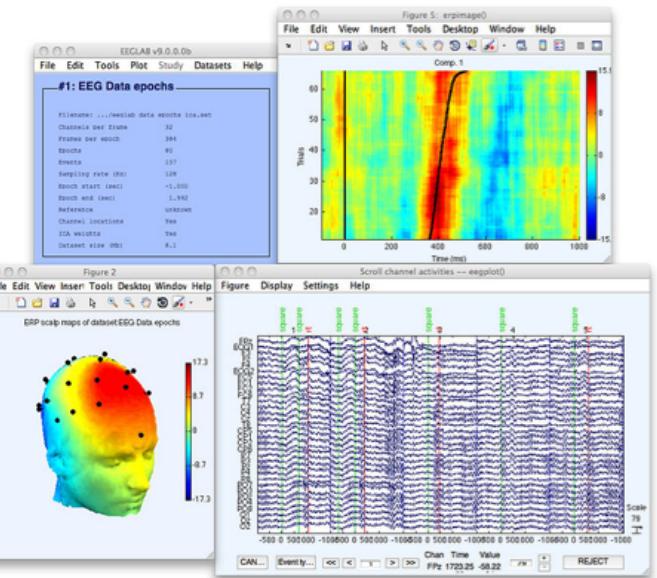


# EEGLAB overview



- 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 8500 on the diffusion list
- NIH funding since 2003

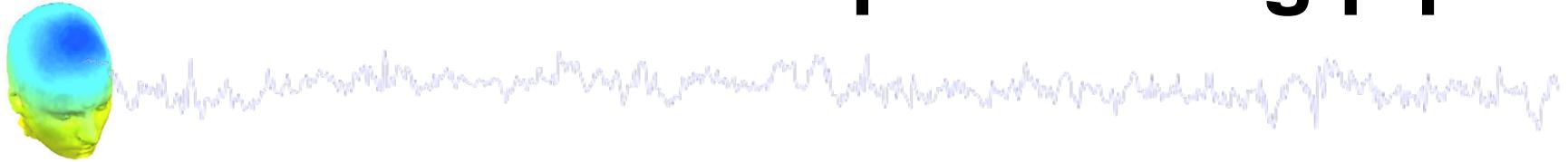


<http://sccn.ucsd.edu/eeglab>

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

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

# EEGLAB standard processing pipeline



## Single subject

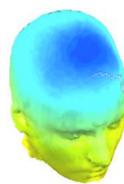
1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
3. Reject artifacts in continuous data by visual inspection
4. Extract epochs from data & reject artifactual epochs
5. Visualize data measures
6. Perform ICA decomposition
  - Perform source localization 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 image shows a screenshot of the EEGLAB Matlab software interface. On the left, there is a terminal window titled "EEGLAB Shell - Konsole" with the following text:

```
/home/arno> matlab -nodesktop
< M A T L A B >
Copyright 1984-2002 The MathWork
Version 6.5.0.180913a Release
Jun 18 2002

Using Toolbox Path Cache. Type "help toolbox_pa

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

>> eeglab
```

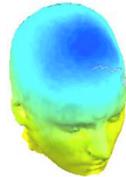
On the right, there is a main application window titled "EEGLAB" with the following text:

No current dataset

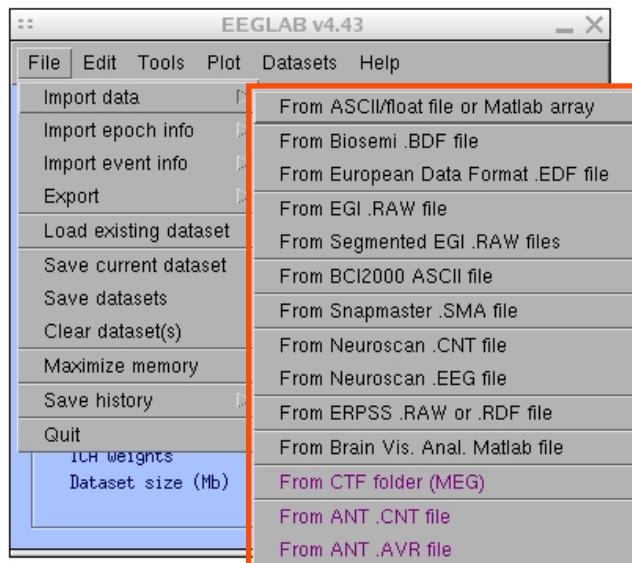
- Create a new or load an existing dataset:  
  Use "/File/Import data" (new)  
  Or "/File/Load existing dataset" (old)
- If new,  
  "/File/Import epoch info" (data epochs), else  
  "/File/Import event info" (continuous data)  
  "/Edit/Dataset info" (add/edit dataset info)  
  "/File/Save dataset"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



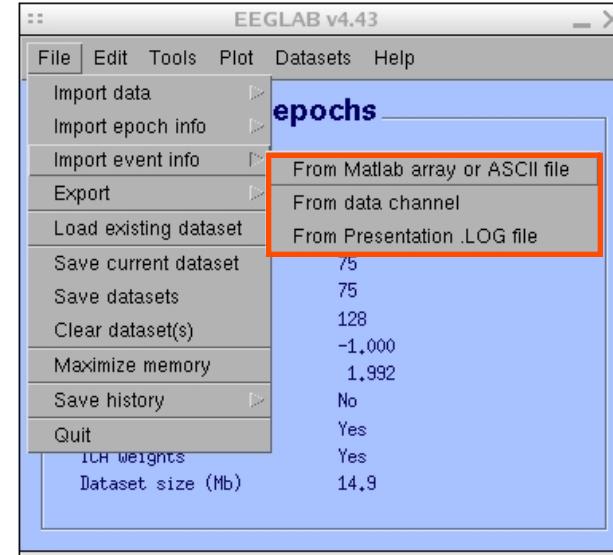
# 1. Importing data



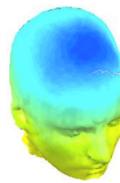
## Import/load data



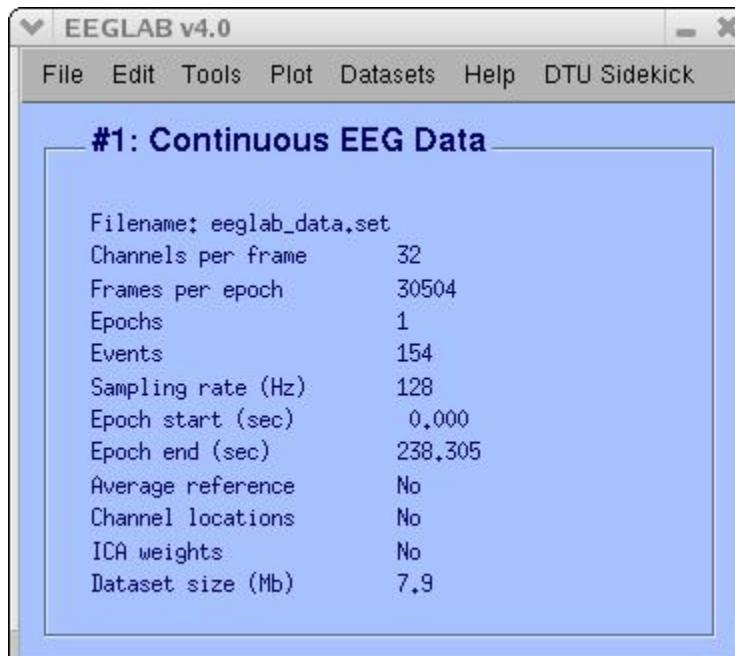
## Import events



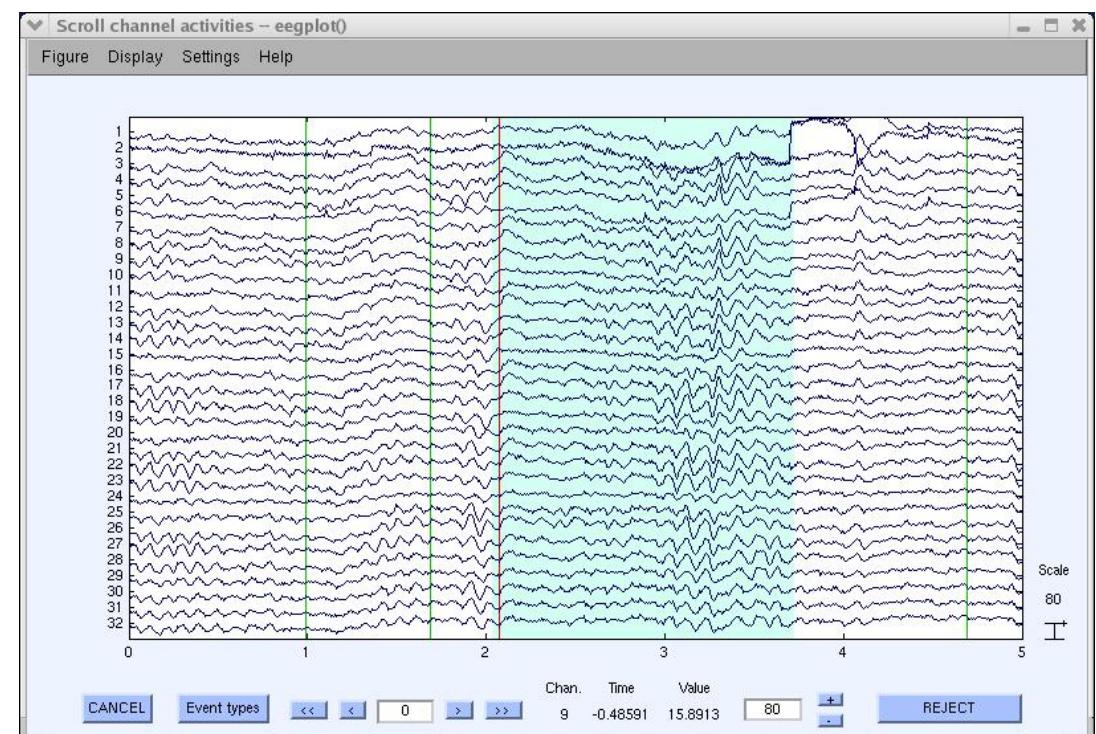
# 1. Importing data



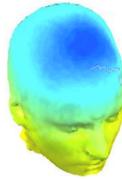
## Data info



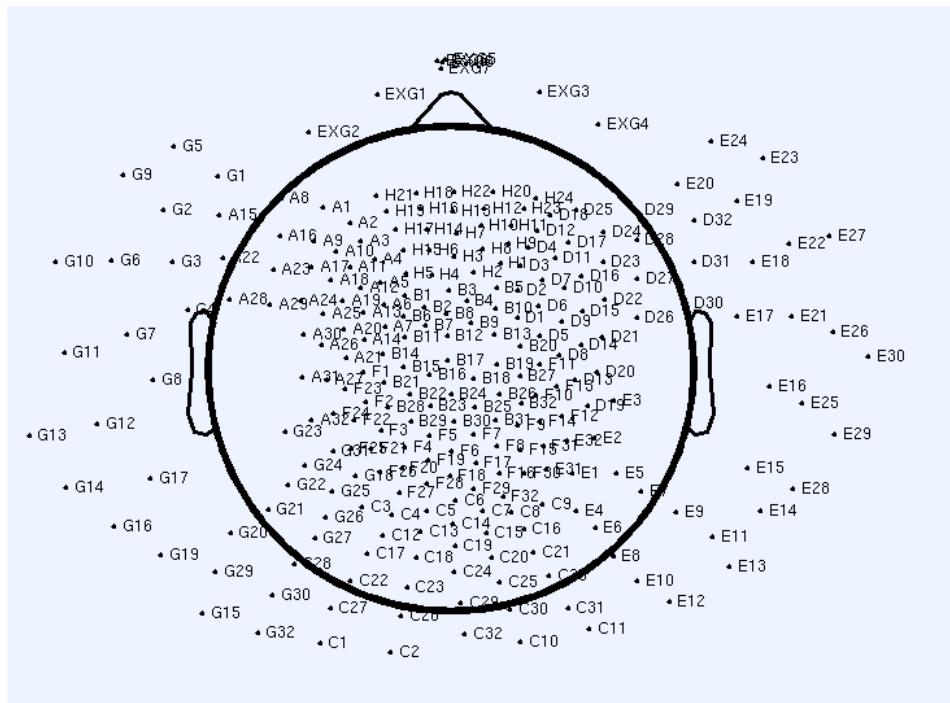
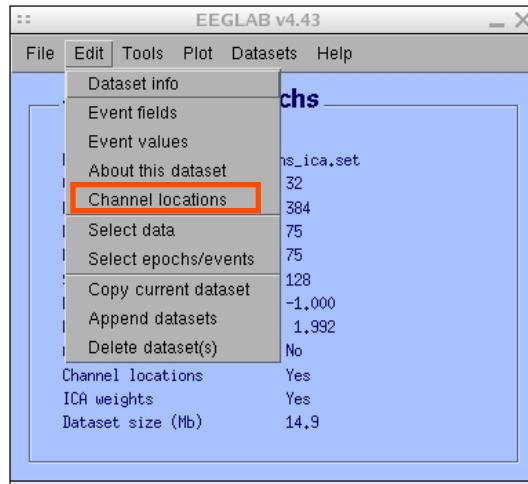
## Scrolling data



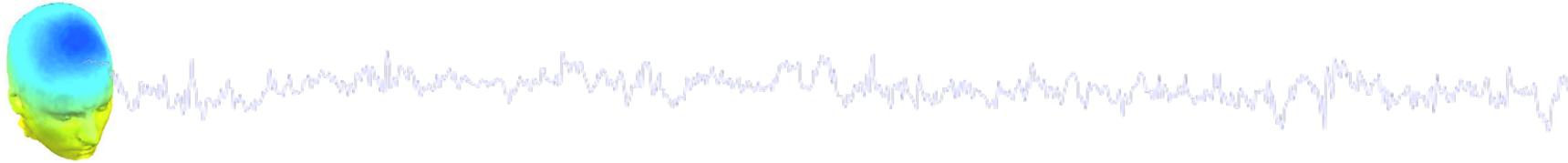
# 1. Importing channel location



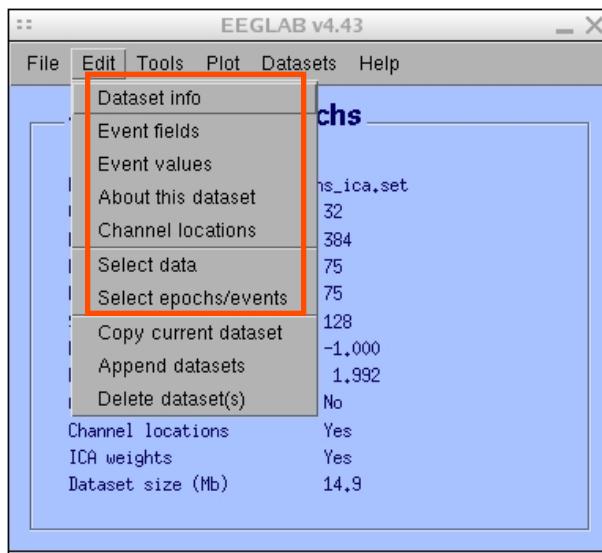
## Import channel location



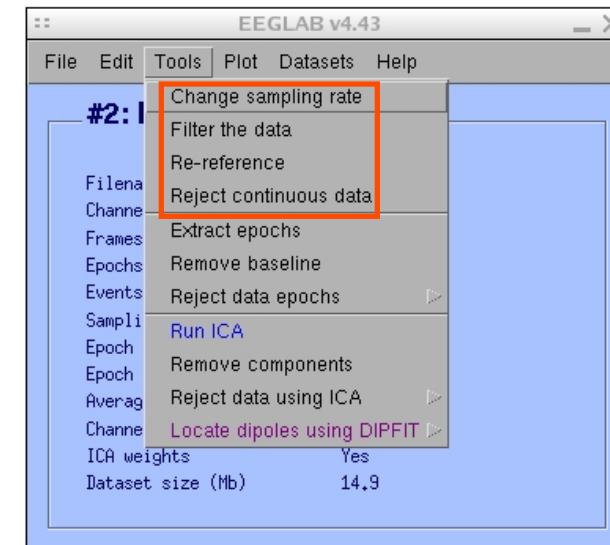
## 2. Edit, Re-reference, Resample, High pass filter data



