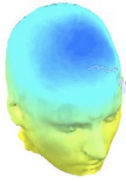
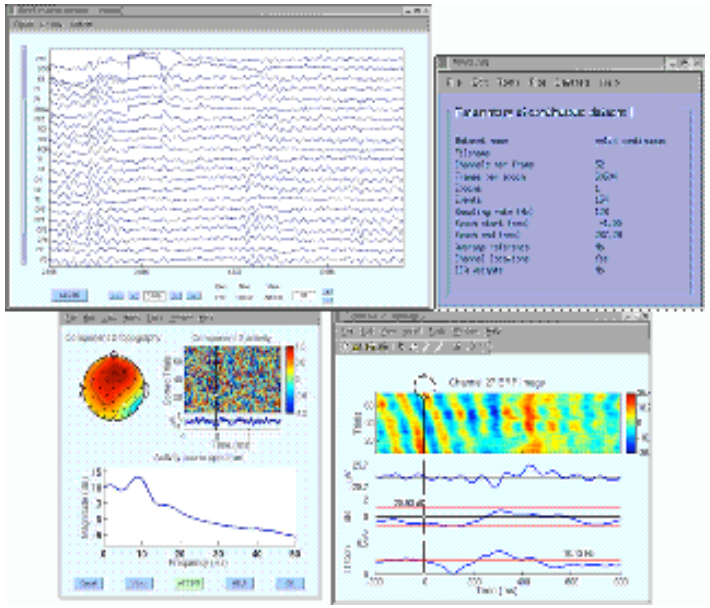
The EEGLAB software

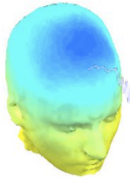


- Collection of over 300 functions (50000 lines of code)
- About 50000 download over the past 6 years
- About 3500 users on the discussion list and 6500 on the diffusion list
- NIH funding (2003-)

http://sccn.ucsd.edu/wiki/EEGLAB09EPIC

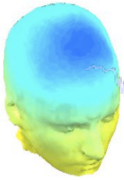


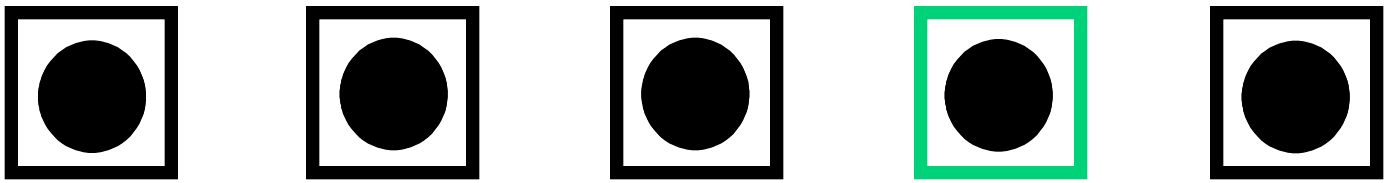
Pros/Cons of Matlab based open source

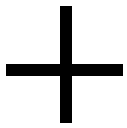


- Pros
  - Easy to program, highly modular and extendable
  - Not dependent on any platform (64-bit)
  - Large community of users (latest development in signal processing research)
  - Cannot imagine more powerful scripting capabilities
- Cons
  - Matlab required
  - Large memory requirements
  - Matlab bugs, possible version differences, cross-platform compatibility problems

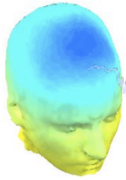
Spatial visual attention task (STUDY)



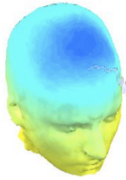


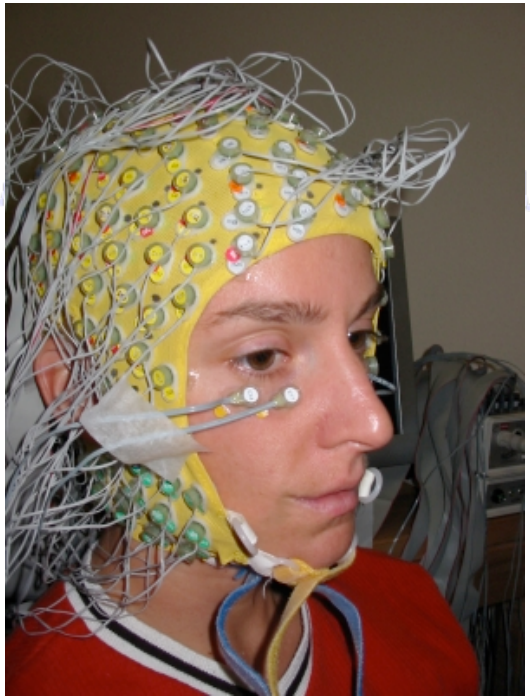


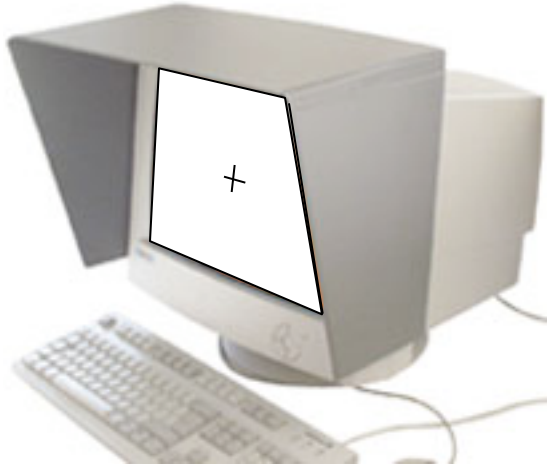
Publication using this data



- Delorme A, Westerfield M, Makeig S., **J Neurosci**. 2007 Oct 31;27(44):11949-59.
- Onton J, Westerfield M, Townsend J, Makeig S., Neurosci Biobehav Rev. 2006;30(6):808-22. Epub 2006 Aug 14. Review.
- Makeig S, Delorme A, Westerfield M, Jung TP, Townsend J, Courchesne E, Sejnowski TJ., **PLoS Biol**. 2004 Jun;2(6):e176. Epub 2004 Jun 15.
- Makeig S, Westerfield M, Jung TP, Enghoff S, Townsend J, Courchesne E, Sejnowski TJ. Science. 2002 Jan 25;295(5555):690-4. **Science** 2002 Feb 22;295(5559):1466.
- Jung TP, Makeig S, Westerfield M, Townsend J, Courchesne E, Sejnowski TJ., **Hum Brain Mapp**. 2001 Nov;14(3):166-85.
- Townsend J, Westerfield M, Leaver E, Makeig S, Jung T, Pierce K, Courchesne E., Brain Res Cogn Brain Res. 2001 Mar;11(1):127-45.
- Jung TP, Makeig S, Westerfield M, Townsend J, Courchesne E, Sejnowski TJ., Clin Neurophysiol. 2000 Oct;111(10):1745-58.
- Makeig S, Westerfield M, Townsend J, Jung TP, Courchesne E, Sejnowski TJ., Philos Trans R Soc Lond B Biol Sci. 1999 Jul 29;354(1387):1135-44.
- Makeig S, Westerfield M, Jung TP, Covington J, Townsend J, Sejnowski TJ, Courchesne E., **J Neurosci**. 1999 Apr 1;19(7):2665-80.



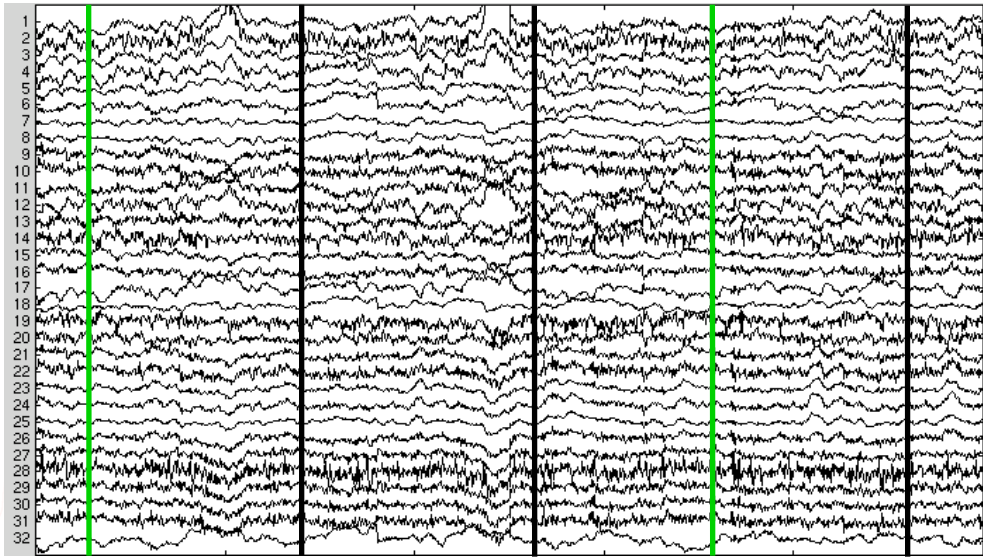




Recording

Distractor

Target

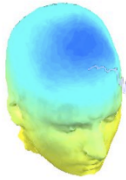


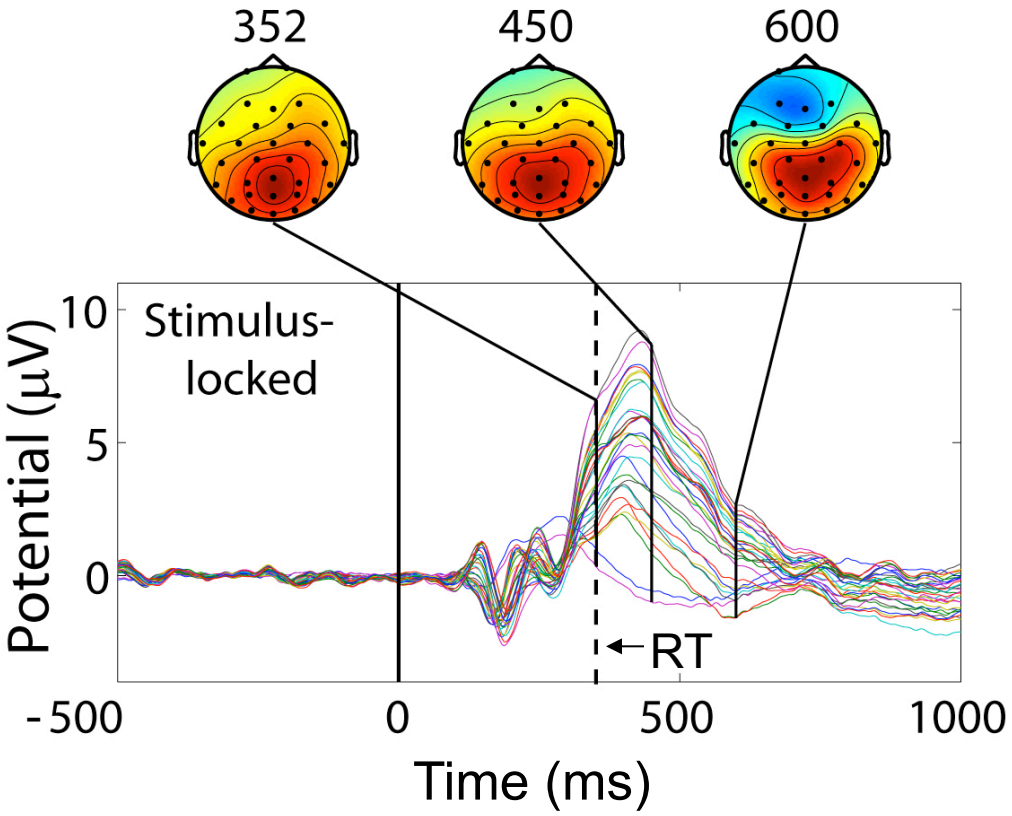
Electrodes

Time (ms)

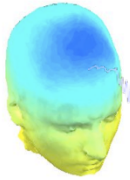
Offline processing

Target trials





EEGLAB standard processing pipeline



Single subject

1. Import binary data, events and channel location
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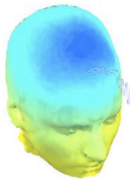
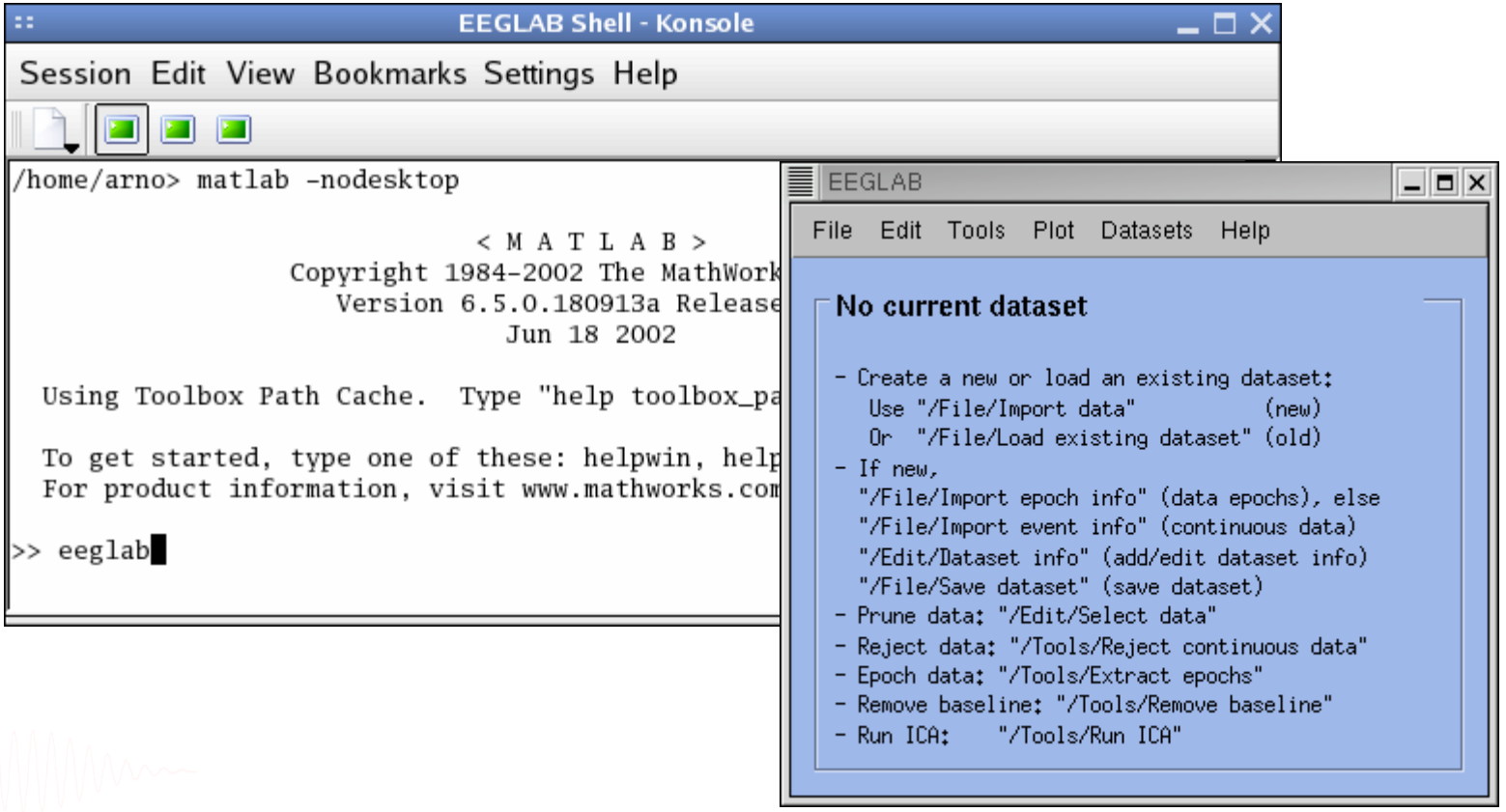
Advanced analysis using scripting and EEGLAB command line functions

