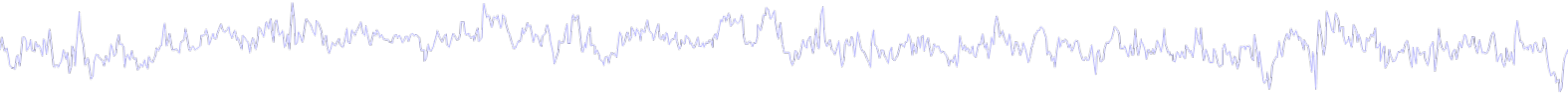


Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

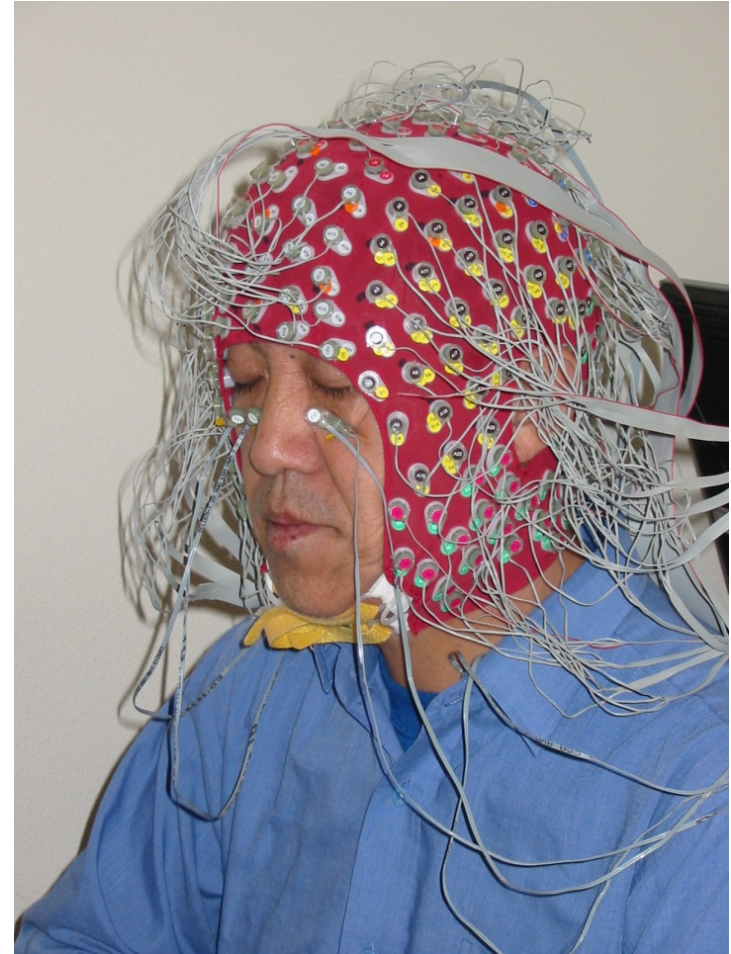
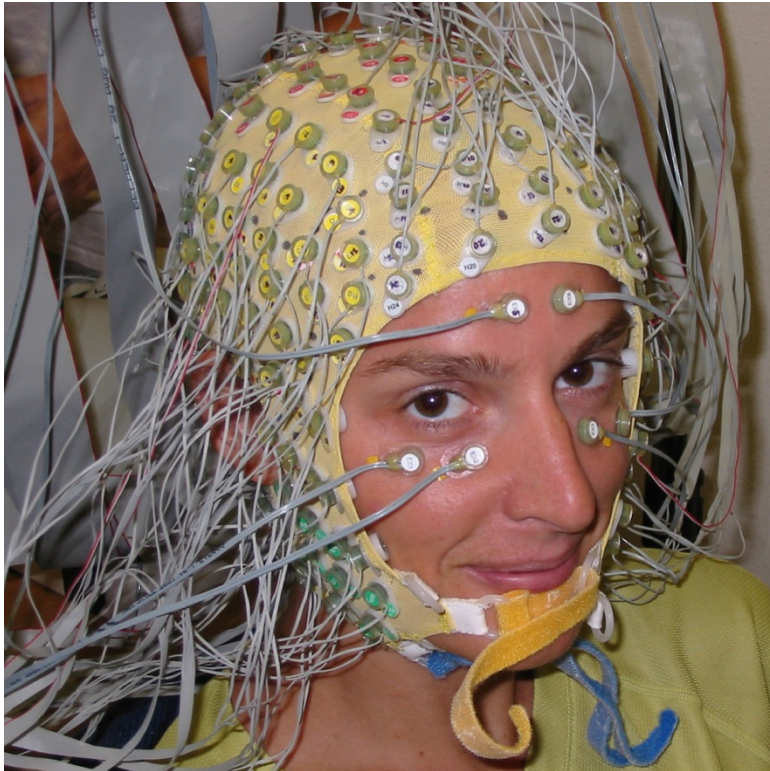
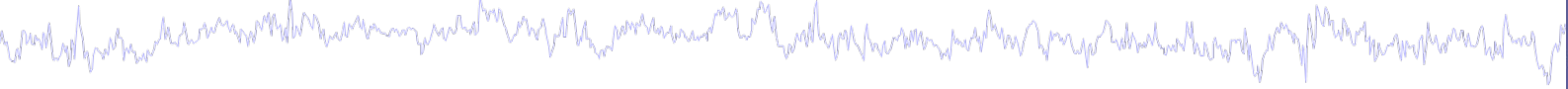
**Identify/reject
bad channels**

