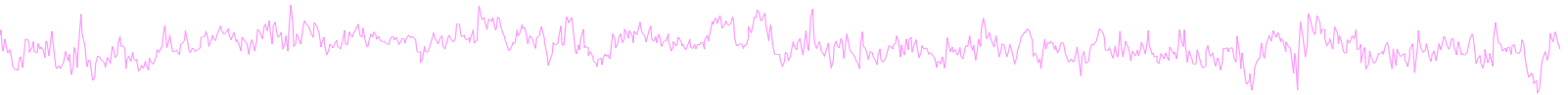
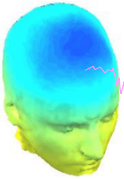


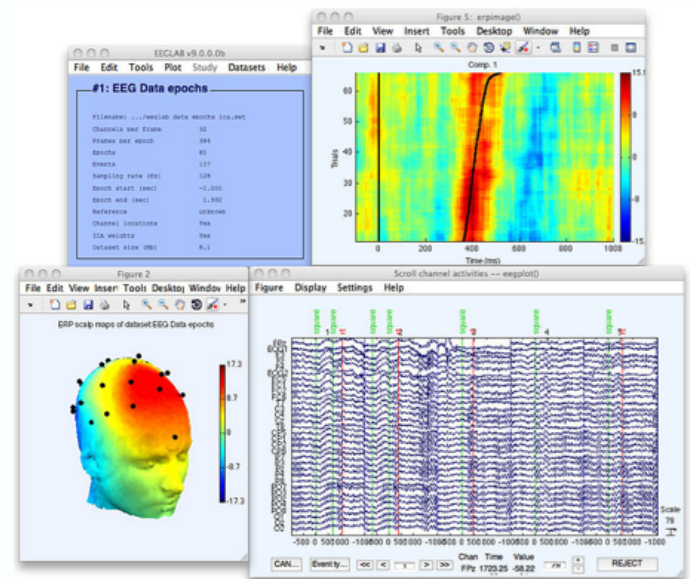
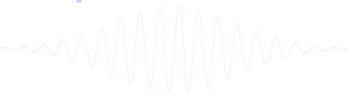
# EEGLAB overview



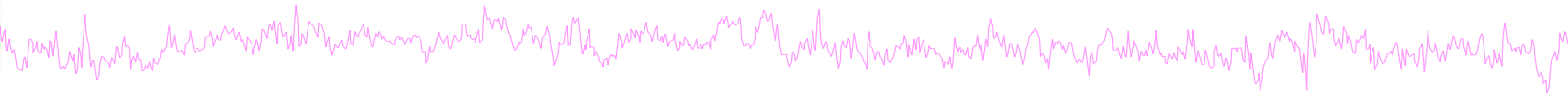
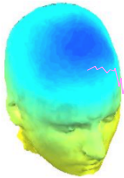
- Collection of about 600 functions (70 000 lines of code)
- About 100 000 download over the past 10 years
- 6 500 users on the discussion list and 10 500 on the diffusion list
- NIH funding since 2003

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

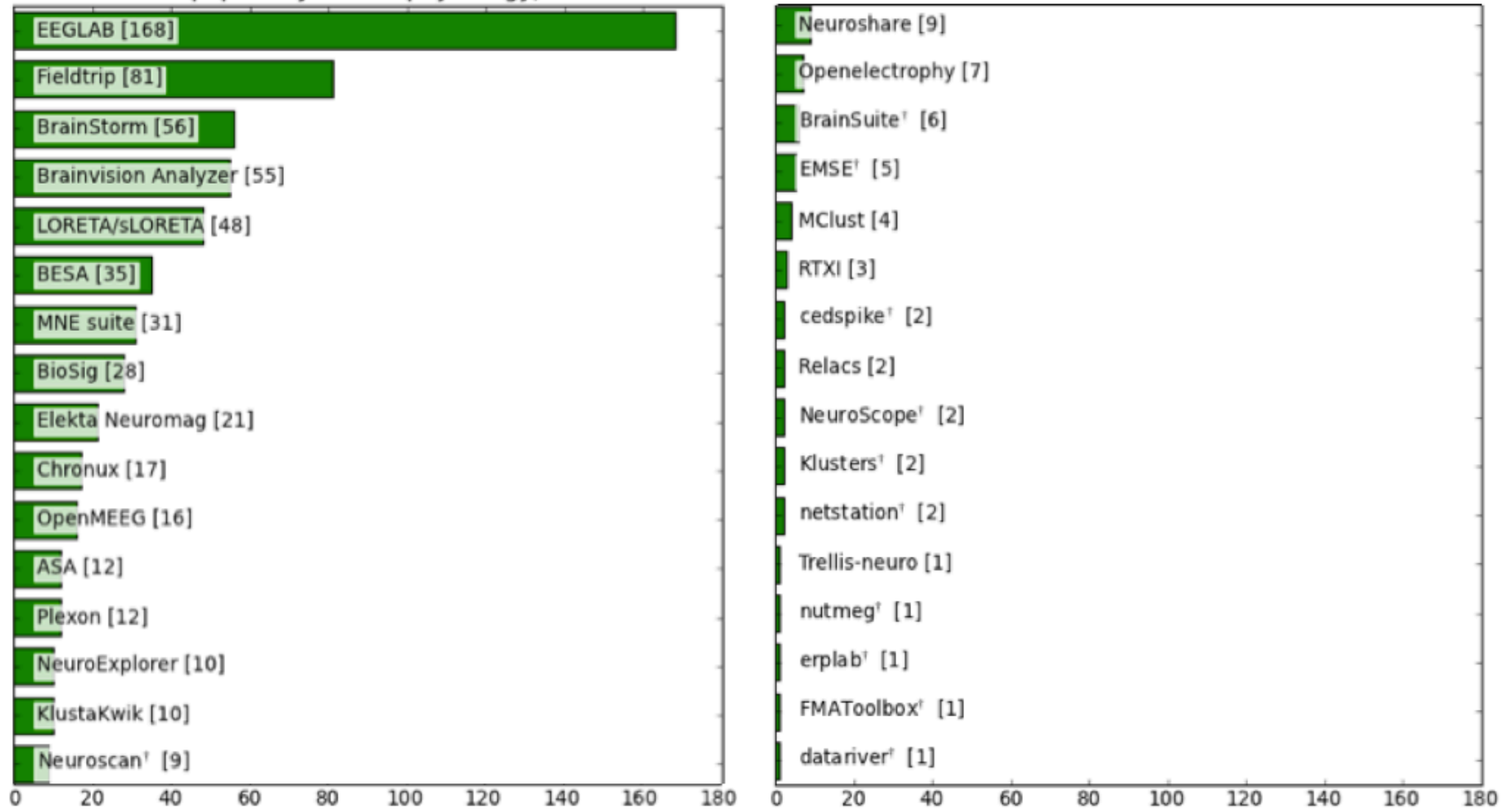
<http://sccn.ucsd.edu/wiki/eeglab>



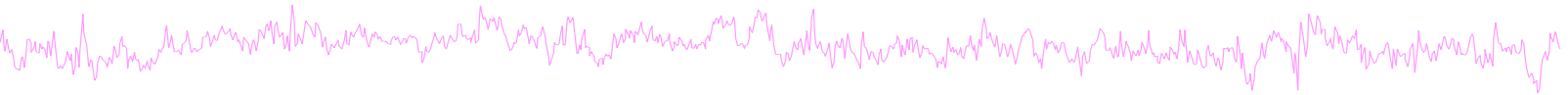
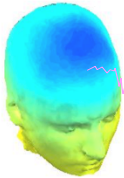
# Hanke & Helcencko, 2011, Frontier in Neuroinformatics



Software popularity: Electrophysiology, MEG/EEG



# 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

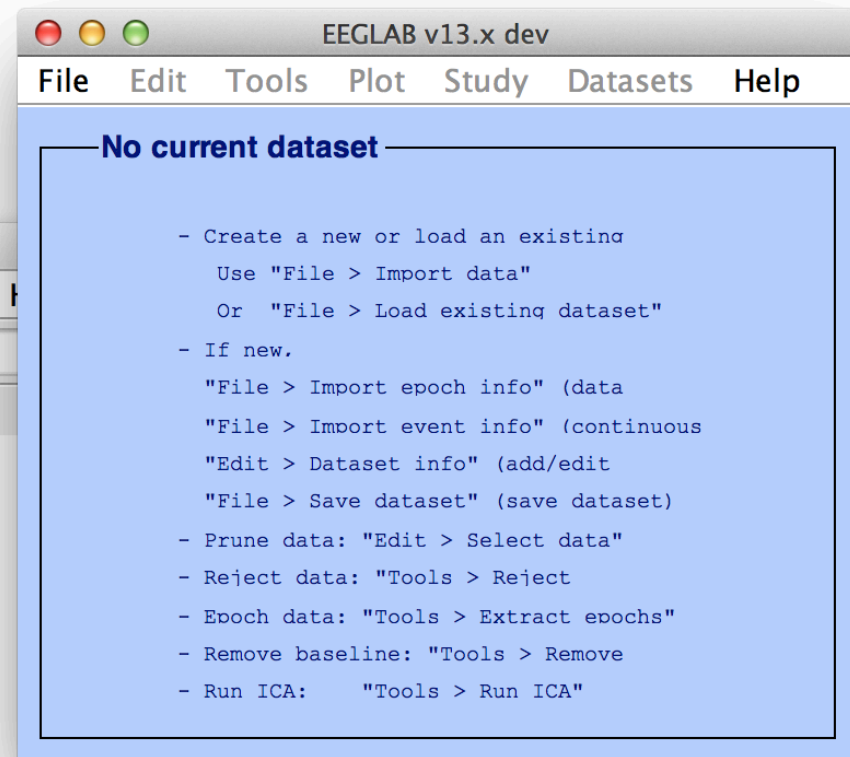
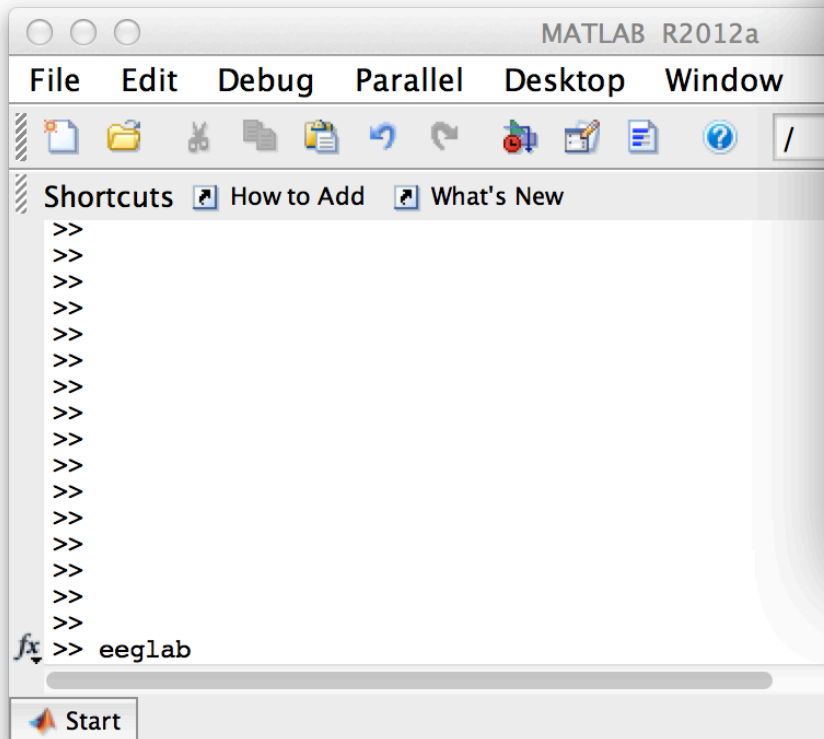
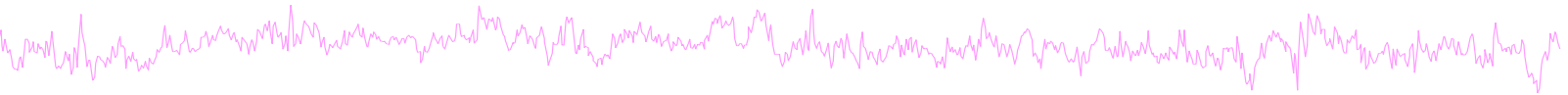
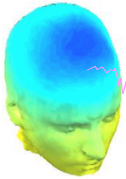
## Multi-subjects

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



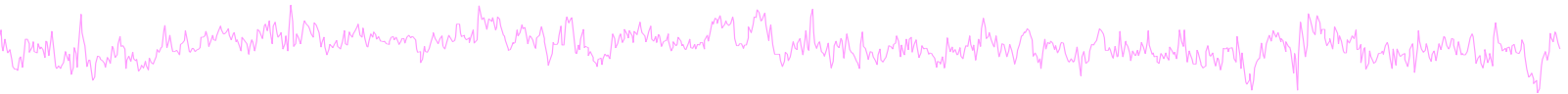
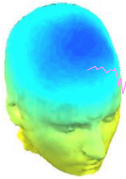
**Advanced analysis using scripting and EEGLAB command line functions**

# The EEGLAB Matlab software

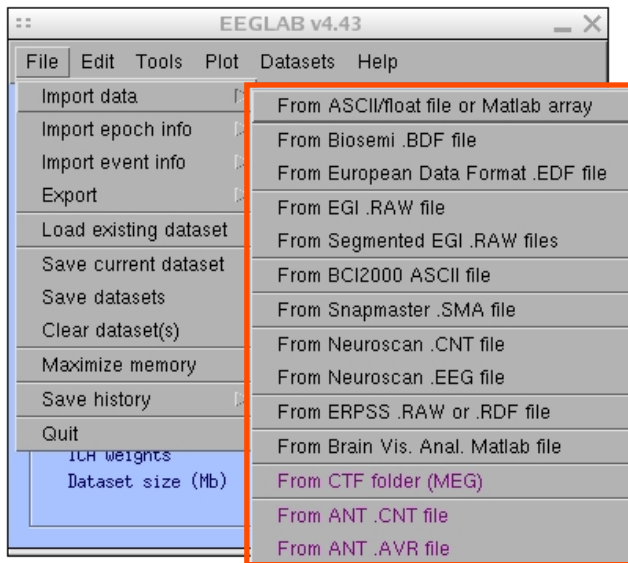




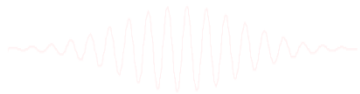
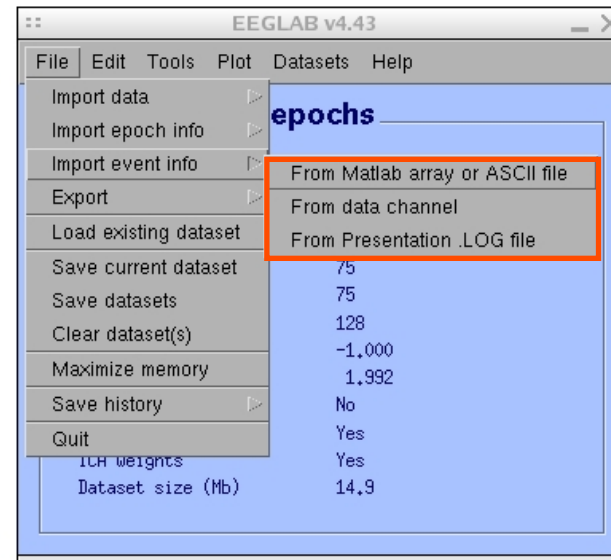
# 1. Importing data



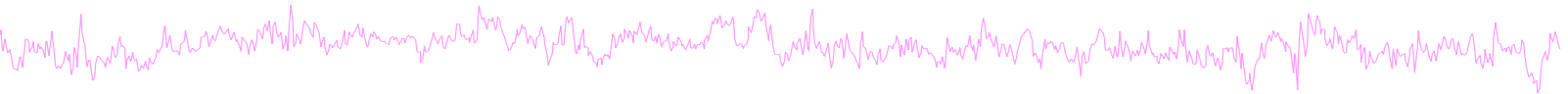
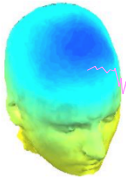
## Import/load data



