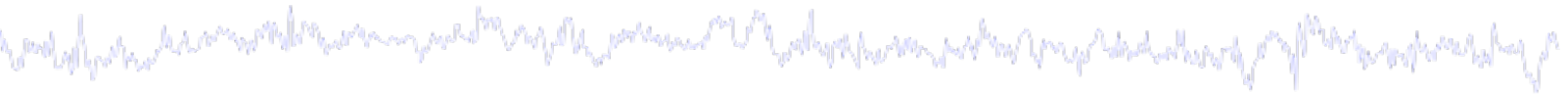
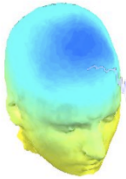
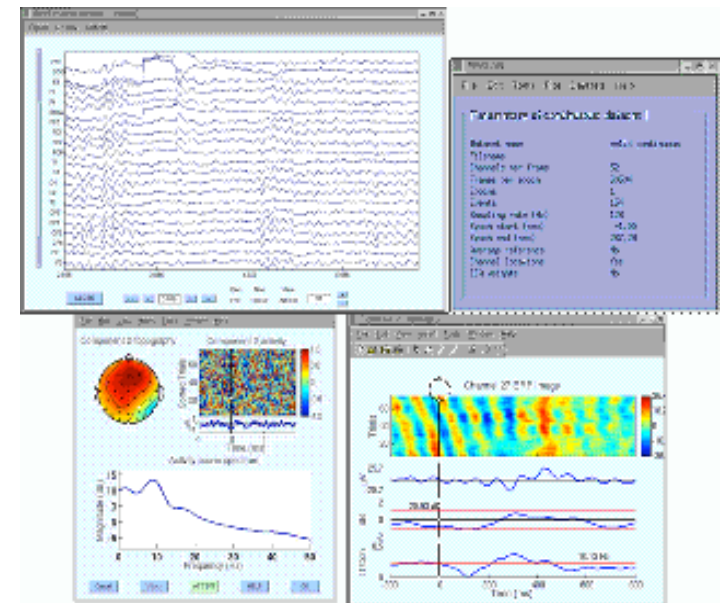


The EEGLAB software

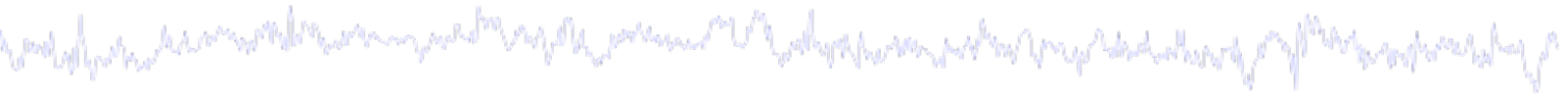
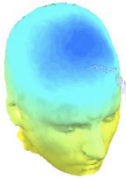


- Collection of over 300 functions (50000 lines of code)
- About 50000 download over the past 6 years
- About 3500 users on the discussion list and 6500 on the diffusion list
- NIH funding (2003-)

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

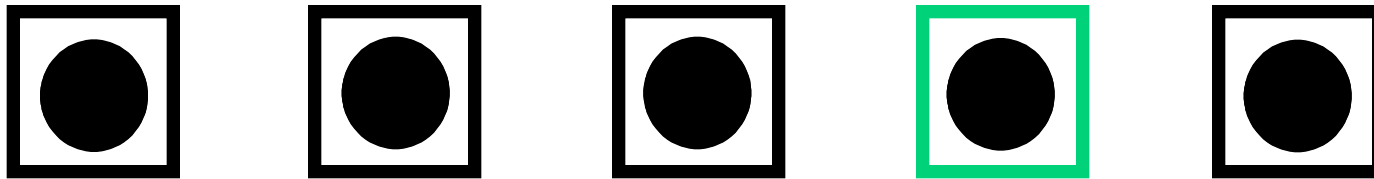
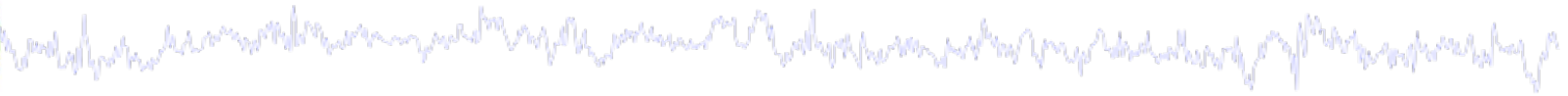
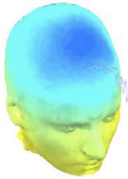


Pros/Cons of Matlab based open source



- 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

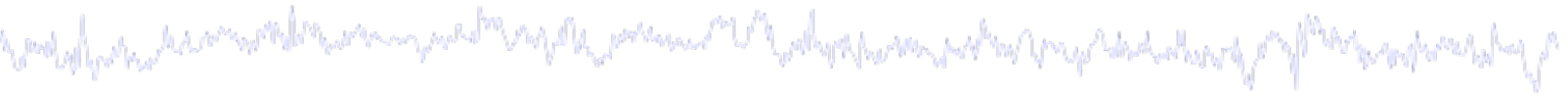
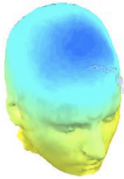
Spatial visual attention task (STUDY)



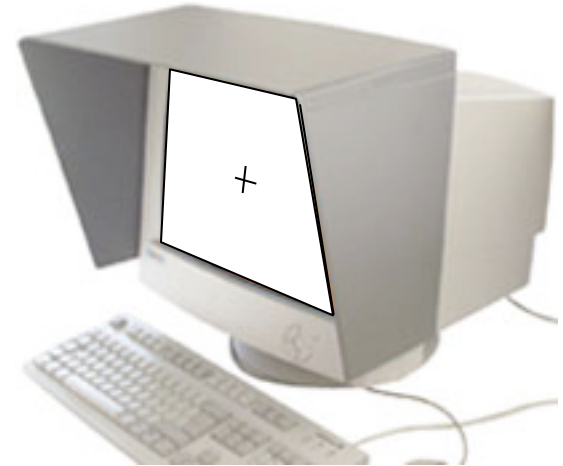
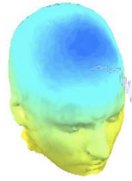
+



Publication using this data

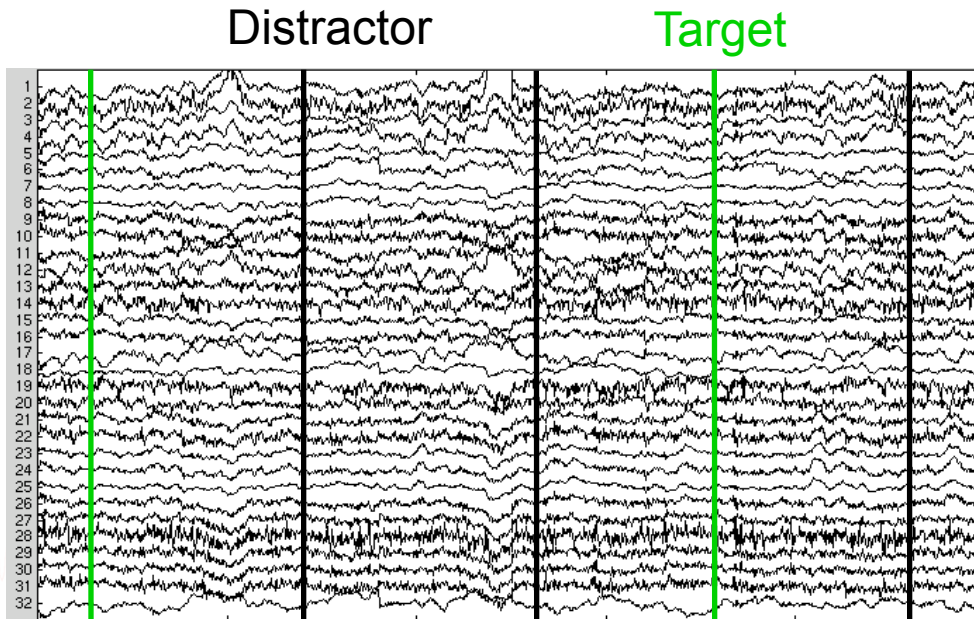


- Delorme A, Westerfield M, Makeig S., **J Neurosci**. 2007 Oct 31;27(44):11949-59.
- Onton J, Westerfield M, Townsend J, Makeig S., *Neurosci Biobehav Rev*. 2006;30(6):808-22. Epub 2006 Aug 14. Review.
- Makeig S, Delorme A, Westerfield M, Jung TP, Townsend J, Courchesne E, Sejnowski TJ., **PLoS Biol**. 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.



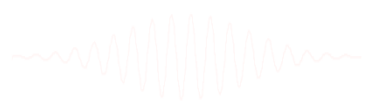
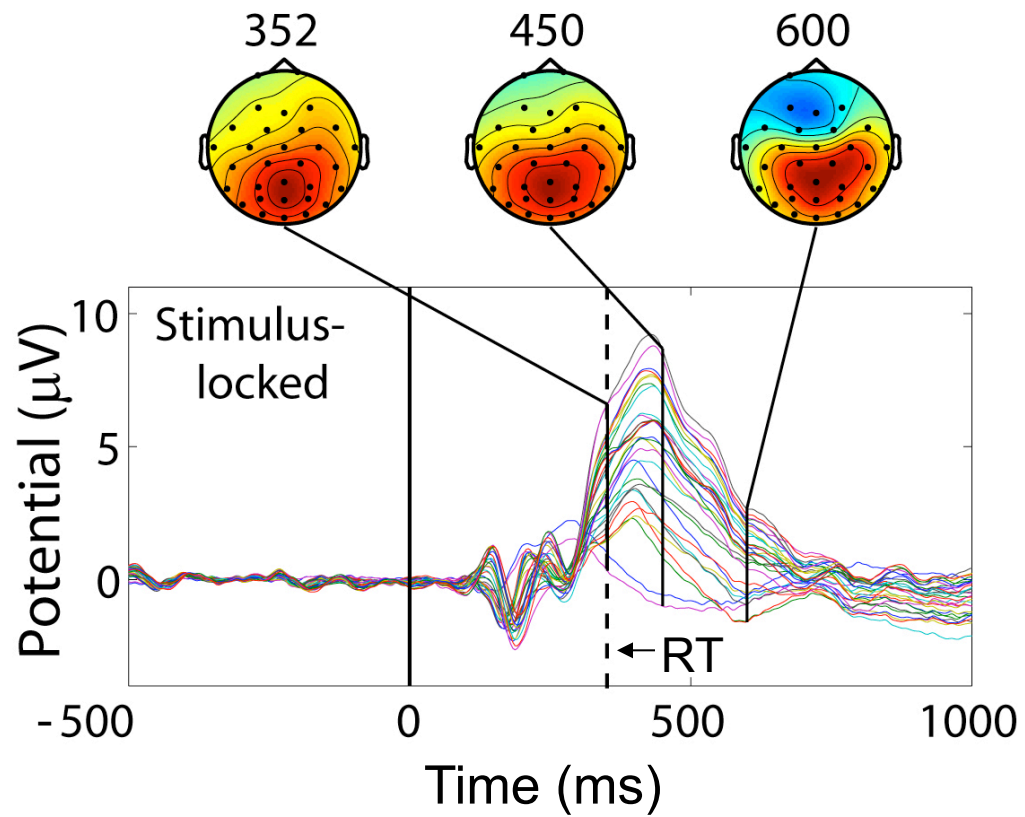
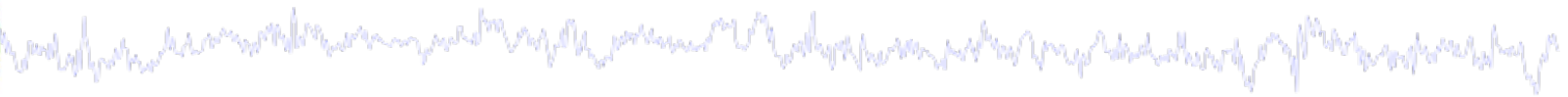
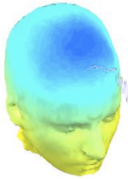
Recording

Electrodes

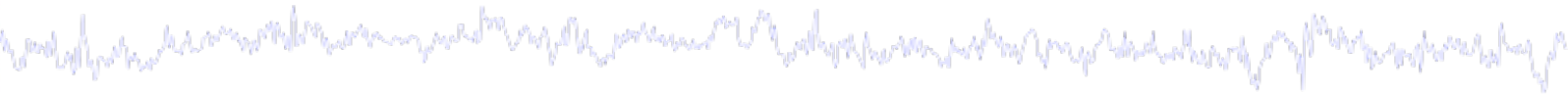
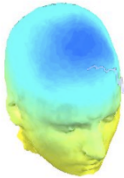


Offline processing

Target trials



EEGLAB standard processing pipeline



Single subject

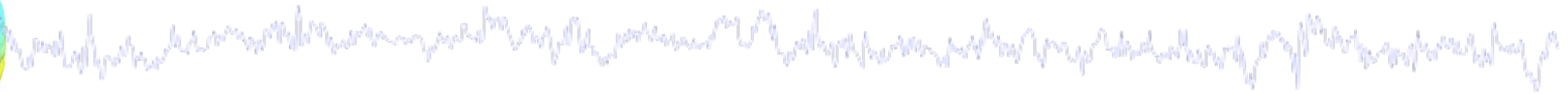
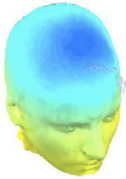
1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
3. Reject artifacts in continuous data by visual inspection
4. Extract epochs from data & reject artifactual epochs
5. Visualize data measures
6. Perform ICA decomposition
 - Perform source localization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

The EEGLAB Matlab software



The screenshot displays the EEGLAB Matlab software interface. On the left is the 'EEGLAB Shell - Konsole' window, which shows the MATLAB command prompt with the following text:

```
/home/arno> matlab -nodesktop

< M A T L A B >
Copyright 1984-2002 The MathWorks
Version 6.5.0.180913a Release
Jun 18 2002

Using Toolbox Path Cache. Type "help toolbox_path" for more information.

To get started, type one of these: helpwin, helpdesk, or help.
For product information, visit www.mathworks.com.

>> eeglab
```

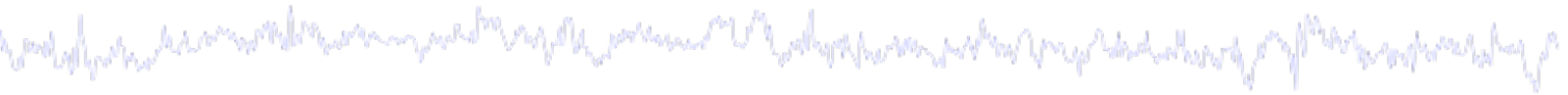
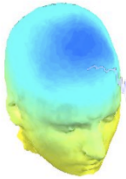
On the right is the 'EEGLAB' window, which displays the 'No current dataset' help text:

No current dataset

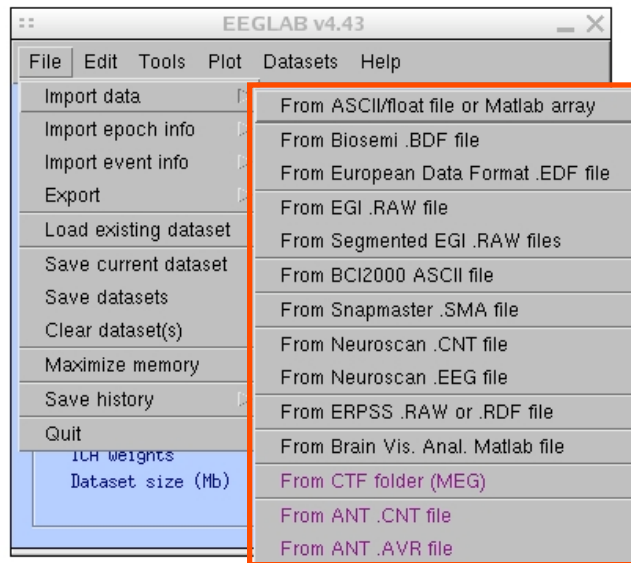
- Create a new or load an existing dataset:
Use "/File/Import data" (new)
Or "/File/Load existing dataset" (old)
- If new,
"/File/Import epoch info" (data epochs), else
"/File/Import event info" (continuous data)
"/Edit/Dataset info" (add/edit dataset info)
"/File/Save dataset" (save dataset)
- Prune data: "/Edit/Select data"
- Reject data: "/Tools/Reject continuous data"
- Epoch data: "/Tools/Extract epochs"
- Remove baseline: "/Tools/Remove baseline"
- Run ICA: "/Tools/Run ICA"



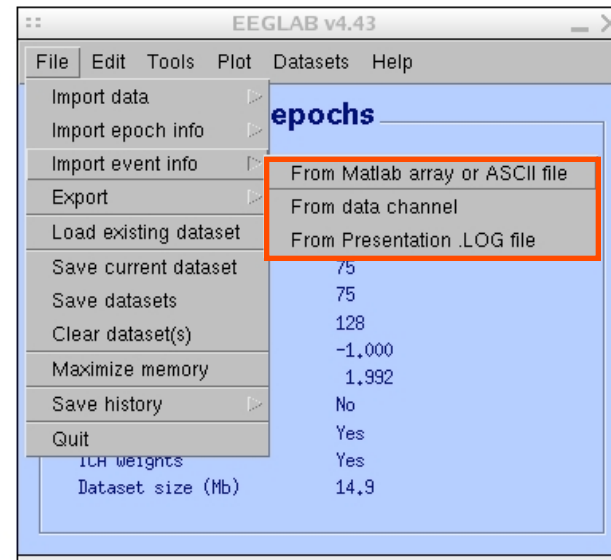
1. Importing data



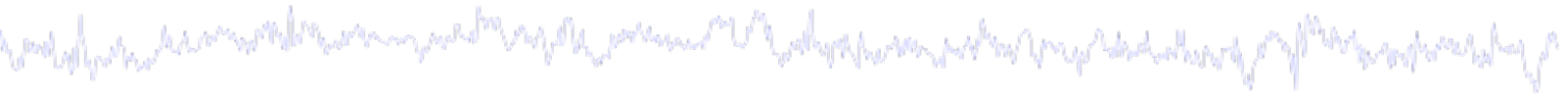
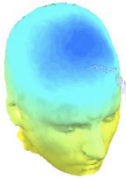
Import/load data



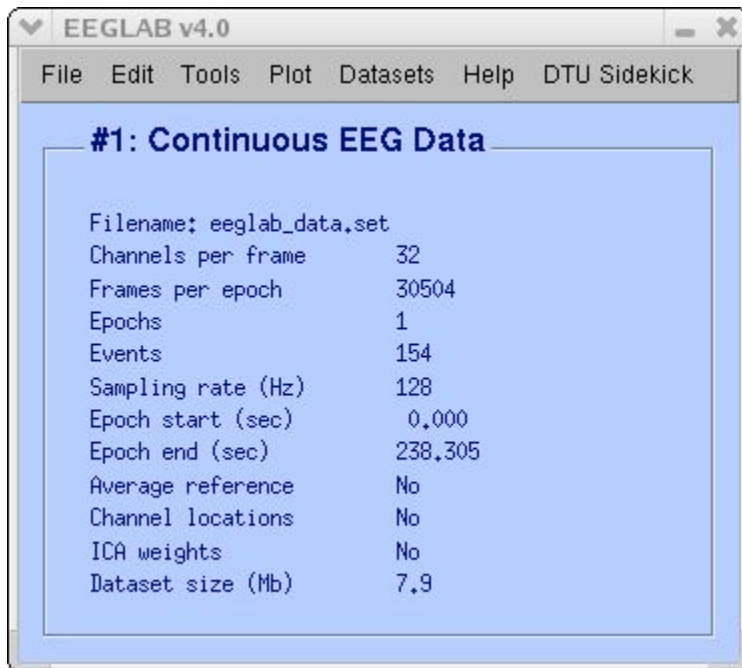
Import events



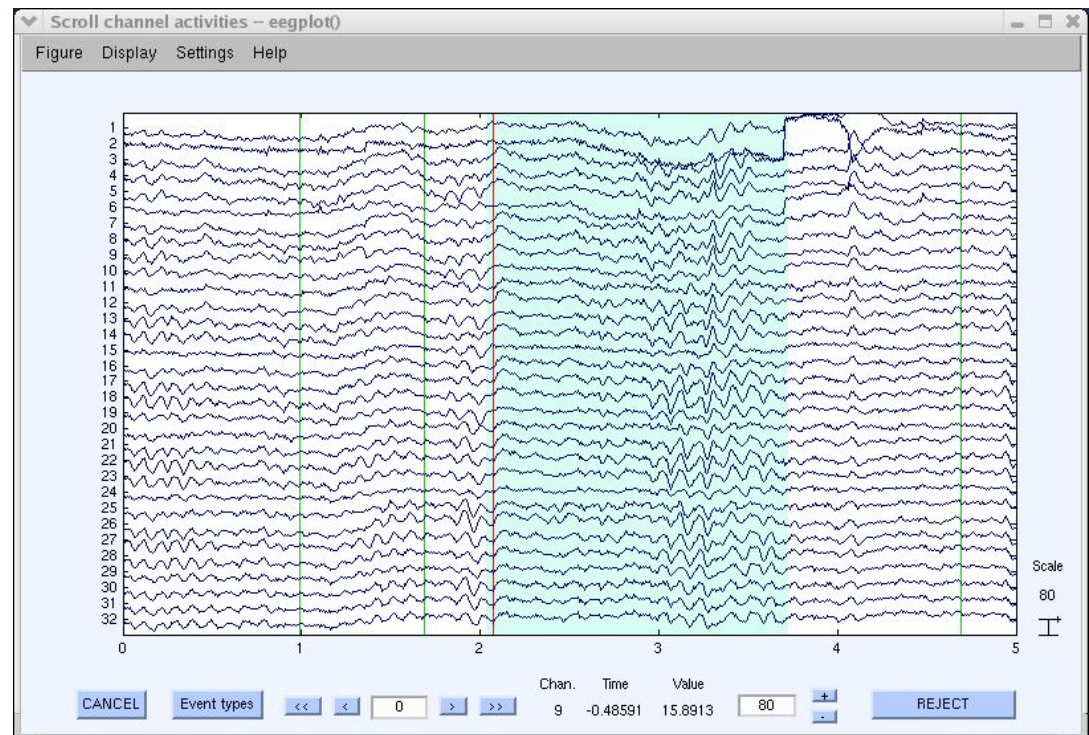
1. Importing data



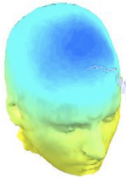
Data info



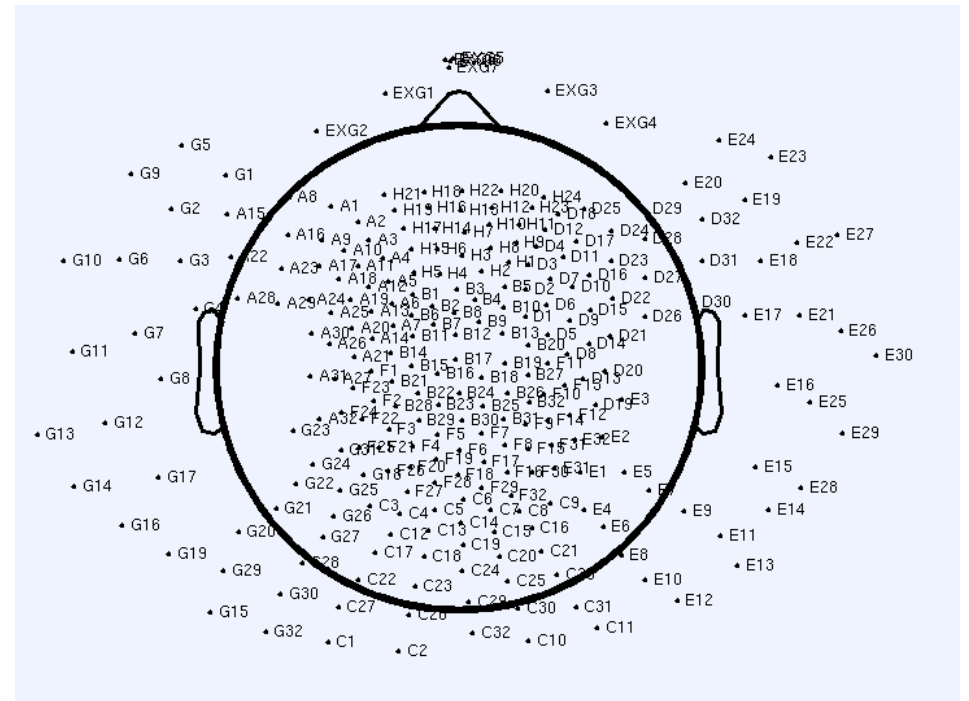
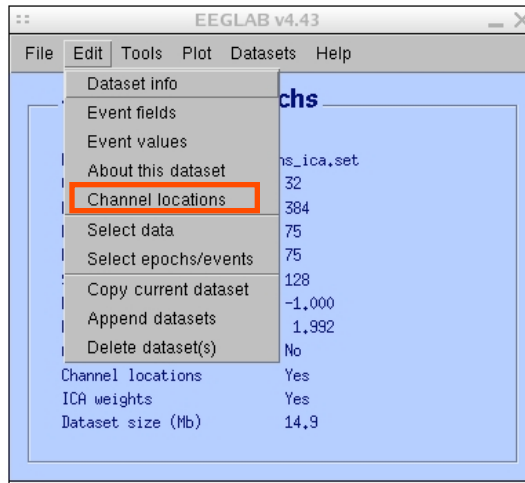
Scrolling data



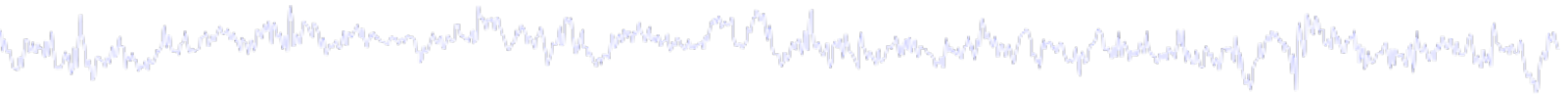
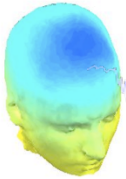
1. Importing channel location



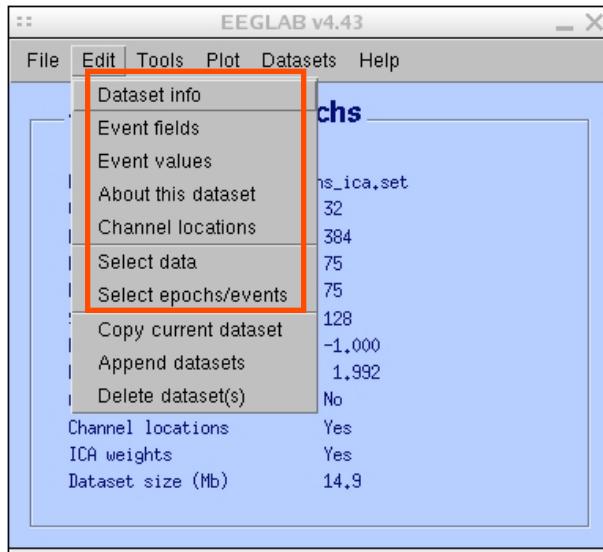
Import channel location



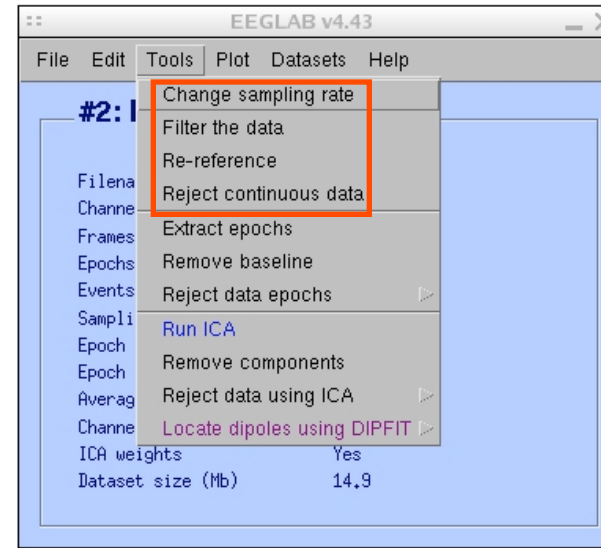
2. Edit, Re-reference, Resample, High pass filter data