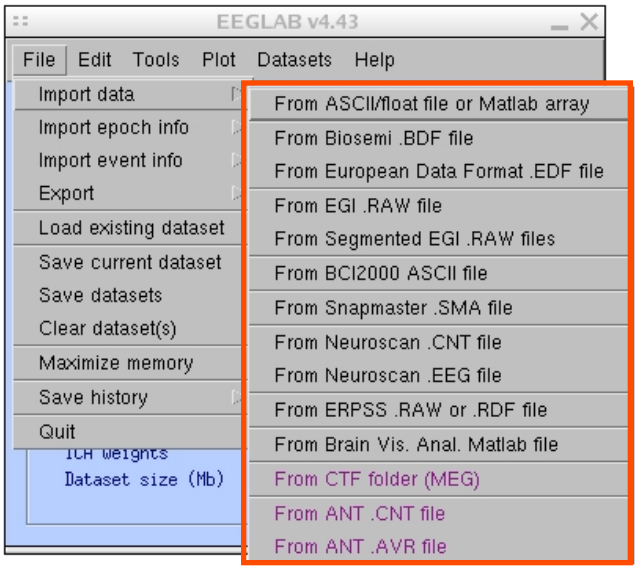
The EEGLAB Matlab software



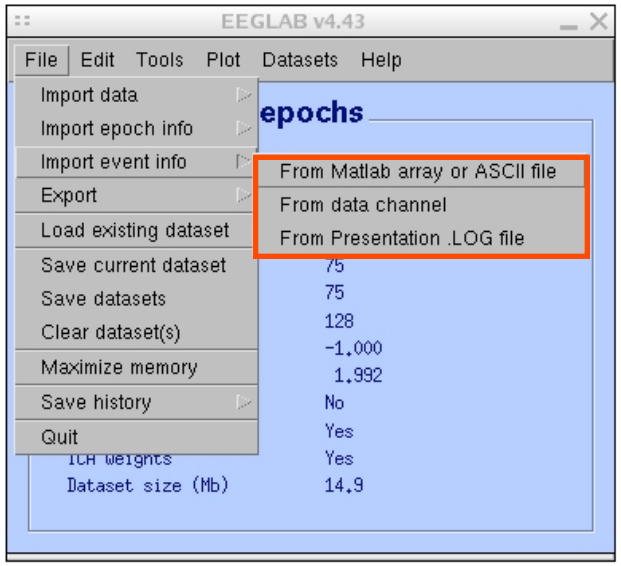


1. Importing data

Import/load data



Import events



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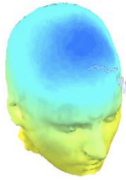


Data info

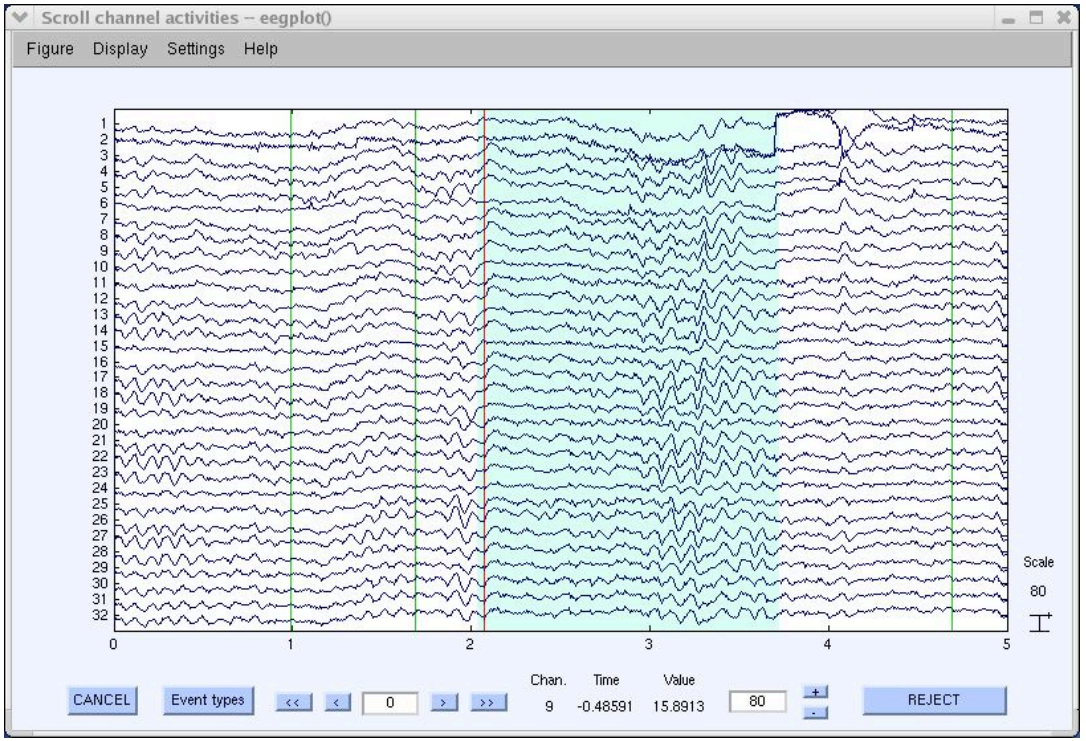
EEGLAB v4.0

File Edit Tools Plot Datasets Help DTU Sidekick

#1: Continuous EEG Data

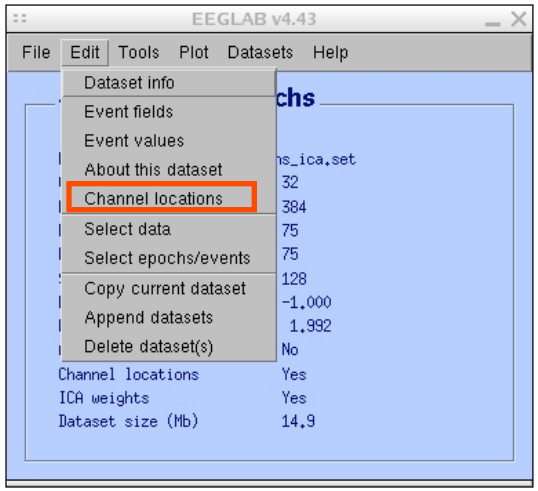
Filename:	eeglab_data.set
Channels per frame	32
Frames per epoch	30504
Epochs	1
Events	154
Sampling rate (Hz)	128
Epoch start (sec)	0.000
Epoch end (sec)	238.305
Average reference	No
Channel locations	No
ICA weights	No
Dataset size (Mb)	7.9

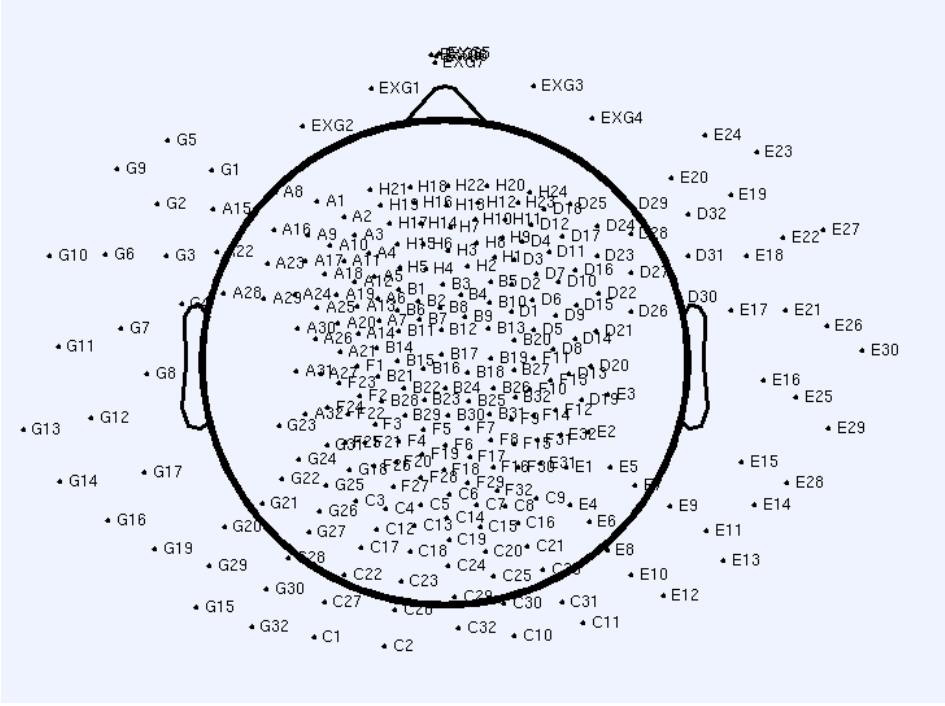
Scrolling data



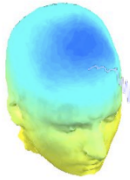
1. Importing channel location

Import channel location

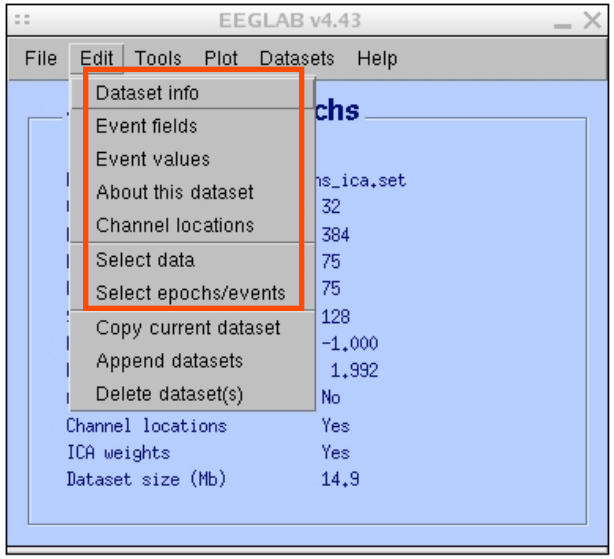




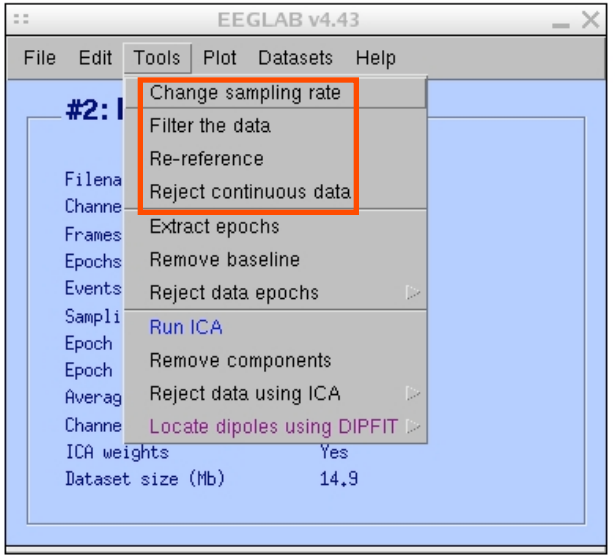
2. Edit, Re-reference, Resample, High pass filter data



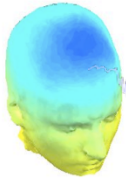
Edit/select data



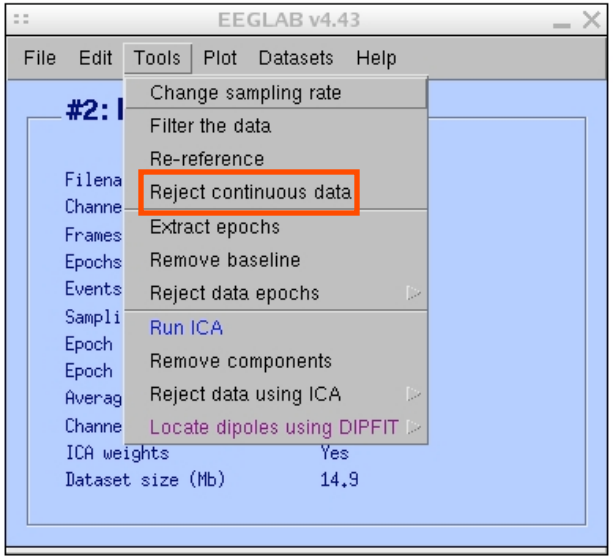
Preprocessing data



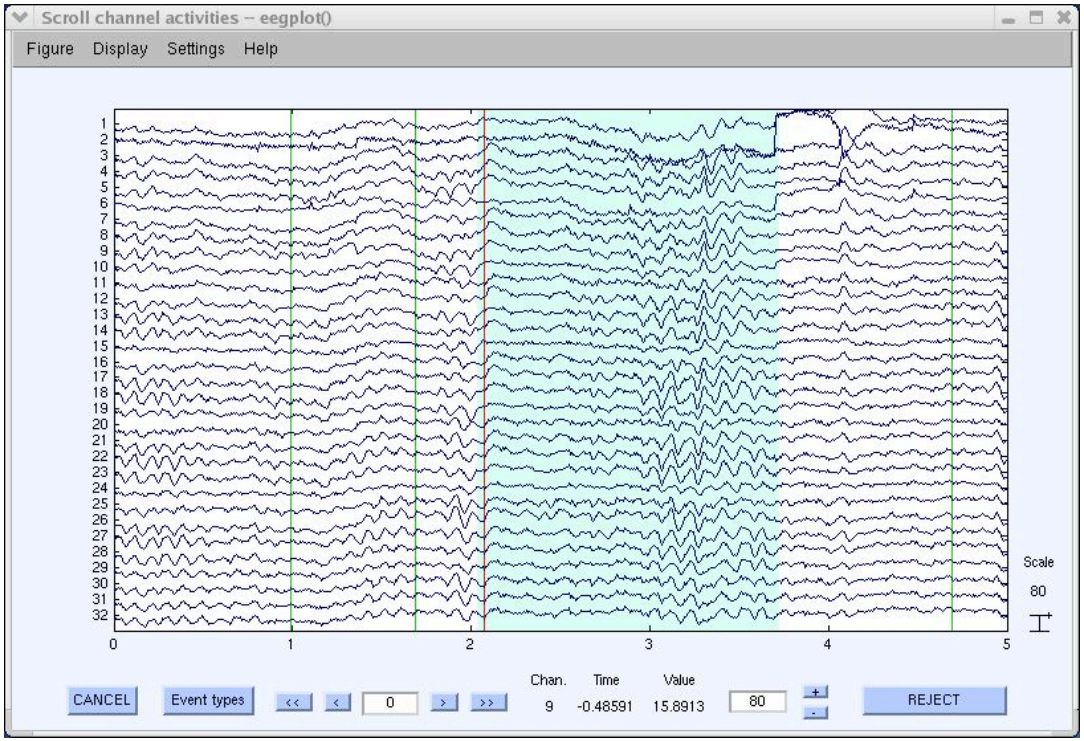
3. Reject artifacts in continuous data by visual inspection



