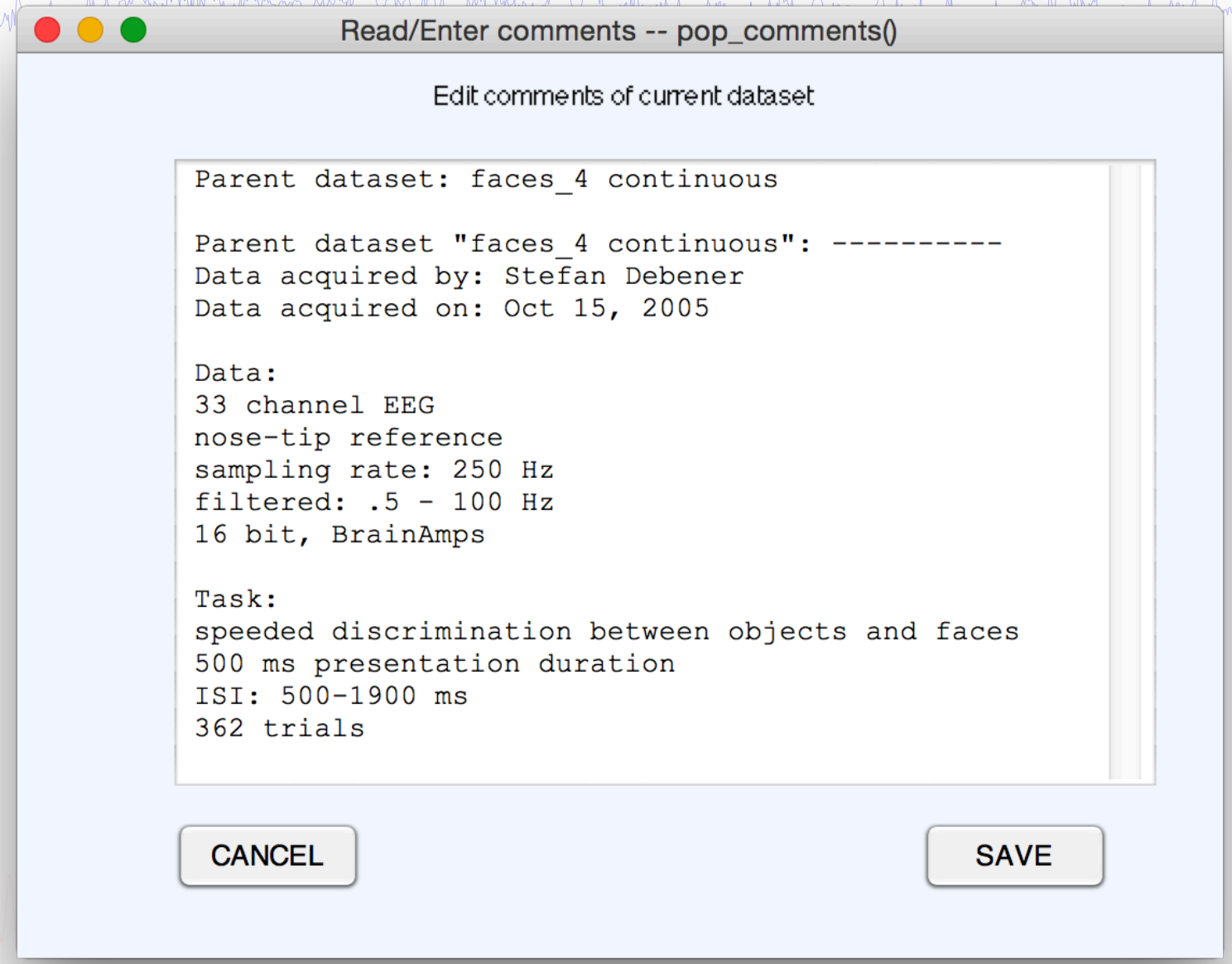


Subtract Baseline [-1000 0]

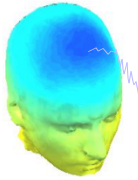
(Some other examples use stern_125Hz.set)

Edit → Dataset Info → Enter Comments





Now what…?



Part 1

Getting an overview of your ICs

Part 2

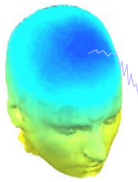
Classifying/Evaluating ICs

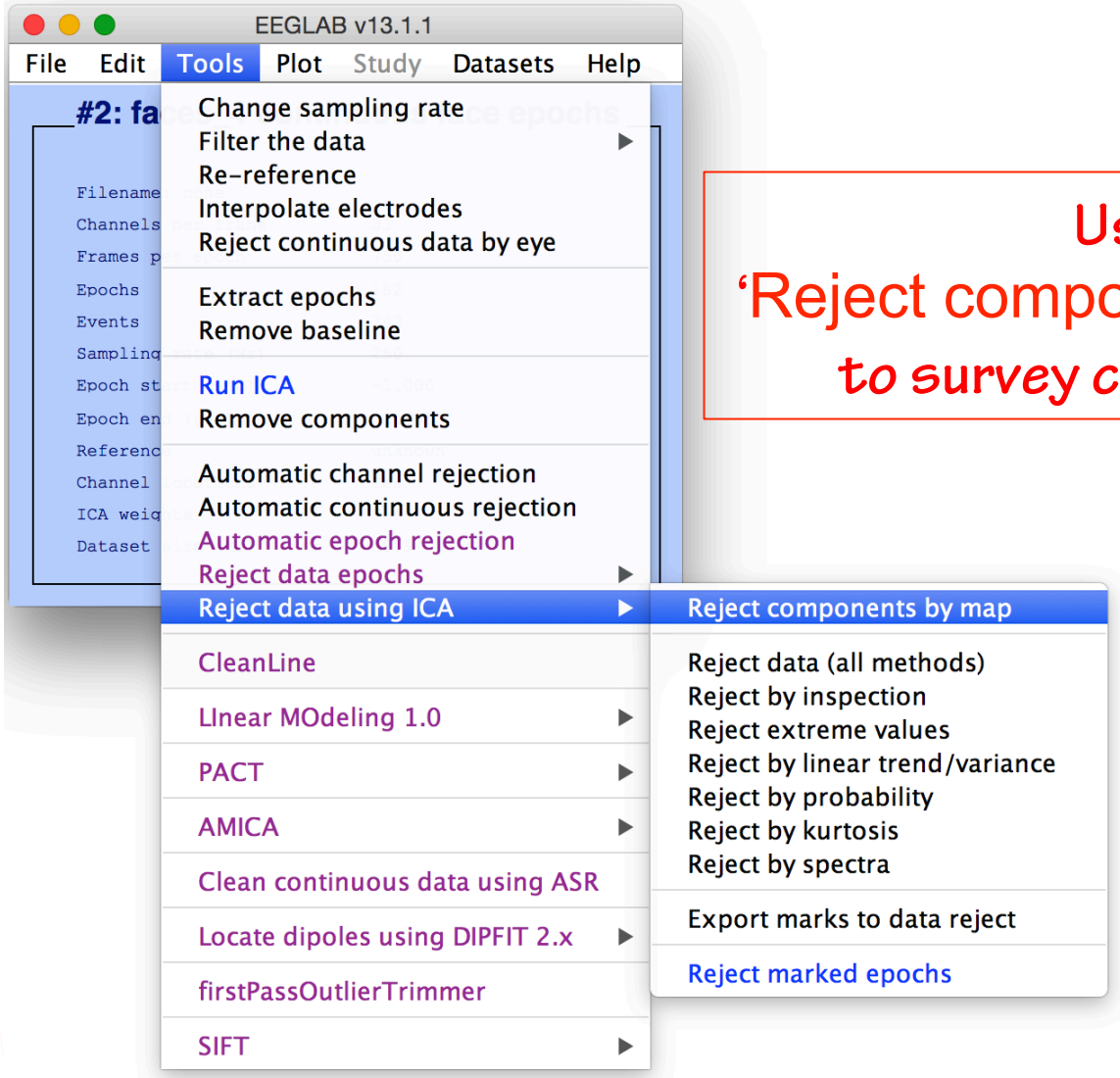
Part 3

Detailed look at IC properties

- ERP
- Spectrum
- ERP images
- ERSP

A convenient ‘trick’…

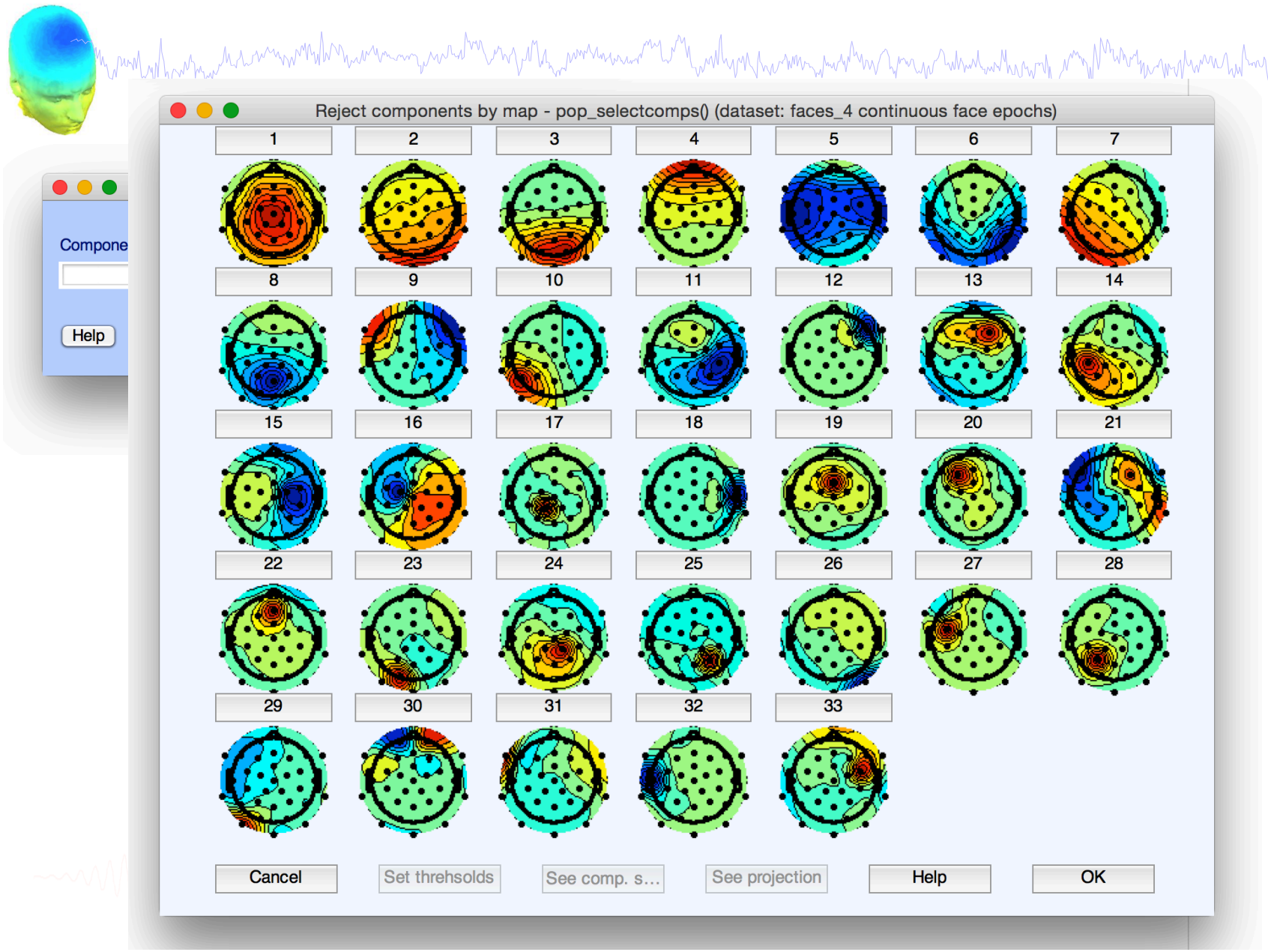




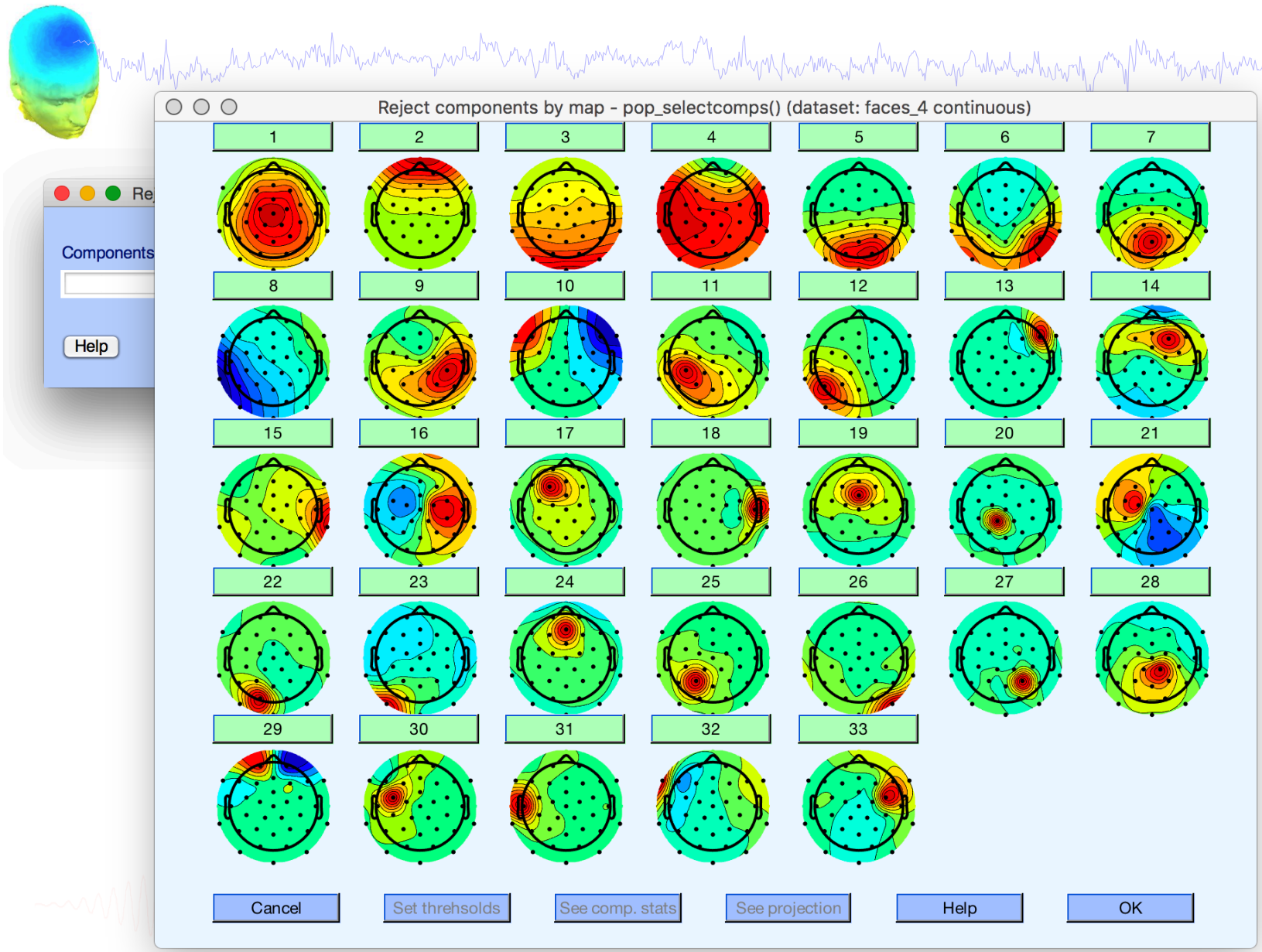
Use
‘Reject components by map’
to survey components

NB: A new plugin
"viewprops"
is available!