**Reject large artifact
time points**

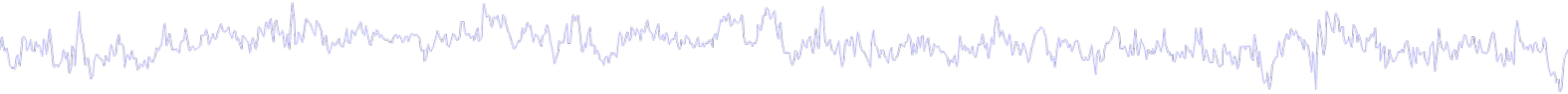
Plot



Dense-array EEG



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

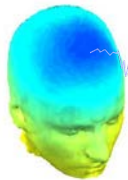
**Identify/reject
bad channels**

**Reject large artifact
time points**

Plot



EEGLAB Matlab toolbox



main graphic interface

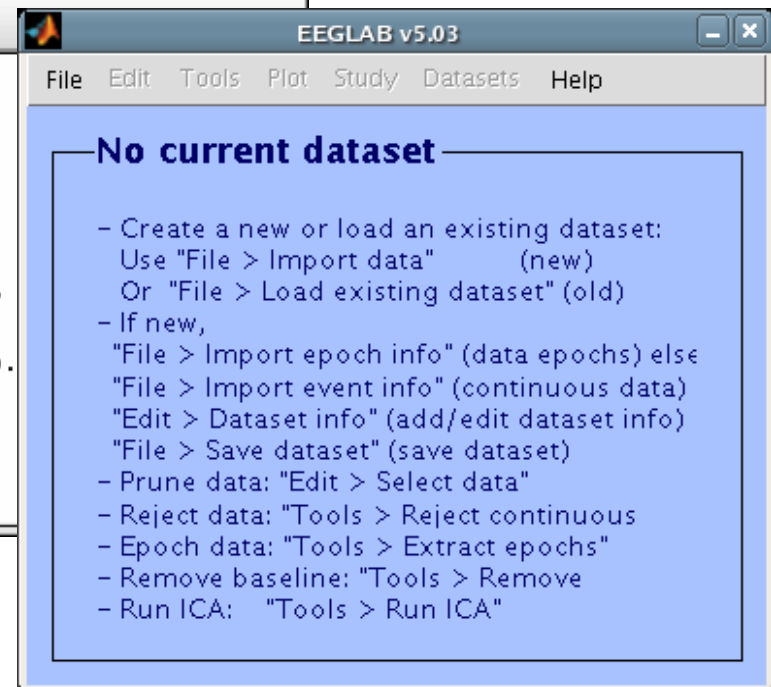
```
EEGLAB Shell - Konsole
Session Edit View Bookmarks Settings Help

/home/arno> matlab -nodesktop

      < M A T L A B >
Copyright 1984-2002 The MathWorks, Inc.
Version 6.5.0.180913a Release 13
Jun 18 2002

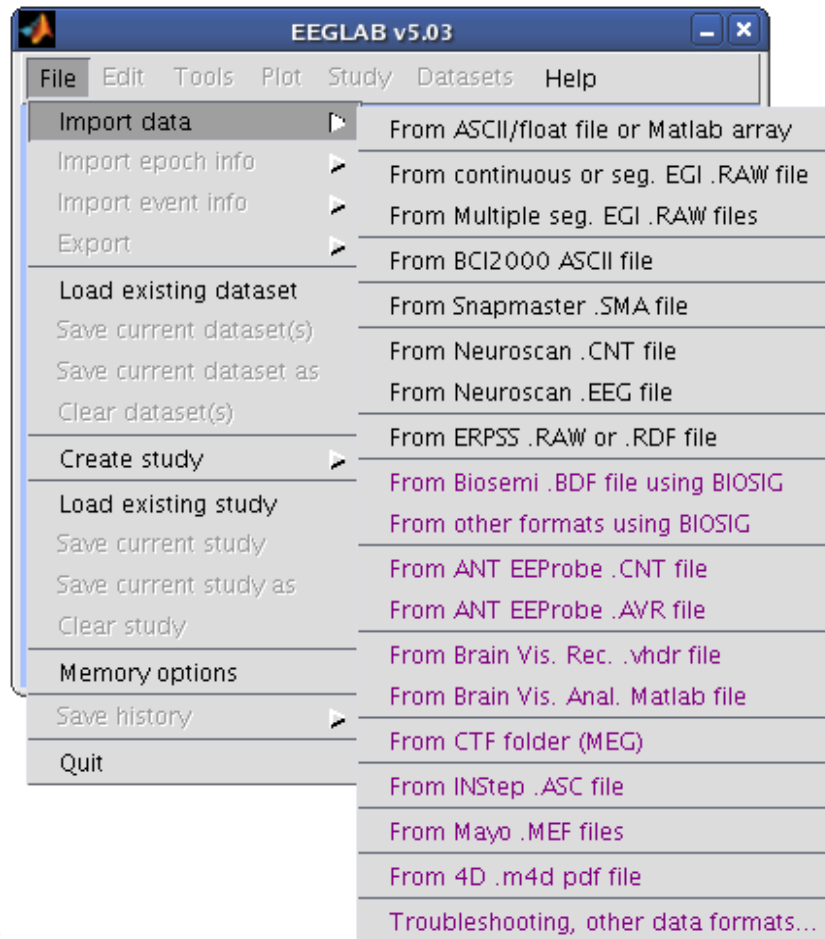
Using Toolbox Path Cache. Type "help toolbox_path_cache" for
To get started, type one of these: helpwin, helpdesk, or demo.
For product information, visit www.mathworks.com.

>> eeglab
```

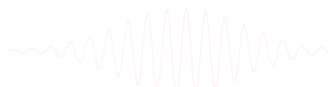


The folder with eeglab.m must be in your Matlab "paths"

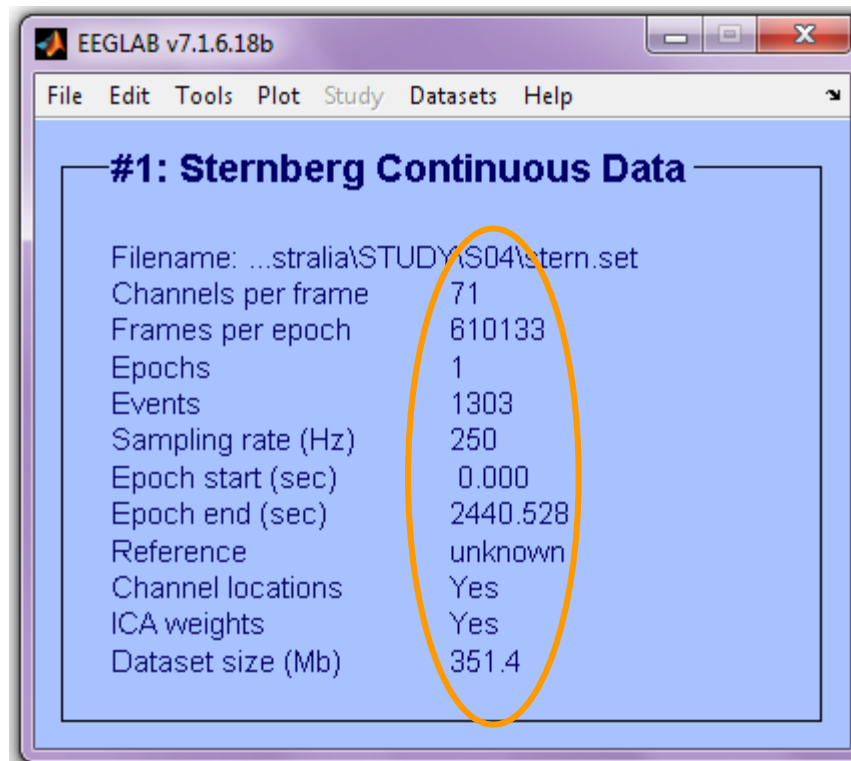
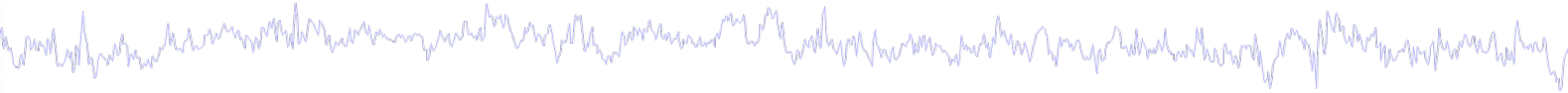
Importing a dataset



