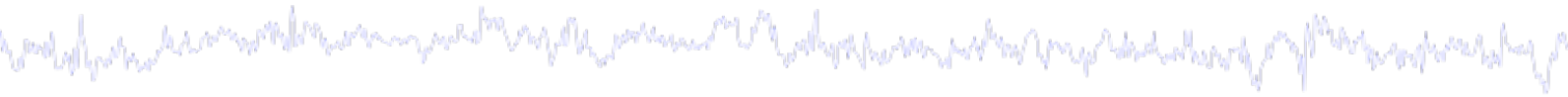
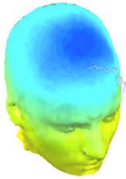
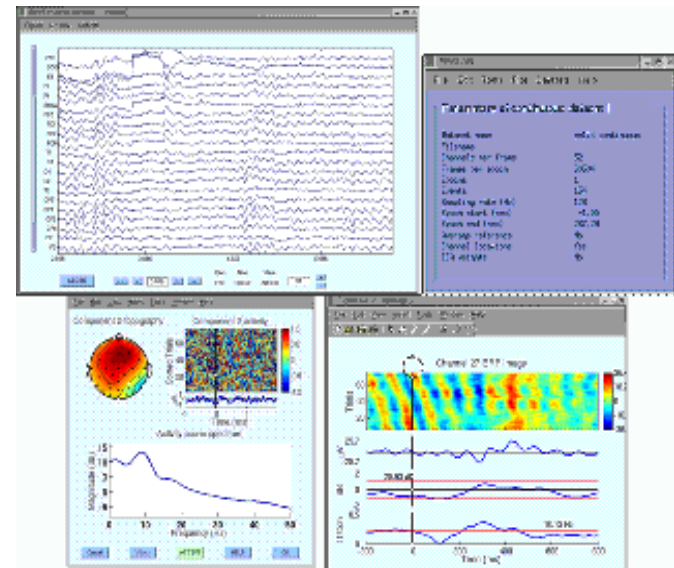


# EEGLAB overview



- Collection of over 300 functions (70000 lines of code)
- About 70 000 download over the past 8 years
- About 3500 users on the discussion list and 6500 on the diffusion list
- NIH funding since 2003

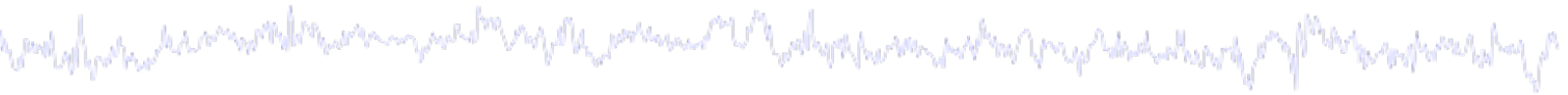
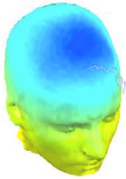


<http://sccn.ucsd.edu/eeglab>

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

[http://sccn.ucsd.edu/wiki/Tenth\\_EEGLAB\\_Workshop](http://sccn.ucsd.edu/wiki/Tenth_EEGLAB_Workshop)

# Pros/Cons of Matlab based open source



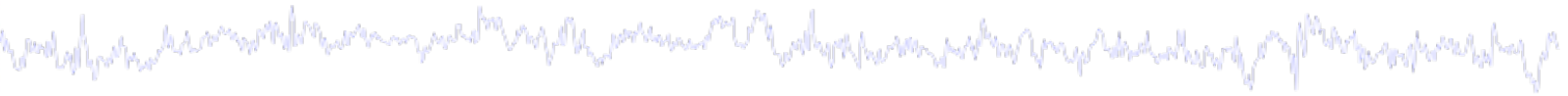
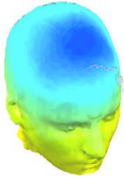
- Pros

- 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 for which you have to pay
- Large memory requirements
- Matlab bugs, possible version differences, cross-platform compatibility problems

# 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

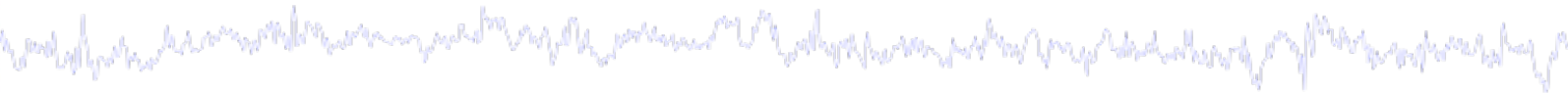
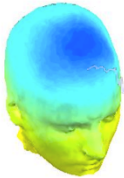
## Multi-subjects

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



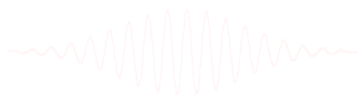
**Advanced analysis using scripting and EEGLAB command line functions**

# The EEGLAB Matlab software

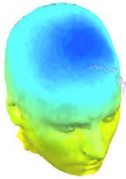


The screenshot displays the EEGLAB Matlab software interface. On the left is a terminal window titled "EEGLAB Shell - Konsole" with a menu bar "Session Edit View Bookmarks Settings Help". The terminal shows the command `matlab -nodesktop` being executed, resulting in the MATLAB startup screen for version 6.5.0.180913a, released on Jun 18 2002. The terminal then shows the command `>> eeglab` being entered. On the right is a help window titled "EEGLAB" with a menu bar "File Edit Tools Plot Datasets Help". The help window displays the text "No current dataset" followed by a list of actions:

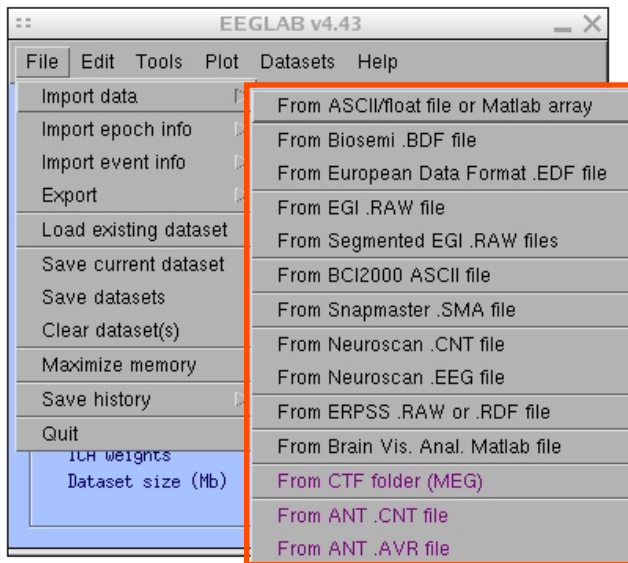
- Create a new or load an existing dataset:
  - Use `"/File/Import data"` (new)
  - Or `"/File/Load existing dataset"` (old)
- If new,
  - `"/File/Import epoch info"` (data epochs), else
  - `"/File/Import event info"` (continuous data)
  - `"/Edit/Dataset info"` (add/edit dataset info)
  - `"/File/Save 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"`



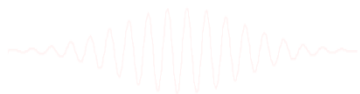
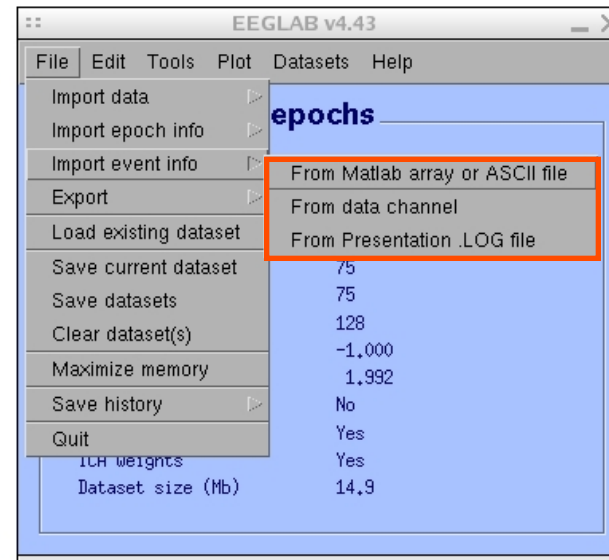
# 1. Importing data



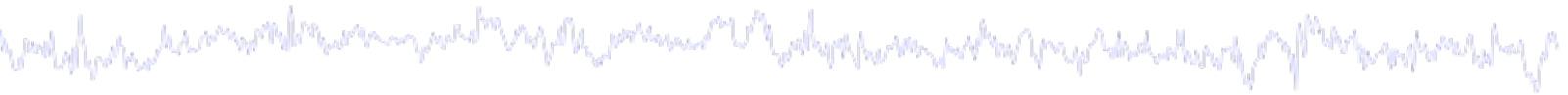
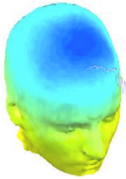
## Import/load data



## Import events



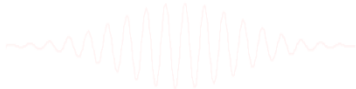
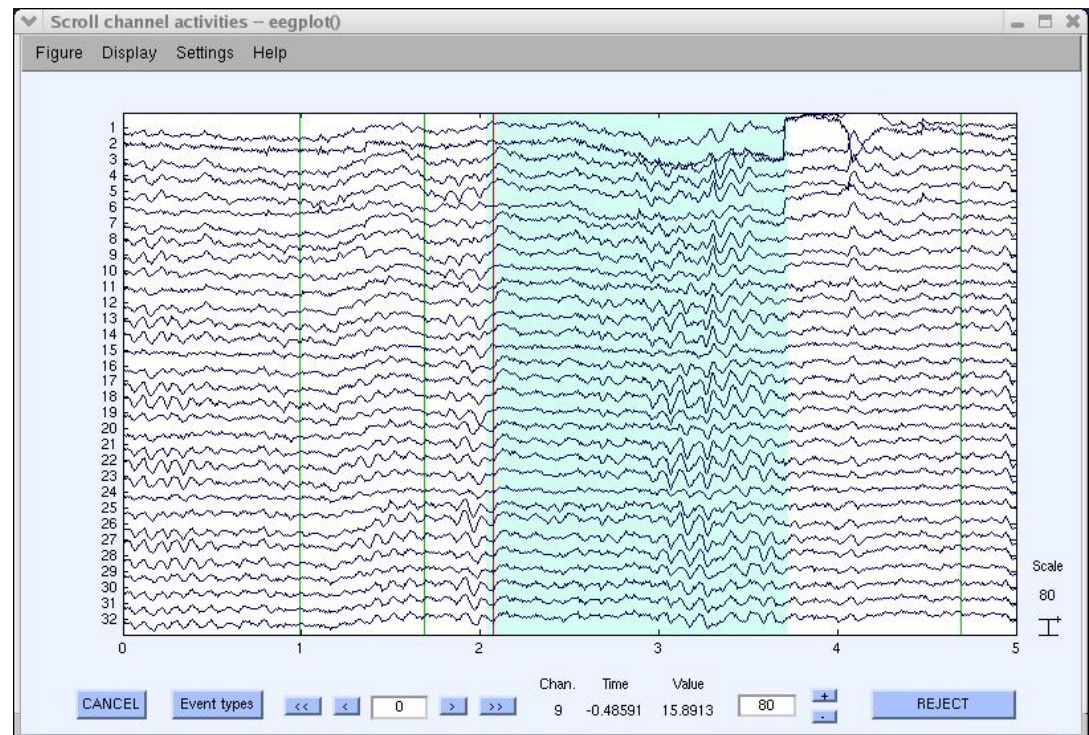
# 1. Importing data



## Data info

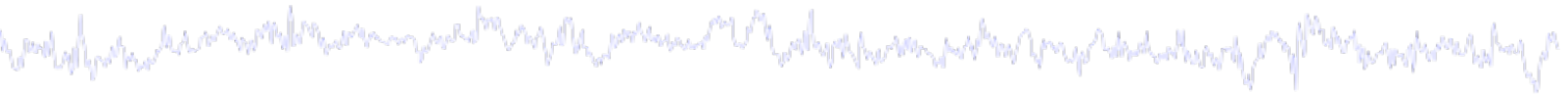
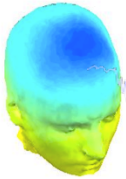


## Scrolling data

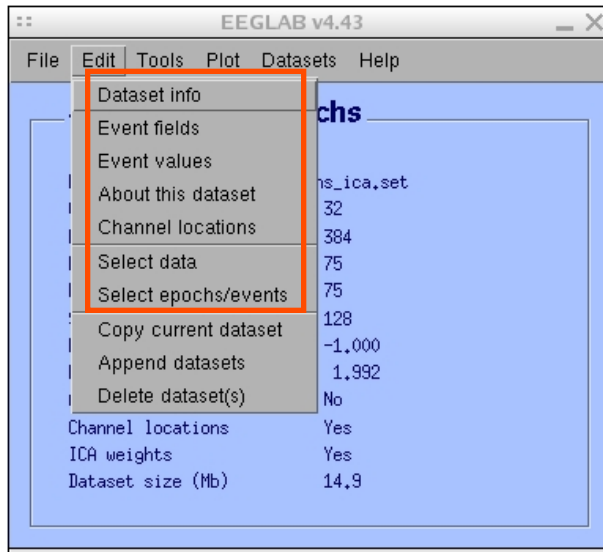




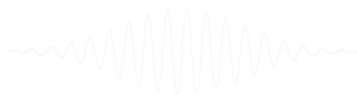
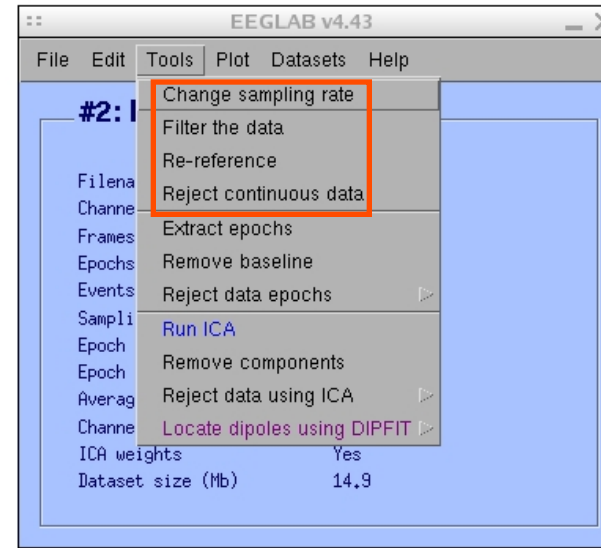
## 2. Edit, Re-reference, Resample, High pass filter data