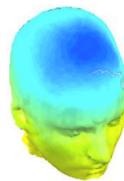
### Edit/select data



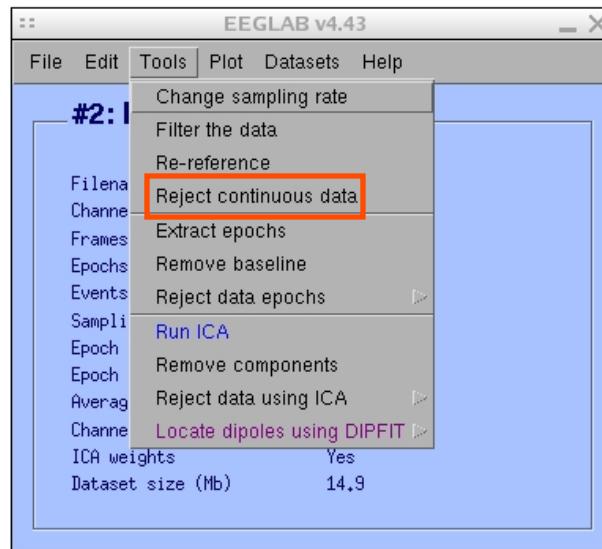
### Preprocessing data



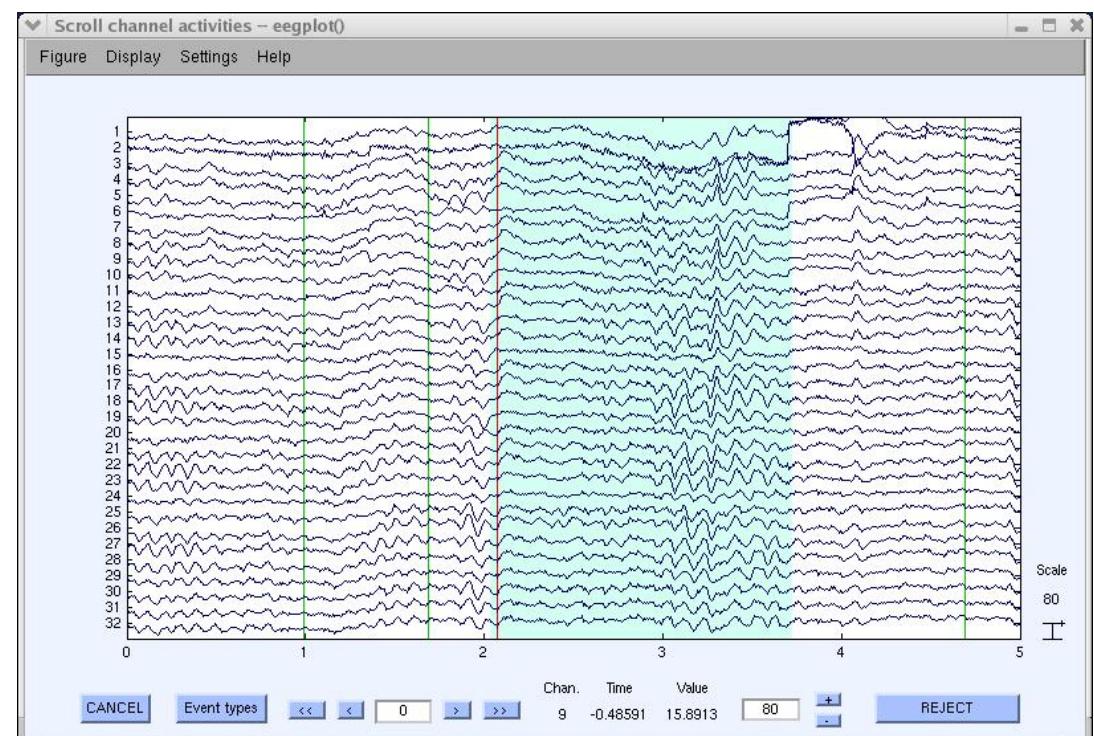
### 3. Reject artifacts in continuous data by visual inspection



#### Data info



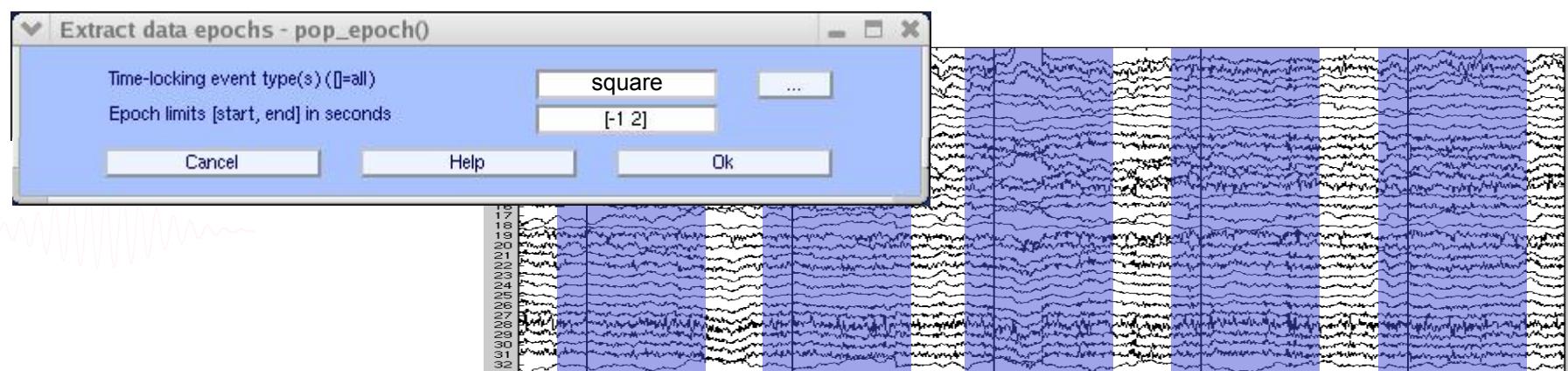
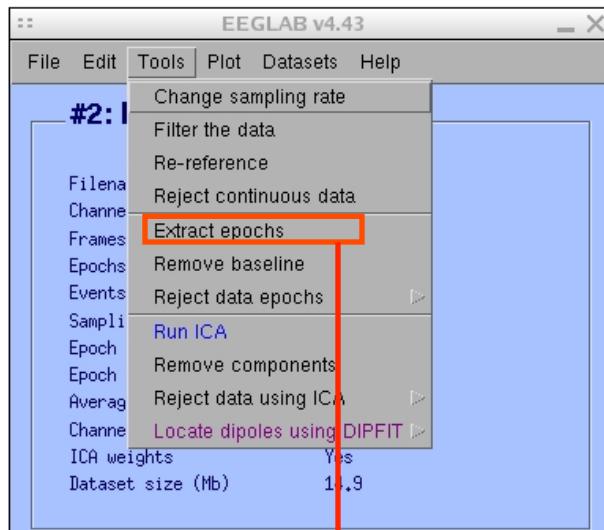
#### Reject portions of continuous data



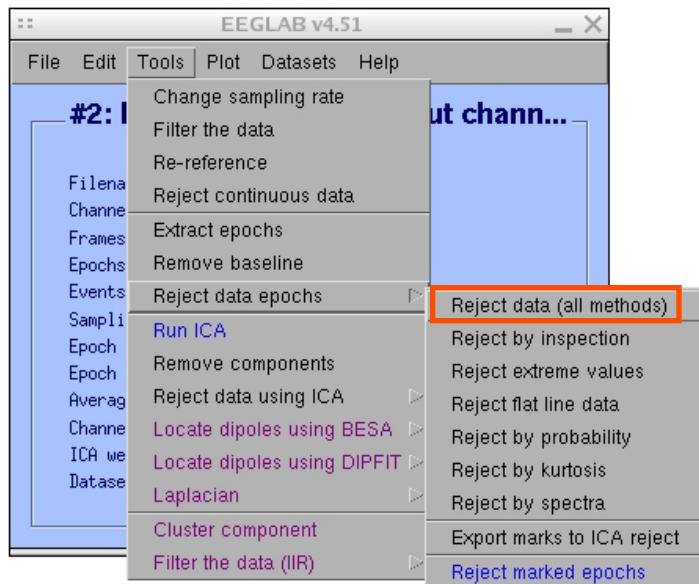
## 4. Extract epochs from data & reject artifactual epochs



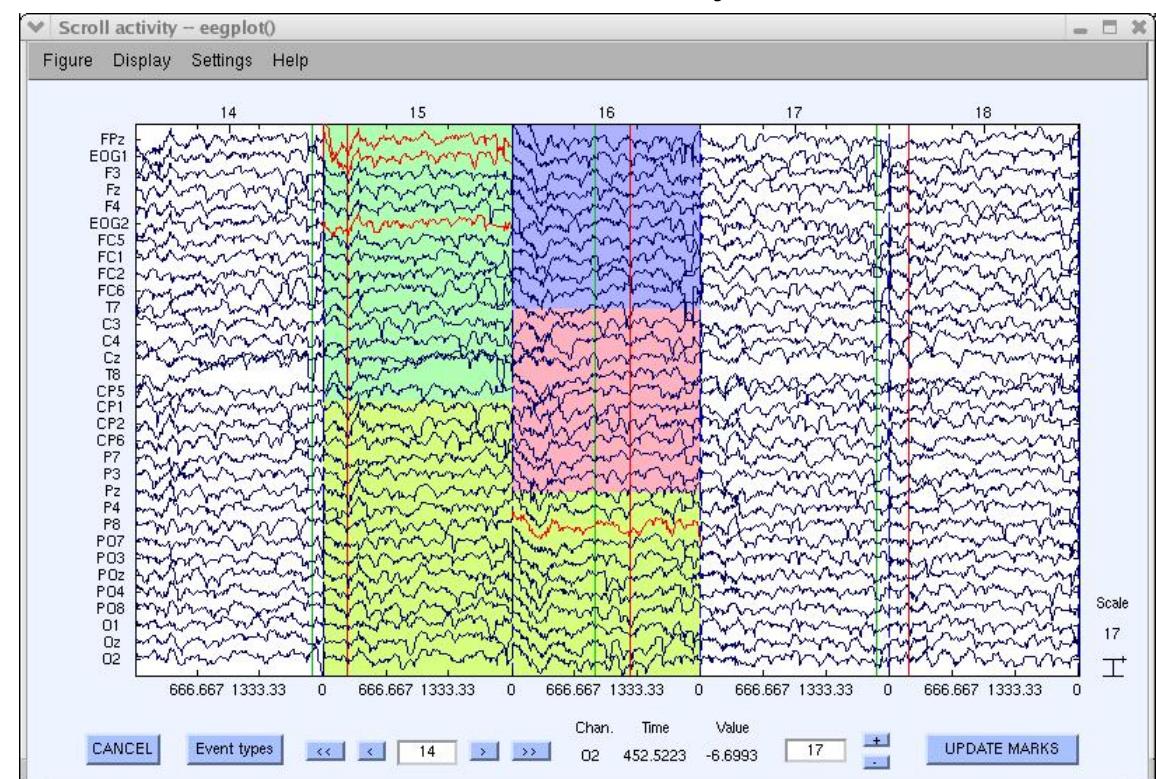
### Preprocessing data



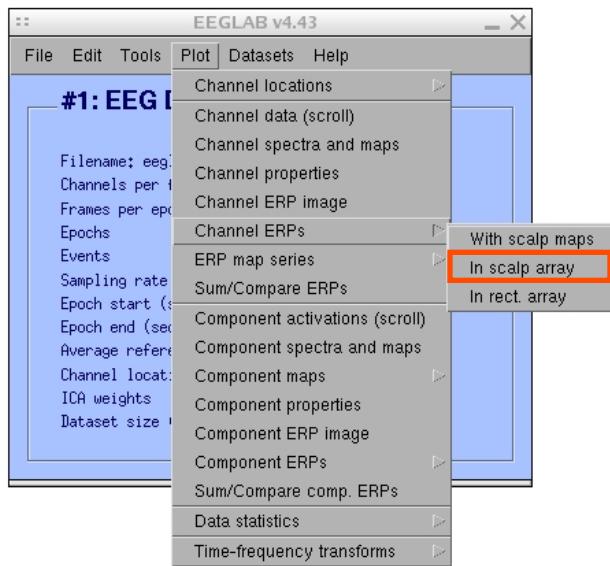
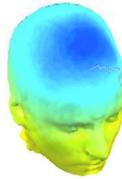
## 4. Extract epochs from data & reject artifactual epochs



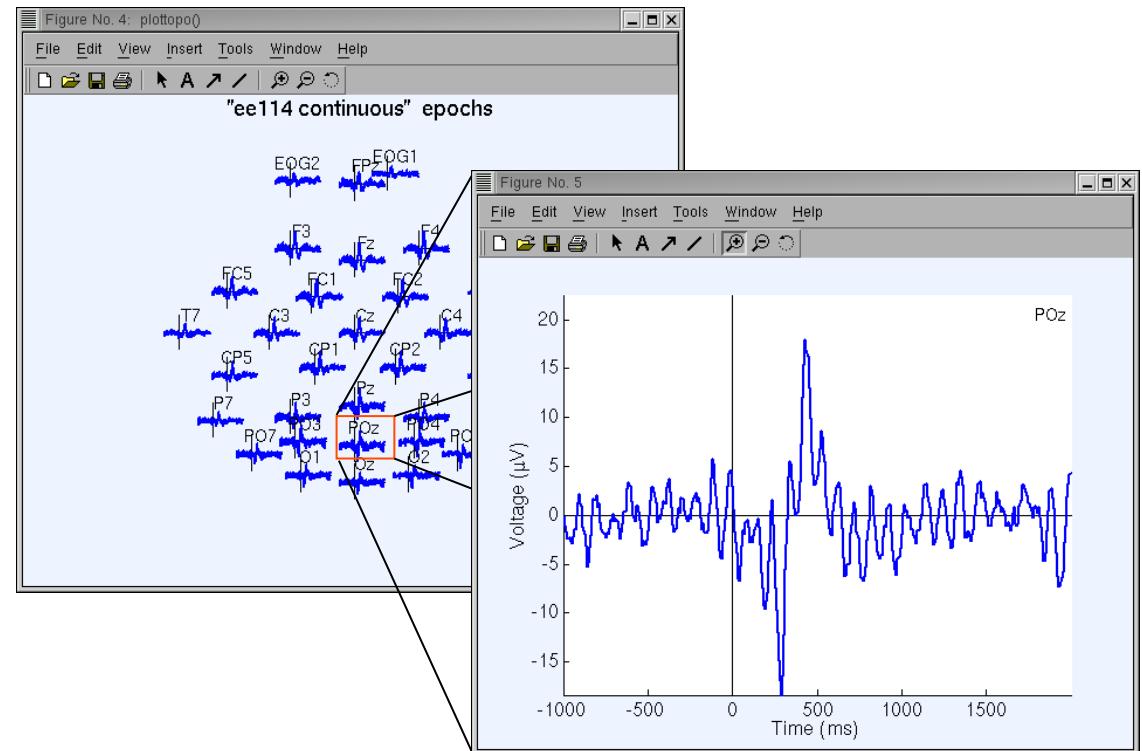
Different color = different rejection methods