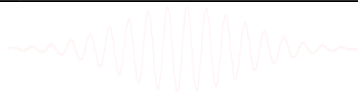
## Import events



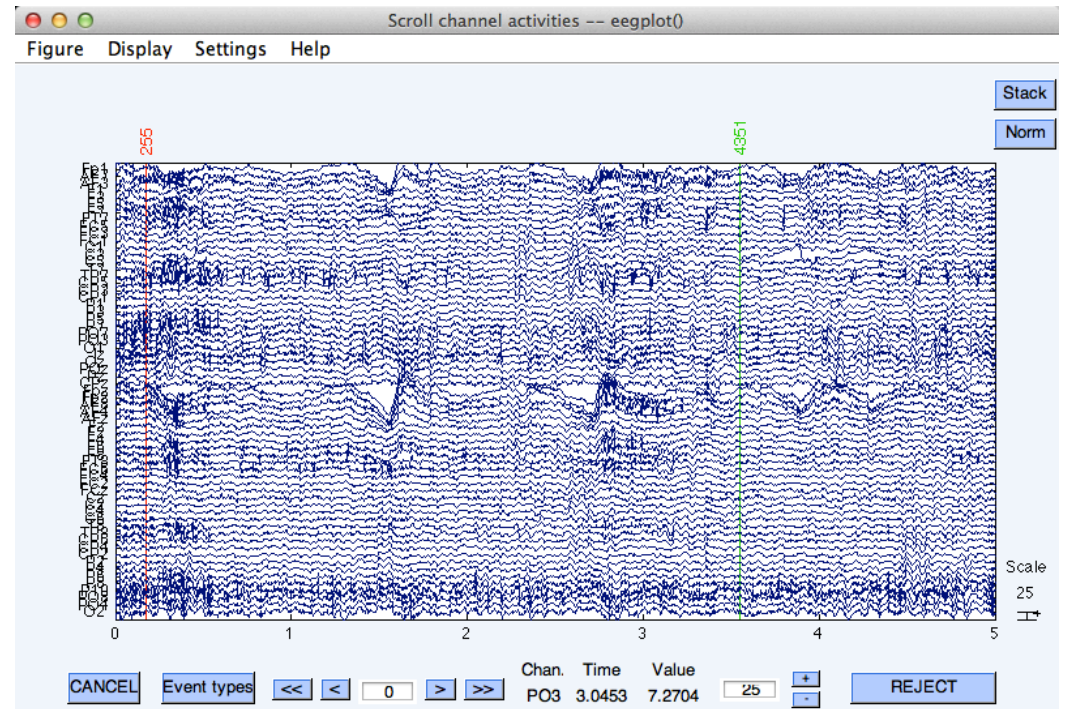
# 1. Importing data



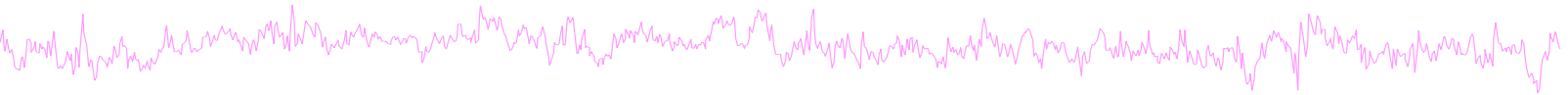
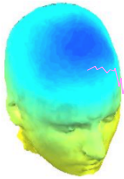
## Data info



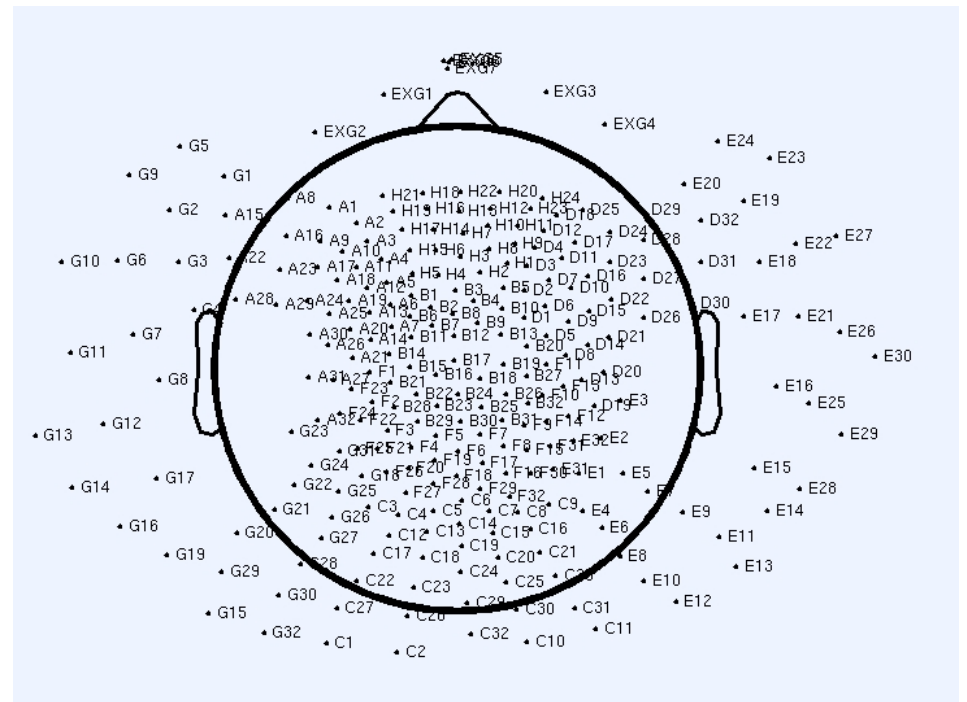
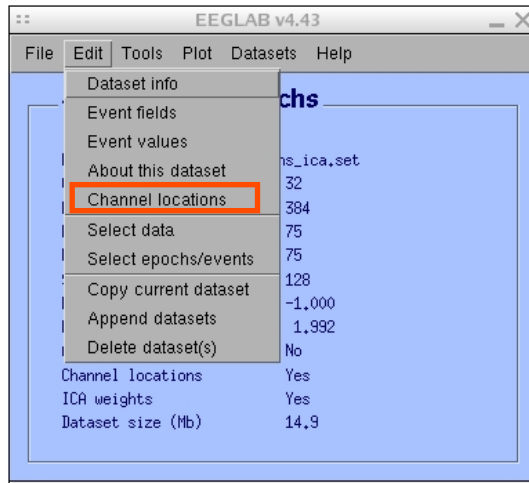
## Scrolling data



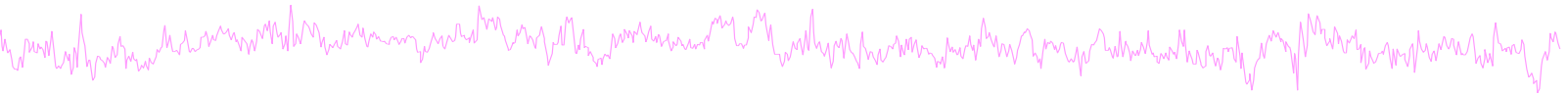
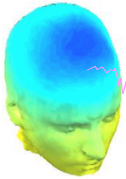
# 1. Importing channel location



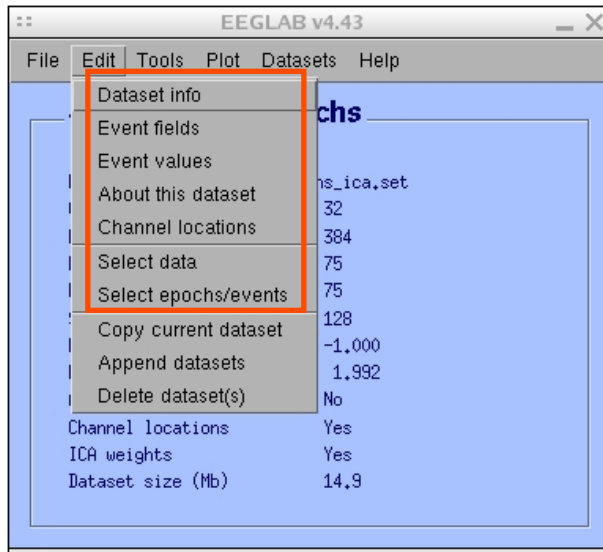
## Import channel location



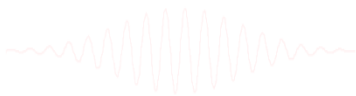
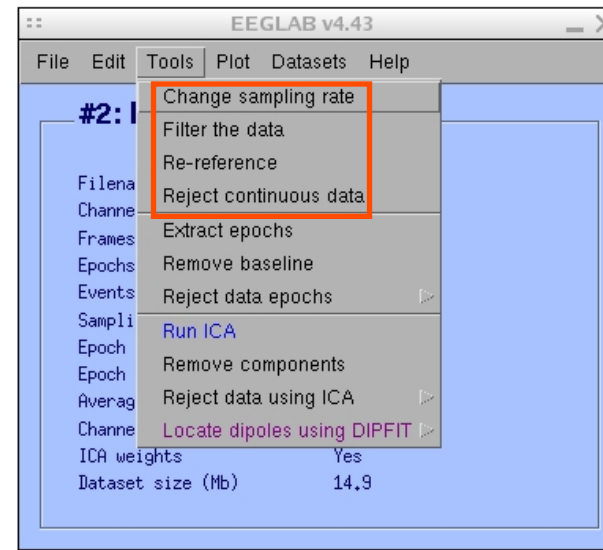
## 2. Edit, Re-reference, Resample, High pass filter data



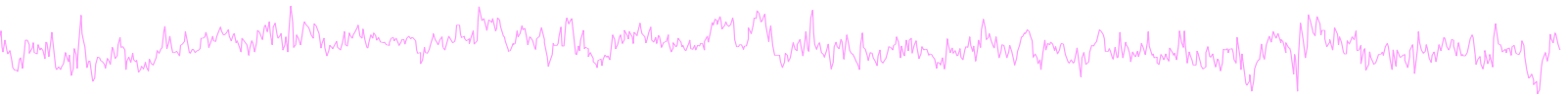
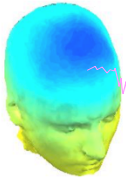
### Edit/select data



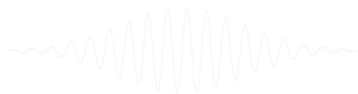
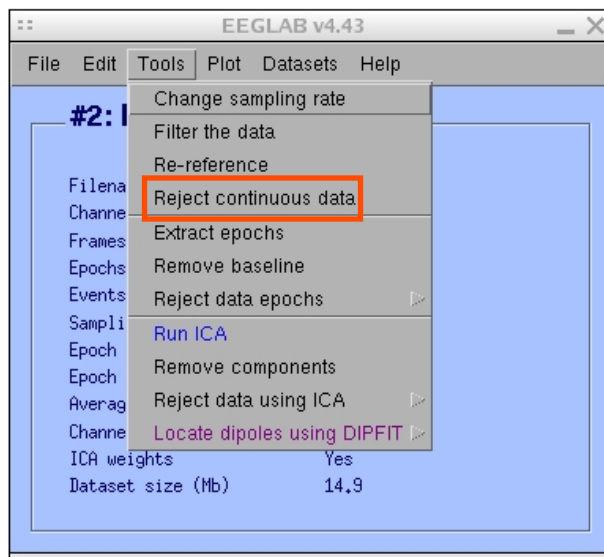
### Preprocessing data



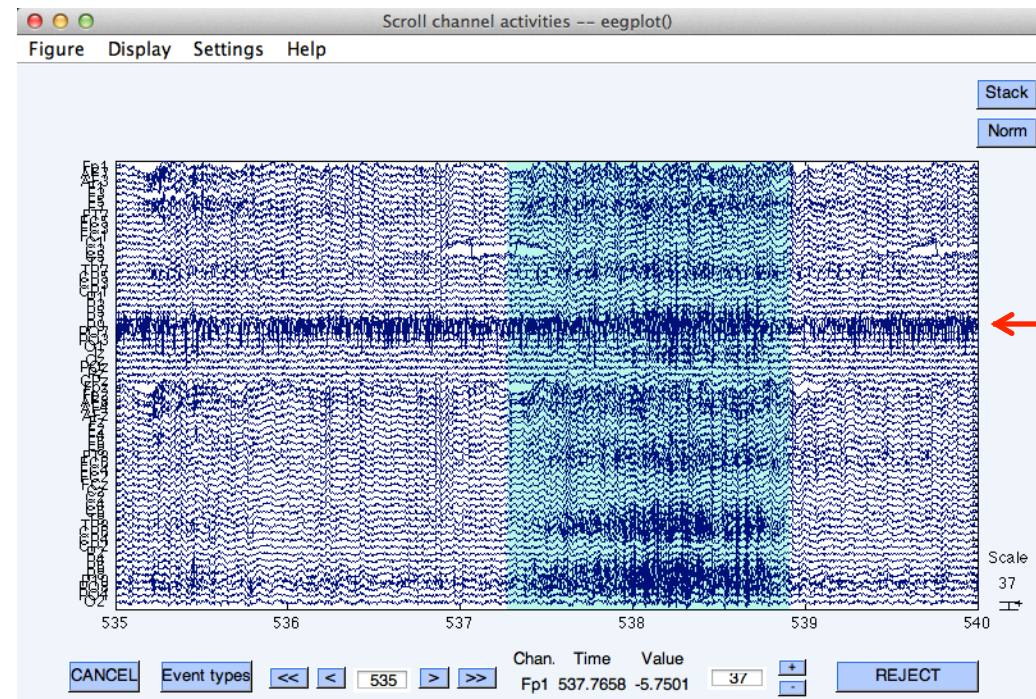
### 3. Reject artifacts in continuous data by visual inspection



#### Data info



#### Reject portions of continuous data

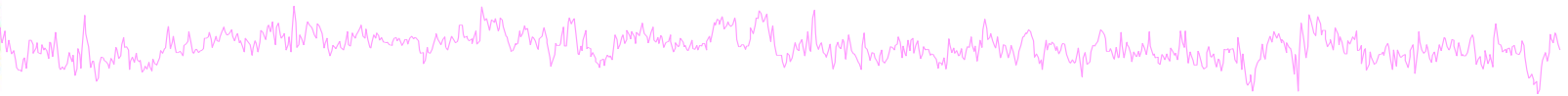
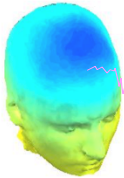


Bad channel

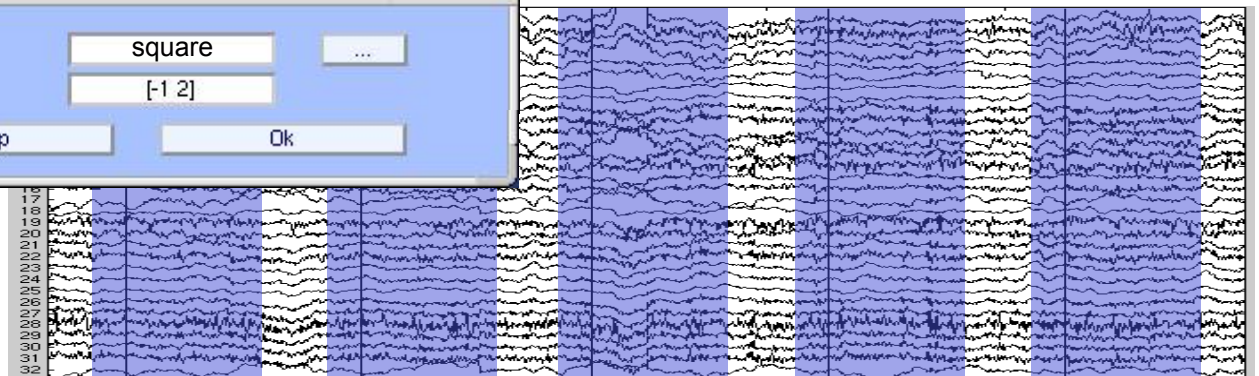
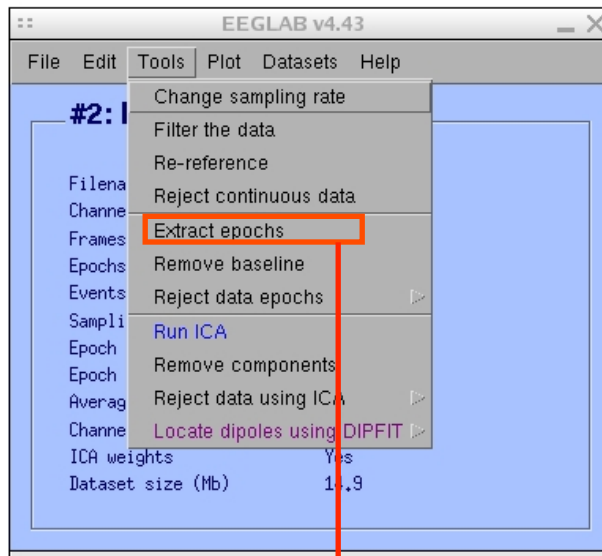
Bad portion of data