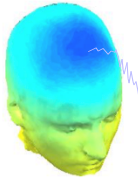
An interactive overview of ICs

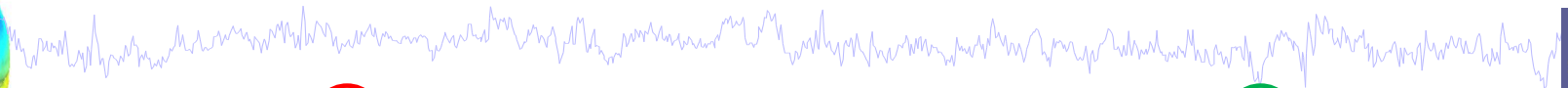


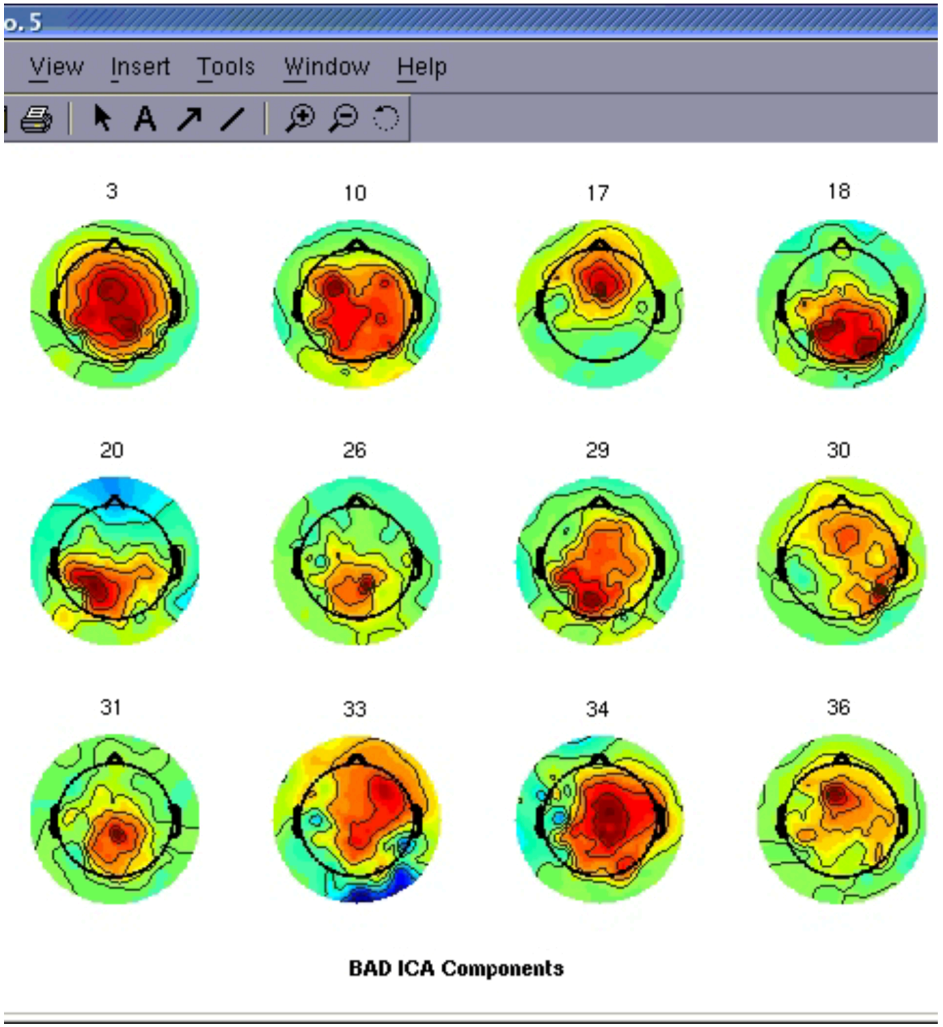
An interactive overview of ICs

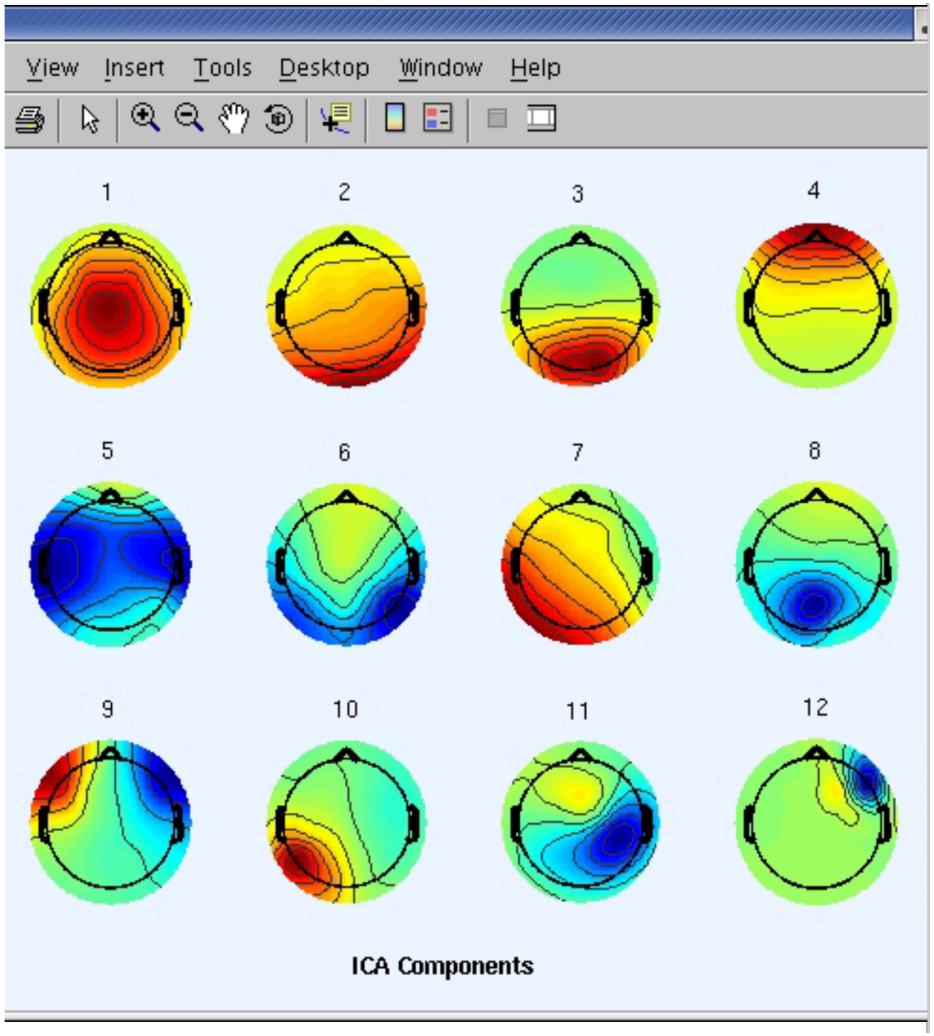


Step 0: Quality of Decomposition

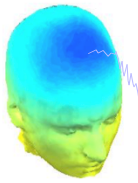


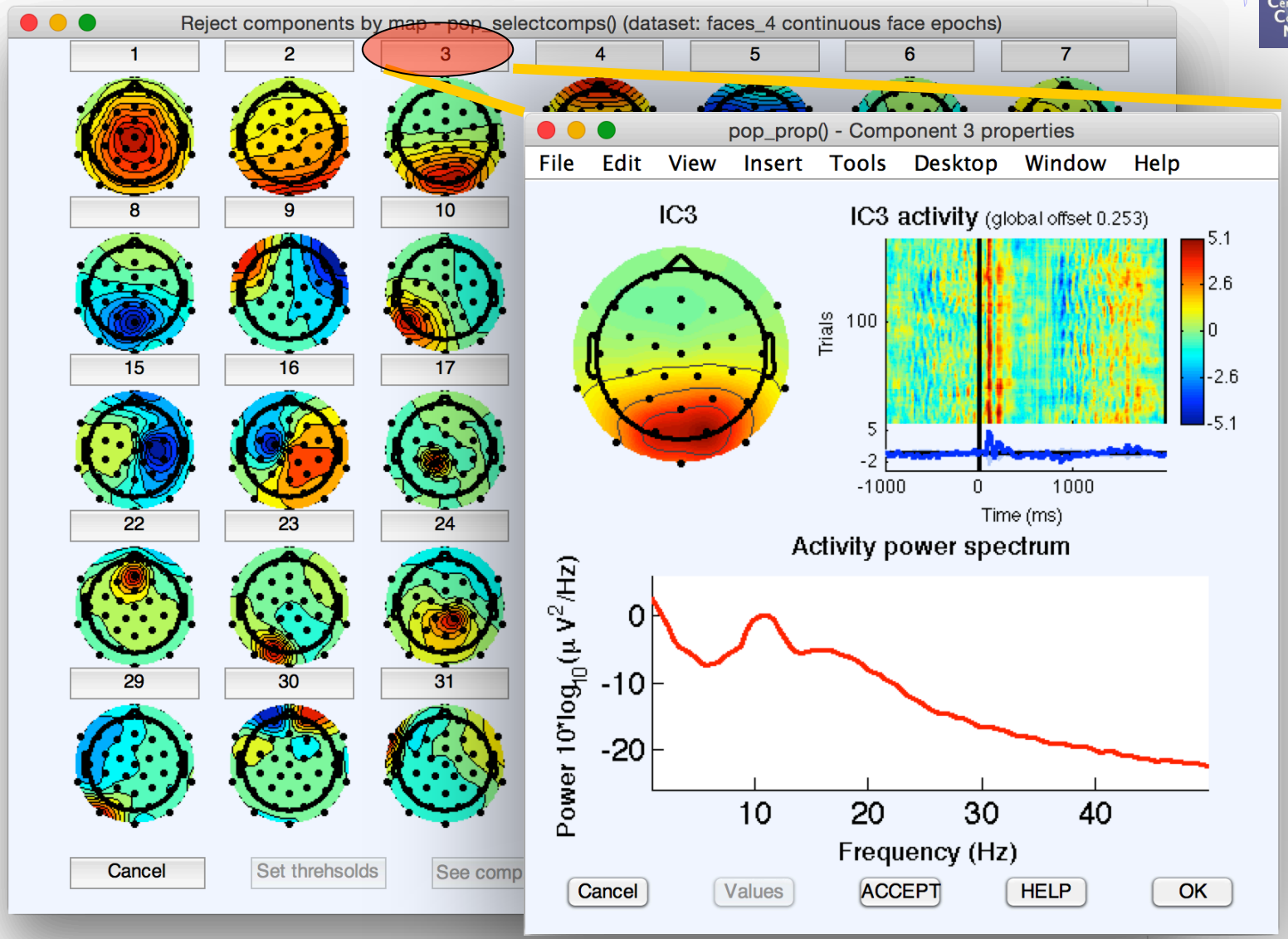




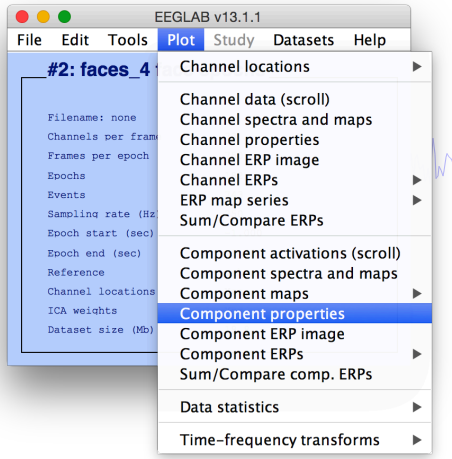


Examining IC Properties



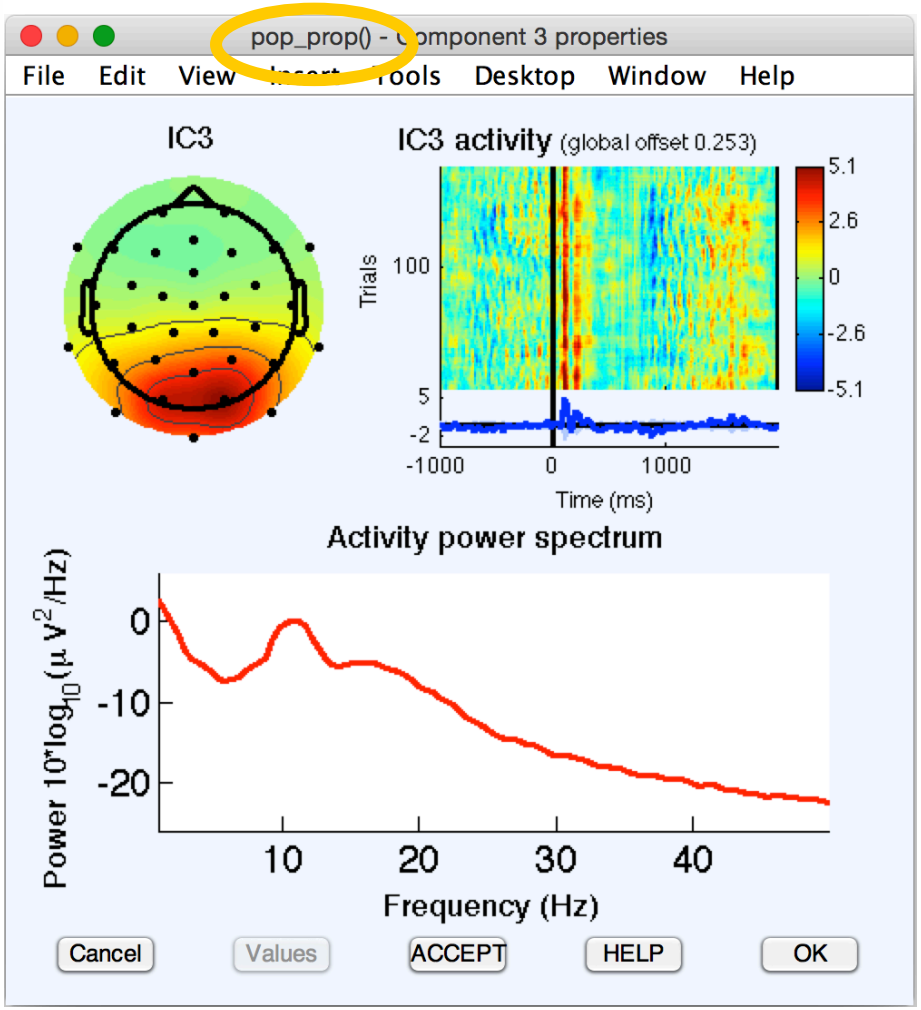


IC Properties



IC Topography

`topoplot()`



ERP Image

&

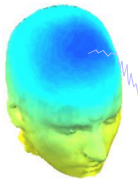
ERP

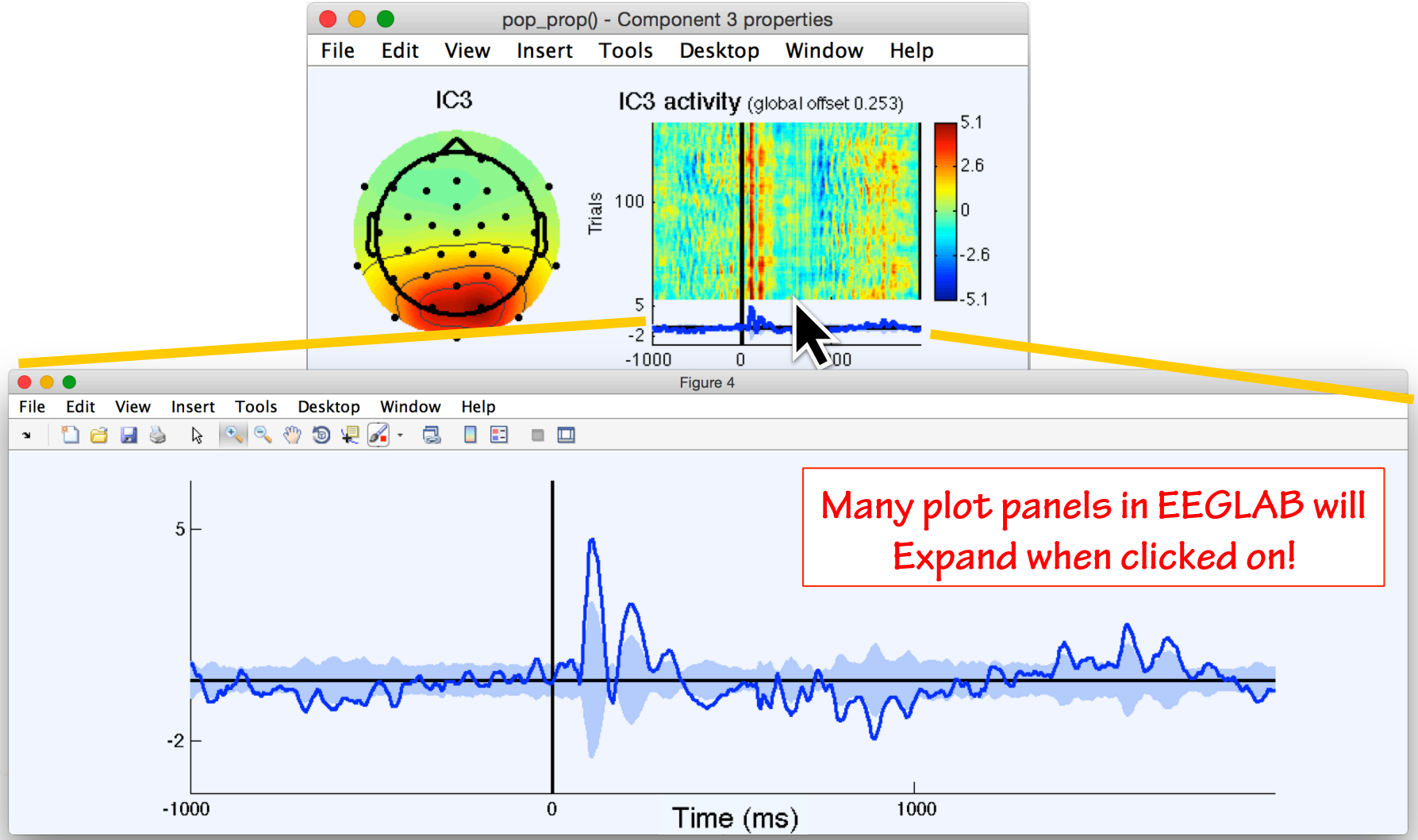
`erpimage()`

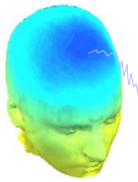
Power Spectrum

`spectopo()`

Click to expand…







Part 1

Getting an overview of your ICs

Part 2

Classifying/Evaluating ICs

Eye Artifacts

Muscle Artifacts

Other Artifacts

Brain ICs

Part 3

Detailed look at IC properties

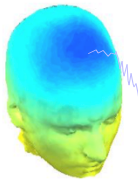
ERP

Spectrum

ERP images

ERSP

Evaluating ICs



Over time, most EEGLAB users develop a *heuristic* sense of which ICs might be brain vs. artifact.

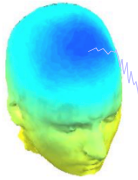
Heuristics are generally based on:

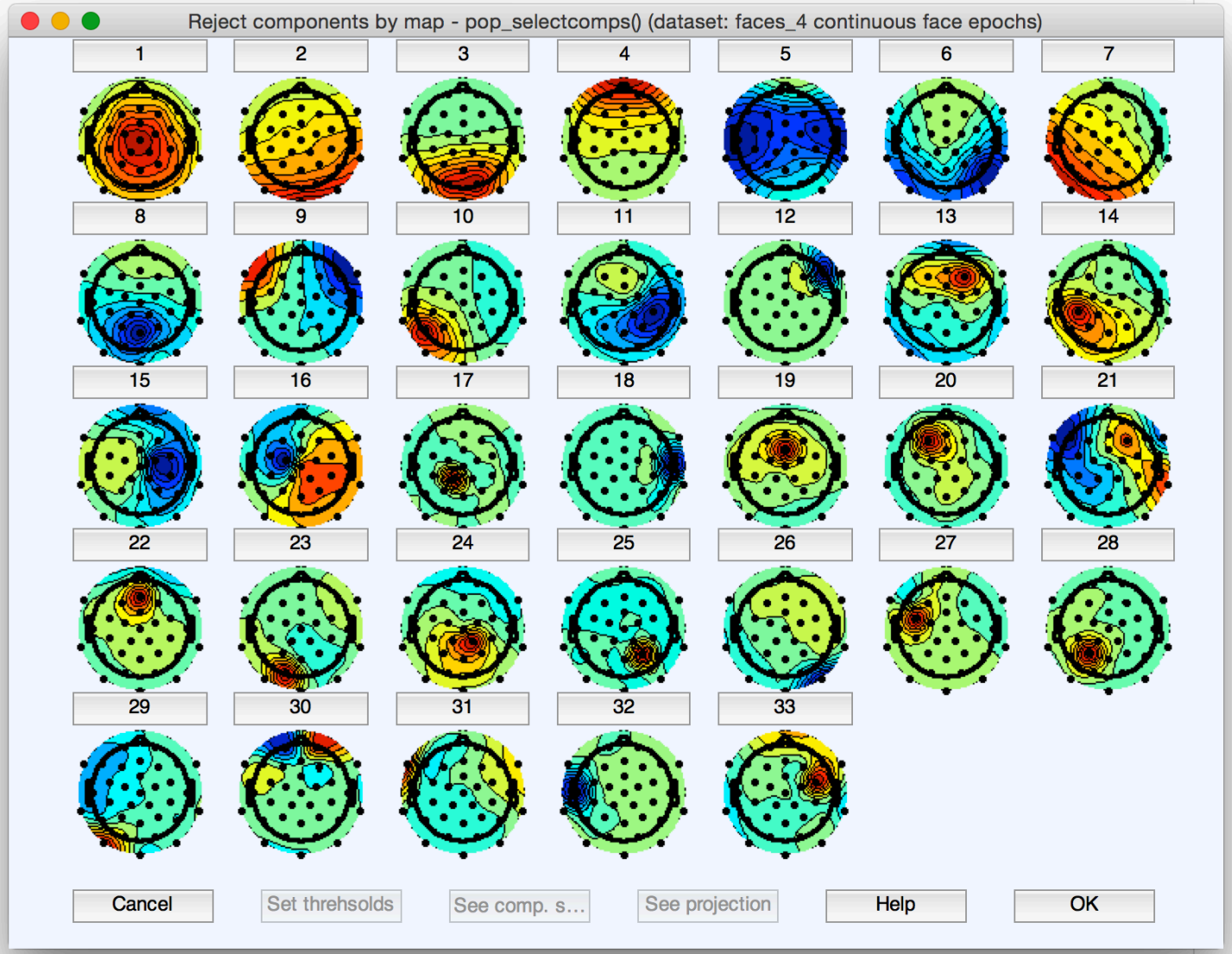
- Topography
- Component Activities (scroll)
- ERP
- Power Spectrum

IC Classification can be used to 'clean' data—study likely brain activity without artifacts

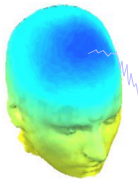
There are new efforts to automate this process, but doing it by hand is a good place to start to build intuition

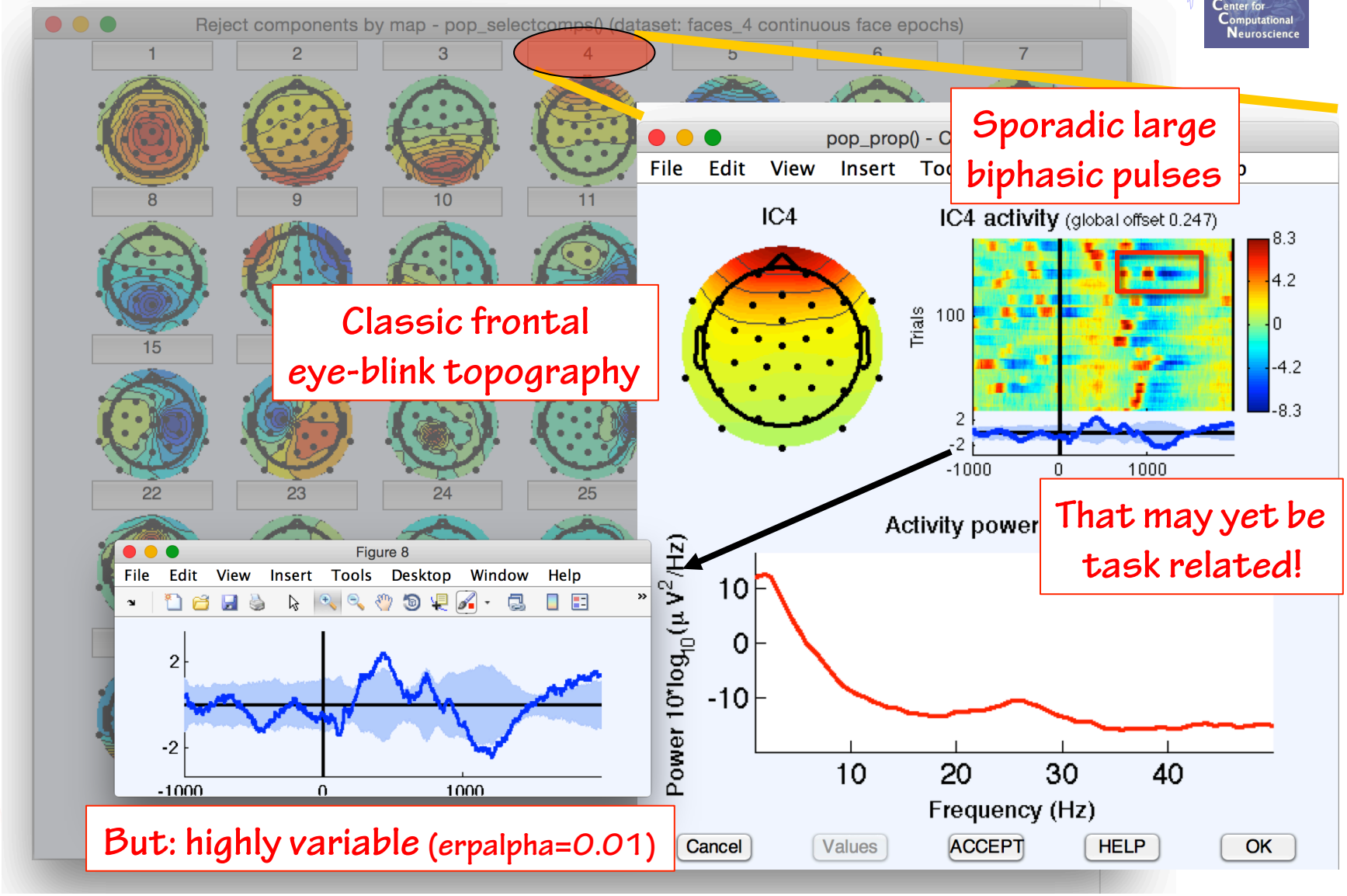
Topography




Reject components by map - pop_selectcomps() (dataset: faces_4 continuous face epochs)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
Cancel
Set threhsolds
See comp. s...
See projection
Help
OK

IC 4 – eyeblink





Sporadic large biphasic pulses

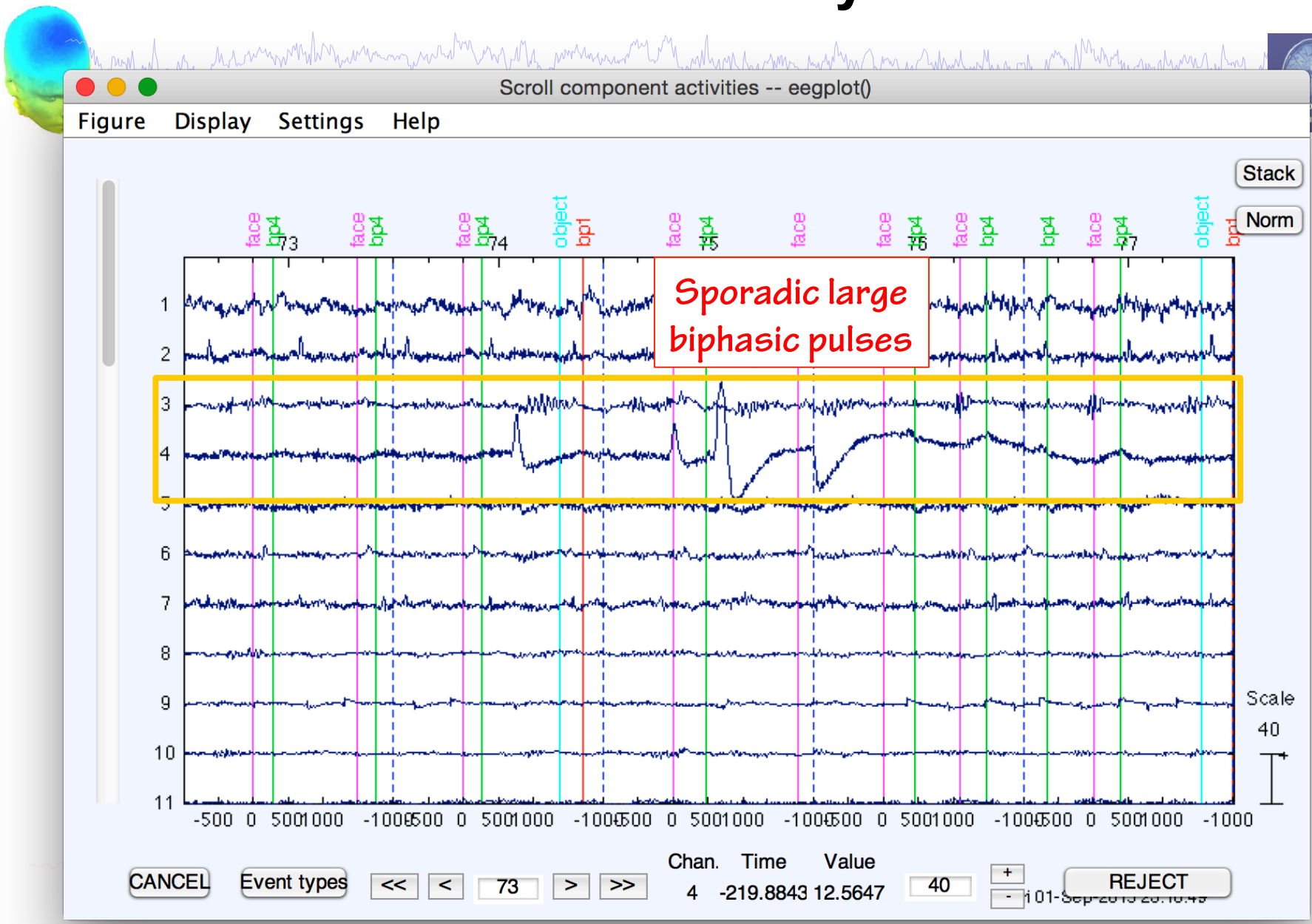
Classic frontal eye-blink topography

That may yet be task related!

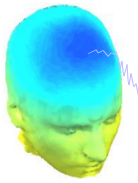
But: highly variable (erpalpha=0.01)

Plot → Component Activations (scroll)

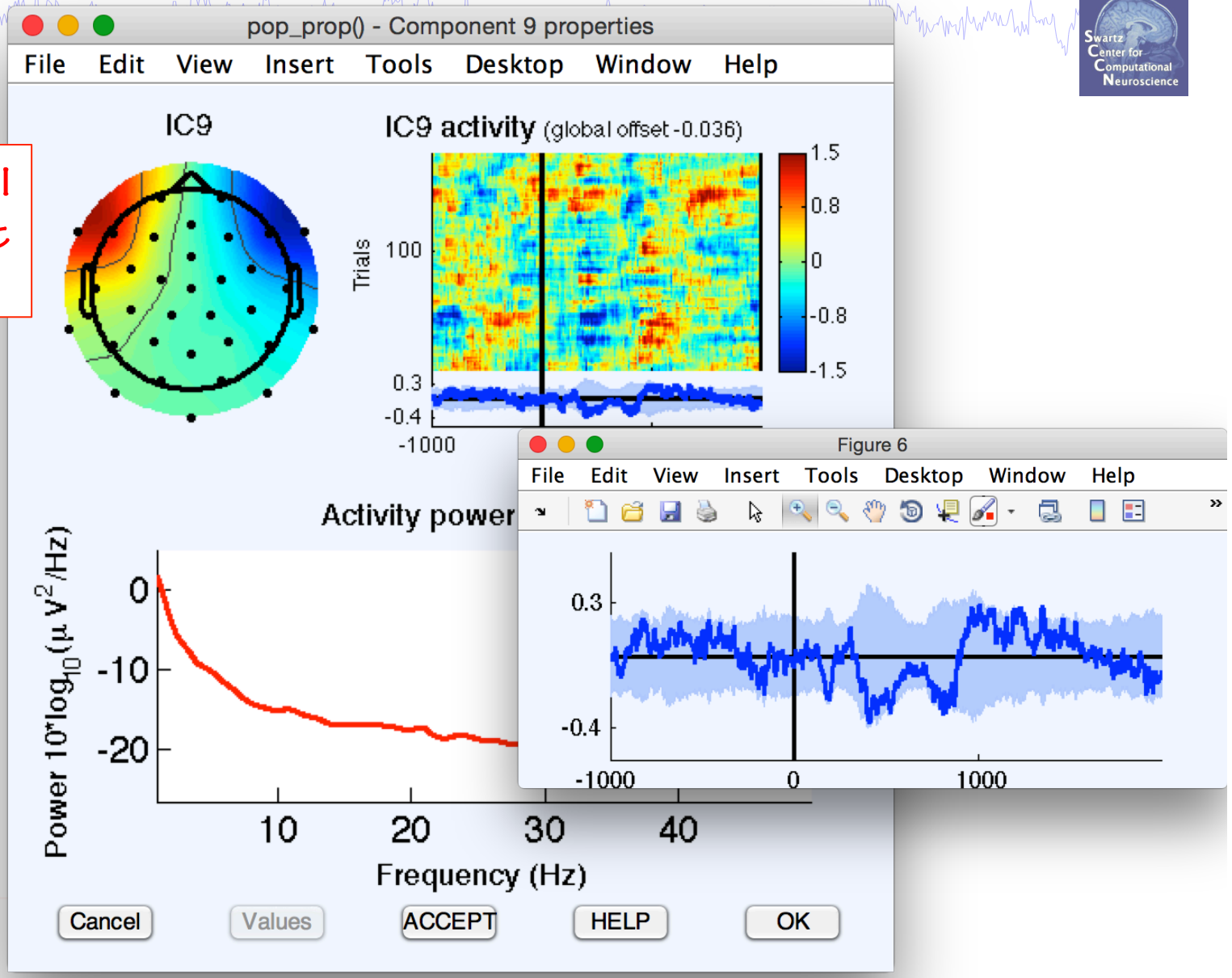
IC 4 Activation – eyeblink



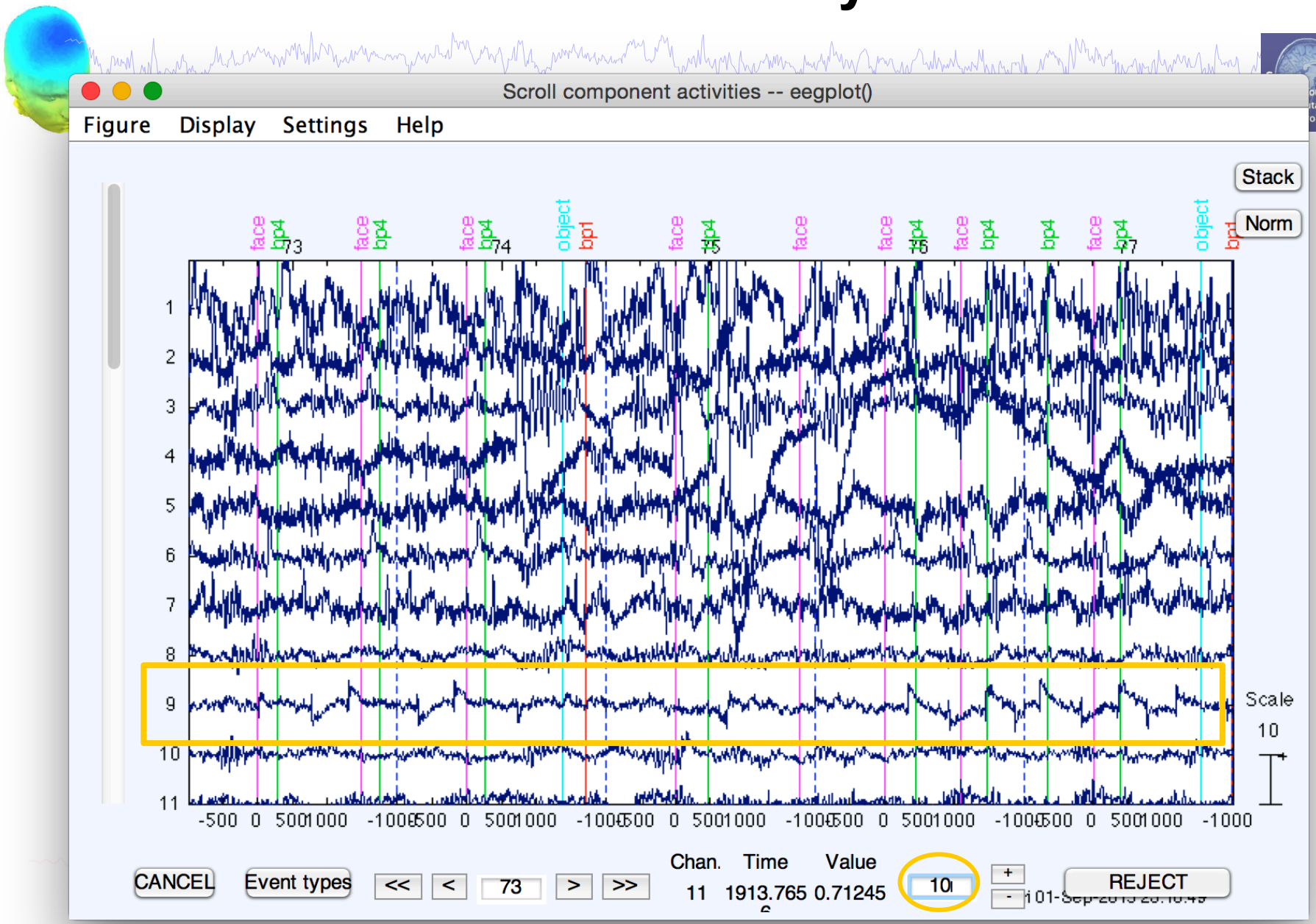
IC 9 – lateral eye movement



Classic frontal eye-movement topography



IC 9 Activation – lateral eye movement

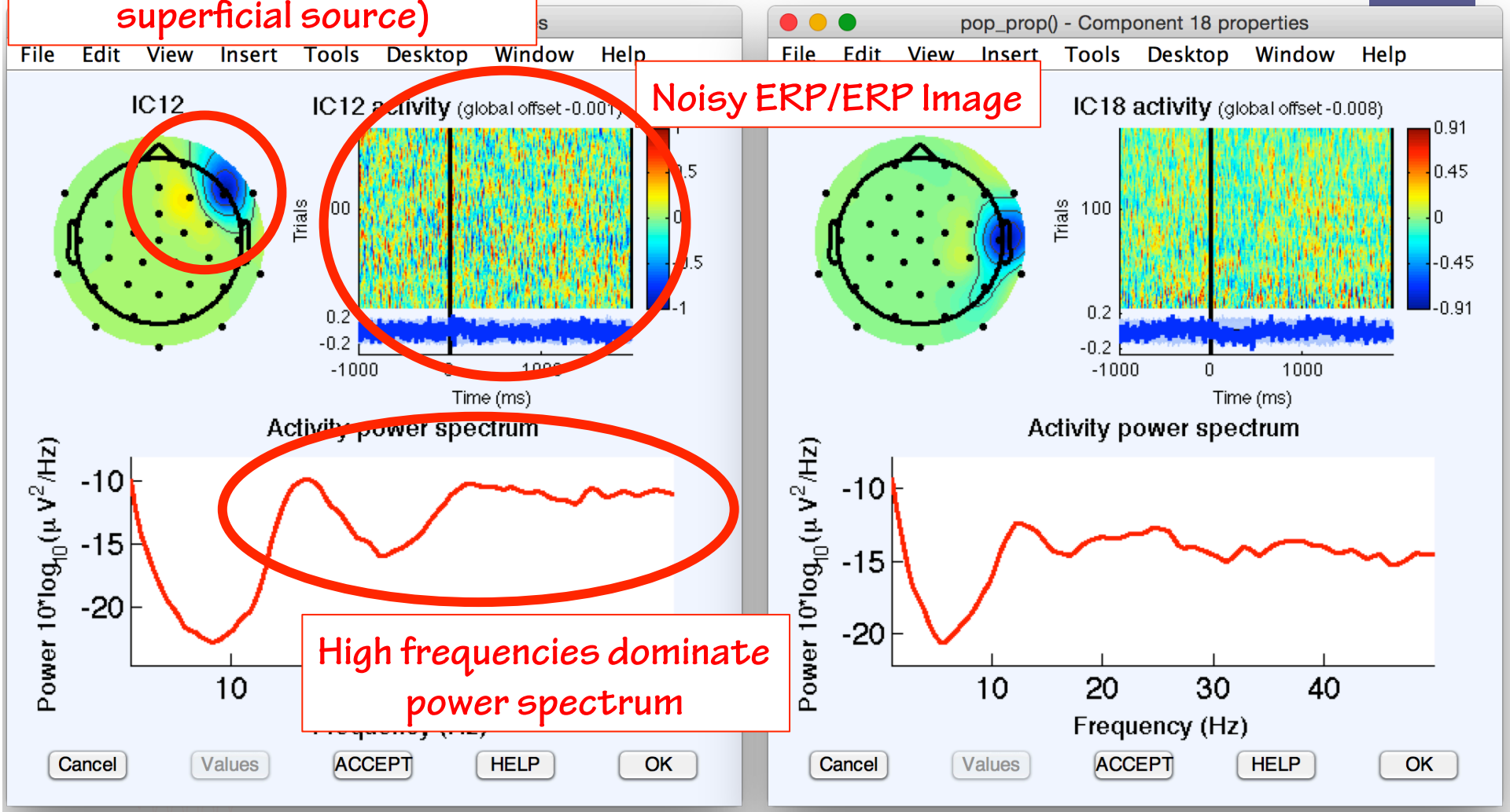


IC 12, 18 – Muscle

Narrowly spaced dipolar topography (consistent with superficial source)