# 5. Visualize data measures

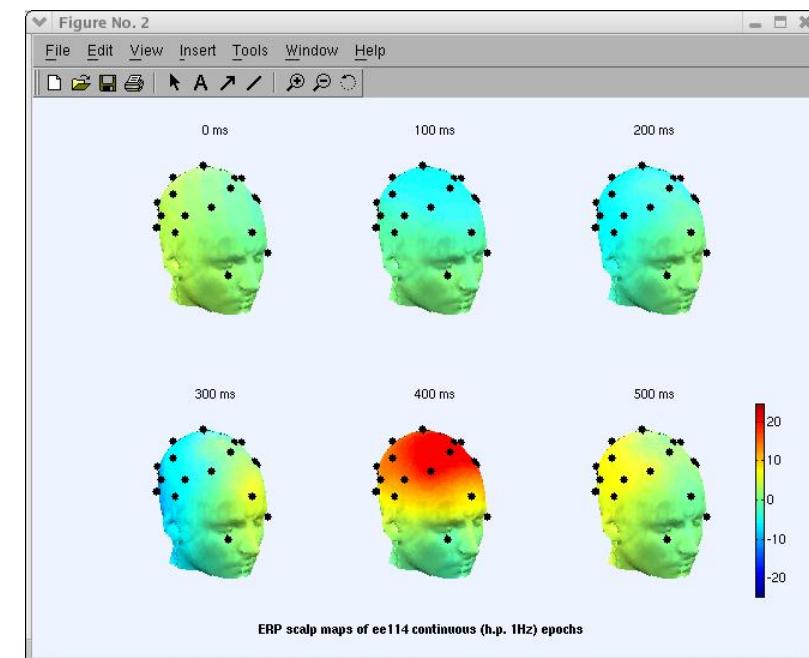
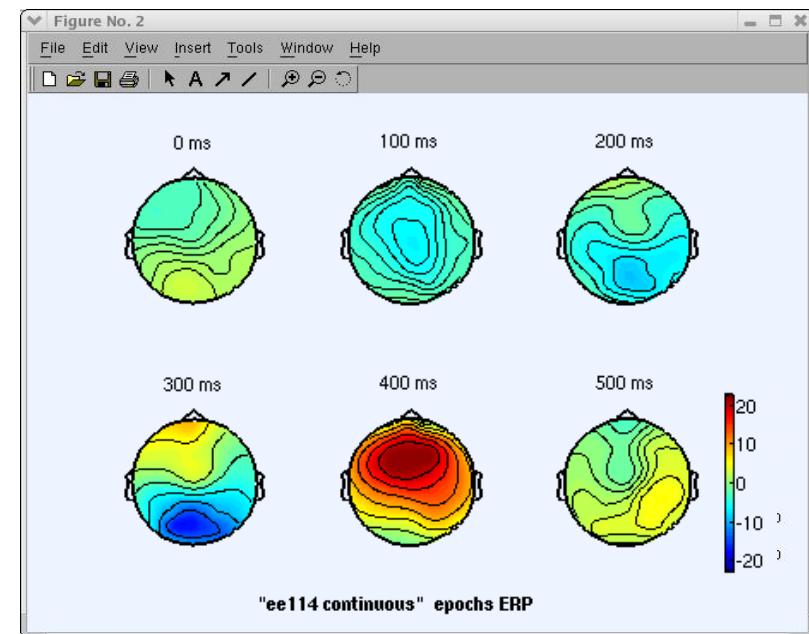
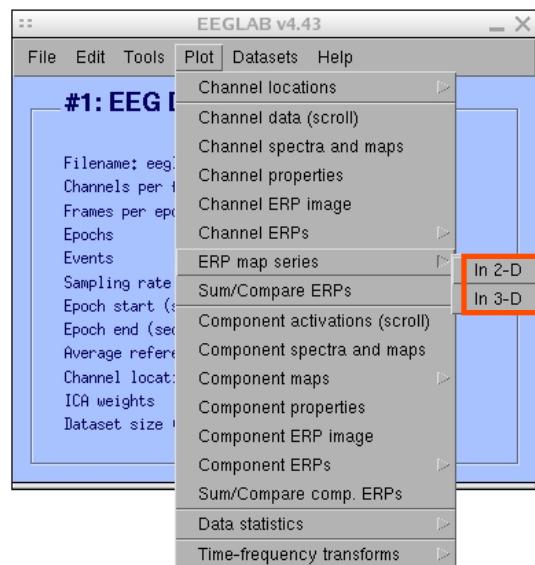


## Plot ERP



# 5. Visualize data measures

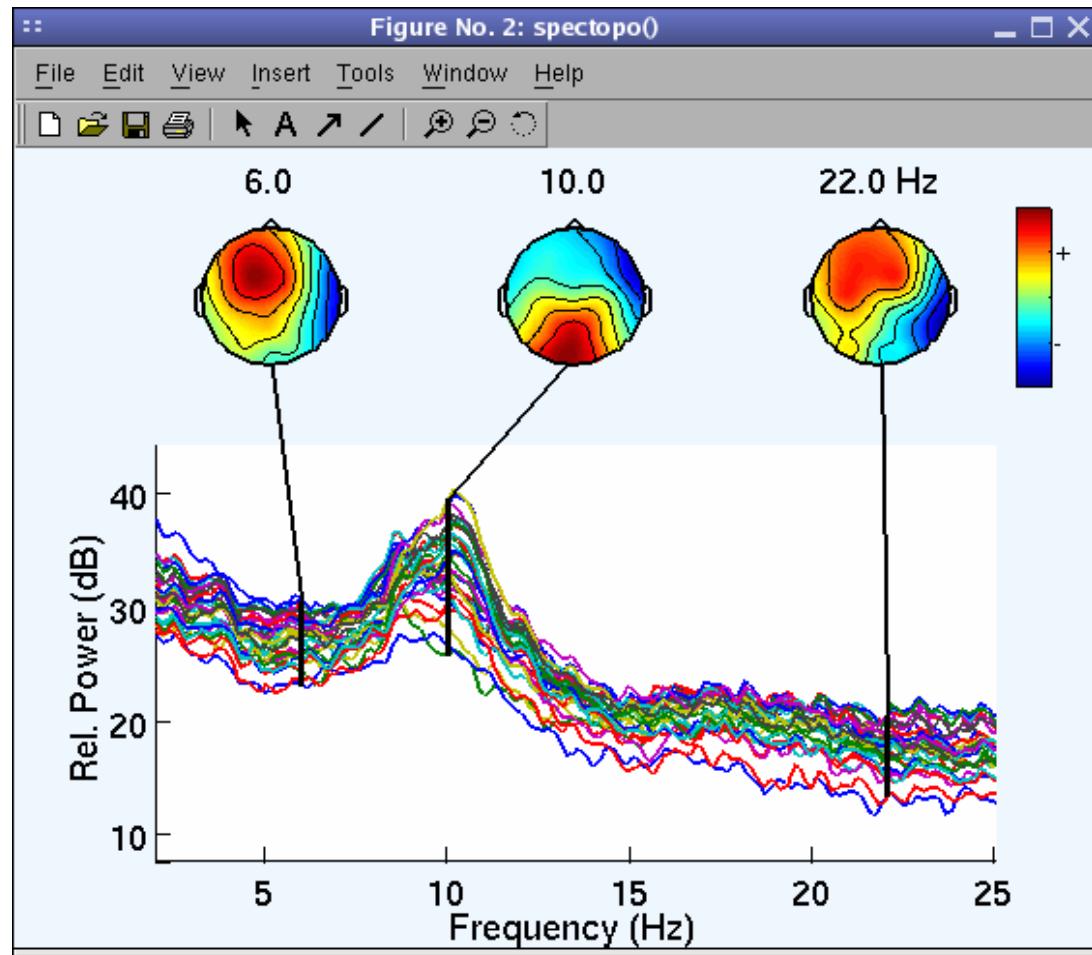
## Plot ERP map series



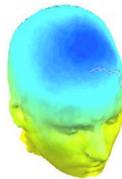
# 5. Visualize data measures



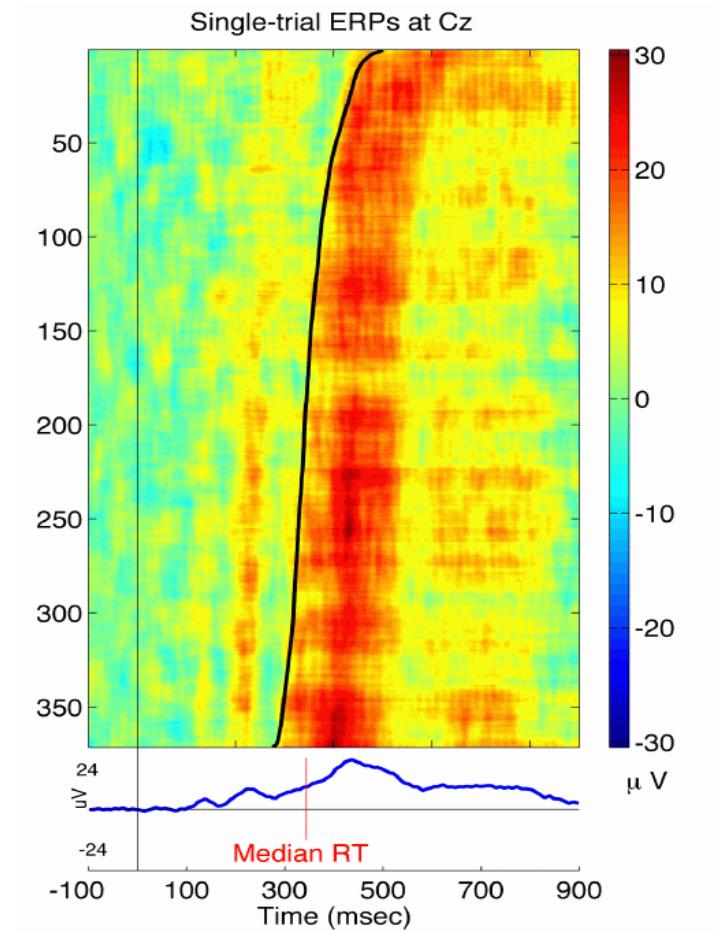
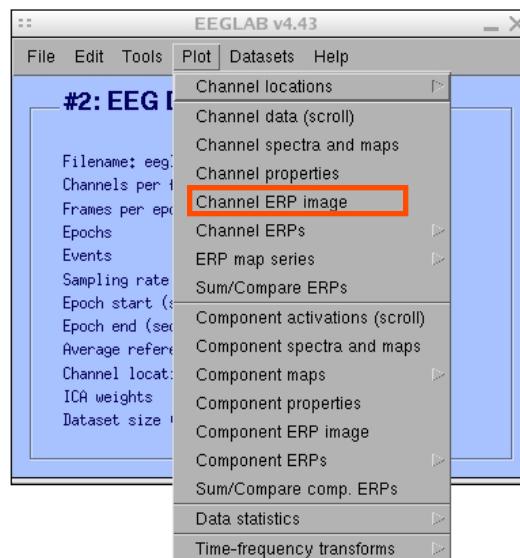
Plot data  
spectrum and  
maps



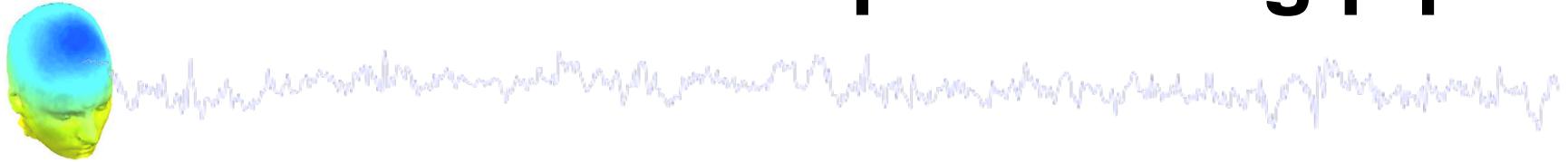
# 5. Visualize data measures



## Plot channel ERPimage



# EEGLAB standard processing pipeline



## Single subject

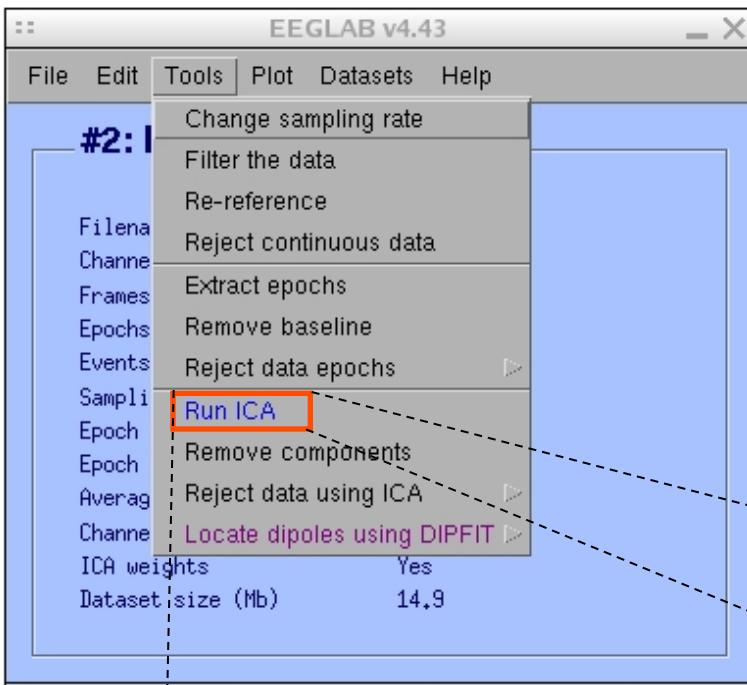
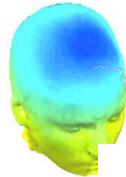
1. Import binary data, events and channel location
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5. Visualize data measures
6. Perform ICA decomposition
  - Perform source localization of components
  - Analyze components contribution to ERP
  - Analyze components contribution to spectrum