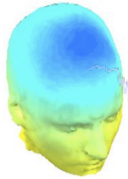
Edit/select data



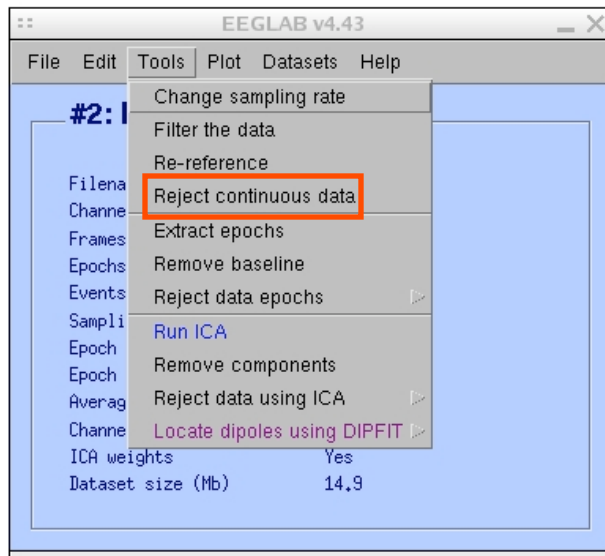
Preprocessing data



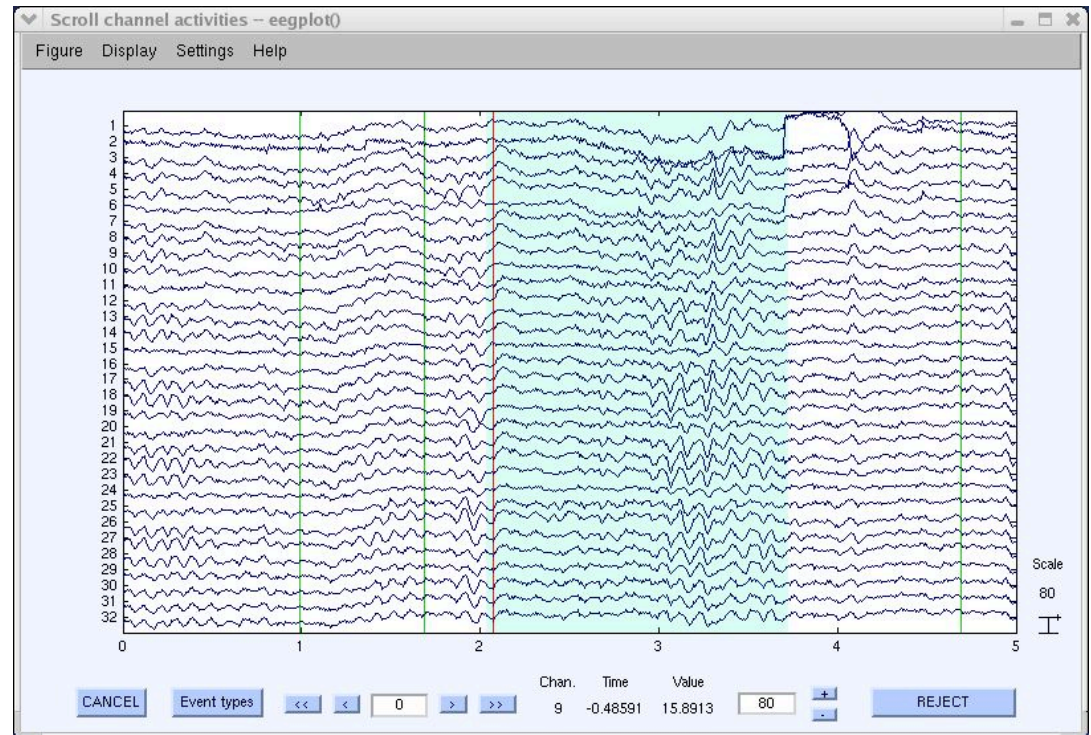
3. Reject artifacts in continuous data by visual inspection



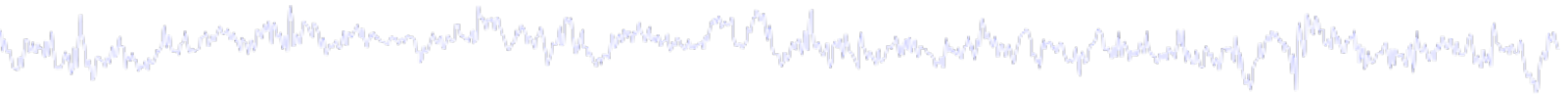
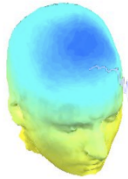
Data info



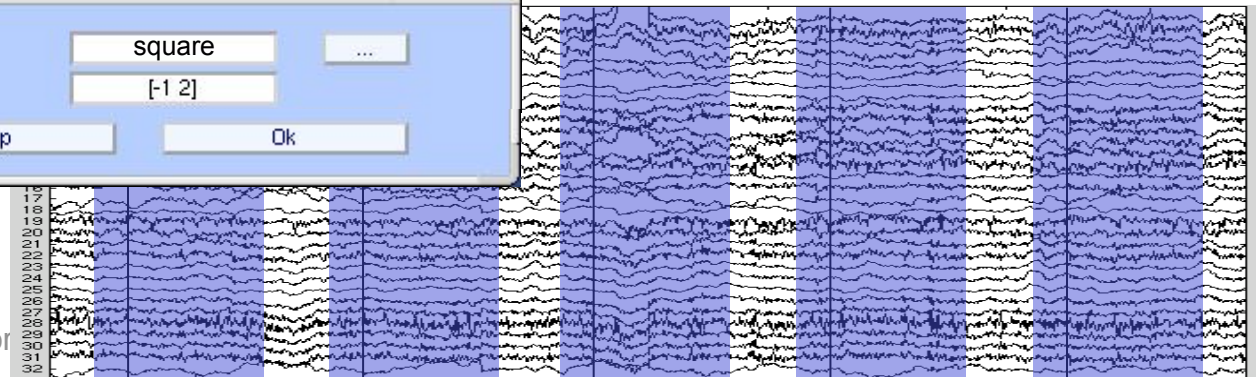
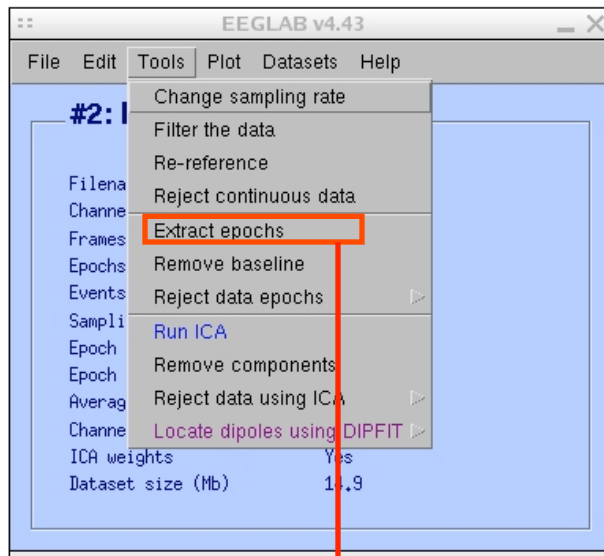
Reject portions of continuous data



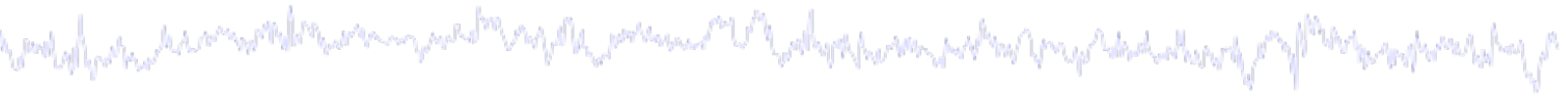
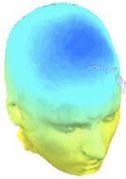
4. Extract epochs from data & reject artifactual epochs



Preprocessing data



4. Extract epochs from data & reject artifactual epochs



EEGLAB v4.51

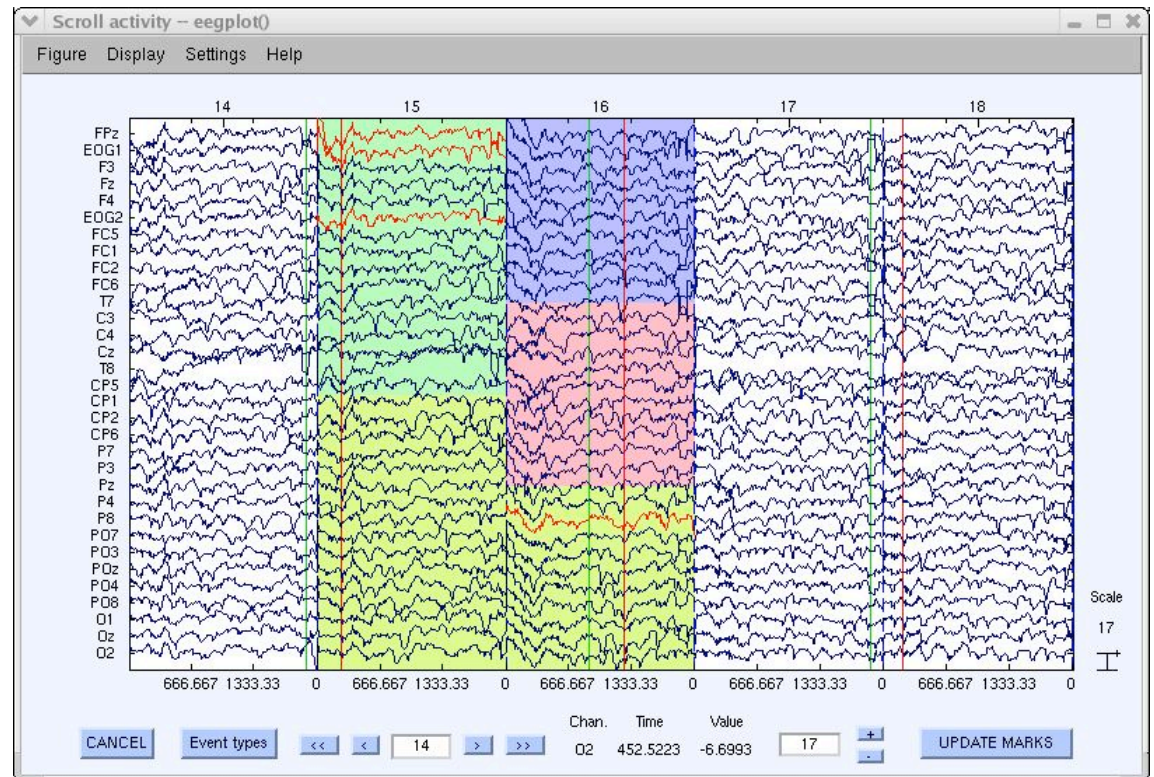
File Edit Tools Plot Datasets Help

#2: I... out chann...

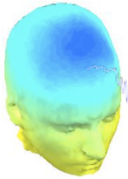
- Change sampling rate
- Filter the data
- Re-reference
- Reject continuous data
- Extract epochs
- Remove baseline
- Reject data epochs
- Run ICA
- Remove components
- Reject data using ICA
- Locate dipoles using BESA
- Locate dipoles using DIPFIT
- Laplacian
- Cluster component
- Filter the data (IIR)

- Reject data (all methods)
- Reject by inspection
- Reject extreme values
- Reject flat line data
- Reject by probability
- Reject by kurtosis
- Reject by spectra
- Export marks to ICA reject
- Reject marked epochs

Different color = different rejection methods



5. Visualize data measures



Plot ERP

EEGLAB v4.43

- File
- Edit
- Tools
- Plot**
- Datasets
- Help

#1: EEG

- Filename: eeg...
- Channels per t...
- Frames per epo...
- Epochs
- Events
- Sampling rate
- Epoch start (s...
- Epoch end (sec...
- Average refer...
- Channel locat...
- ICA weights
- Dataset size

Channel locations

Channel data (scroll)

Channel spectra and maps

Channel properties

Channel ERP image

Channel ERPs

- With scalp maps
- In scalp array**
- In rect. array

ERP map series

Sum/Compare ERPs

Component activations (scroll)

Component spectra and maps

Component maps

Component properties

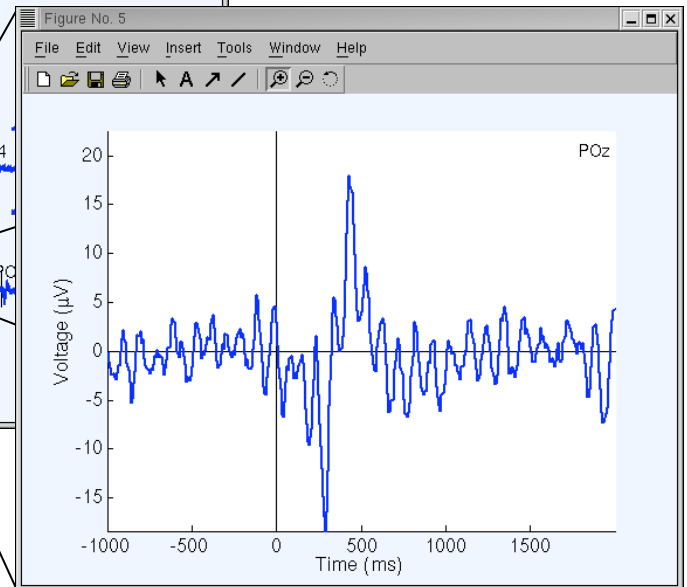
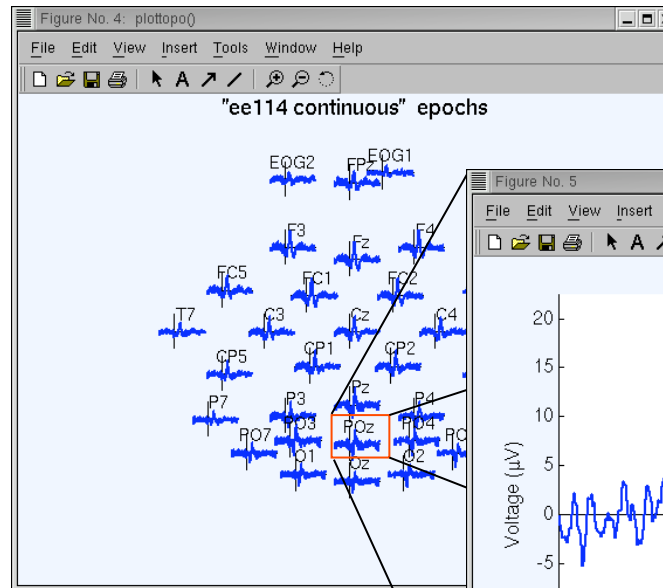
Component ERP image