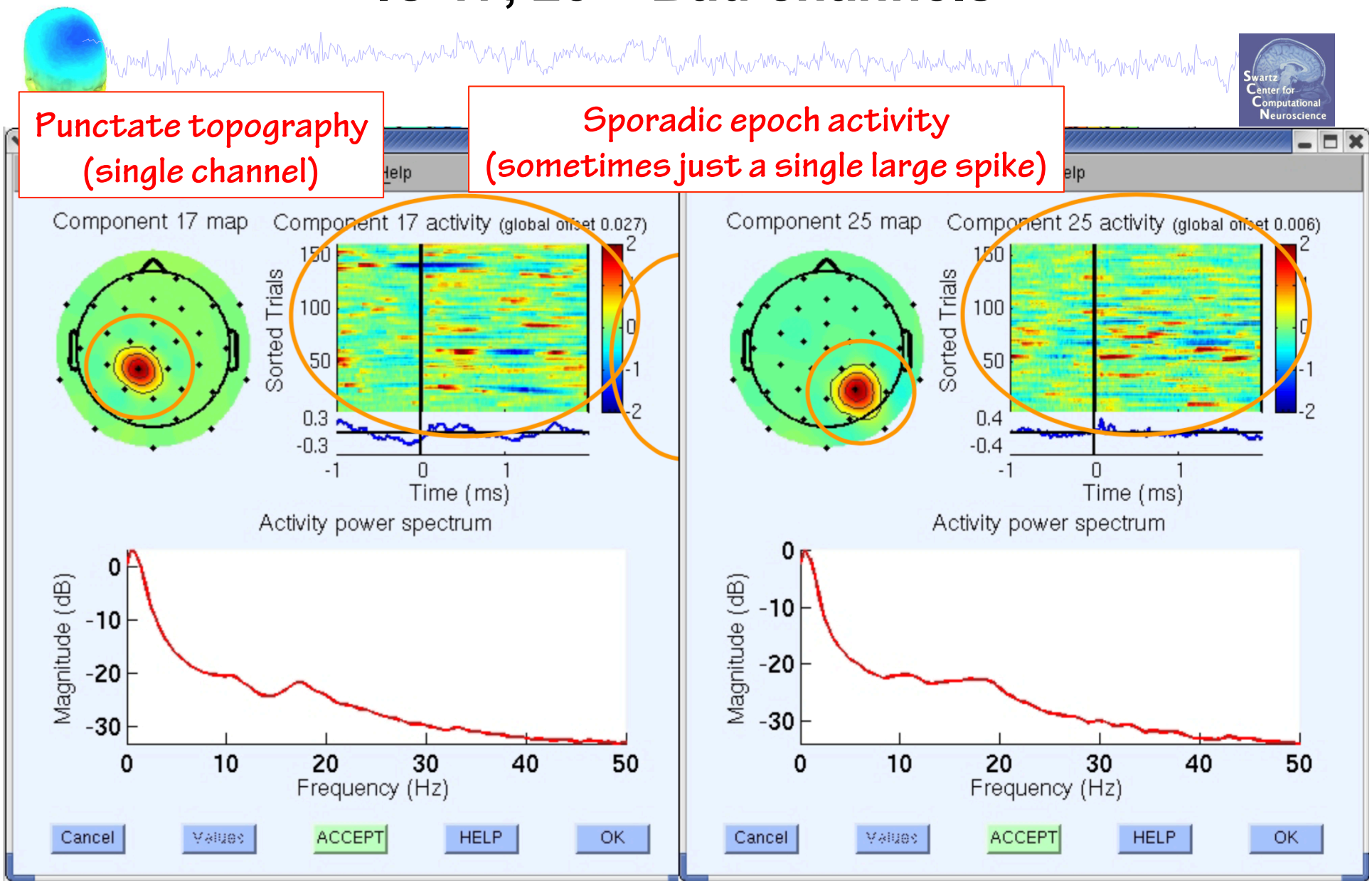
Noisy ERP/ERP Image

High frequencies dominate power spectrum

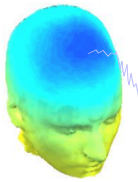


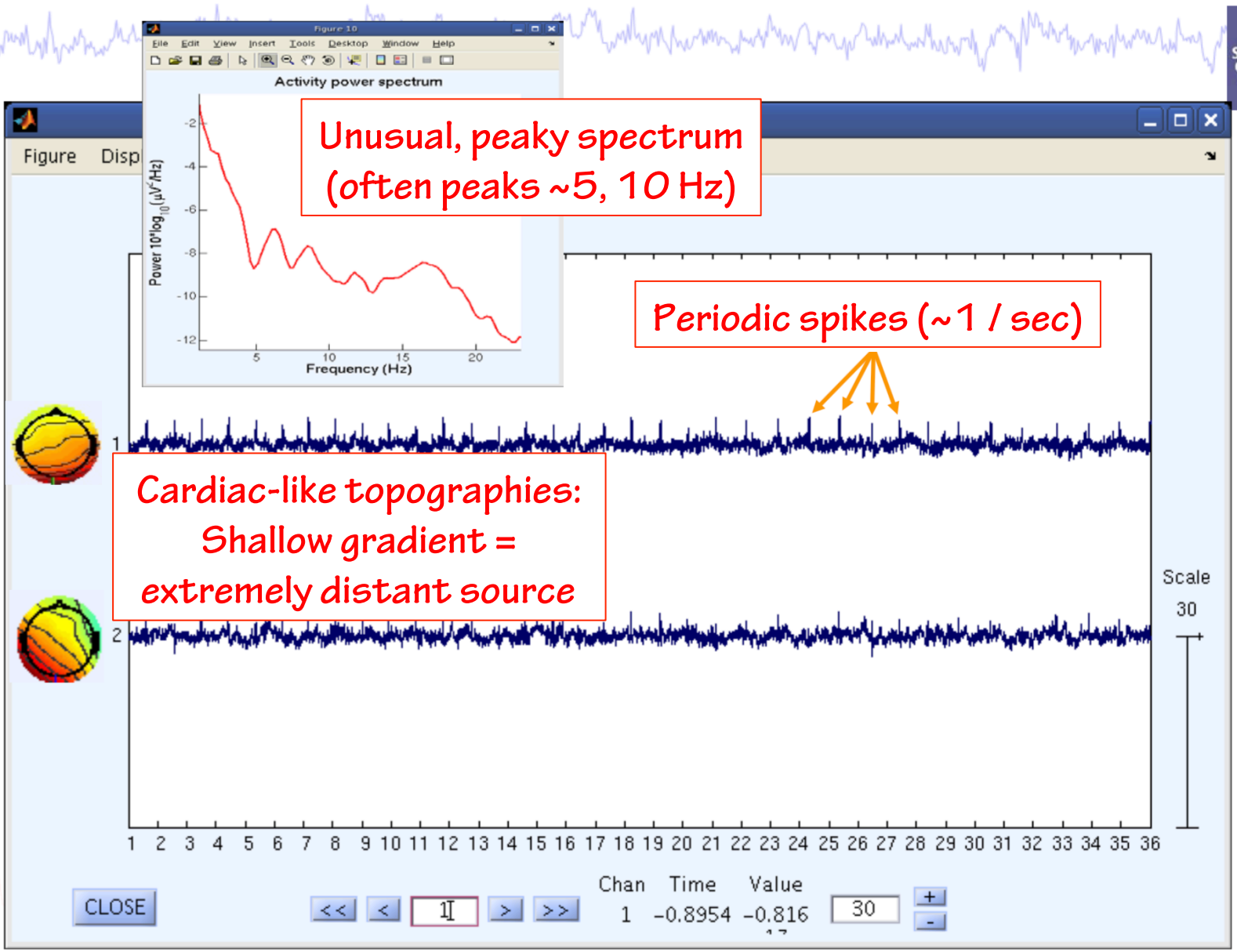
IC 12, 18 Activation – Muscle

IC 17, 25 – Bad channels

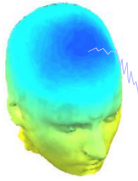


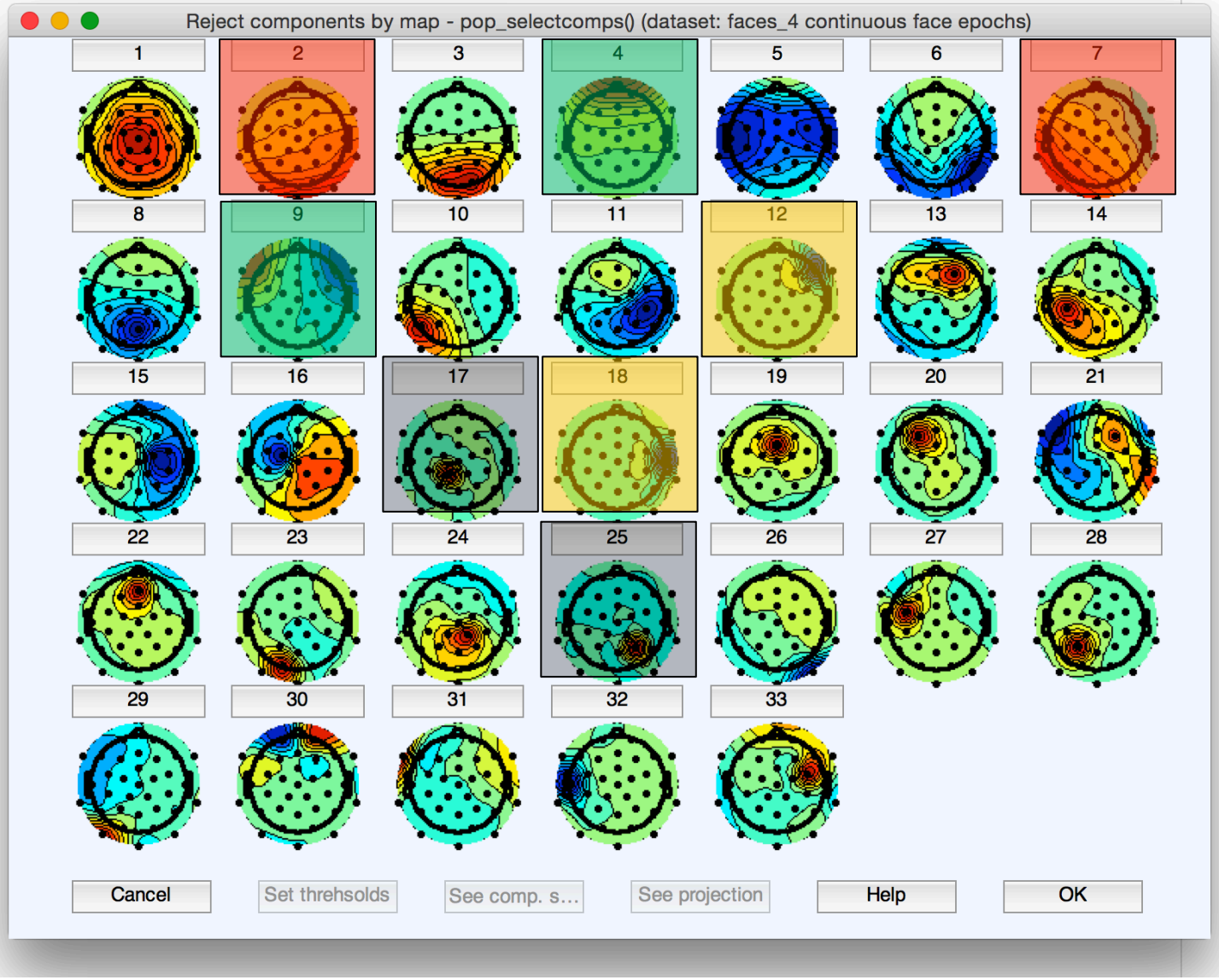
IC 2, 7 – Cardiac





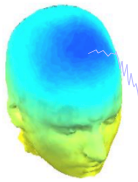
Artifacts

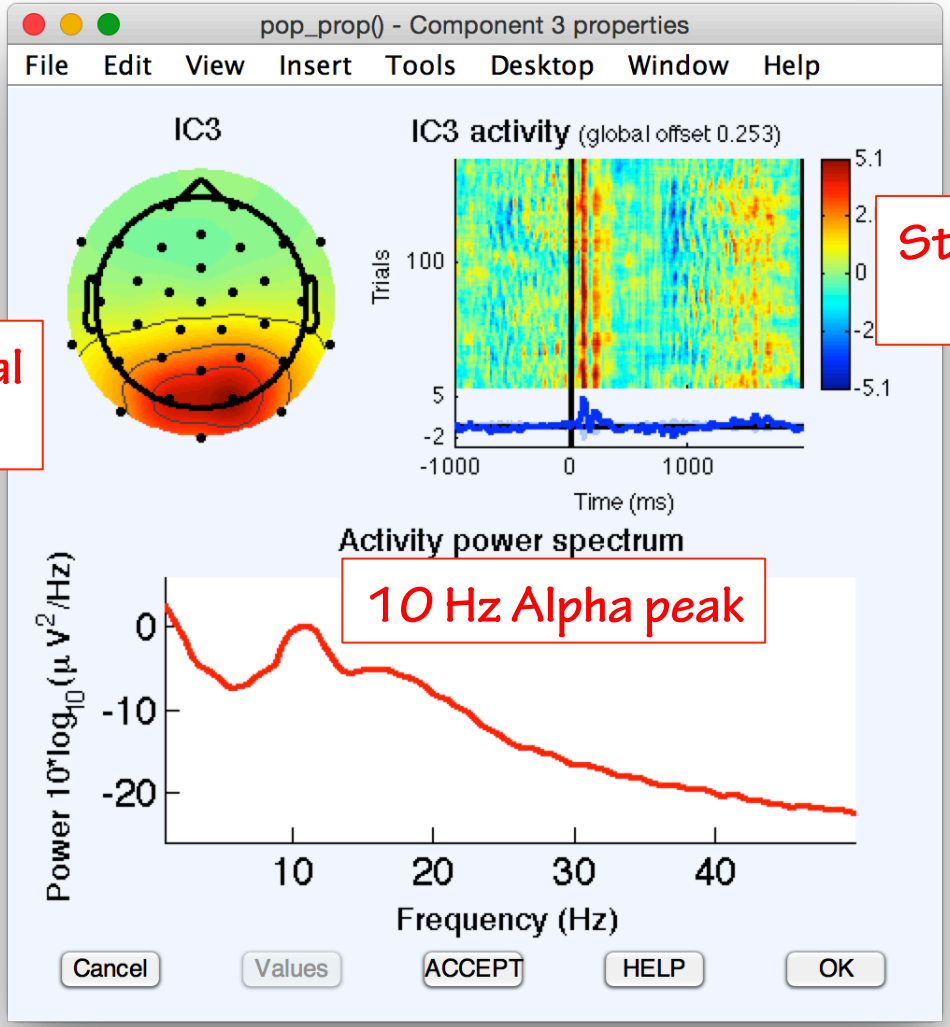




Eye
Muscle
Cardiac
Badchan

Brain ICs

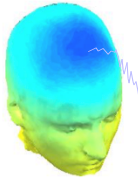


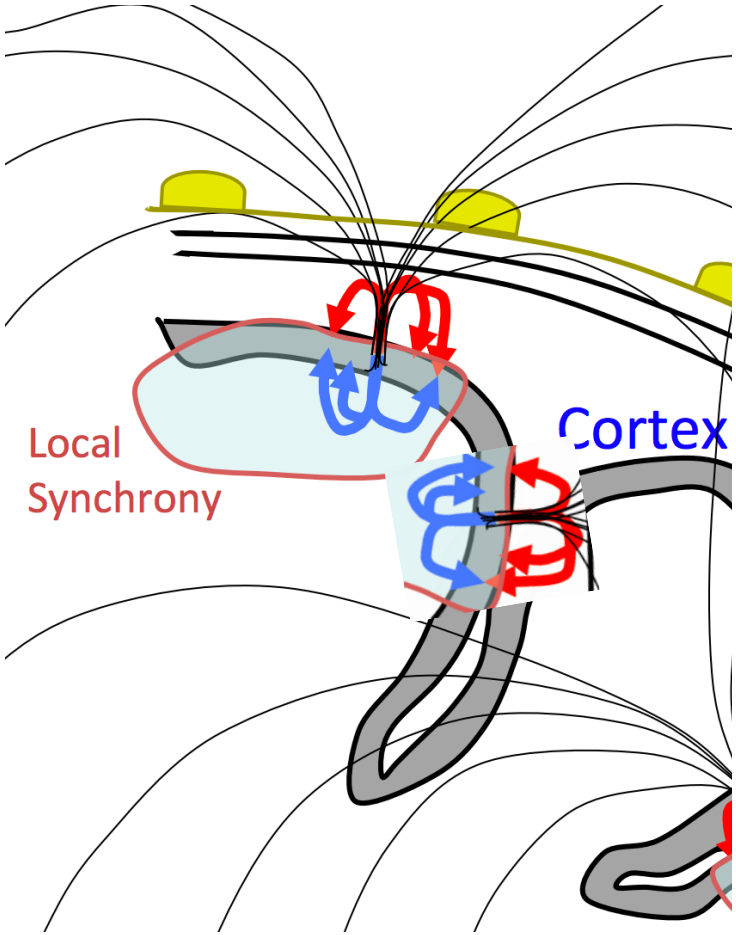


Classic occipital topography

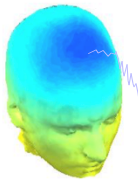
Strongly task-related ERP Image & ERP

Dipole orientation matters

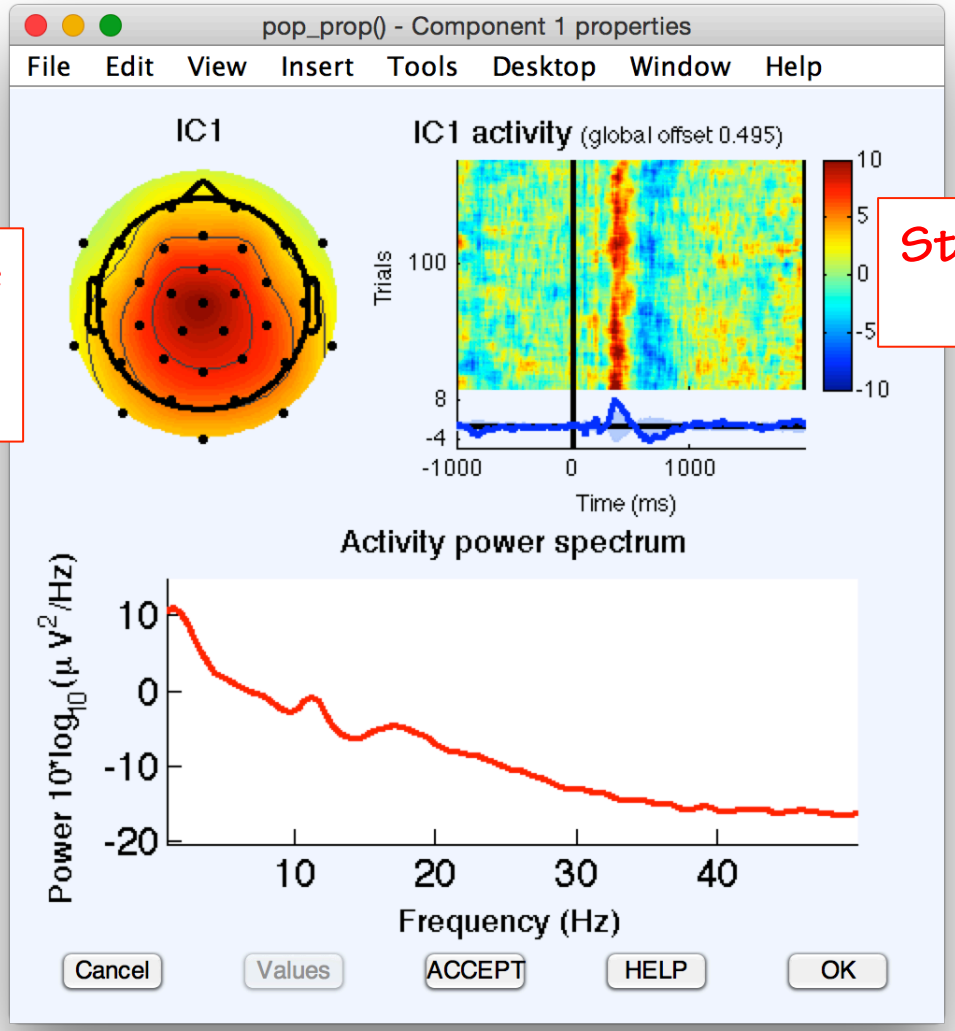




Brain ICs

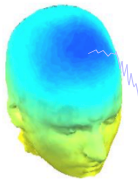


Classic radial-dipole source topography



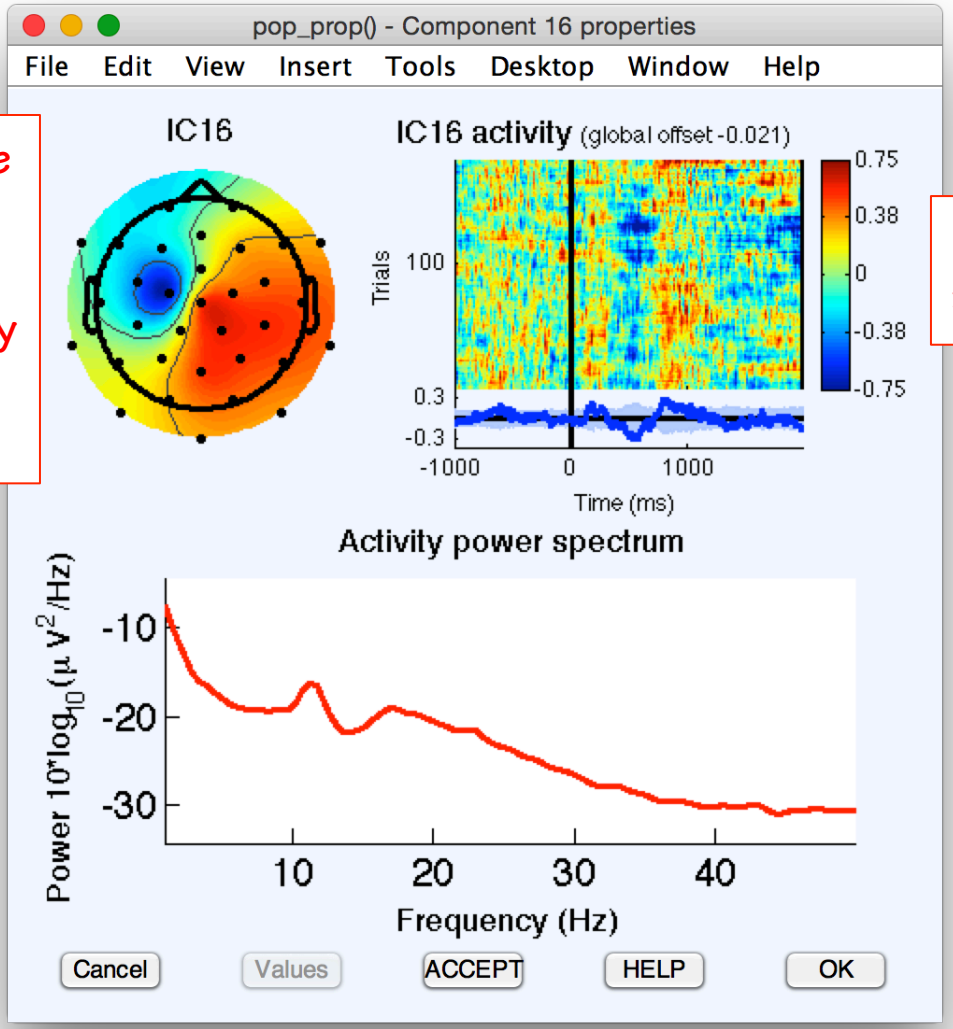
Strongly task-related ERP Image & ERP

Brain ICs



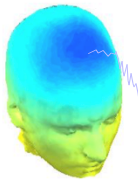
Classic tangential-dipole source topography

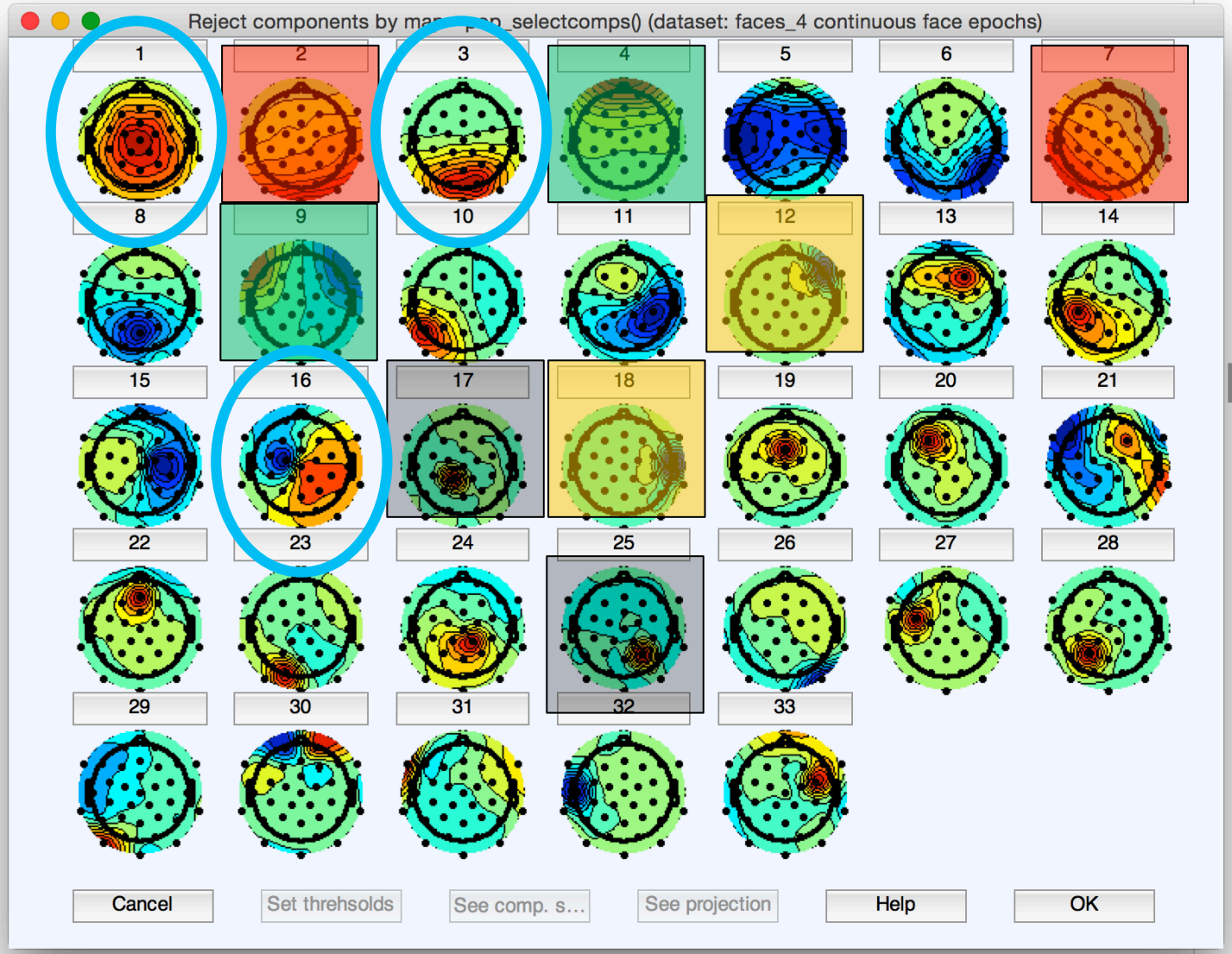
two peaks, not as closely spaced as muscle: deeper



Task-related ERP Image & ERP

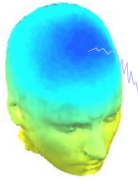
IC Classification…so far





Eye
Muscle
Cardiac
Badchan
Brain

Now what…?