### Edit/select data

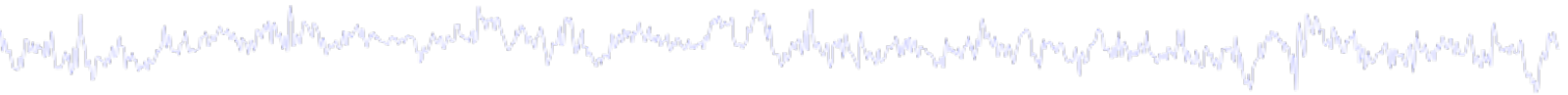
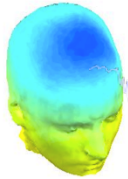


### Preprocessing data

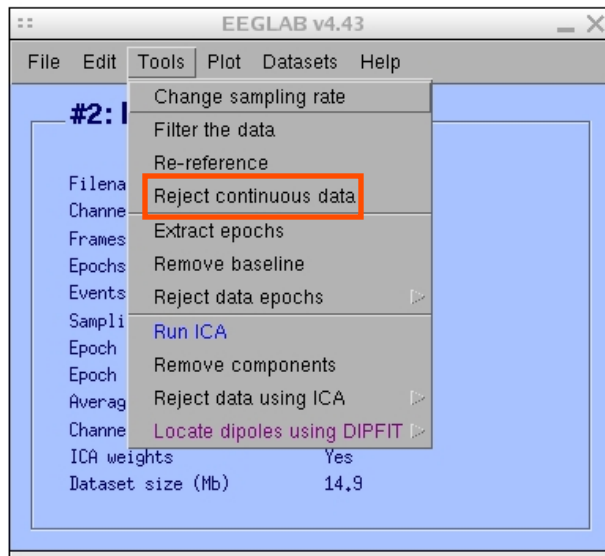




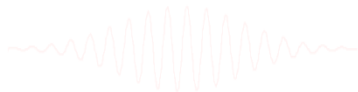
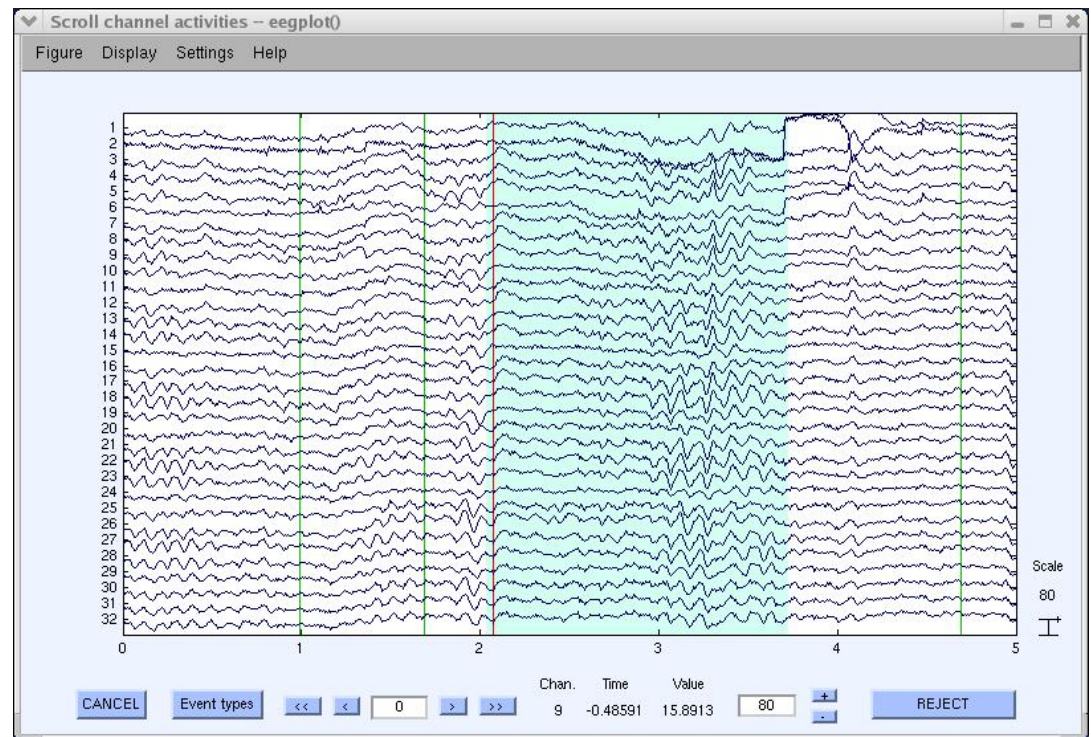
# 3. Reject artifacts in continuous data by visual inspection



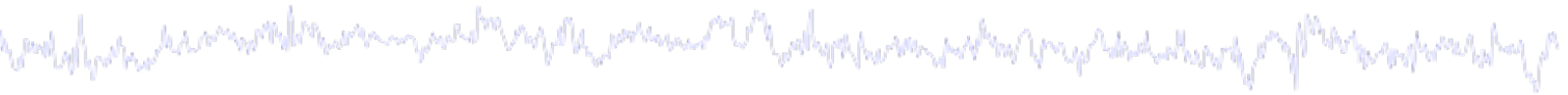
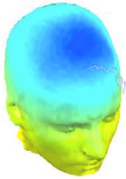
## Data info



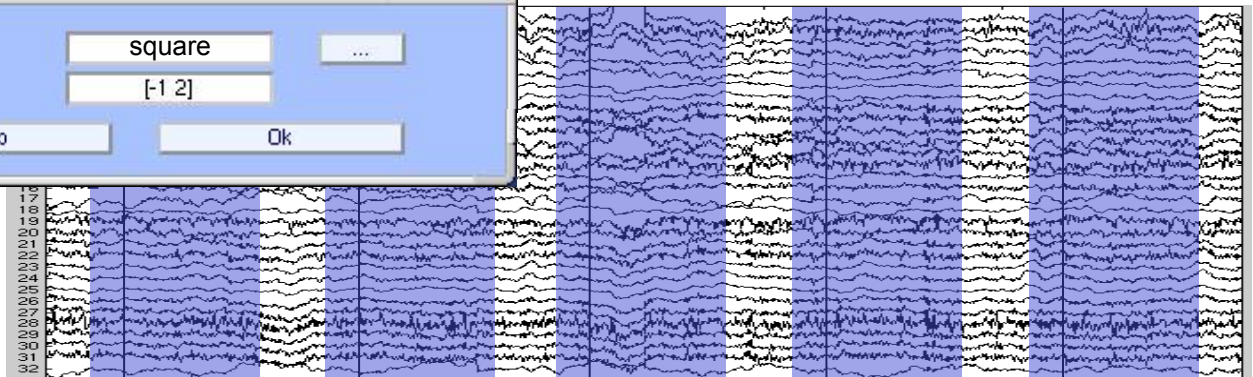
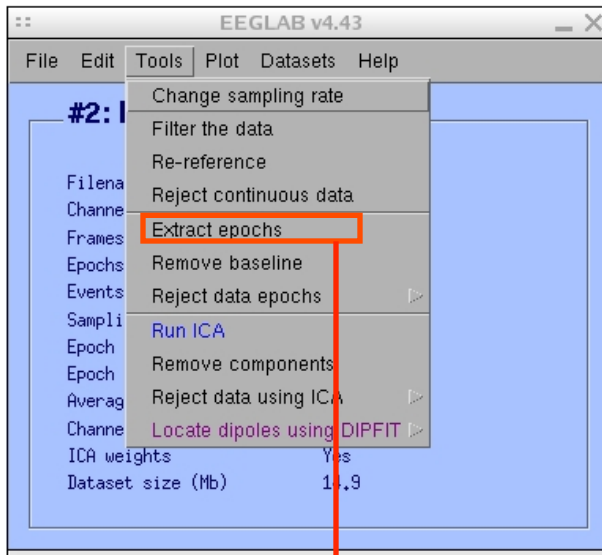
## Reject portions of continuous data



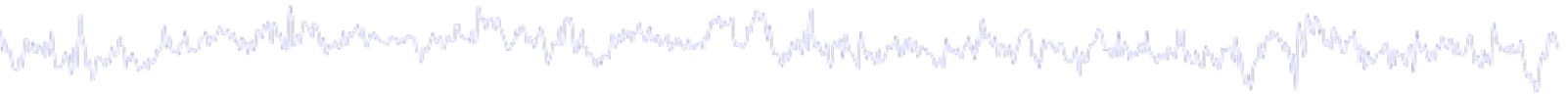
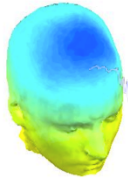
# 4. Extract epochs from data & reject artifactual epochs



## Preprocessing data



# 4. Extract epochs from data & reject artifactual epochs



EEGLAB v4.51

File Edit Tools Plot Datasets Help

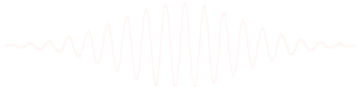
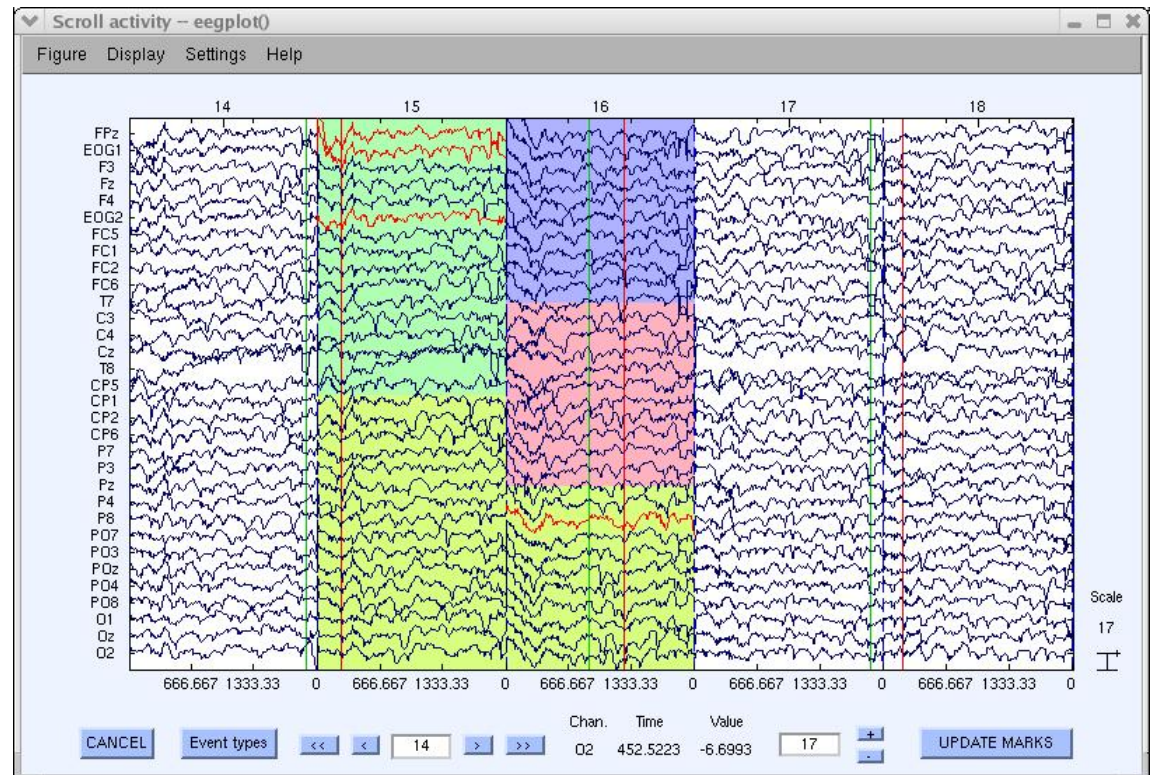
#2: I

Change sampling rate  
Filter the data  
Re-reference  
Reject continuous data  
Extract epochs  
Remove baseline  
Reject data epochs  
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

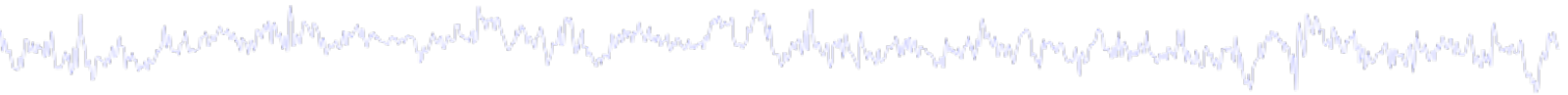
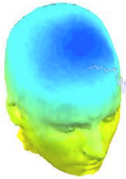
Run ICA  
Remove components  
Reject data using ICA  
Locate dipoles using BESA  
Locate dipoles using DIPFIT  
Laplacian  
Cluster component  
Filter the data (IIR)