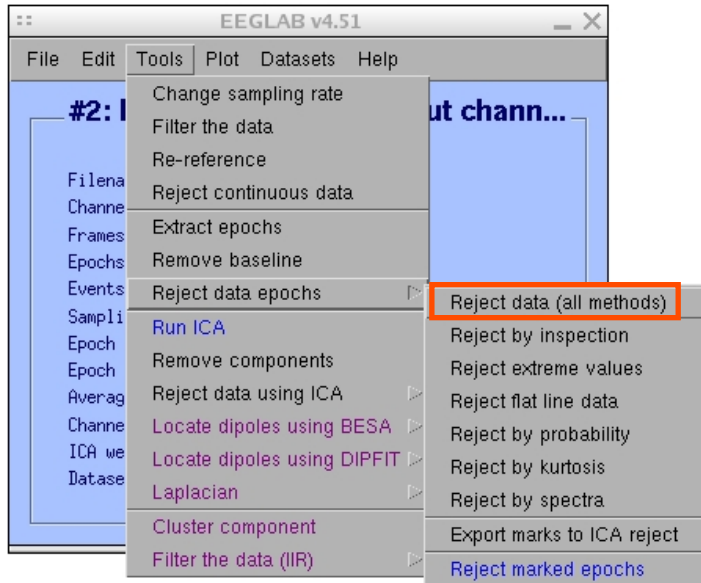
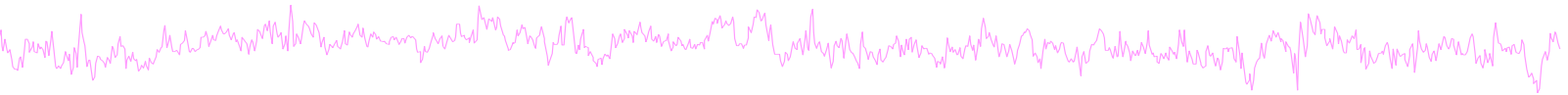
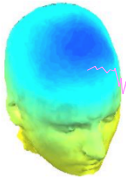
## 4. Extract epochs from data & reject artifactual epochs



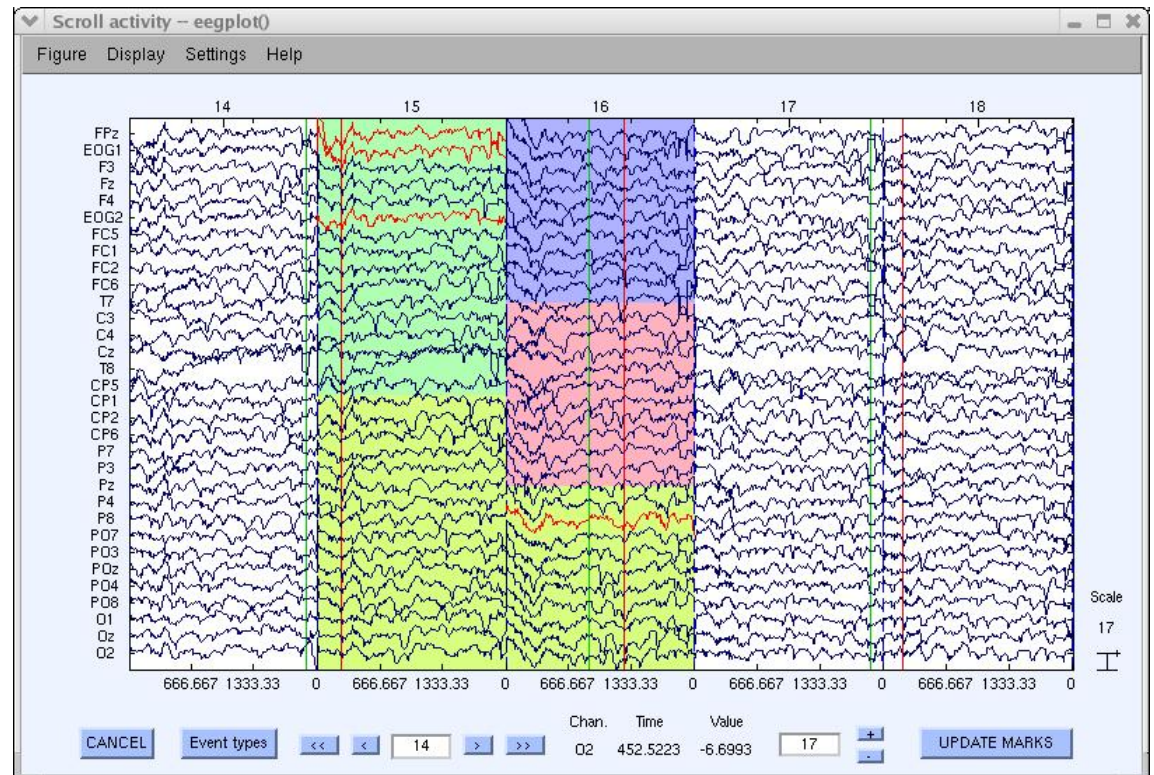
### Preprocessing data



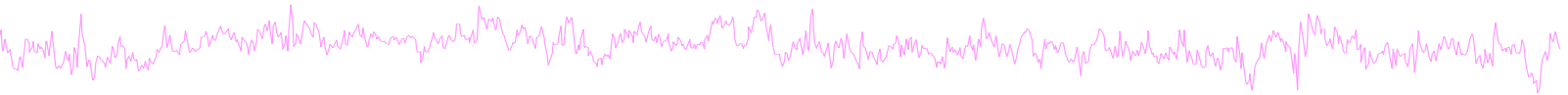
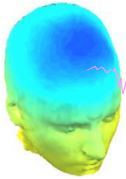
## 4. Extract epochs from data & reject artifactual epochs



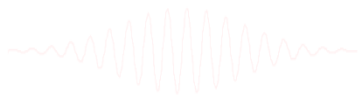
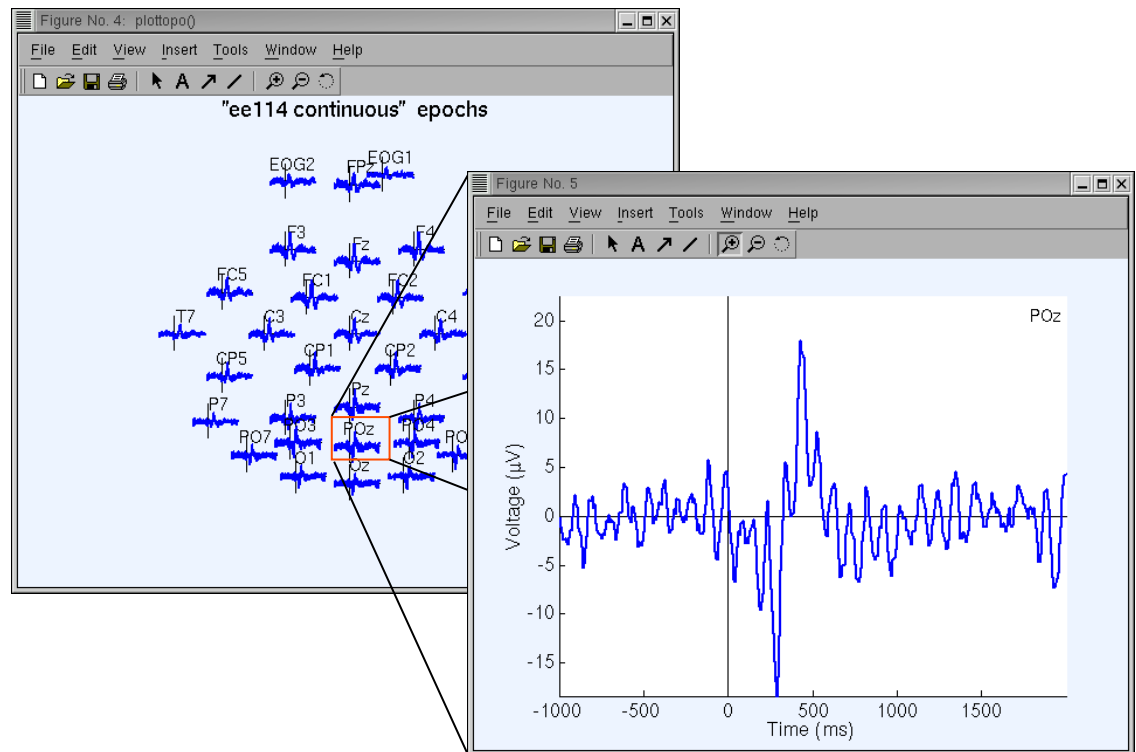
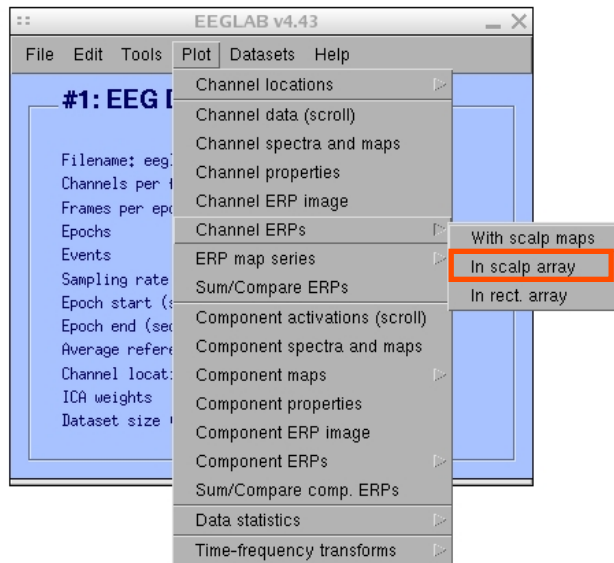
Different color = different rejection methods



## 5. Visualize data measures



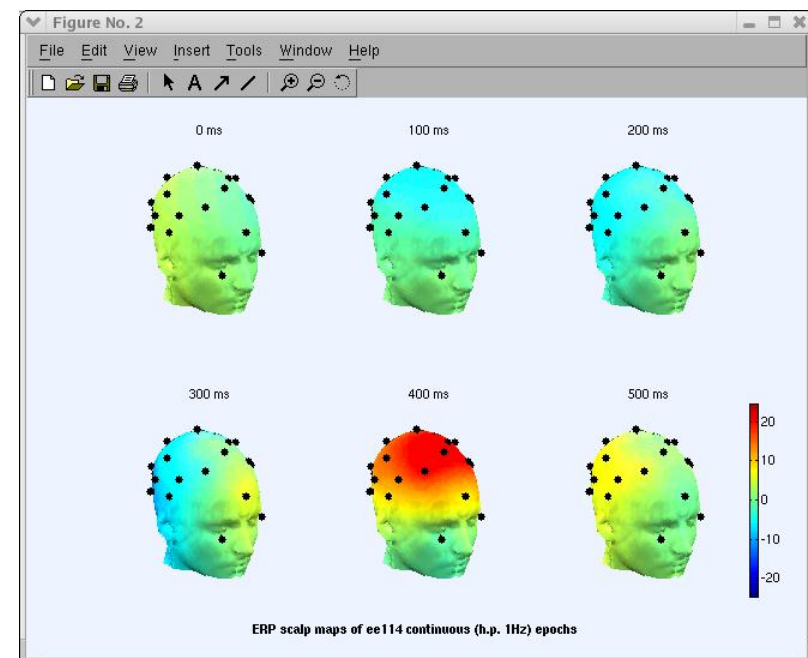
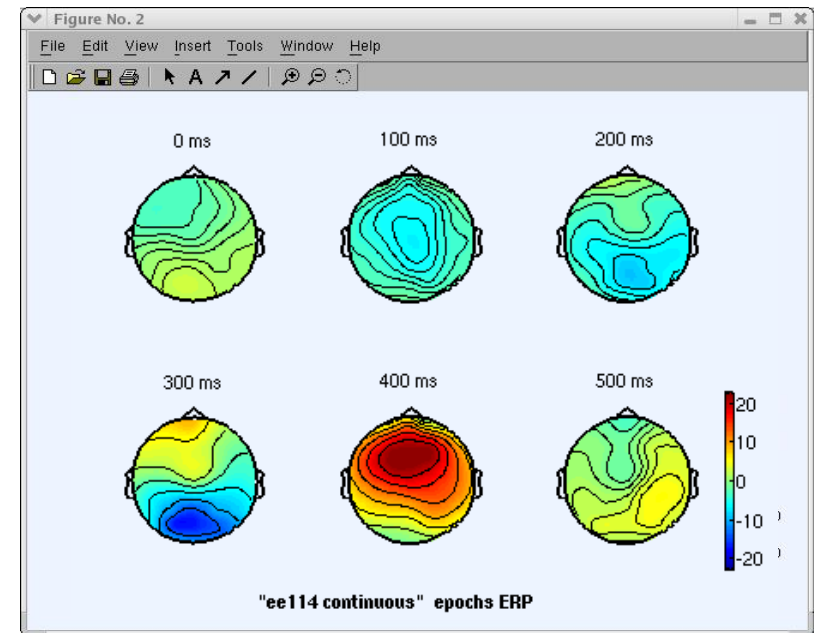
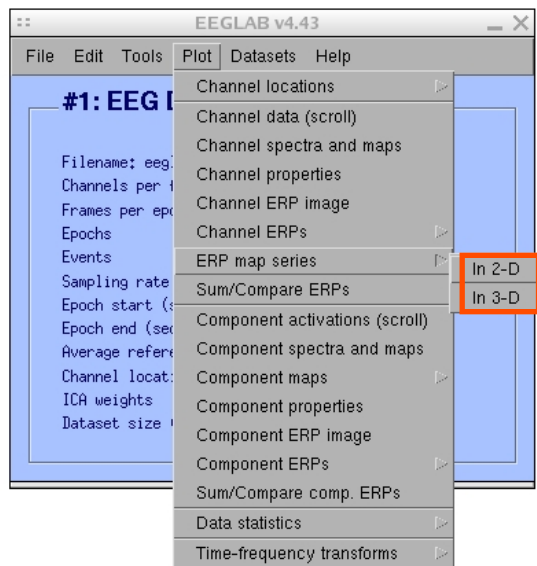
### Plot ERP



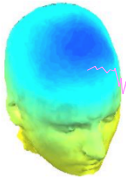


## 5. Visualize data measures

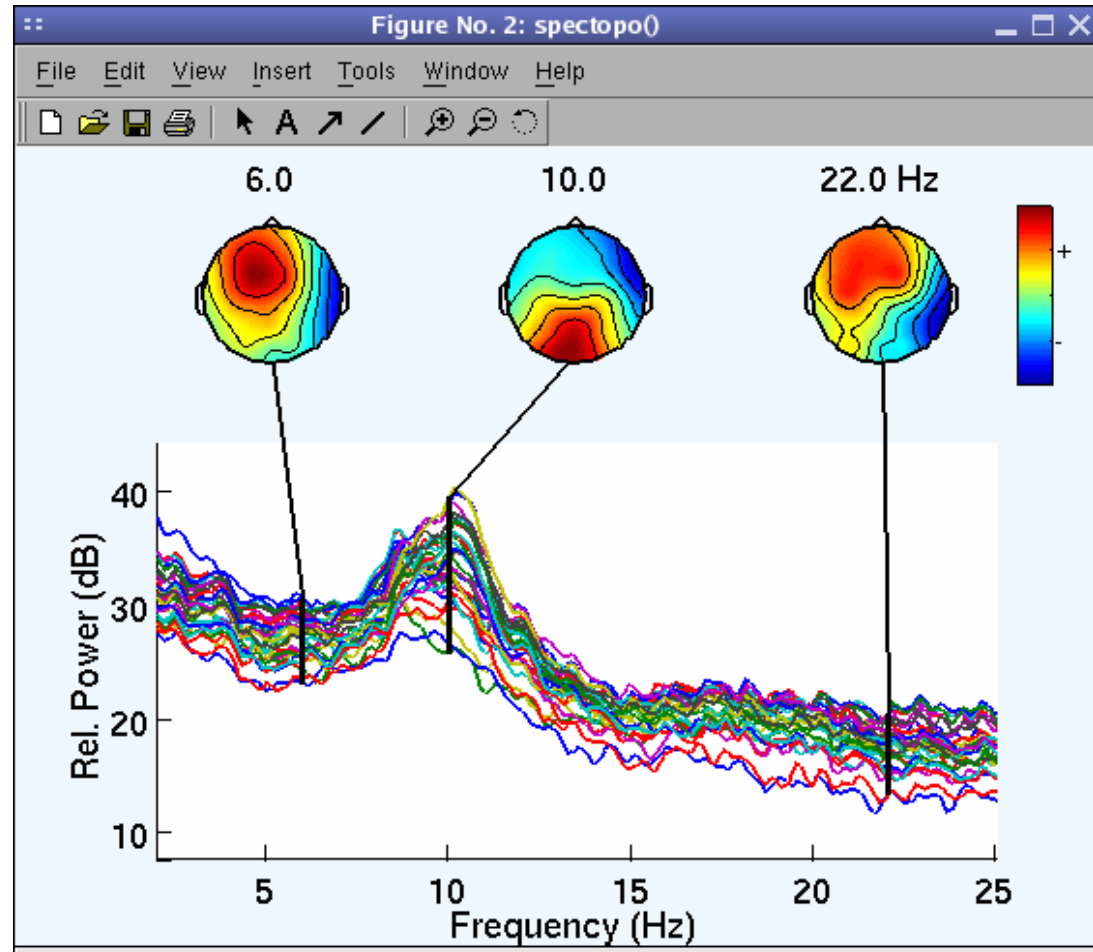
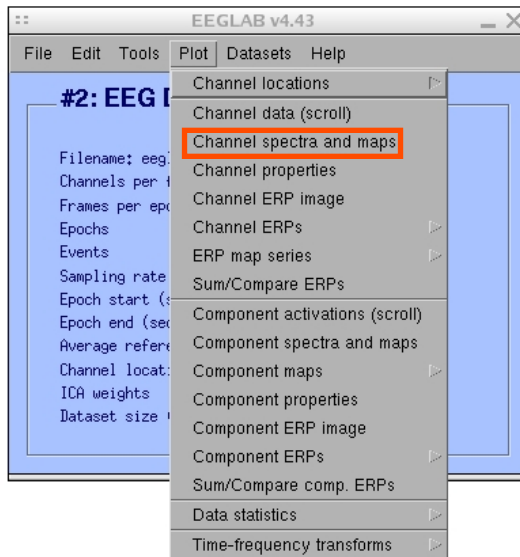
Plot ERP  
map series