Part 1

Getting an overview of your ICs

Part 2

Classifying/Evaluating ICs

Part 3

Detailed look at IC properties

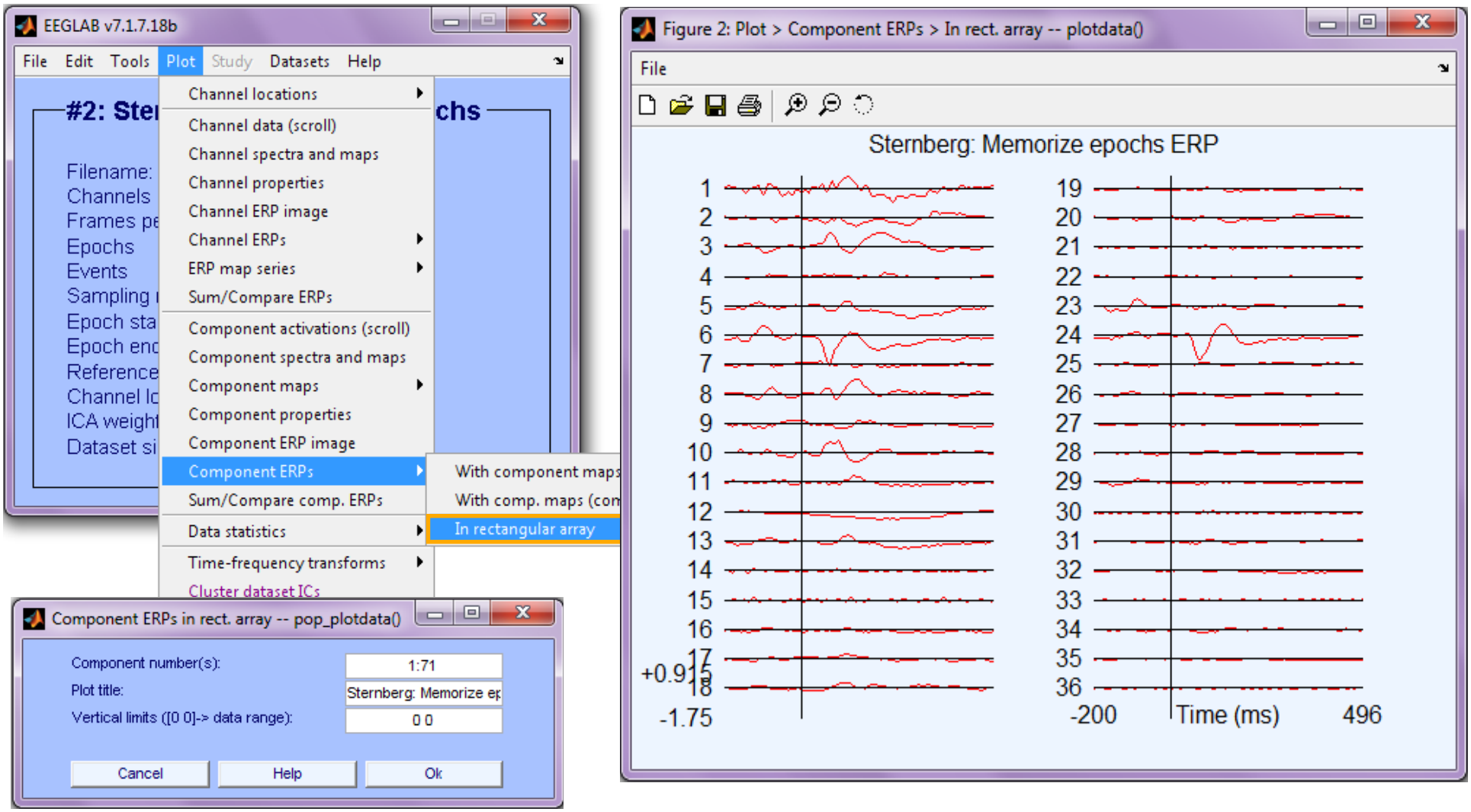
ERP

Spectrum

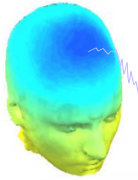
ERP images

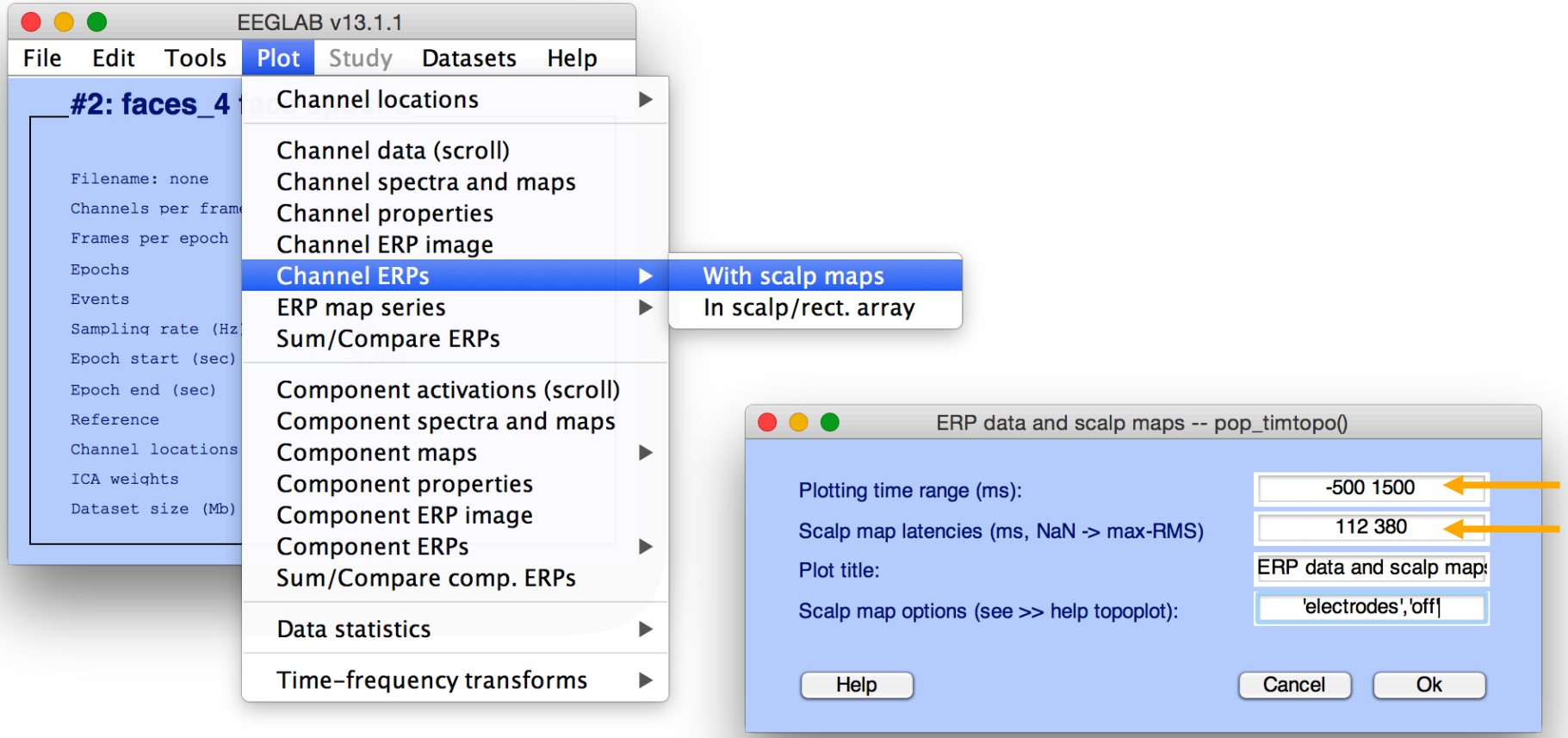
ERSP

Component ERPs

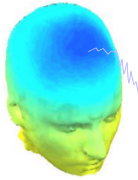


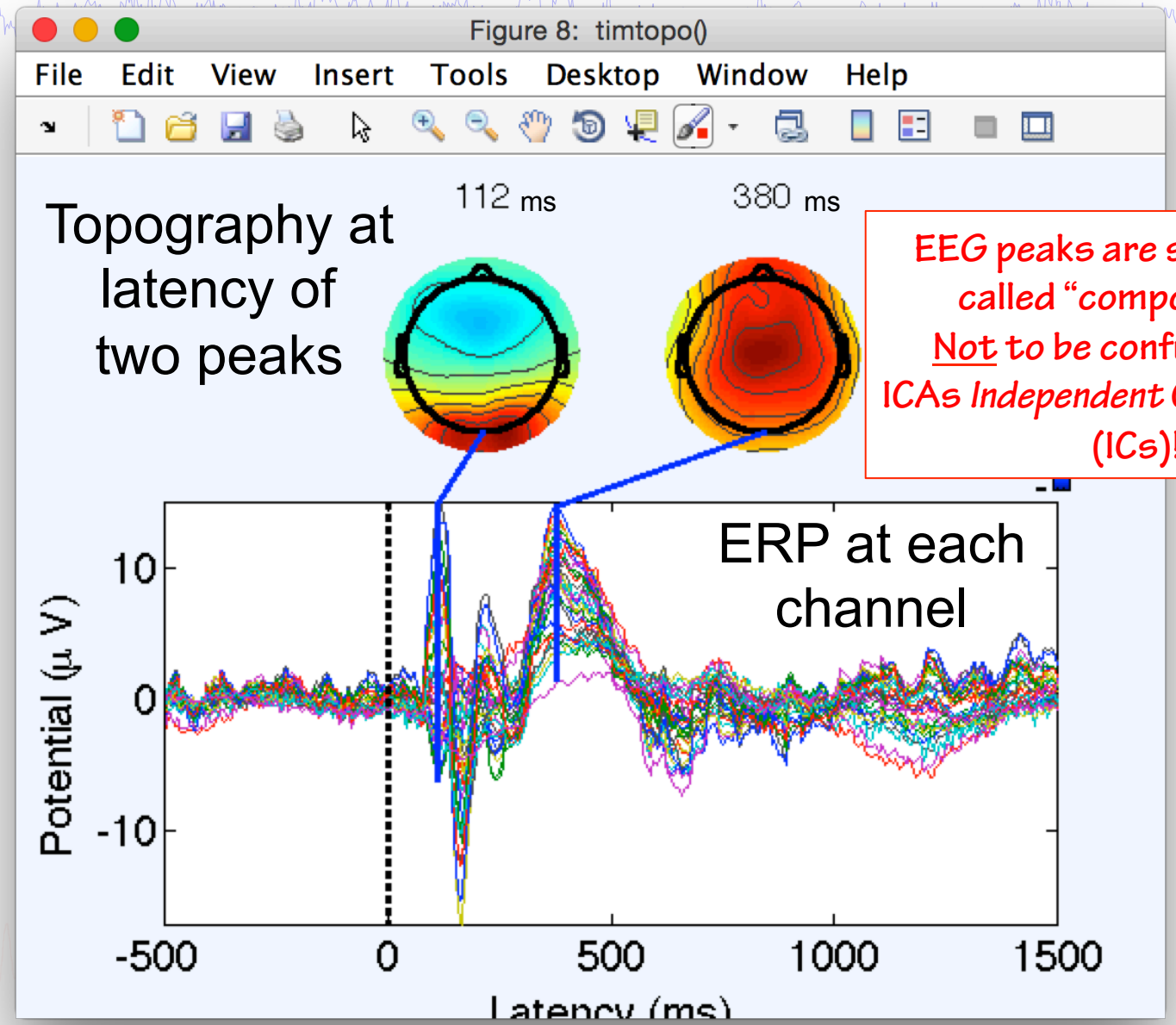
A step back: Electrode-level ERP





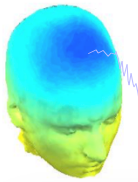
Traditional ERP: Time-locked activity at each channel

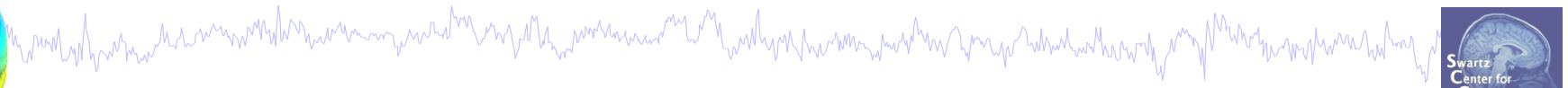


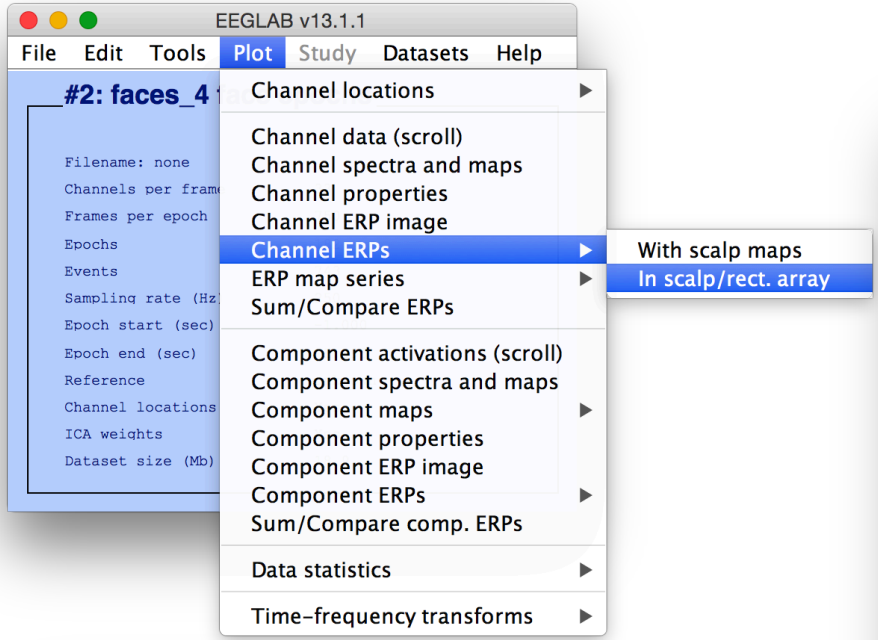


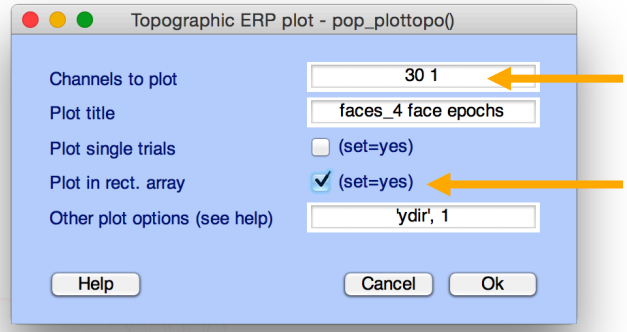
EEG peaks are sometimes called "components."
Not to be confused with ICAs *Independent* Components (ICs)!

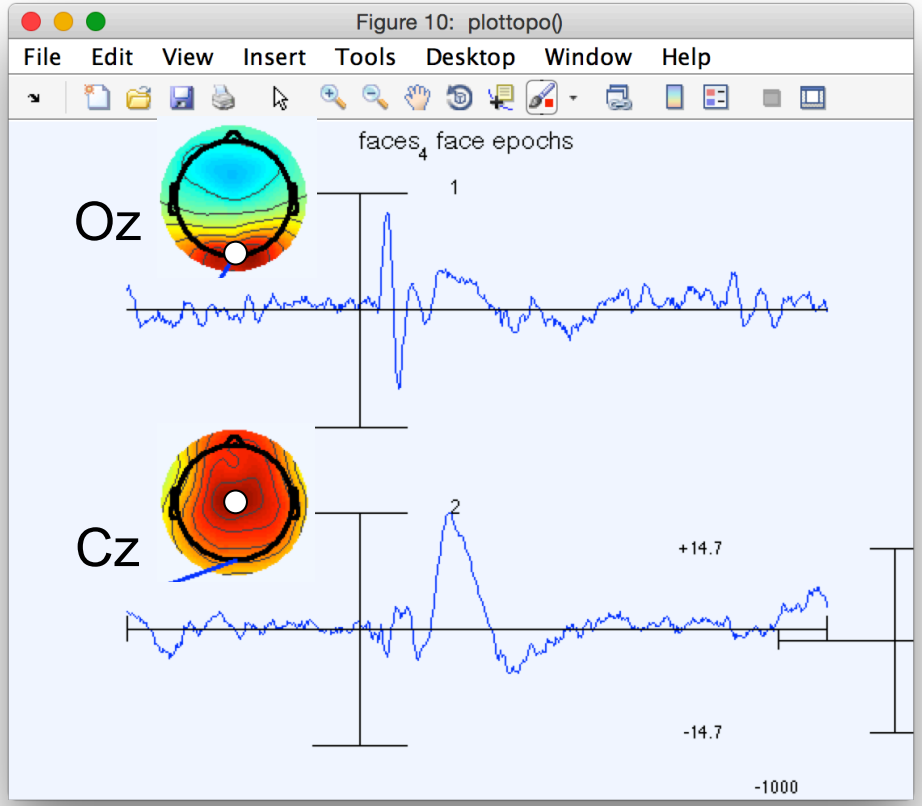
ERP at two channels



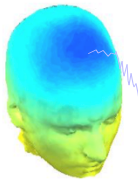


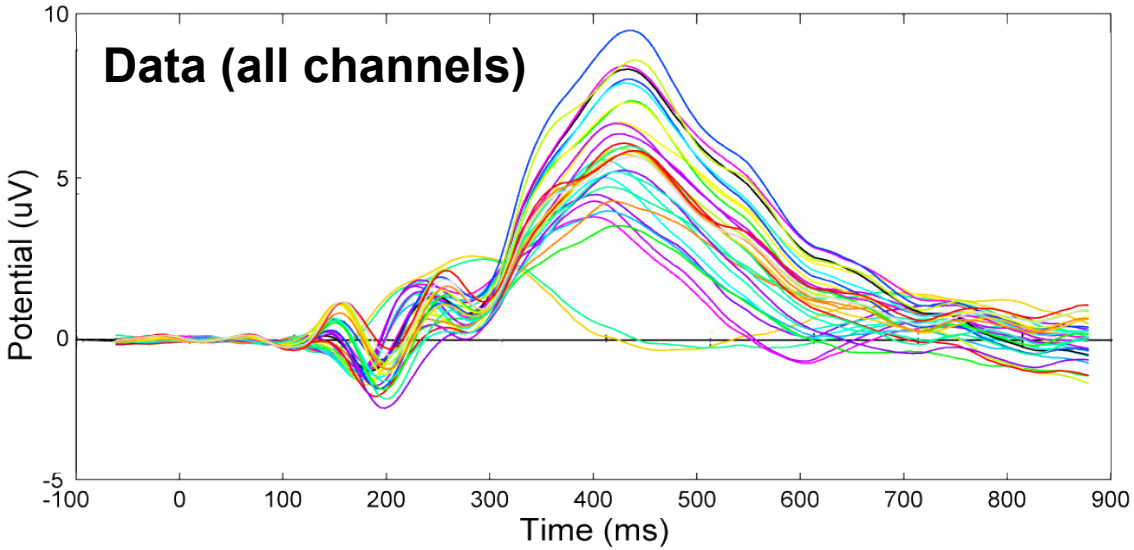


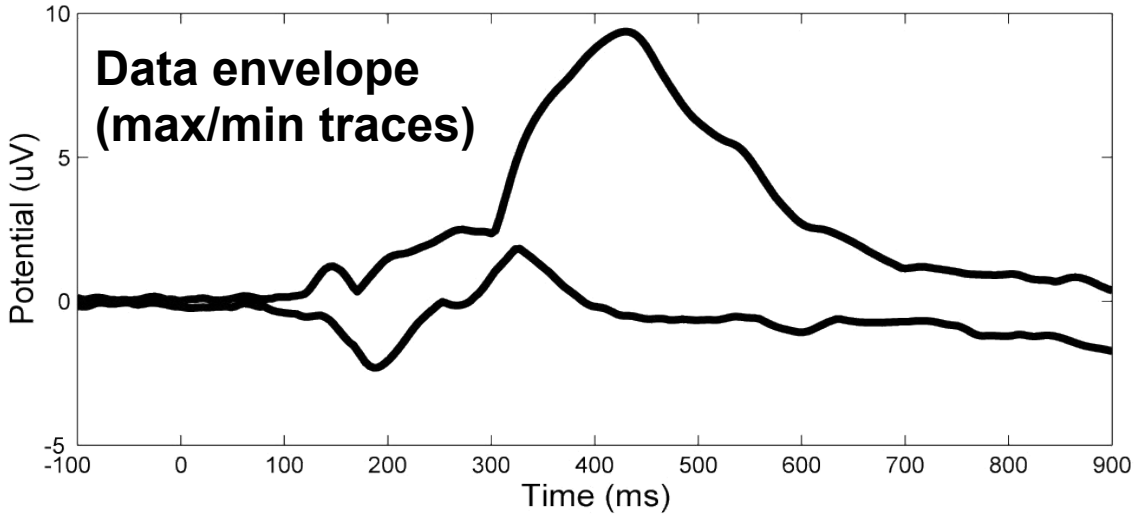




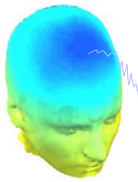
Definition: The data envelope

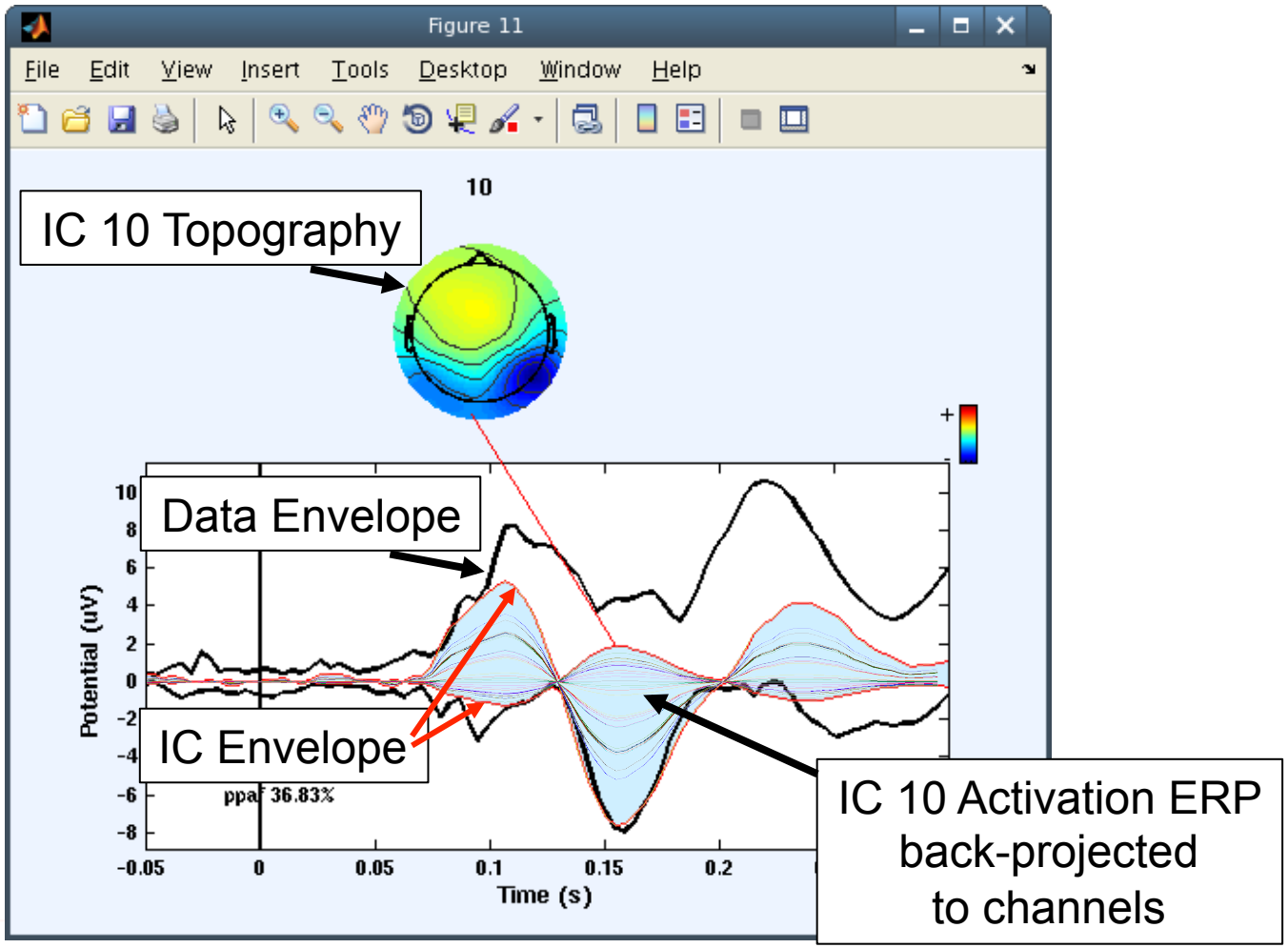




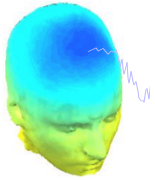


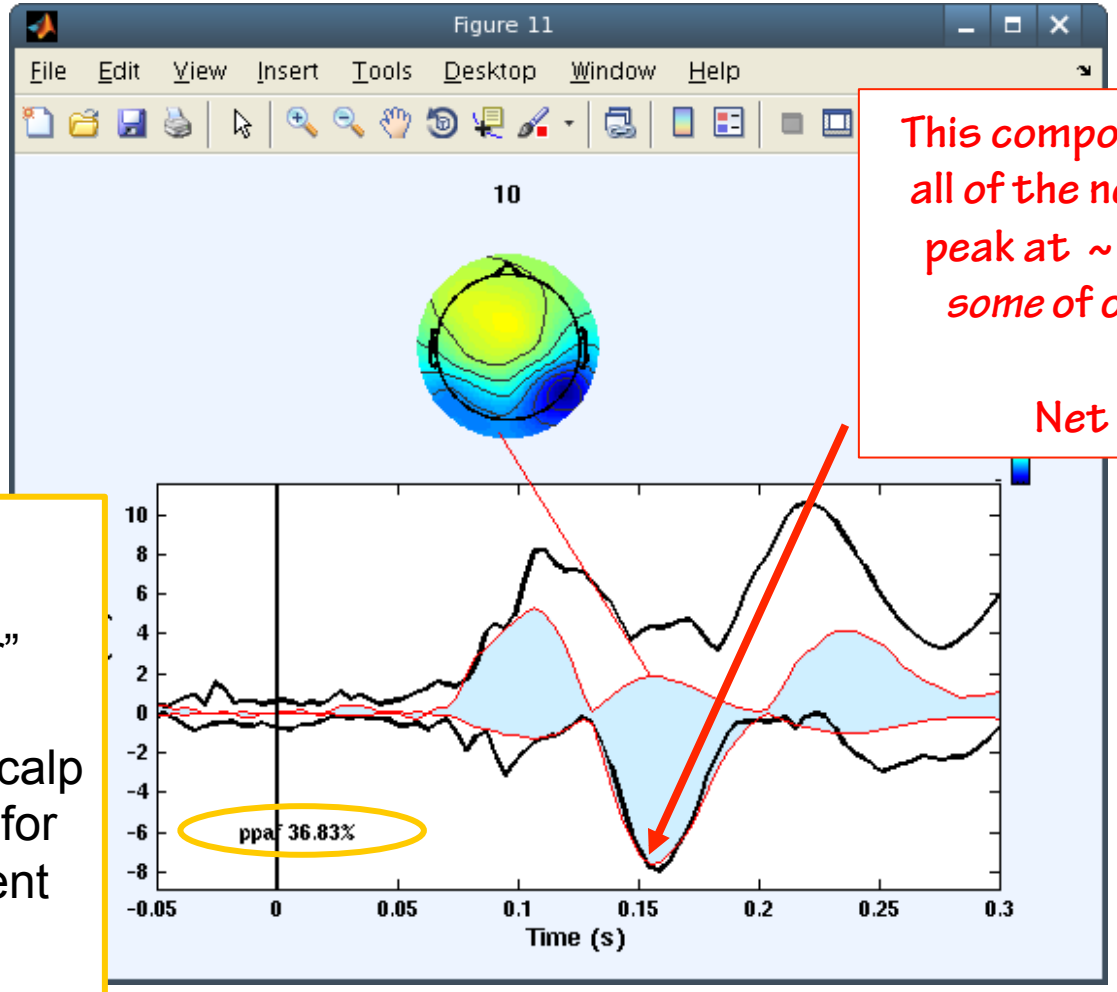
Definition: IC Envelope





Key: Scalp ERP peaks are often the sum of multiple independent source processes





This component accounts for all of the negative scalp ERP peak at ~150 ms, but *only* some of other ERP peaks

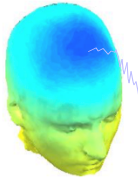
Net PVAF: 37%

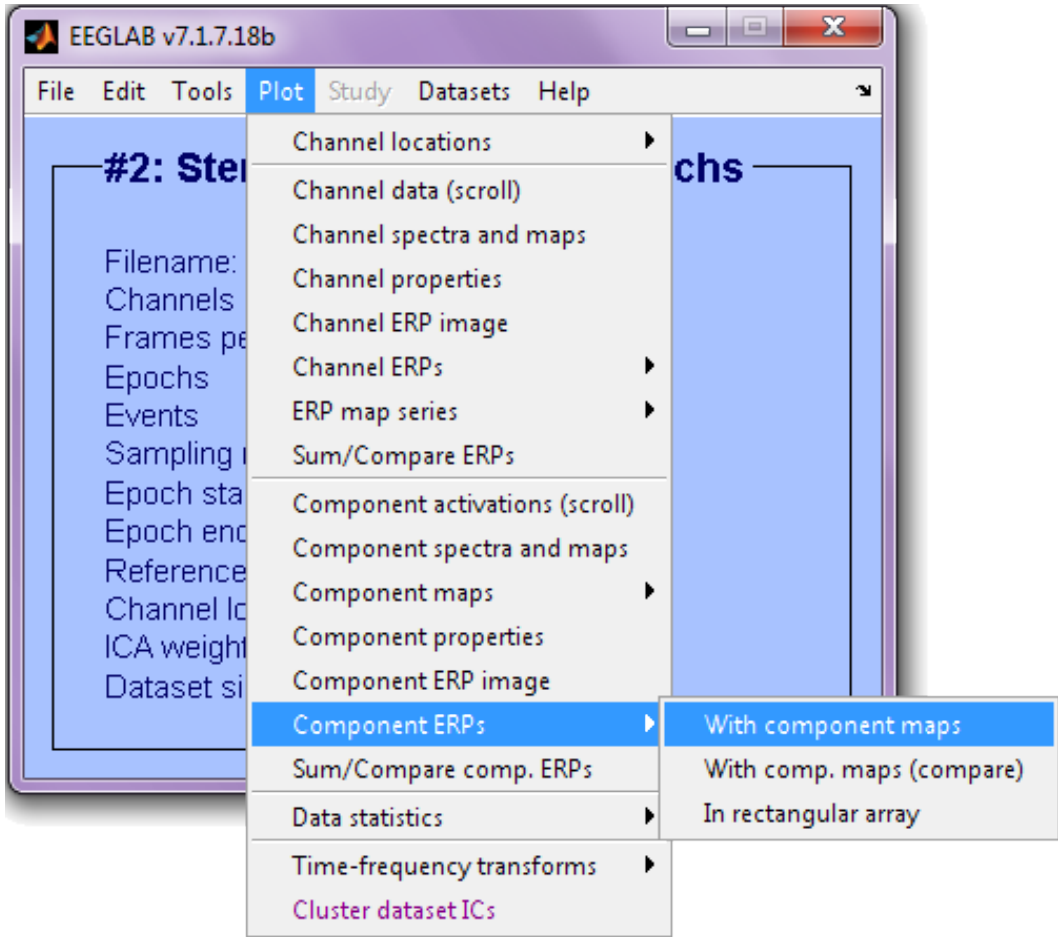
PVAF
"% Variance Accounted For"