File name  
Channel  
Frames  
Epochs  
Events  
Sampling  
Epoch  
Epoch  
Average  
Channel  
ICA weights  
Dataset

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 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

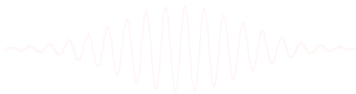
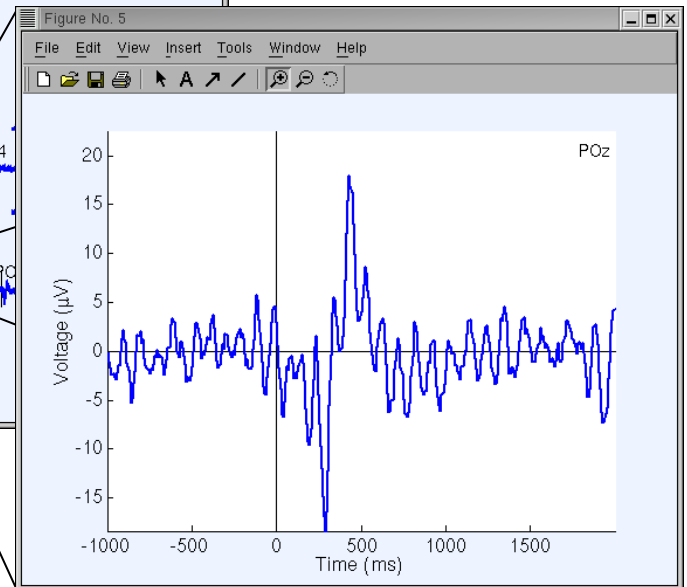
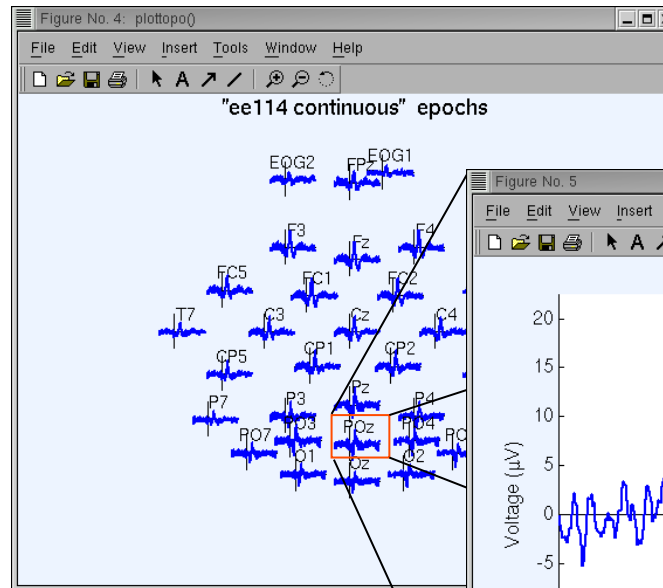
Component ERP image

Component ERPs

Sum/Compare comp. ERPs

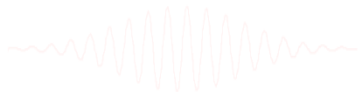
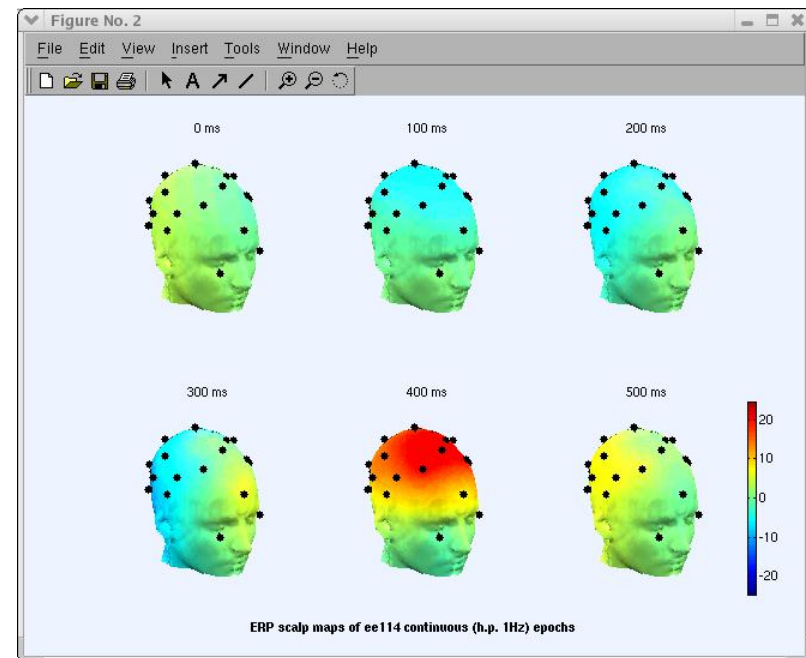
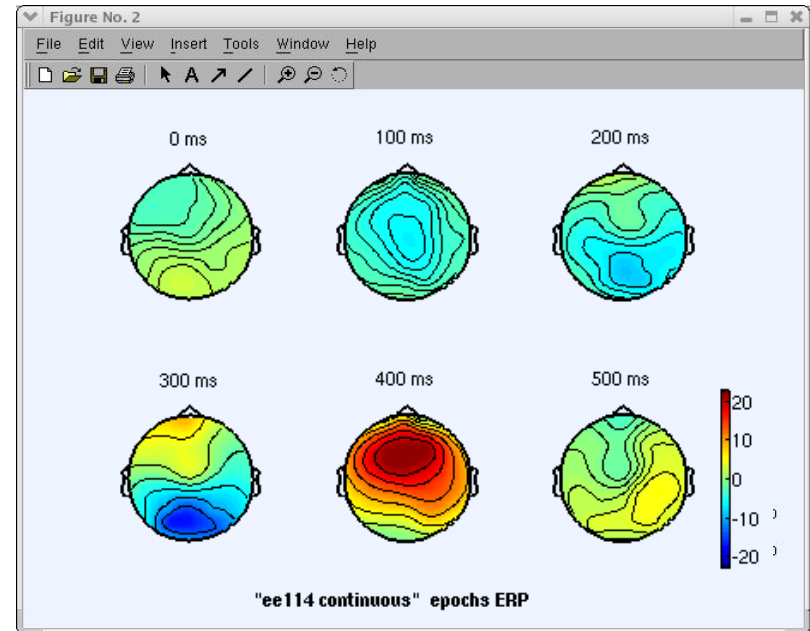
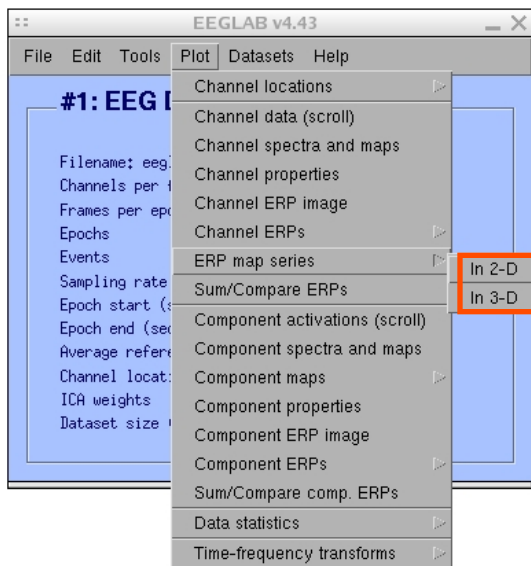
Data statistics

Time-frequency transforms

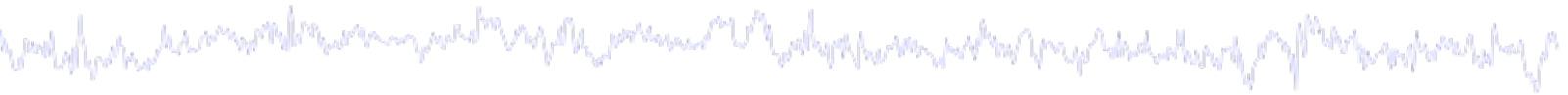
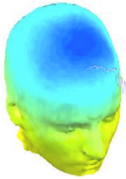


# 5. Visualize data measures

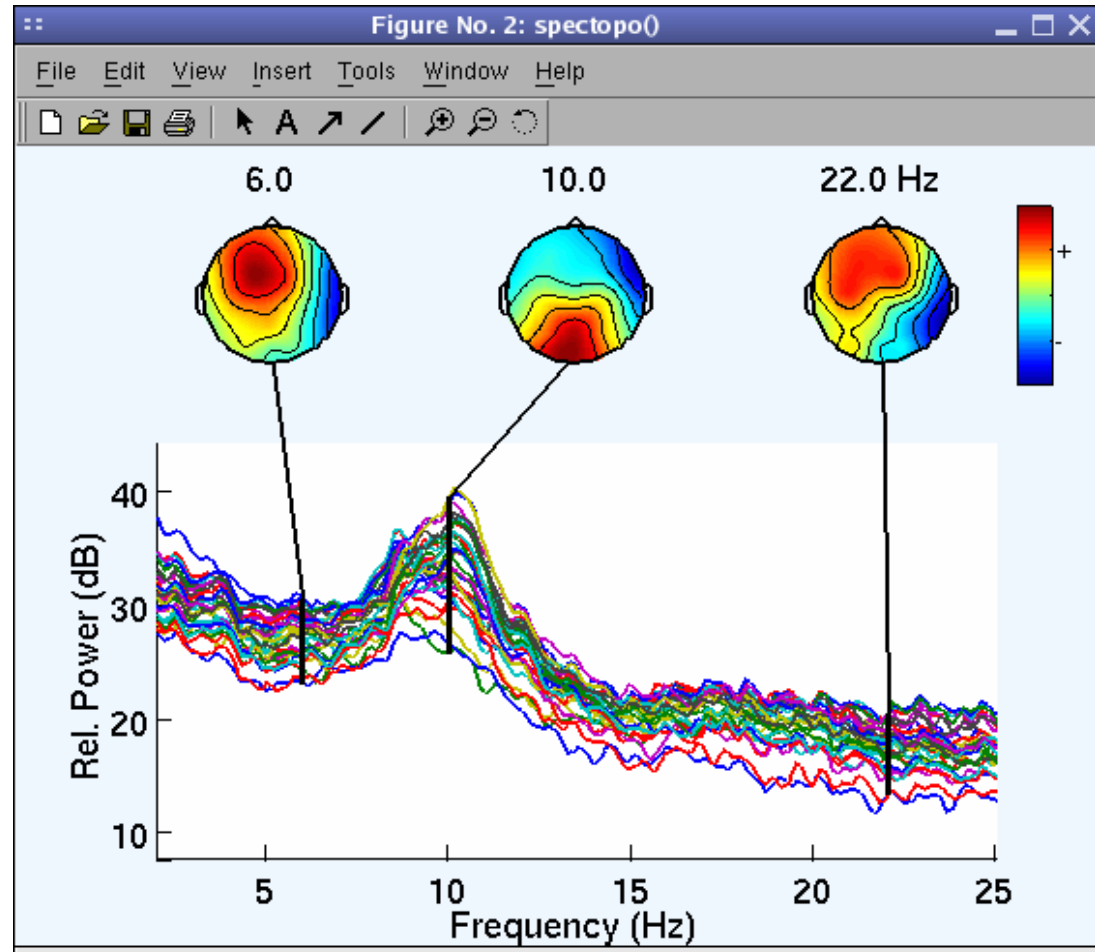
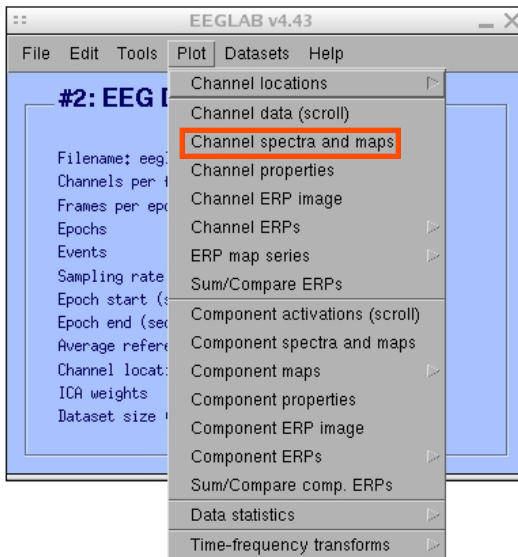
Plot ERP  
map series



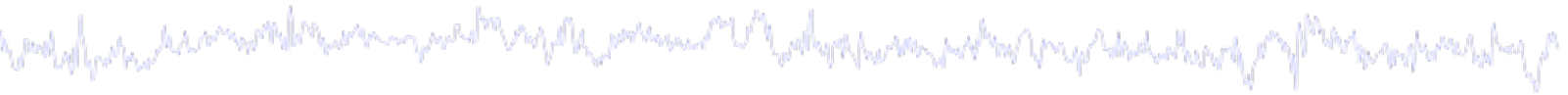
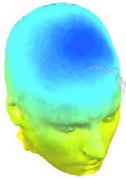
# 5. Visualize data measures