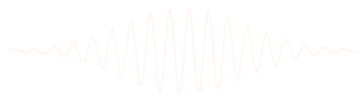
**EEGLAB supports many
different raw data formats**



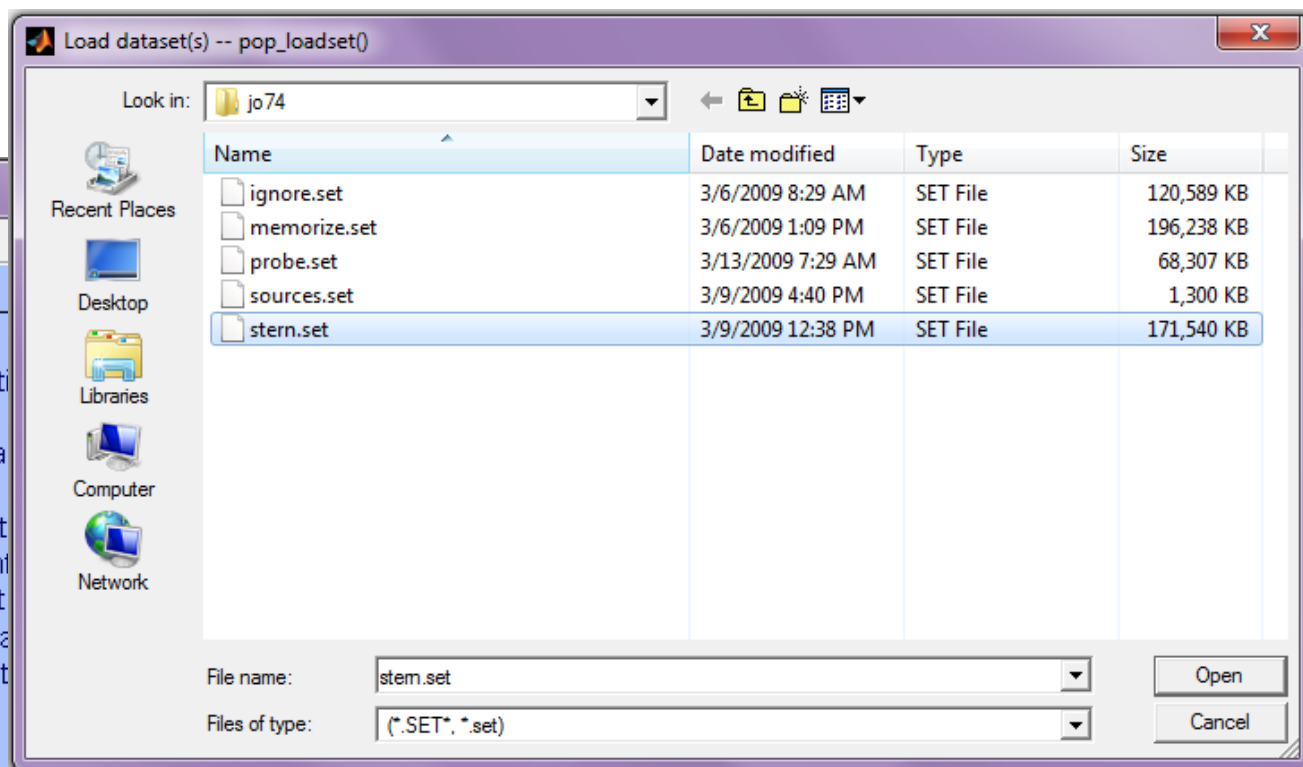
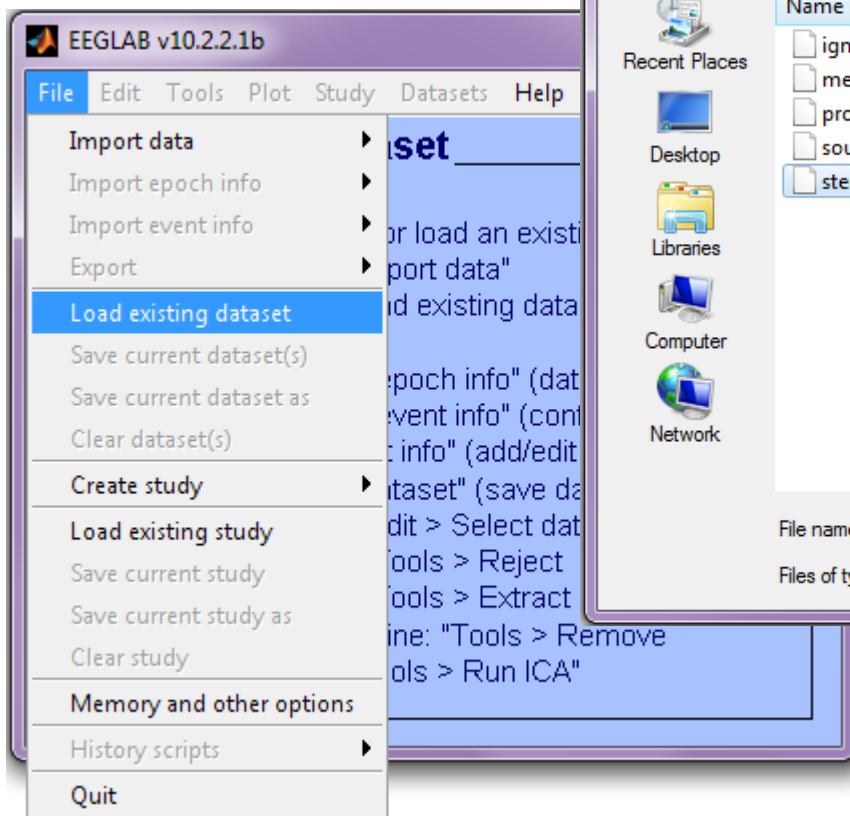
Imported EEG data