The variance of scalp EEG accounted for by this component

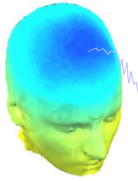
*ppaf

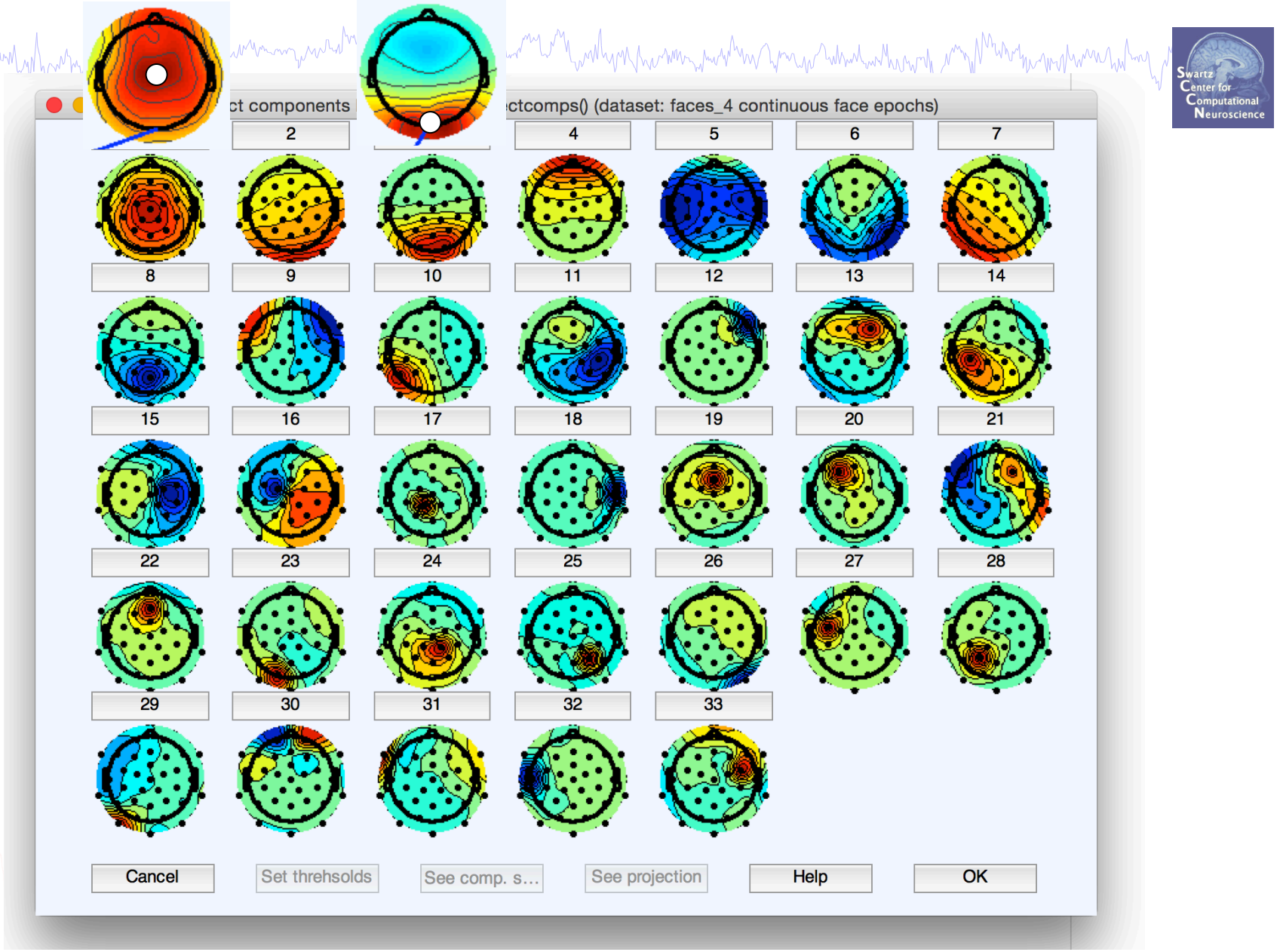
Component ERP envelope



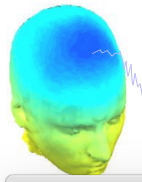


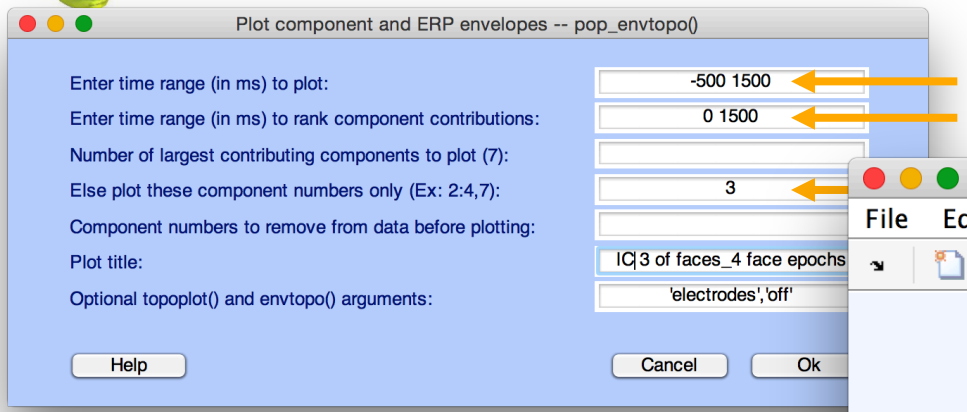
ERP peak- and IC Component-topographies

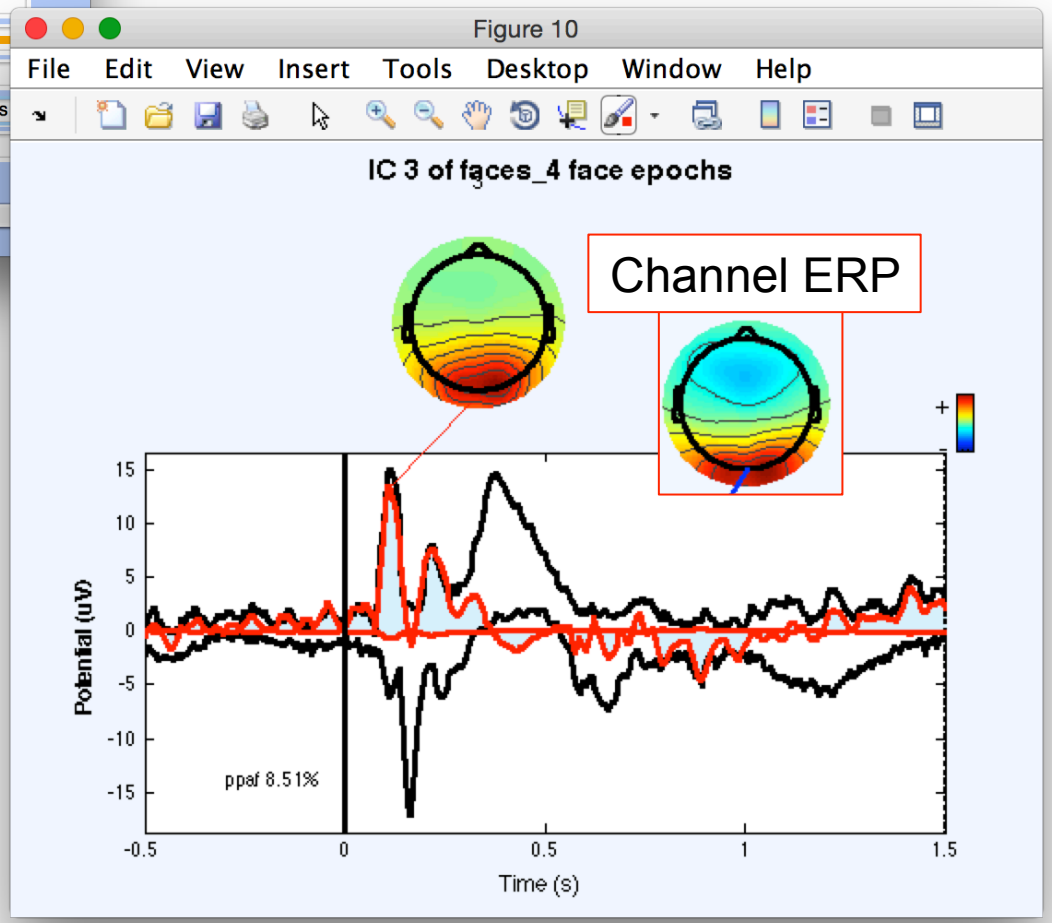




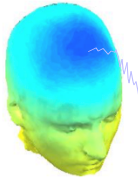
Component 3 ERP envelope

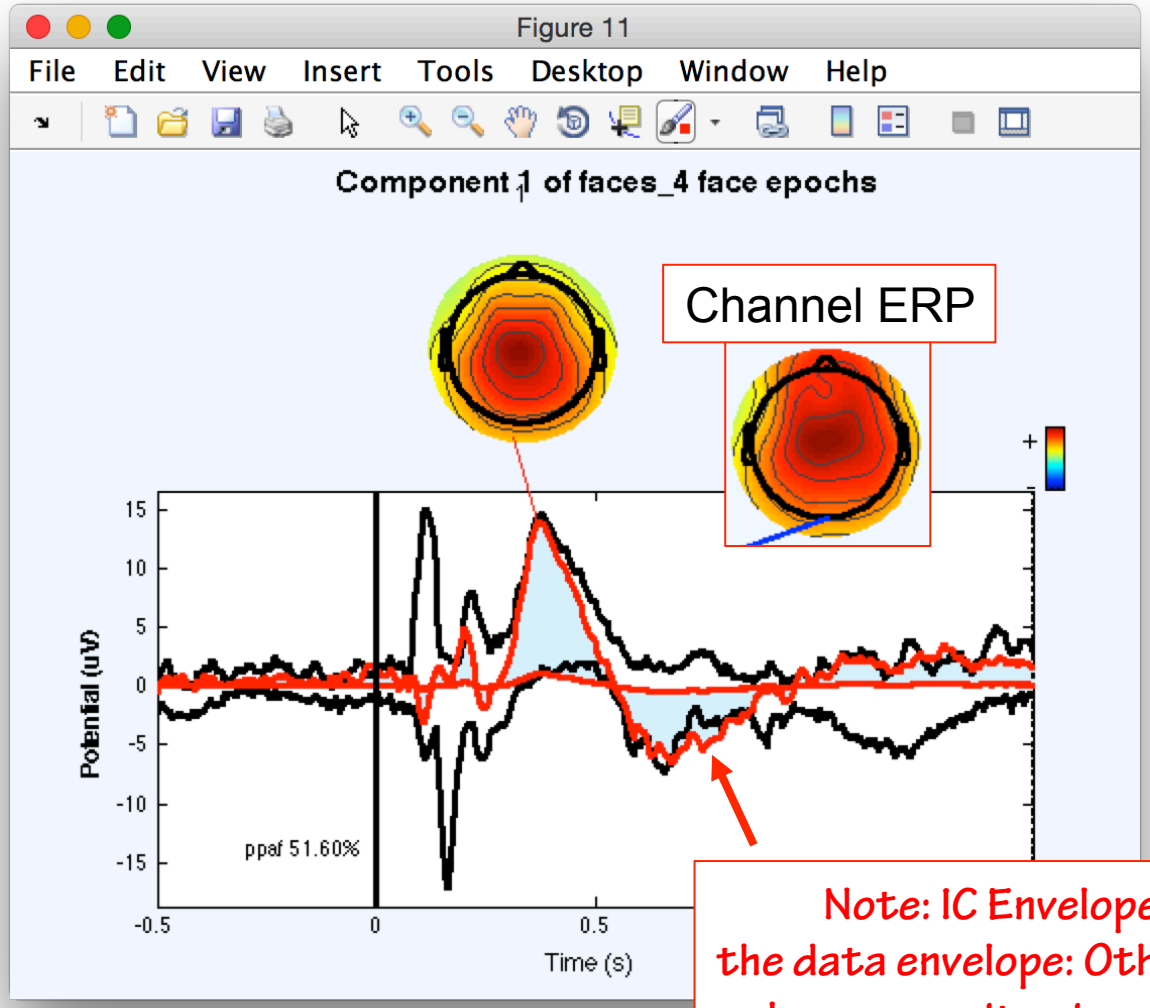






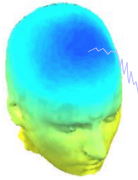
Component 1 ERP envelope



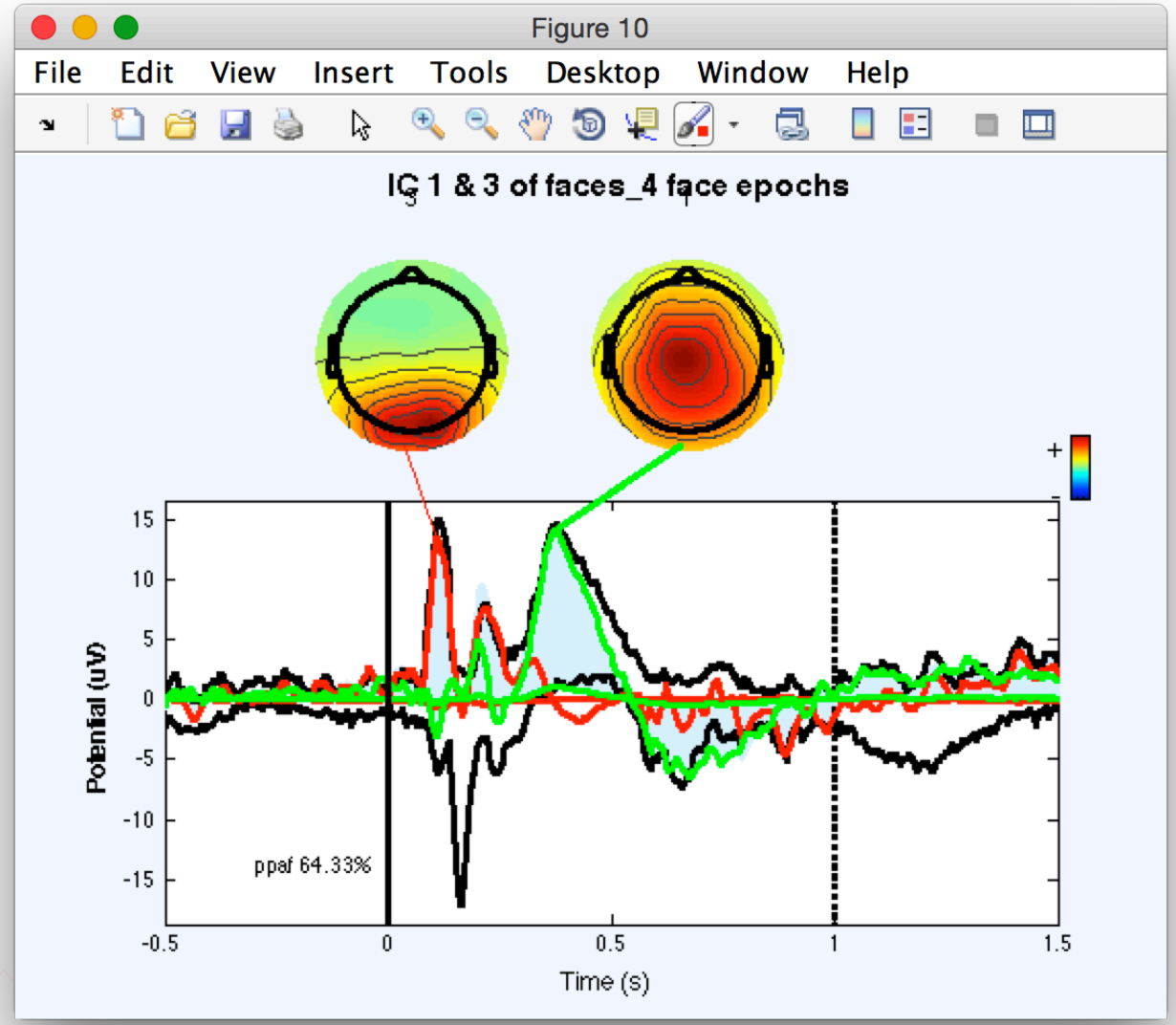


Note: IC Envelope can *exceed* the data envelope: Other component(s) have opposite sign at this latency.

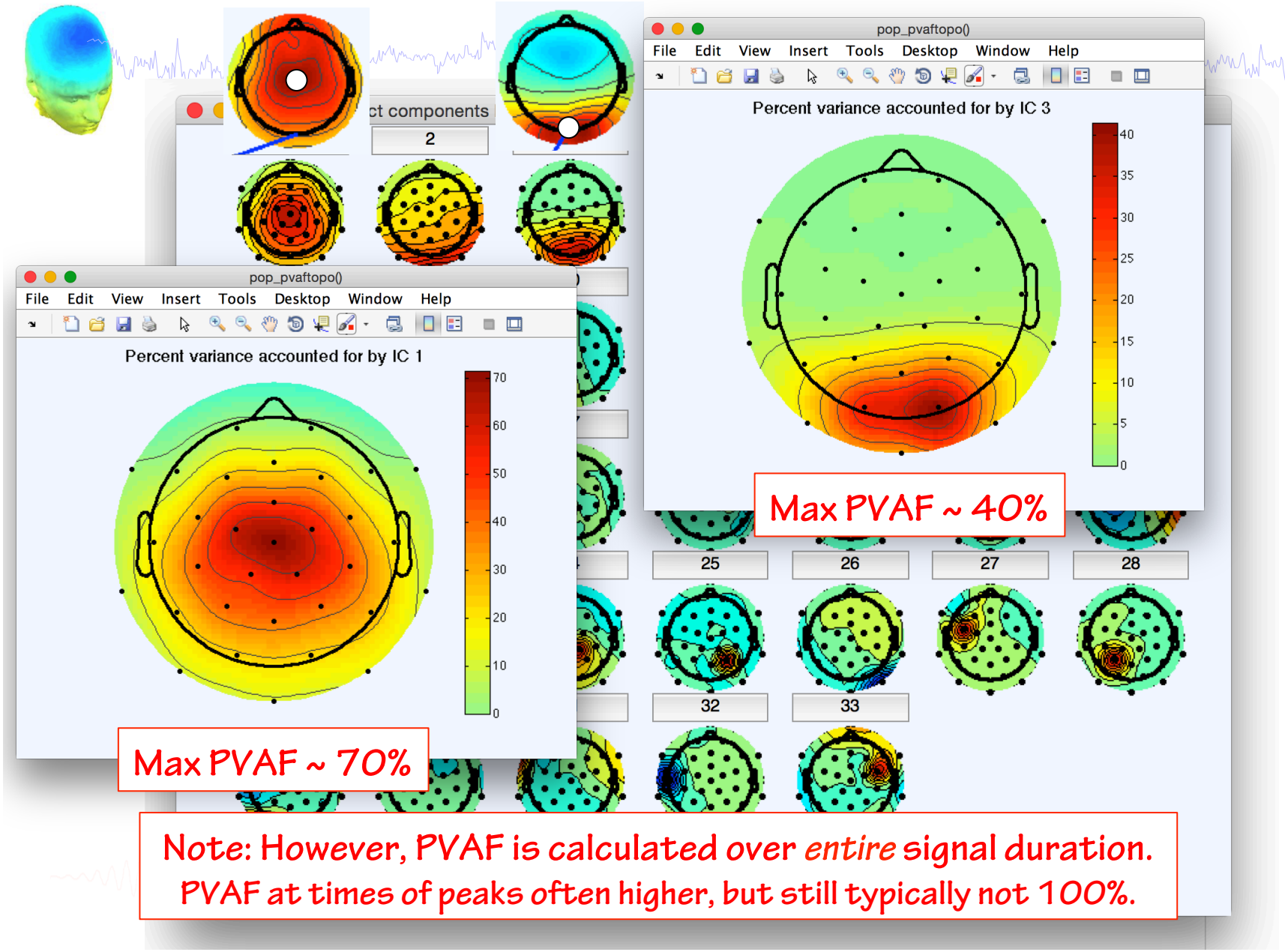
Component 1 + 3 ERP envelope



Else plot these component numbers only (Ex: 2:4,7): 1 3

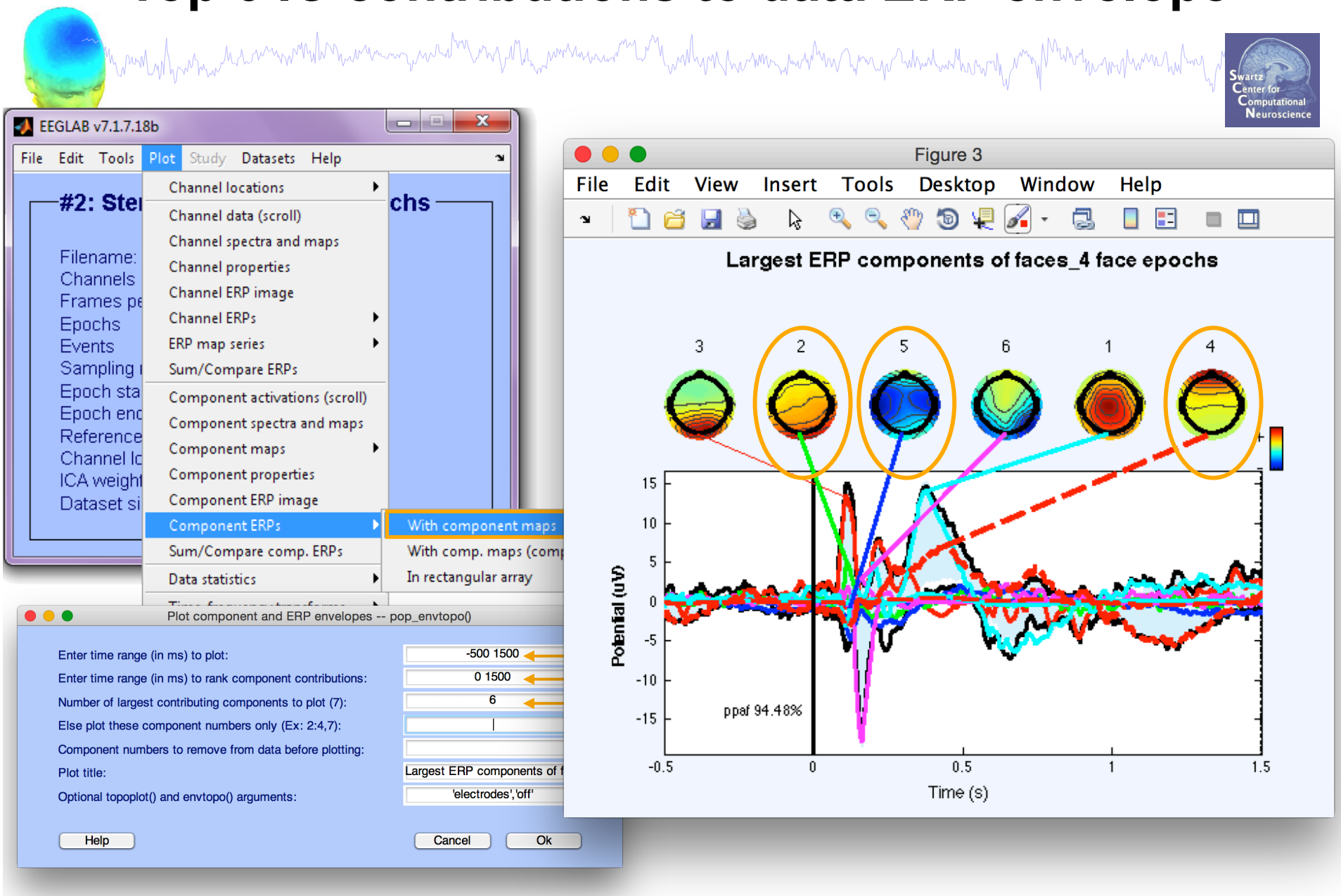


pvaftopo plugin (Makoto Miyakoshi)



Note: However, PVAF is calculated over *entire* signal duration.
PVAF at times of peaks often higher, but still typically not 100%.

Top 6 IC contributions to data ERP envelope

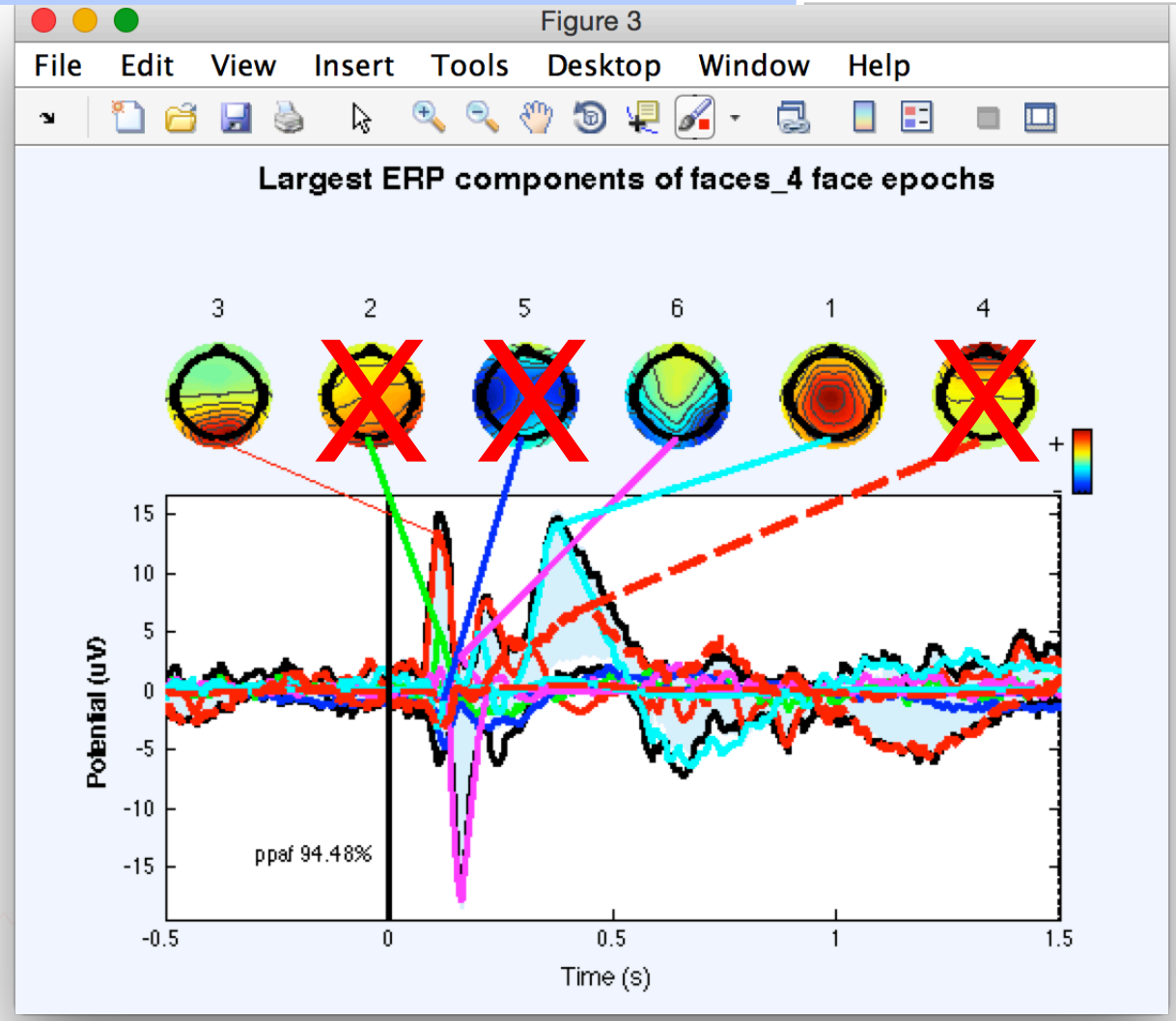


Non-artifact IC contrib. to data ERP envelope

Component numbers to remove from data before plotting: 2 4 5 7 9 12 17 18 25

Plot title: Largest non-artifact ERP compor

Artifact Components



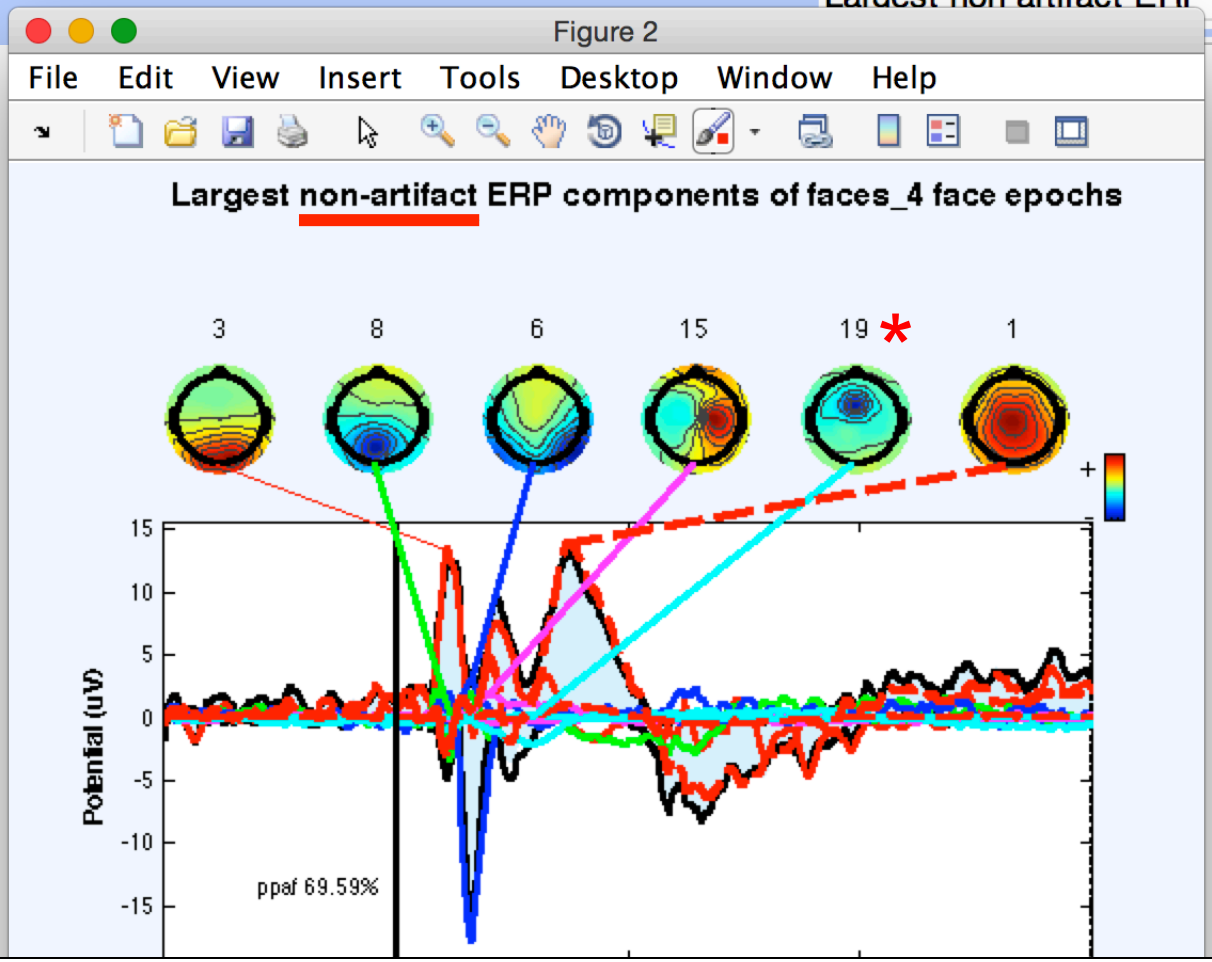
Non-artifact IC contrib. to data ERP envelope