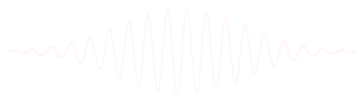
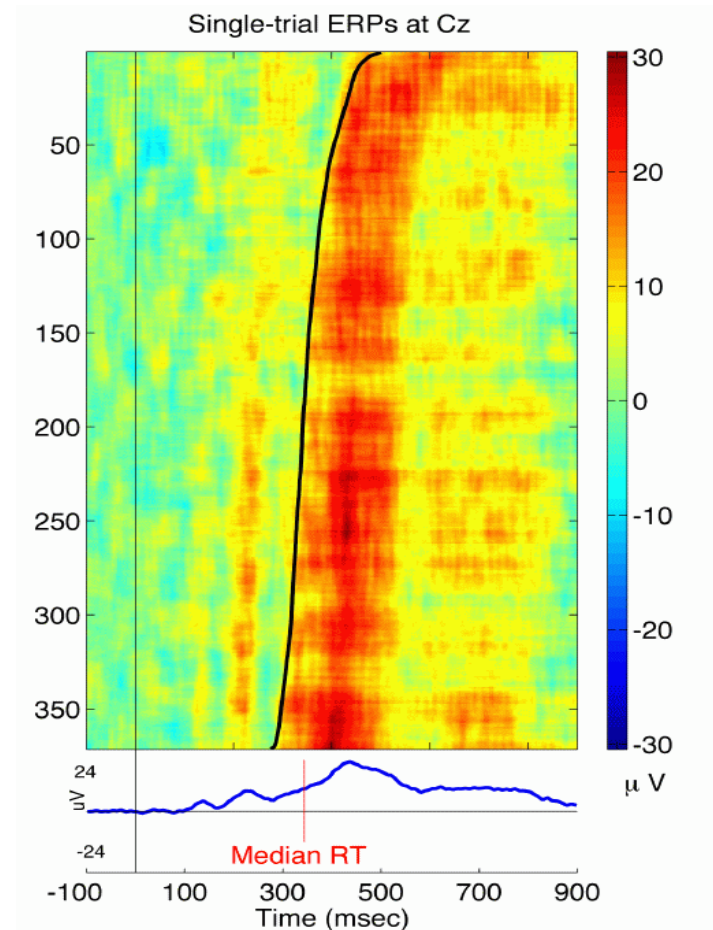
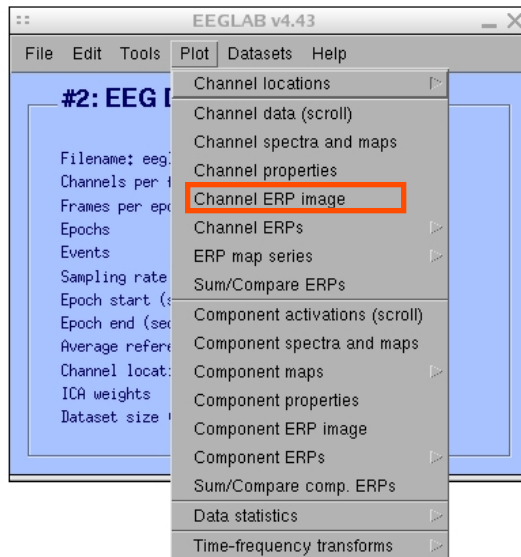
Plot data  
spectrum and  
maps



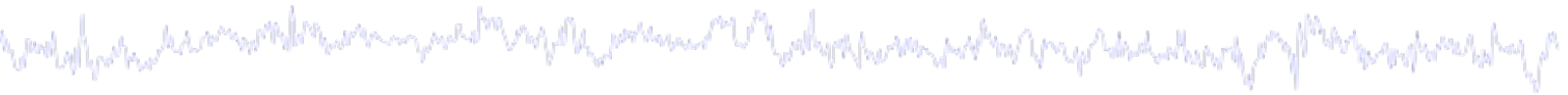
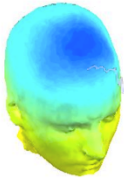
# 5. Visualize data measures



## 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

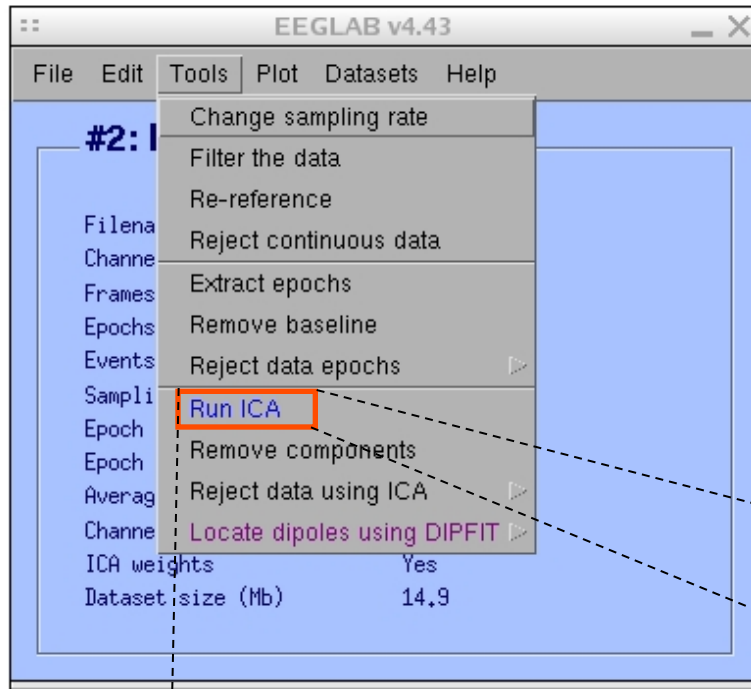
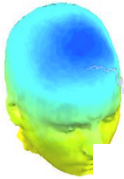
1. Build study
2. Pre-compute measures
3. Cluster components
4. Analyze clusters

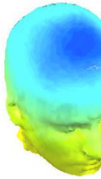


**Advanced analysis using scripting and EEGLAB command line functions**



# 6. Perform ICA decomposition





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 Set threshold

Component 3 properties

File Edit View Insert Tools Window Help

Component 3 map

Component 3 activity (global offset 0.010)

Sorted Trials

Time (ms)

Activity power spectrum

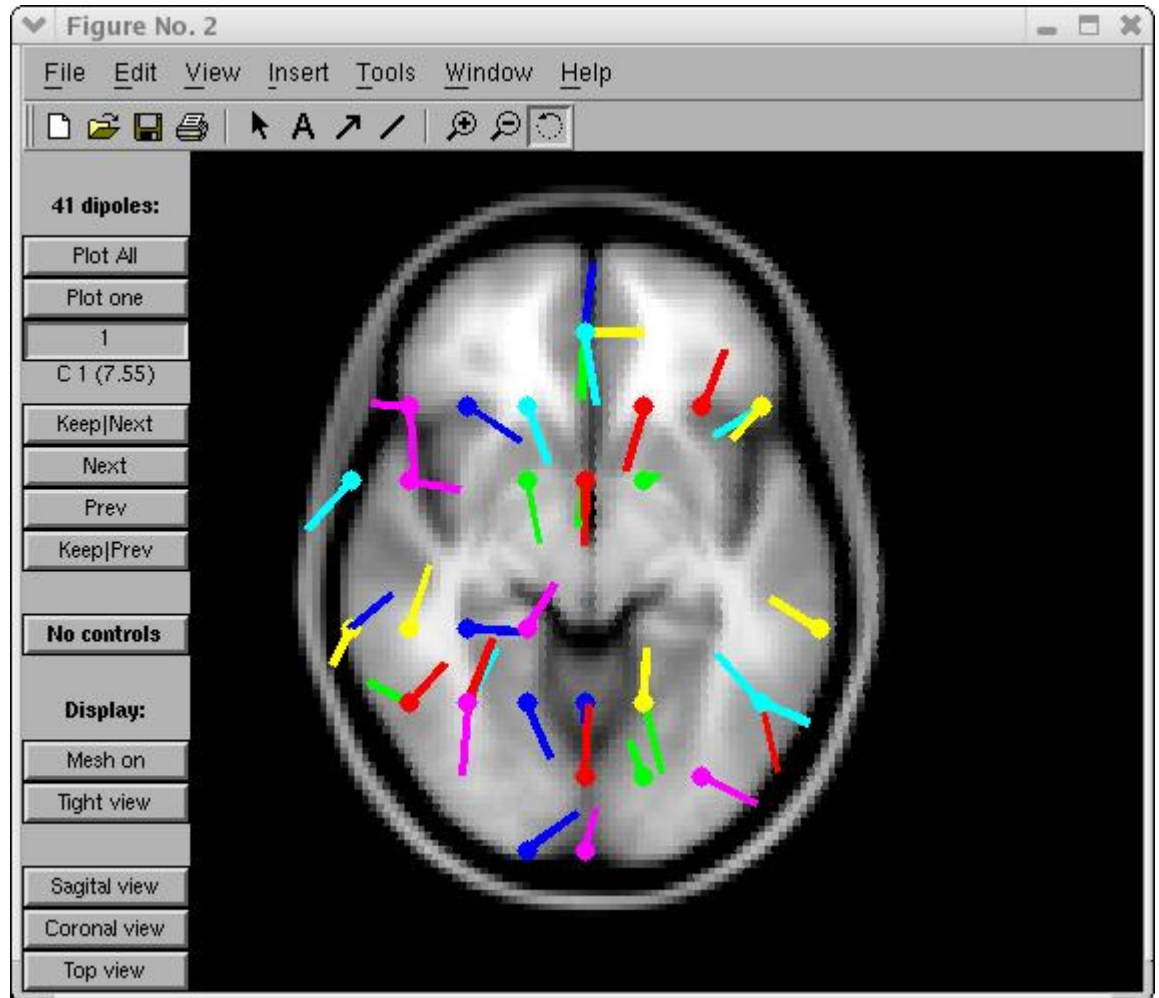
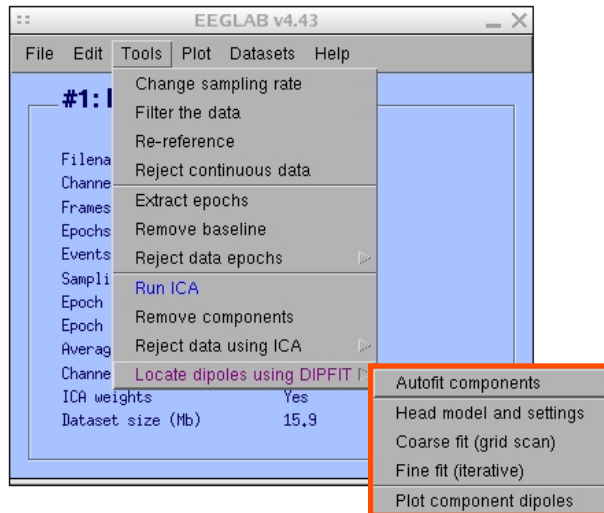
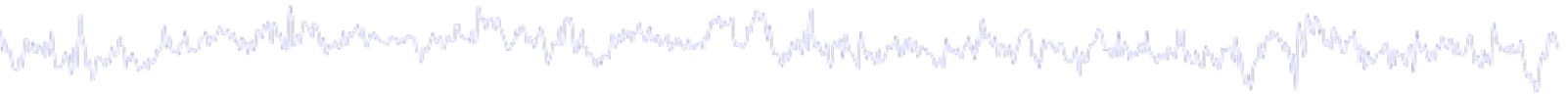
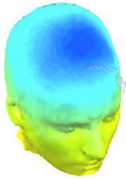
Magnitude (dB)

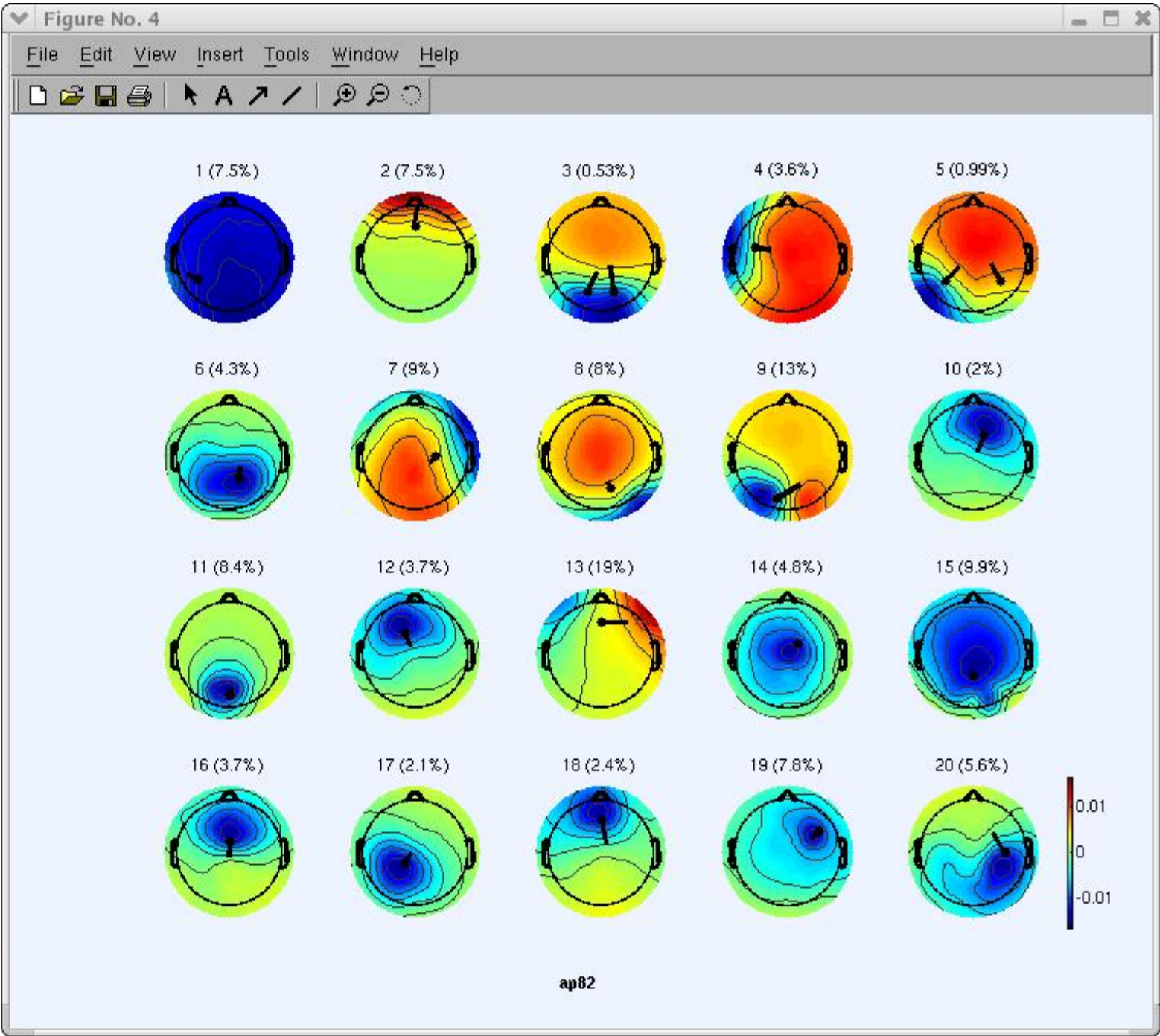
Frequency (Hz)