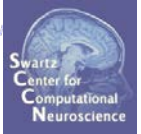
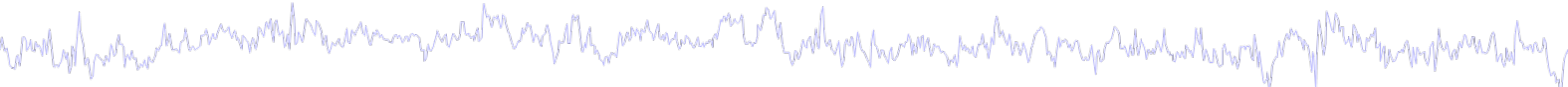
EEGLAB GUI
displays dataset
basics



Load an existing dataset



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

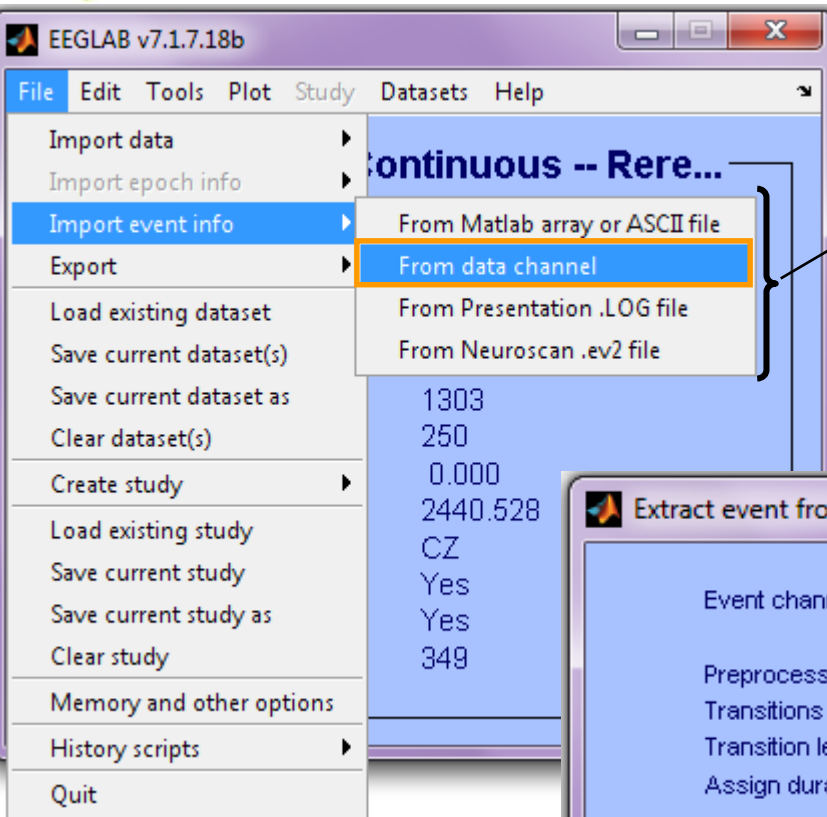
**Identify/reject
bad channels**

**Reject large artifact
time points**

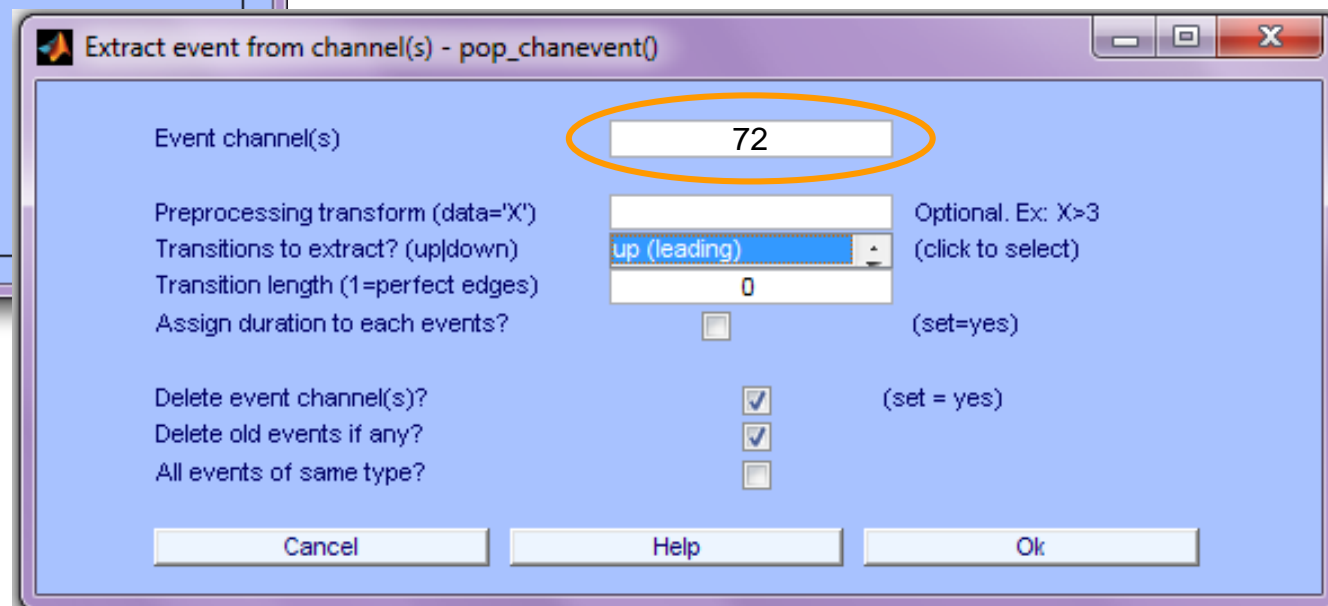
Plot



Import data events

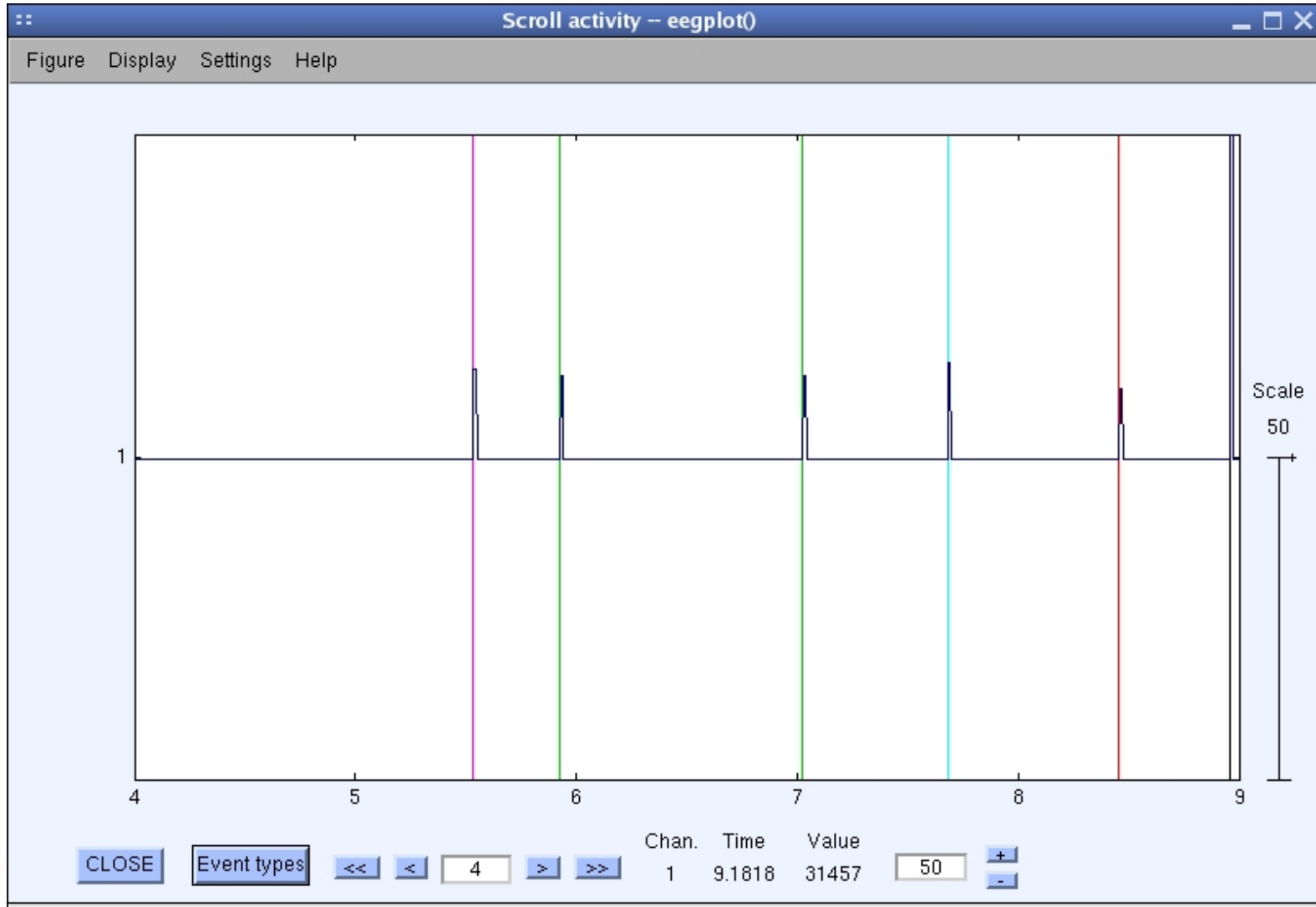
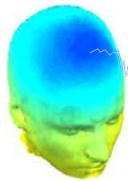


- Import events from Matlab array or ASCII file
- **Import events from data channel**
- Import from Presentation event file
- Import from Neuroscan file

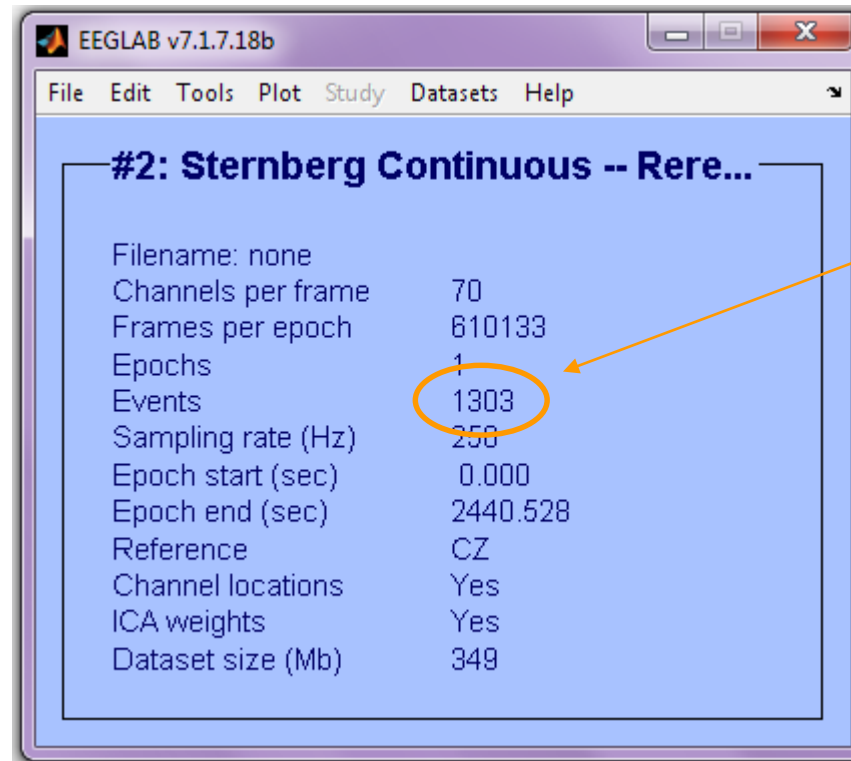
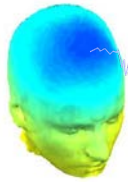


(Often imported automatically
during data import)

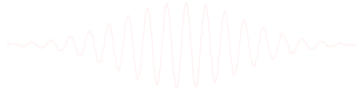
Appearance of an event channel in raw data



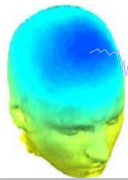
Imported data events



If event import was successful, you will see an appropriate number here



Review event values



EEGLAB v7.1.7.18b

File Edit Tools Plot Study Datasets Help

Dataset info
Event fields
Event values
About this dataset
Channel locations
Select data
Select data using events
Select epochs or events
Copy current dataset
Append datasets
Delete dataset(s)
ICA weights
Dataset size (Mb)

Continuous -- Rere...