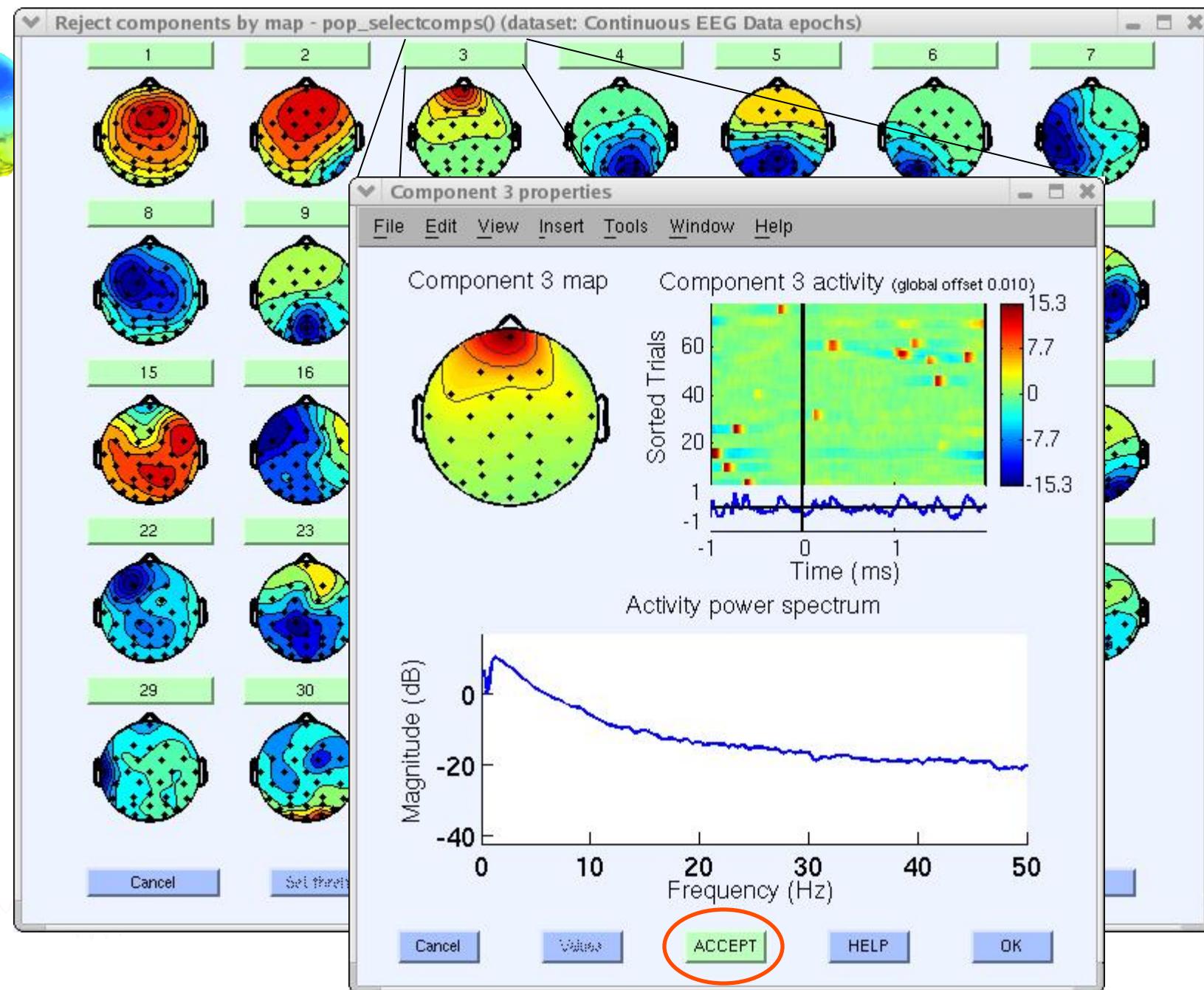
## Multi-subjects

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

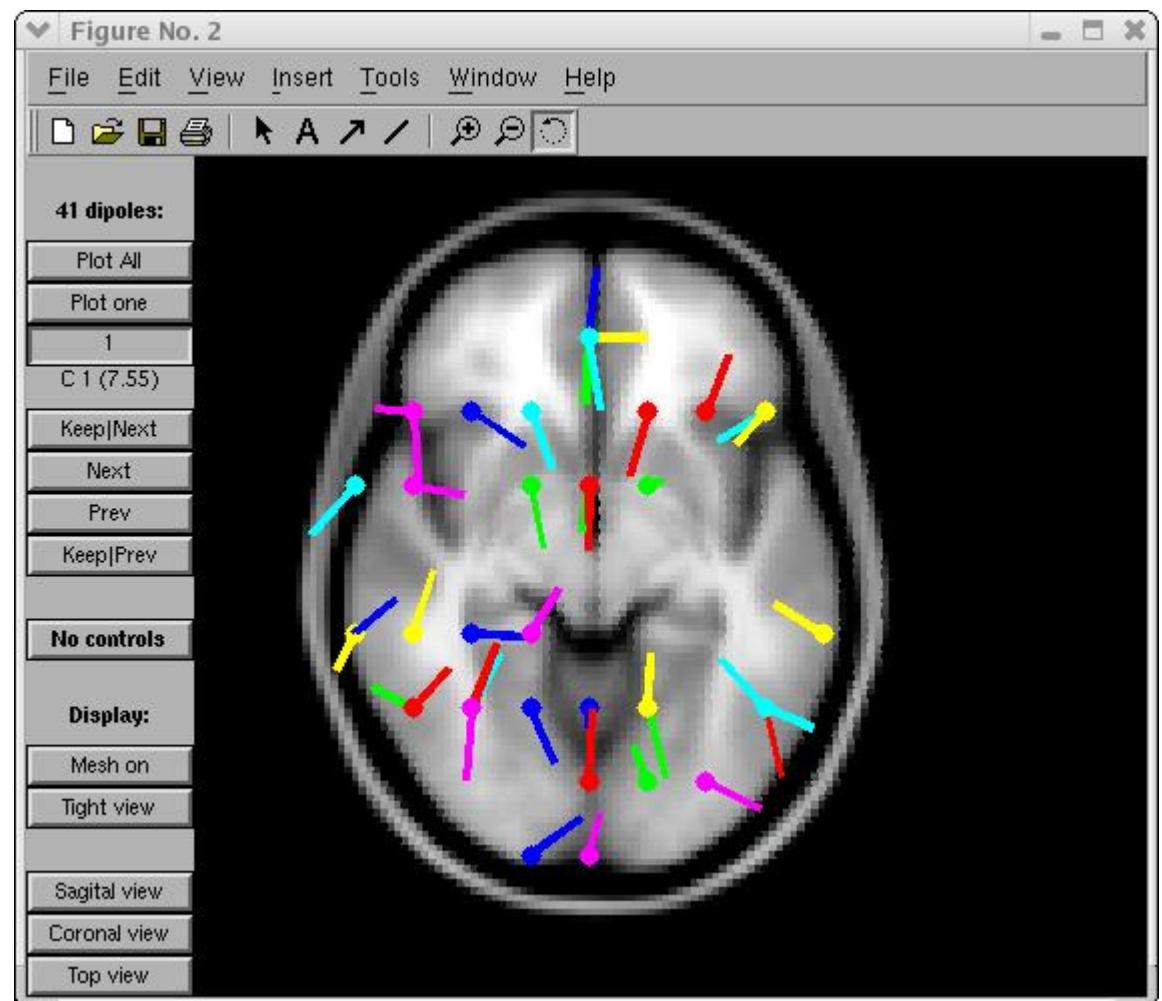
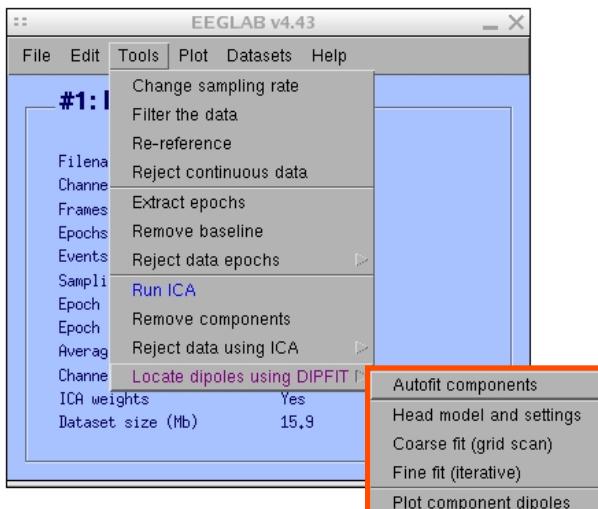
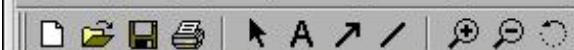


Figure No. 4

File Edit View Insert Tools Window Help



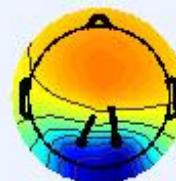
1 (7.5%)



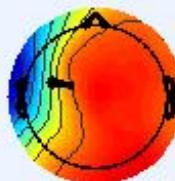
2 (7.5%)



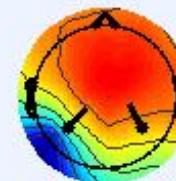
3 (0.53%)



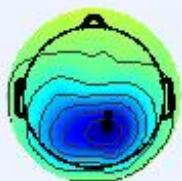
4 (3.6%)



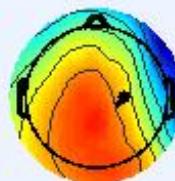
5 (0.99%)



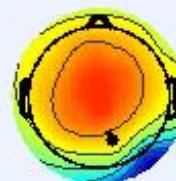
6 (4.3%)



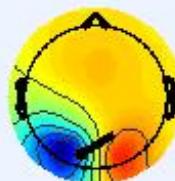
7 (9%)



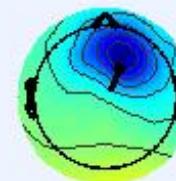
8 (8%)



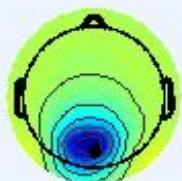
9 (13%)



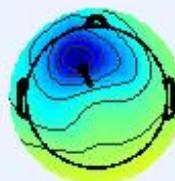
10 (2%)



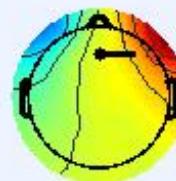
11 (8.4%)



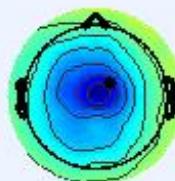
12 (3.7%)



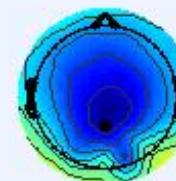
13 (19%)



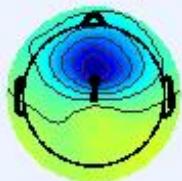
14 (4.8%)



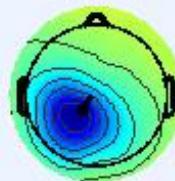
15 (9.9%)



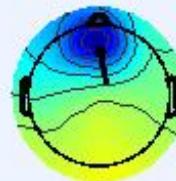
16 (3.7%)



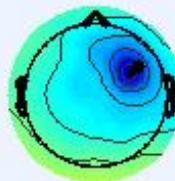
17 (2.1%)



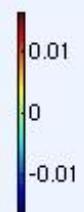
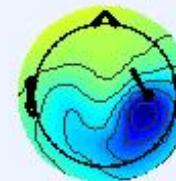
18 (2.4%)



19 (7.8%)

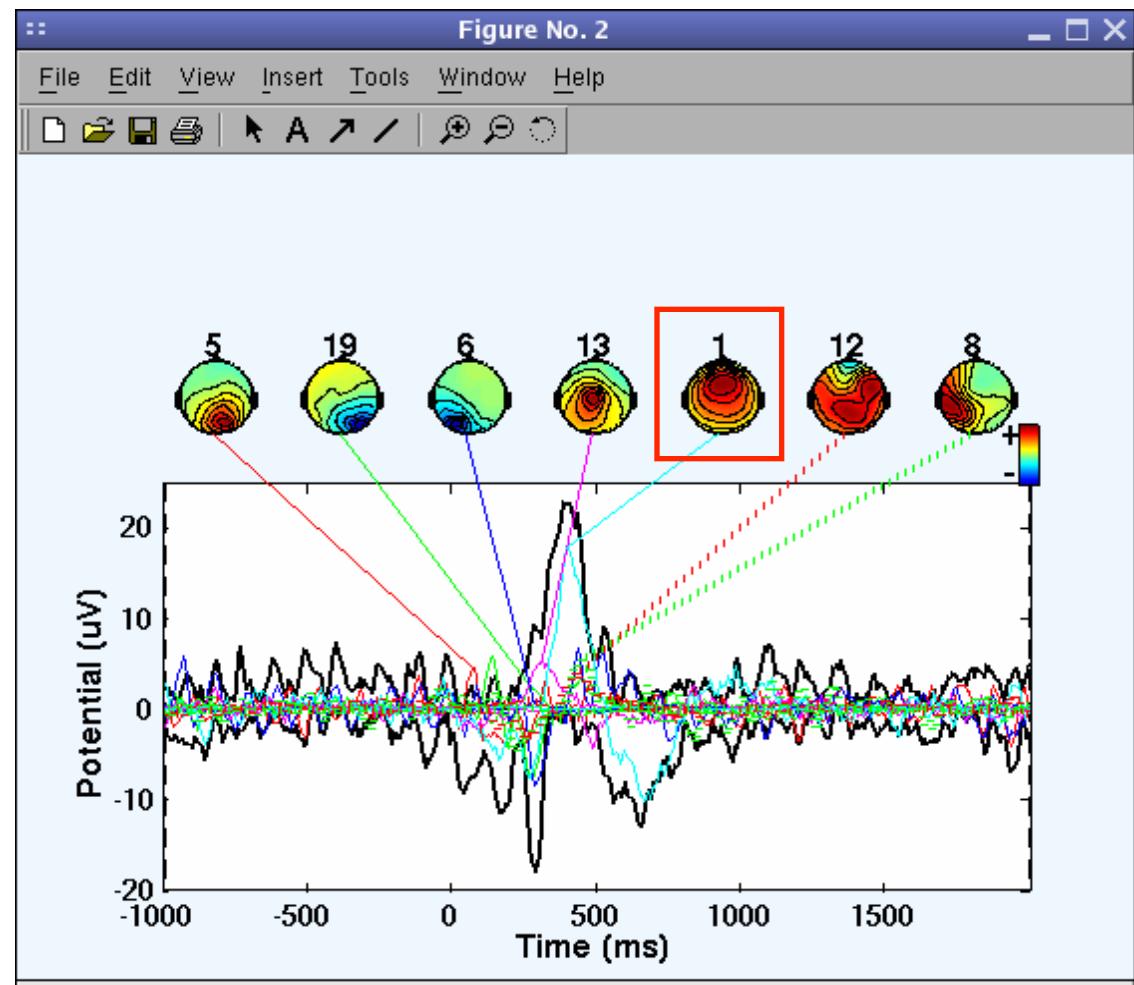
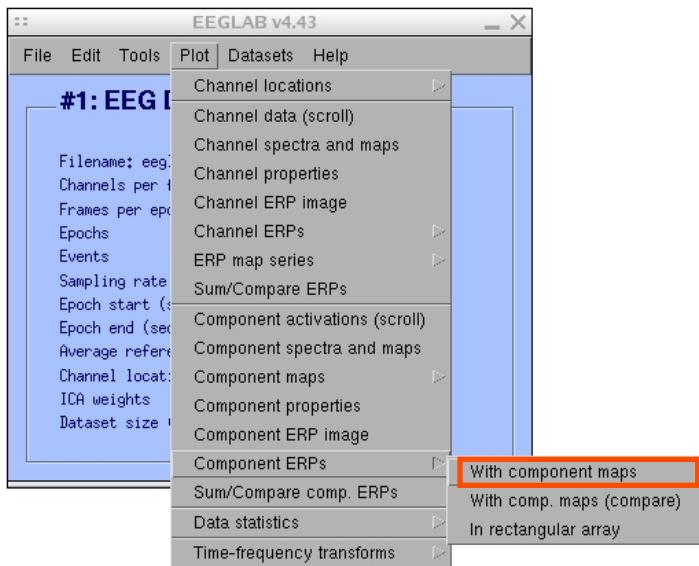
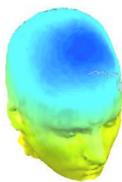


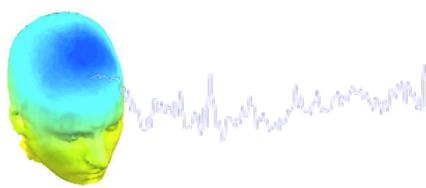
20 (5.6%)



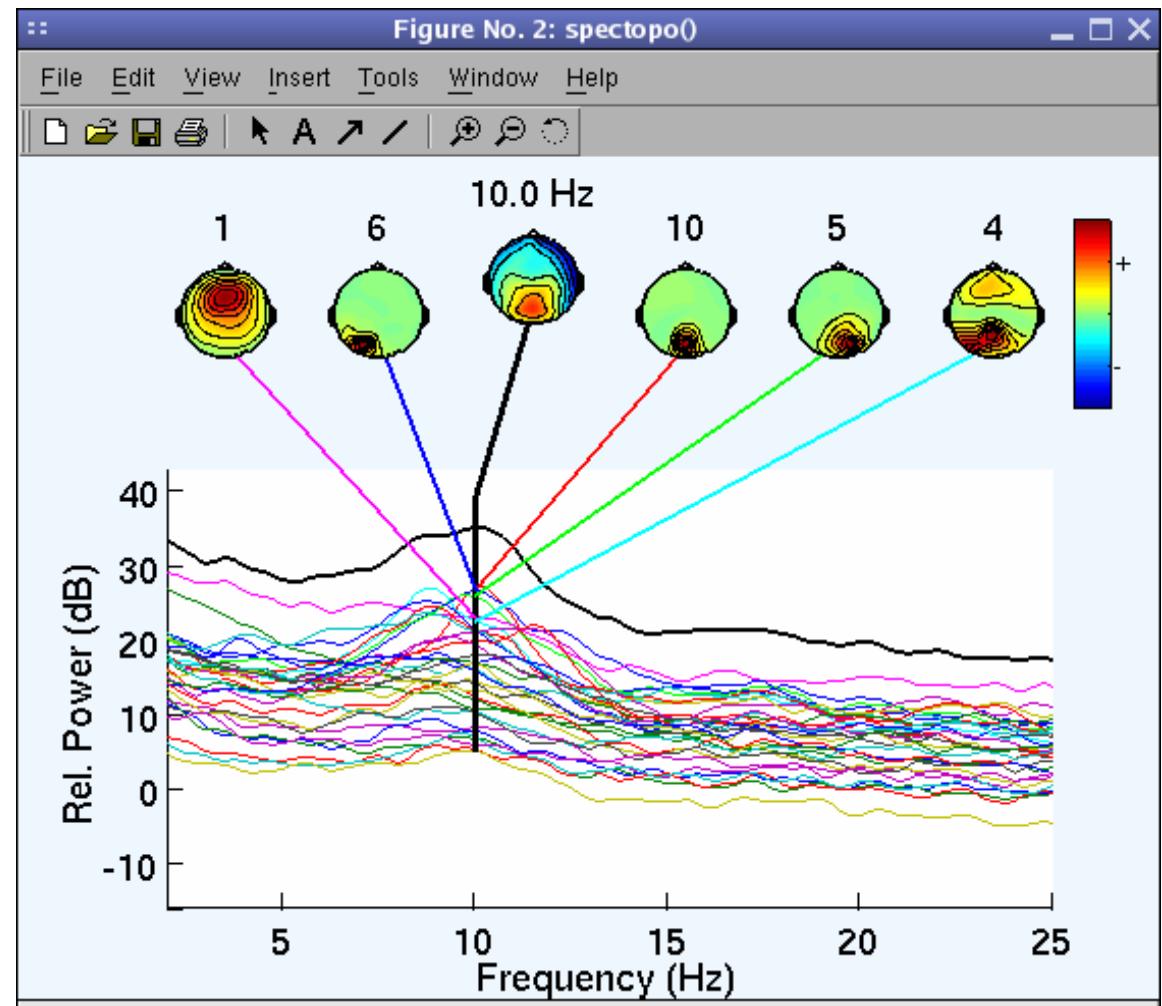
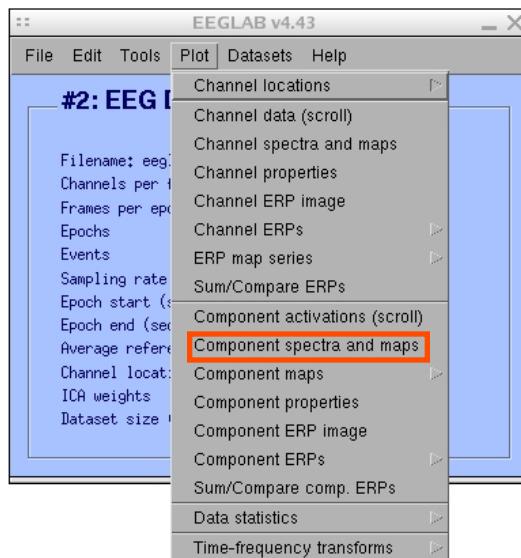
ap82