Cancel Values **ACCEPT** HELP OK

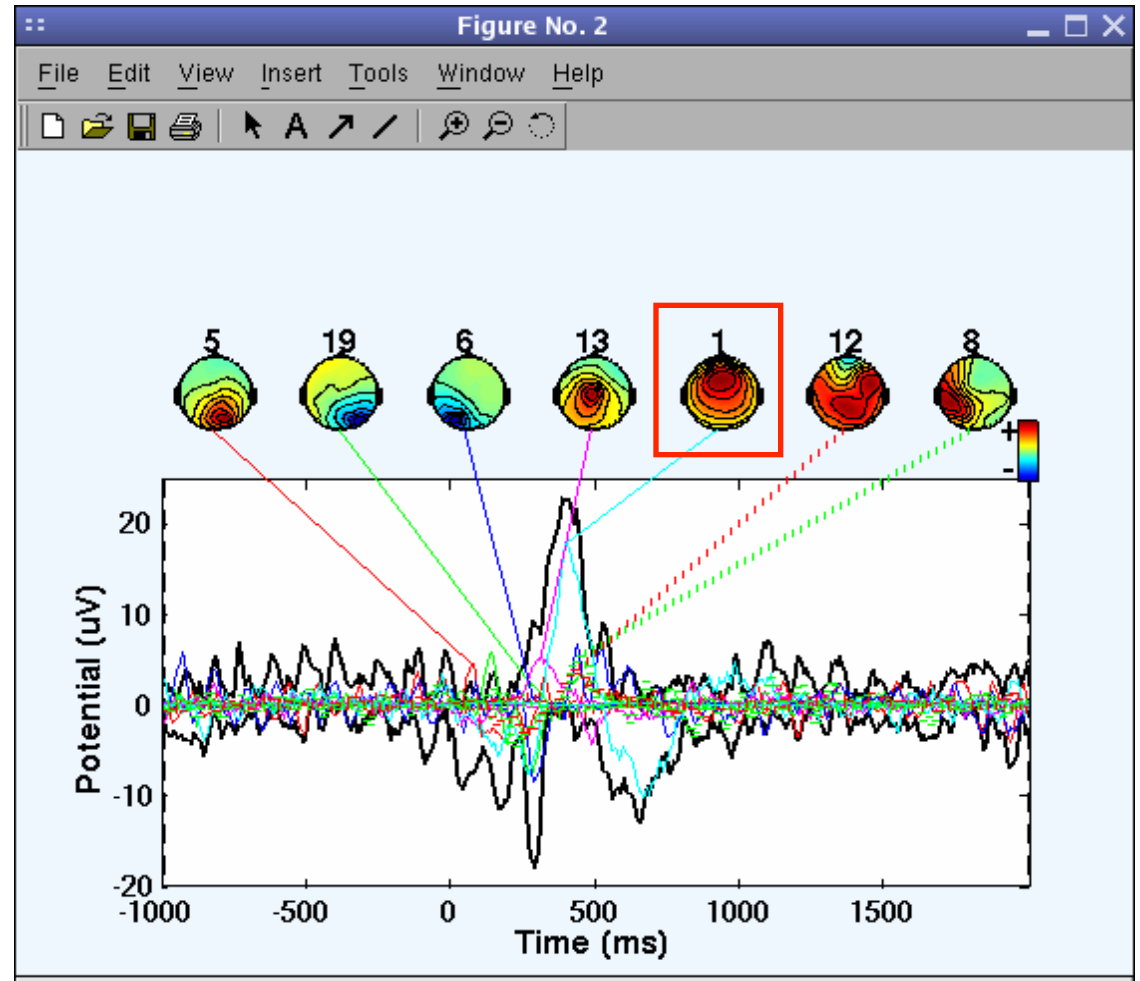
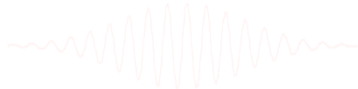
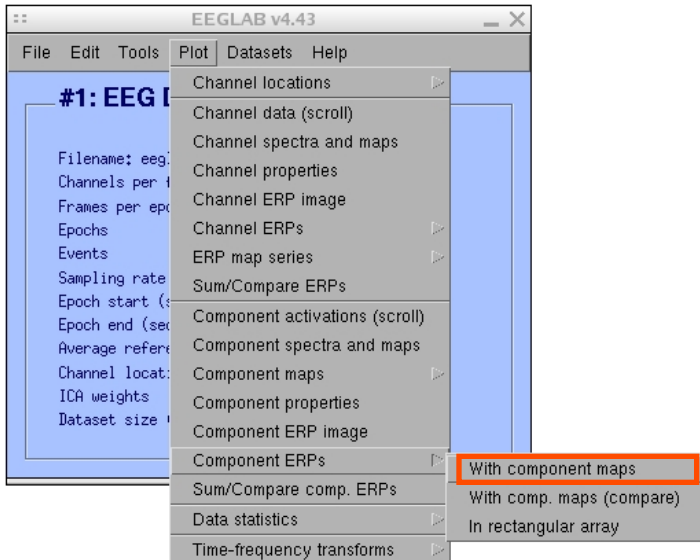
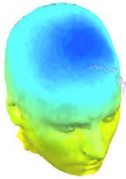
Detailed description: The image shows a software interface for EEG component selection. The main window displays a grid of 30 topographic maps, numbered 1 to 30. Map 3 is highlighted with a green border and a callout box. The callout box, titled 'Component 3 properties', contains three sub-panels: 1) 'Component 3 map' showing a topographic map of the brain with a red-to-yellow activity pattern. 2) 'Component 3 activity (global offset 0.010)' showing a heatmap of activity across sorted trials (0 to 60) over time (-1 to 1 ms), with a color scale from -15.3 to 15.3. 3) 'Activity power spectrum' showing a line graph of magnitude (dB) vs frequency (Hz) from 0 to 50 Hz, with a peak at approximately 5 Hz. At the bottom of the callout box, the 'ACCEPT' button is circled in red.

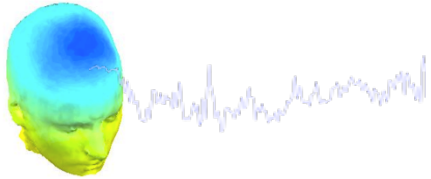
# Localizing components



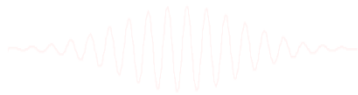
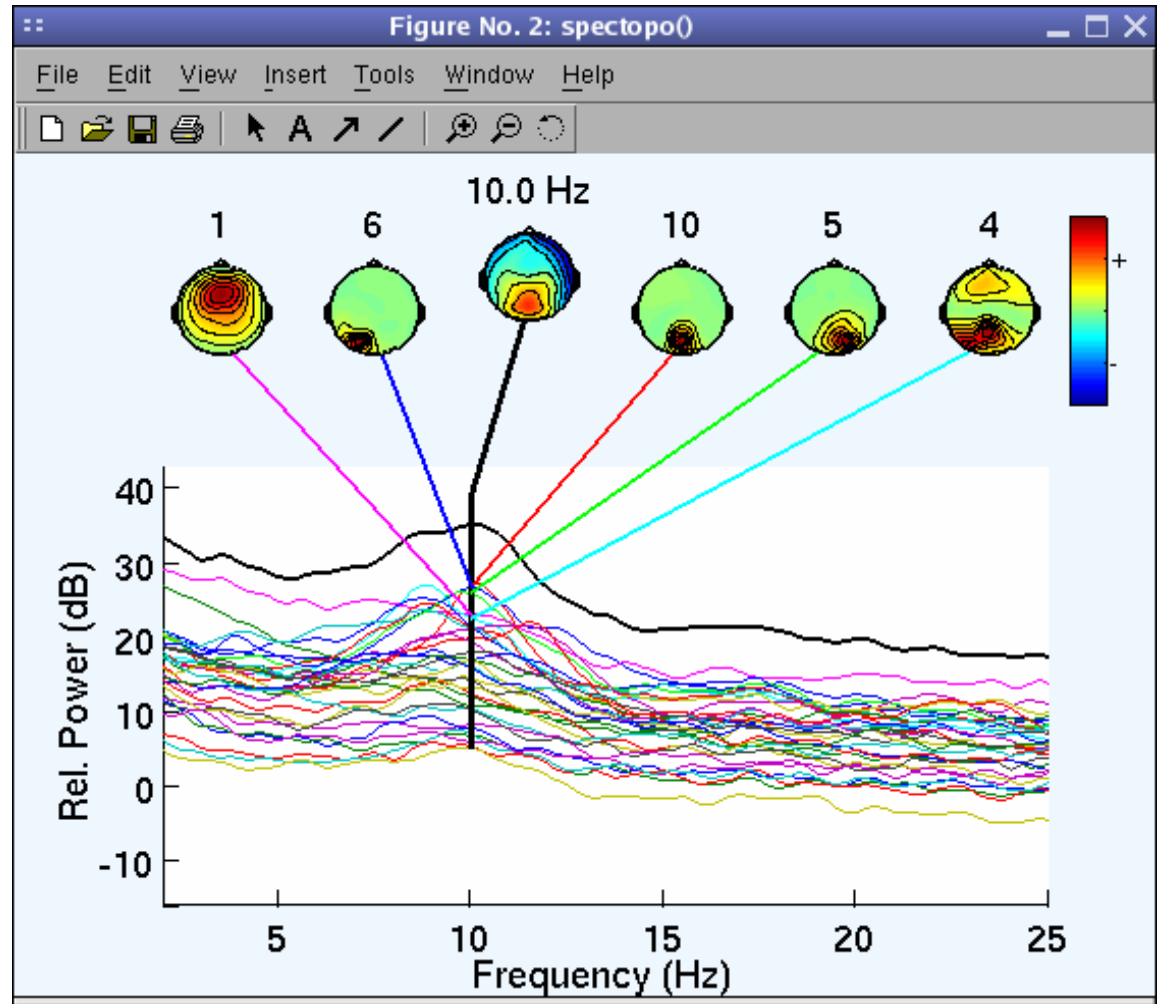
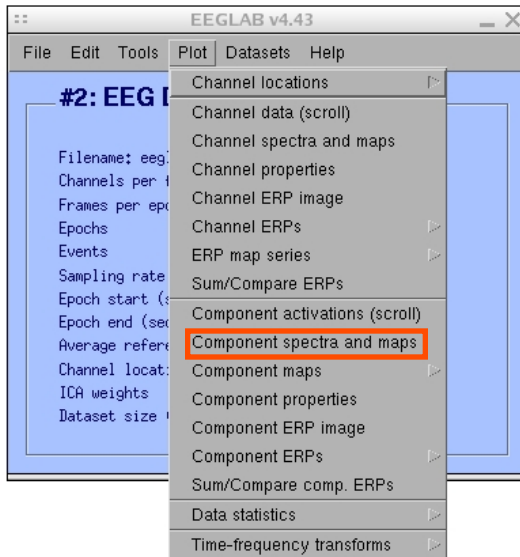