70
610133
1
1303
250
0.000
2440.528
CZ
Yes
Yes
349

Edit event values -- pop_editeventvals()

Edit event field values (currently 1303 events)

Basic fields

Number of possible event fields is unlimited

Trial	1
Event_Type	Picture
Type	nonWMM
Latency (sec)	3.112
Ttime	0
Uncertainty	2
Duration	50283
Uncertainty2	3
ReqTime	0
ReqDur	50000
Init_index	1
Init_time	0.0227
Duration (sec)	0
Load	

Delete event

Delete CURRENT event

Append event AFTER current event

Event Num

Insert event << < 1 > >> Append event

Re-order events (for review only)

Main sorting field: No field selected ☐ Click for decreasing order

Secondary sorting field: No field selected ☐ Click for decreasing order

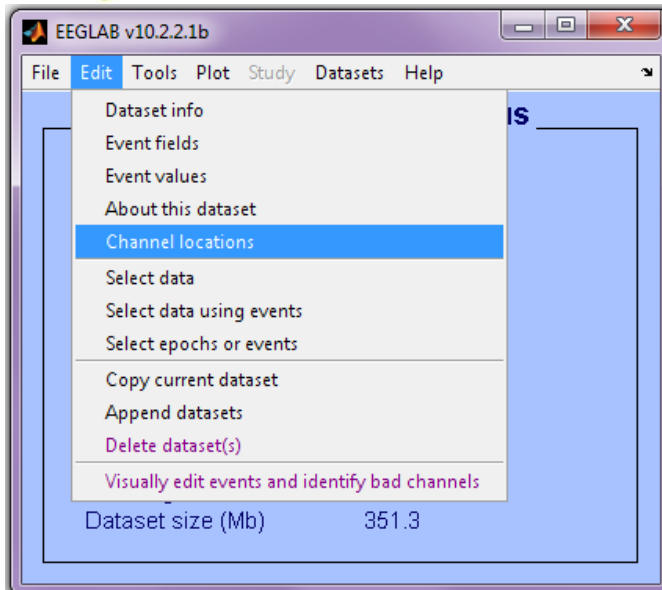
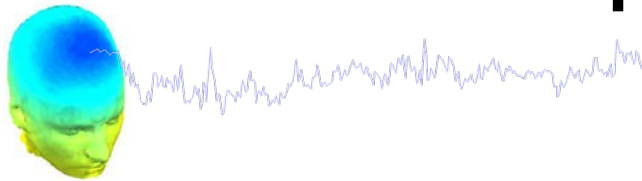
Re-sort

Cancel Help Ok

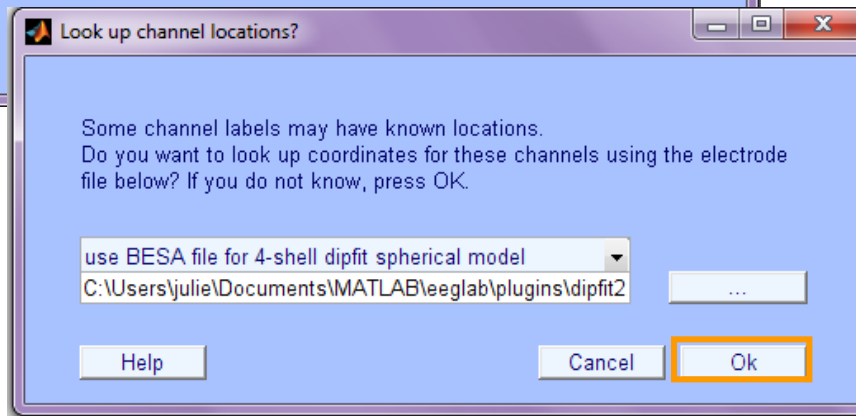
Insert event BEFORE current event

To resort: first select Main sorting field

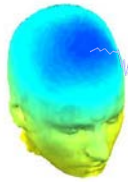
Import channel locations



9 file formats supported:
['loc'|'sph'|'sfp'|'xyz'|'asc'|'polhemus'|'besa'|'chanedit'|'custom']



Import channel locations



Edit channel info -- pop_chanedit()

Channel information ("field_name"):

Channel label ("label")	LEYE
Polar angle ("theta")	-45.1543
Polar radius ("radius")	0.54374
Cartesian X ("X")	0.79487
Cartesian Y ("Y")	0.79917
Cartesian Z ("Z")	-0.15585
Spherical horiz. angle ("sph_theta")	45.1543
Spherical azimuth angle ("sph_phi")	-7.8725
Spherical radius ("sph_radius")	1.1379
Channel type	EEG
Reference	
Index in backup 'urchanlocs' structure	
Channel in data array (set=yes)	<input checked="" type="checkbox"/>

Channel number (of 71)

Channel indices: 1:71
Type (e.g. EEG): EEG

Buttons: Delete chan, Insert chan, <<, <, >, >>, Append chan, Plot 2-D, Plot radius (0.2-1, []=auto), Nose along +X, Plot 3-D (xyz), Read locations, Read locs help, Look up locs, Save (as .ced), Save (other types), Help, Cancel, Ok

Opt. head center
Rotate axis
Transform axes

XYZ -> polar & sph.
Sph. -> polar & xyz
Polar -> sph. & xyz

Set head radius
Set channel types
Set reference

Convert channel locations -- pop_chancenter()

Optimize center location ☒ or specify center 0 0 0

Channel indices to ignore for best-sphere matching

Help Cancel Ok

Force electrode location -- forclocs()

X/Y value Coordinate Electrode list

0 X (rotate X-Z plane) Cz Pick

Help Cancel Ok

Set channel ...

Channel indices 1:71
Type (e.g. EEG) EEG

Help Cancel Ok

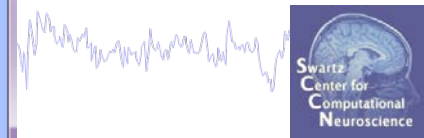
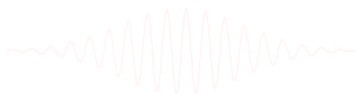
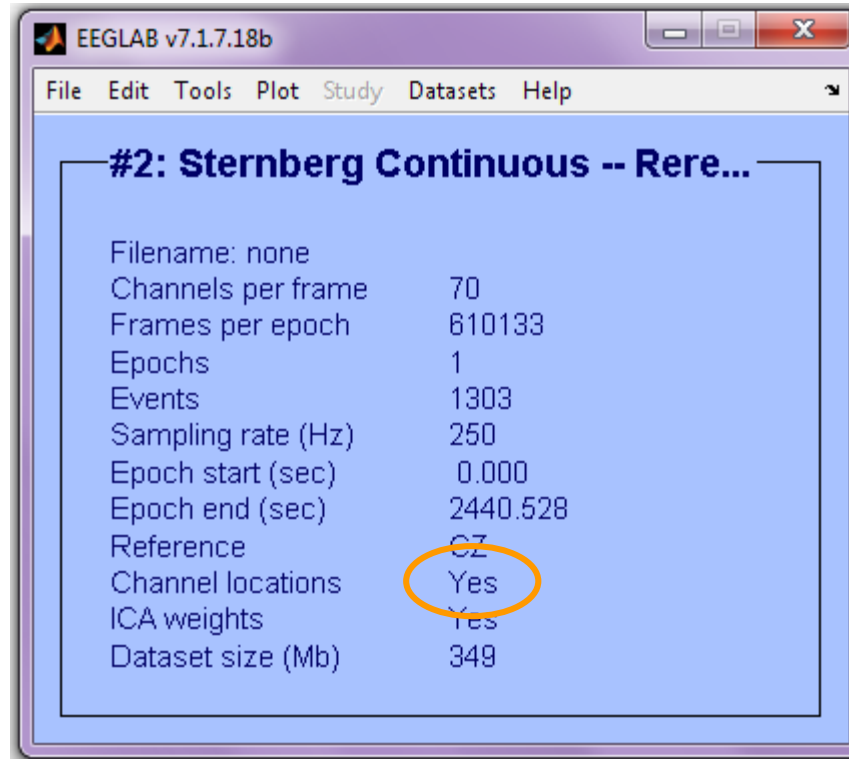
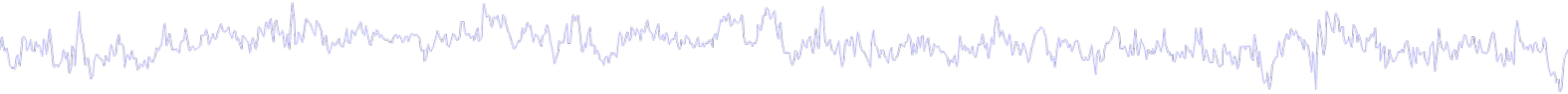