# Component contribution to the ERP

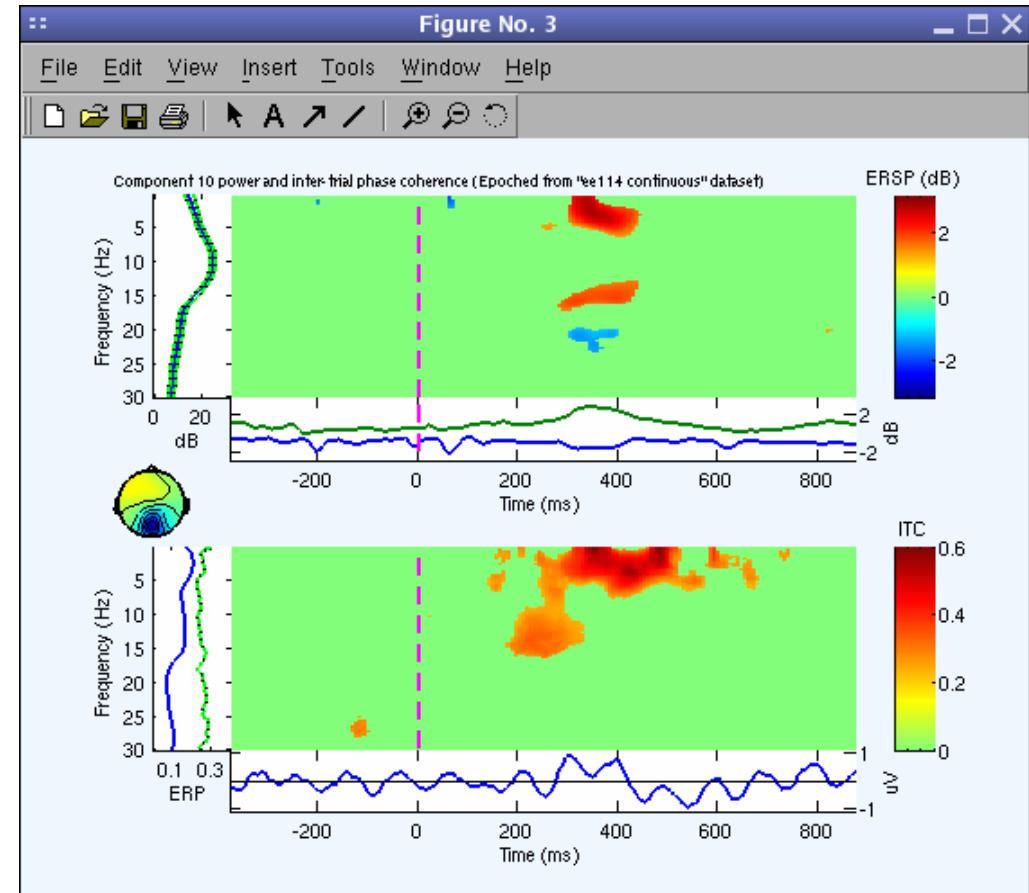
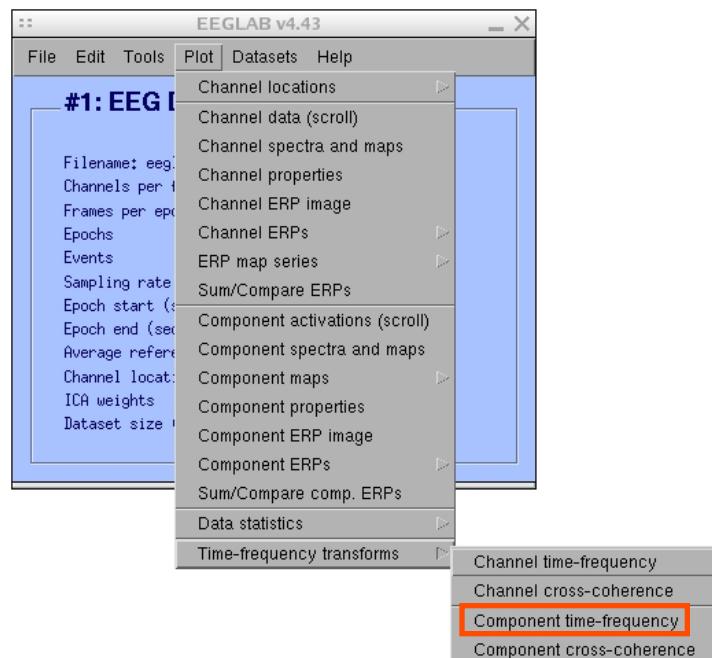
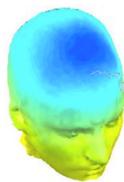




# Component contribution to the EEG spectrum



# Component time-frequency



# EEGLAB standard processing pipeline



## Single subject

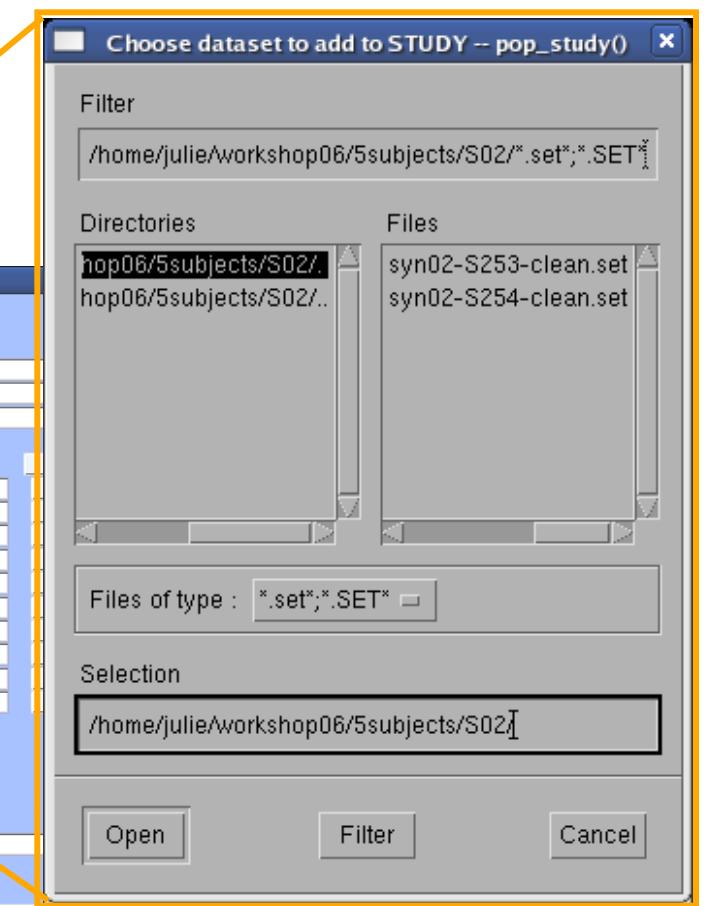
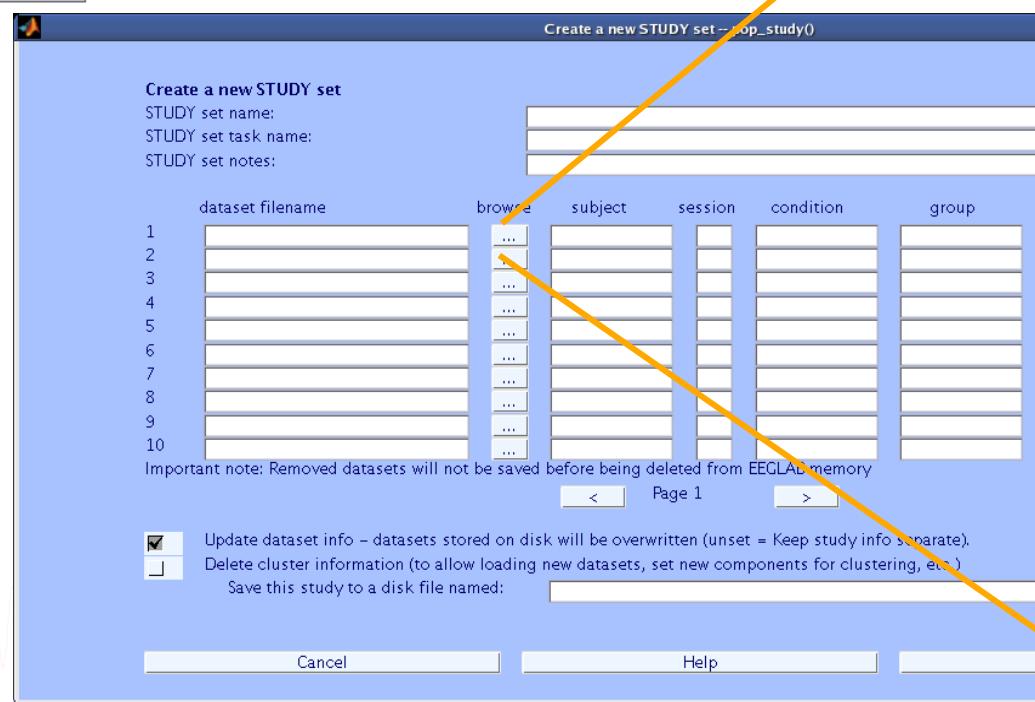
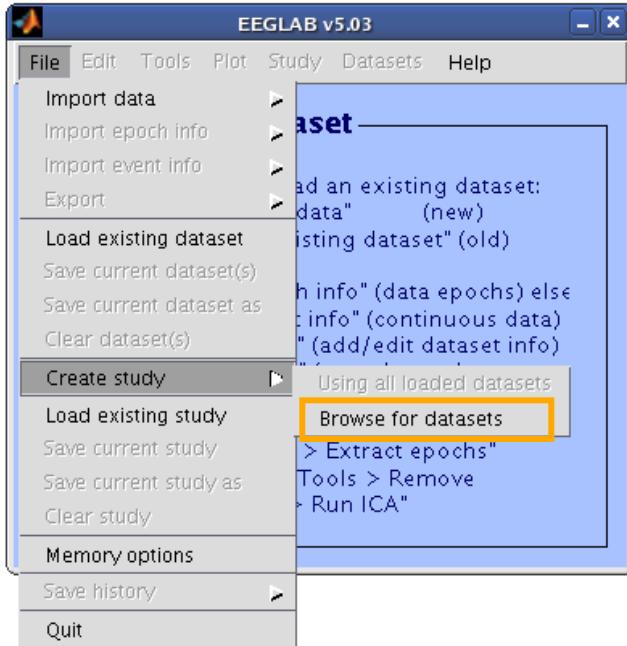
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  - Analyze components contribution to ERP
  - Analyze components contribution to spectrum

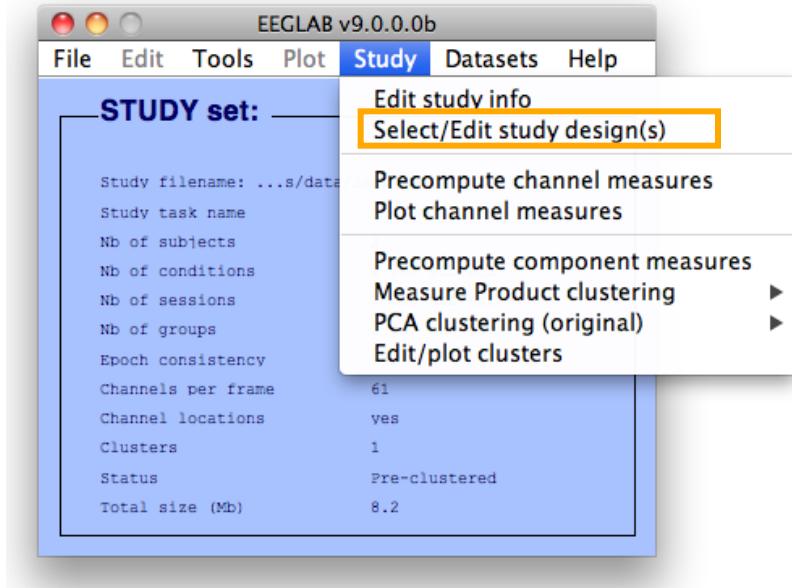
## Multi-subjects

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

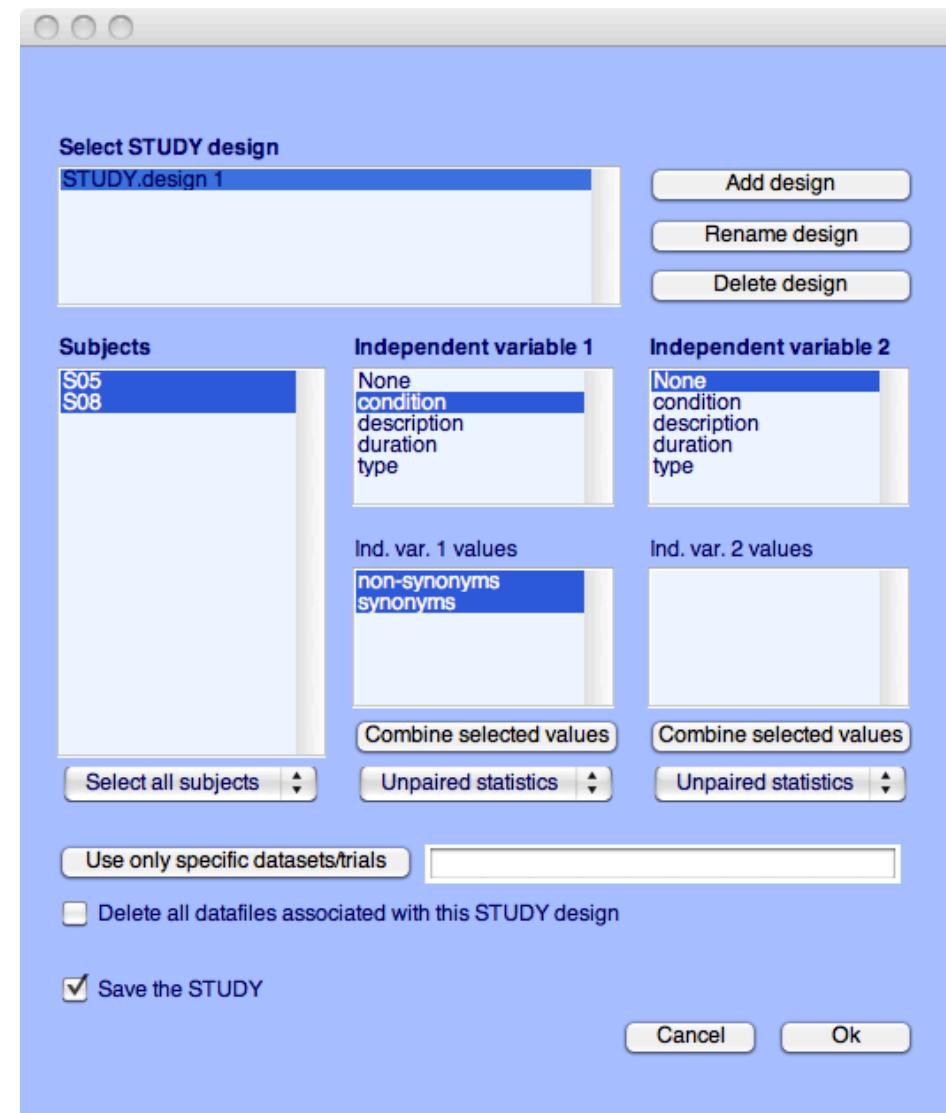
Advanced analysis using scripting and EEGLAB command line functions