# Component contribution to the ERP

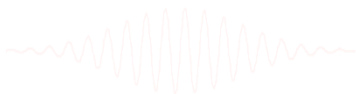
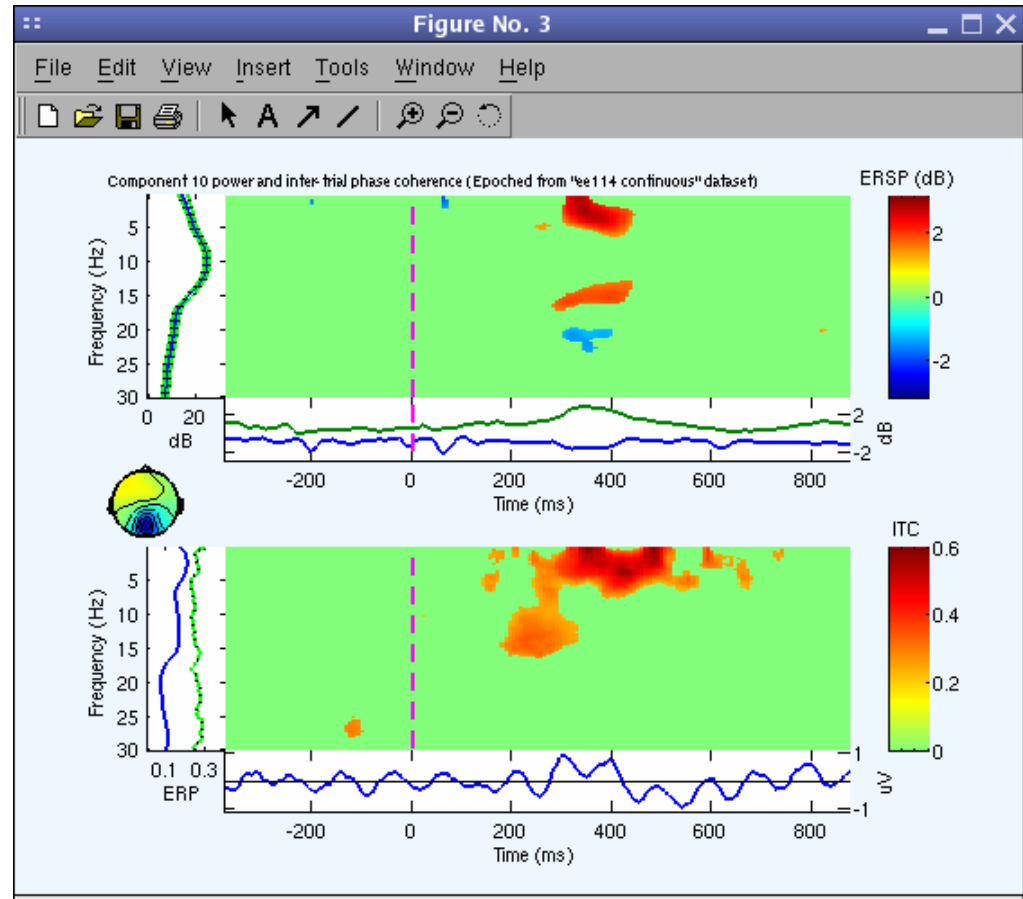
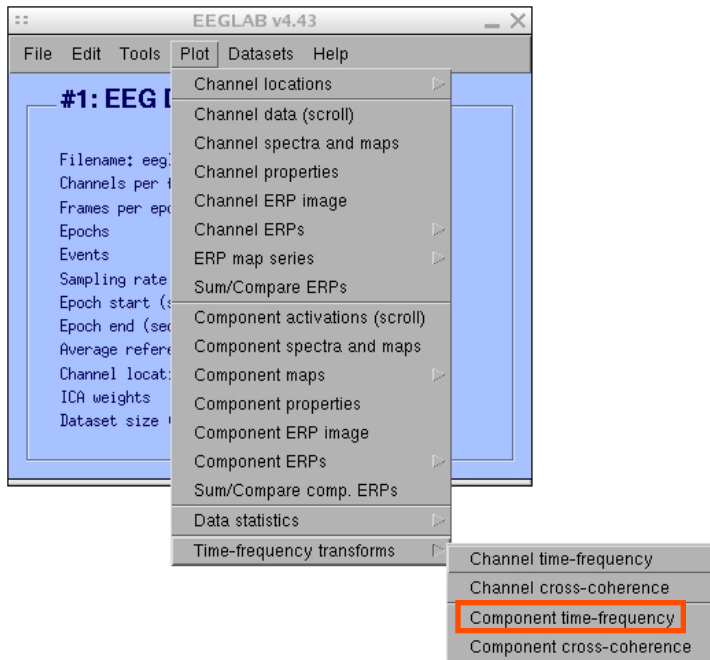
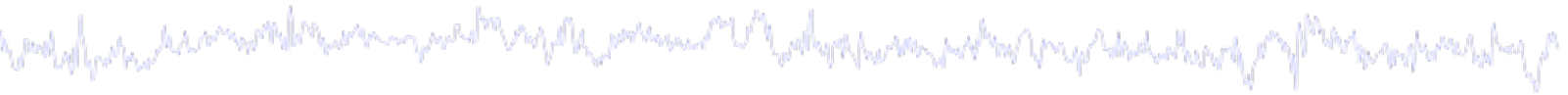
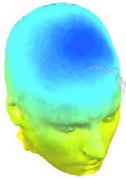




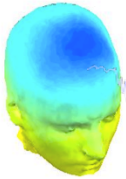
# Component contribution to the EEG spectrum



# 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

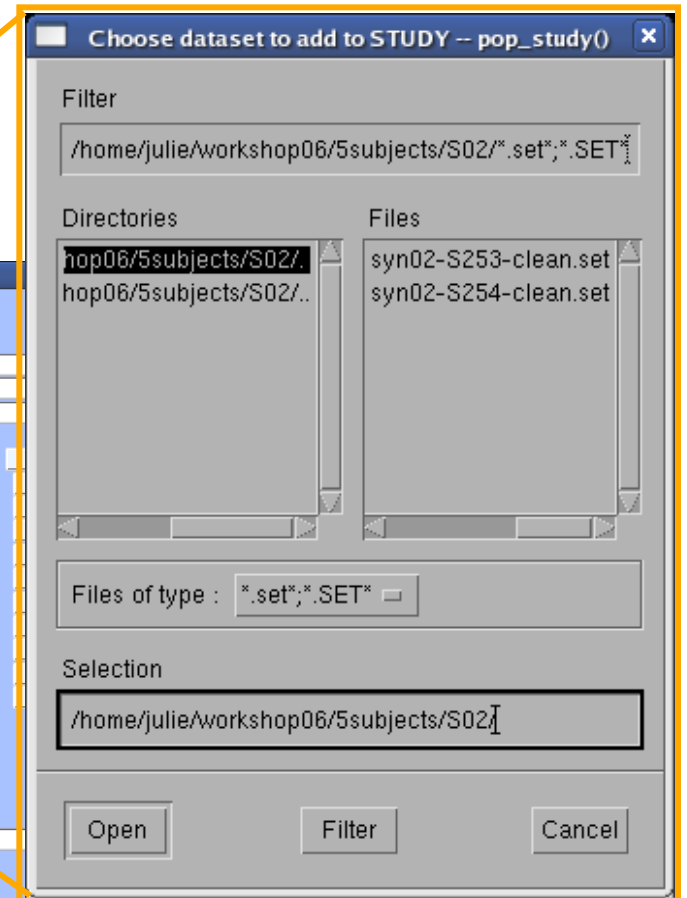
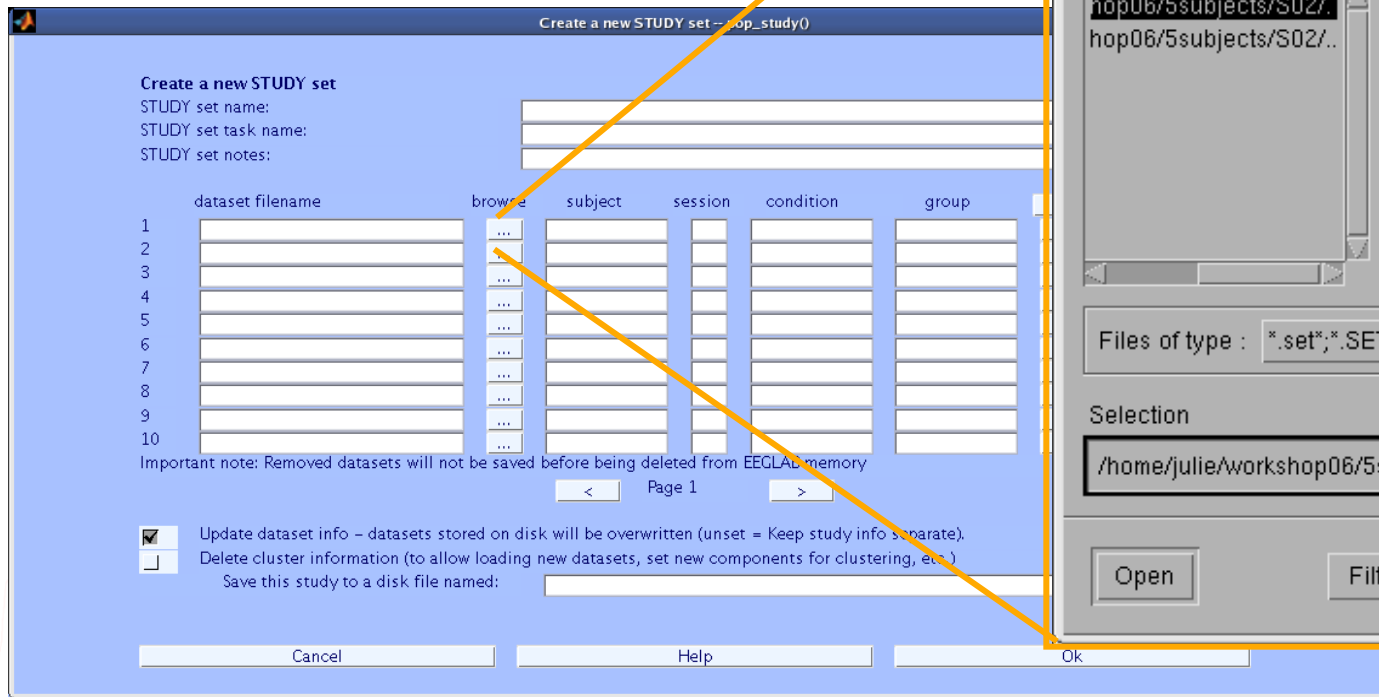
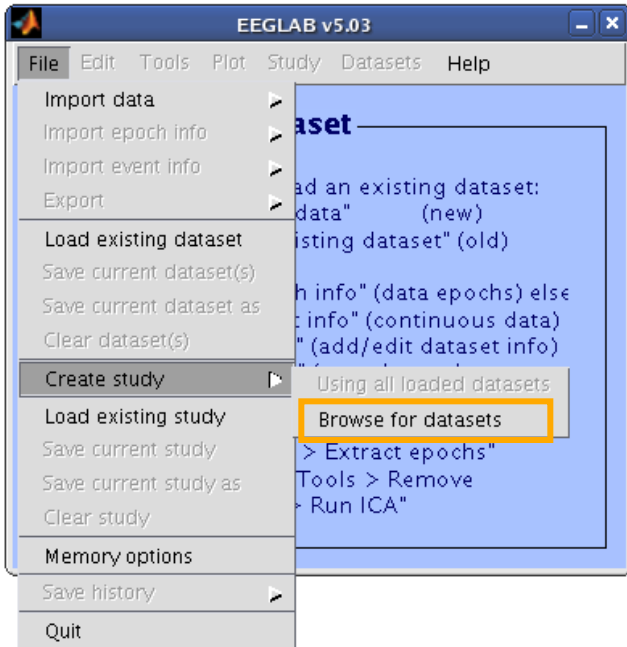
1. Build study and STUDY design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



Advanced analysis using scripting and EEGLAB command line functions



# 1. Build a STUDY



EEGLAB v9.0.0.0b

File Edit Tools Plot **Study** Datasets Help

**STUDY set:**

Study filename: ...s/data  
 Study task name  
 Nb of subjects  
 Nb of conditions  
 Nb of sessions  
 Nb of groups  
 Epoch consistency  
 Channels per frame 61  
 Channel locations yes  
 Clusters 1  
 Status Pre-clustered  
 Total size (Mb) 8.2

Edit study info  
**Select/Edit study design(s)**  
 Precompute channel measures  
 Plot channel measures  
 Precompute component measures  
 Measure Product clustering ▶  
 PCA clustering (original) ▶  
 Edit/plot clusters

# Edit STUDY design



Select STUDY design

STUDY.design 1

Add design  
 Rename design  
 Delete design

**Subjects**

S05  
 S08

Select all subjects

**Independent variable 1**

None  
 condition  
 description  
 duration  
 type

Ind. var. 1 values

non-synonyms  
 synonyms

Combine selected values  
 Unpaired statistics

**Independent variable 2**

None  
 condition  
 description  
 duration  
 type

Ind. var. 2 values

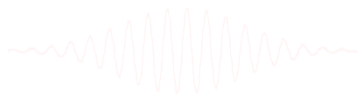
Combine selected values  
 Unpaired statistics

Use only specific datasets/trials

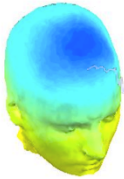
Delete all datafiles associated with this STUDY design