Component numbers to remove from data before plotting: 2 4 5 7 9 12 17 18 25

Plot title: Largest non-artifact ERP compor

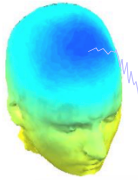
Artifact Components

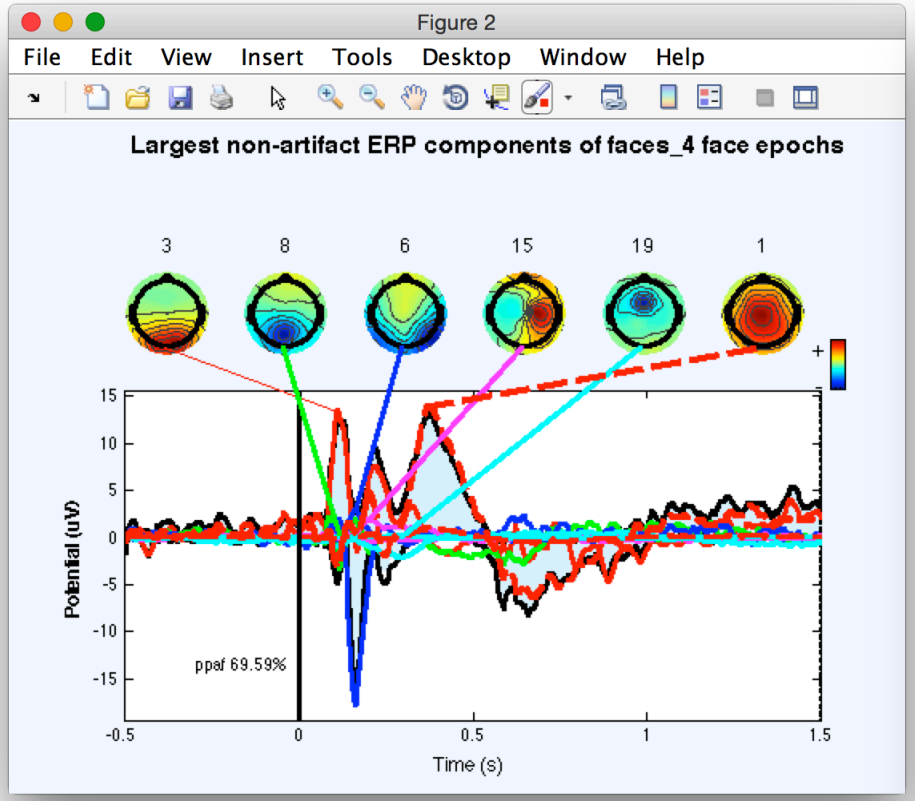
Center for Computational Neuroscience

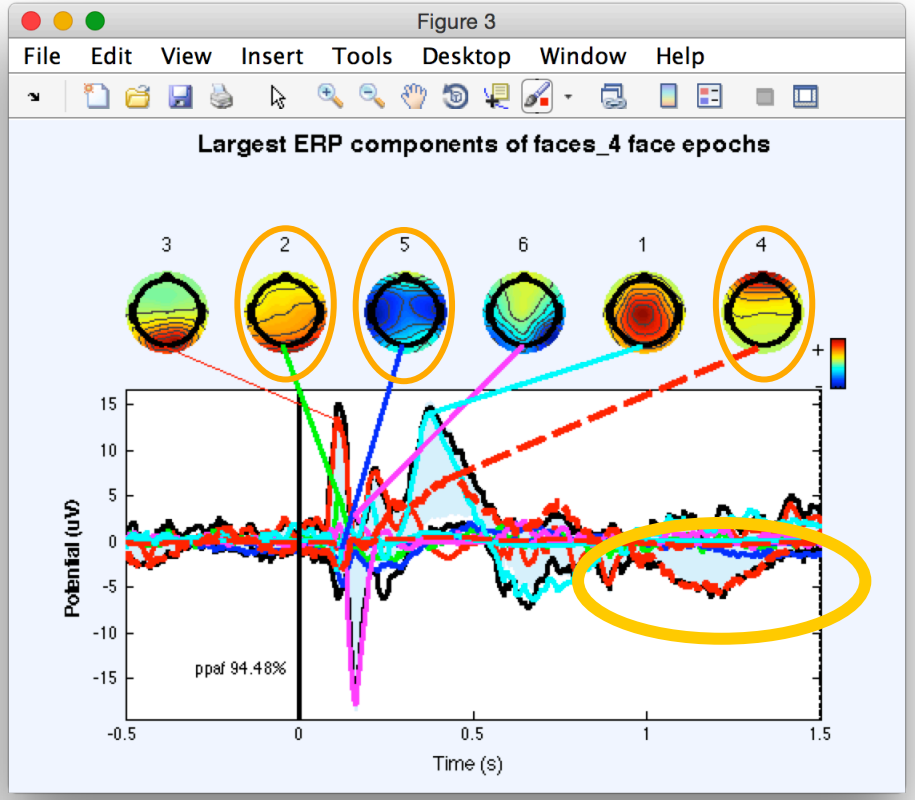



```
pop_envtopo(EEG, [-500  1500] ,'limcontrib', [0 1500], ...
'compsplot',[6],'subcomps',[2 4 5 7 9 12 17 18 25], ...
'title', 'Largest non-artifact ERP components of faces_4 face epochs',...
'electrodes','off');
```

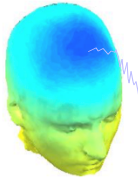
Compare: Effect of removing artifacts



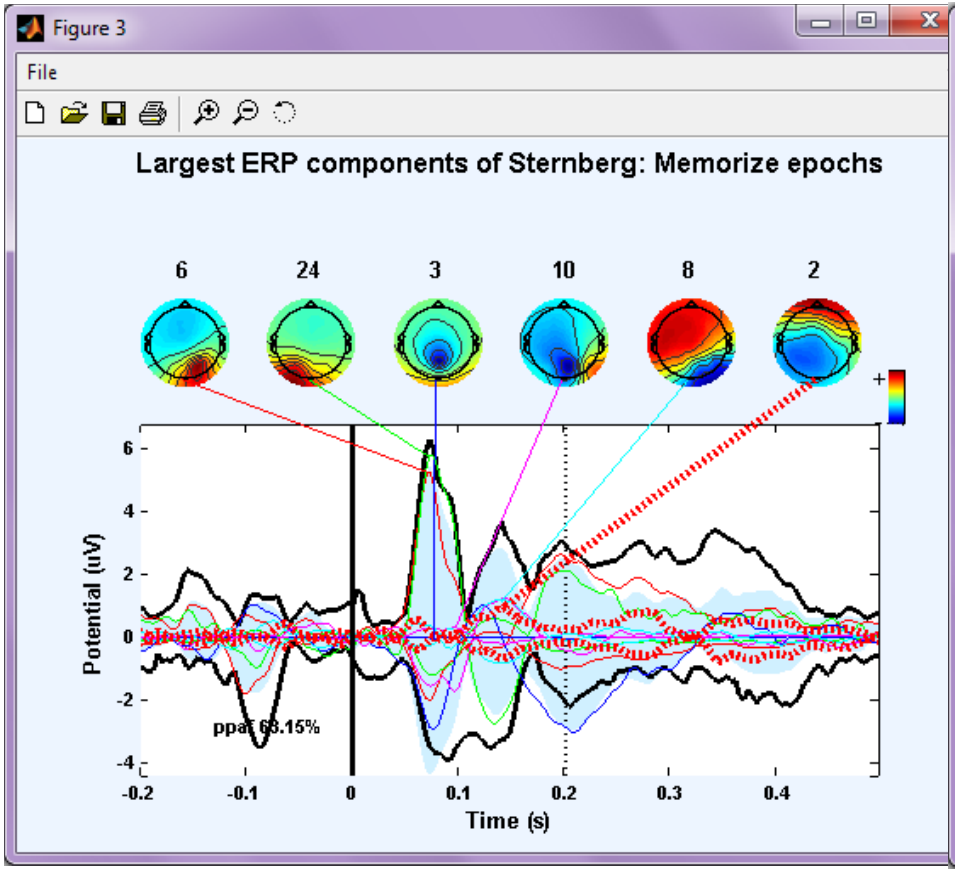


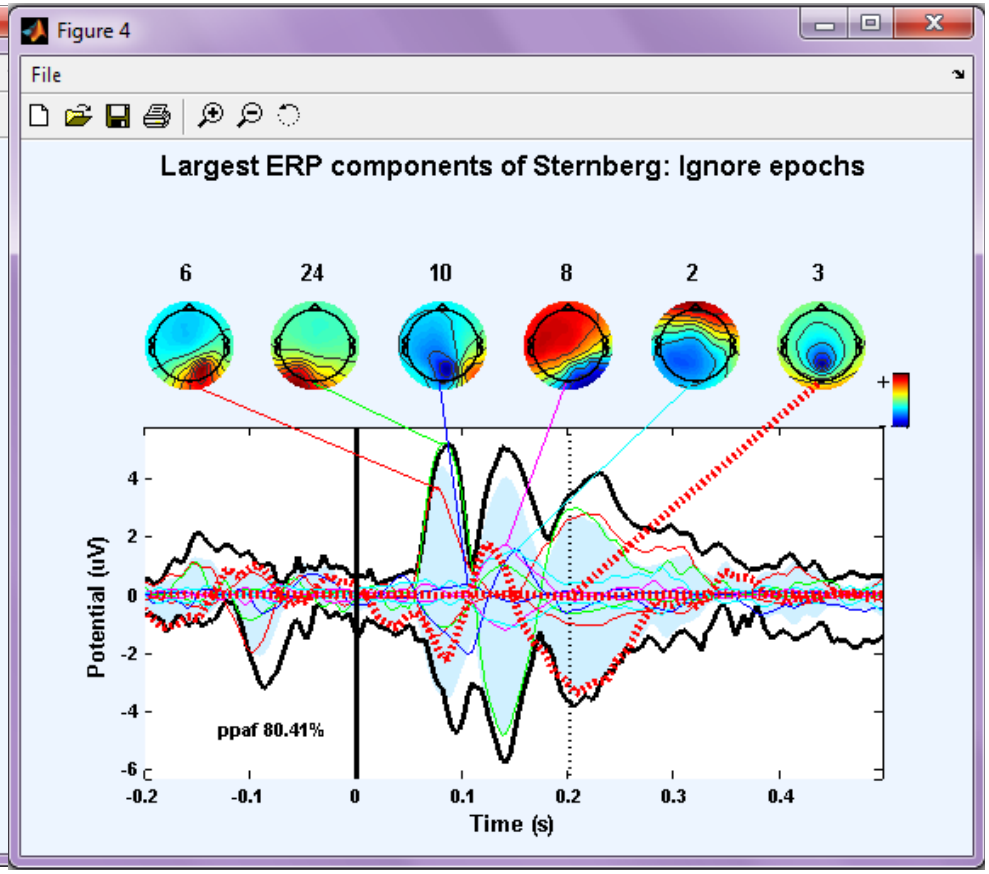


IC ERP difference



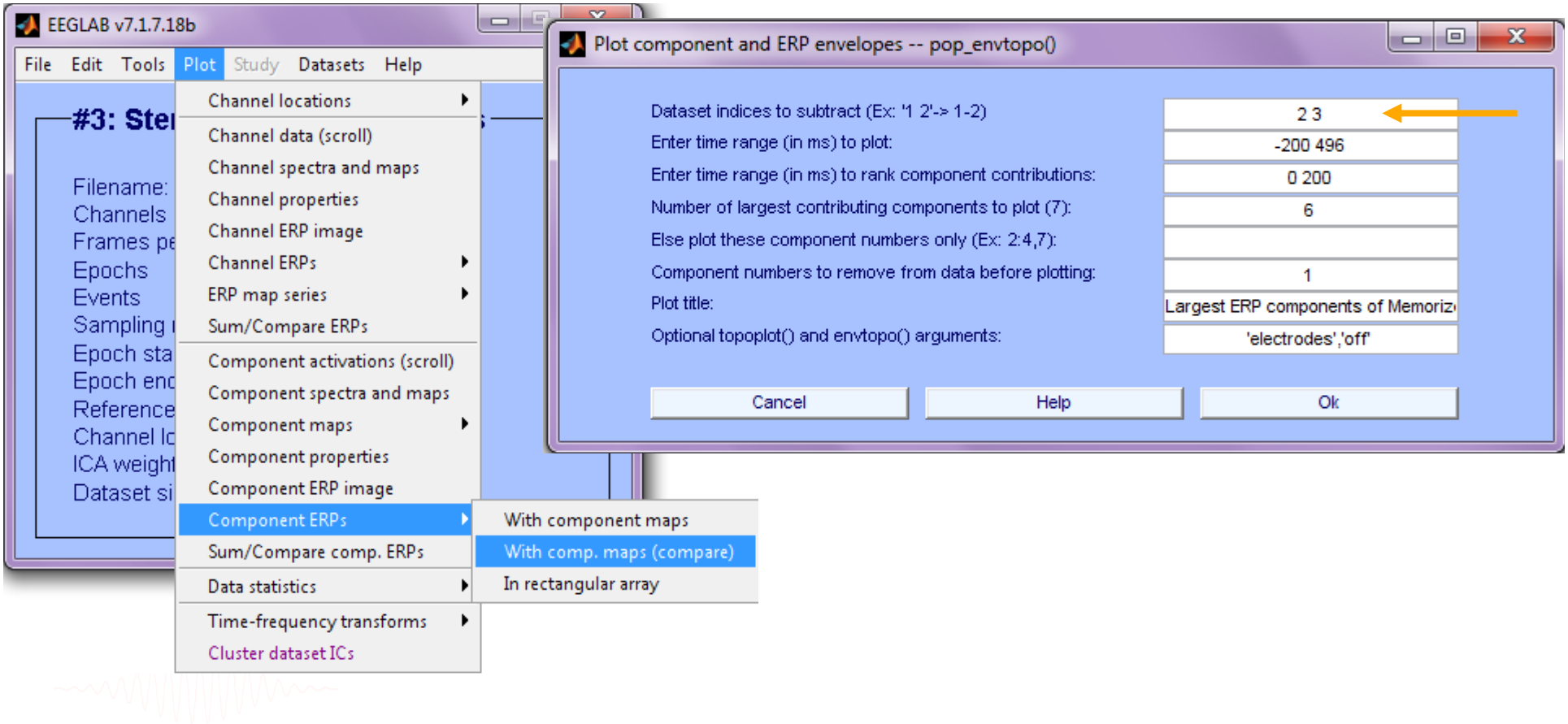
What is the IC ERP difference between these 2 conditions?



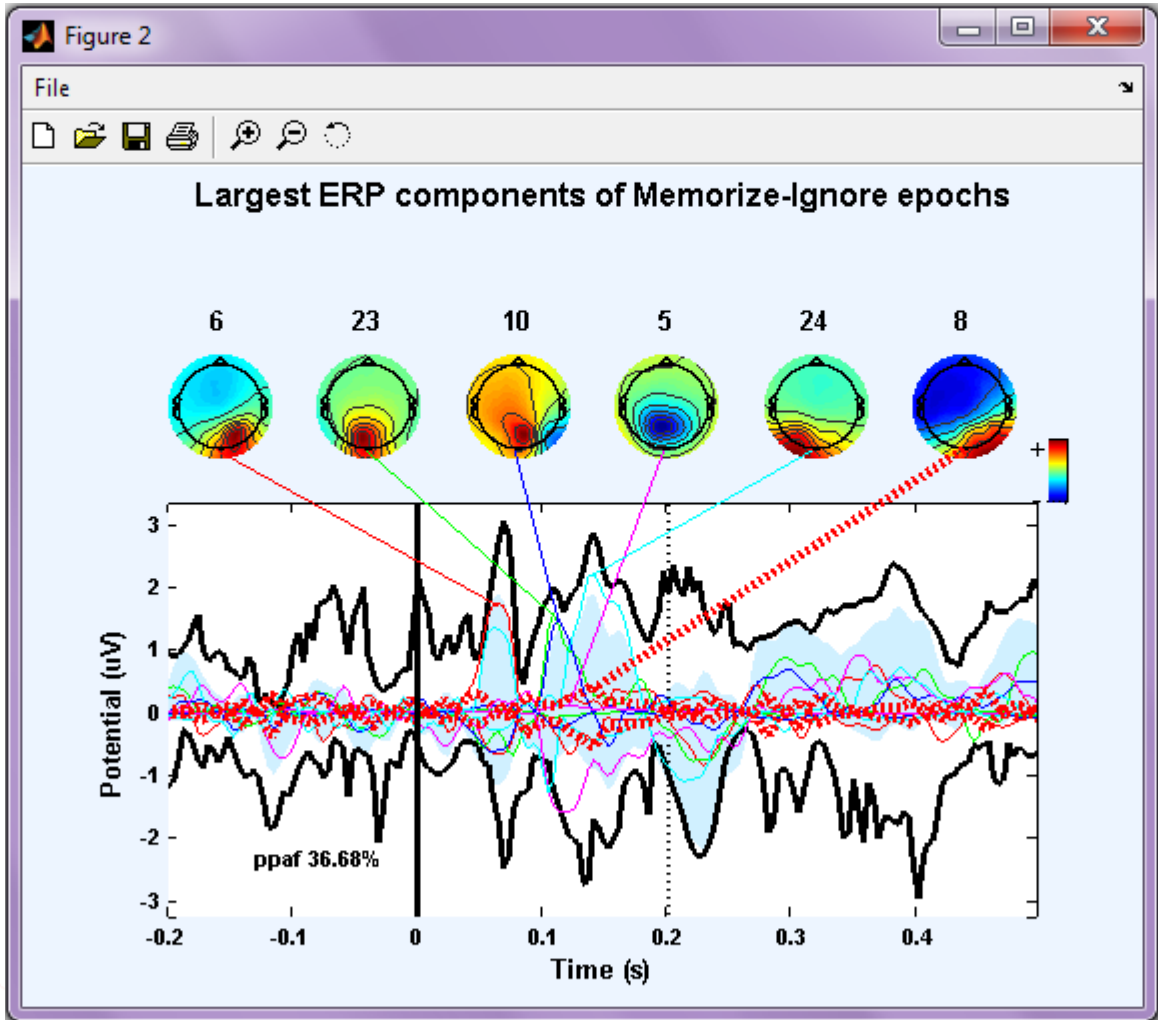


(Data: stern_125Hz.set)

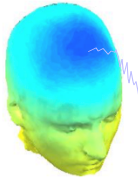
IC ERP difference



IC ERP difference



Now what…?



Part 1

Getting an overview of your ICs

Part 2

Classifying/Evaluating ICs

Part 3

Detailed look at IC properties

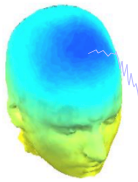
ERP

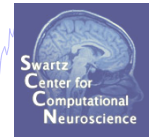
Spectrum (see next lecture)

ERP images

ERSP

Plot component power spectrum





Component spectra and maps -- pop_spectopo()

Epoch time range to analyze [min_ms max_ms]:	0 2440528
Frequency (Hz) to analyze:	10
Electrode number to analyze ([]=elec with max power; 0=whole scalp):	0
Percent data to sample (1 to 100):	20
Components to include in the analysis:	1:71
Number of largest-contributing components to map:	5
Else, map only these component numbers:	
[Checked] Compute comp spectra; [Unchecked] (data-comp) spectra:	☑
Plotting frequency range ([min max] Hz):	2 25
Spectral and scalp map options (see topoplot):	'electrodes','off'

Cancel Help

EEGLAB v7.1.7.18b

File Edit Tools Pl

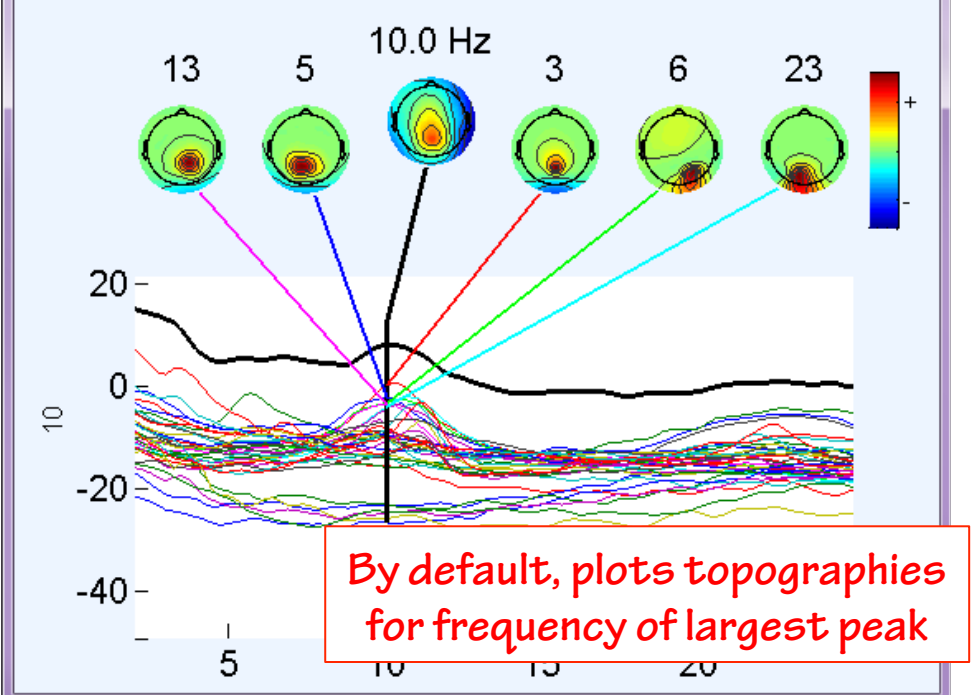
#1: Ste ta

Filename:
Channels
Frames pe
Epochs
Events
Sampling
Epoch sta
Epoch enc
Reference
Channel lo
ICA weight
Dataset si

- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Sum/Compare ERPs
- Component activations (scroll)
- **Component spectra and maps**
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Sum/Compare comp. ERPs
- Data statistics

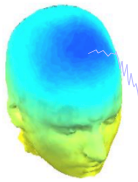
Figure 2: spectopo()

File



By default, plots topographies for frequency of largest peak

Select the frequency for topographies



Component spectra and maps -- pop_spectopo()

Epoch time range to analyze [min_ms max_ms]:	0 2440528
Frequency (Hz) to analyze:	6
Electrode number to analyze ([]=elec with max power; 0=whole scalp):	0
Percent data to sample (1 to 100):	20
Components to include in the analysis:	1:71
Number of largest-contributing components to map:	5
Else, map only these component numbers:	
[Checked] Compute comp spectra; [Unchecked] (data-comp) spectra:	☑
Plotting frequency range ([min max] Hz):	2 25
Spectral and scalp map options (see topoplot):	'electrodes','off'

Cancel

EEGLAB v7.1.7.18b

File Edit Tools Pl

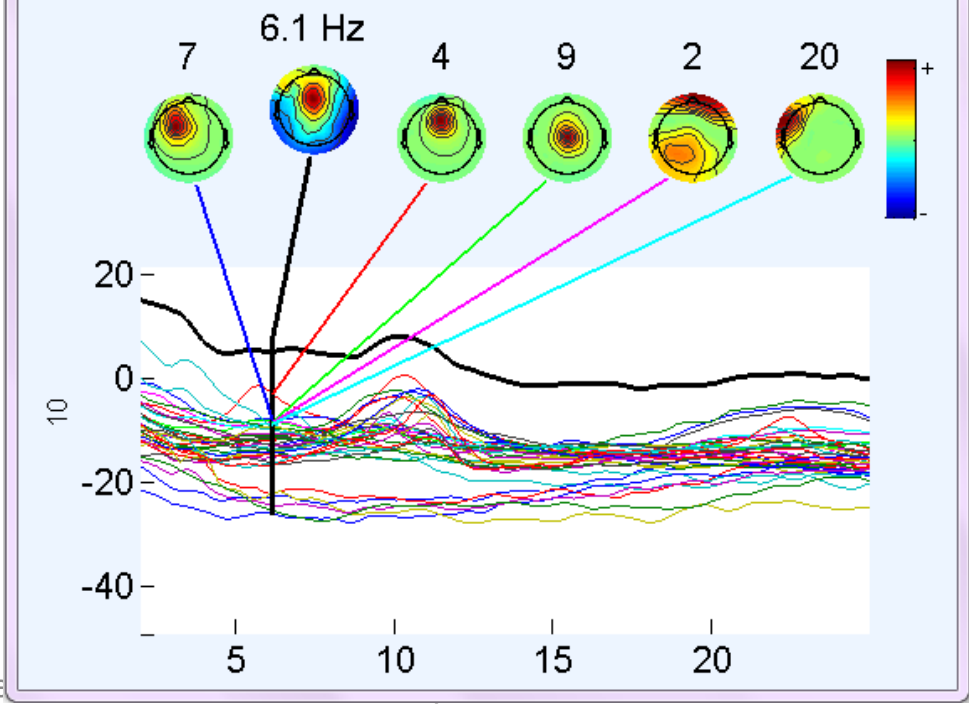
#1: Ste ta

Filename:
Channels
Frames pe
Epochs
Events
Sampling
Epoch sta
Epoch enc
Reference
Channel lo
ICA weight
Dataset si

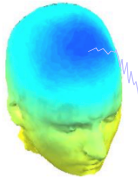
- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Sum/Compare ERPs
- Component activations (scroll)
- **Component spectra and maps**
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Sum/Compare comp. ERPs
- Data statistics

Figure 2: spectopo()

File



Now what…?