Data info

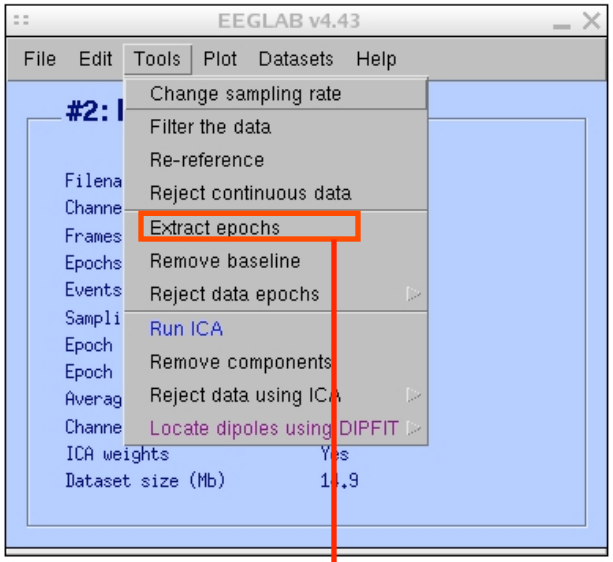


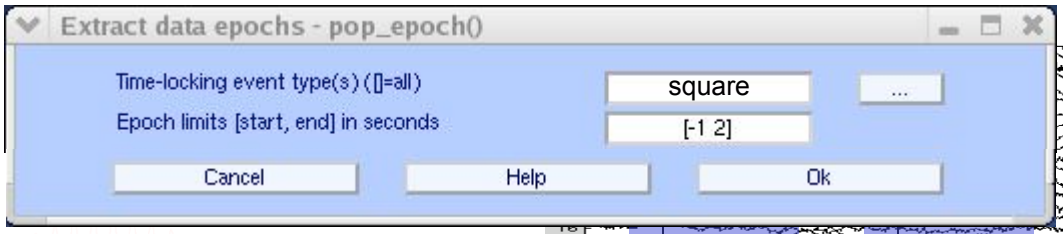
Reject portions of continuous data

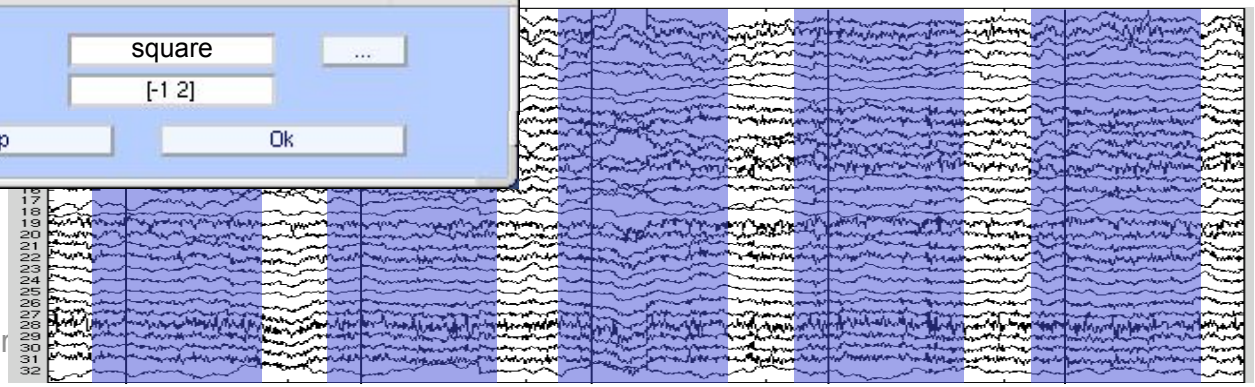


4. Extract epochs from data & reject artifactual epochs

Preprocessing data







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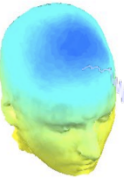
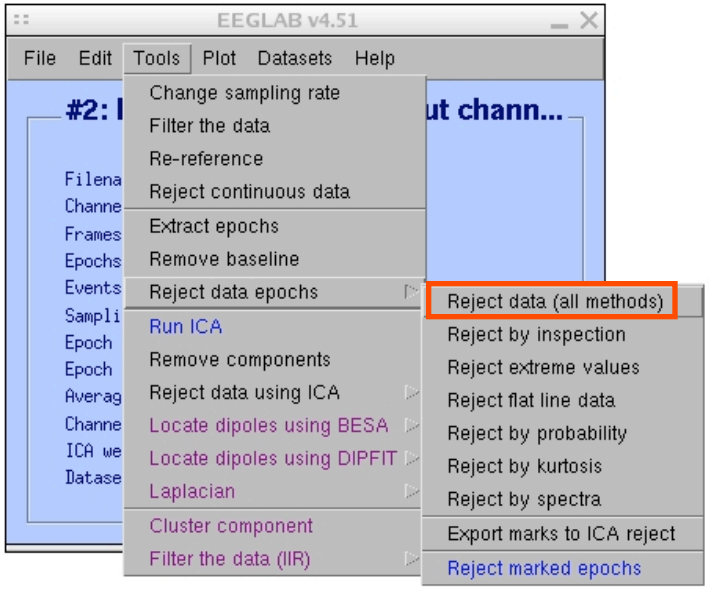
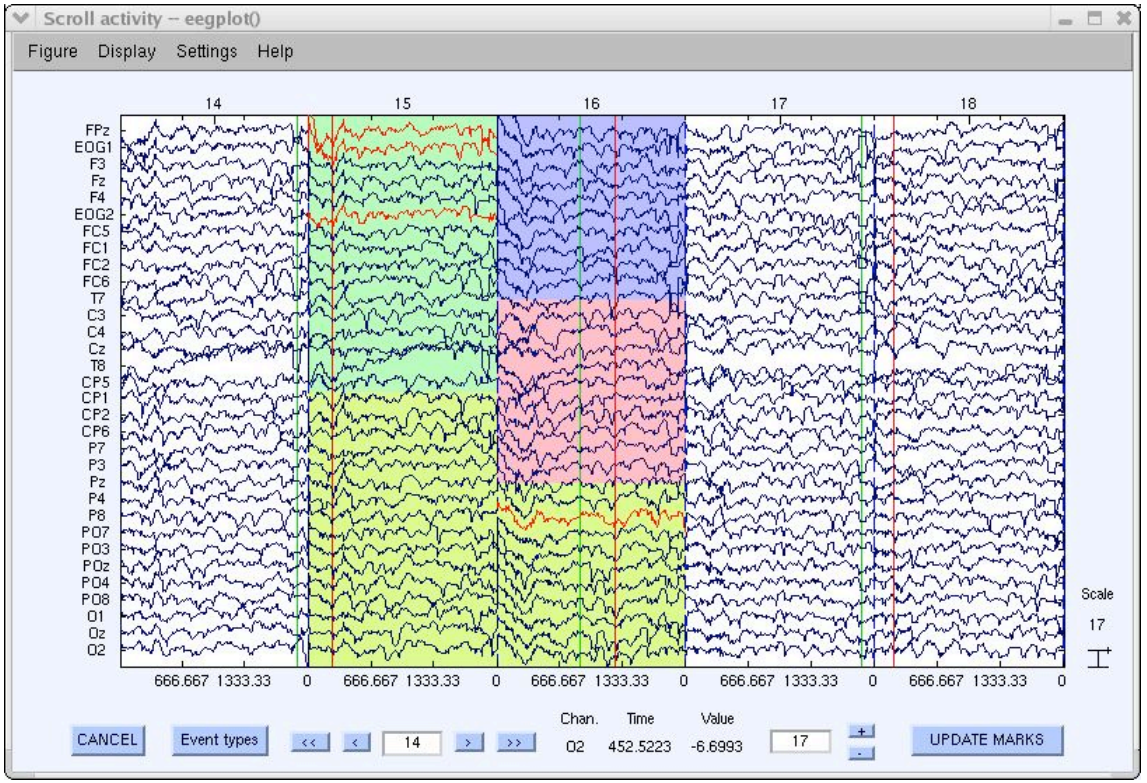
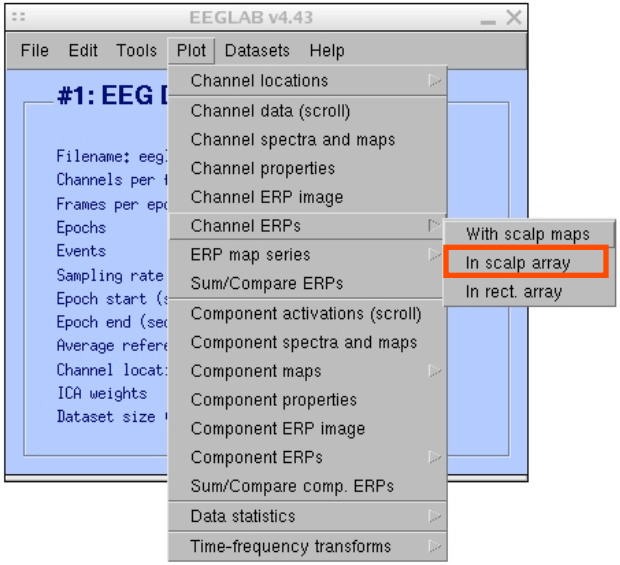




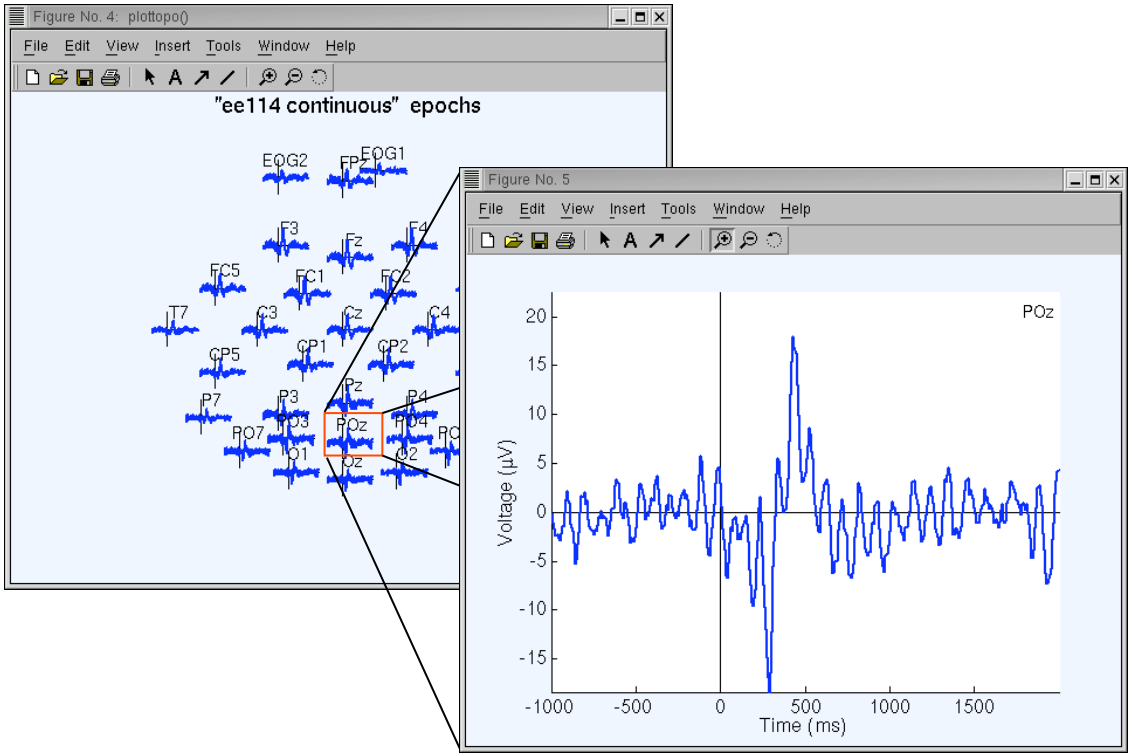
Different color = different rejection methods