Save the STUDY

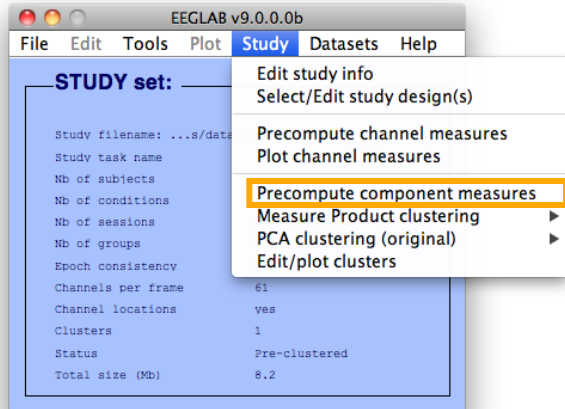
Cancel Ok



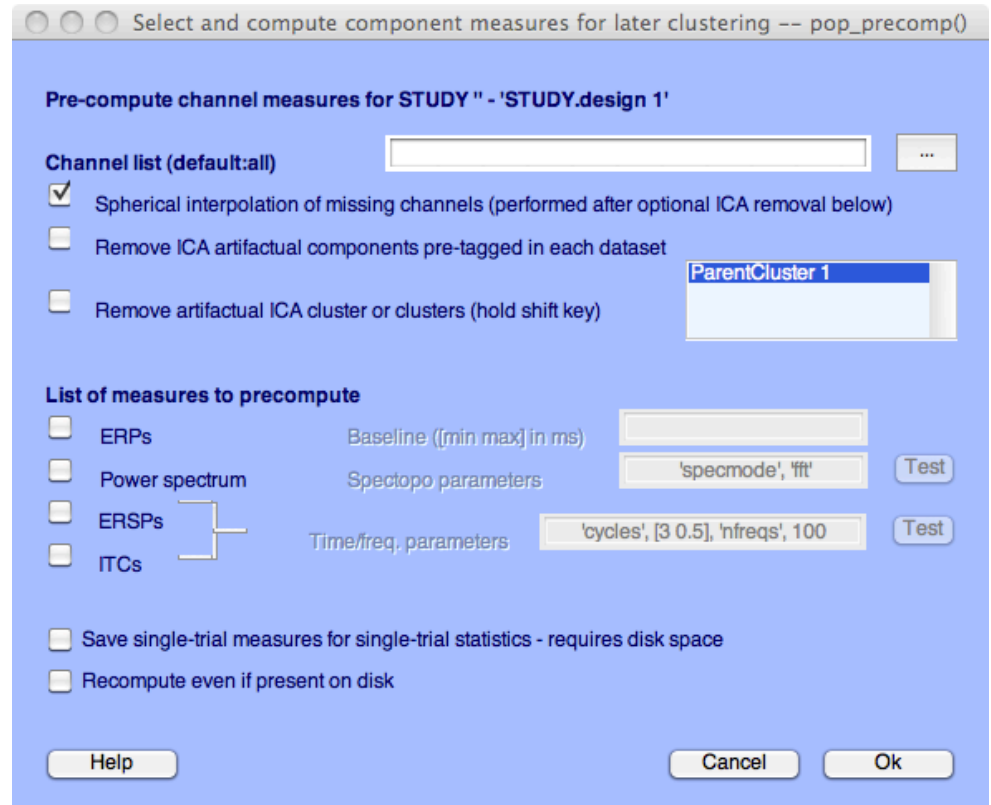
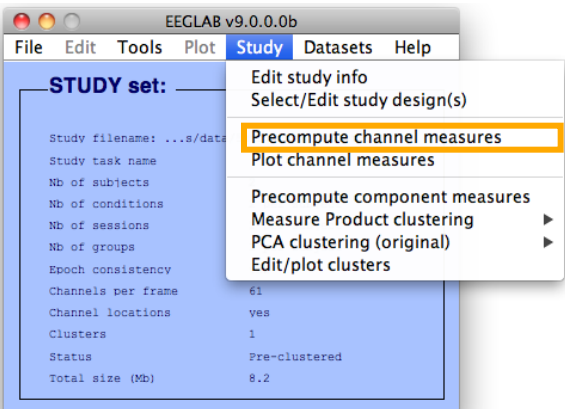
# 2. Pre-compute measures



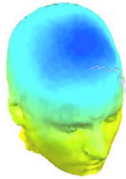
Components



Channels



# 3. Cluster components



EEGLAB v6.0b

File Edit Tools Plot **Study** Datasets Help

**STUDY set: Attention**

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)

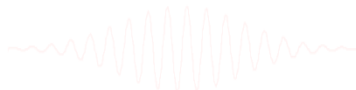
ParentCluster 1 (181 ICs)

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

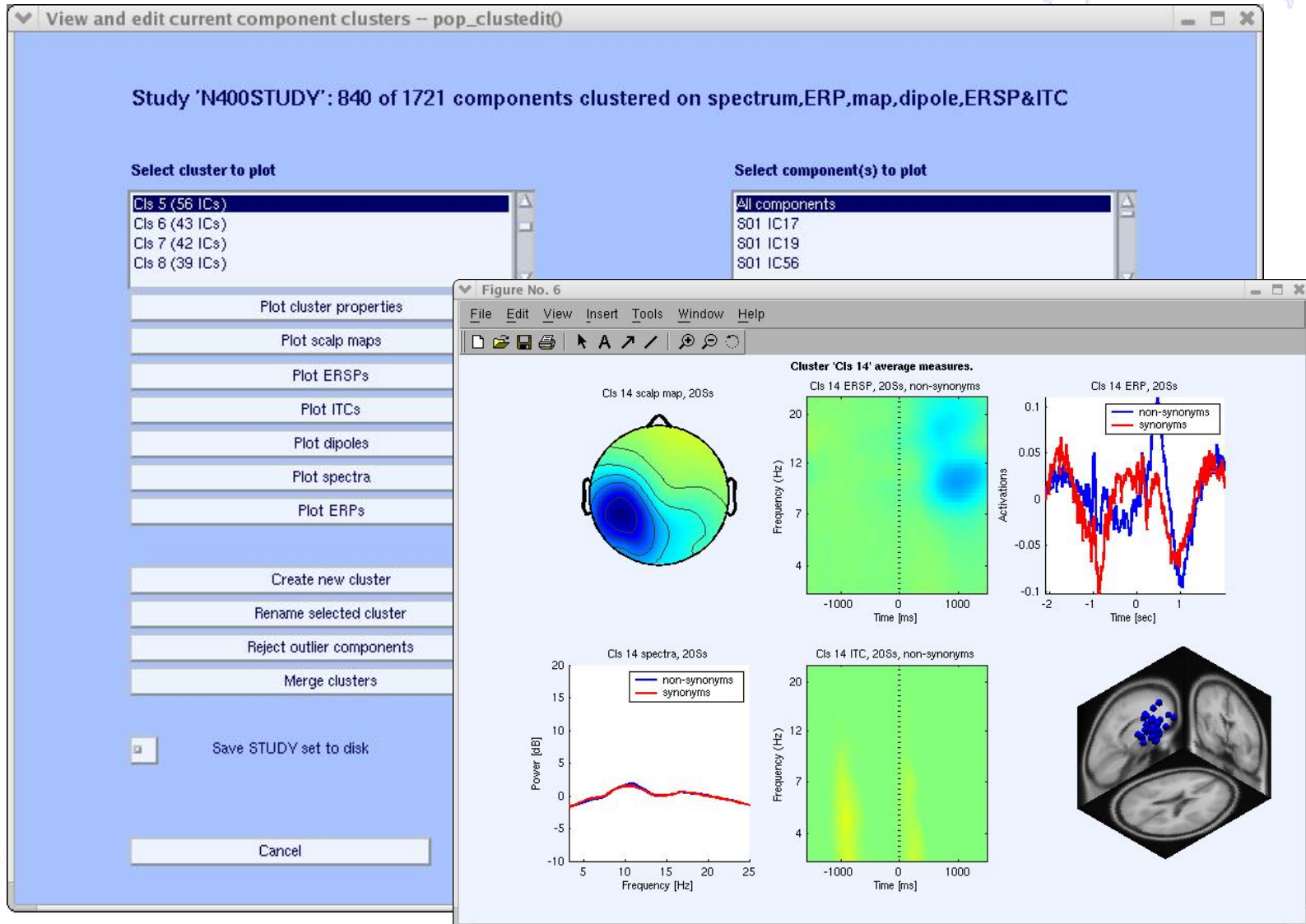
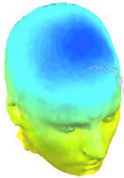
Load	Dims.	Norm.	Rel. Wt.	
<input checked="" type="checkbox"/> spectra	10	<input checked="" type="checkbox"/>	1	Freq. range [Hz] 3 25
<input checked="" type="checkbox"/> ERPs	10	<input checked="" type="checkbox"/>	1	Time range [ms] 0 600
<input checked="" type="checkbox"/> dipoles	3	<input checked="" 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			

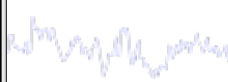
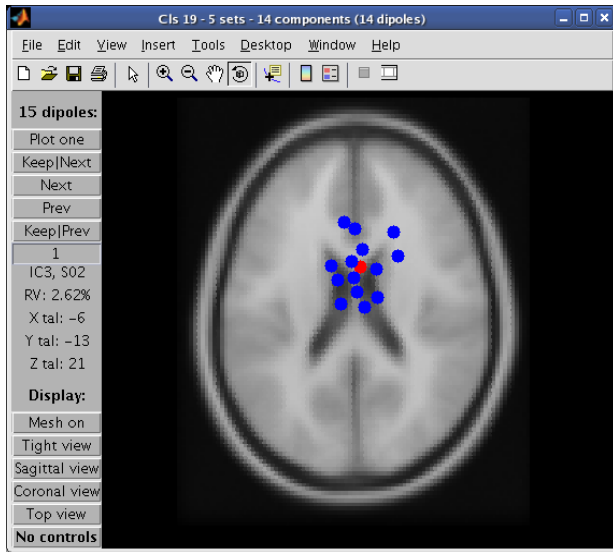
Save STUDY to file /home/julie/WorkshopSD2007/STUDY/attention.study ...

Cancel Help Ok



# 4. Analyze clusters

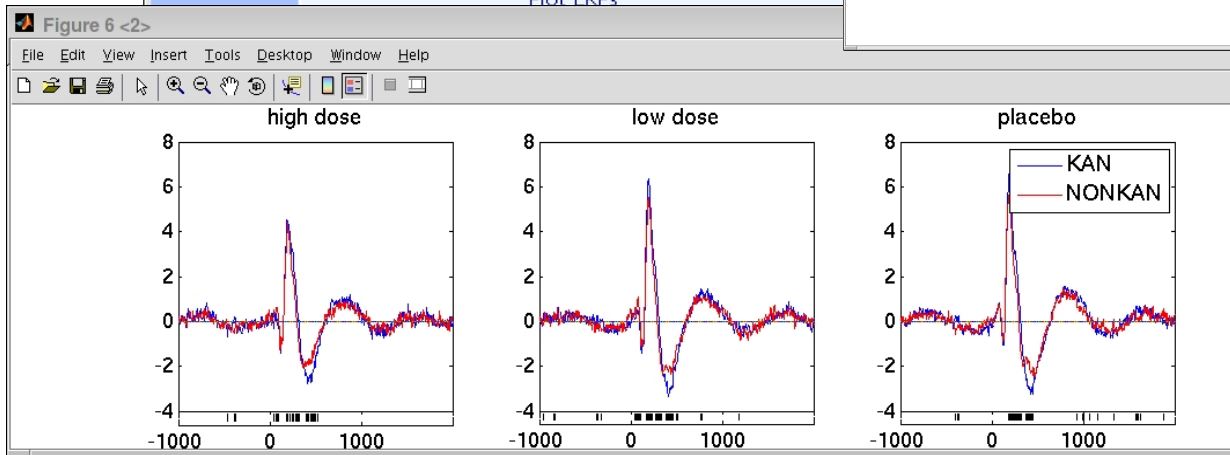
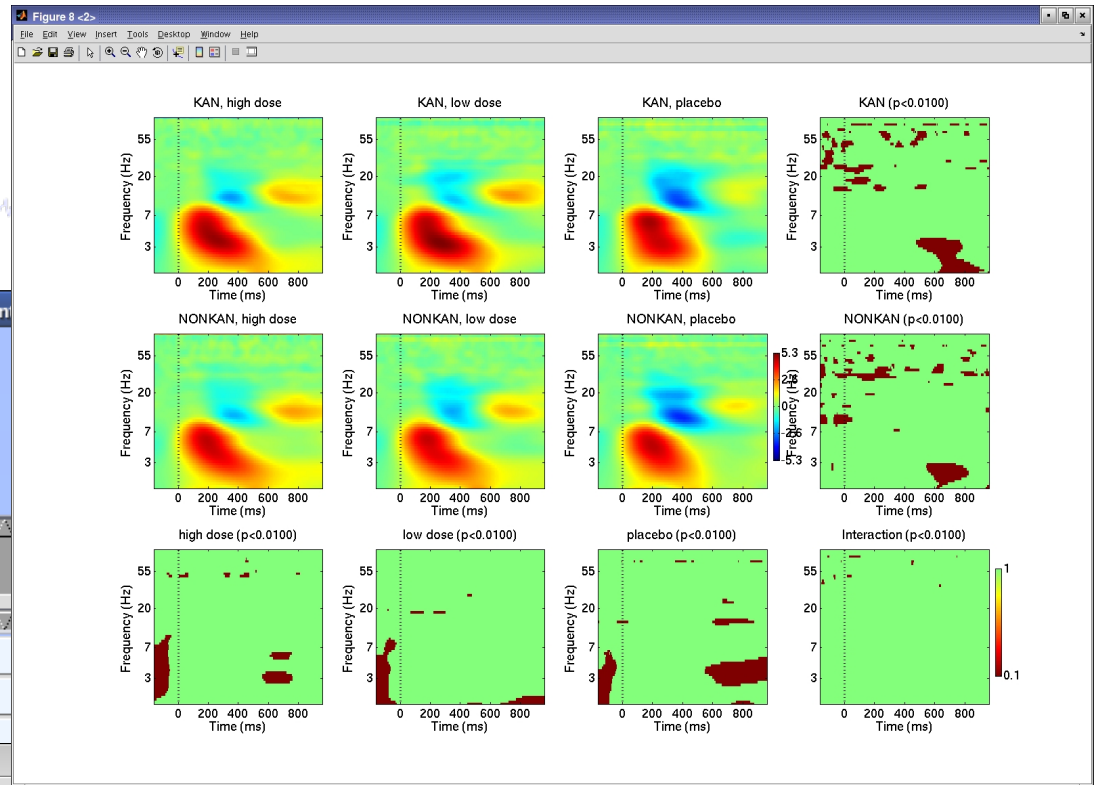