Part 1

Getting an overview of your ICs

Part 2

Classifying/Evaluating ICs

Part 3

Detailed look at IC properties

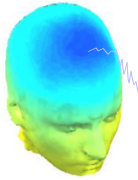
ERP

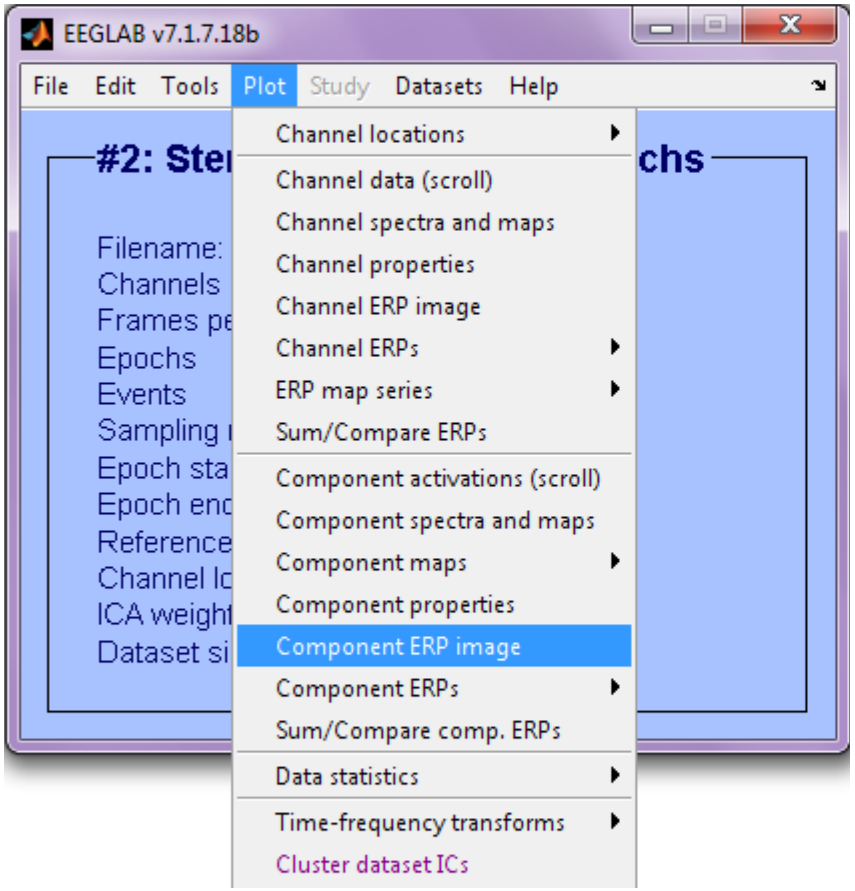
Spectrum

ERP images

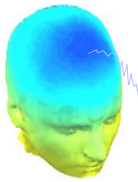
ERSP

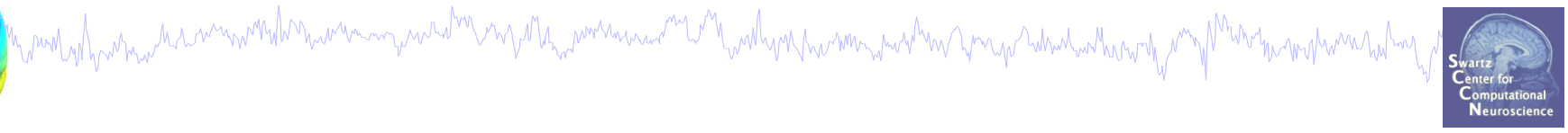
Component ERP image





ERP Image basics





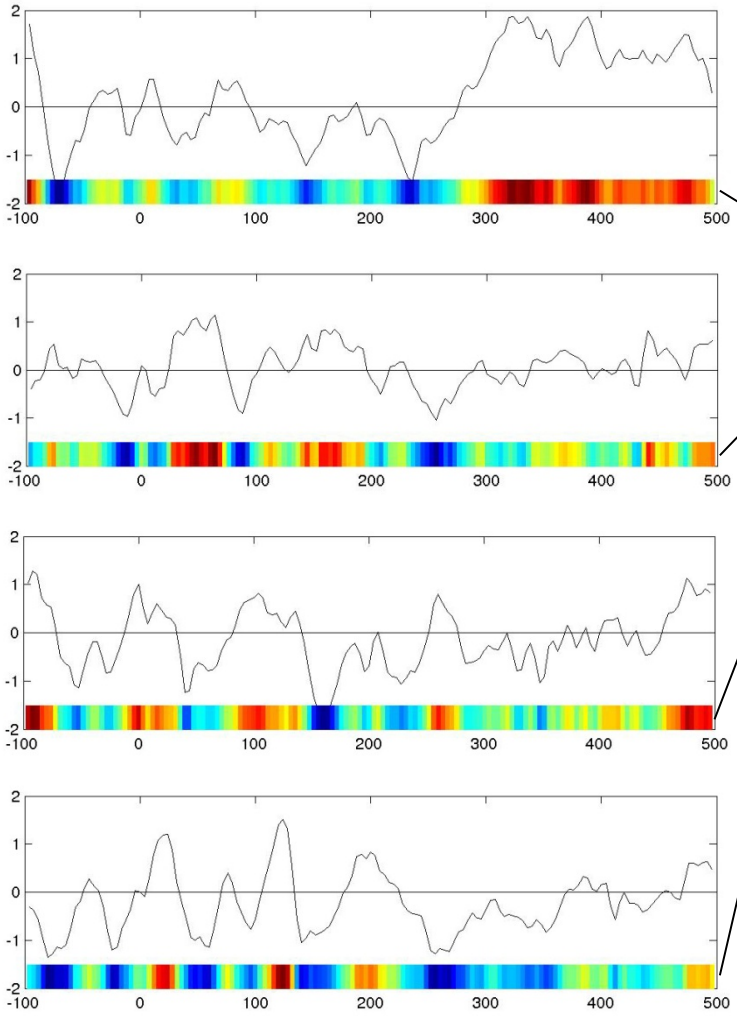
Swartz Center for Computational Neuroscience

Trial 1

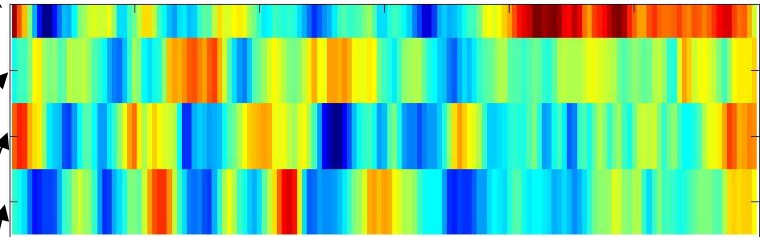
Trial 2

Trial 3

Trial 4

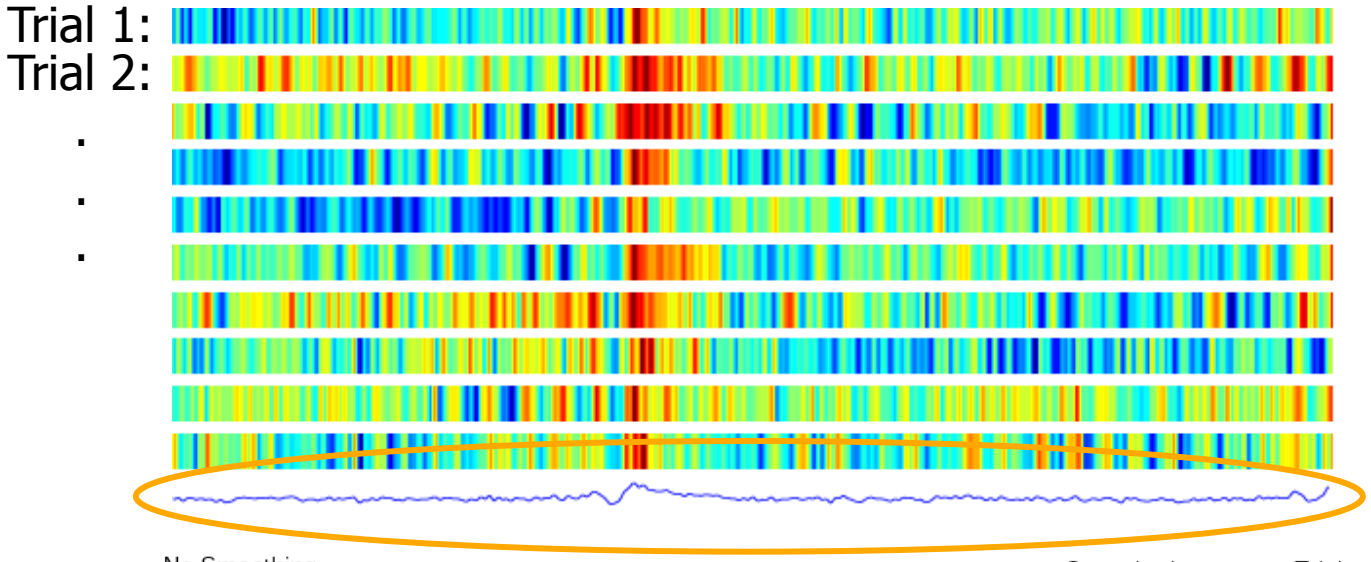


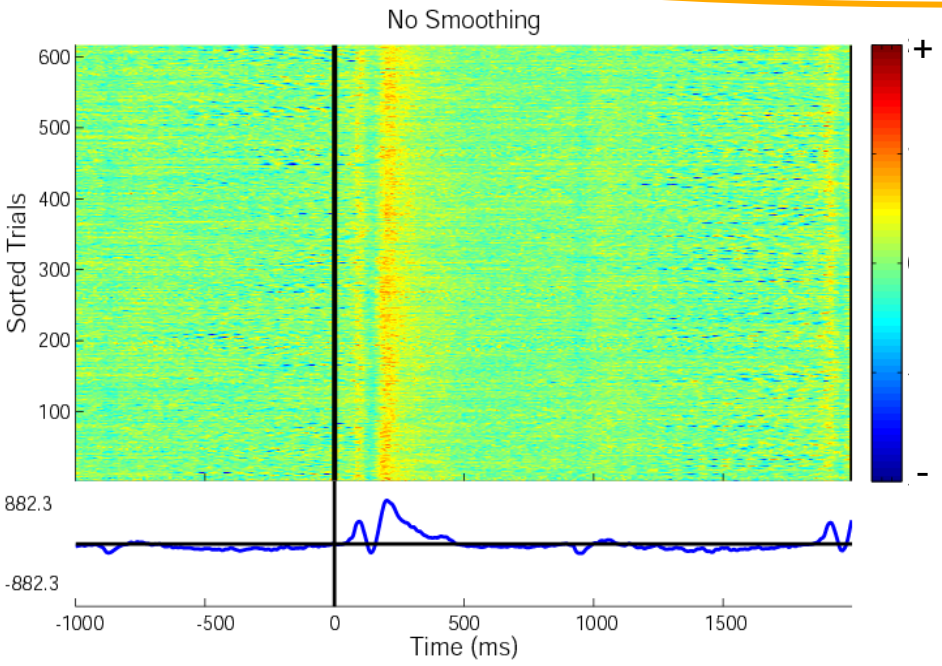
ERP Image

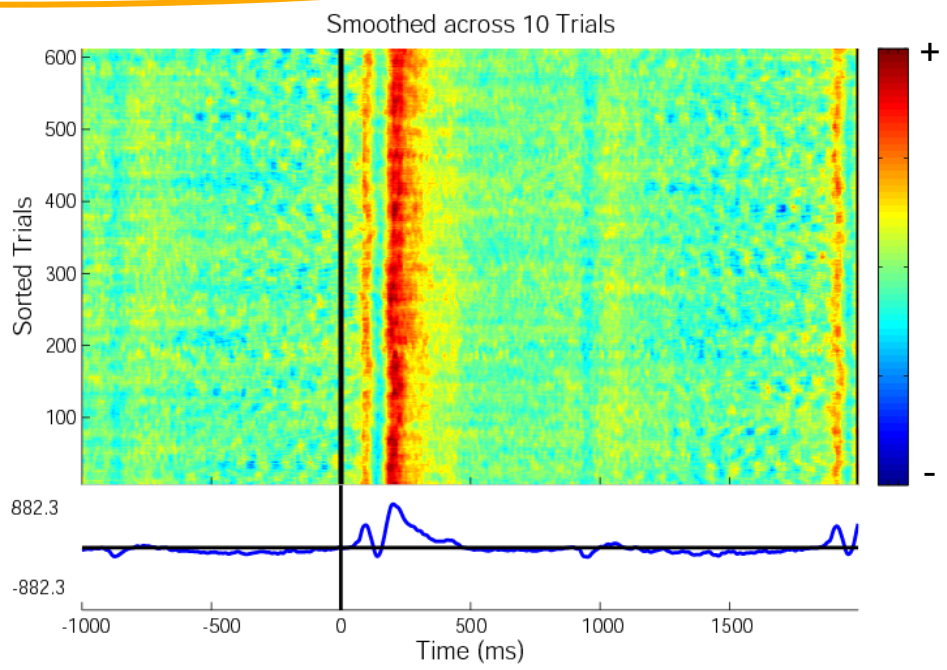


by default, sorted by time-on-task
(1st trial, 2nd trial, ...)

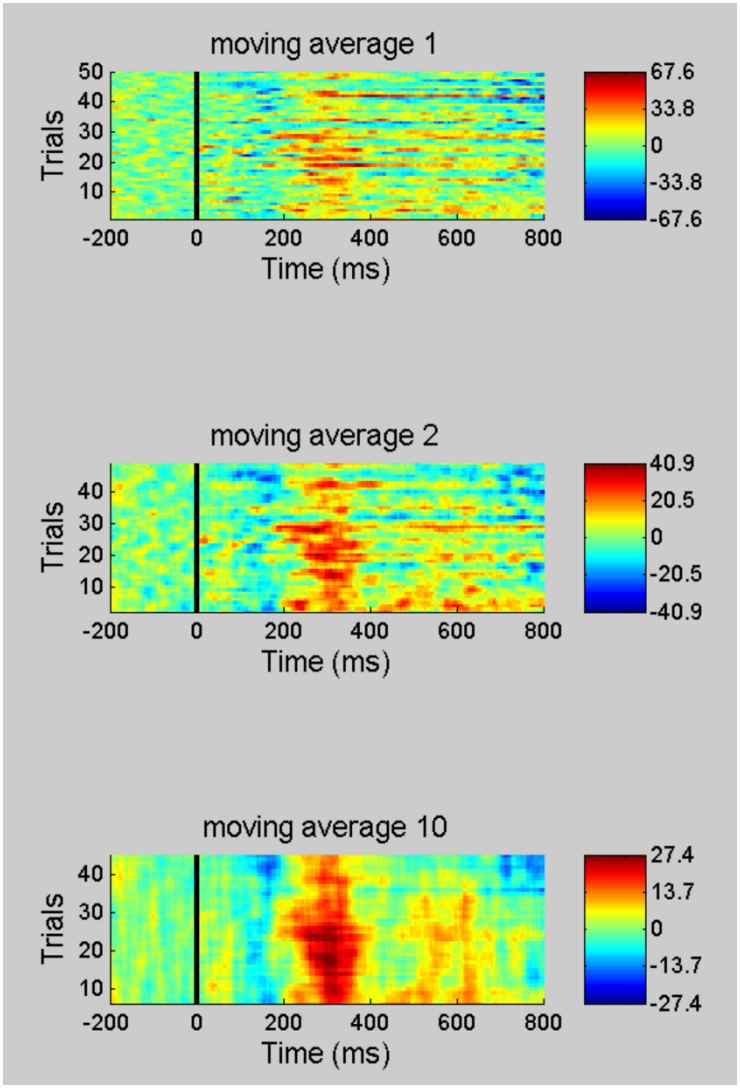
ERP Image basics



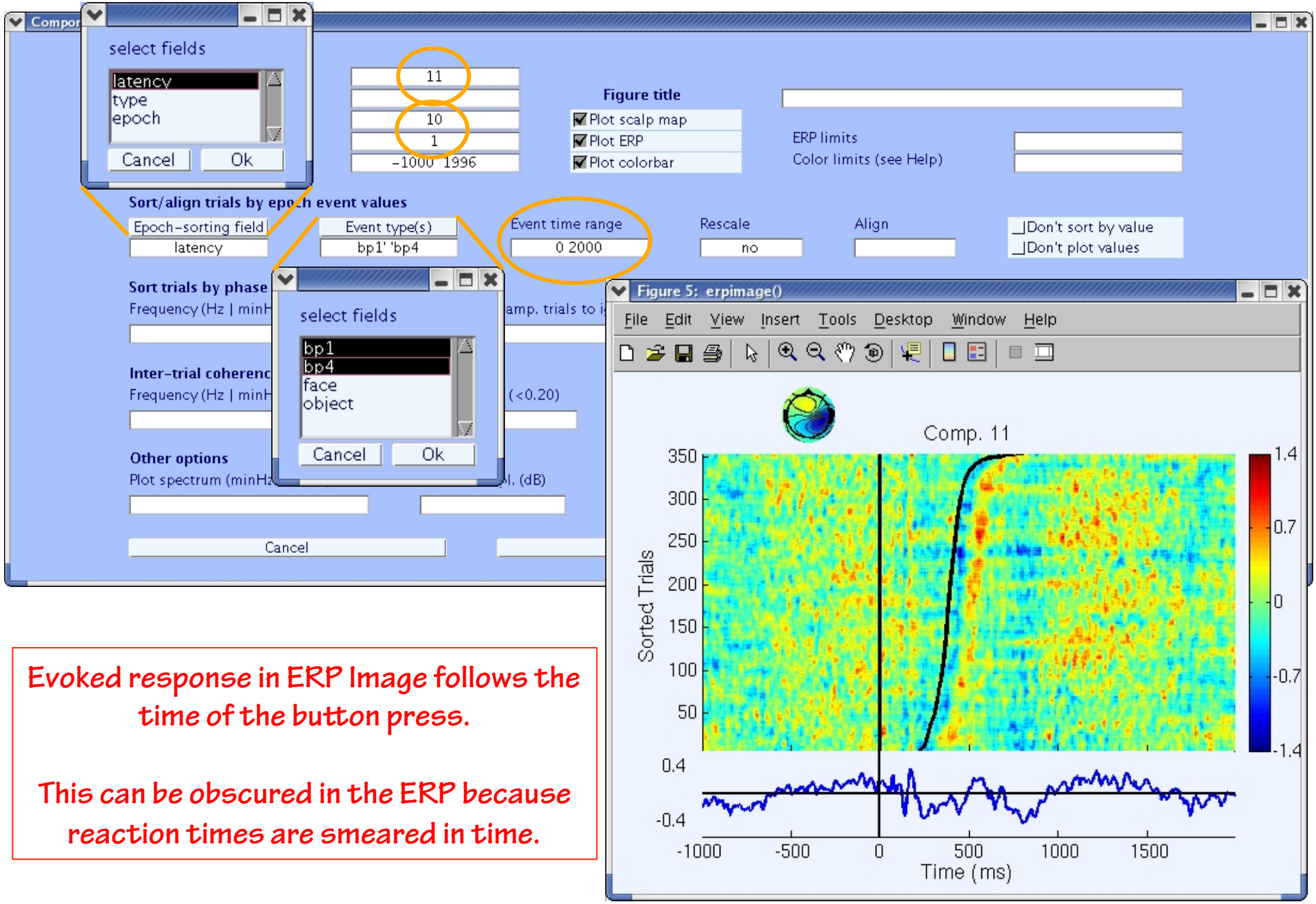




ERP Images: smoothing across trials



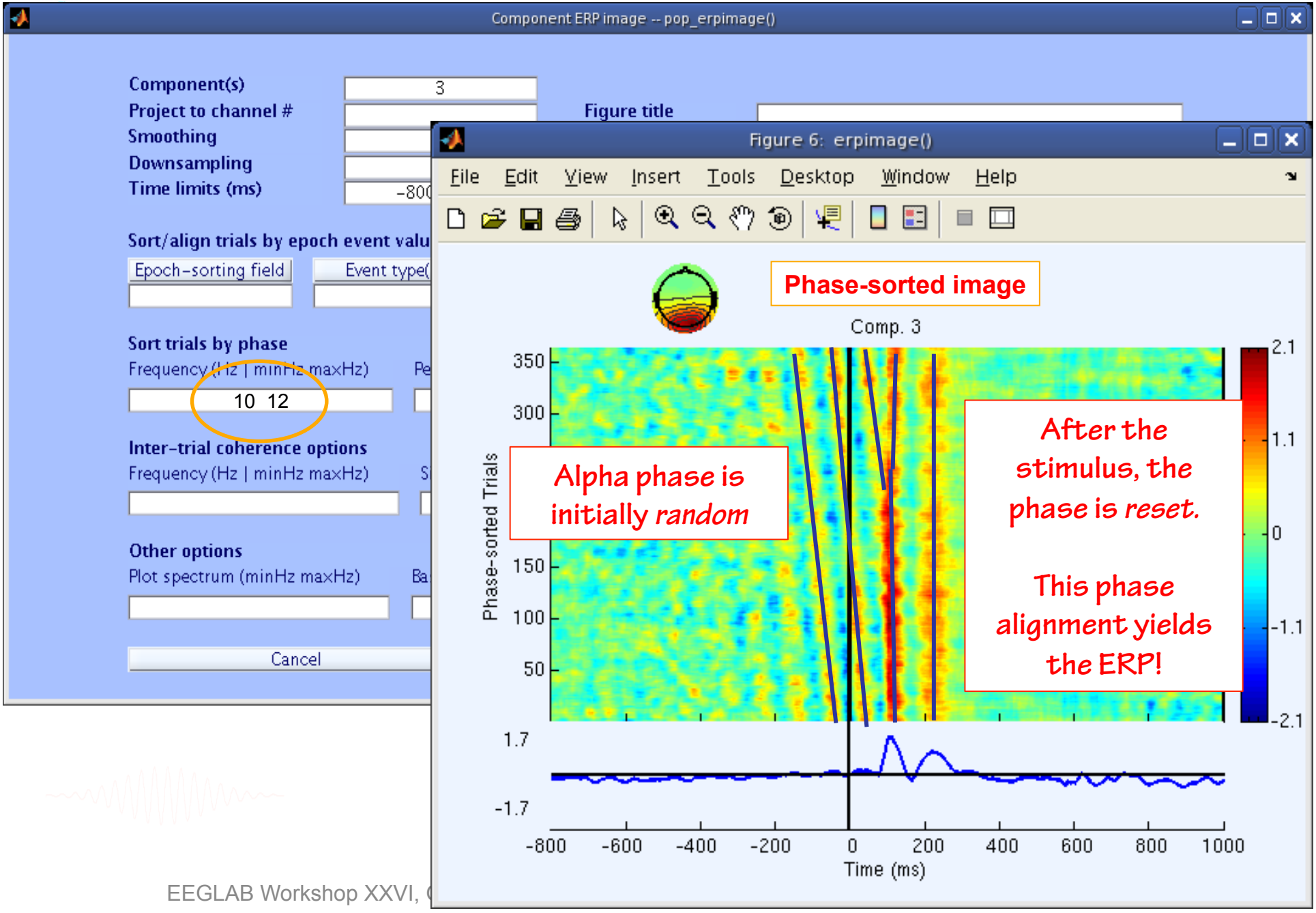
Component ERP Image: Sort by RT



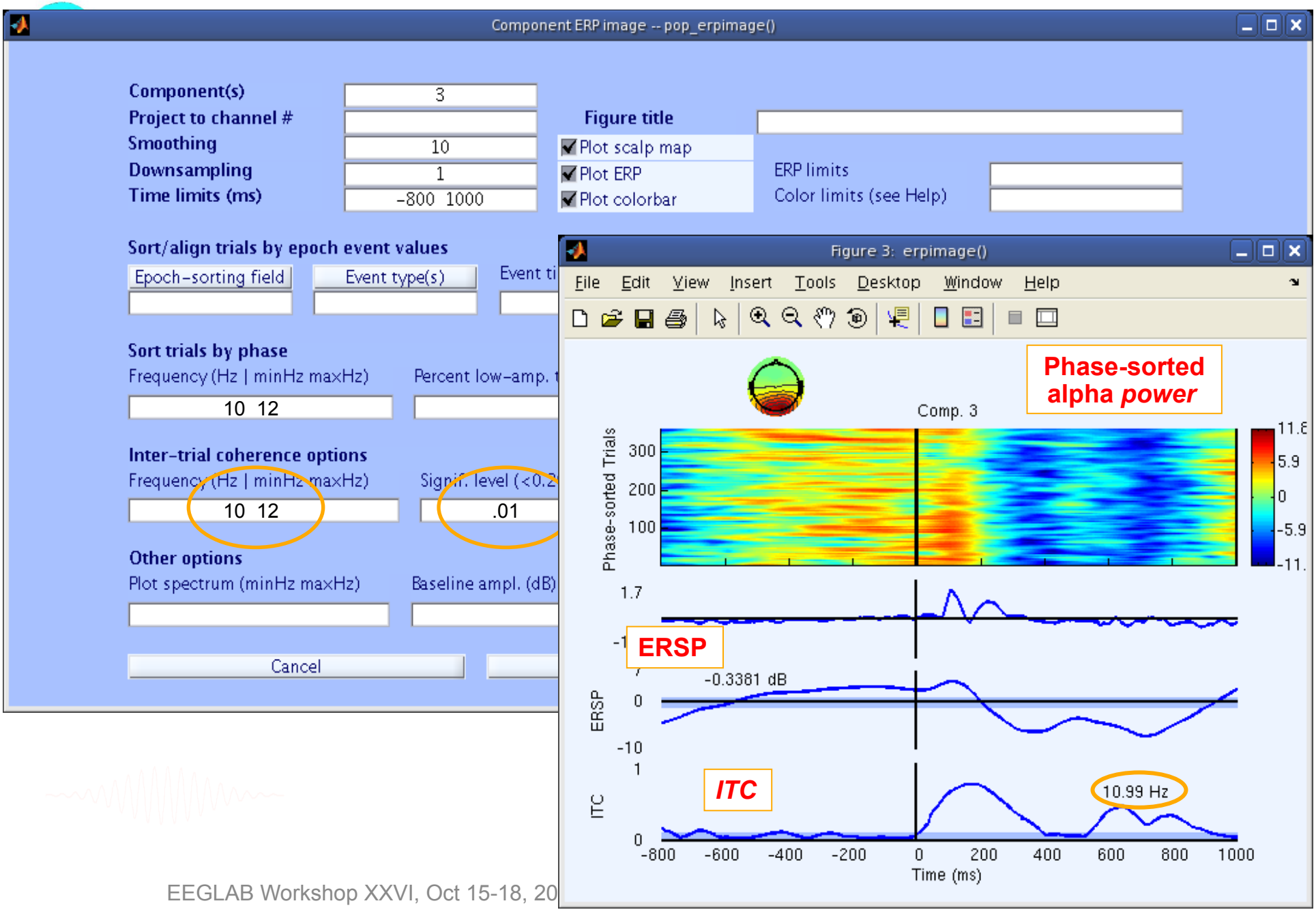
Evoked response in ERP Image follows the time of the button press.

This can be obscured in the ERP because reaction times are smeared in time.

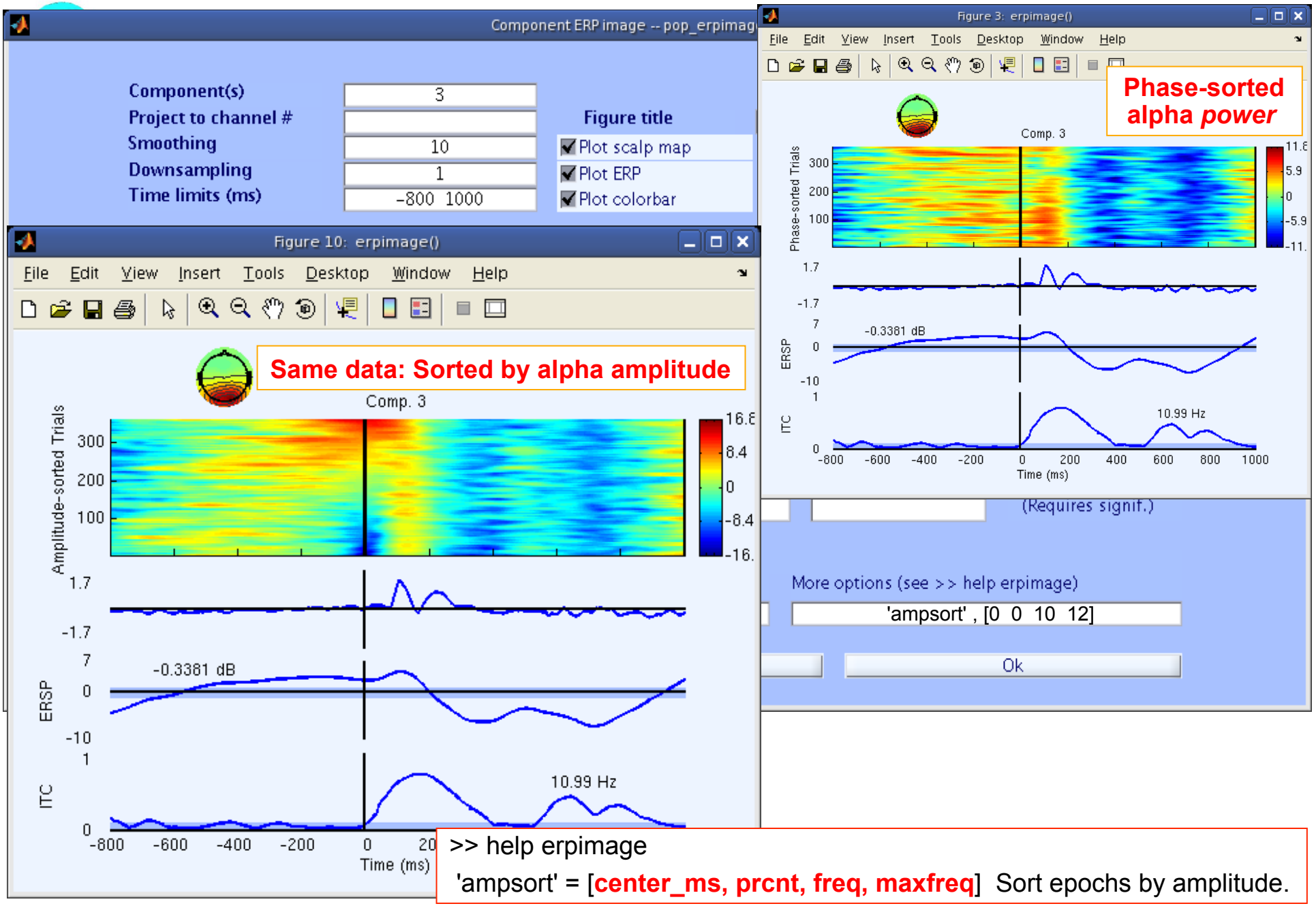
Component ERP Images: Sort by phase



Component ERP Images: ITC



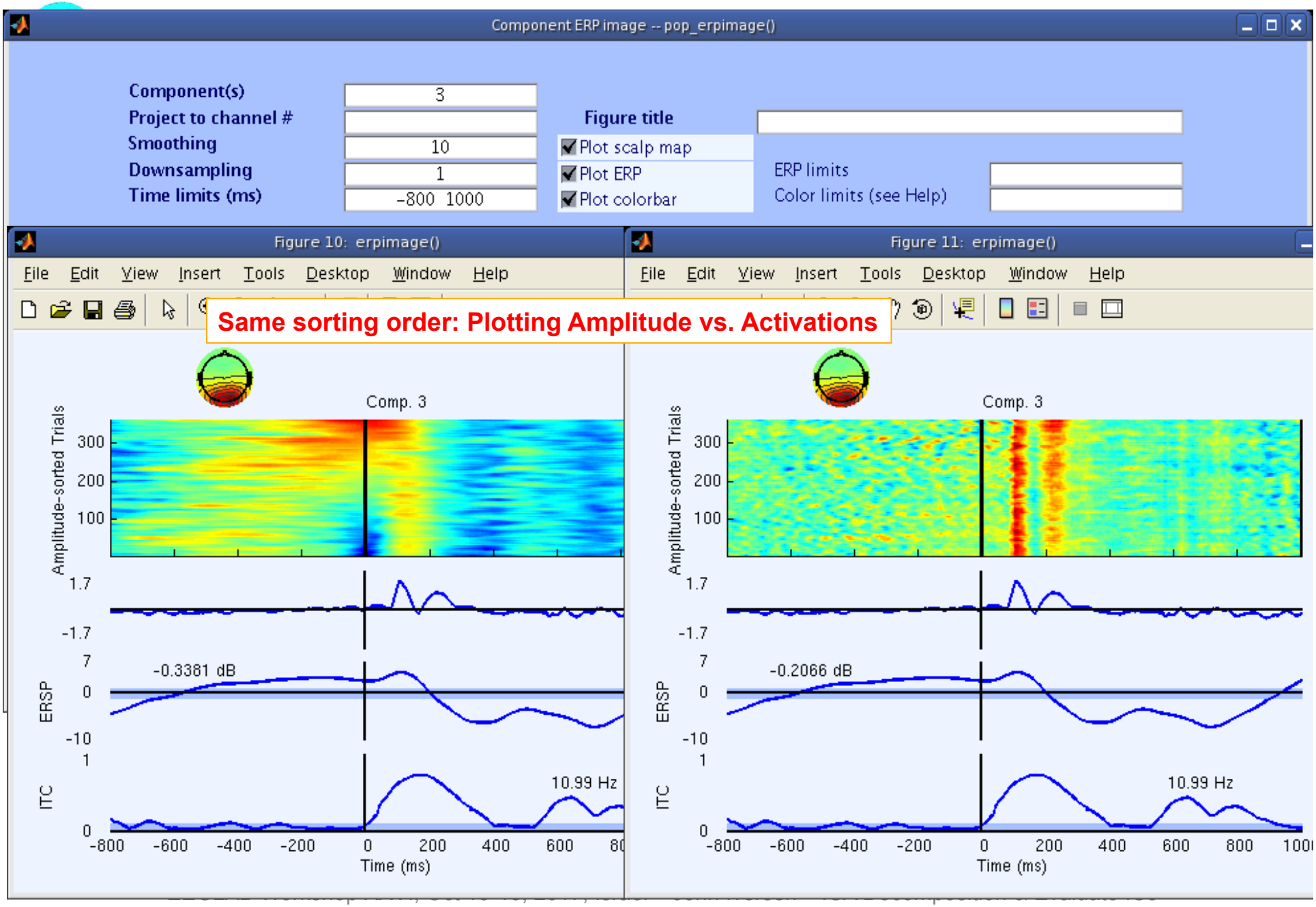
Component ERP Images: Sort by amplitude



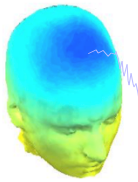
>> help erpimage

'ampsort' = [**center_ms, prcnt, freq, maxfreq**] Sort epochs by amplitude.