Component ERPs

Sum/Compare comp. ERPs

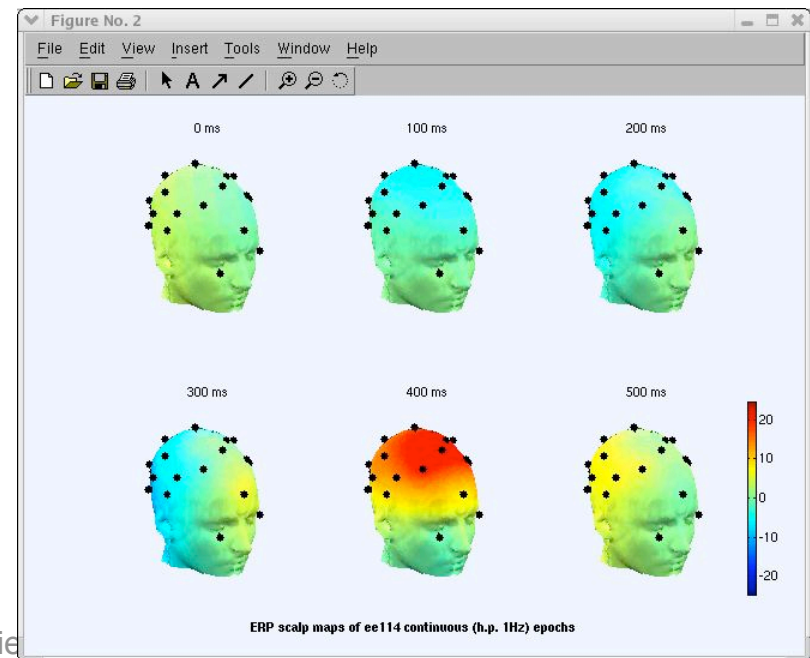
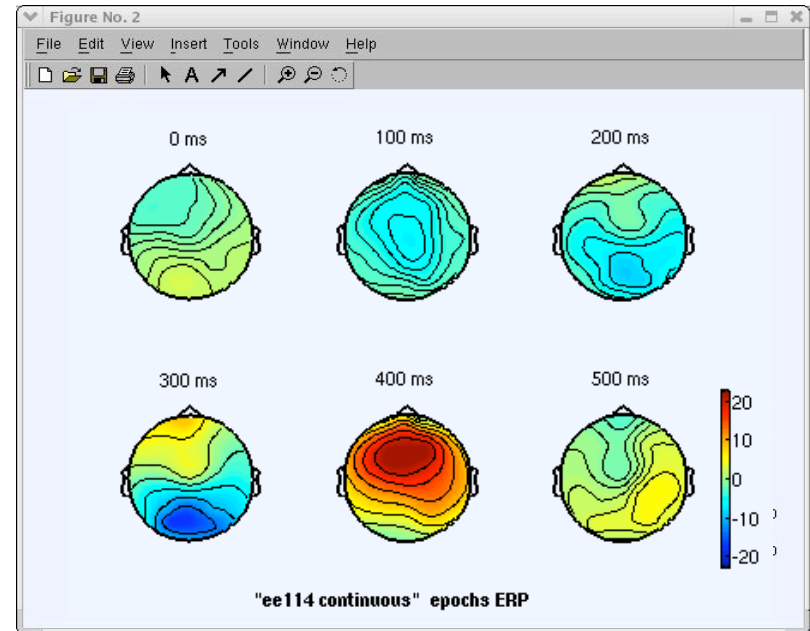
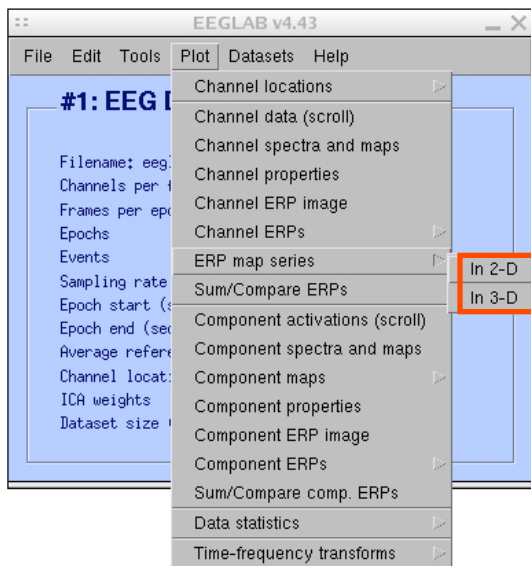
Data statistics

Time-frequency transforms

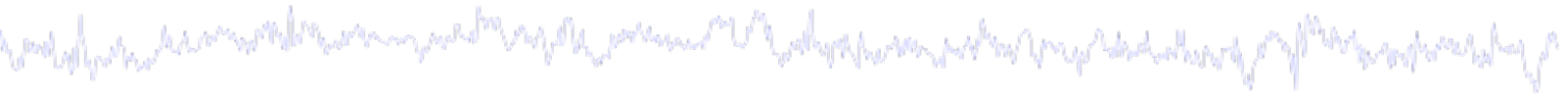
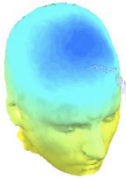


5. Visualize data measures

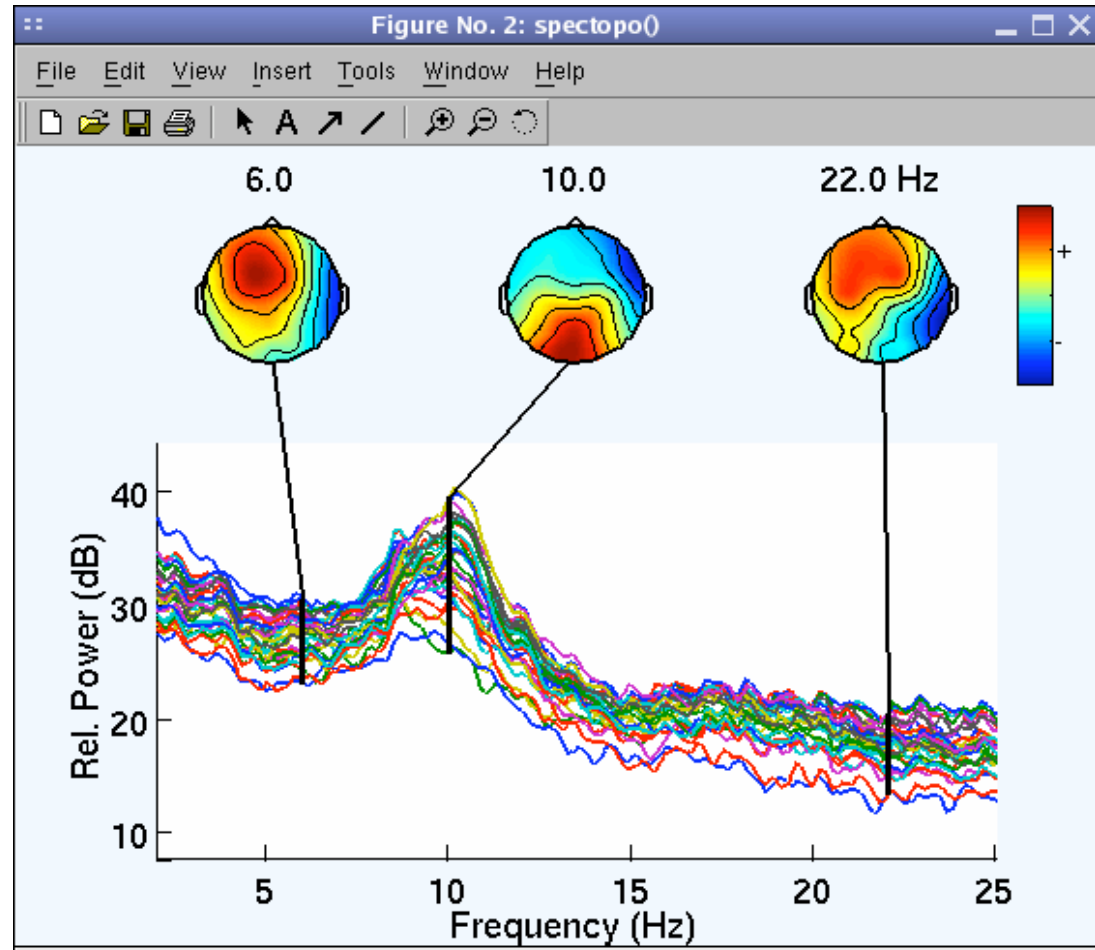
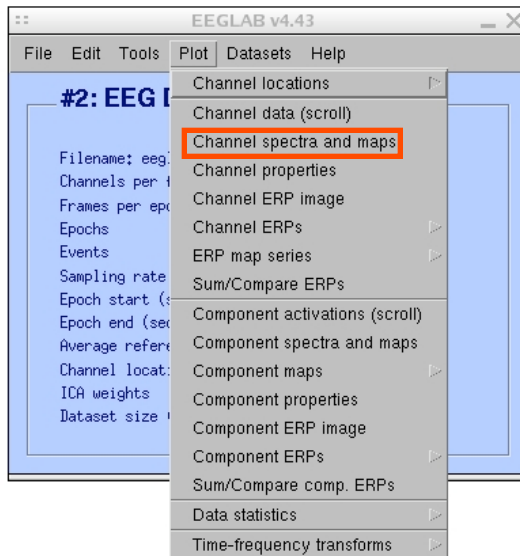
Plot ERP
map series



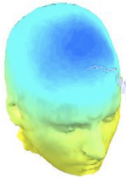
5. Visualize data measures



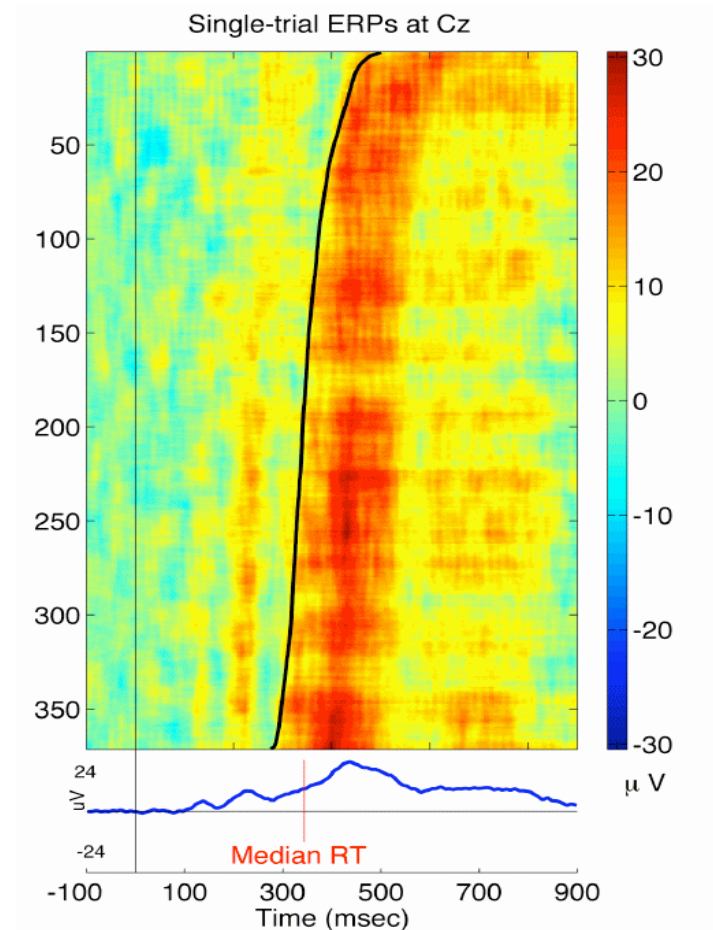
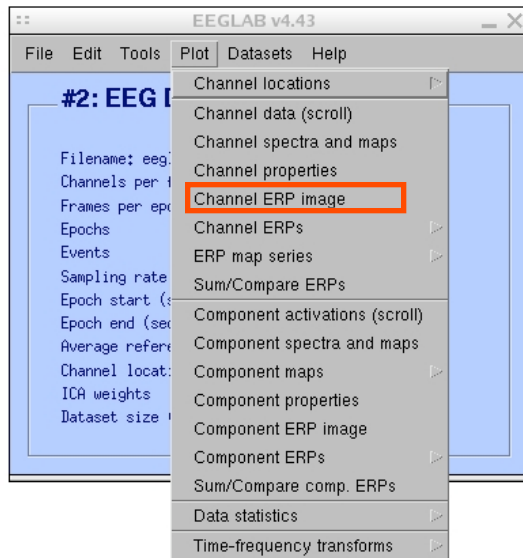
Plot data
spectrum and
maps



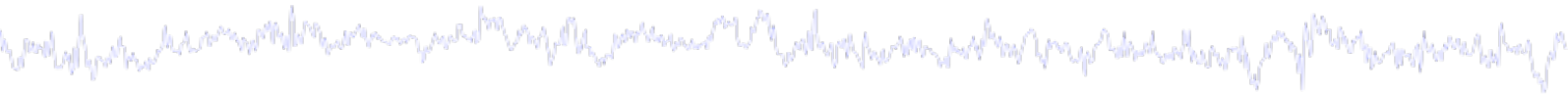
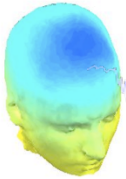
5. Visualize data measures



Plot channel ERP image



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

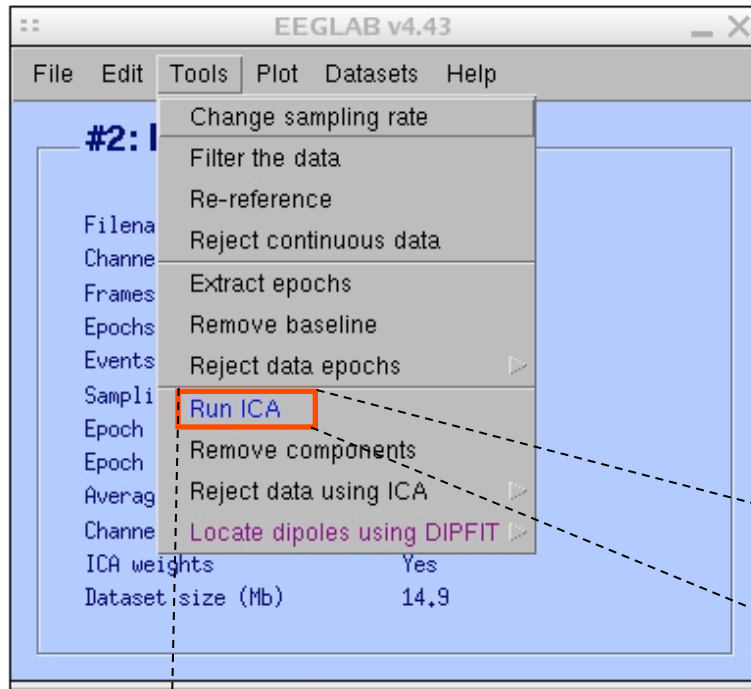
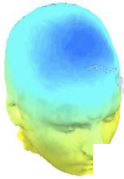
Multi-subjects