Figure 4 displays a 3D scatter plot of 100 data points, labeled PO1 through PO100, within a 3D coordinate system. The axes are labeled X, Y, and Z. The points are distributed in a cluster, with a red dashed line indicating a specific path or boundary. The plot is shown in a software window titled "Figure 4".

Imported channel locations



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

**Identify/reject
bad channels**

**Reject large artifact
time points**

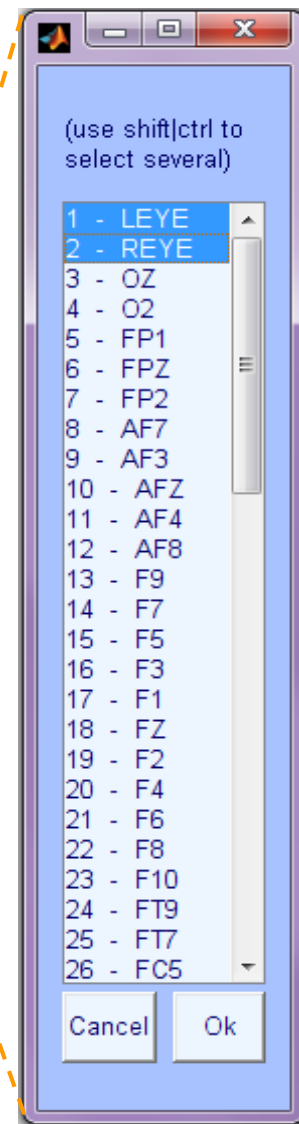
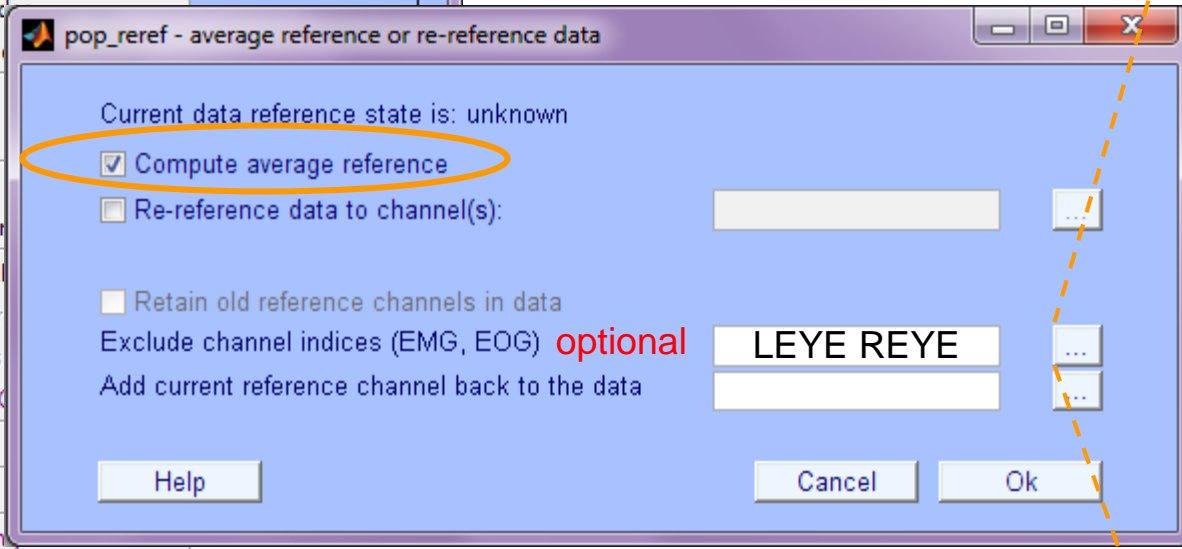
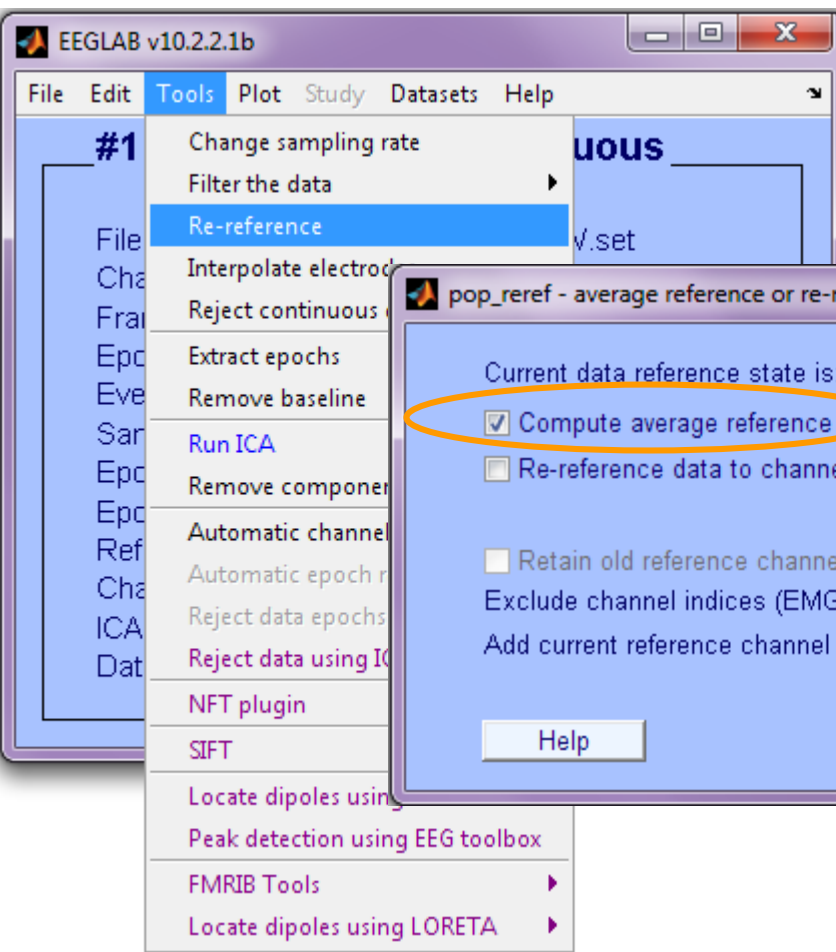
Plot