Component ERP Images: Amplitude vs. Activations



Now what…?



Part 1

Getting an overview of your ICs

Part 2

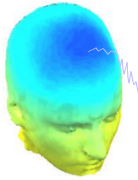
Classifying/Evaluating ICs

Part 3

Detailed look at IC properties

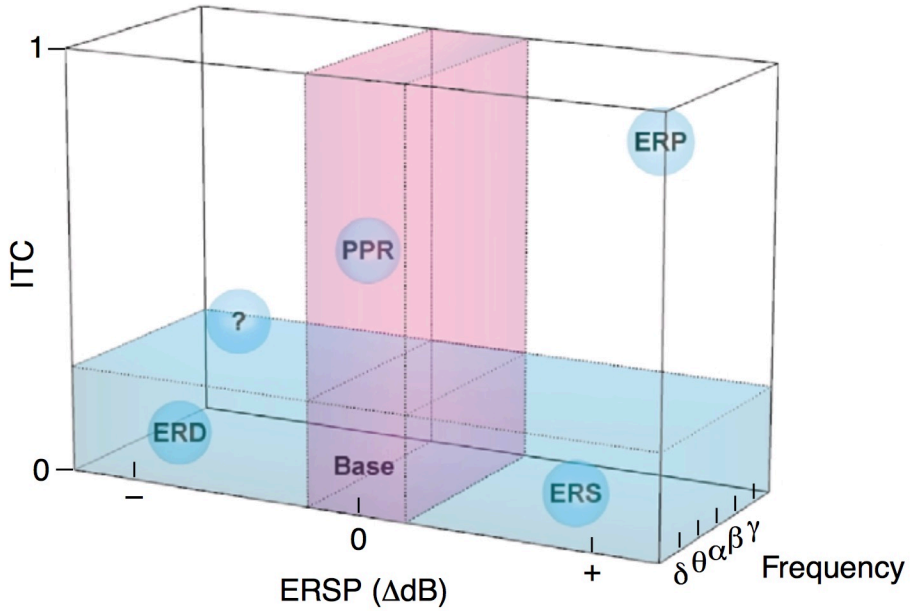
- ERP
- Spectrum
- ERP images
- ERSP (see next lecture)

Definition: ERSP

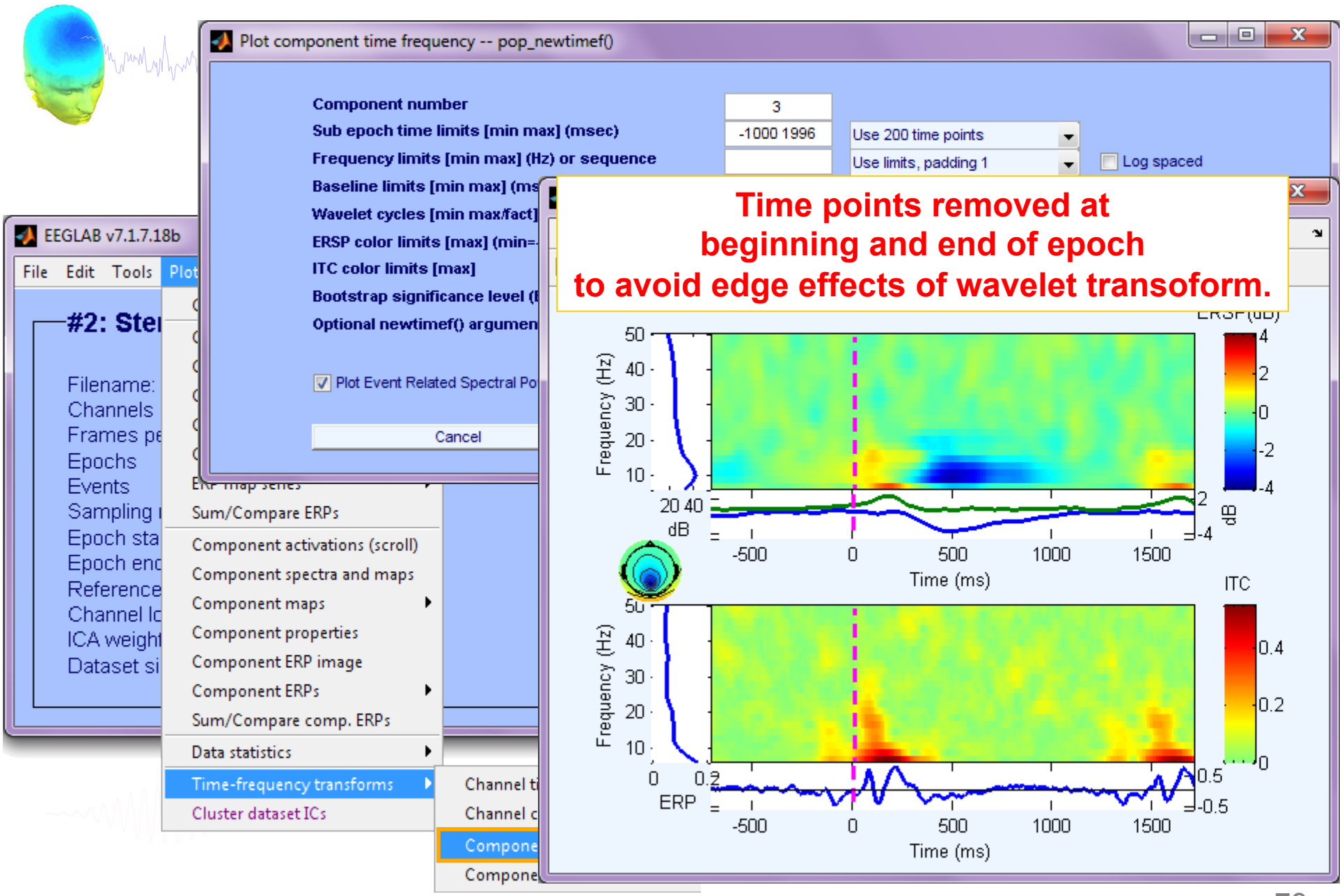


Event Related Spectral Perturbation

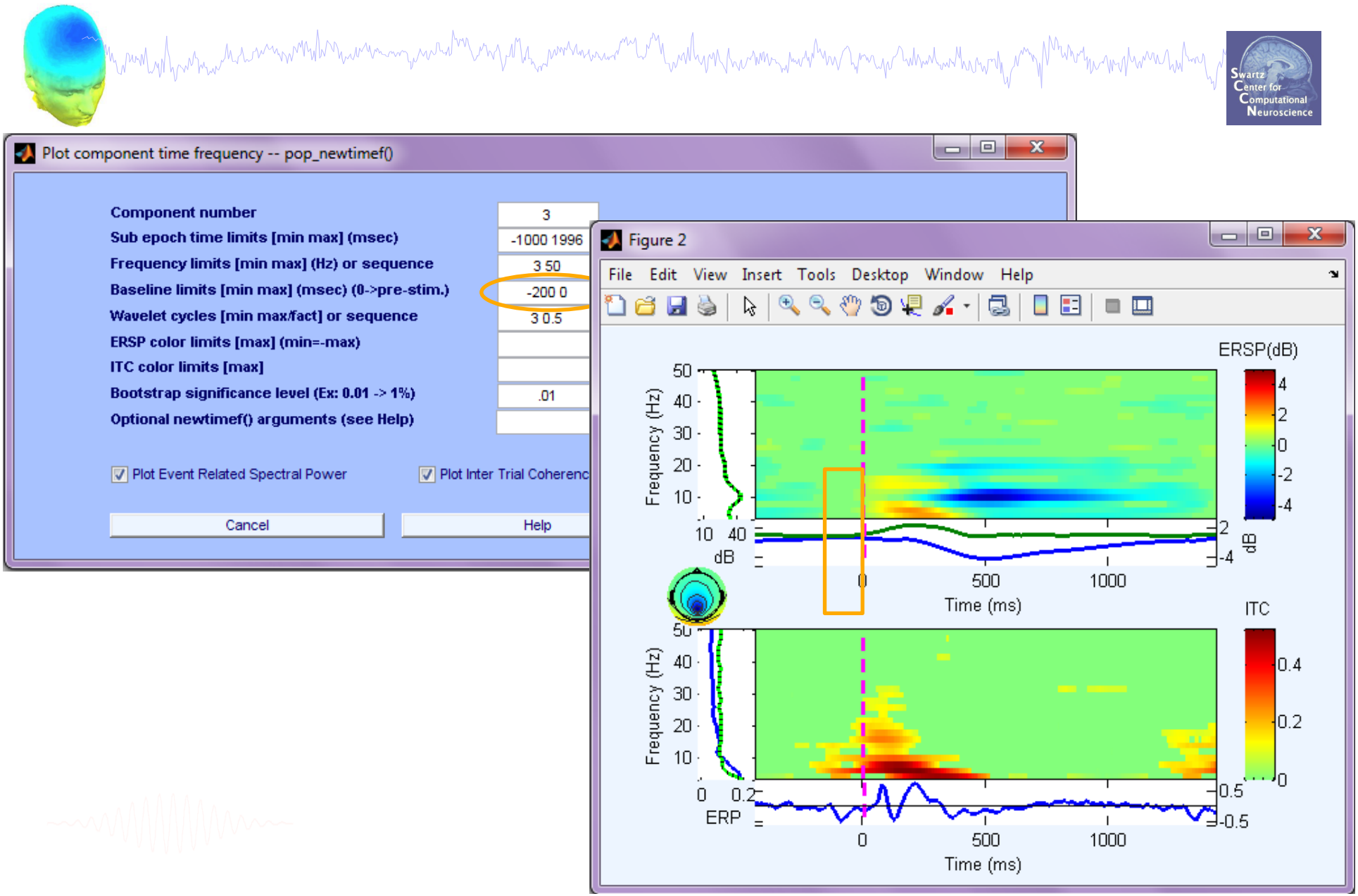
Change in power in different frequency bands relative to a baseline. ERS , ERD



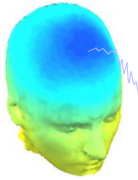
Plot IC ERSP


Plot component time frequency -- pop_newtimef()
Component number
3
Sub epoch time limits [min max] (msec)
-1000 1996
Use 200 time points
Frequency limits [min max] (Hz) or sequence
Use limits, padding 1
Log spaced
Baseline limits [min max] (ms
Wavelet cycles [min max/fact]
ERSP color limits [max] (min=
ITC color limits [max]
Bootstrap significance level (
Optional newtimef() argumen
Plot Event Related Spectral Po
Cancel
EEGLAB v7.1.7.18b
File Edit Tools Plot
#2: Ste
Filename:
Channels
Frames pe
Epochs
Events
Sampling
Epoch sta
Epoch enc
Reference
Channel lo
ICA weight
Dataset si
Sum/Compare ERPs
Component activations (scroll)
Component spectra and maps
Component maps
Component properties
Component ERP image
Component ERPs
Sum/Compare comp. ERPs
Data statistics
Time-frequency transforms
Cluster dataset ICs
Channel t
Channel c
Compone
Compone
Time points removed at
beginning and end of epoch
to avoid edge effects of wavelet transoform.
Frequency (Hz)
50
40
30
20
10
20 40
dB
-500
0
500
1000
1500
Time (ms)
ERSP(dB)
4
2
0
-2
-4
ITC
0.4
0.2
0
0
0.2
ERP
0.5
-0.5

Plot IC ERSP


Plot component time frequency -- pop_newtimef()
Component number
3
Sub epoch time limits [min max] (msec)
-1000 1996
Frequency limits [min max] (Hz) or sequence
3 50
Baseline limits [min max] (msec) (0->pre-stim.)
-200 0
Wavelet cycles [min max/fact] or sequence
3 0.5
ERSP color limits [max] (min=-max)
ITC color limits [max]
Bootstrap significance level (Ex: 0.01 -> 1%)
.01
Optional newtimef() arguments (see Help)
Plot Event Related Spectral Power
Plot Inter Trial Coherenc
Cancel
Help
Figure 2
File Edit View Insert Tools Desktop Window Help
ERSP(dB)
Frequency (Hz)
Time (ms)
dB
ITC
ERP

Further Resources



Some attempts to automate the IC classification:

"Automatic Classification of Artifactual ICA-Components for Artifact Removal in EEG Signals"

Irene Winkler, Stefan Haufe and Michael Tangermann (2011)

http://www.behavioralandbrainfunctions.com/content/7/1/30

Bigdely-Shamlo's EyeCatch (2013)

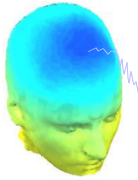
https://www.researchgate.net/publication/257602145_EyeCatch_Data-mining_over_half_a_million_EEG_independent_components_to_construct_a_fully-automated_eye-component_detector

Luca Pion-Tonachini (ongoing)

Crowd-sourcing heuristic knowledge about IC components to build automatic classifier

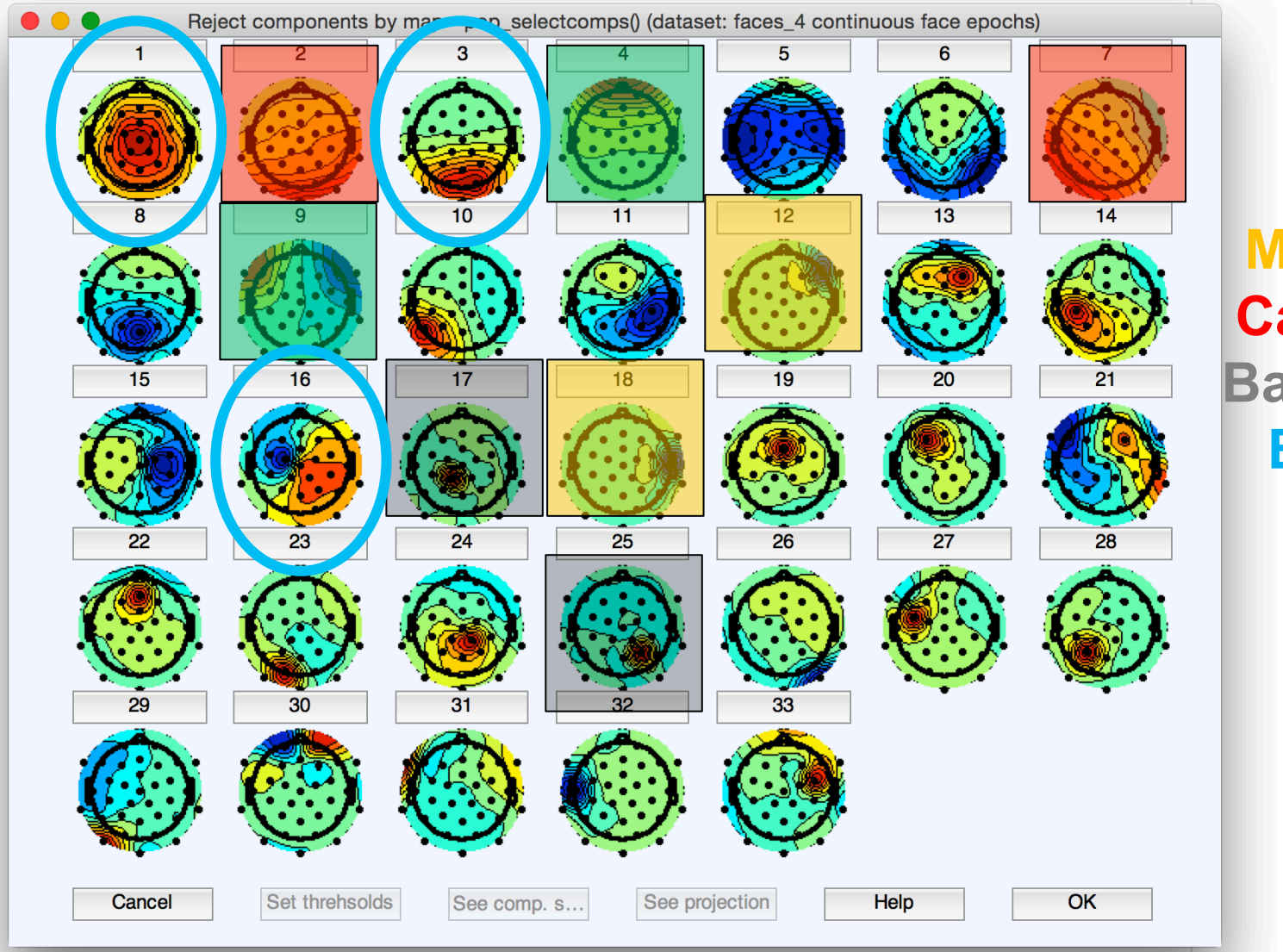
We'll play the game later: http://reaching.ucsd.edu:8000

IC Evaluation Practicum (Day 1)



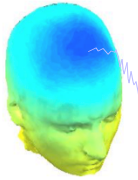
- **ICA Component Classifier Competition**
- **Traditional Practicum using faces_4.set**

IC Classification…so far



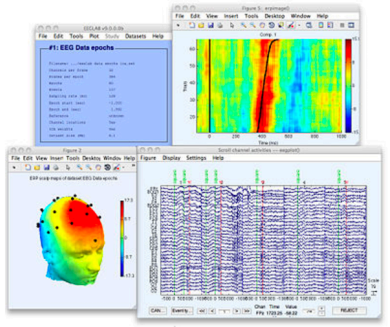
Eye
Muscle
Cardiac
Badchan
Brain

IC Evaluation Practicum (Day 1)



https://sccn.ucsd.edu/eeglab

What is EEGLAB?



EEGLAB is an interactive Matlab toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. EEGLAB runs under Linux, Unix, Windows, and Mac OS X.

EEGLAB provides an interactive graphic user interface (GUI) allowing users to flexibly and interactively process their high-density EEG and other dynamic brain data using independent component analysis (ICA) and/or time/frequency analysis (TFA), as well as standard averaging methods. EEGLAB also incorporates extensive tutorial and help windows, plus a command history function that eases users' transition from GUI-based data exploration to building and running batch or custom data analysis scripts. EEGLAB offers a wealth of methods for visualizing and modeling event-related brain dynamics, both at the level of individual EEGLAB 'datasets' and/or across a collection of datasets brought together in an EEGLAB 'studyset.'

For experienced Matlab users, EEGLAB offers a structured programming environment for storing, accessing, measuring, manipulating and visualizing event-related EEG data. For creative research programmers and methods developers, EEGLAB offers an extensible, open-source platform through which they can share new methods with the world research community by publishing EEGLAB 'plug-in' functions that appear automatically in the EEGLAB menu of users who download them. For example, novel EEGLAB plug-ins might be built and released to 'pick peaks' in ERP or time/frequency results, or to perform specialized import/export, data visualization, or inverse source modeling of EEG, MEG, and/or ECOG data.

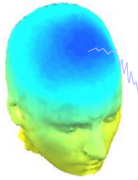
EEGLAB Features

- Graphic user interface
- Multiformat data importing
- High-density data scrolling
- Interactive plotting functions
- Semi-automated artifact removal
- ICA & time/frequency transforms
- Event & channel location handling
- Forward/inverse head/source modeling
- Defined EEG data structure
- Many advanced plug-in/extension toolboxes

Q: I've used ICA to decompose my data -- now how can I learn to recognize which independent component processes of EEG data represent brain sources activity and which capture activity from other non-brain sources?

Try using ICLabel to first learn about and then practice labeling EEG independent components (ICs). You can also help to create a more accurate automated IC classifier using machine learning algorithms on crowd-sourced data. The results are being incorporated into a self-updating EEGLAB plug-in that will become more accurate the more labels you and others contribute.

Automating IC Identification



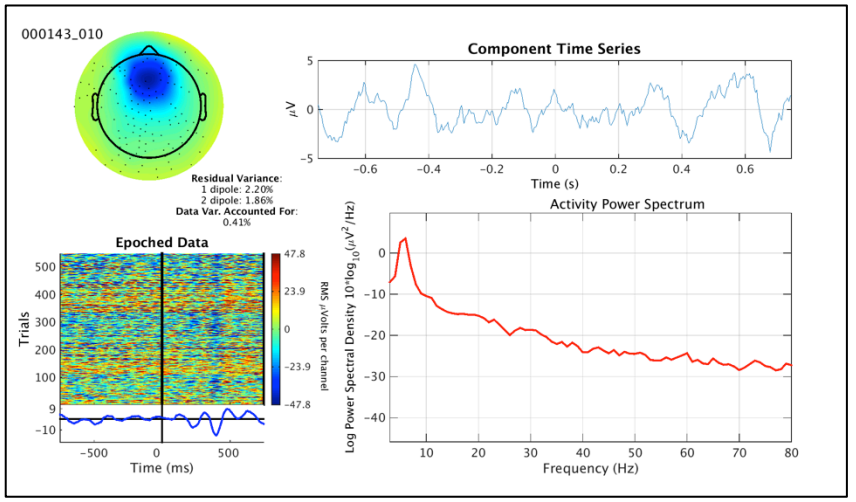
Luca Pion-Tonachini (lpionton@ucsd.edu)

Goal: Create an automated, high confidence EEG component labeler.

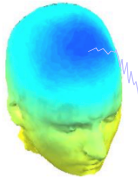
Motivation: Typically we rely on expert knowledge to pick which components to work with, but can be very time consuming with large datasets or inconvenient / infeasible when automation is the goal (BCI).

Plan:

1. Aggregate Data
2. Gather Labels
   reaching.ucsd.edu:8000/tutorial
3. Process Labels
4. Train Classifiers
   Real-time and offline versions



– let's play…



Tutorial: EEG Independent Component Labeling

Overview
Why Help Us?
How To Label
Telling Components Apart

Practice Labeling
Leave A Comment

Return To Labeling

Overview

We would like you to help us label independent components from EEG datasets to create an automated classifier. For more information, see Why Help Us?.

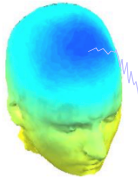
Steps to doing so

1. Register or Log In.
2. Look at the image presented. For help reading it, see How To Label. It is essential that you go over the instructions before you start.
3. For each component presented, try to decide what type of component you are looking at. To learn how to do this, see Telling Components Apart and perform Practice Labeling.
4. Click the appropriate button or buttons to label the component. For help with our categories, first read How To Label.
5. Then click on "Next" to view a new component.

That's it! Please read the text in all the links above and perform some Practice Labels. Then click Begin Labeling.

If you have any suggestions, please Leave A Comment. Also – we have a Leaderboard!

Practice First…

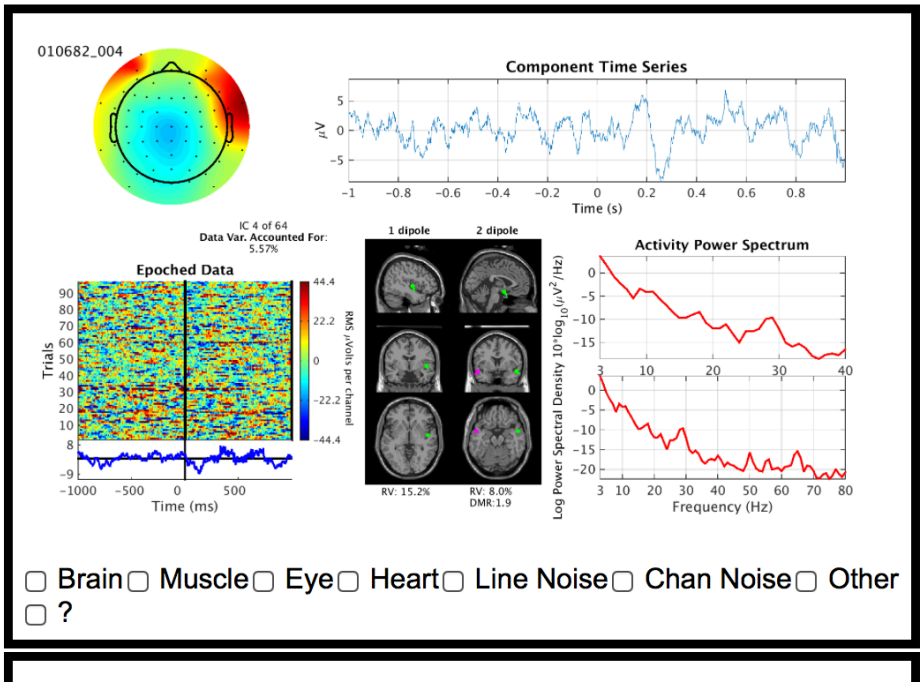


Practice

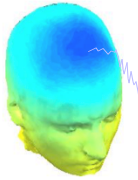
Example component images are provided below. Click on all the labels your fe
follows:

- White: no labels
- Grey: correct but insufficient labels
- Green: all labels correct
- Red: one or more labels are incorrect

Marking "?" is ignored here as that category is user dependent.



Practicum



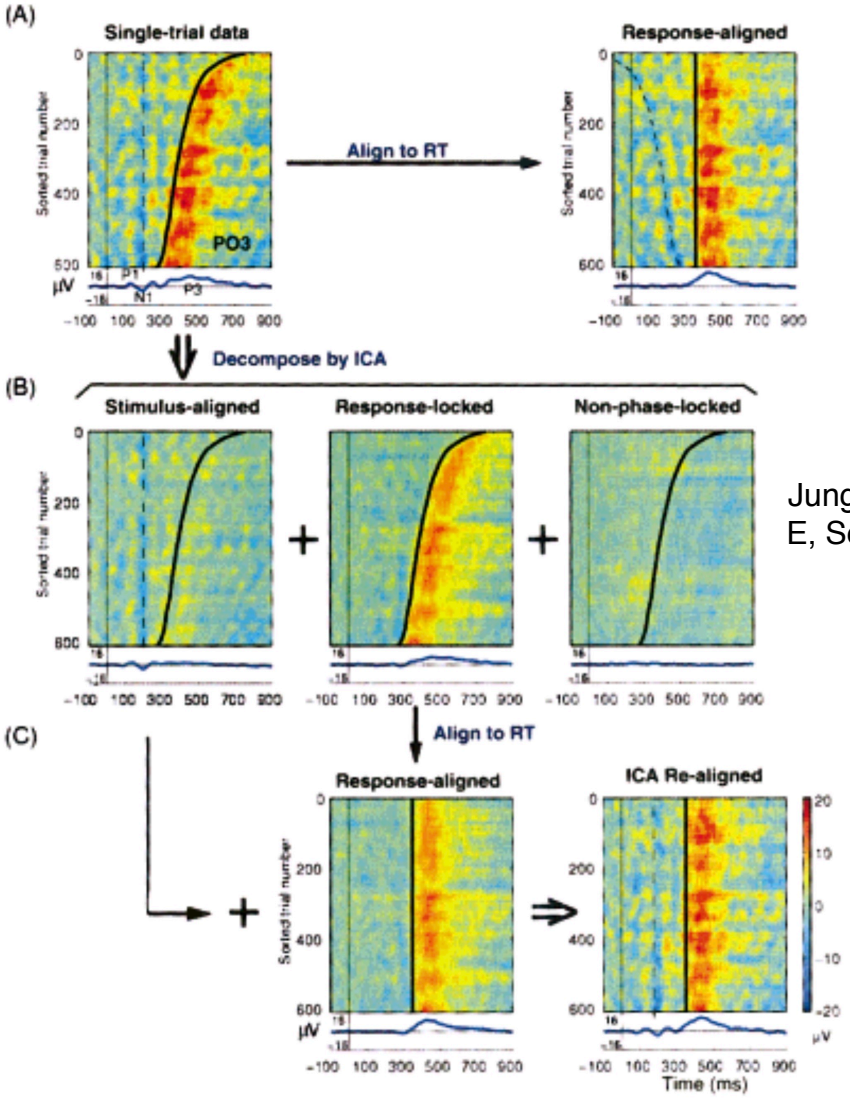
- **ALL**
  - Download then load faces_4.set, epoch on face

- **Novice, Intermediate**
  - From the GUI, open the 'Reject component by map' interface
  - Explore and classify several additional ICs: muscle, channel, brain
    ~ Justify your classification
  - Redo the "Plot → Component ERPs → With component maps" excluding your additional artifacts. What change do you observe?
  - Pick a brain IC. Plot an ERP Image
    ~ Try sorting by phase, is there any relationship to the IC activation pattern? What about power in a frequency band of choice?

- **Intermediate**
  - Plot ERP Image sorted by response latency
    ~ Figure out how to realign trials to response latency instead (Hint 'Align')
  - Plot ERSPs for selected ICs
    ~ Explore parameter options. Why is each useful?
  - Plot component cross-coherence for pairs of ICs

- **ALL (Time permitting)**
  - Create second dataset, epoched on object
  - Examine ERP differences between the conditions using "Plot → Component ERPs → With component maps (compare)"
  - For ICs most different between conditions, compare ERP Image, ERSP

Realigning Trials: Stimulus vs. Response



Jung T-P, Makeig SD, Westerfield M, Townsend J, Courchesne E, Sejnowski TJ (2001) Analysis and visualization of single-trial event-related potentials. Hum Brain Mapp 14:166–85.

Nice method for generating dual ERPs