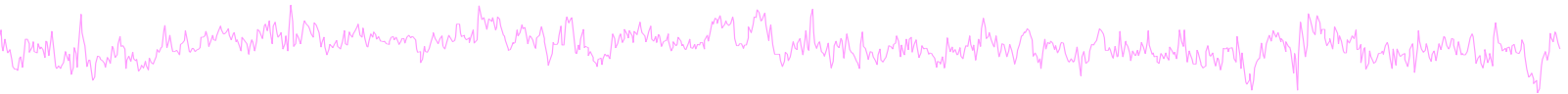
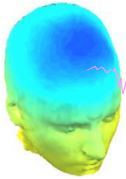
## 5. Visualize data measures



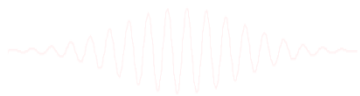
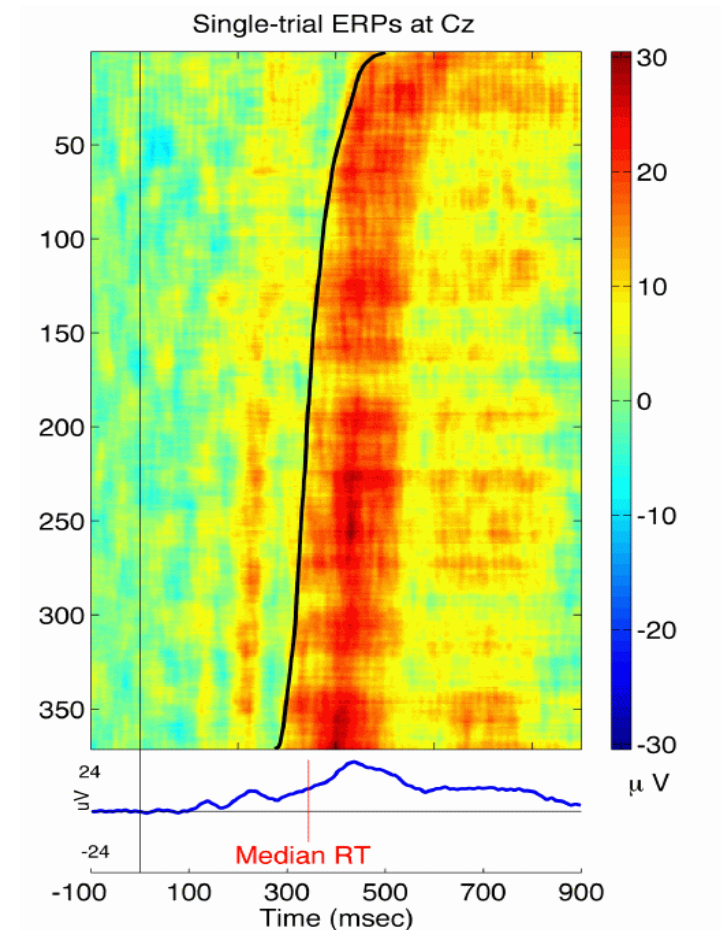
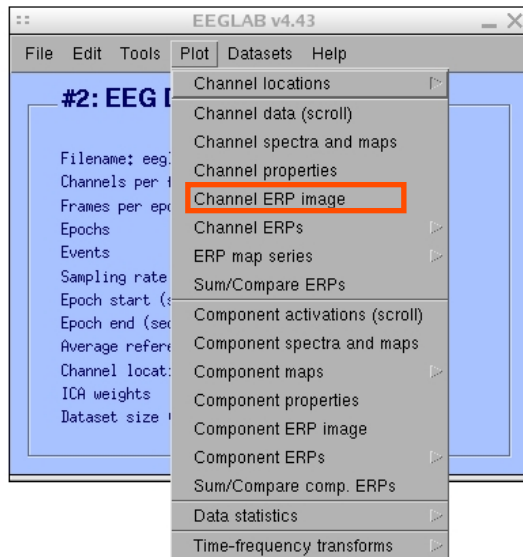
Plot data  
spectrum and  
maps



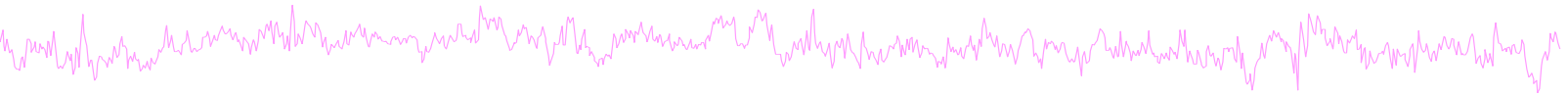
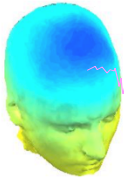
# 5. Visualize data measures



## Plot channel ERPimage



# EEGLAB standard processing pipeline



## Single subject

1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
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6. Perform ICA decomposition
  - Perform source localization of components
  - Analyze components contribution to ERP
  - Analyze components contribution to spectrum

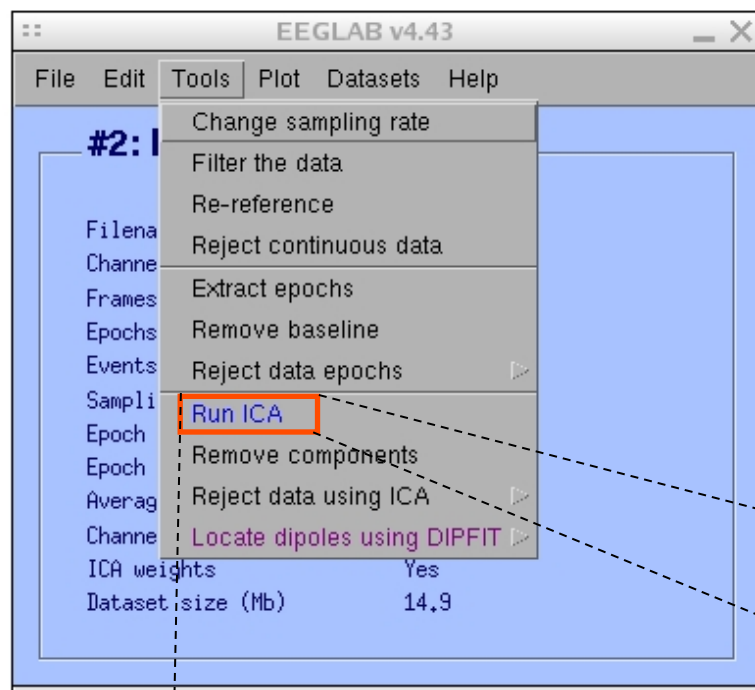
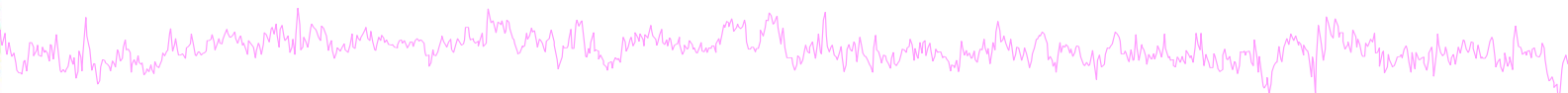
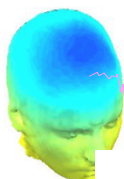
## Multi-subjects

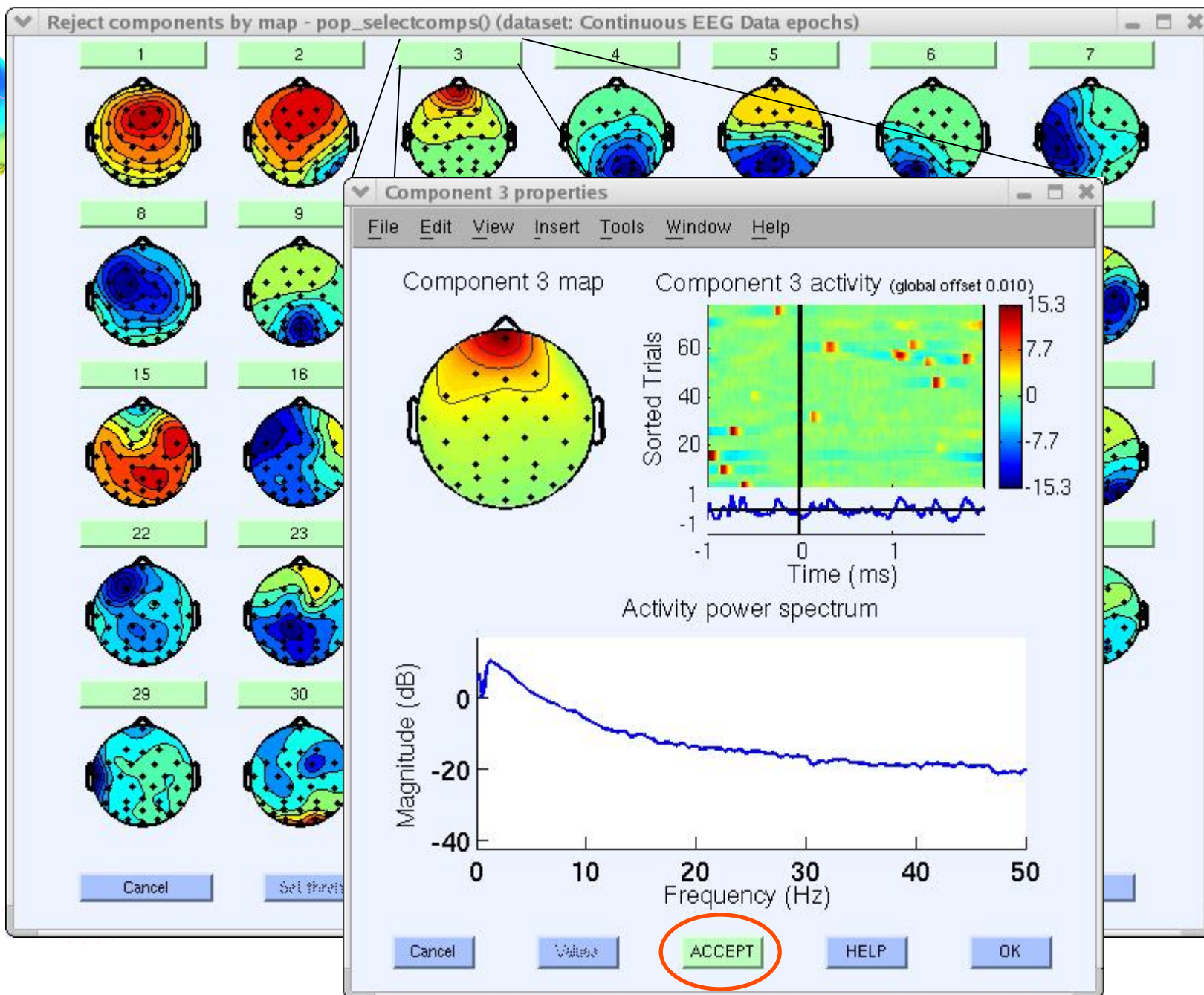
1. Build study
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



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

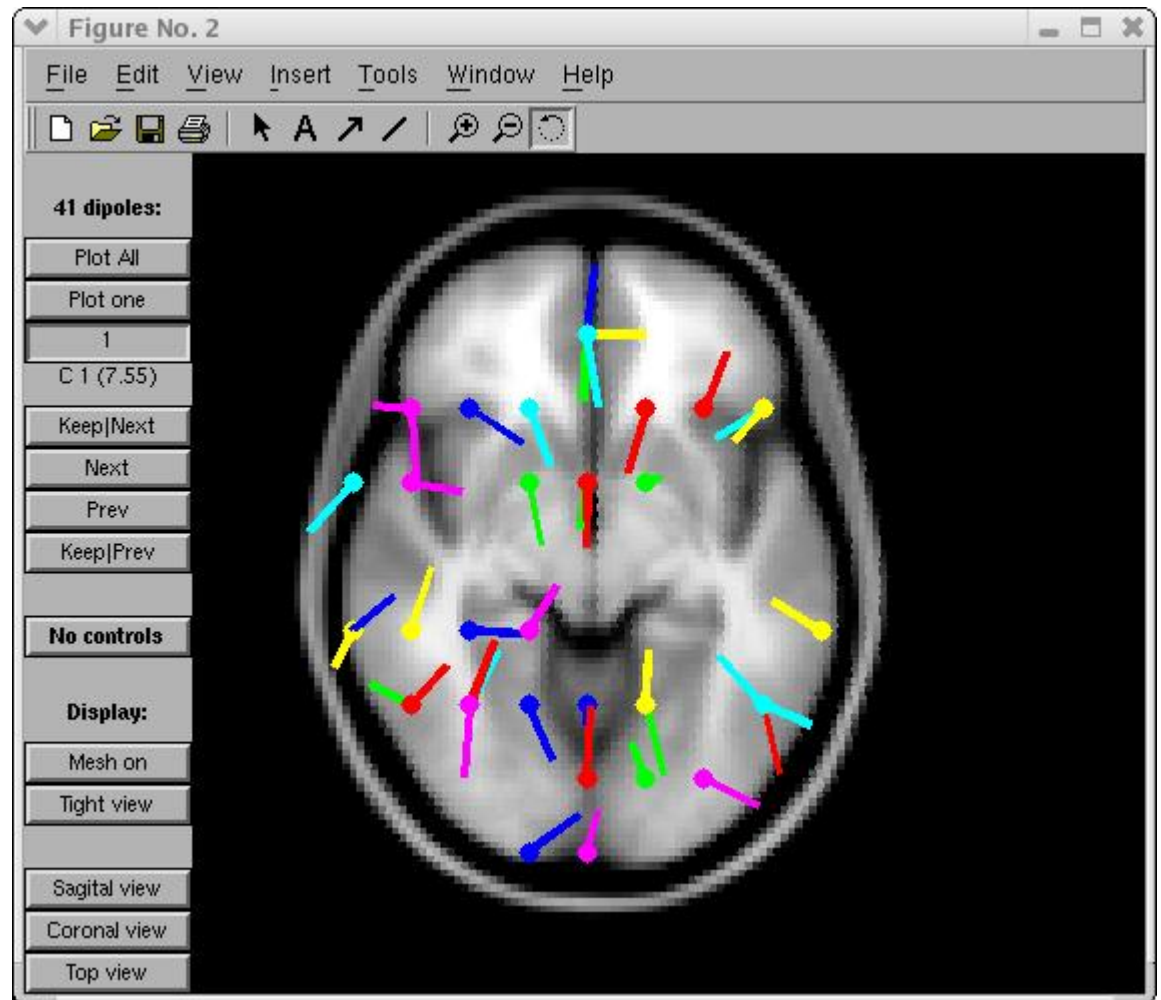
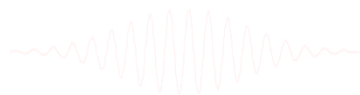
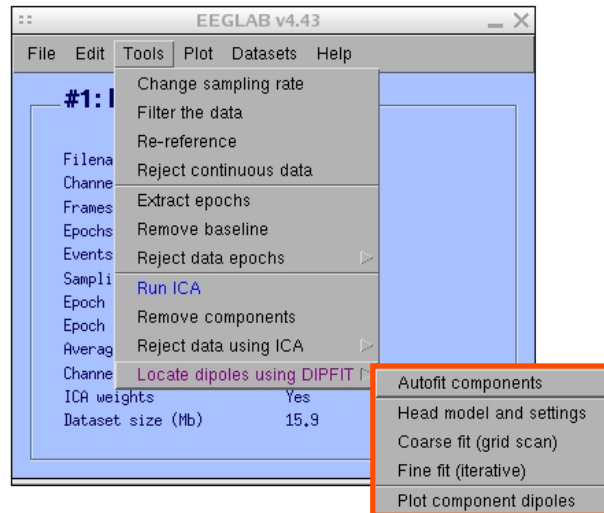
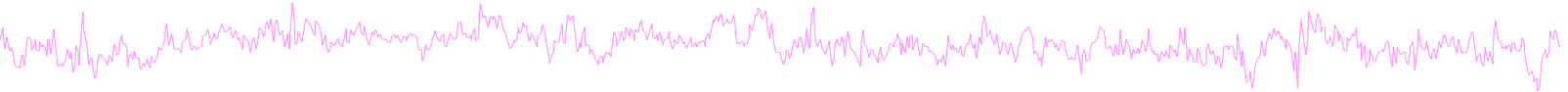
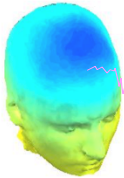
## 6. Perform ICA decomposition