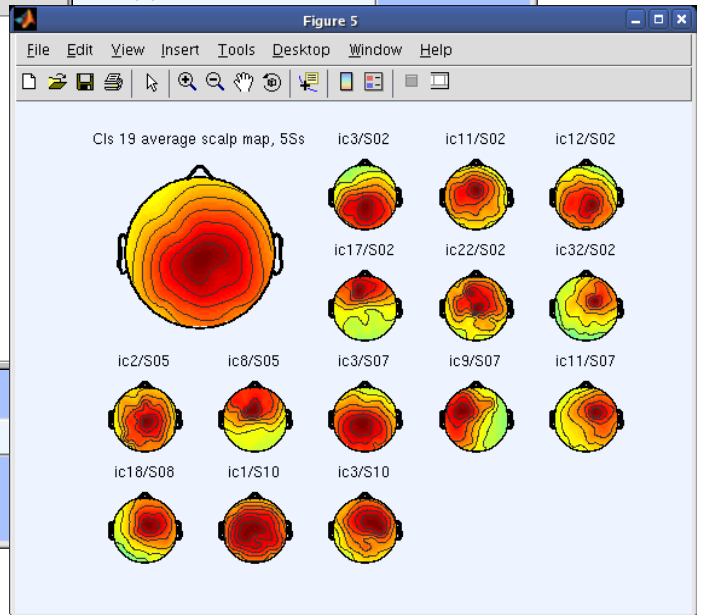
View and edit current  
nts clustered

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

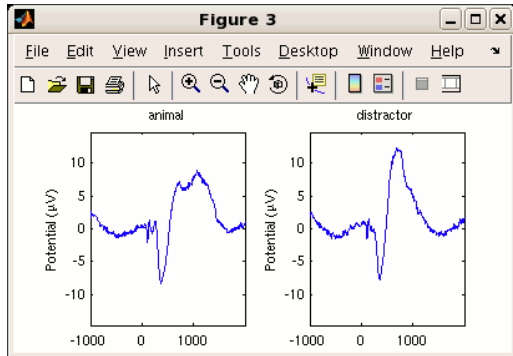
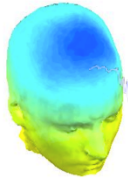
Plot scalp maps  
Plot dipoles  
Plot FRPs



Cancel    Help



# Channel plotting



**View and edit current channels -- pop\_chanplot()**

Study "

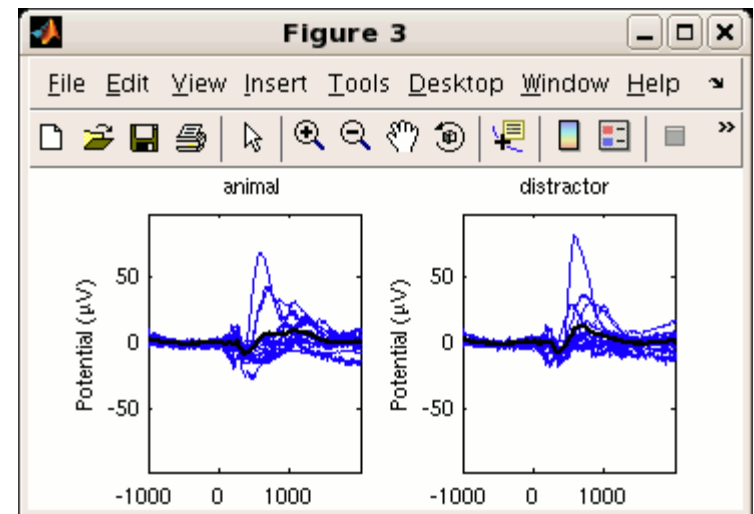
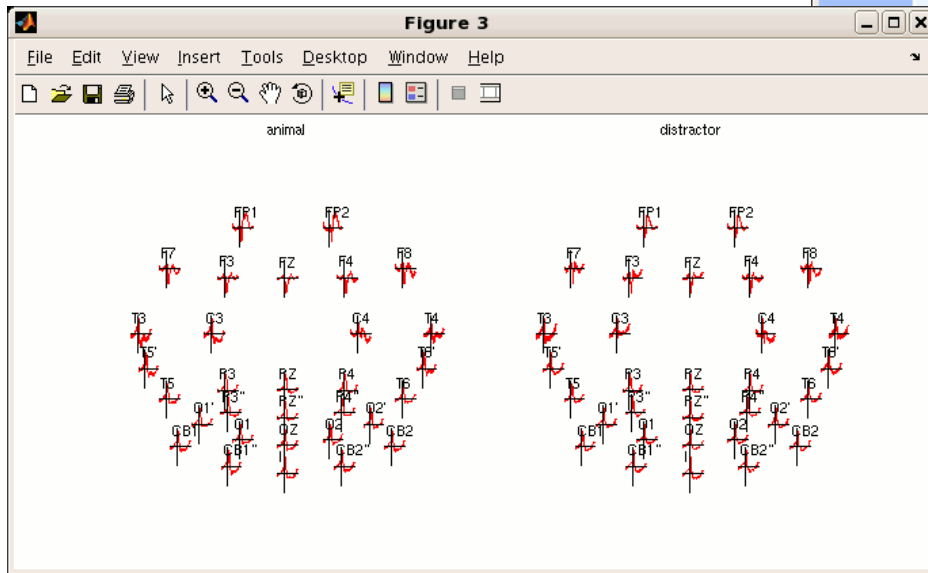
Select channel to plot

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

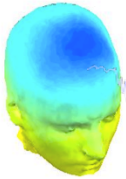
Select subject(s) to plot

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

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 and design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



**Advanced analysis using scripting and EEGLAB command line functions**



# 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

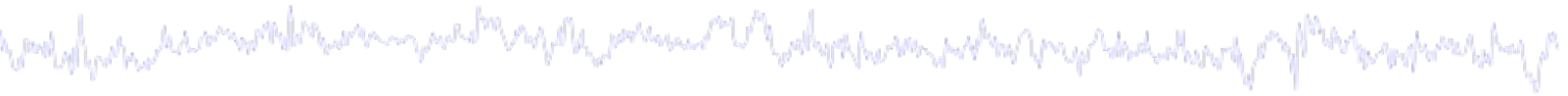
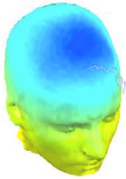
ICA scalp maps

ICA activity

Epoch/event information

Channel location

# 3 levels of functions



**Administrative functions: handle EEG and ALLEEG structures**

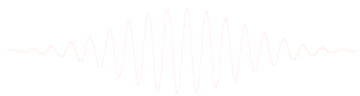
`eeglab()`, `eeg_checkset()`, `pop_delset()`, ...

**Pop functions: interactive functions using EEG structure**

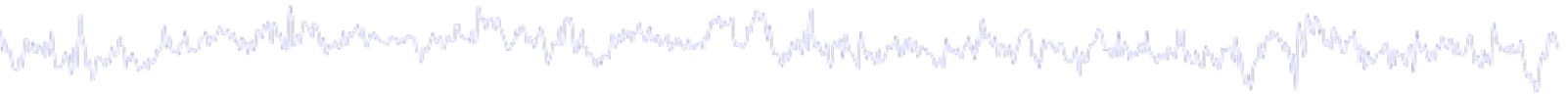
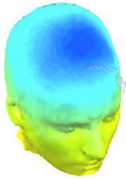
`pop_erpimage()`, `pop_topoplot()`, `pop_envtopo()`, ...

**Signal processing functions: perform signal processing**

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

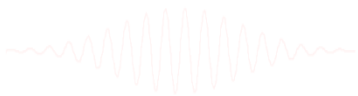


# Command line tools

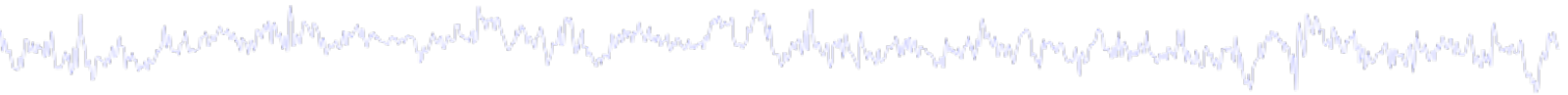
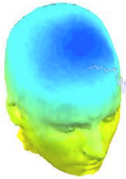


(Menus write both dataset and global history)

- 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...



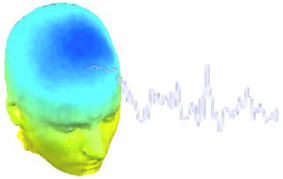
# Current and future directions



- Source localization (NFT – Zeynep Akalin)
- Connectivity toolbox (Tim Mullen)
- Analysis of large studies and parallel processing
- Study design
- Multi-modality imaging
  
- Improved memory mapping features
- Improved plug-in facility and script library
- Shared data resource (HEAD-IT)
- Open source community development (SVN server)



## Monday, June 14



**8:30 - 9:00 am Check-in open**

9:00 – 10:00 am -- Mining event-related brain dynamics (Scott Makeig)

10:00 – 10:30 am -- EEGLAB overview (Arnaud Delorme) PDF

**-- Break (10:30-11:00) --**

11:00 – 11:45 am -- Data import and channel analysis (Julie Onton) PDF

11:45 am – 12:30 pm -- ICA theory (Jason Palmer)

**-- 12:30-1:30 Lunch --**

1:30 – 2:15 pm -- Performing artifact rejection and ICA decomposition (Julie Onton) PDF

2:15 – 3:00 pm -- Using time-frequency decomposition (Arnaud Delorme) PDF

**-- Break (3:00-3:30) --**

3:30– 4:15 pm -- Evaluating ICA components (Julie Onton) PDF

4:15 – 5:00 pm -- Using bootstrap statistics (Arnaud Delorme)

## Tuesday, June 15

9:00 – 9:45 am -- Basic scripting using EEGLAB “history” and EEG structure (Julie Onton)

9:45 – 10:30 am – Forward and inverse source models (Scott Makeig)

**-- Break (10:30-11:00) --**

11:00 – 11:45 am -- Dipole modeling with the DIPFIT plugin (Julie Onton)

11:45 – 12:30 pm -- Using the NFT head modeling toolbox (Julie Onton)

**-- 12:30-1:30 Lunch --**

1:30 – 2:15 pm -- Advanced IC analysis (Julie Onton)

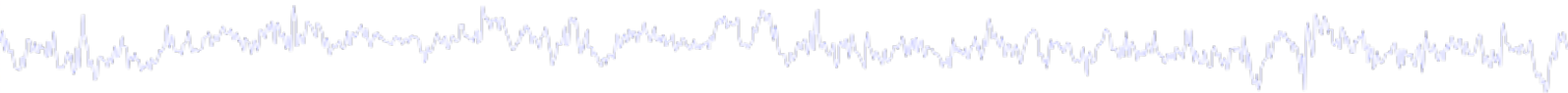
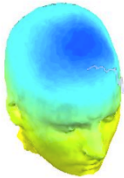
2:15 – 3:00 am -- Building a STUDY and STUDY basics (Julie Onton)

**-- Break (3:00-3:30) --**

3:30 – 4:15 am -- Plotting and editing STUDY IC clusters (Arnaud Delorme)

4:15 – 5:00 pm -- Advanced study menu function (Arnaud Delorme)





### Wednesday, June 16

9:00 am – 9:45 am — Advanced STUDY (cluster) analysis (Julie Onton)

9:45 am – 10:30 am — FAQs about EEGLAB and EEGLAB plugins (Arnaud Delorme)

-- Break (10:30-11:00) --

11:00 am – 12:00 pm — STUDY (cluster) analysis (Julie Onton)

**12:00–5:00pm – Excursion: An outdoors group experience of Finnish traditions including smoke sauna.**

### Thursday, June 17

9:00 – 9:45 pm -- Modeling effective connectivity by measuring EEG information flow (Tim Mullen)

9:45 – 10:30 pm -- Using the Information Flow Analysis Toolbox (Tim Mullen)

-- Break (10:30-11:00 am) --

**11:00 am - 12:30 pm — Small group research projects**

-- 12:30 - 1:30 pm Lunch --

**1:30 pm – 3:00 pm – Continued group research and presentations of results**

-- Break (3:00-3:30) --

3:30 – 4:30 pm -- New directions in electrophysiology research and applications (Scott Makeig)

**4:30 - 4:45 pm -- General discussion**

-- Workshop close --

## First EEGLAB Workshop

University of California San Diego  
La Jolla, California,  
Oct. 28-30, 2004  
following the Society for  
Neuroscience meeting  
in San Diego



# Workshops

**Third EEGLAB Workshop**  
Singapore, Nov. 15-18, 2006



## Second EEGLAB Workshop

Porto, Portugal, Sept. 17-19, 2004  
preceeding the SPR meeting in Lisbon



## Fourth EEGLAB Workshop

Aspet (pyrénées), France, June 26-29, 2007



....

## Tenth EEGLAB Workshop

Finland, June 15-18, 2010