# 1. Build a STUDY



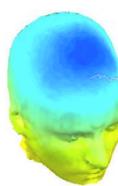


# Edit STUDY design

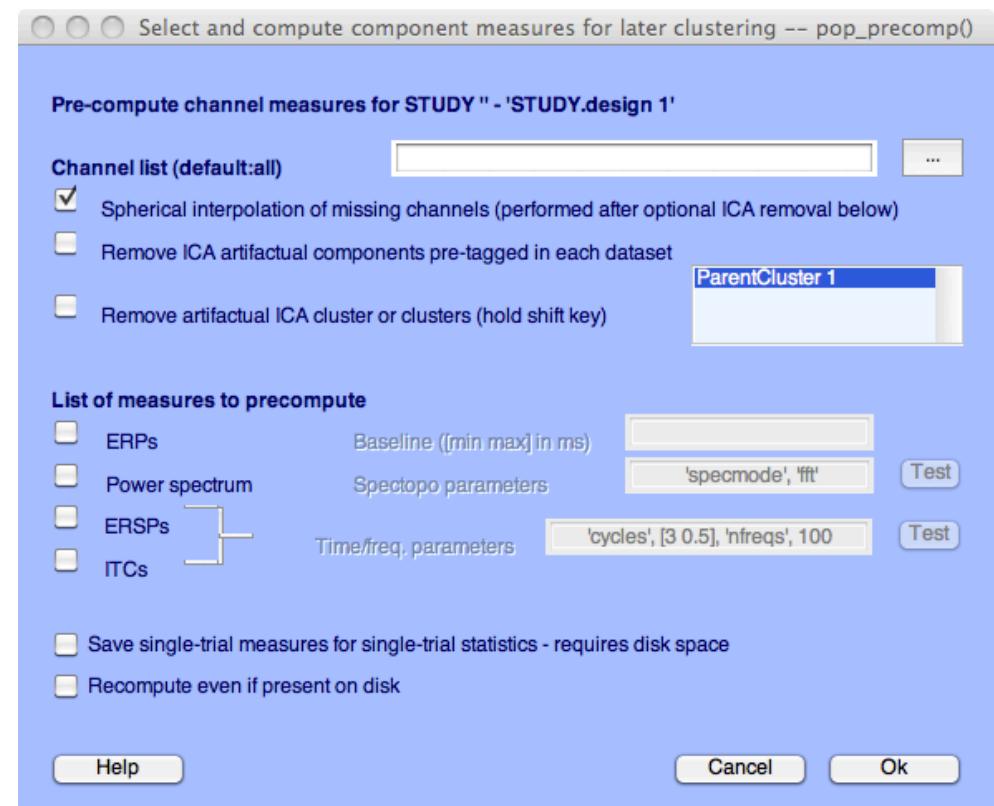
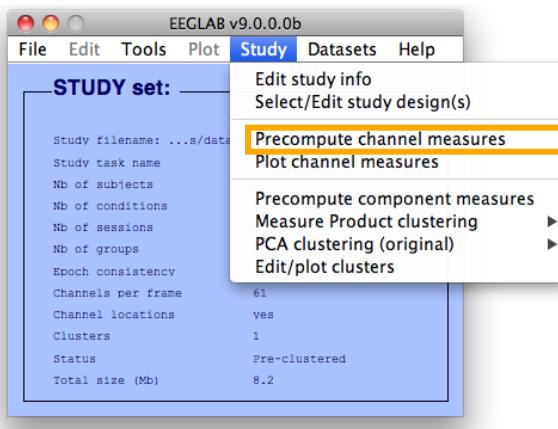
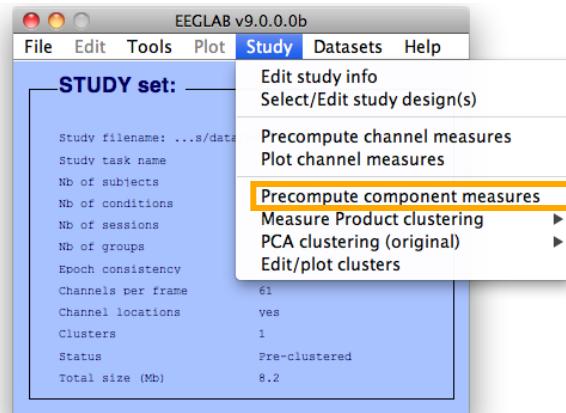


# Channels

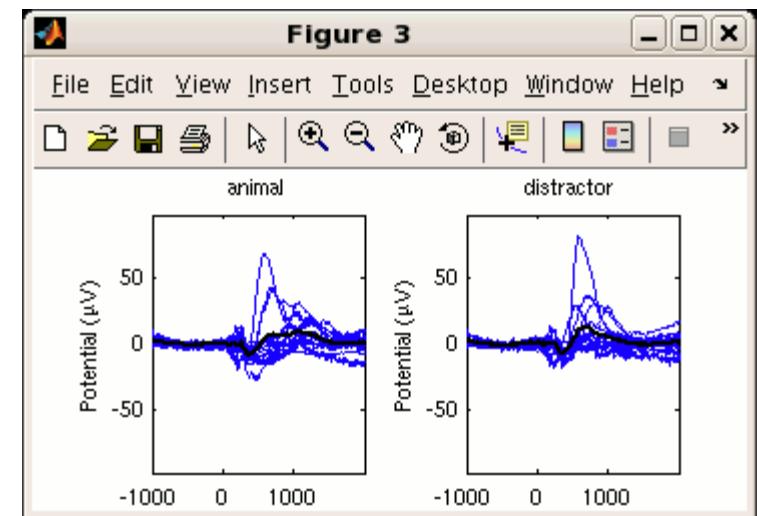
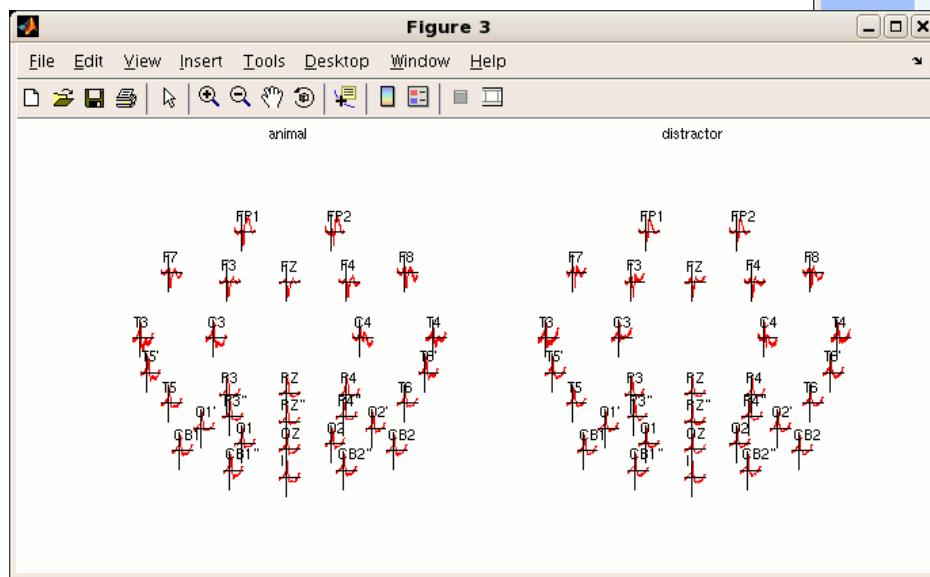
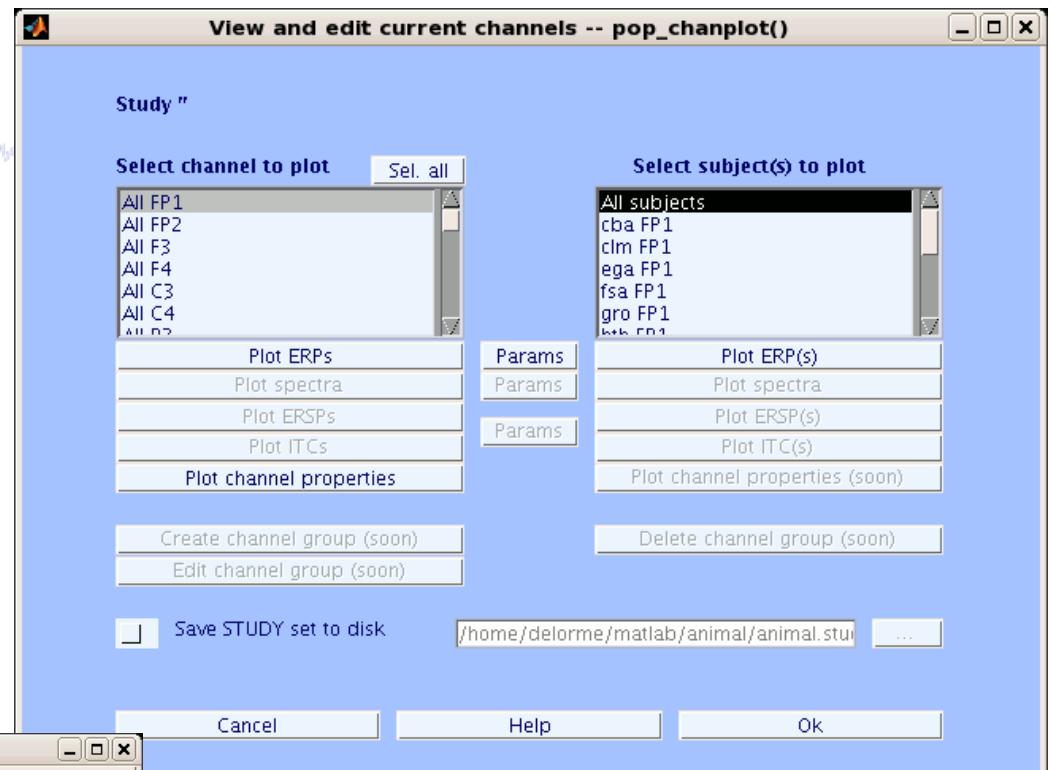
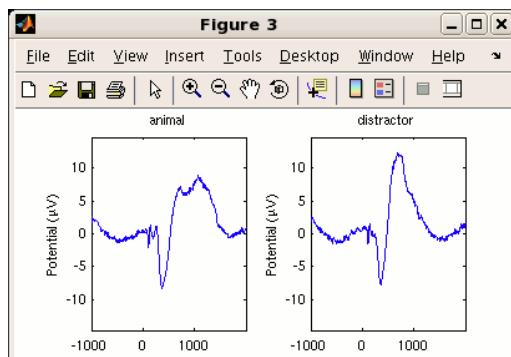
# Components



# 2. Pre-compute measures



# Channel plotting



# 3. Cluster components



EEGLAB v6.0b

File Edit Tools Plot Study Datasets Help

**STUDY set: Attention**

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

Build preclustering array

Select and compute component measures for later clustering -- pop\_prelust()

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
<input checked="" type="checkbox"/> ERPs	10	<input checked="" type="checkbox"/>	1
<input checked="" type="checkbox"/> dipoles	3	<input checked="" type="checkbox"/>	10
<input type="checkbox"/> scalp maps	10	<input checked="" type="checkbox"/>	1
<input checked="" type="checkbox"/> ERSPs	20	<input checked="" type="checkbox"/>	1
<input checked="" type="checkbox"/> ITCs	10	<input checked="" type="checkbox"/>	1
<input type="checkbox"/> Final dimensions	10	<input type="checkbox"/>	Help

Freq.range [Hz] 3.25  
Time range [ms] 0.600

Absolute values

Use channel values

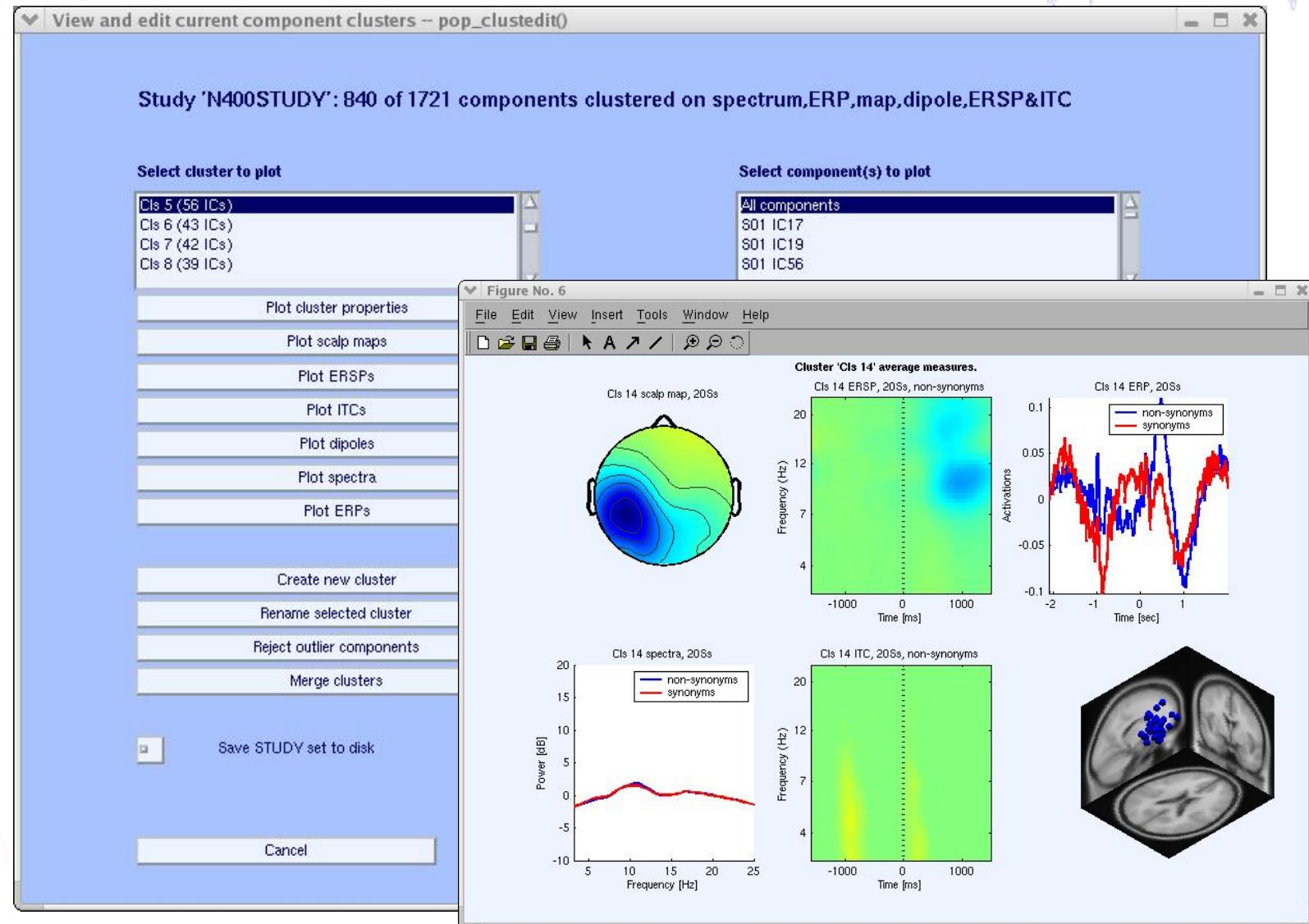
Time range [ms] 0.1500  
Freq. range [Hz] 3.45