5. Visualize data measures

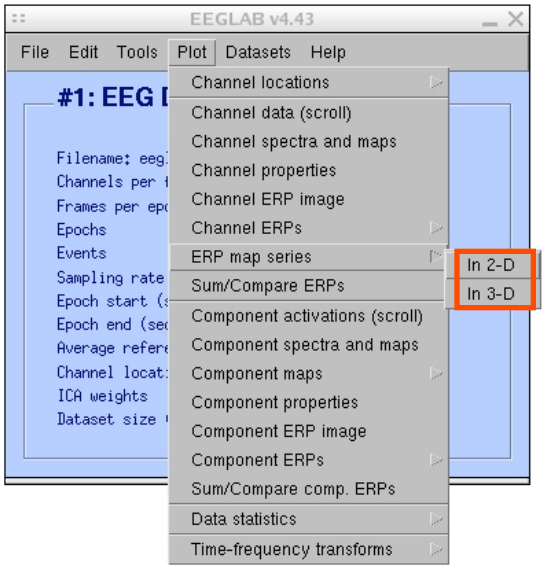


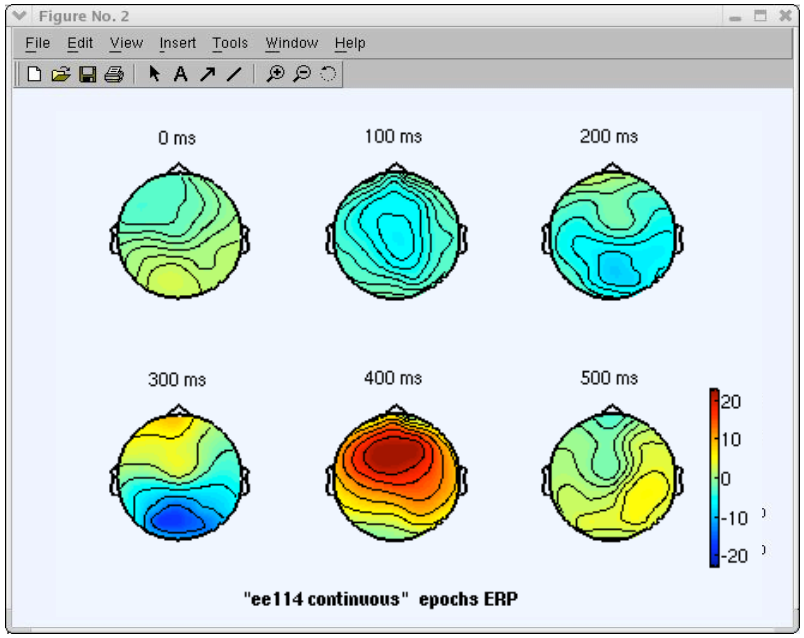
Plot ERP

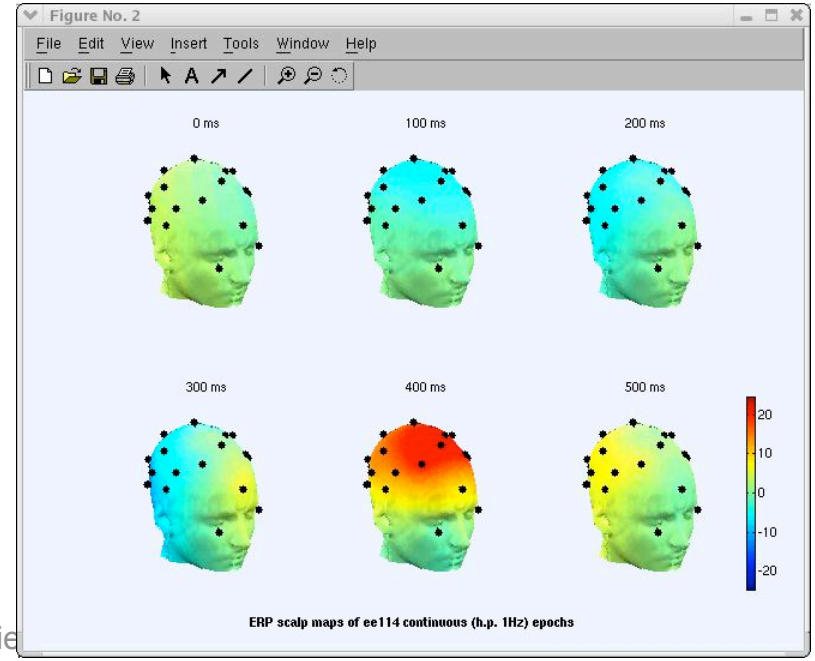


5. Visualize data measures

Plot ERP
map series







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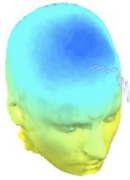
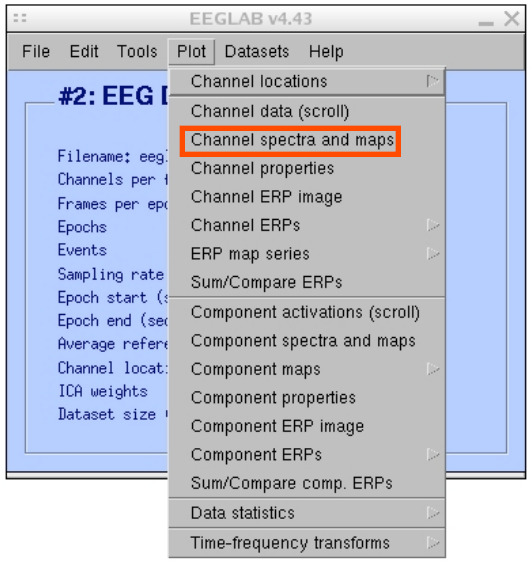
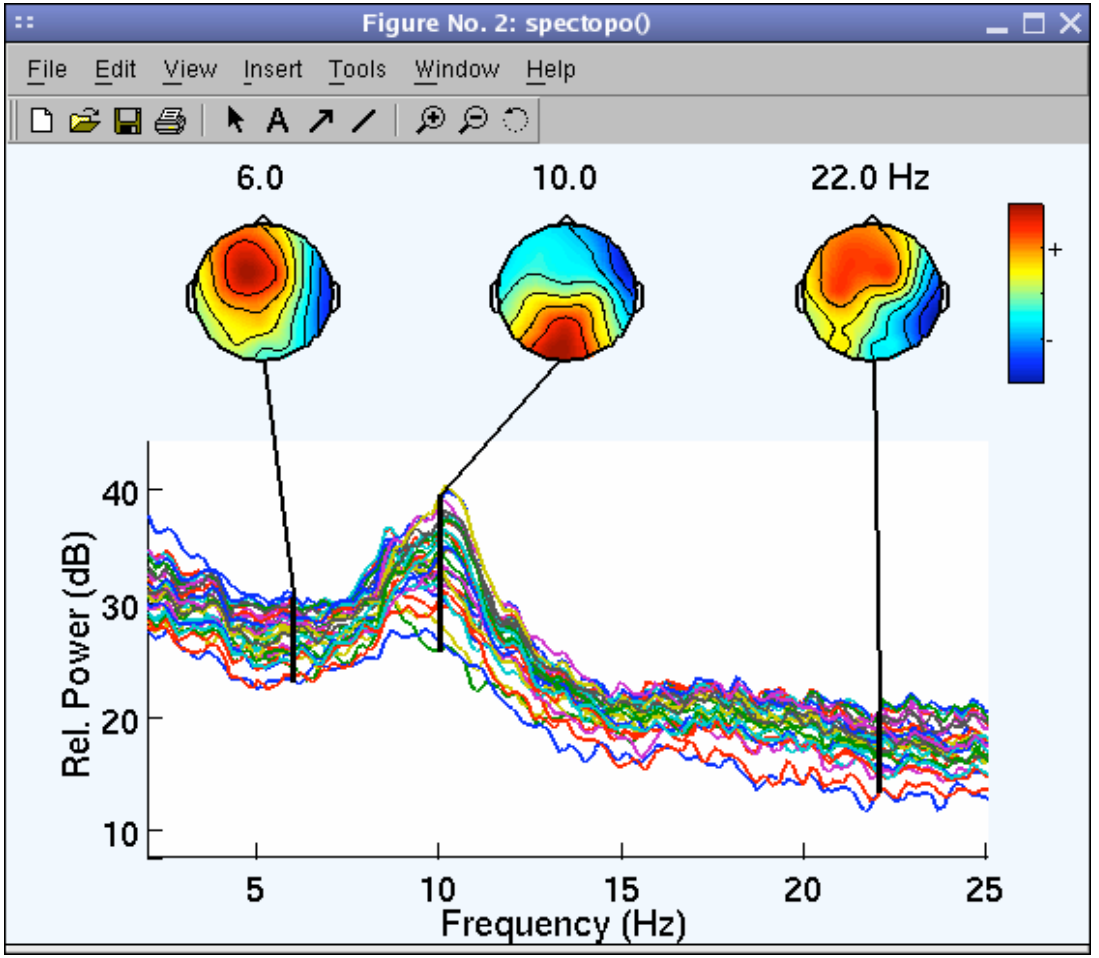