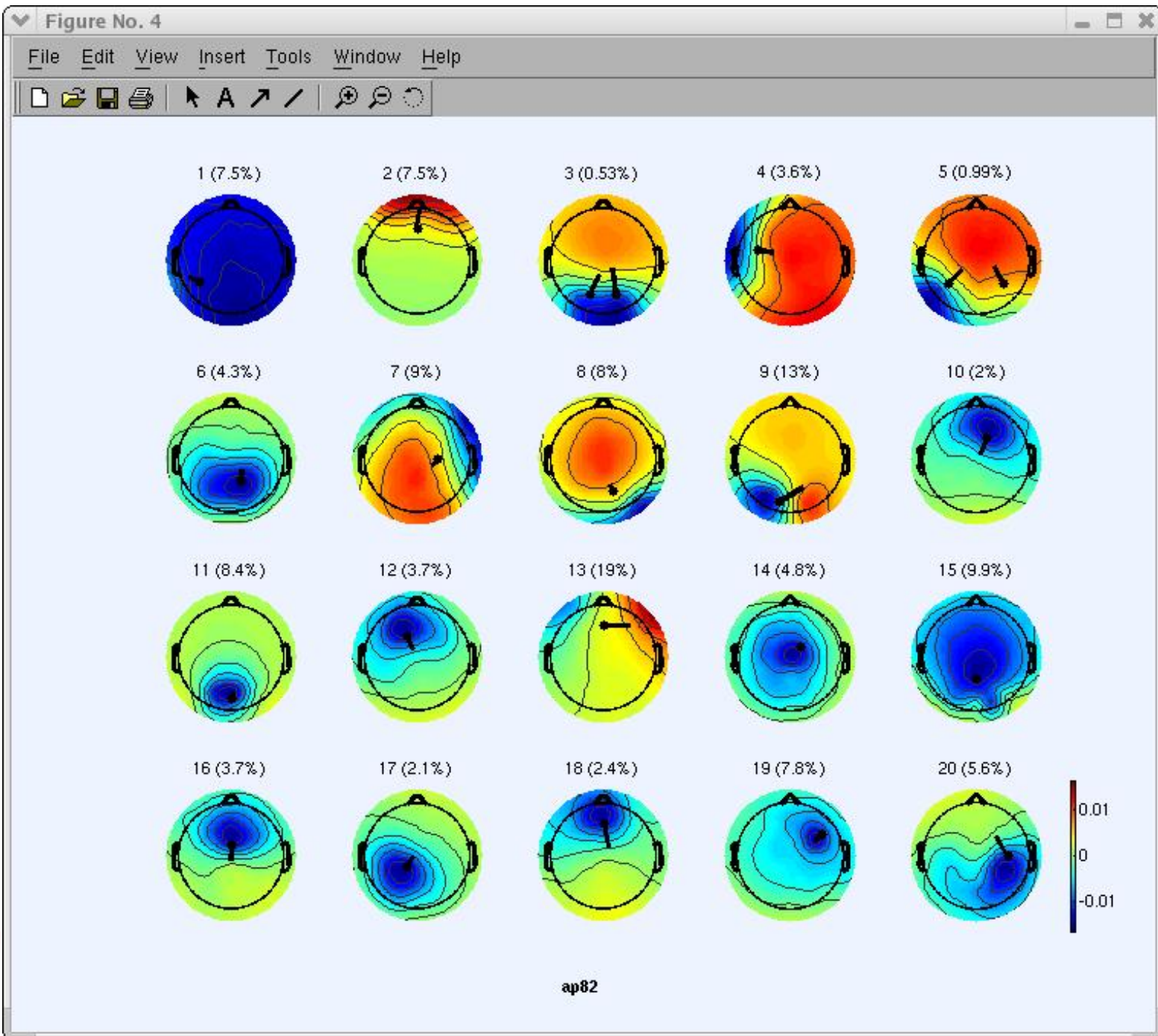






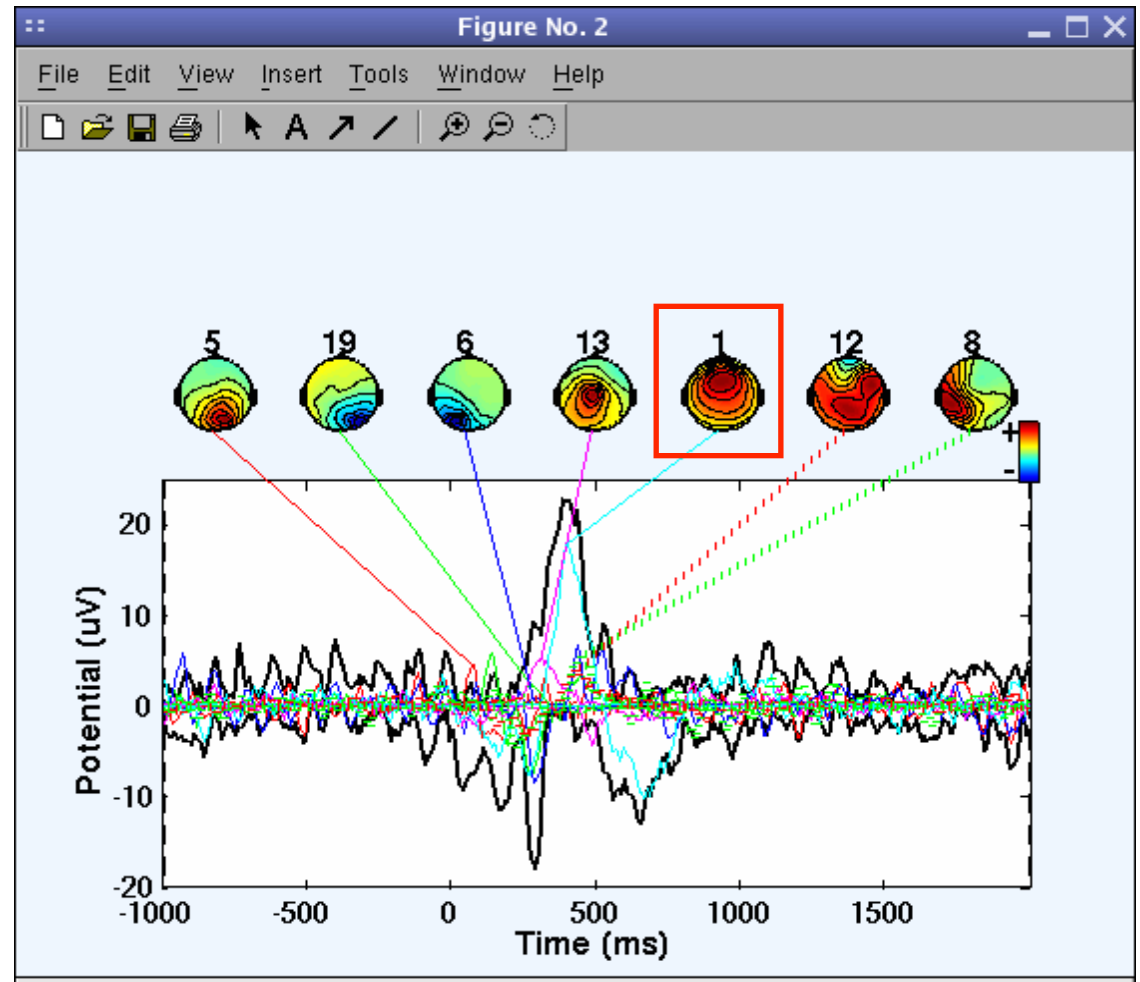
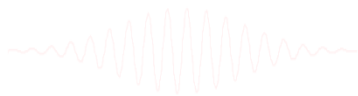
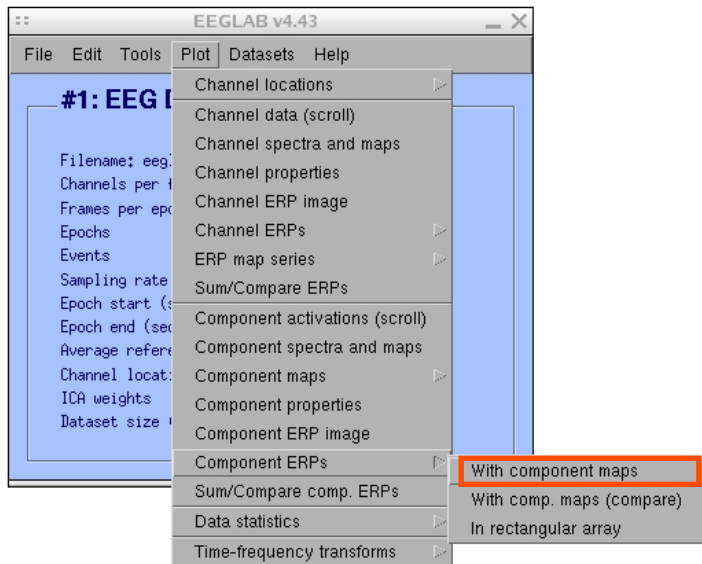
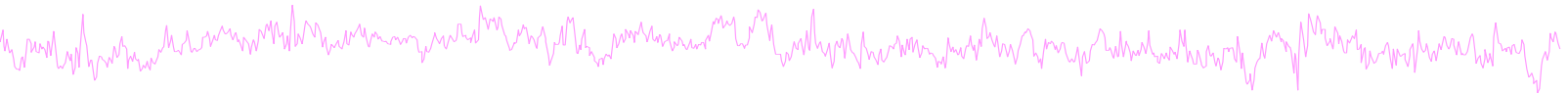
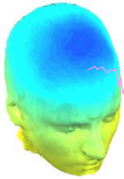
# Localizing components

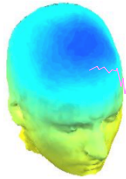




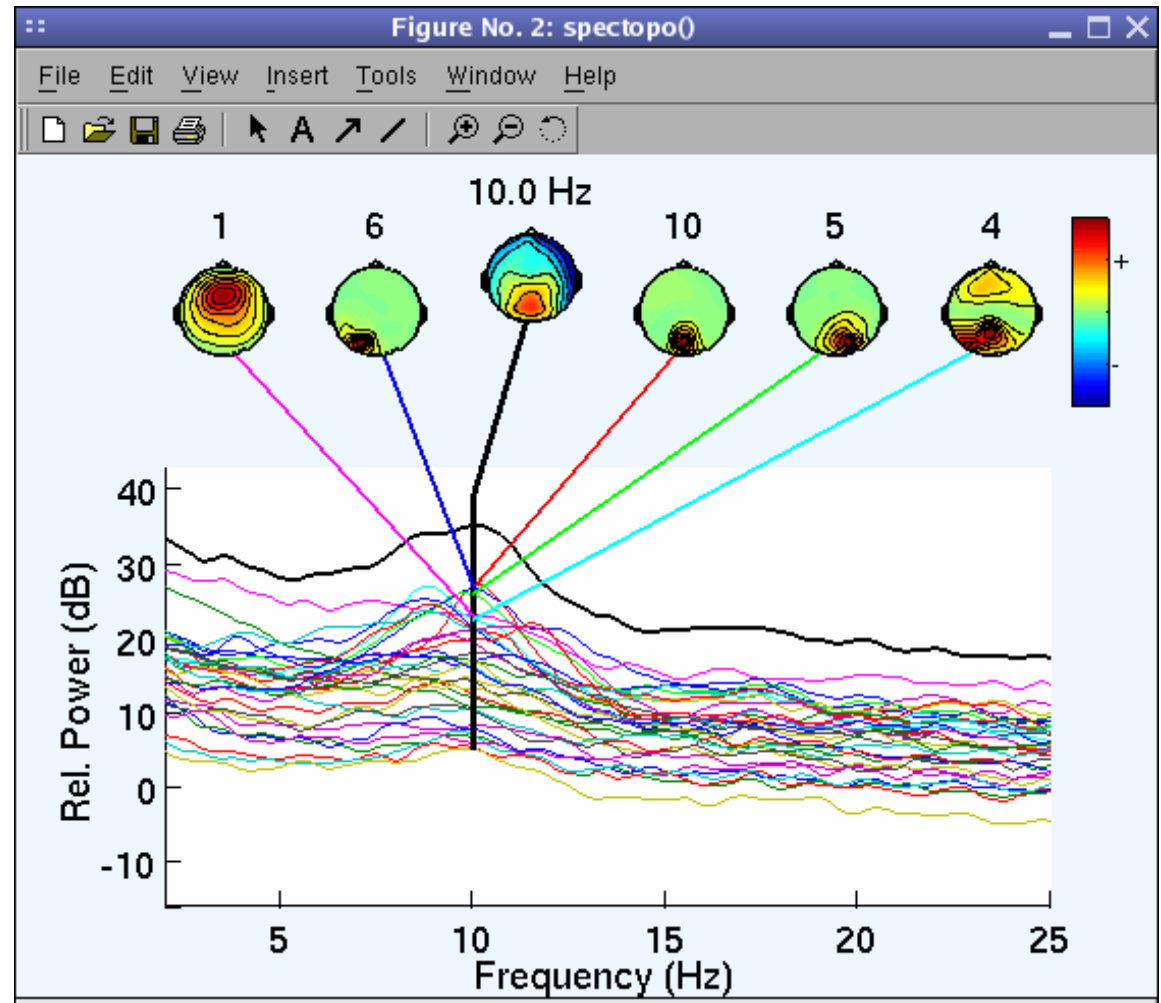
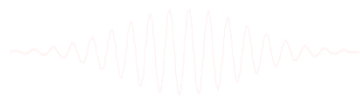
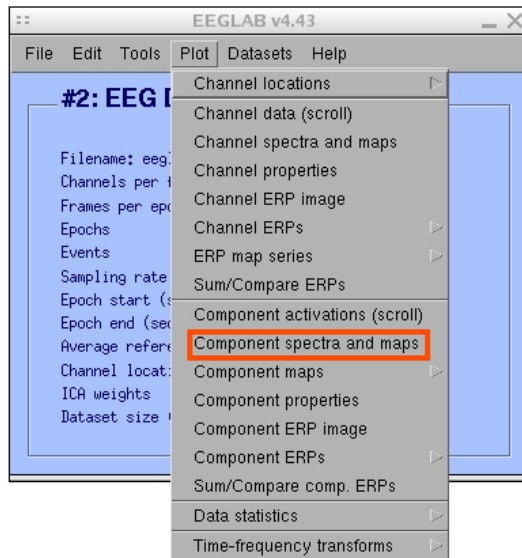
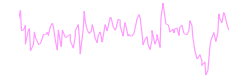