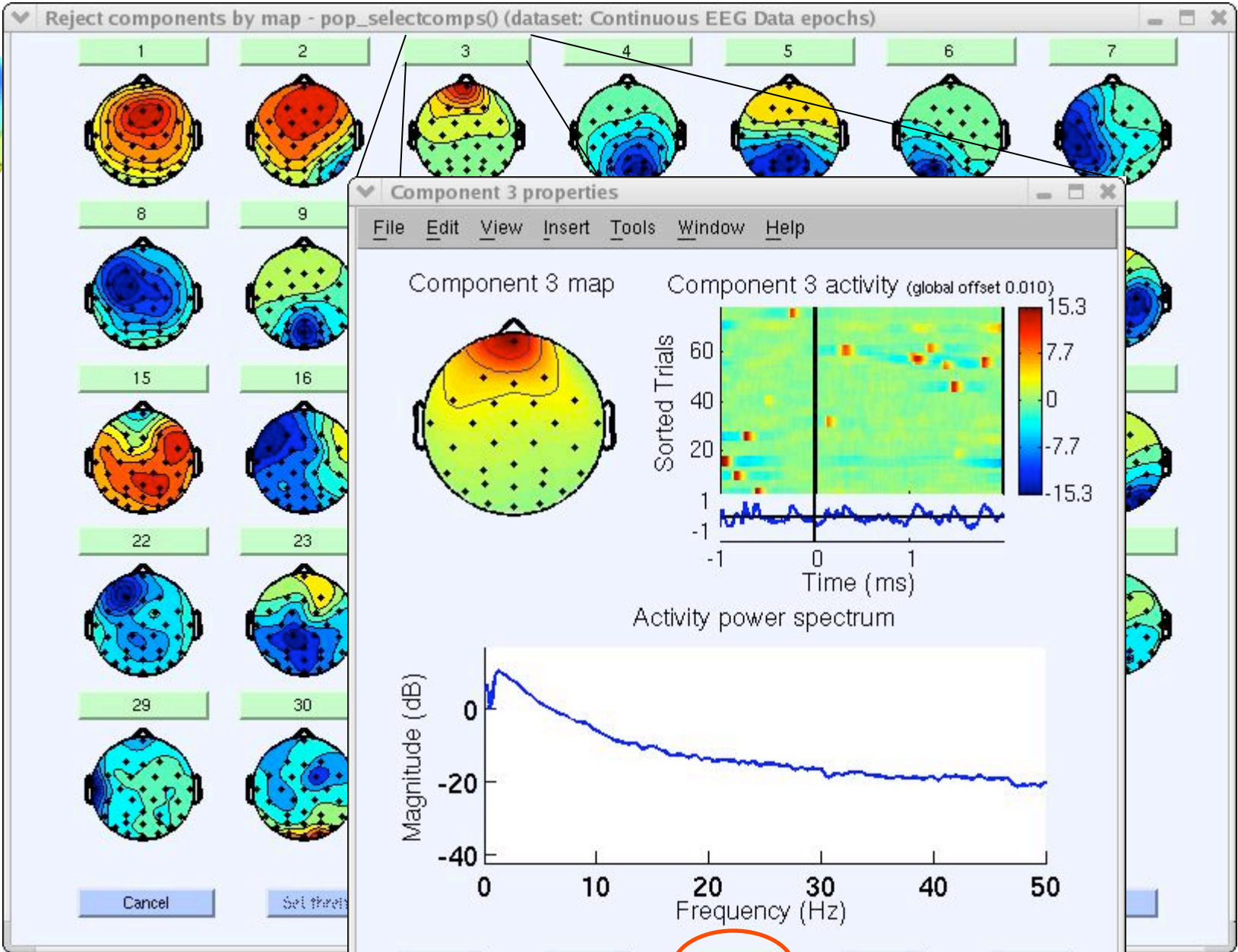
1. Build study
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



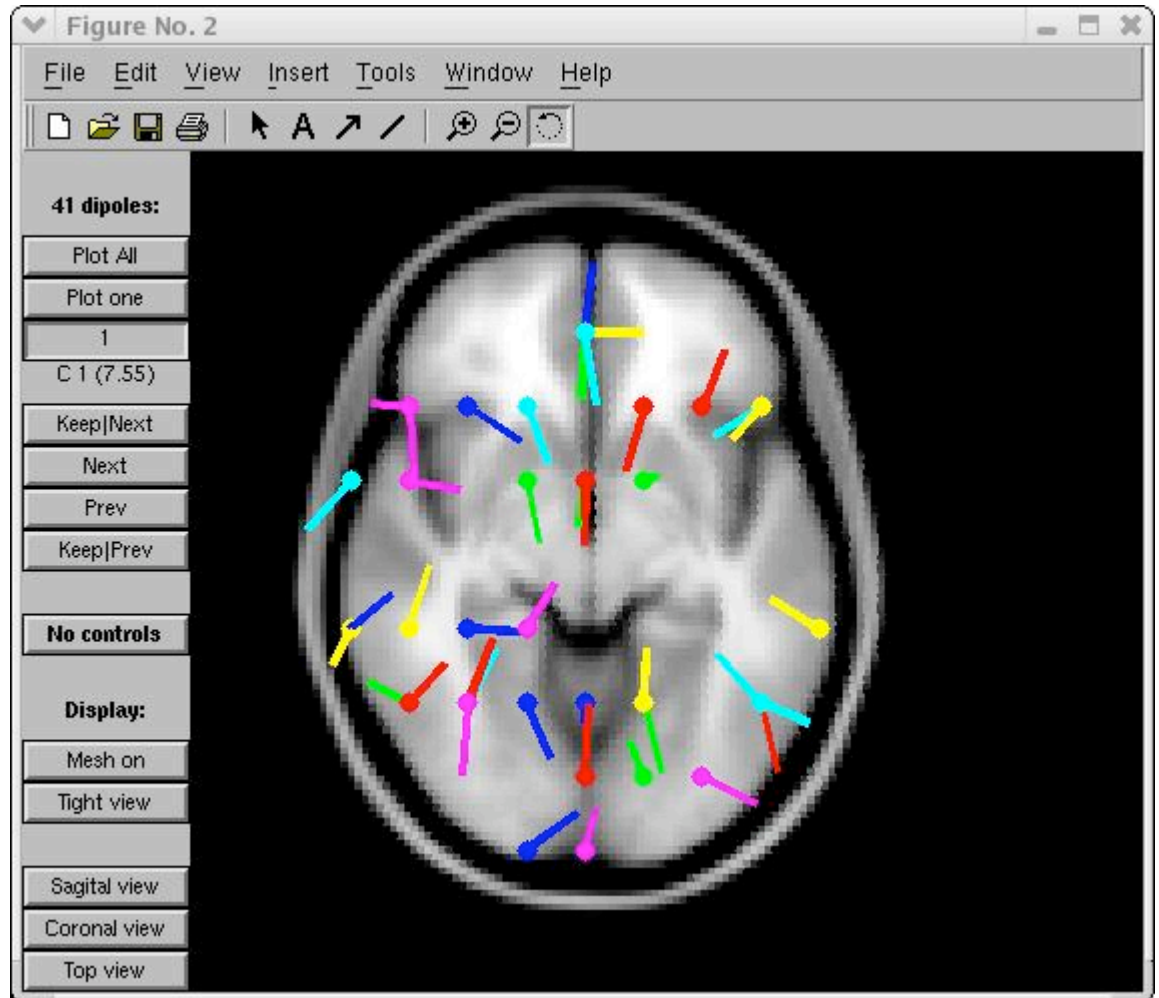
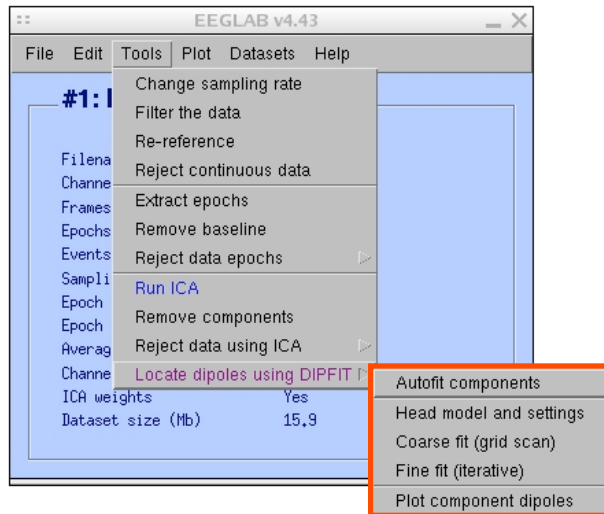
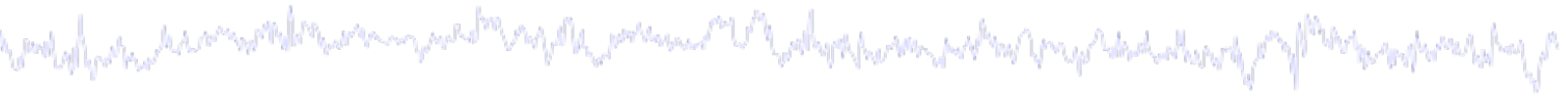
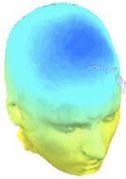
Advanced analysis using scripting and EEGLAB command line functions

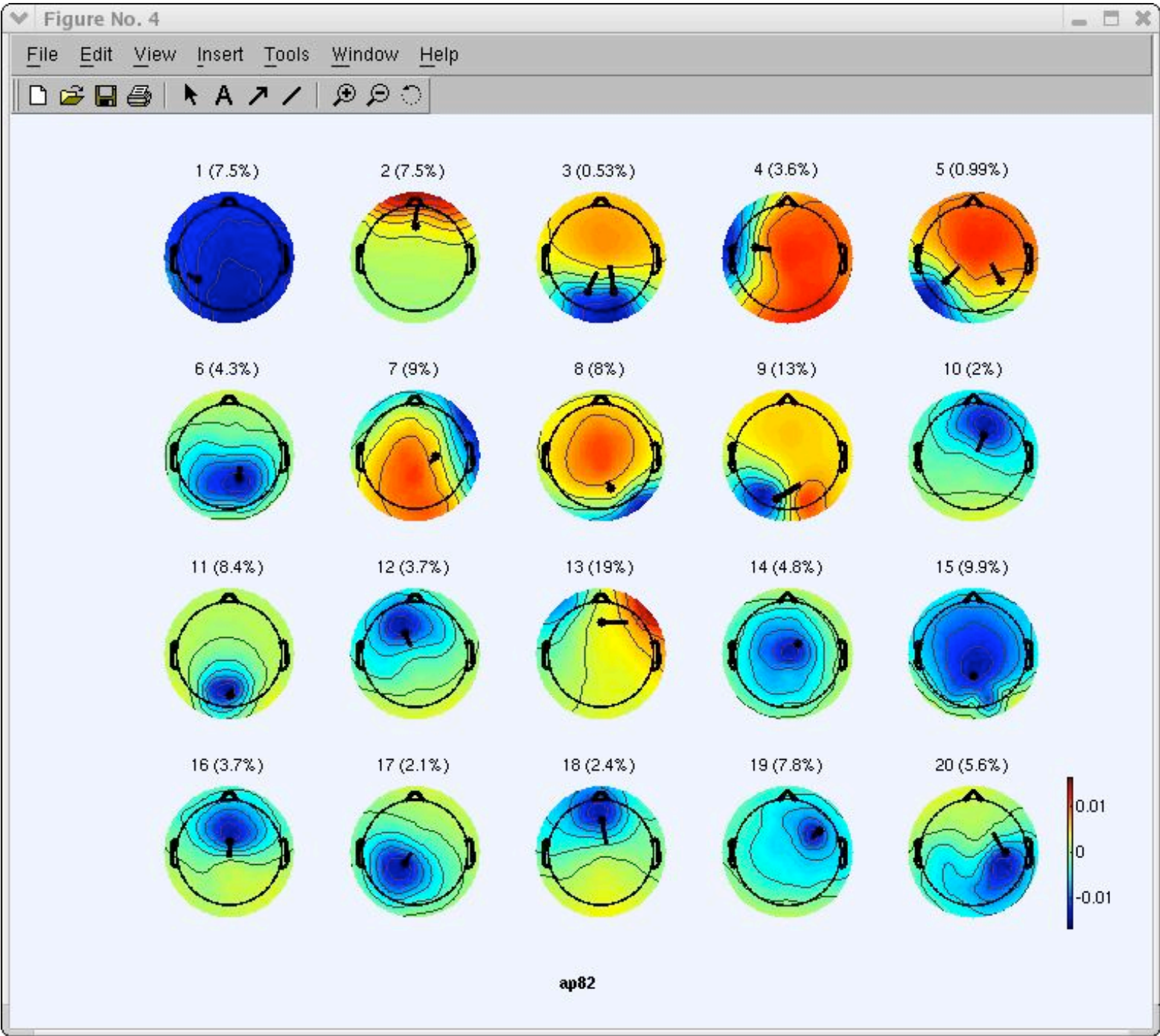
6. Perform ICA decomposition



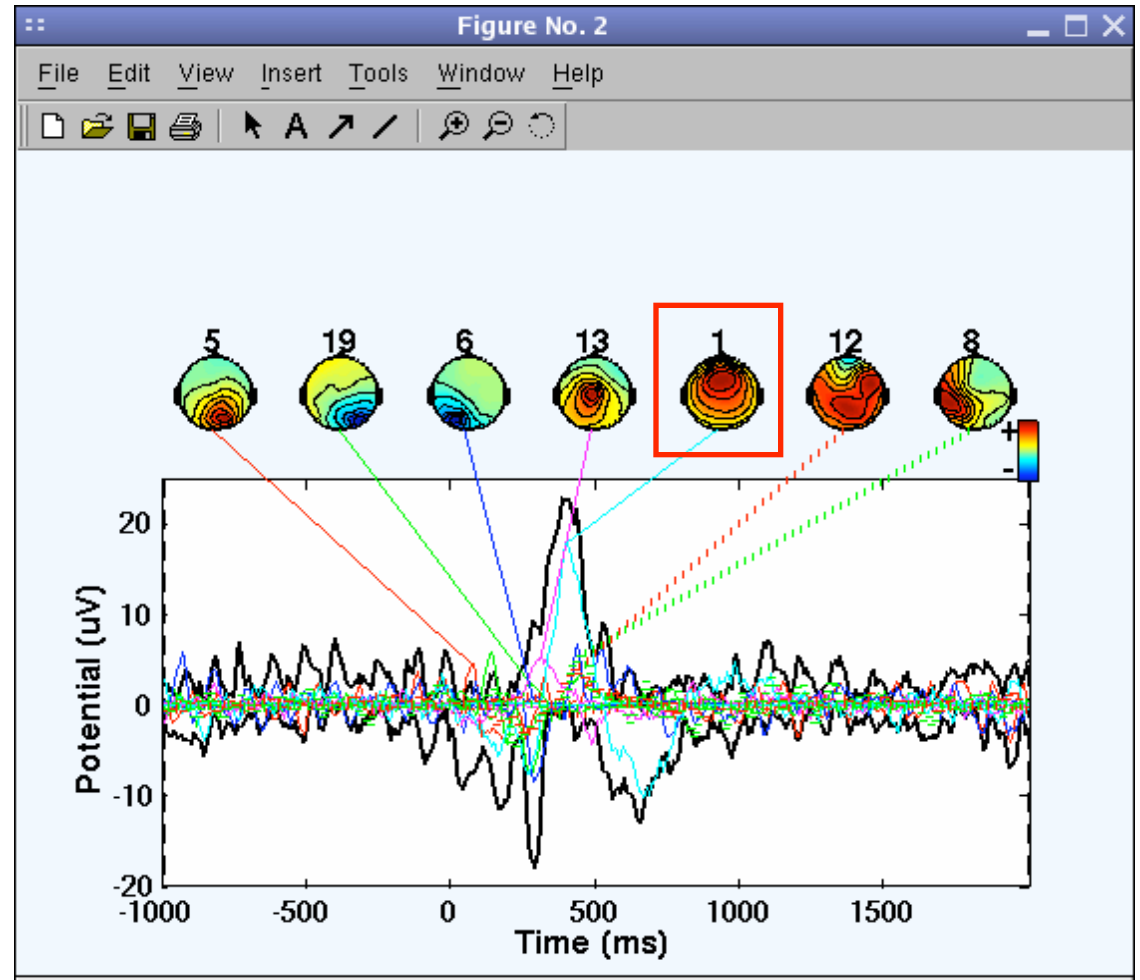
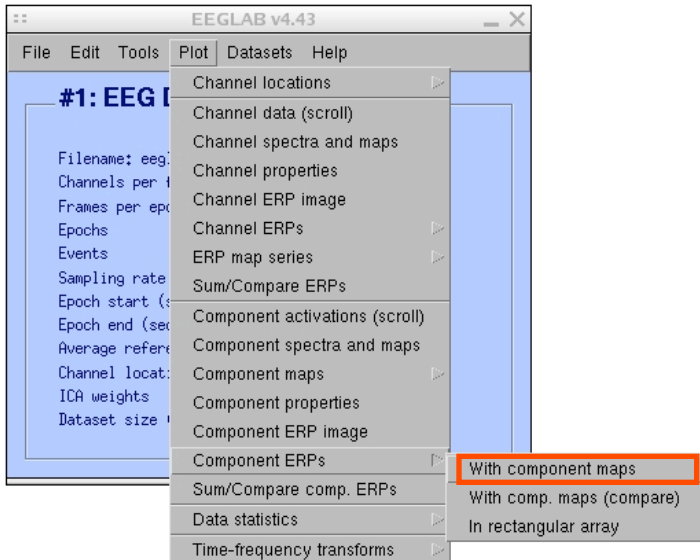
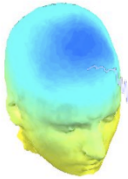