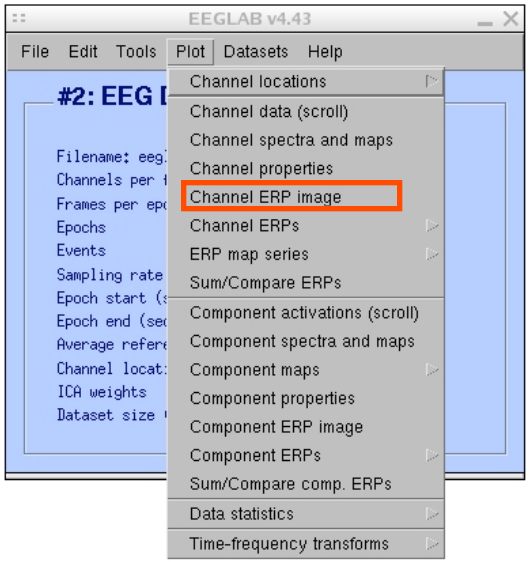
Plot data spectrum and maps

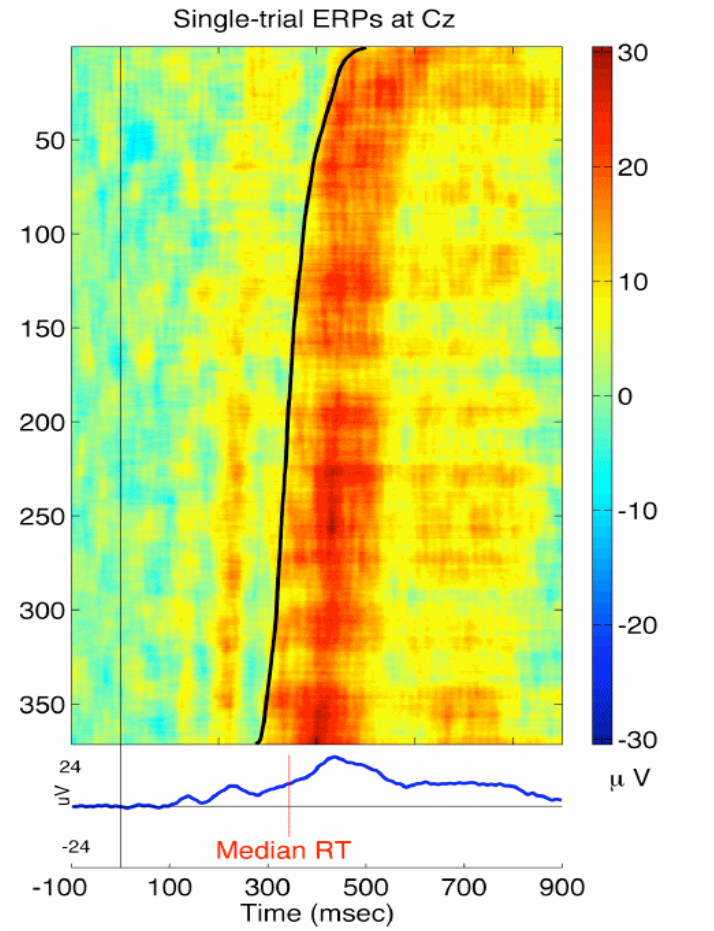




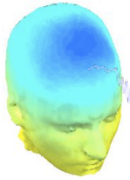
5. Visualize data measures

Plot channel ERPimage





EEGLAB standard processing pipeline



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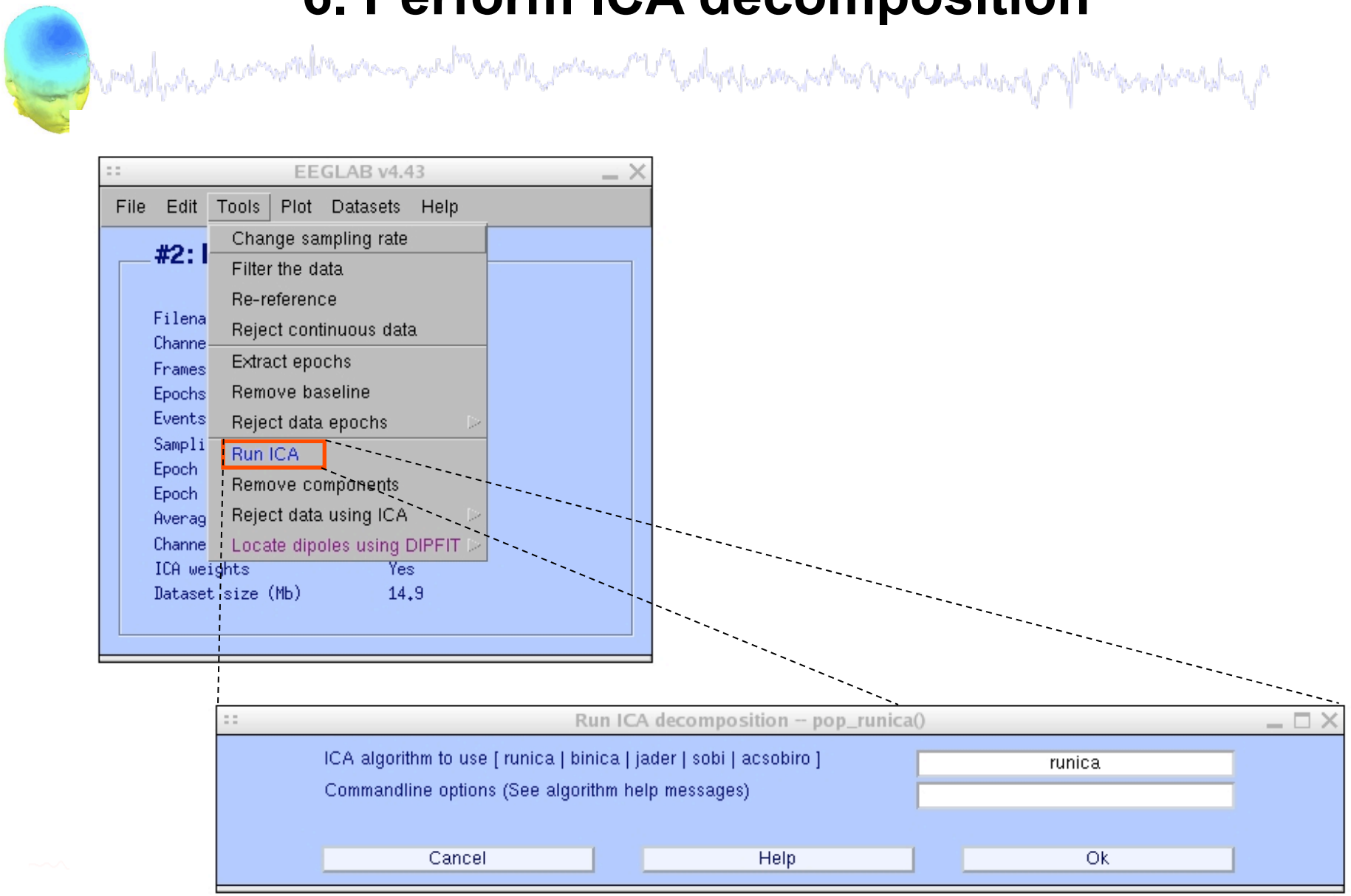
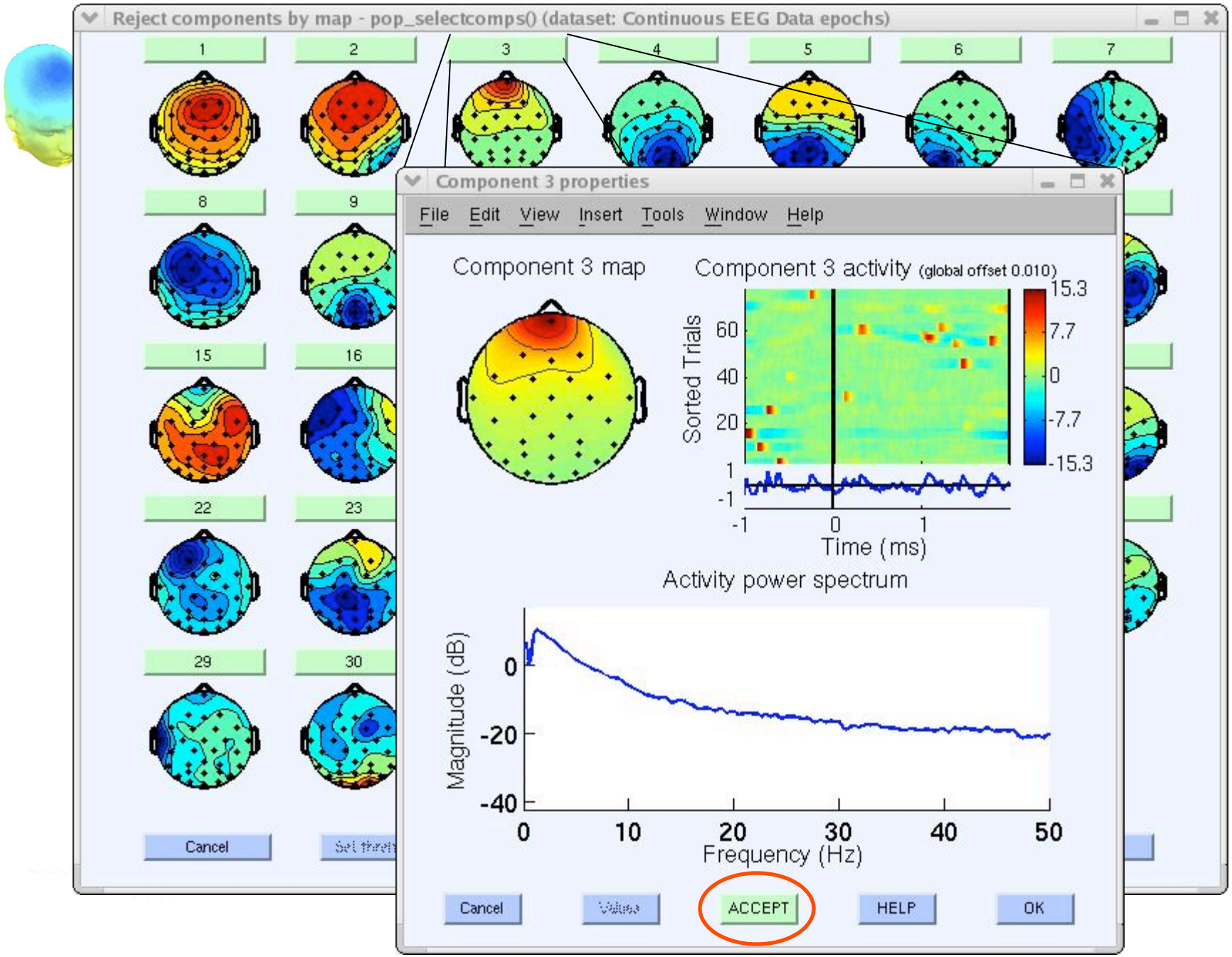
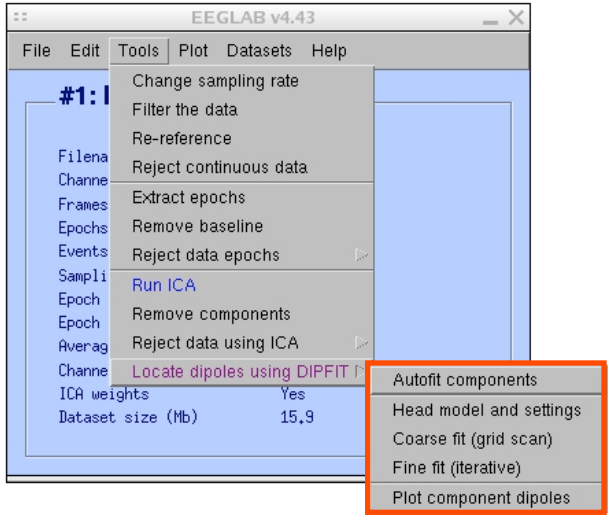
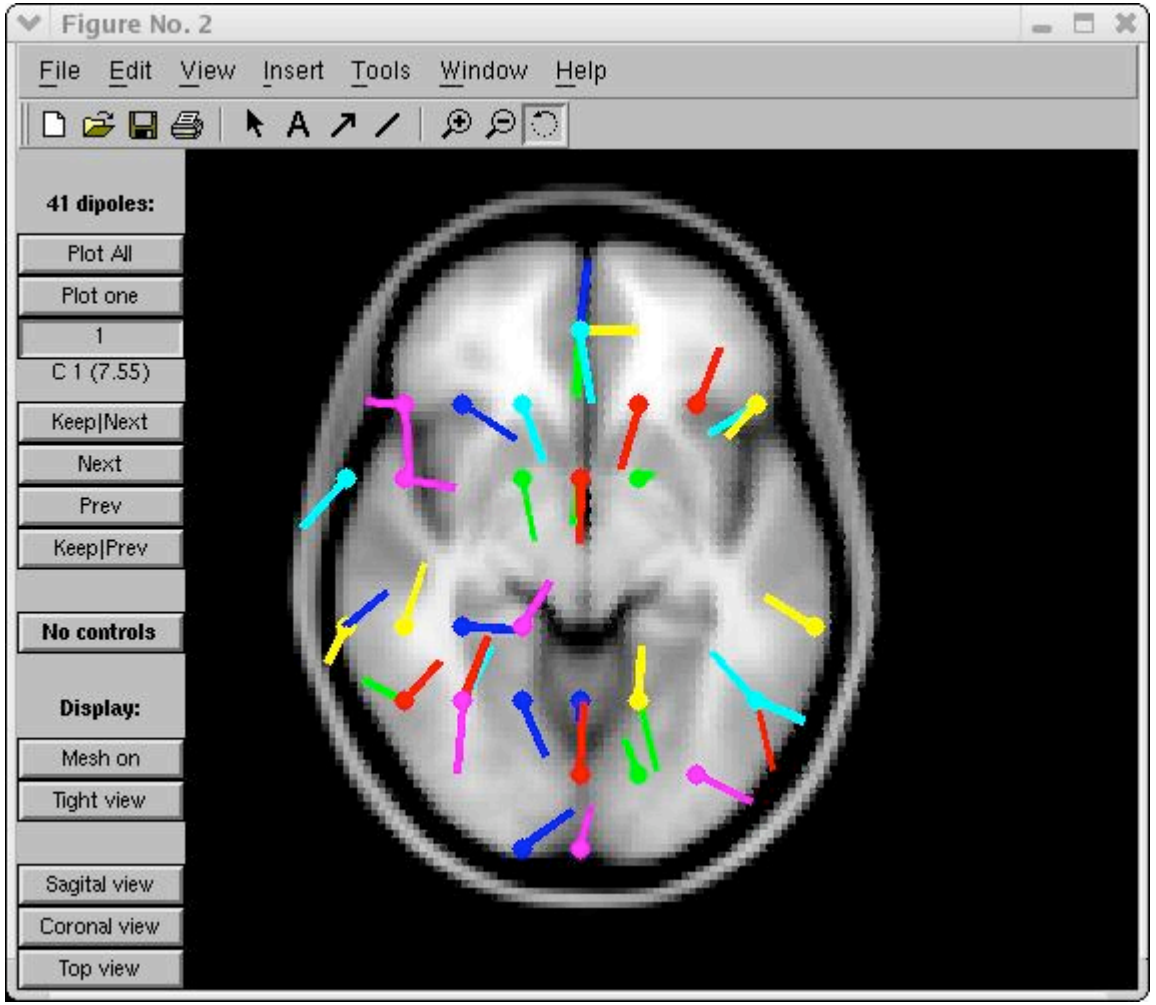



Reject components by map - pop_selectcomps() (dataset: Continuous EEG Data epochs)
1
2
3
4
5
6
7
8
9
15
16
22
23
29
30
Cancel
Component 3 properties
File Edit View Insert Tools Window Help
Component 3 map
Component 3 activity (global offset 0.010)
Sorted Trials
60
40
20
1
-1
15.3
7.7
0
-7.7
-15.3
-1
0
1
Time (ms)
Activity power spectrum
Magnitude (dB)
0
-20
-40
0
10
20
30
40
50
Frequency (Hz)
Cancel
ACCEPT
HELP
OK

Localizing components





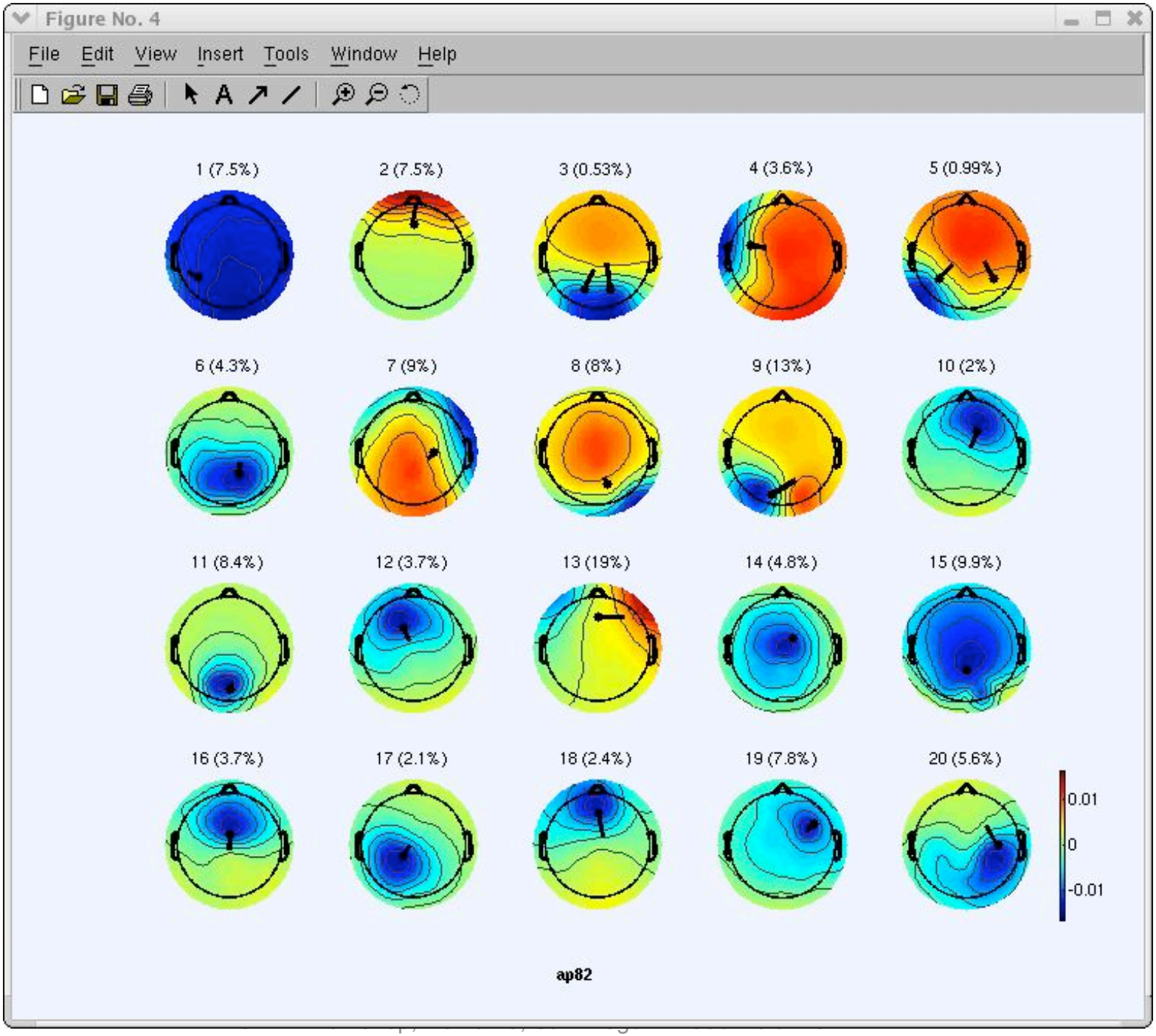
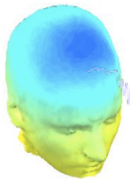
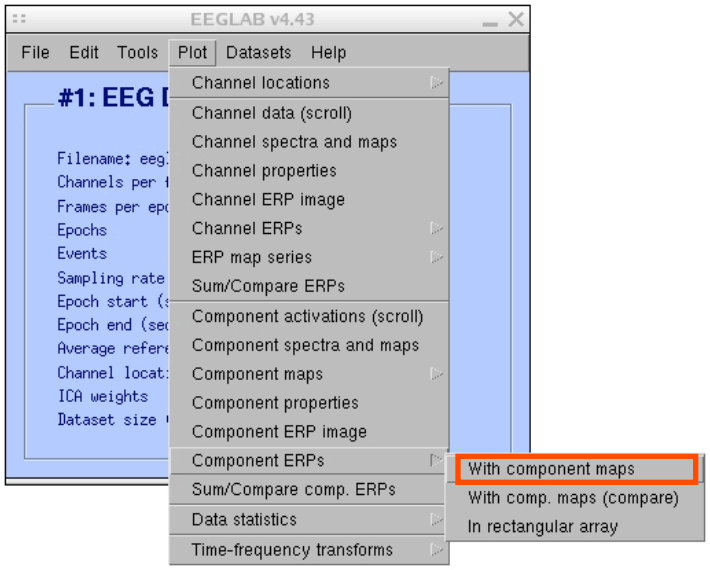
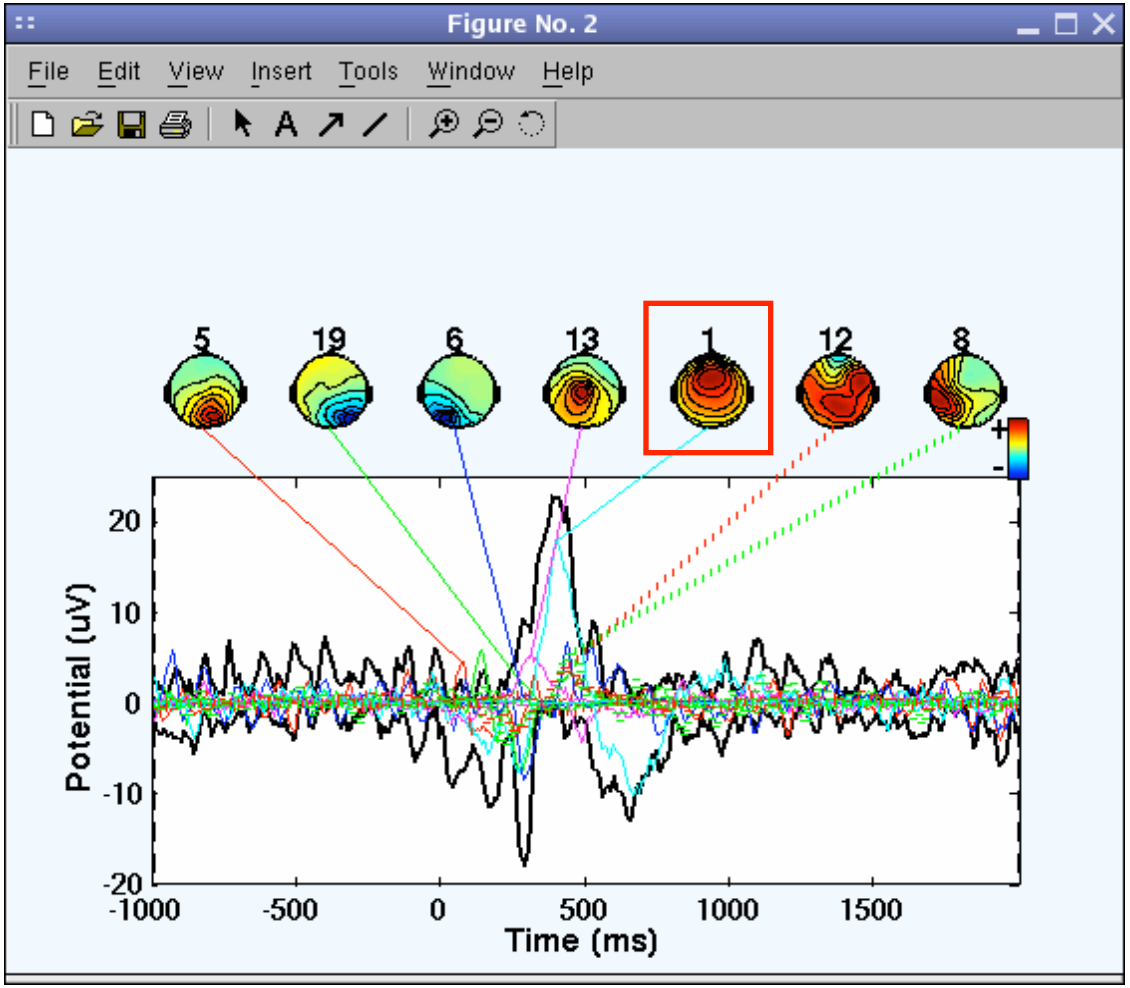