# Component contribution to the ERP

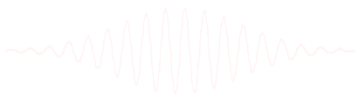
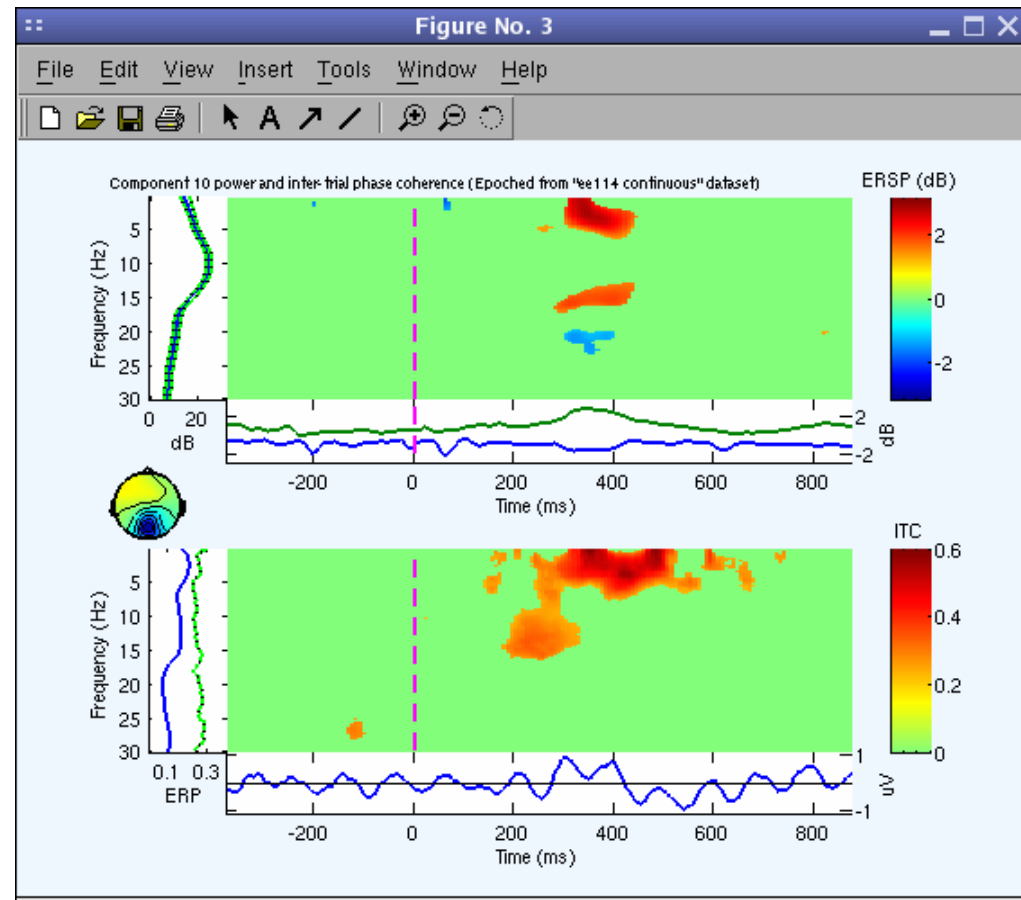
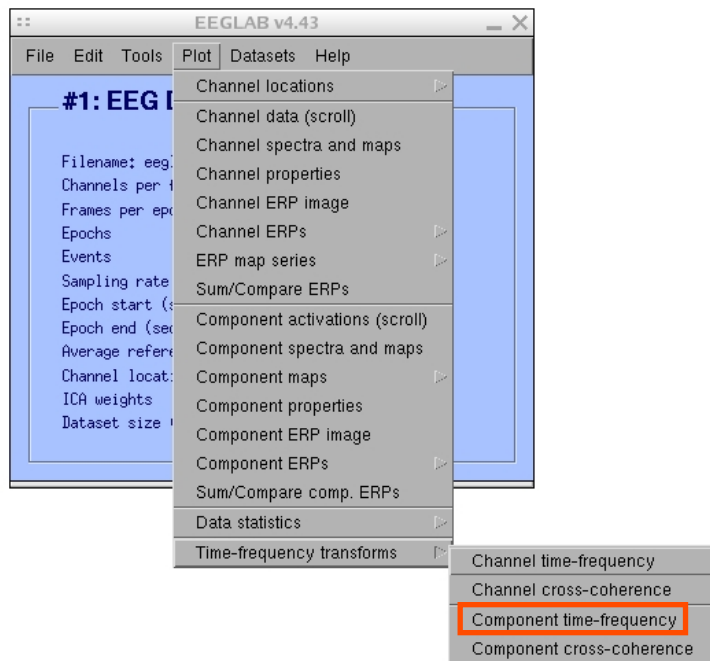
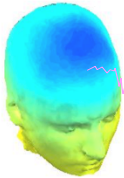




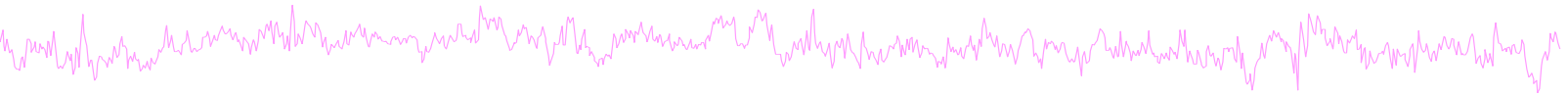
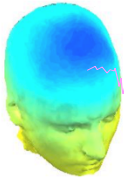
# Component contribution to the EEG spectrum



# Component time-frequency



# EEGLAB standard processing pipeline



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  - Perform source localization of components
  - Analyze components contribution to ERP
  - Analyze components contribution to spectrum

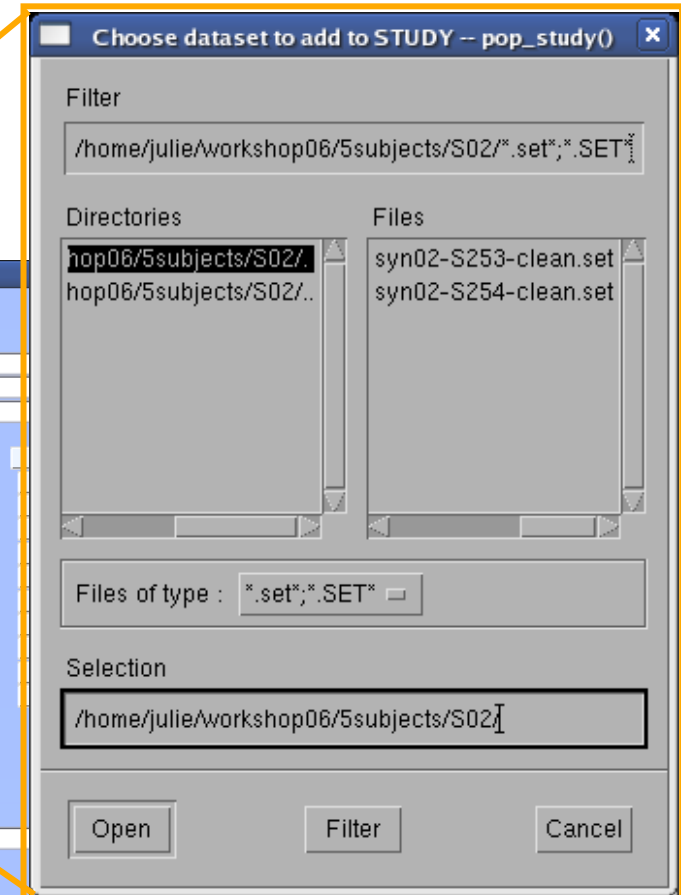
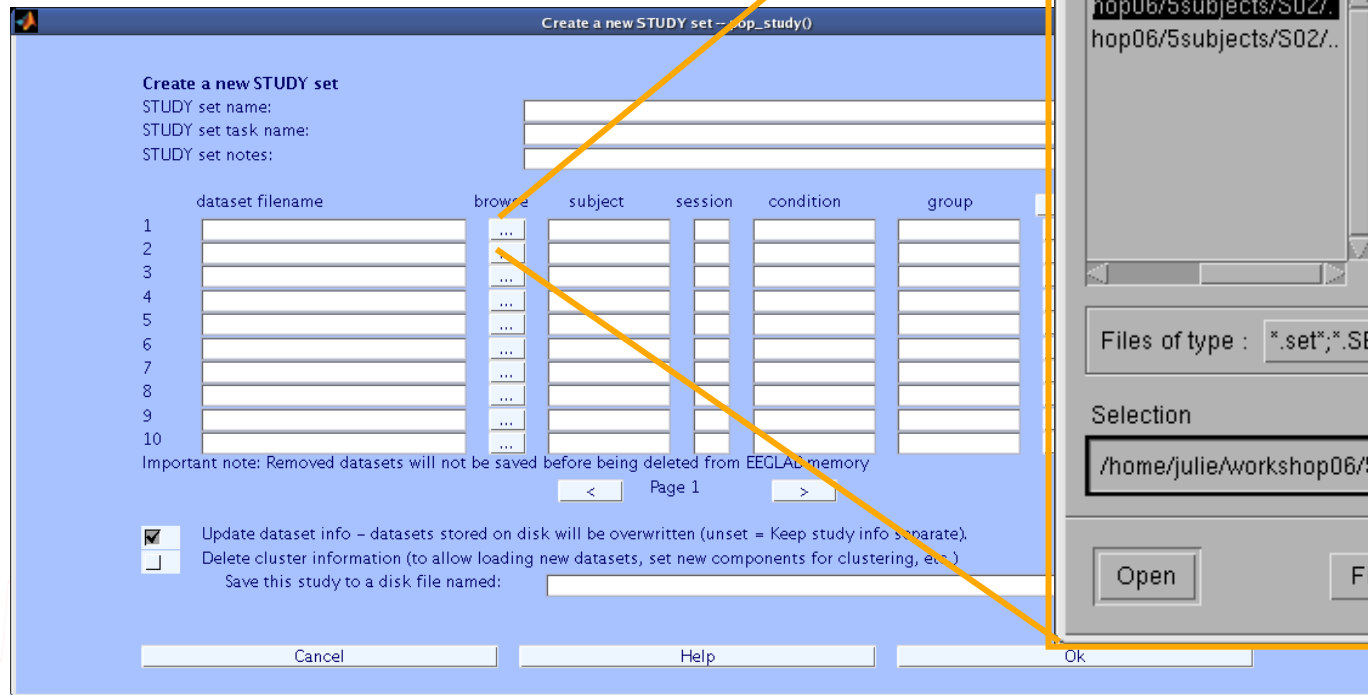
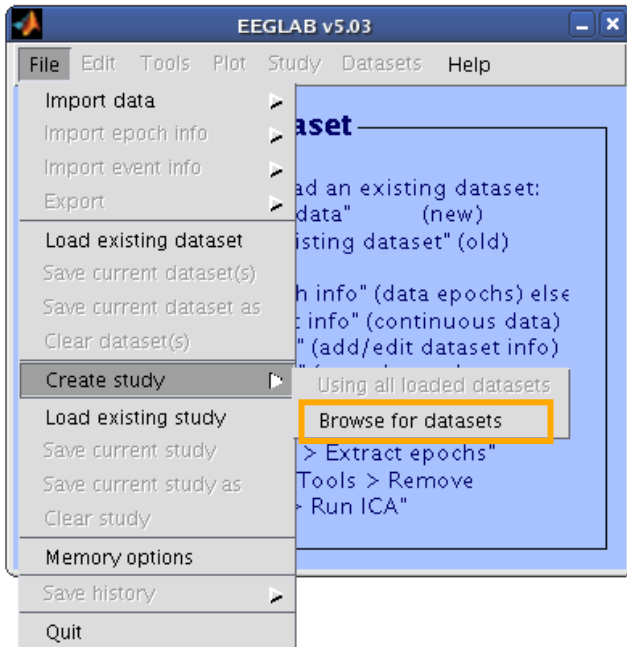
## Multi-subjects

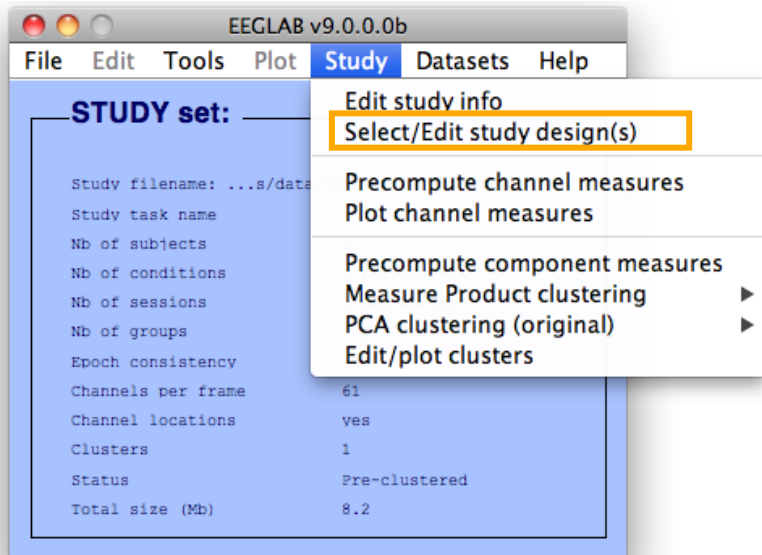
1. Build study and STUDY design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



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

# 1. Build a STUDY





# Edit STUDY design



Select STUDY design

STUDY.design 1

Add design  
Rename design  
Delete design

Subjects

S05  
S08

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

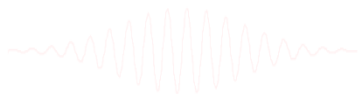
Combine selected values  
Unpaired statistics

Use only specific datasets/trials

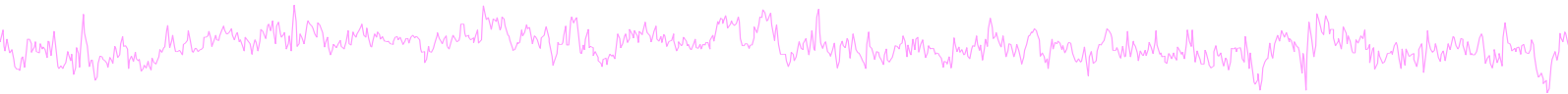
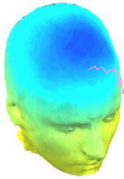
☐ Delete all datafiles associated with this STUDY design

☒ Save the STUDY

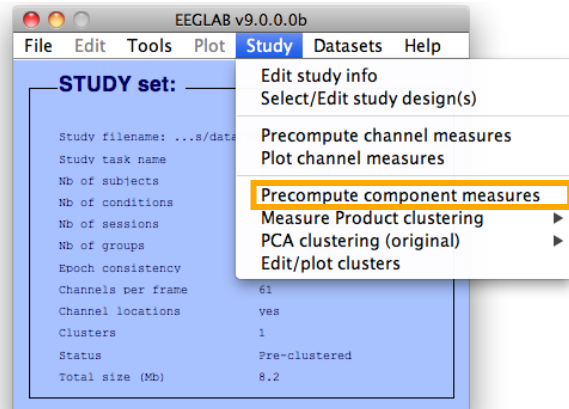
Cancel Ok



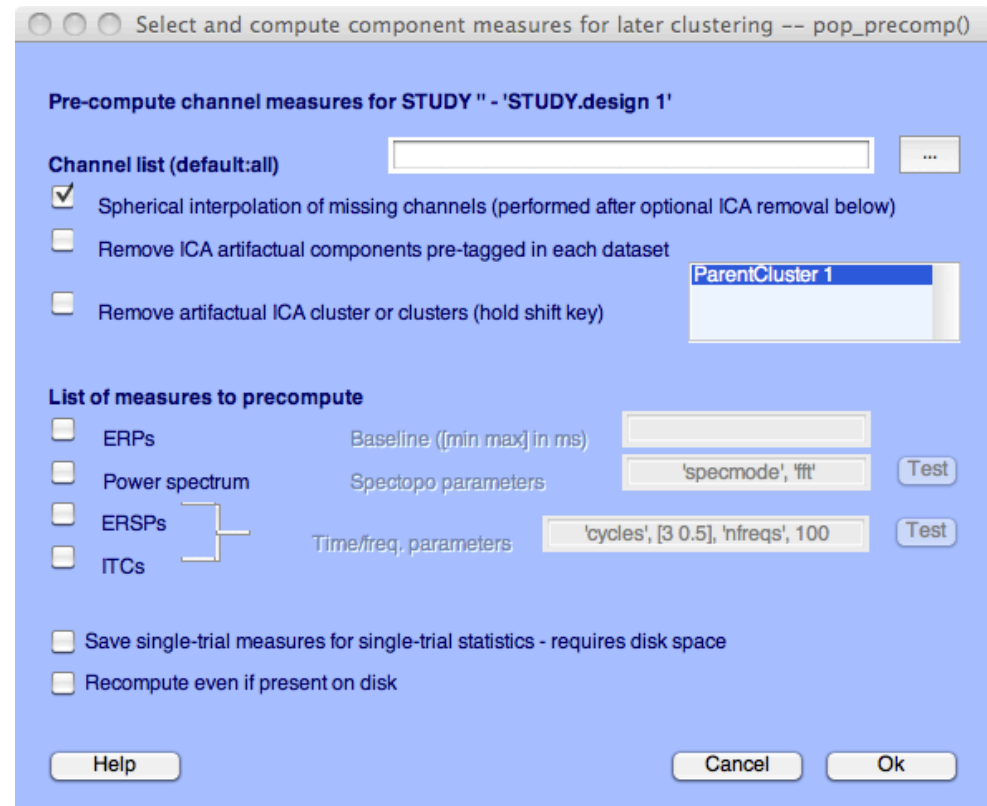
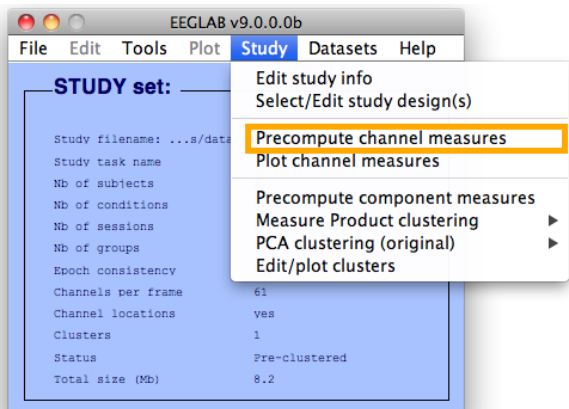
## 2. Pre-compute measures