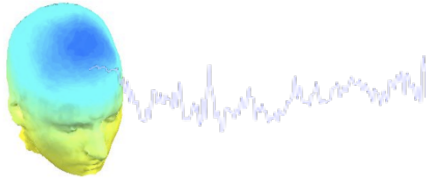
Localizing components



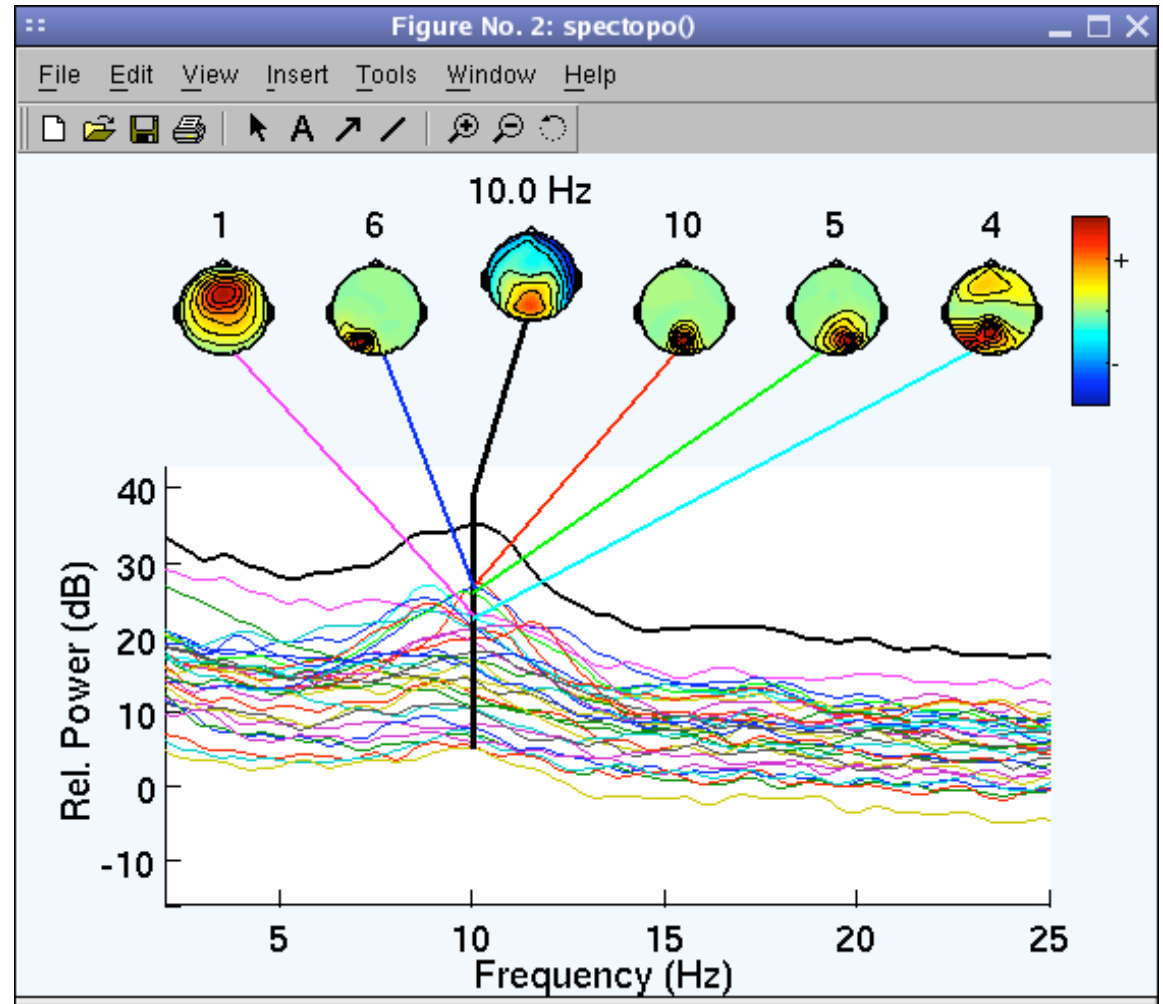
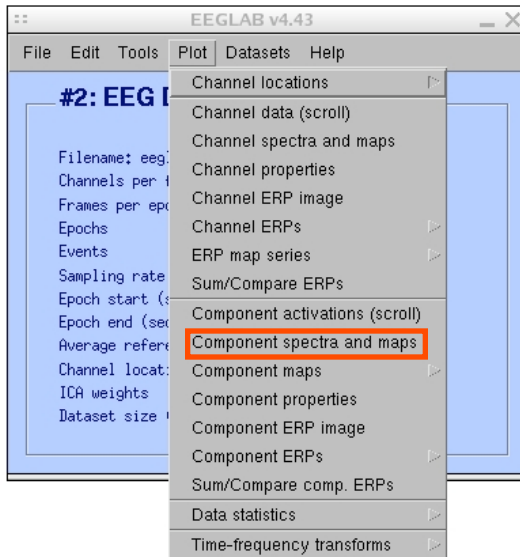


Component contribution to the ERP

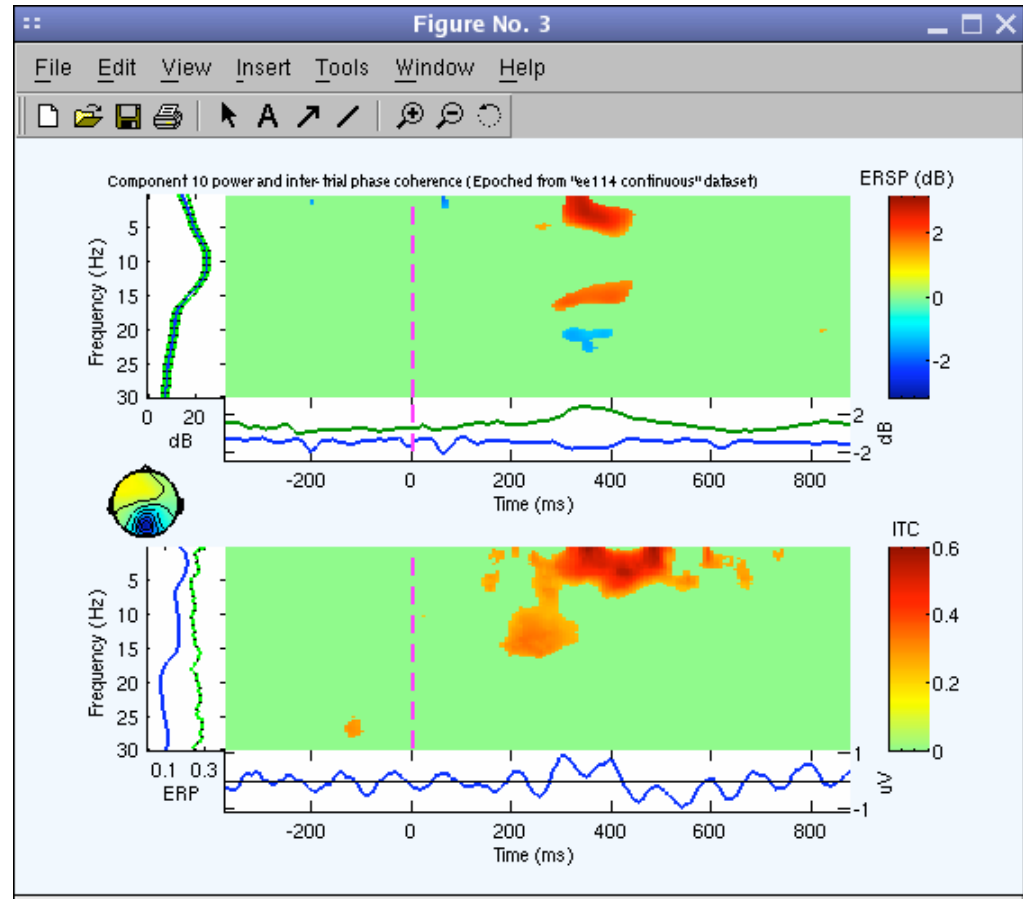
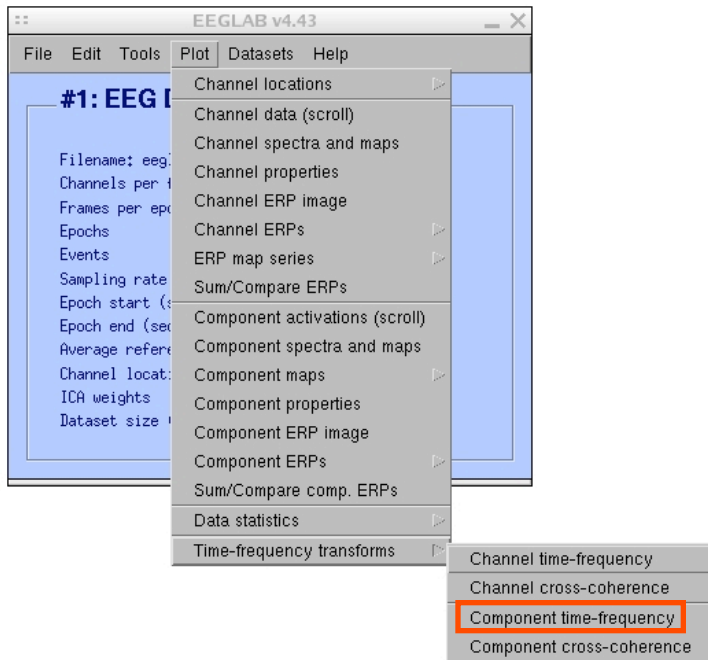
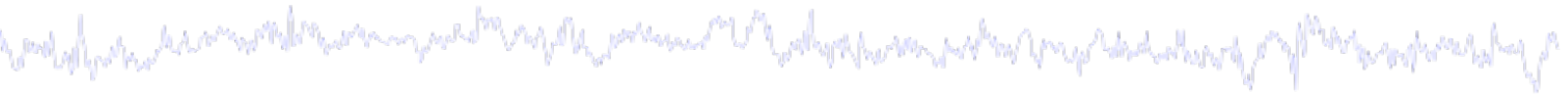
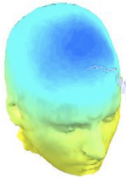




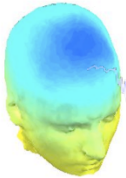
Component contribution to the EEG spectrum