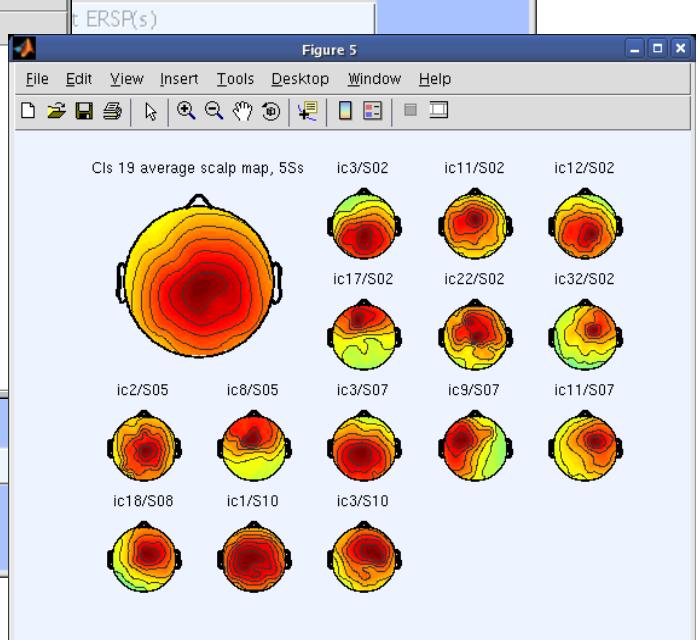
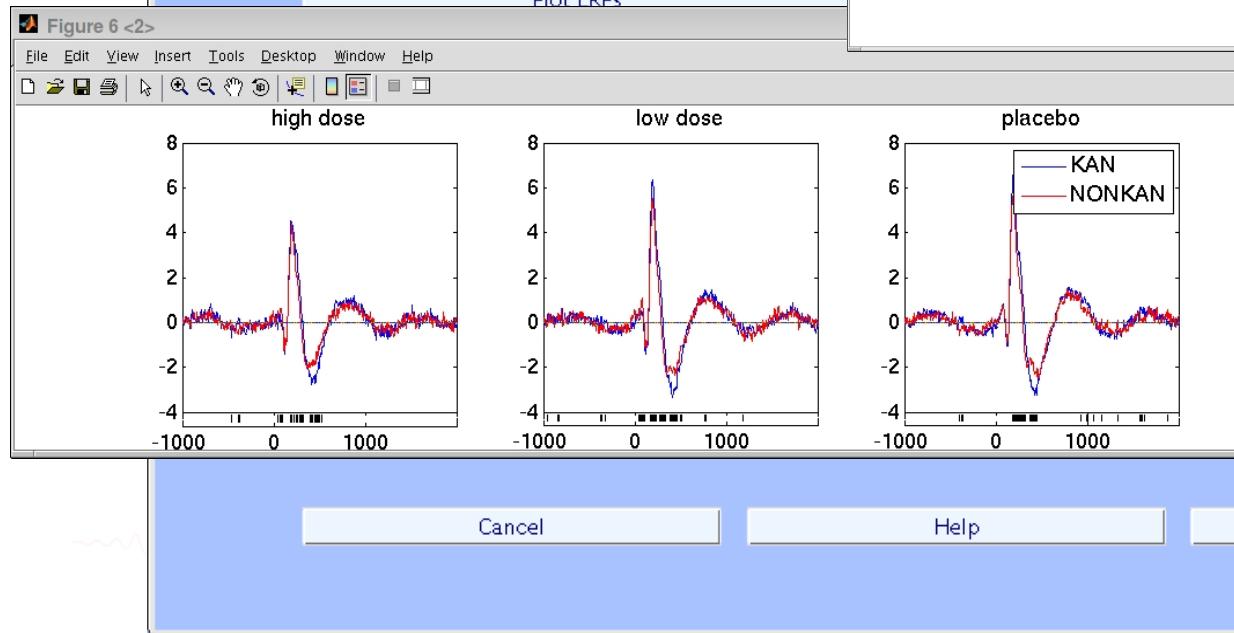
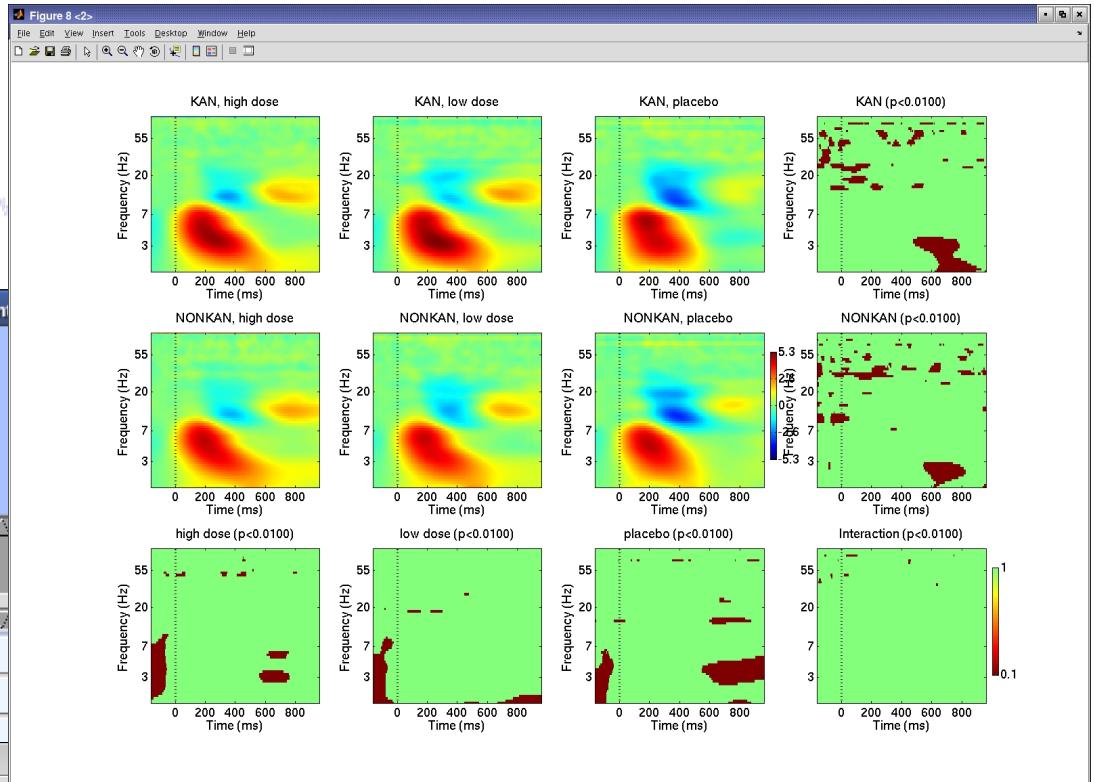
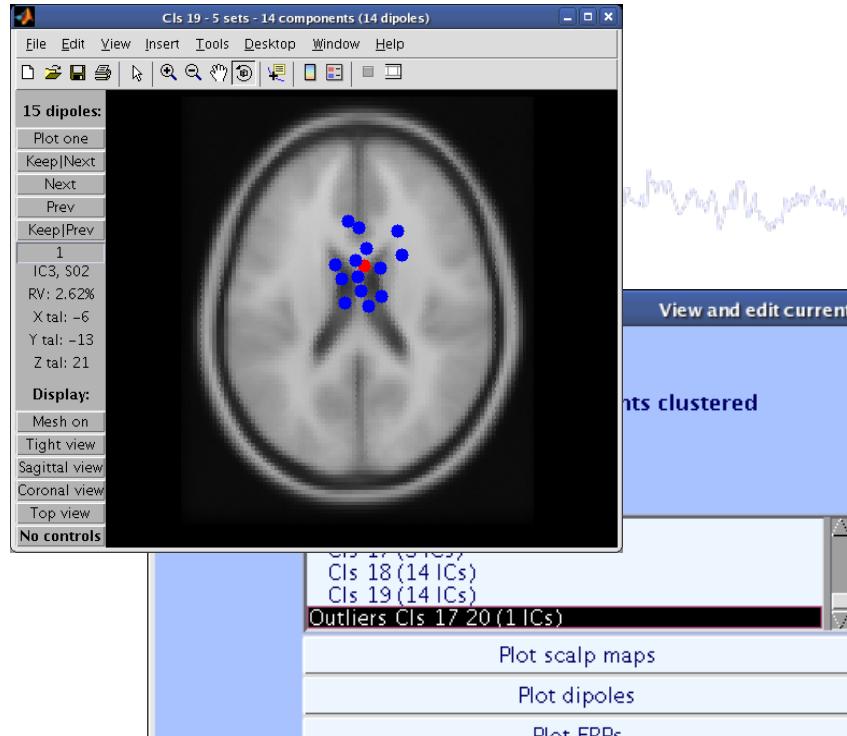
Time range [ms] 0.600  
Freq. range [Hz] 2.30

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

Cancel Help Ok

# 4. Analyze clusters





# 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:'ee114squaresepochechs.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]  
averref:'no'  
rt:[]  
eventdescription:{1x5 cell}  
epochdescription:{}  
specdata:[]  
specicaact:[]  
reject:[1x1 struct]  
stats:[1x1 struct]  
splinofile:[]  
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

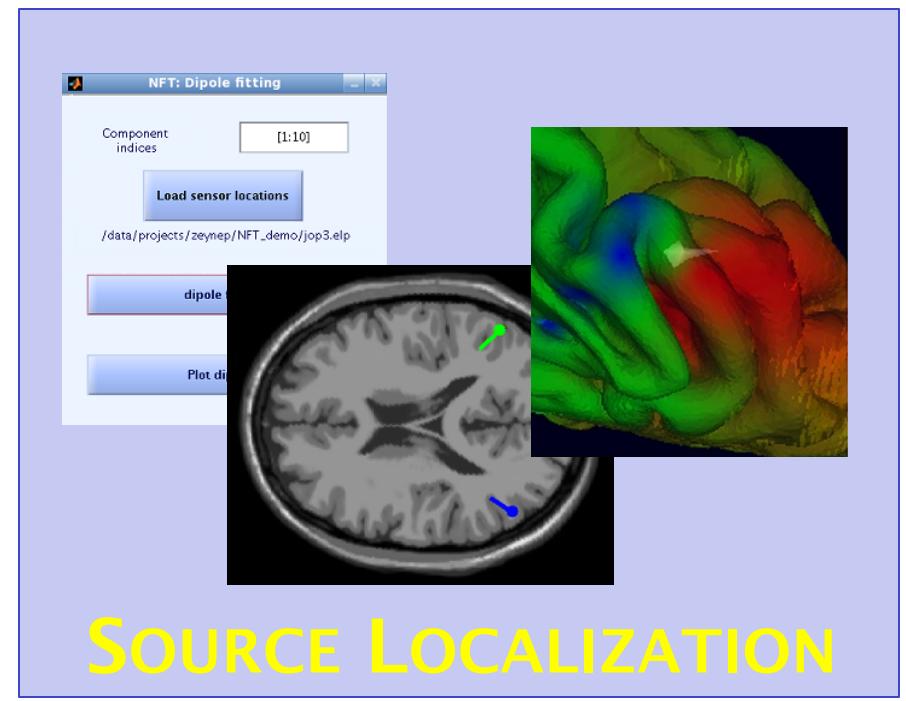
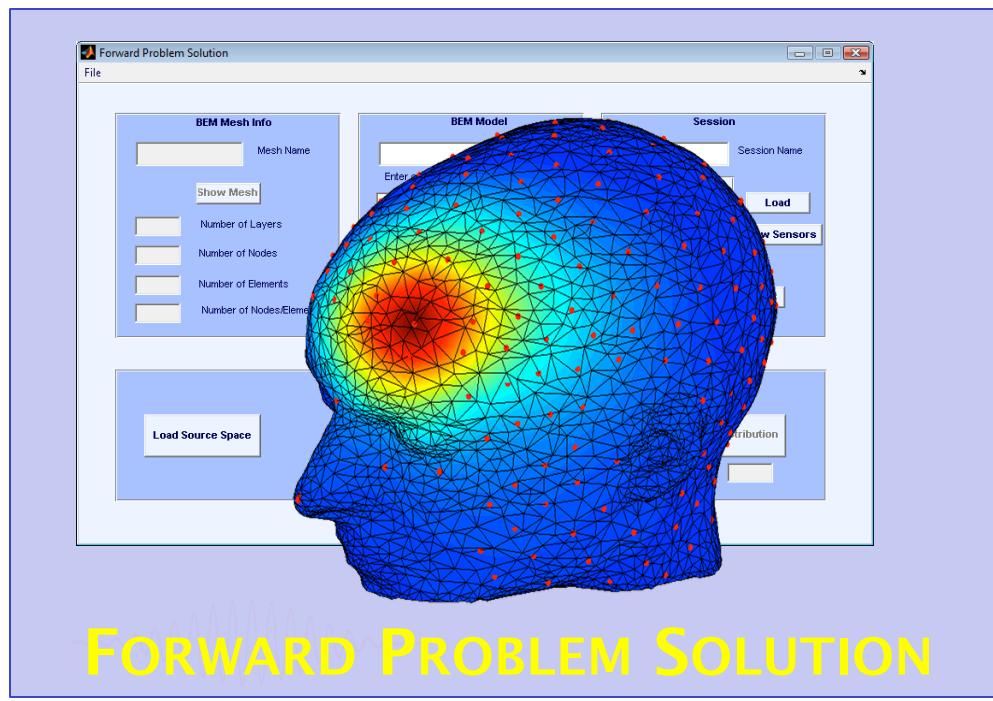
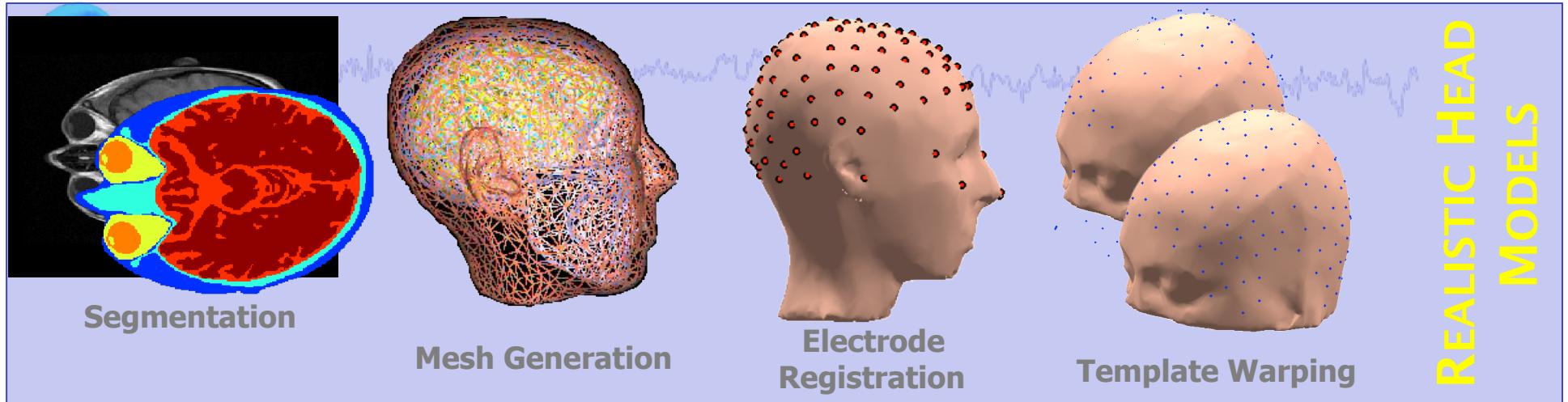


(“eegh” Menus write both dataset and global history)

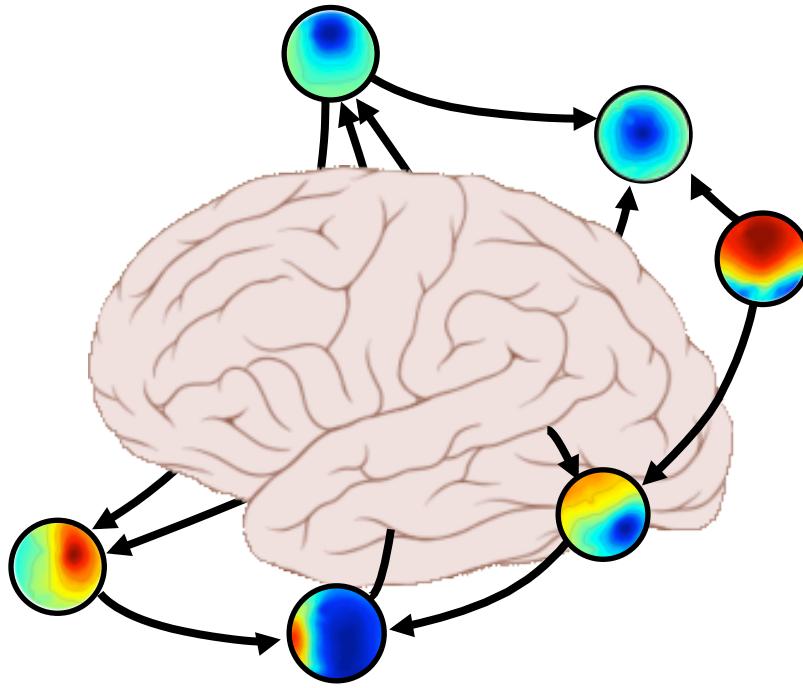
- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, ...)
- Custom processing...