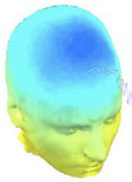
Figure No. 4
File Edit View Insert Tools Window Help
1 (7.5%)
2 (7.5%)
3 (0.53%)
4 (3.6%)
5 (0.99%)
6 (4.3%)
7 (9%)
8 (8%)
9 (13%)
10 (2%)
11 (8.4%)
12 (3.7%)
13 (19%)
14 (4.8%)
15 (9.9%)
16 (3.7%)
17 (2.1%)
18 (2.4%)
19 (7.8%)
20 (5.6%)
0.01
0
-0.01
ap82

Component contribution to the ERP

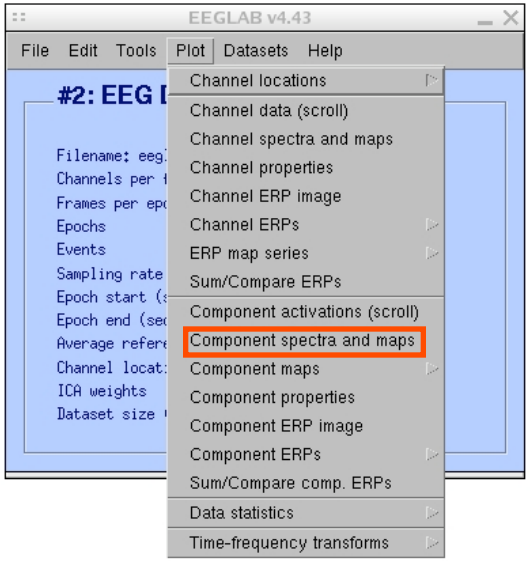


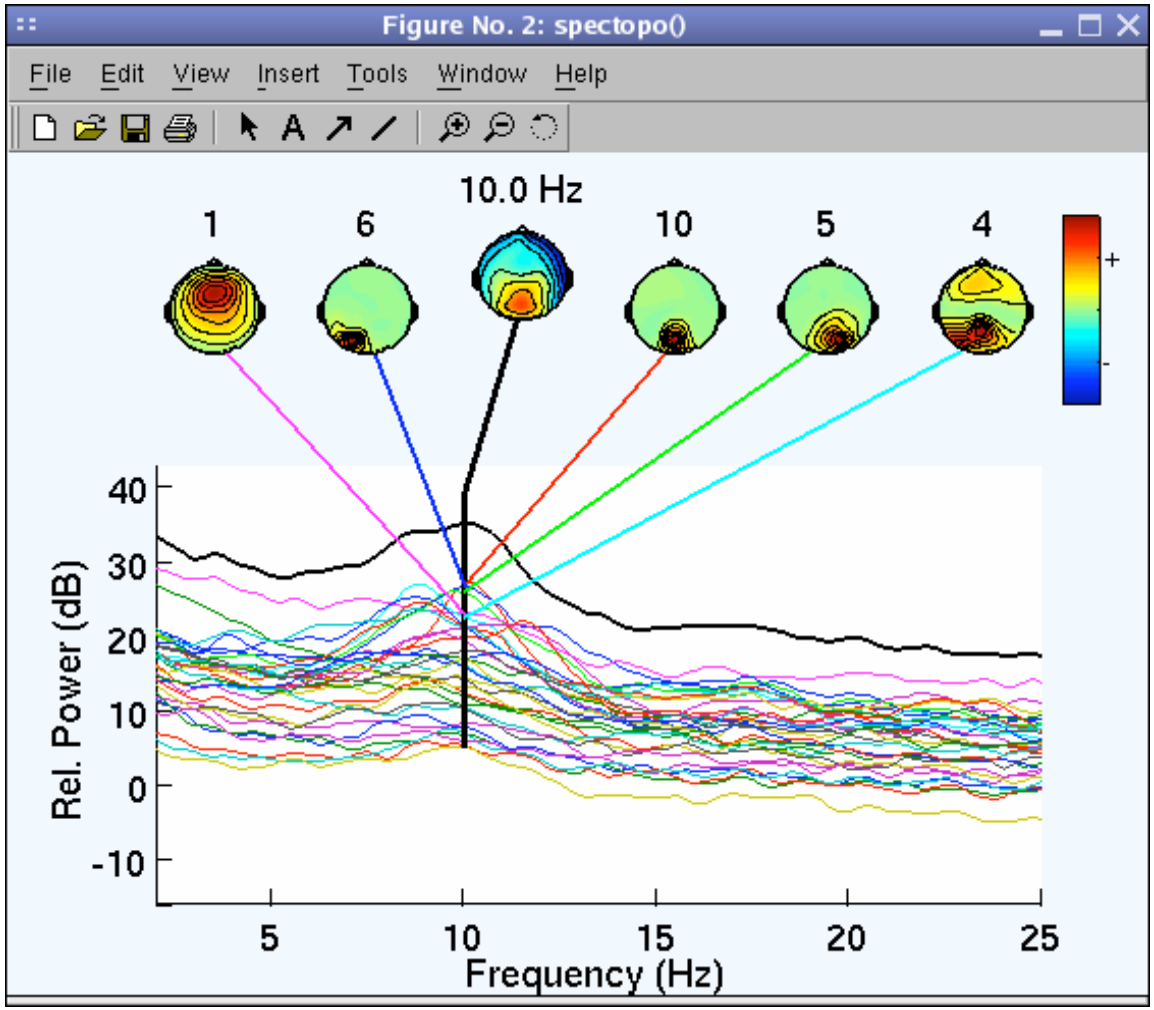




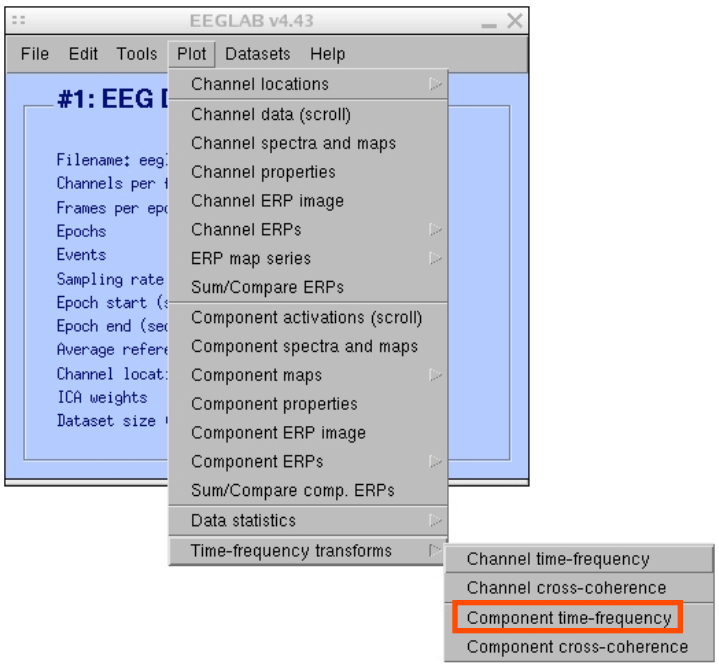


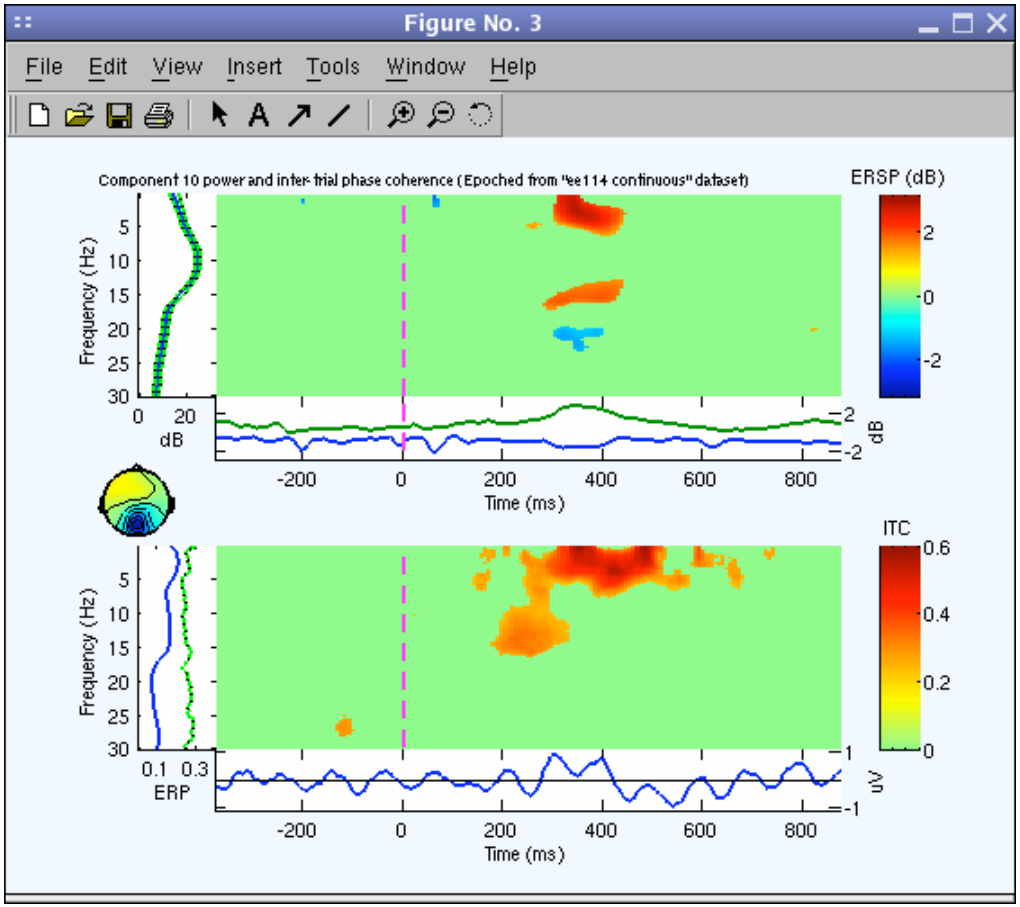
Component contribution to the EEG spectrum



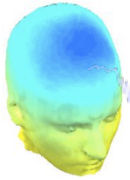


Component time-frequency





EEGLAB standard processing pipeline



Single subject

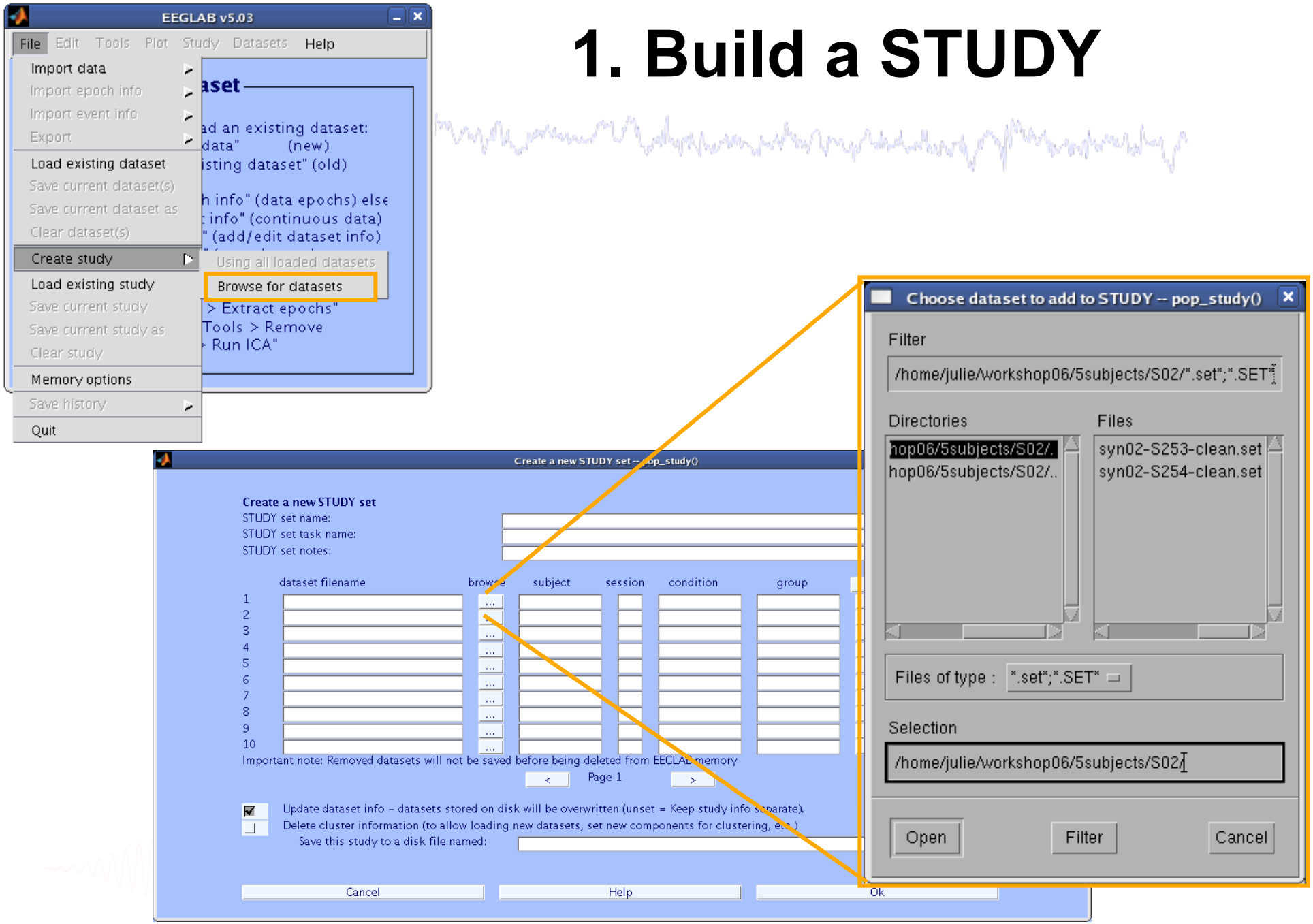
1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
3. Reject artifacts in continuous data by visual inspection
4. Extract epochs from data & reject artifactual epochs
5. Visualize data measures
6. Perform ICA decomposition
   - Perform source localization of components
   - Analyze components contribution to ERP
   - Analyze components contribution to spectrum

Multi-subjects

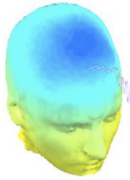
1. Build study
2. Pre-compute measures
3. Cluster components
4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions

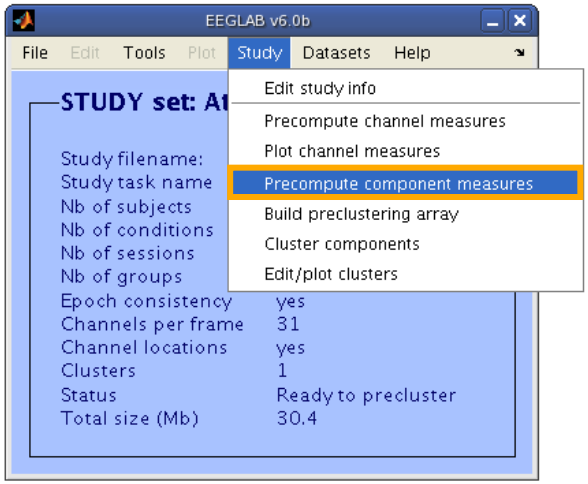
1. Build a STUDY

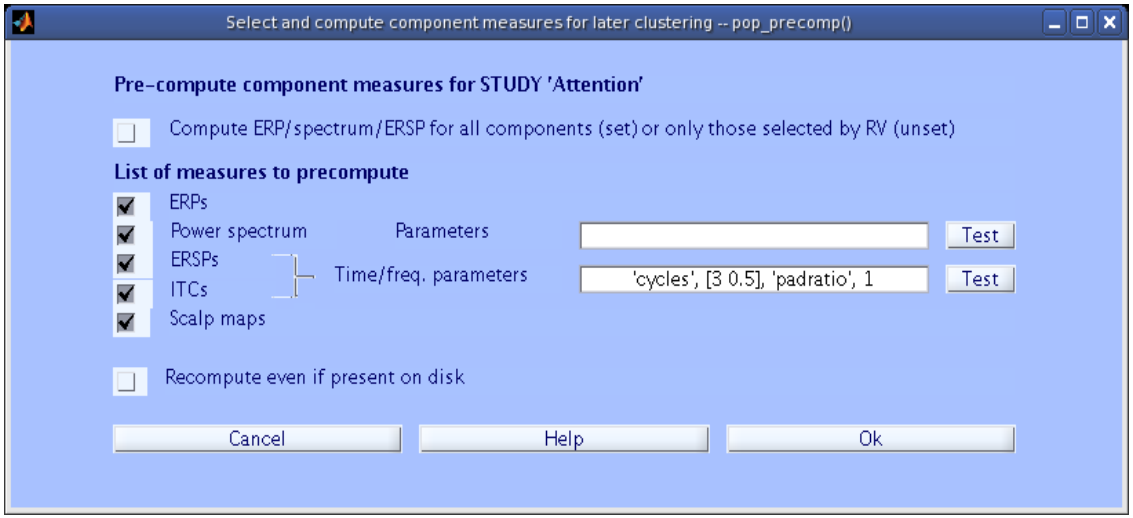


2. Pre-compute measures

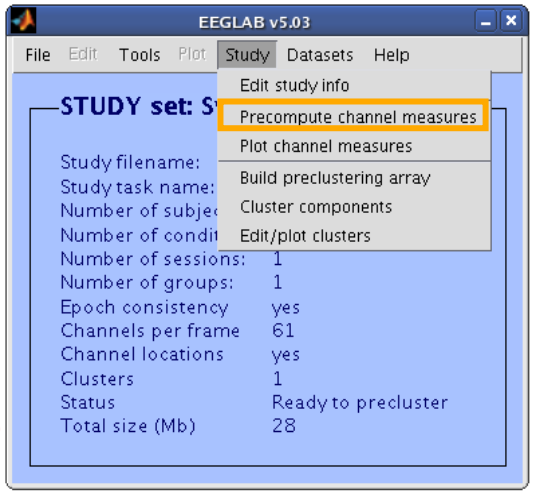


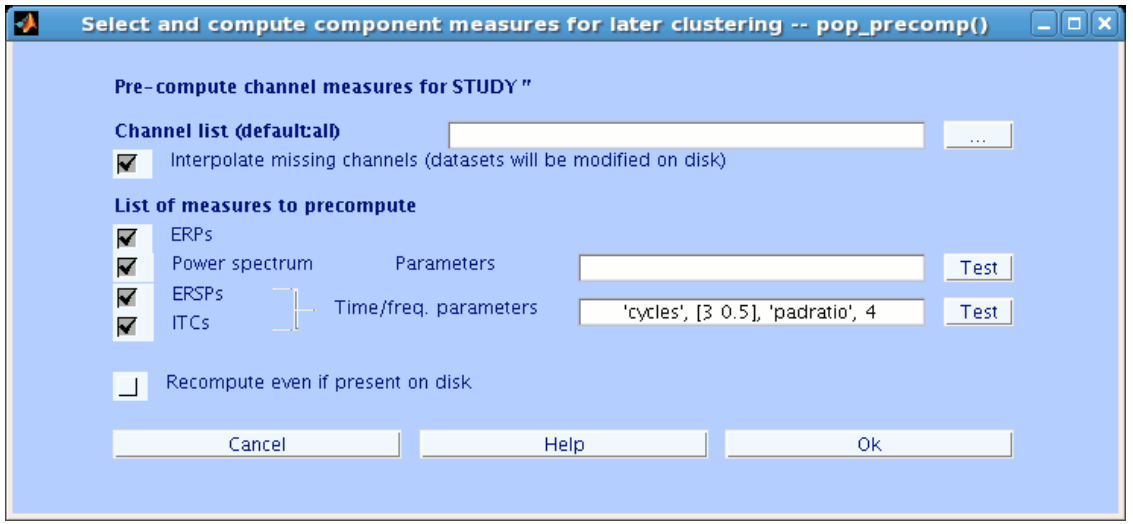
Components



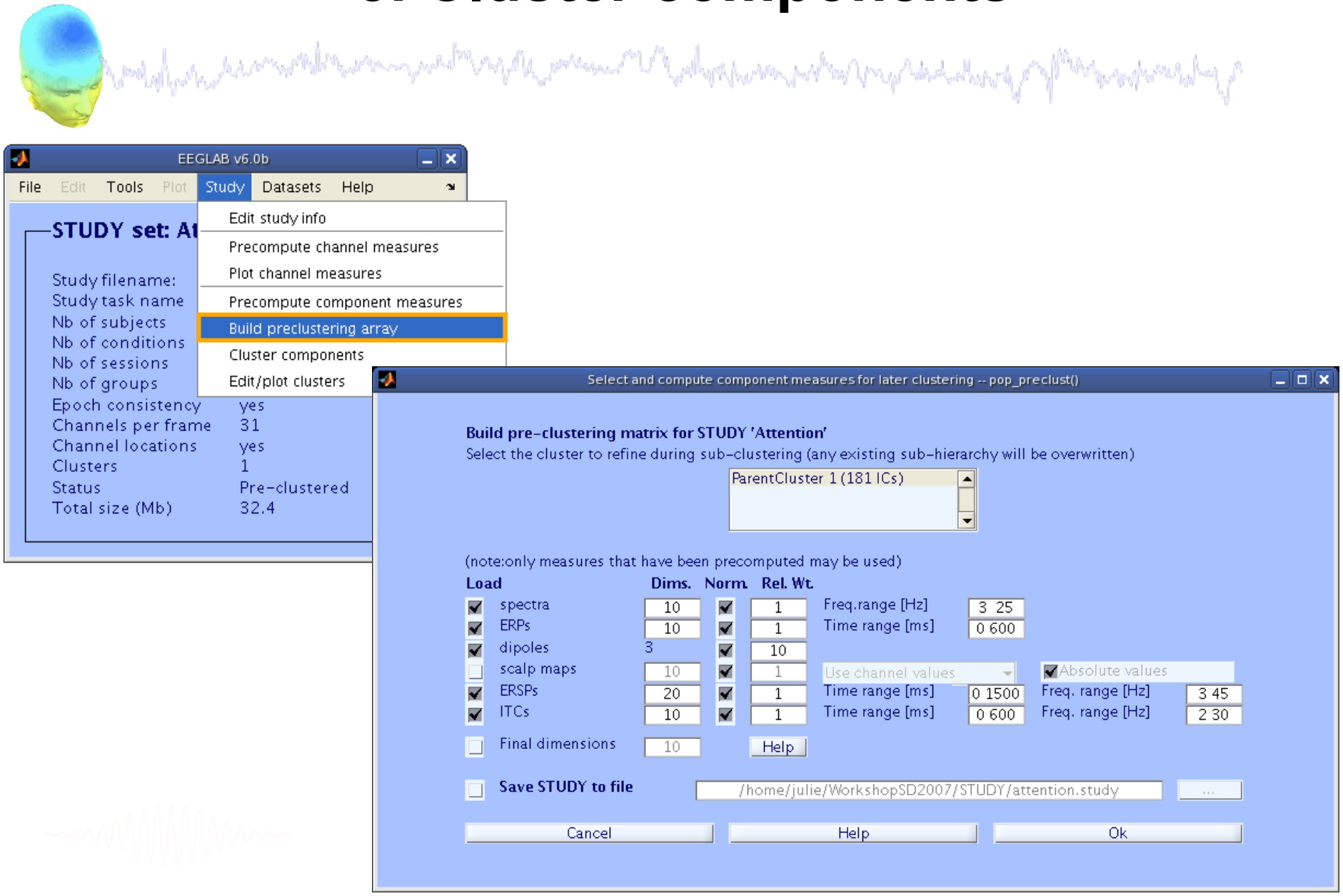


Channels

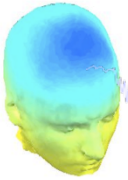


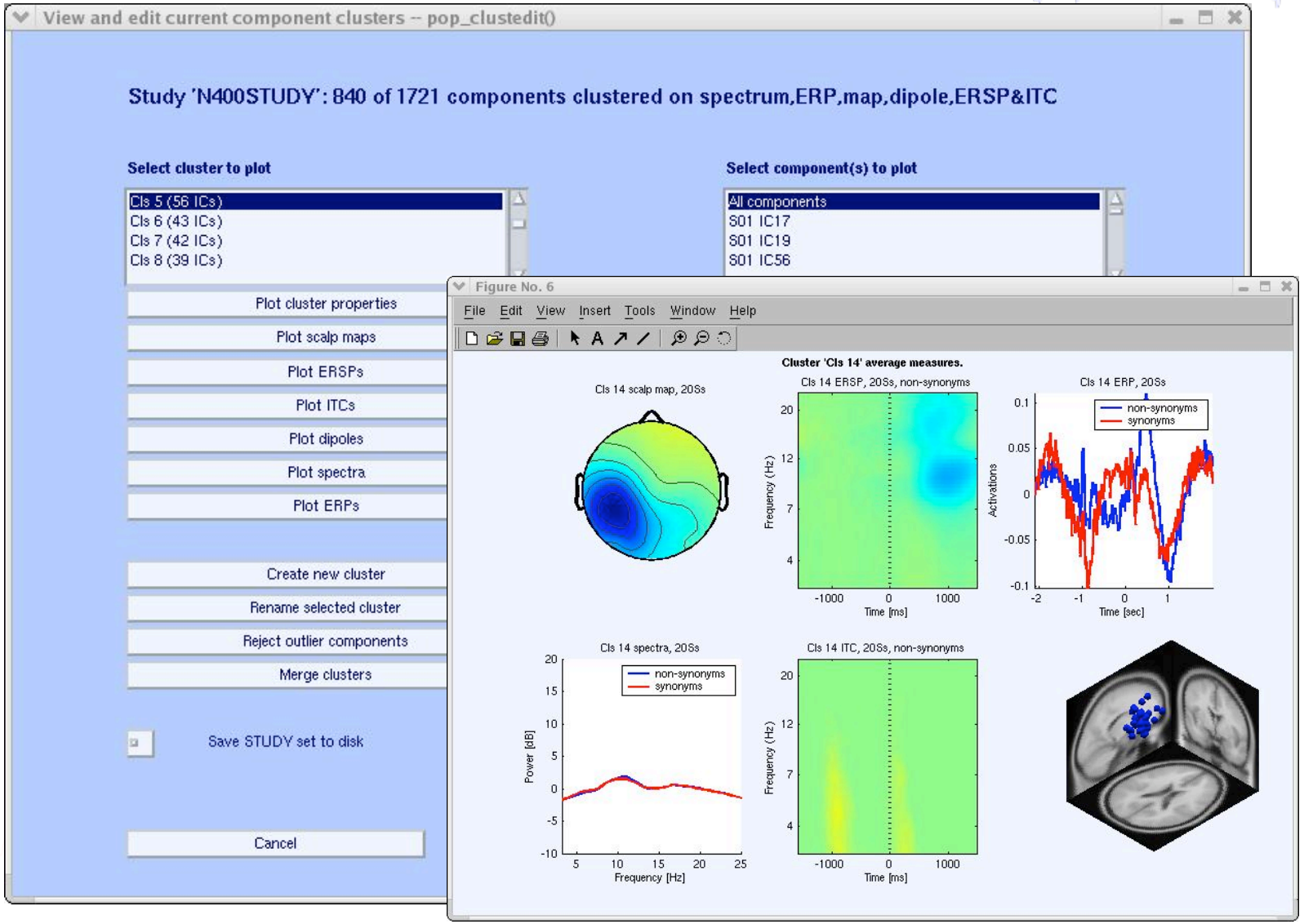


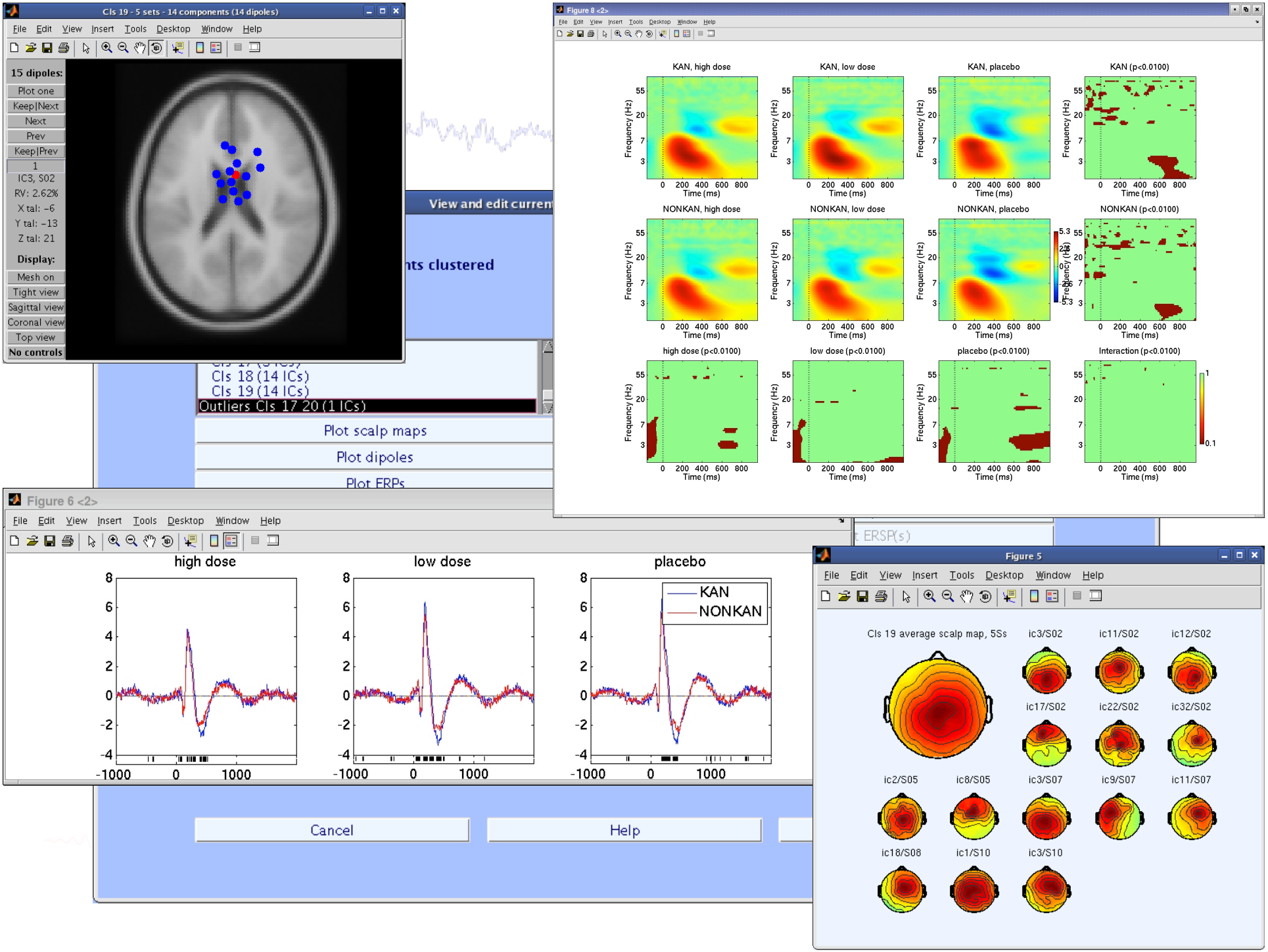
3. Cluster components



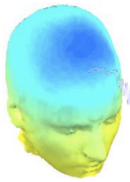
4. Analyze clusters

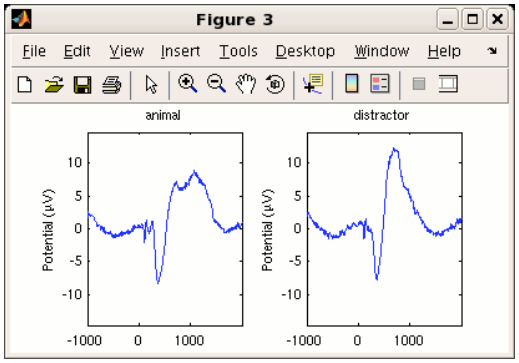


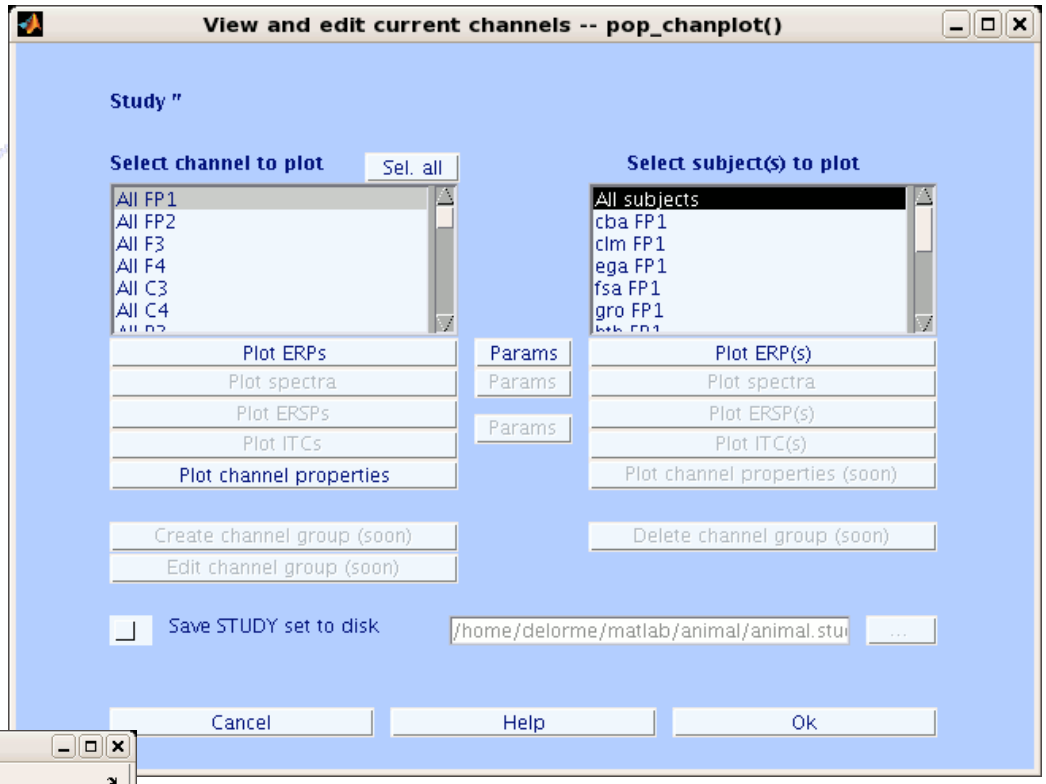


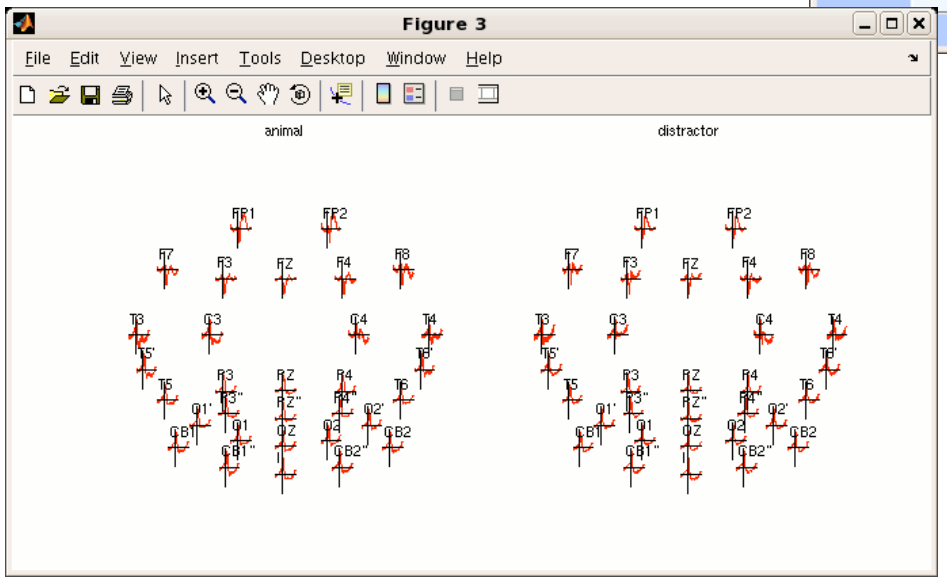

Cls 19 - 5 sets - 14 components (14 dipoles)
File Edit View Insert Tools Desktop Window Help
15 dipoles:
Plot one
Keep|Next
Next
Prev
Keep|Prev
1
IC3, S02
RV: 2.62%
X tal: -6
Y tal: -13
Z tal: 21
Display:
Mesh on
Tight view
Sagittal view
Coronal view
Top view
No controls
View and edit curren
nts clustered
Cls 18 (14 ICs)
Cls 19 (14 ICs)
Outliers Cls 17 20 (1 ICs)
Plot scalp maps
Plot dipoles
Plot ERPs
Figure 8 <2>
KAN, high dose
KAN, low dose
KAN, placebo
KAN (p<0.0100)
NONKAN, high dose
NONKAN, low dose
NONKAN, placebo
NONKAN (p<0.0100)
high dose (p<0.0100)
low dose (p<0.0100)
placebo (p<0.0100)
Interaction (p<0.0100)
Frequency (Hz)
Time (ms)
Figure 6 <2>
high dose
low dose
placebo
KAN
NONKAN
Cancel
Help
Figure 5
Cls 19 average scalp map, 5Ss
ic3/S02
ic11/S02
ic12/S02
ic17/S02
ic22/S02
ic32/S02
ic2/S05
ic8/S05
ic3/S07
ic9/S07
ic11/S07
ic18/S08
ic1/S10
ic3/S10

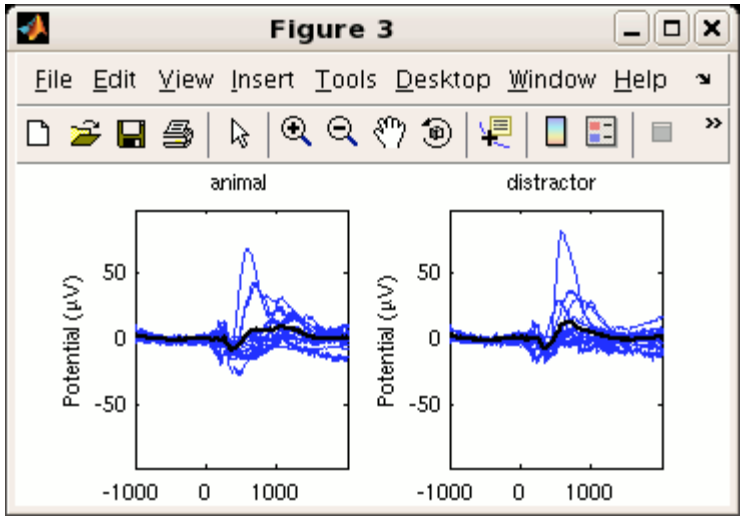
Channel plotting



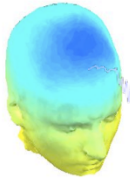








EEGLAB standard processing pipeline