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

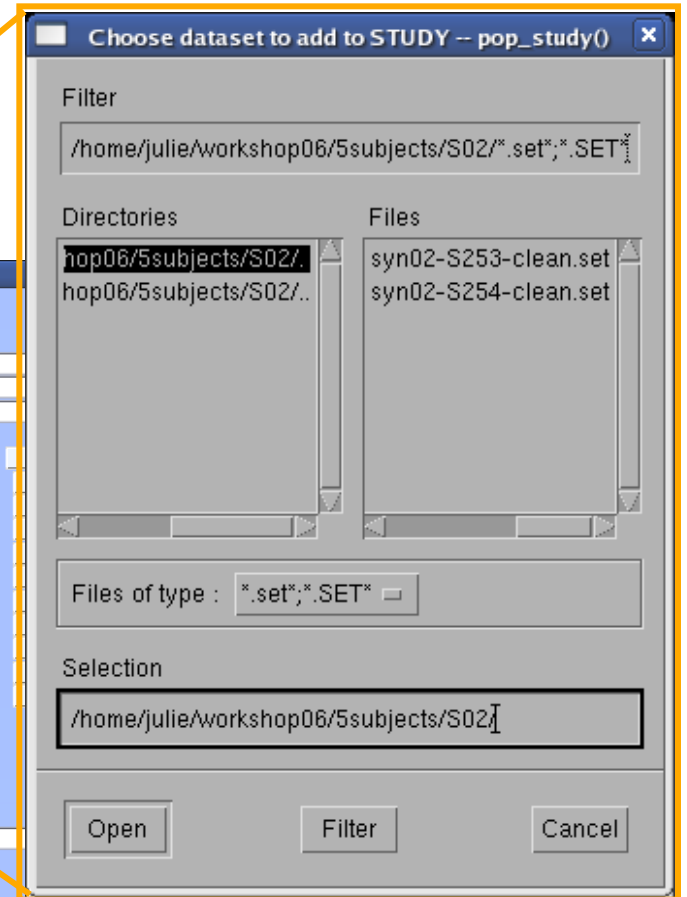
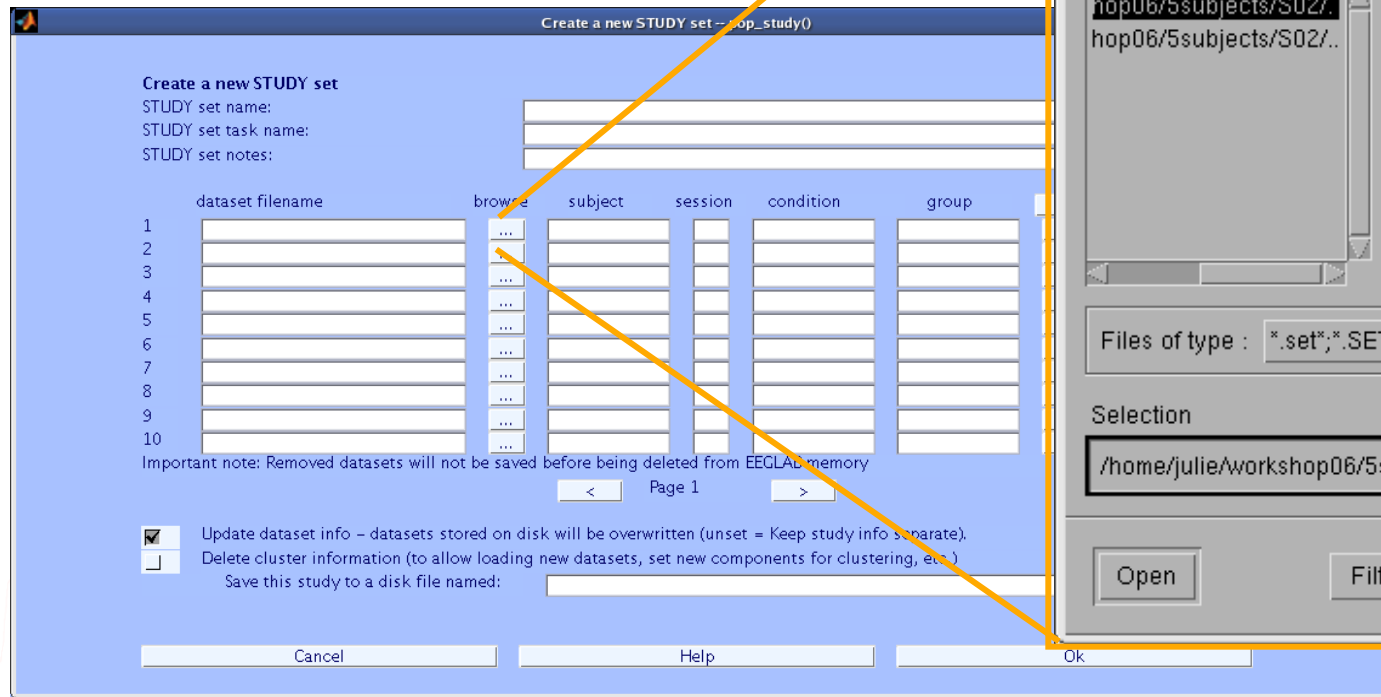
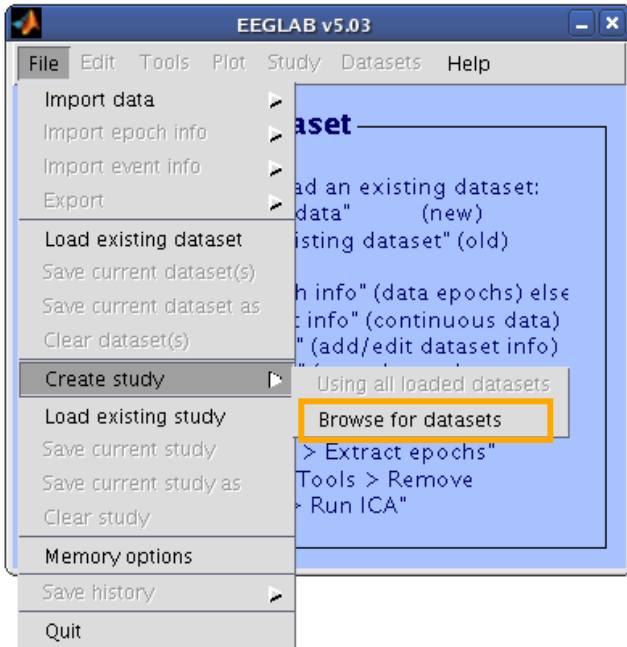
Multi-subjects

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

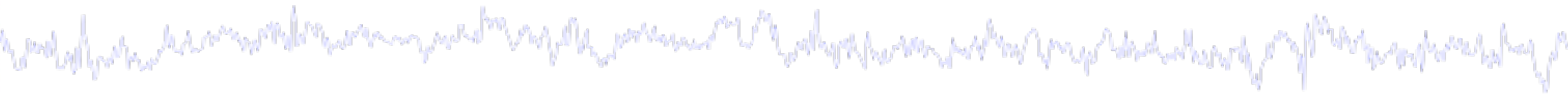
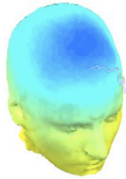


Advanced analysis using scripting and EEGLAB command line functions

1. Build a STUDY



2. Pre-compute measures



Components

EEGLAB v6.0b

File Edit Tools Plot **Study** Datasets Help

STUDY set: Attention

- Edit study info
- Precompute channel measures
- Plot channel measures
- Precompute component measures**
- Build preclustering array
- Cluster components
- Edit/plot clusters

Study filename:
Study task name:
Nb of subjects:
Nb of conditions:
Nb of sessions:
Nb of groups:
Epoch consistency: yes
Channels per frame: 31
Channel locations: yes
Clusters: 1
Status: Ready to precluster
Total size (Mb): 30.4

Select and compute component measures for later clustering -- pop_precomp()

Pre-compute component measures for STUDY 'Attention'

Compute ERP/spectrum/ERSP for all components (set) or only those selected by RV (unset)

List of measures to precompute

- ERPs
- Power spectrum Parameters: [] Test
- ERSPs } Time/freq. parameters: 'cycles', [3 0.5], 'padratio', 1 Test
- ITCs
- Scalp maps

Recompute even if present on disk

Cancel Help Ok

Channels

EEGLAB v5.03

File Edit Tools Plot **Study** Datasets Help

STUDY set: S...

- Edit study info
- Precompute channel measures**
- Plot channel measures
- Build preclustering array
- Cluster components
- Edit/plot clusters

Study filename:
Study task name:
Number of subjects:
Number of conditions:
Number of sessions: 1
Number of groups: 1
Epoch consistency: yes
Channels per frame: 61
Channel locations: yes
Clusters: 1
Status: Ready to precluster
Total size (Mb): 28

Select and compute component measures for later clustering -- pop_precomp()

Pre-compute channel measures for STUDY "

Channel list (default:all) [] ...

Interpolate missing channels (datasets will be modified on disk)

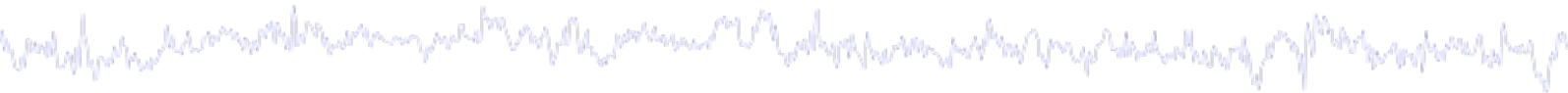
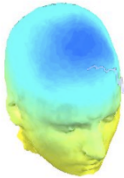
List of measures to precompute

- ERPs
- Power spectrum Parameters: [] Test
- ERSPs } Time/freq. parameters: 'cycles', [3 0.5], 'padratio', 4 Test
- ITCs

Recompute even if present on disk

Cancel Help Ok

3. Cluster components



EEGLAB v6.0b

File Edit Tools Plot **Study** Datasets Help

STUDY set: At

Study filename:
Study task name
Nb of subjects
Nb of conditions
Nb of sessions
Nb of groups
Epoch consistency: yes
Channels per frame: 31
Channel locations: yes
Clusters: 1
Status: Pre-clustered
Total size (Mb): 32.4

- Edit study info
- Precompute channel measures
- Plot channel measures
- Precompute component measures
- Build preclustering array**
- Cluster components
- Edit/plot clusters

Select and compute component measures for later clustering -- pop_preclust()

Build pre-clustering matrix for STUDY 'Attention'
Select the cluster to refine during sub-clustering (any existing sub-hierarchy will be overwritten)

ParentCluster 1 (181 ICs)

(note: only measures that have been precomputed may be used)

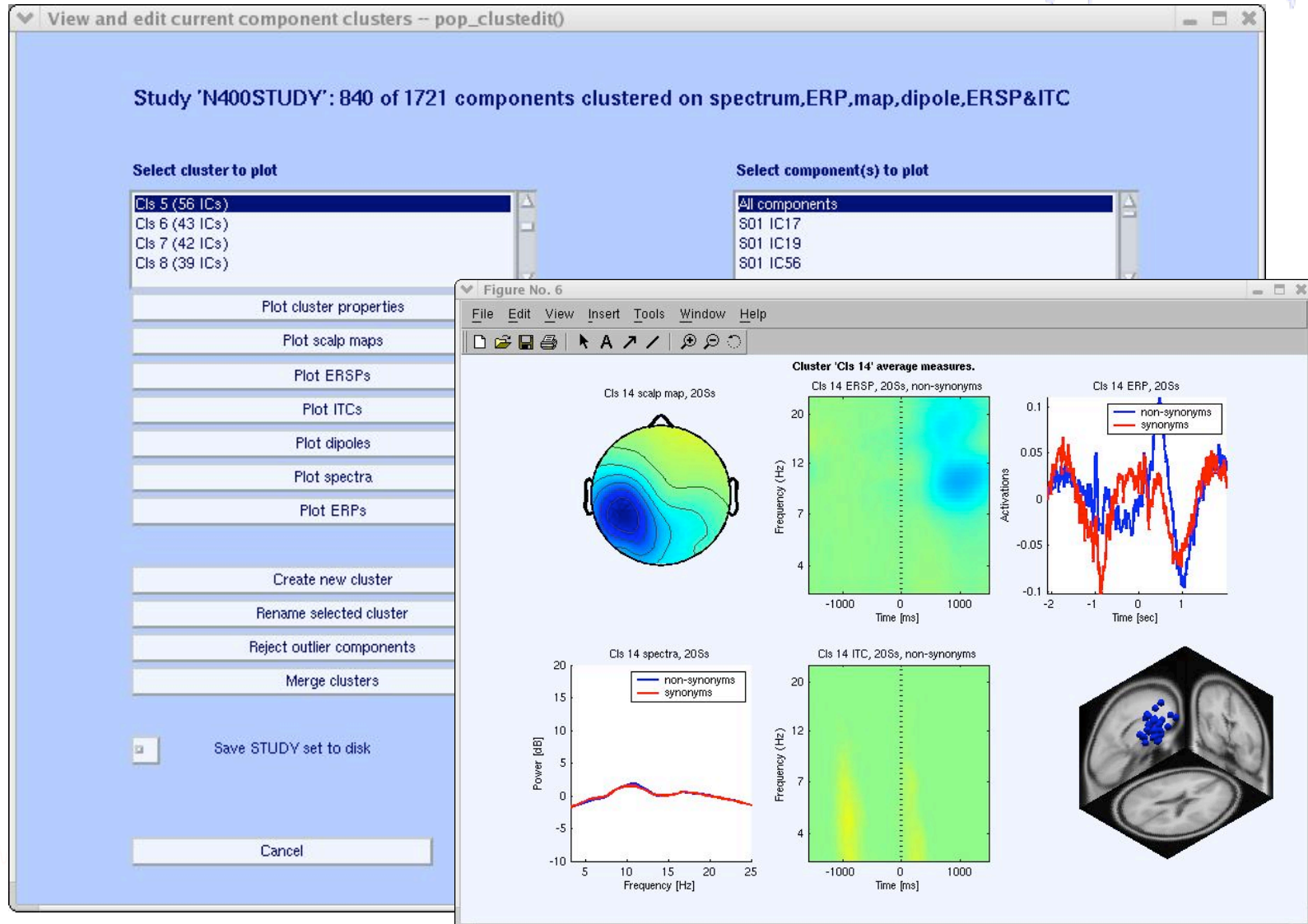
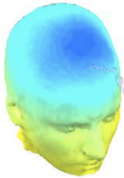
Load	Dims.	Norm.	Rel. Wt.	
<input checked="" type="checkbox"/> spectra	10	<input checked="" type="checkbox"/>	1	Freq. range [Hz] 3 25
<input checked="" type="checkbox"/> ERPs	10	<input checked="" type="checkbox"/>	1	Time range [ms] 0 600
<input checked="" type="checkbox"/> dipoles	3	<input checked="" type="checkbox"/>	10	
<input type="checkbox"/> scalp maps	10	<input checked="" type="checkbox"/>	1	Use channel values <input checked="" type="checkbox"/> Absolute values
<input checked="" type="checkbox"/> ERSPs	20	<input checked="" type="checkbox"/>	1	Time range [ms] 0 1500 Freq. range [Hz] 3 45
<input checked="" type="checkbox"/> ITCs	10	<input checked="" type="checkbox"/>	1	Time range [ms] 0 600 Freq. range [Hz] 2 30
<input type="checkbox"/> Final dimensions	10			

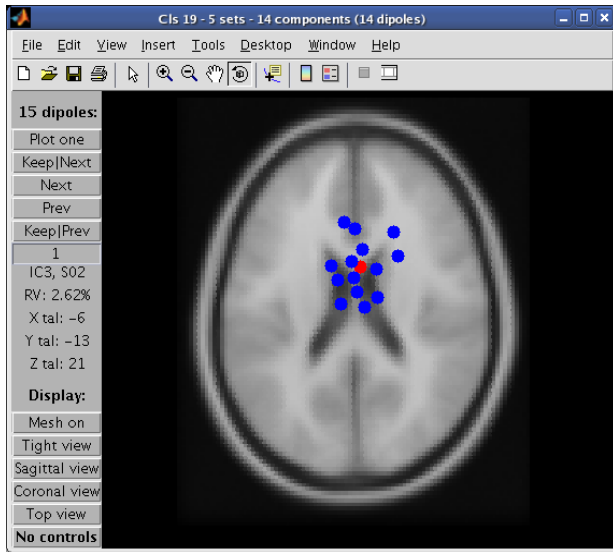
Save STUDY to file /home/julie/WorkshopSD2007/STUDY/attention.study