# NFT: Neuroelectromagnetic Forward Head Modeling Toolbox



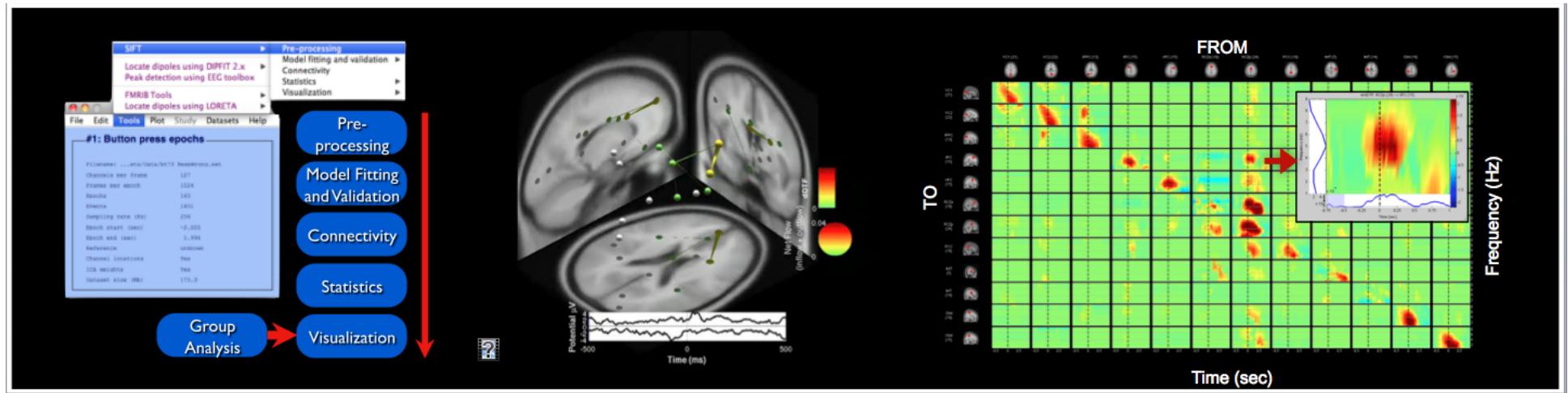
<http://sccn.ucsd.edu/nft>



# SIFT

Source Information Flow Toolbox

*"It makes you cool"*



# BCILAB - C. Kothe

Review/edit approach BCILAB 0.9 Data Source Offline Analysis Online Analysis Settings Help

Selected approach lastapproach ("Spectrally Weighted C...")

Calibration data source lastdata ("imag.vhdr")

Parameter Search

Loss/Performance Metric Automatically chosen

Cross-validation folds 5

Spacing around test trials 5

Performance estimates

Cross-validation folds 10

Number of test trials 5

Outer cluster

Node pool (use current config)

Specspace as lastmodel

Testspace as laststats

Cancel OK

Approach properties:

- Signal Processing
- SignalProcessing
  - FilterOrdering
  - Resampling
    - SamplingRate
    - ChannelSelection
    - Rereferencing
  - ICA
    - SurfaceLaplacian
    - FIRFilter
    - Projection
    - IIRFilter
    - Standardization
    - SparseReconstruction
  - EpochExtraction
    - TimeWindow
    - EventTypes
    - BaselineRemoval
    - WindowSelection
    - SpectralTransform
  - SpectralSelection
    - FrequencySpecification
  - Feature Extraction
  - FeatureExtraction
    - PatternPairs
    - ParameterP
    - ParameterQ
    - SpectralPrior
    - MaxIterations
  - PluginFunctions
    - FeatureAdaptor
- ICA
  - Annotate the Signal with a spatial ICA (flt\_ica).

Help

Figure 2: Common Spatial Patterns

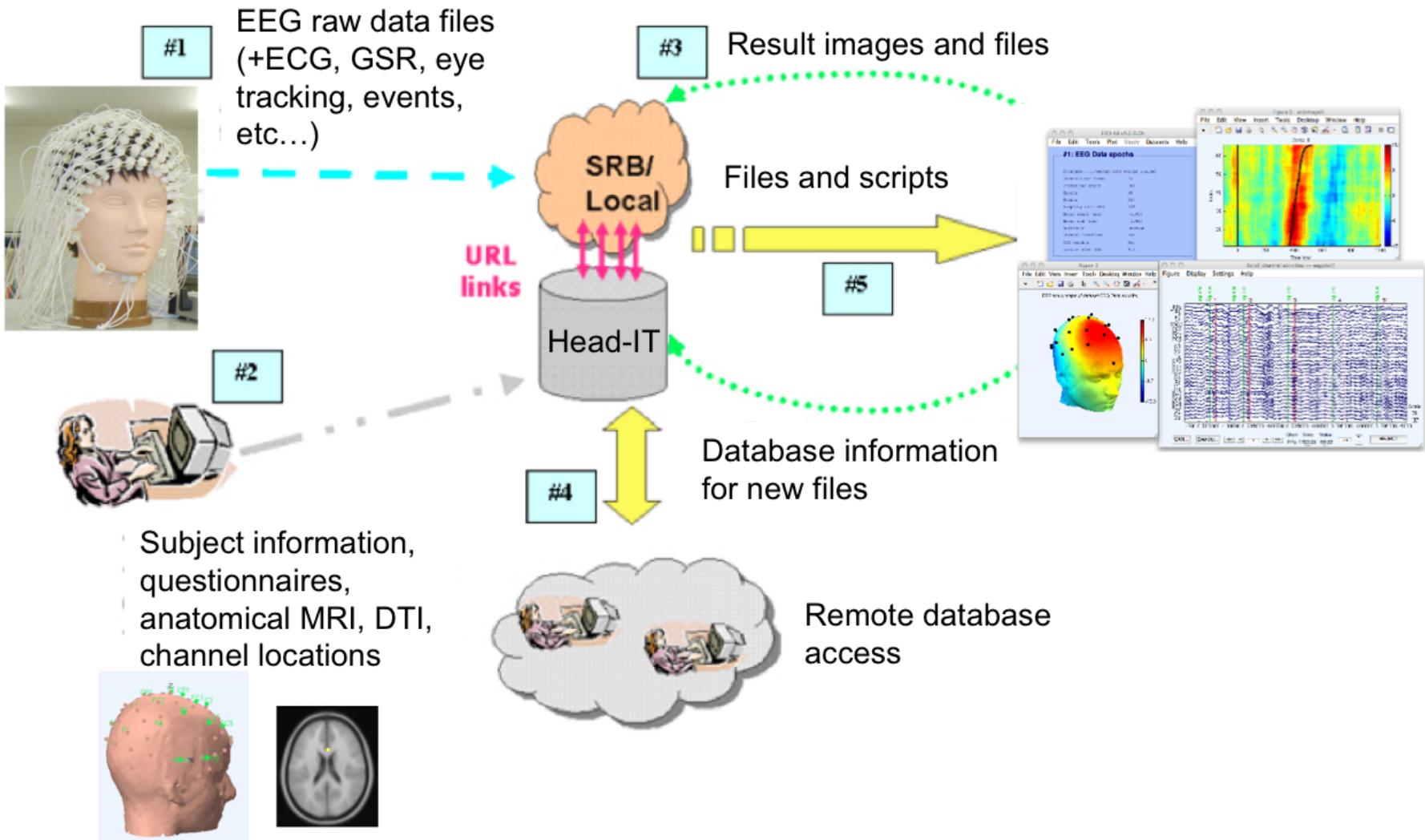
Spec-CSP Pattern 1 Spec-CSP Pattern 2 Spec-CSP Pattern 3

Spec-CSP Pattern 6 Spec-CSP Pattern 5 Spec-CSP Pattern 4

The BCILAB 0.9 software interface is displayed. The main window shows a grid of spatial patterns and corresponding time-series plots. The spatial patterns are represented by circular topoplots with electrode positions marked by dots. The time-series plots show amplitude over time (0 to 40 units) for each pattern. Below the plots, there are two rows of three patterns each, labeled Spec-CSP Pattern 1 through 6. The top row contains Spec-CSP Pattern 1, 2, and 3. The bottom row contains Spec-CSP Pattern 6, 5, and 4. The left side of the interface features a tree-based 'Approach properties' panel with categories like Signal Processing, ICA, and Feature Extraction. A central toolbar provides various signal processing tools. The top menu bar includes options like Data Source, Offline Analysis, Online Analysis, Settings, and Help. A context menu is open over the ICA section, listing options such as 'New approach...', 'Modify approach...', 'Review/edit approach...', 'Save approach...', 'Train new model...', 'Apply model to data...', 'Visualize model...', 'Investigate results...', and 'Transform data by model...'. On the right side, there are several configuration panels for calibration, parameter search, and performance metrics. A code editor window at the bottom right displays MATLAB code related to the analysis.

```
on, 'ZO', 0, 'F1', 1, 'Err', 2,
    'n-SlackShrink', 1, '1-Sla
    'poly', 1, 'rbf', 2, 'sigmoid
    'SubsetHeuristic', 1, 'FixedI
    1, '12', 2);
    'slack', 1, 'margin', 2
    -o %d -l %d -w %d -e %f
```

# EEG database: HEAD-IT framework



# 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 Workshop*

## *Program Session I*



**Thursday, Nov. 18**

**8:00 - 8:30 am Check-in open (park early!)**

8:30 – 10:00 am - Mining event-related brain dynamics I (Scott Makeig)

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

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

11:00 am – 12:00 pm - Time-frequency decomposition (Arnaud Delorme)

12:00 pm – 12:30 pm - Independent component analysis (ICA) theory I (Jason Palmer)

**12:30-1:30 Lunch on your own on campus**

1:30 pm – 2:00 pm - ICA theory II (Jason Palmer)

2:00 – 3:00 pm - Data import and channel analysis (Klaus Gramann)

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

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

4:30– 5:30 pm - Basic scripting using EEGLAB "history" and the EEG structure (Julie Onton)

5:30 – 6:30 pm - Free time to explore EEGLAB using tutorial data and/or your own data

**Friday, Nov 19**

8:30 – 9:15 pm - Using bootstrap statistics (David Groppe)

9:15 – 10:30 am - The new 'STUDY.design' facility and multi-subject plotting (Arnaud Delorme)

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

11:00 – 11:45 am – Forward and inverse source modeling (Zeynep Akalin Acar)

11:45 – 12:30 am – Using the DIPFIT toolbox (Julie Onton)

**12:30-3:00 Networking excursion: Picnic lunch and short hike in scenic Torrey Pines Reserve**

4:00 – 4:30 am - STUDY component clustering (Arnaud Delorme)

4:30 – 5:30 pm - Advanced uses of 'STUDY.design' statistics (Arnaud Delorme)

5:30 – 6:30 pm - Free time to work on tutorial projects and/or own data

**Saturday, Nov 20**

8:30 – 9:30 am – Mining event-related dynamics II (Scott Makeig)

9:30 – 10:00 pm — Building EEGLAB plug-ins (Arnaud Delorme)

10:00 – 10:30 am - Small groups work on tutorial projects

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

11:00 – 11:45 am - Continued work on tutorial projects

11:45 – 12:30 am – Group project presentations and General Discussion (all)

**12:30-1:30 Lunch on campus**

# *EEGLAB Workshop*

## *Program Session II*



### Saturday, Nov 20

- 1:30 – 2:30 pm – Comparing EEG dynamics across subjects using the Measure Projection toolbox (Nima Bigdely Shamlo)  
2:30 – 3:00 pm - Modeling effective connectivity by measuring source EEG information flow: theory (Tim Mullen)

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

- 3:30 – 5:00 pm - Modeling effective connectivity by measuring EEG information flow: practicum (Tim Mullen)  
5:00 – 6:30 pm - Free time to work on tutorial projects and/or own data

### Sunday, Nov 21

- 8:30 – 9:30 am – The NFT head modeling toolbox: overview (Zeynep Akalin Acar)  
9:30 – 10:30 am – The NFT head modeling toolbox: practicum (Zeynep Akalin)

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

- 11:30 – 12:00 pm - Imaging human agency with Mobile brain/body imaging (MoBI) (Scott Makeig)  
12:00 – 12:30 pm - The ERICA software environment for real-time, interactive experimental control and analysis (Andrey Vankov)

#### 12:30-1:30 Lunch on campus

- 1:00 – 2:10 pm - MoBI Lab demos (Dev Sarma, Grace Leslie, Nima Bigdley-Shamlo)  
2:10 – 2:30 pm - HeadIT: A resource for human electrophysiological data and tools (Jeff Grethe)  
2:30 – 3:00 pm - EEG classification and cross-validation using the BCILAB toolbox: overview (Christian Kothe)

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

- 3:30 – 5:00 pm - EEG classification and cross-validation using the BCILAB toolbox: practicum (Christian Kothe)  
5:00 – 6:30 pm - Free time to work on tutorial projects and/or own data

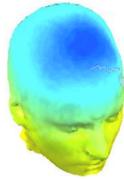
### Monday, Nov 22

- 8:30 – 9:15 am - New directions in electrophysiology: Mobile brain monitoring by wearable/wireless EEG (Tzyy Ping Jung)  
9:15 – 9:30 am - Mobile brain monitoring demo using 15-channel wireless dry electrode cap (TP Jung)  
10:00 – 10:30 am - Small groups work on tutorial projects

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

- 11:00 am – 12:00 pm --- Continued work on tutorial projects  
12:00 am – 12:30 pm --- Project results presentation and general discussion (all)

#### 12:30 pm - Workshop close



# EEGLAB articles

Delorme, A., Makeig, S. (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1), 9-21.

Makeig, S., Debener, S., Onton, J., Delorme, A. (2004) Mining event related dynamics. *Trends in cognitive Neuroscience*, 8(5), 204-210.

Delorme, A., Kothe, C., Bigdely, N., Vankov, A., Oostenveld, R., Makeig, S. Matlab Tools for BCI Research? In "human-computer interaction and brain-computer interfaces". Editors : Tan, D. and Nijholt, A. To appear in 2010. Springer Publishing.

Delorme, A., Mullen, T., Kothe, C., Bigdely-Shamlo, N., Akalin, Z., Vankov, A., Makeig, S. EEGLAB, MPT, NetSIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing. *Computational Intelligence*, accepted.

Delorme, A., Makeig, S. Open Source Programming for Interpreted Language: Graphic Interface and Macro Bridging Interface. *IEEE International Conference on Signal Image Technology and Internet Based Systems*. In press.