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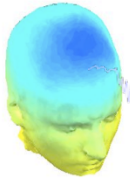
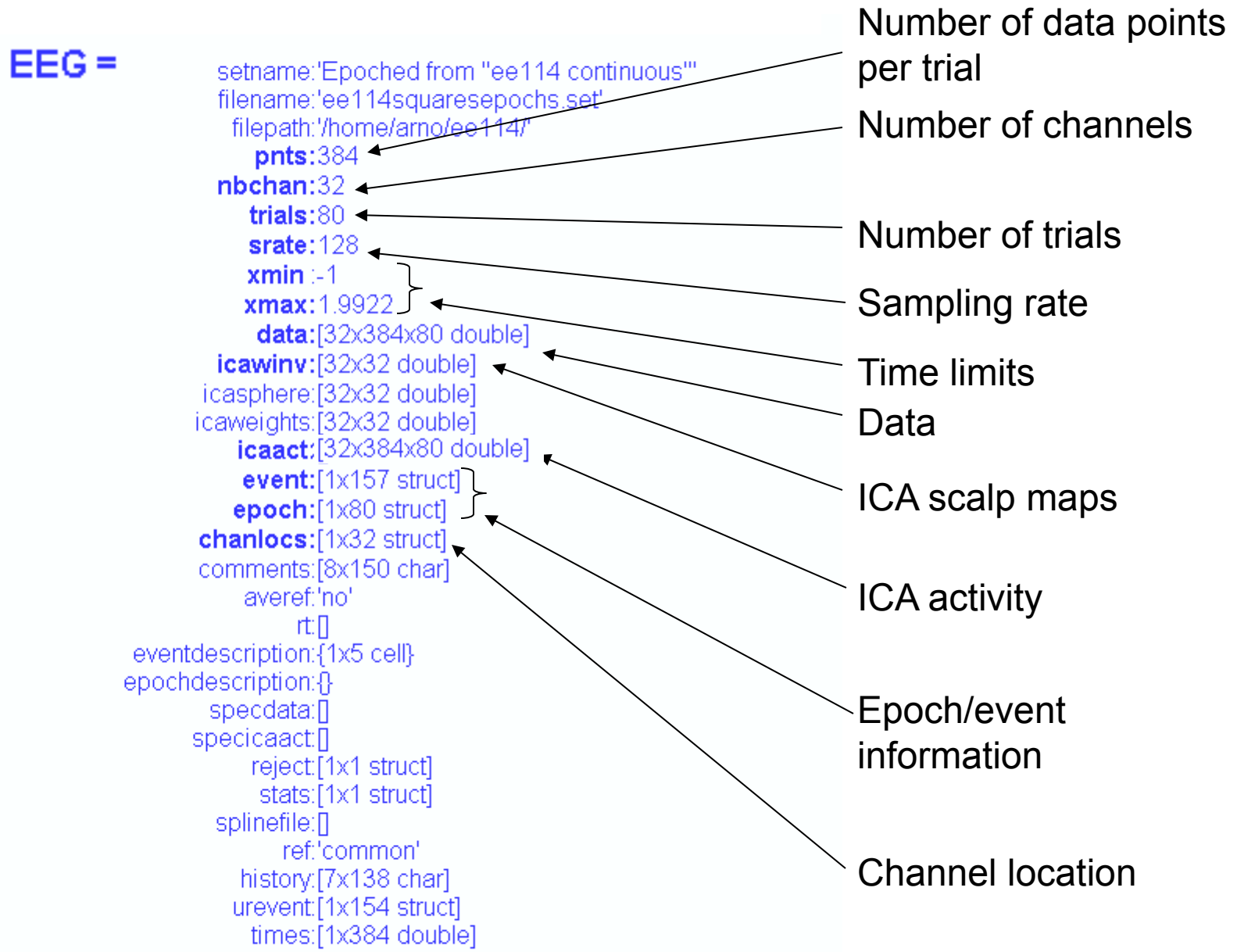
Advanced analysis using scripting and EEGLAB command line functions

EEGLAB Data Structures

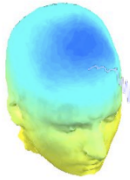


1. EEG - root ‘dataset’ structure
   - .data - the dataset data (2-D, 3-D matrix)
   - .chanlocs - channel locations substructure
   - .event - data events substructure
   - .epoch - data epochs substructure
3. ALLEEG - vector of loaded EEG datasets
4. CURRENTSET - index in ALLEEG of current EEG dataset
5. STUDY - root ‘studyset’ structure
   - .cluster - component clustering substructure

EEG structure



3 levels of functions



Administrative functions: handle EEG and ALLEEG structures

eeglab(), eeg_checkset(), pop_delset(), …

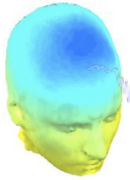
Pop functions: interactive functions using EEG structure

pop_erpimage(), pop_topoplot(), pop_envtopo(), …

Signal processing functions: perform signal processing

erpimage(), topoplot(), envtopo(), …

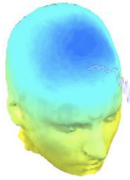
Command line tools



(Menus write both dataset and global history)

- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, …)
- Selecting data/epoch based on event context
- Custom processing…

Future directions



- Signal processing and source localization
- Analysis of large studies and parallel processing
- Multi-modality imaging
- Bootstrap statistics and correction for multiple comparisons

- Improved plug-in facility and script library
- Shared data resource (BIRN)
- Better binary format handling
- Wiki documentation http://sccn.ucsd.edu/wiki/EEGLAB
- Open source community development