Cancel Help Ok



4. Analyze clusters





View and edit current

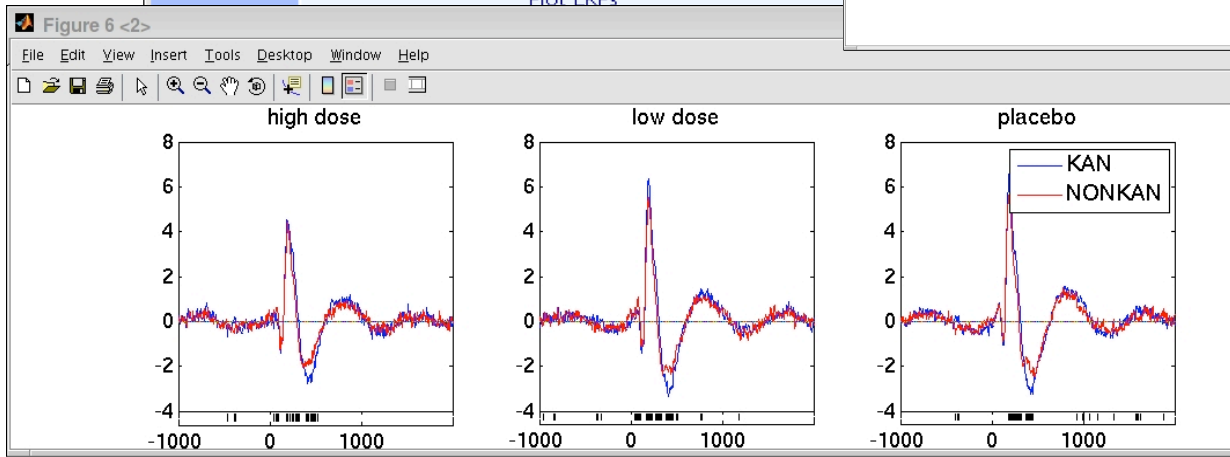
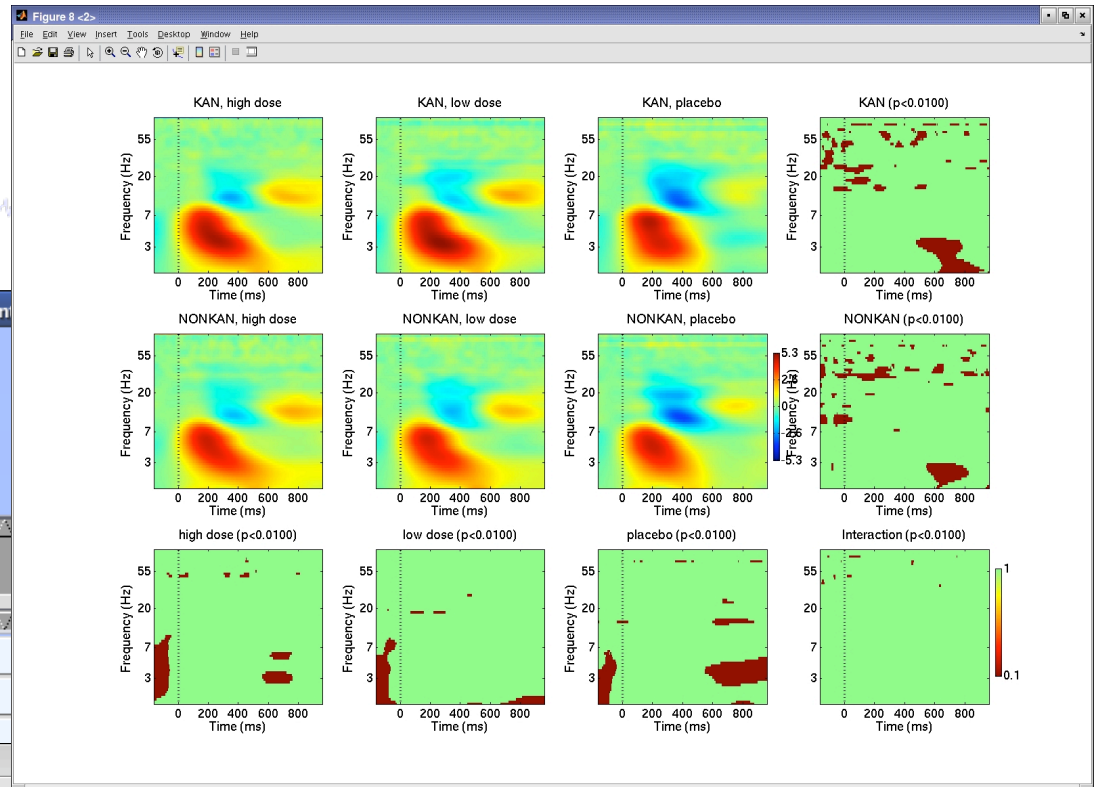
nts clustered

Cls 17 (S02)
 Cls 18 (14 ICs)
 Cls 19 (14 ICs)
 Outliers Cls 17 20 (1 ICs)

Plot scalp maps

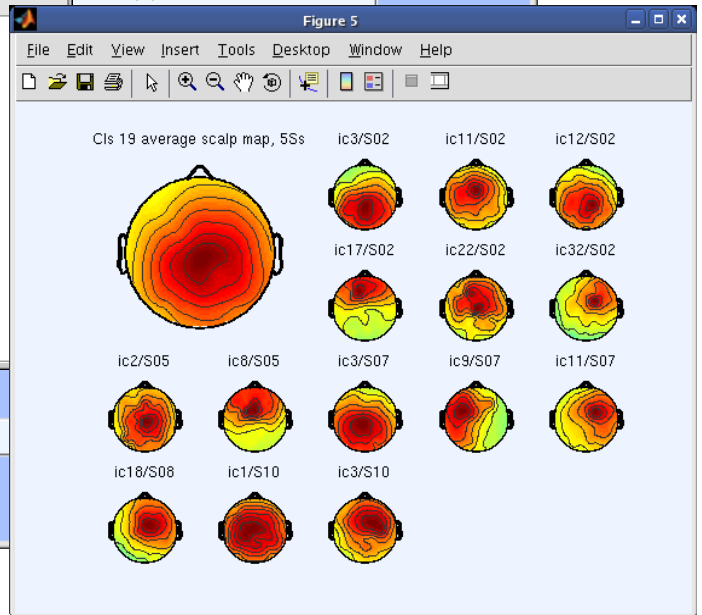
Plot dipoles

Plot FRPs

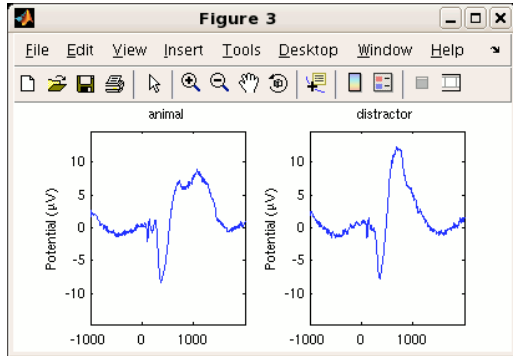
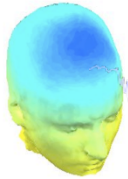


Cancel

Help



Channel plotting



View and edit current channels -- pop_chanplot()

Study "

Select channel to plot

- All FP1
- All FP2
- All F3
- All F4
- All C3
- All C4
- All P2

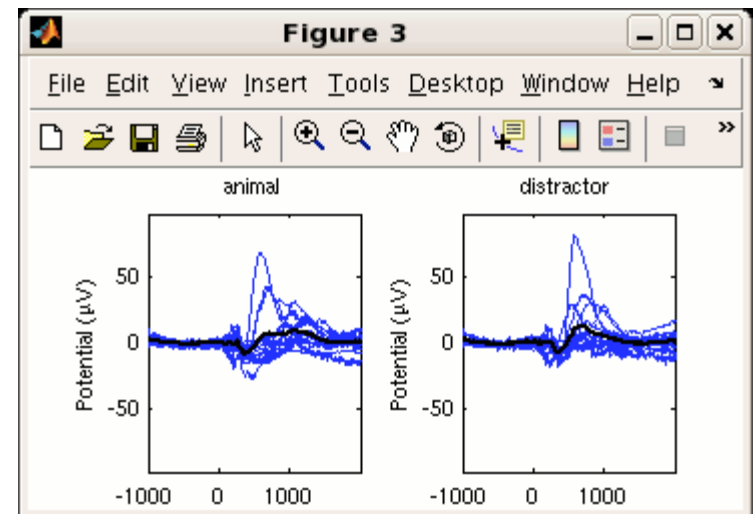
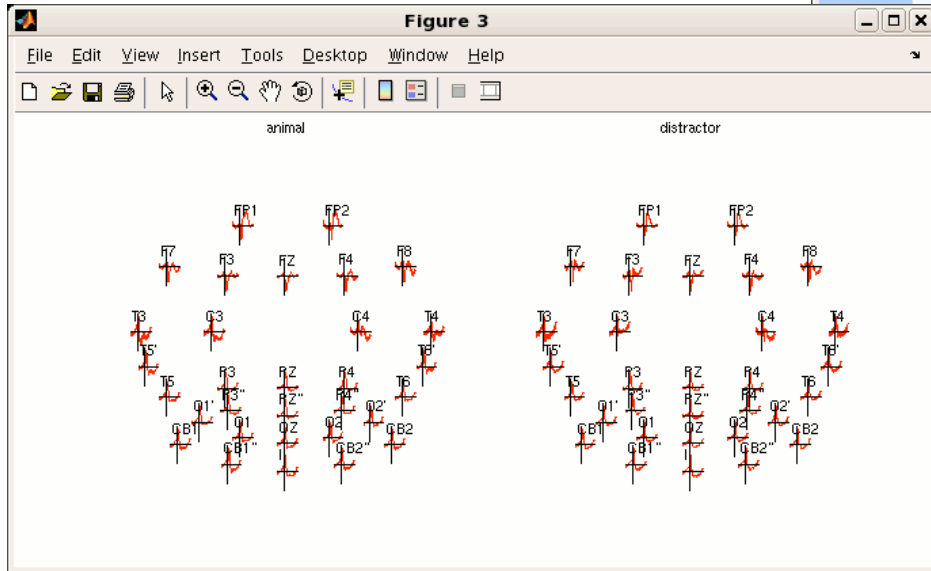
Create channel group (soon)
Edit channel group (soon)

Select subject(s) to plot

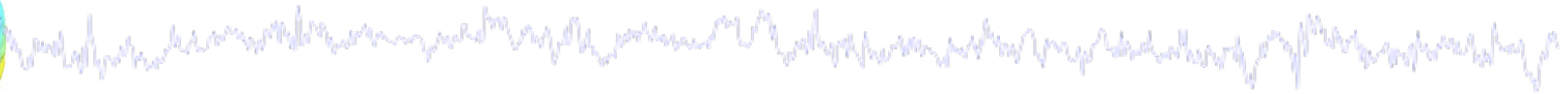
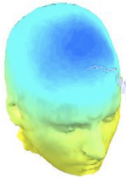
- All subjects
- cba FP1
- clm FP1
- ega FP1
- fsa FP1
- gro FP1
- hsh FP1

Delete channel group (soon)

Save STUDY set to disk



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

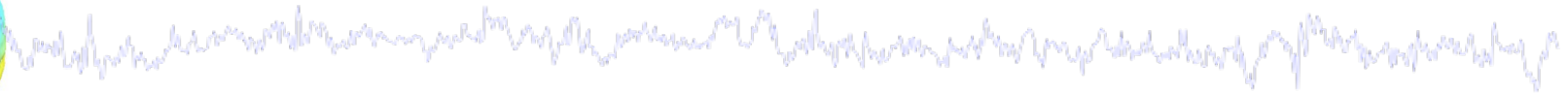
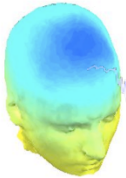
Multi-subjects

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



Advanced analysis using scripting and EEGLAB command line functions

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 'studysset' structure
 - .cluster - component clustering substructure



EEG structure

EEG =

```
setname:'Epoched from "ee114 continuous"  
filename:'ee114squareepochs.set'  
filepath:'/home/arno/ee114/'  
pnts:384  
nbchan:32  
trials:80  
srate:128  
xmin :-1  
xmax:1.9922  
data:[32x384x80 double]  
icawinv:[32x32 double]  
icasphere:[32x32 double]  
icaweights:[32x32 double]  
icaact:[32x384x80 double]  
event:[1x157 struct]  
epoch:[1x80 struct]  
chanlocs:[1x32 struct]  
comments:[8x150 char]  
averef:'no'  
rt:[]  
eventdescription:{1x5 cell}  
epochdescription:{}  
specdata:[]  
specicaact:[]  
reject:[1x1 struct]  
stats:[1x1 struct]  
splinefile:[]  
ref:'common'  
history:[7x138 char]  
urevent:[1x154 struct]  
times:[1x384 double]
```

Number of data points
per trial

Number of channels

Number of trials

Sampling rate

Time limits

Data

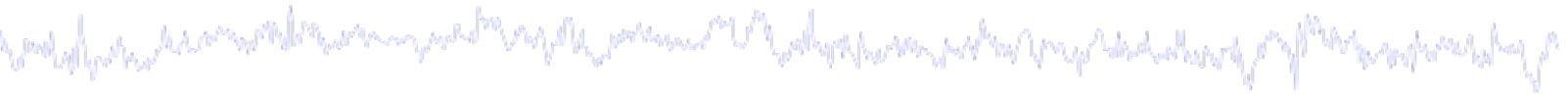
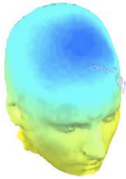
ICA scalp maps

ICA activity

Epoch/event
information

Channel location

3 levels of functions



Administrative functions: handle EEG and ALLEEG structures

`eeglab()`, `eeg_checkset()`, `pop_delset()`, ...

Pop functions: interactive functions using EEG structure

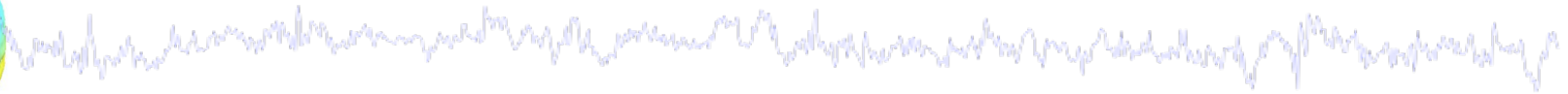
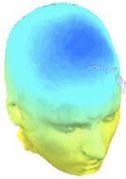
`pop_erpimage()`, `pop_topoplot()`, `pop_envtopo()`, ...

Signal processing functions: perform signal processing

`erpimage()`, `topoplot()`, `envtopo()`, ...



Command line tools

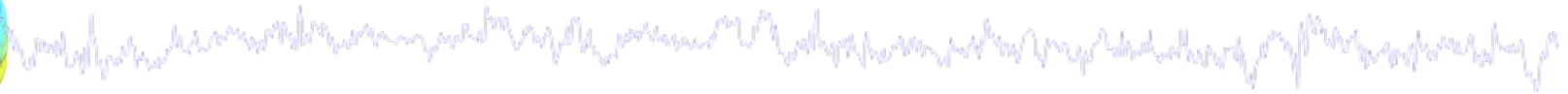
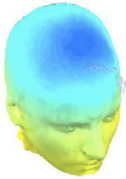


(Menus write both dataset and global history)

- 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