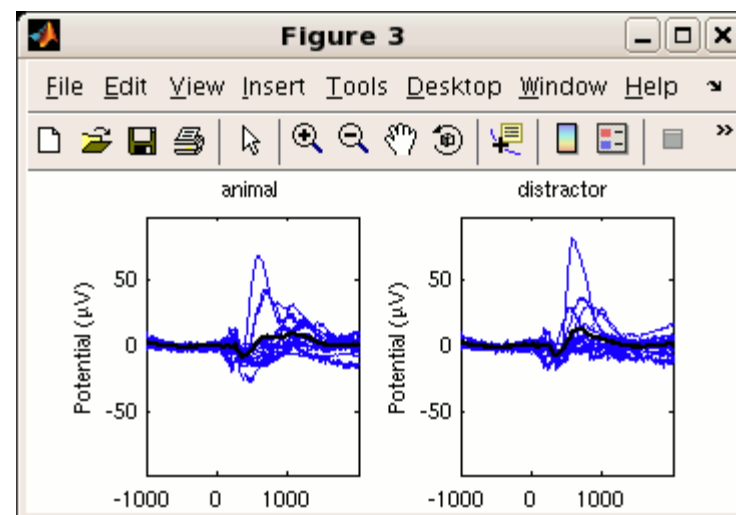
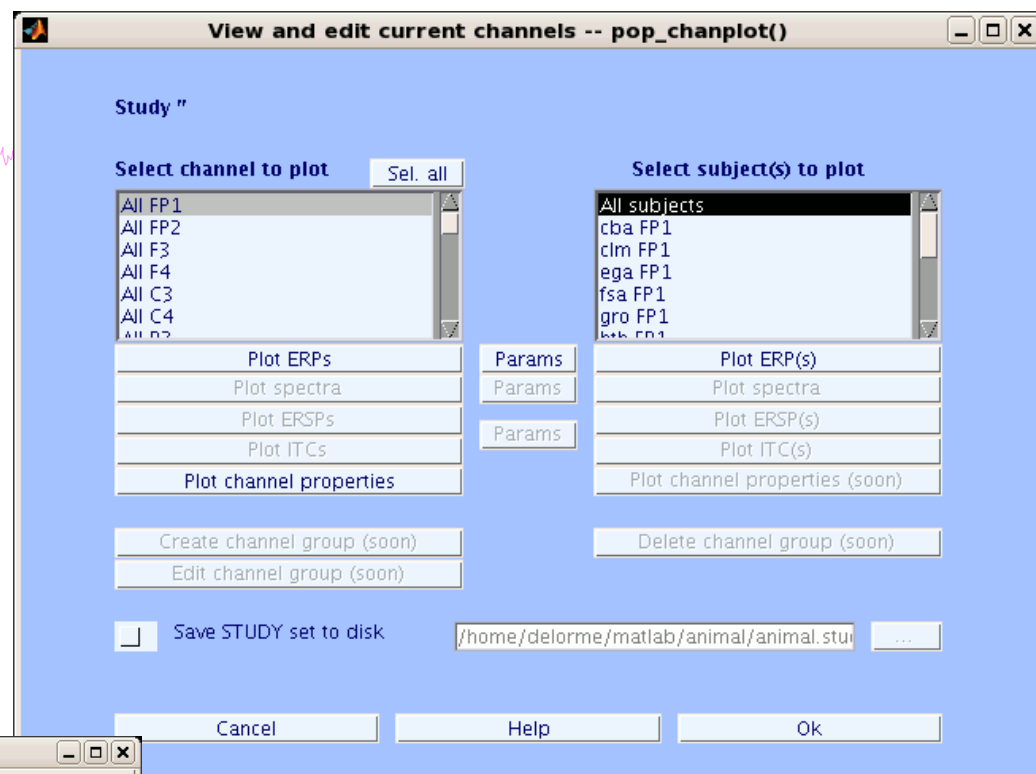
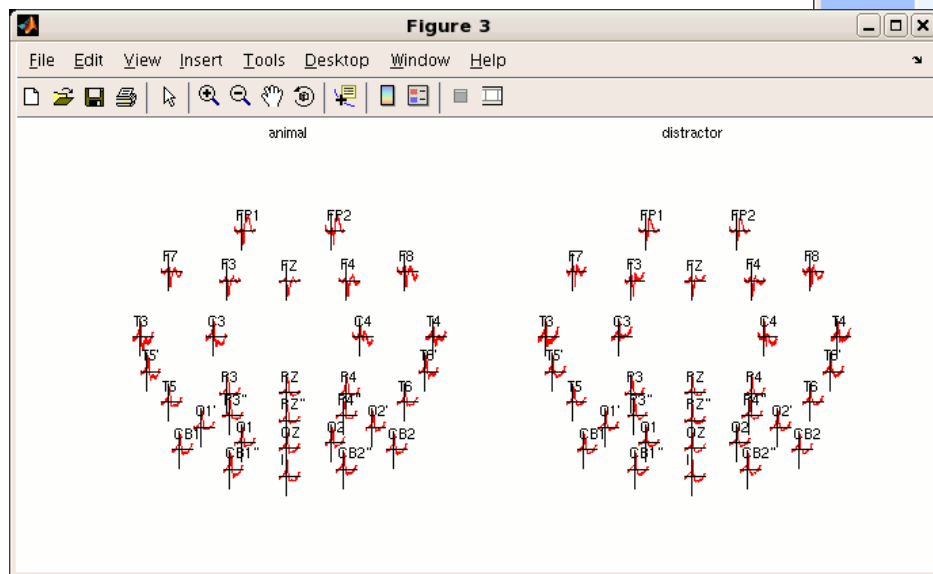
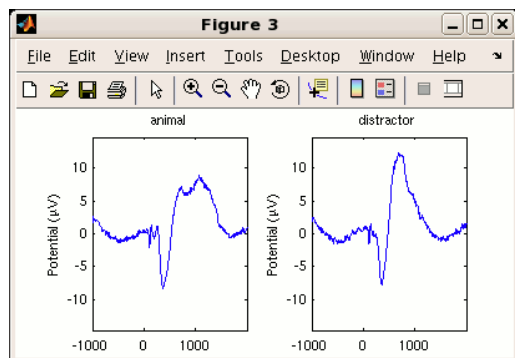


Components



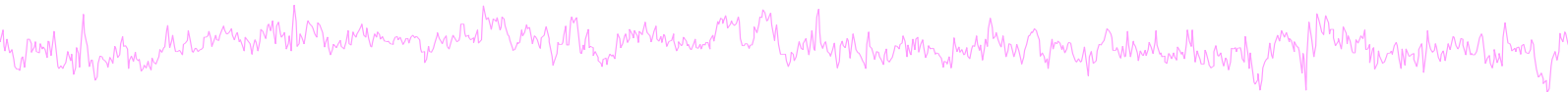
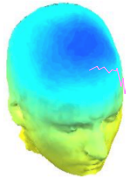
Channels







# 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)

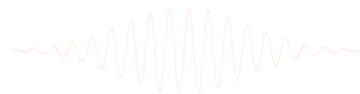
Load	Dims.	Norm.	Rel. Wt.
<input checked="" type="checkbox"/> spectra	10	<input checked="" type="checkbox"/>	1
<input checked="" type="checkbox"/> ERPs	10	<input checked="" type="checkbox"/>	1
<input checked="" type="checkbox"/> dipoles	3	<input checked="" type="checkbox"/>	10
<input type="checkbox"/> 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		

Help

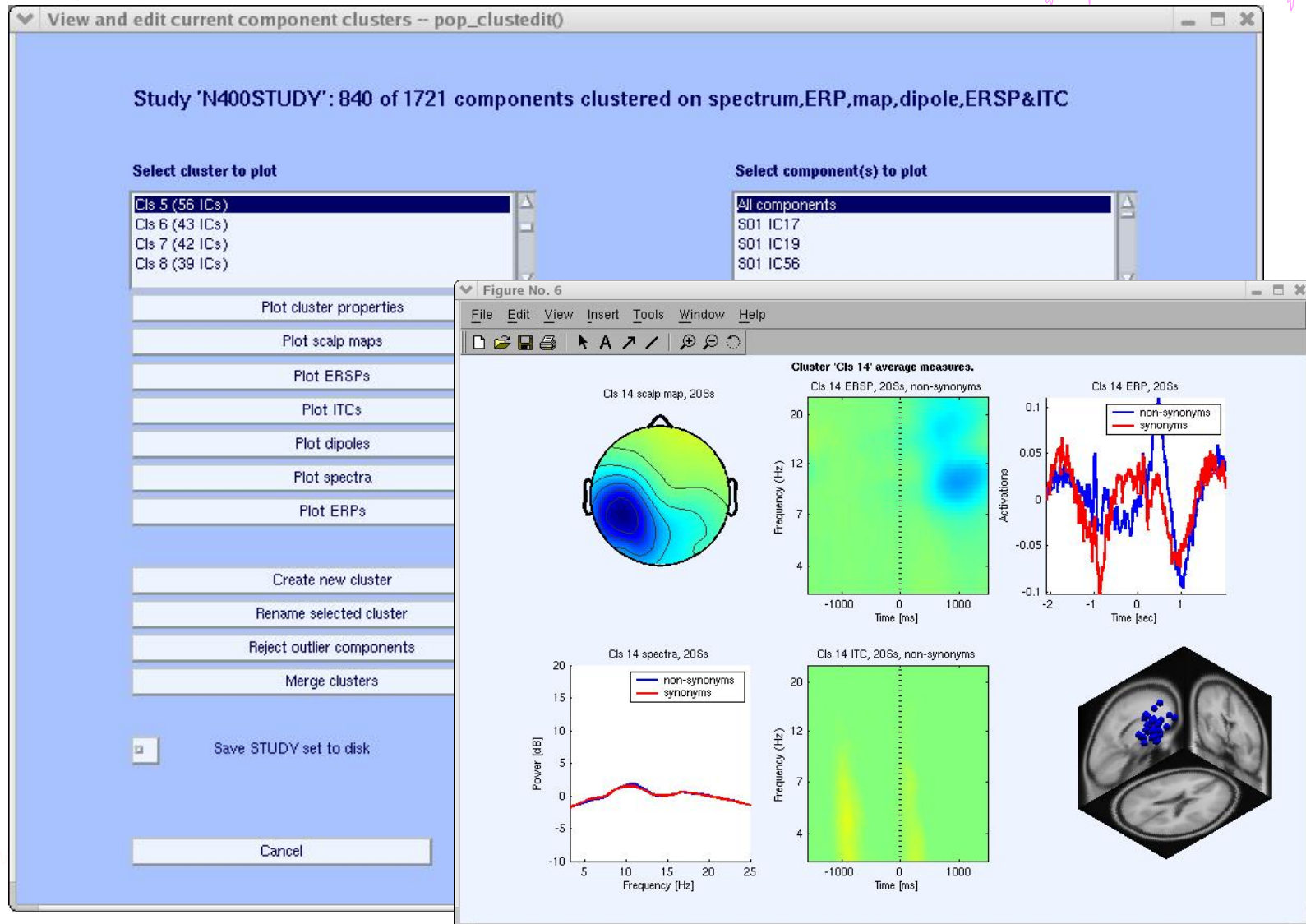
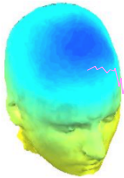
☐ Save STUDY to file: /home/julie/WorkshopSD2007/STUDY/attention.study ...

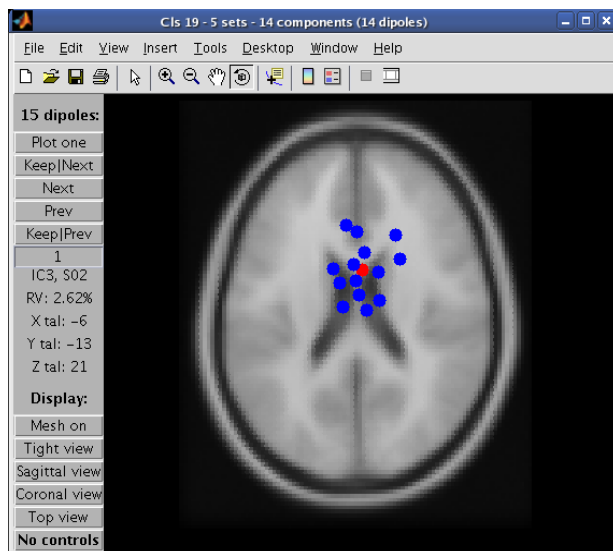
Cancel Help Ok

Additional settings:  
Freq. range [Hz]: 3 25  
Time range [ms]: 0 600  
Use channel values: [dropdown]  
Absolute values: ☒  
Freq. range [Hz]: 3 45  
Time range [ms]: 0 1500  
Freq. range [Hz]: 2 30



# 4. Analyze clusters





View and edit current

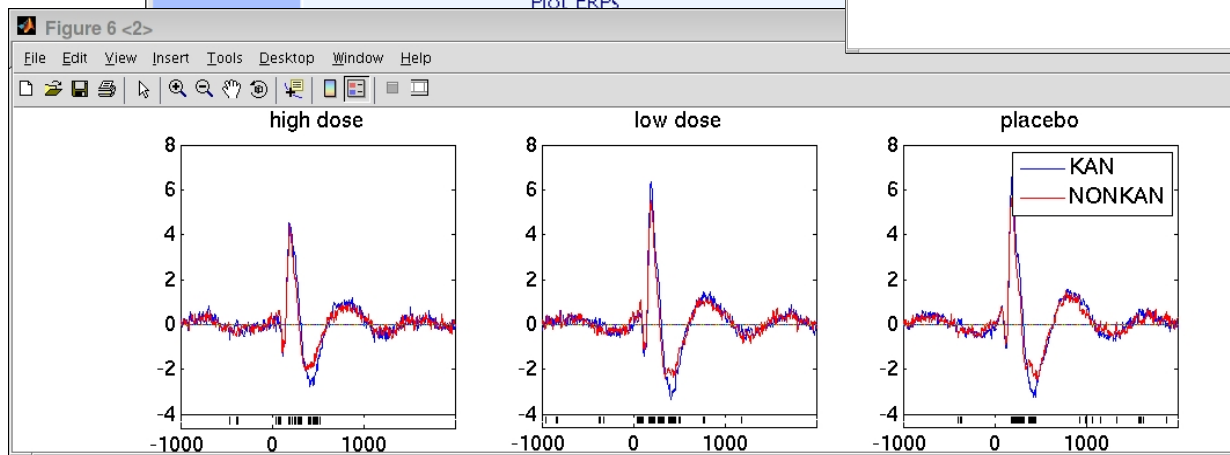
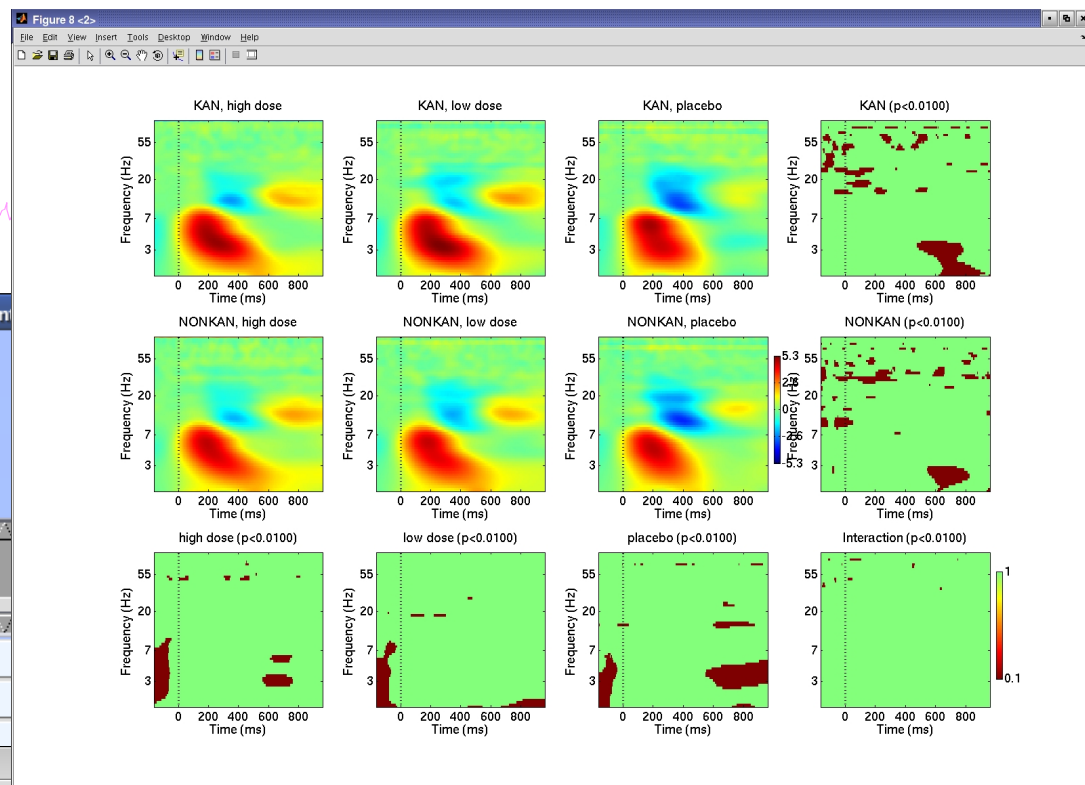
nts clustered

Clis 17 (8 ICs)  
Clis 18 (14 ICs)  
Clis 19 (14 ICs)  
Outliers Clis 17 20 (1 ICs)

Plot scalp maps

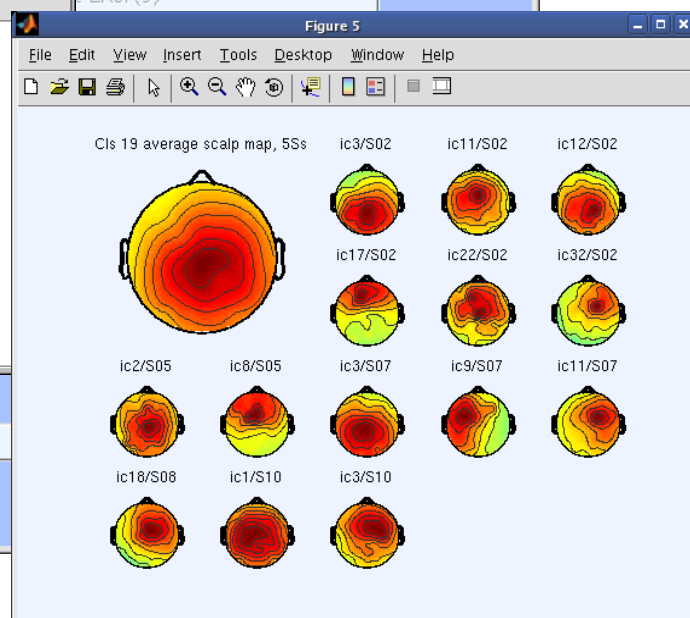
Plot dipoles

Plot ERPs

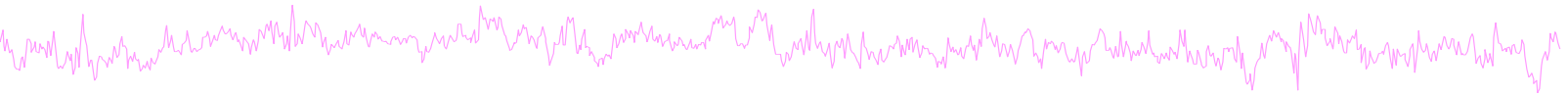
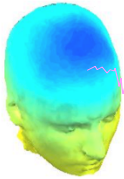


Cancel

Help



# 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

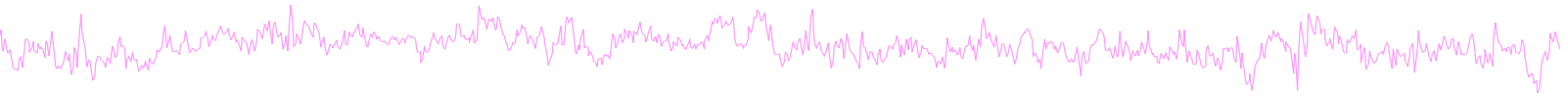
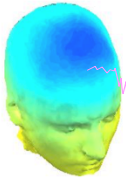
ICA scalp maps

ICA activity

Epoch/event  
information

Channel location

# 3 levels of functions



Administrative functions: handle EEG and ALLEEG structures

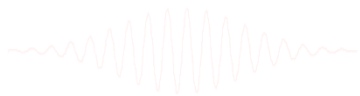
`eeglab()`, `eeg_checkset()`, `pop_delset()`, ...

Pop functions: interactive functions using EEG structure

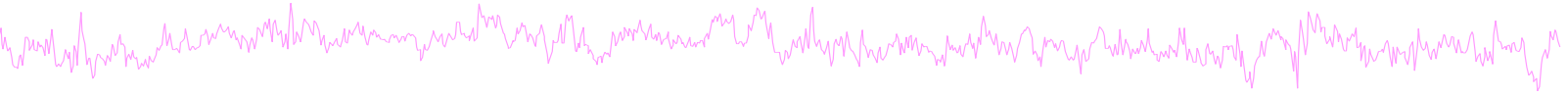
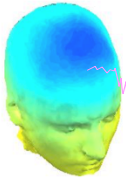
`pop_erpimage()`, `pop_topoplot()`, `pop_envtopo()`, ...

Signal processing functions: perform signal processing

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

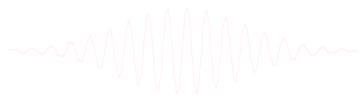


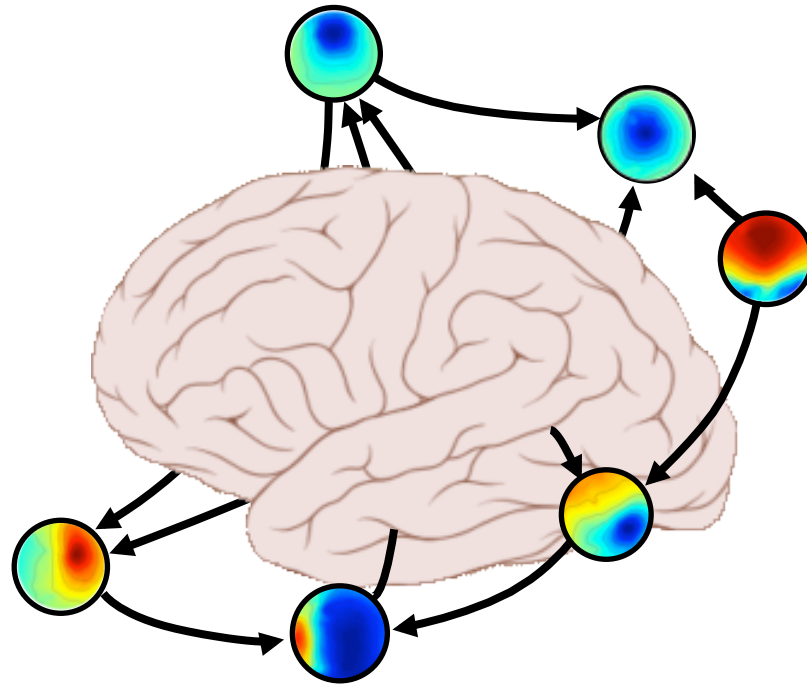
# Command line tools



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

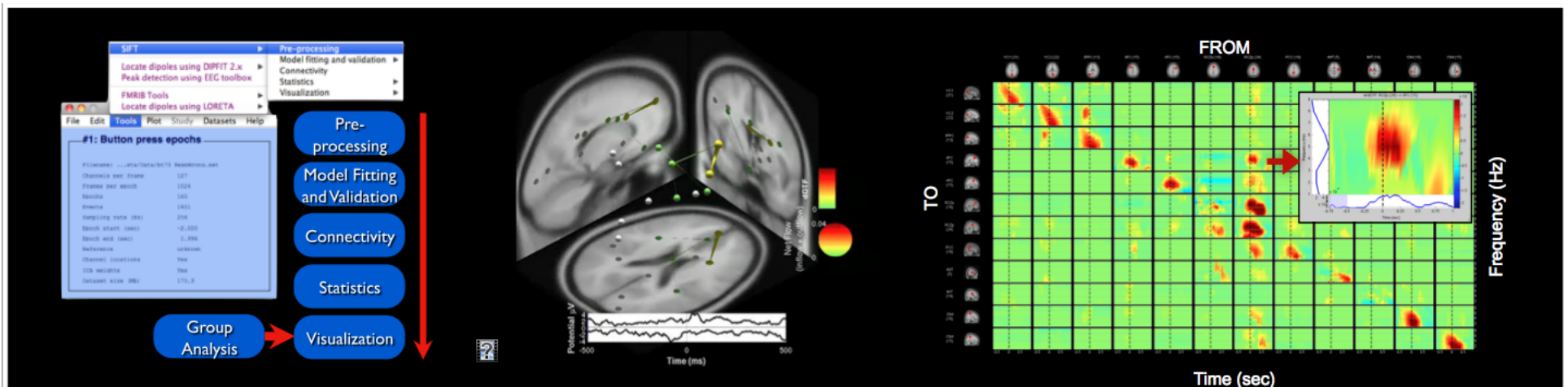
- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, ...)
- Custom processing...





# SIFT

Source Information Flow Toolbox





# BCILAB - C. Kothe

**Review/edit approach** **BCILAB 0.9** **Create a model**

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 Pattern**

File Edit View Insert Tools

Spec-CSP Pattern 1, Spec-CSP Pattern 2, Spec-CSP Pattern 3, Spec-CSP Pattern 6, Spec-CSP Pattern 5, Spec-CSP Pattern 4

Performance estimates

Number of clusters: 10, Number of test trials: 5

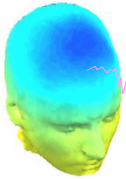
Cluster selection: (use current config)

Space as: lastmodel, Space as: laststats

Cancel OK

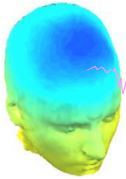
```
on, 'ZO', 0, 'F1', 1, 'Err', 2,
'n-SlackShrink', 1, '1-Sl
poly', 1, 'rbf', 2, 'sigmoic
SubsetHeuristic', 1, 'FixedI
1, 'l2', 2);
ling, 'slack', 1, 'margin', 2
```

# Pros/Cons of Matlab based open source



- Pros
  - Easy to program, highly modular and extendable
  - Not dependent on any platform (64-bit) and highly optimized
  - Large community of users (latest development in signal processing research)
  - Powerful scripting capabilities
- Cons
  - Matlab required for which you have to pay
  - Large memory requirements
  - Matlab bugs, possible version differences, cross-platform compatibility problems
  - Poor graphical interface

# 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., Mullen, T., Kothe, C., Bigdely-Shamlo, N., Akalin, Z., Vankov, A., Makeig, S. (2011) EEGLAB, MPT, NetSIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing. *Computational Intelligence*, article ID 130714.

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

Delorme, A., Makeig, S. (2009) Open Source Programming for Interpreted Language: Graphic Interface and Macro Bridging Interface. 2009 Fifth International Conference on Signal-Image Technology & Internet-Based Systems (SITIS, indexed in IEEE), Nov. 29 2009-Dec. 4 2009, 430-434.

Delorme, A., Palmer, J., Onton, J., Oostenveld, R., Makeig, S. (2012) Independent EEG sources are dipolar. *PLoS One*, 7(2).

Delorme, A., Miyakoshi, M., Jung, T.P., Makeig, S. (2014) Grand average ERP-image plotting and statistics: A method for comparing variability in event-related single-trial EEG activities across subjects and conditions. *J Neurosci Methods*. 2014 Oct 22. pii: S0165-0270(14)00363-X. doi: 10.1016/j.jneumeth.2014.10.003

# Workshop program (and PDFs)

## Day 1 - Wednesday, 2nd of September, 2015

8:30 – 9:00 Morning refreshments at the Bar in The Edge

9:00 – 10:15 Mining event-related brain dynamics I (Scott Makeig)

10:15 – 10:45 EEGLAB overview (Arnaud Delorme)

10:45 – 11:00 Break. Tea and Coffee Served in the Bar in The Edge

11:00 – 11:45 ICA theory (Arnaud Delorme)

11:45 – 12:30 ICA evaluation (John Iversen)

12:30 – 14:00 Lunch Served in The Bar in The Edge

14:00 – 15:30 Importing data, rejecting data, and performing ICA decomposition (John Iversen)

15:30 – 15:45 Break—Tea and Coffee Served in the Bar in The Edge

15:45 – 17:00 Evaluating ICA components practicum (John Iversen)

17:00 - 19:00 Poster Session and Social, held in The Bar

## Day 2 - Thursday, 3rd September, 2015

8:30 – 9:00 Morning refreshments at the Bar in The Edge

9:00 – 9:45 Why cluster ICA components? (Scott Makeig)

9:45 – 10:45 Creating a STUDY and STUDY design (Arnaud Delorme)

10:45 - 11:00 Break. Tea and Coffee Served in the Bar in The Edge

11:00 - 12:30 EEGLAB STUDY statistics and plotting (Arnaud Delorme)

12:30 – 14:00 Lunch Served in The Bar in The Edge

14:00 – 15:30 Statistics and LIMO EEG (Cyril Pernet)

15:30 – 15:45 LIMO EEGLAB integration (Arnaud Delorme)

15:45 – 16:00 Break—Tea and Coffee Served in the Bar in The Edge

16:00 - 21:00 Group excursion to Yorkshire Sculpture Park. Coaches leave at 16:00

### Day 3 - Friday, 4th September, 2015

8:30 – 9:00 Morning refreshments at The Bar in The Edge

9:00 – 10:45 Time-frequency decomposition: Theory and practice (John Iversen)

10:45 – 11:00 Break—Tea and Coffee Served in the Bar in The Edge

11:00 – 11:45 Forward and inverse source imaging - Dipfit, NFT, and NIST (Scott Makeig)

11:45 – 12:30 New directions in source imaging (Scott Makeig)

12:30 - 14:00 Lunch Served in The Bar in The Edge

14:00 – 14:45 EEGLAB basic scripting (John Iversen)

14:45 – 15:45 EEGLAB scripting for custom plotting (John Iversen)

15:45 – 16:00 Break. Tea and Coffee Served in the Bar in The Edge

16:00 – 17:00 EEGLAB scripting for STUDY data (Arnaud Delorme)

### Day 4 - Saturday, 5th September, 2015

8:30 – 9:00 Morning refreshments at The Bar in The Edge

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

10:00 – 10:45 EEGLAB Challenge Practicum (all)

10:45 - 11:00 Break—Tea and Coffee Served in the Bar in The Edge

11:00 – 11:30 EEGLAB Challenge Practicum (all)

11:30 – 12:30 Participant Challenge presentations, Q & A, and closing remarks (all)

12:30 – 13:30 Lunch Served in The Bar in The Edge.

13:30 - Close