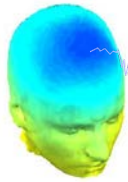
Re-reference data (if necessary/desired)



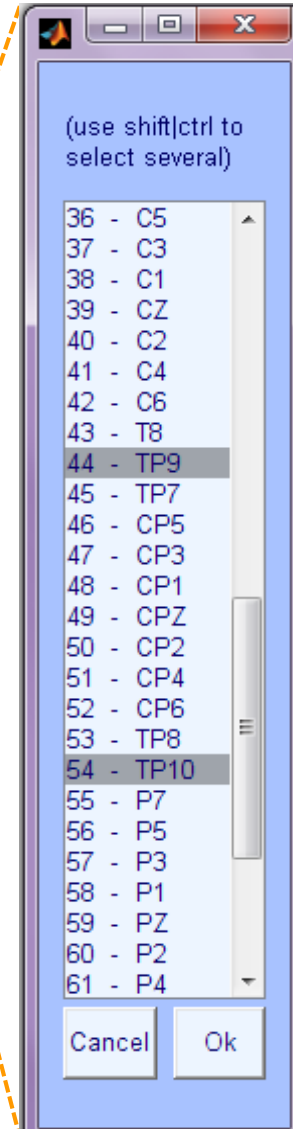
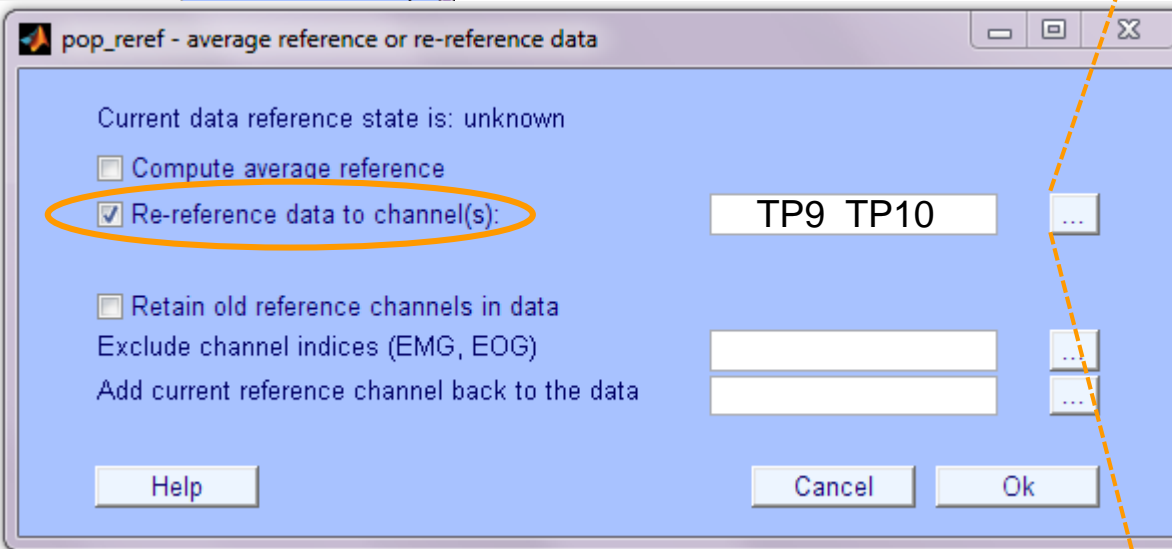
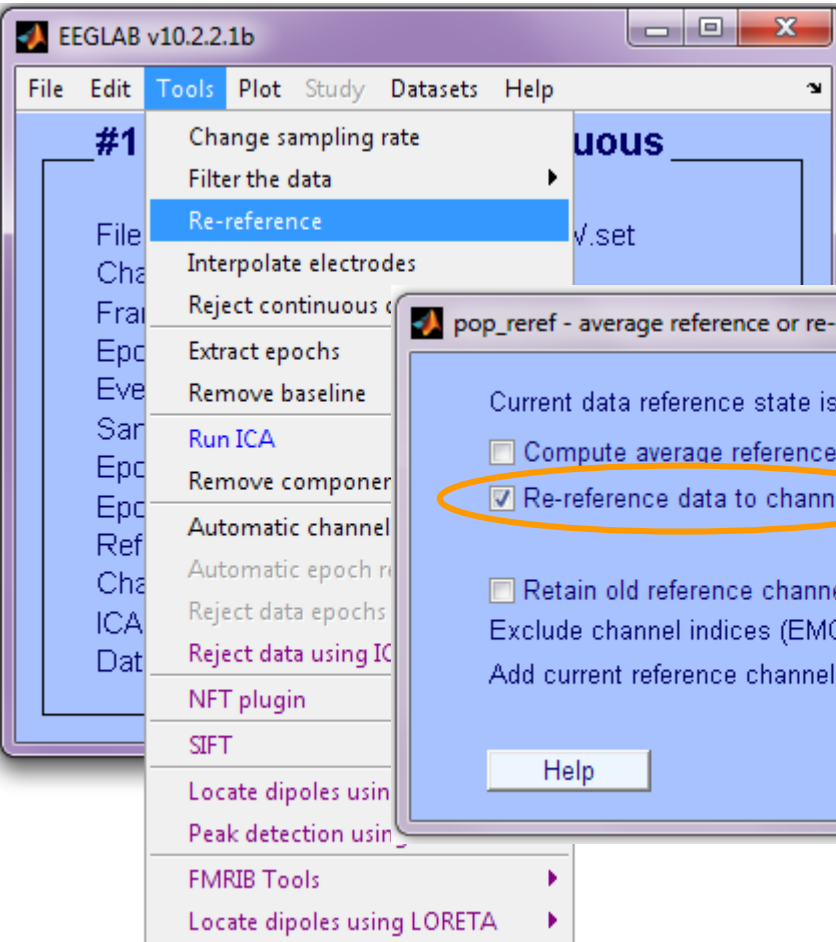
For example,
average reference



Re-reference data (if necessary/desired)

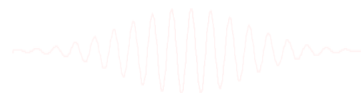
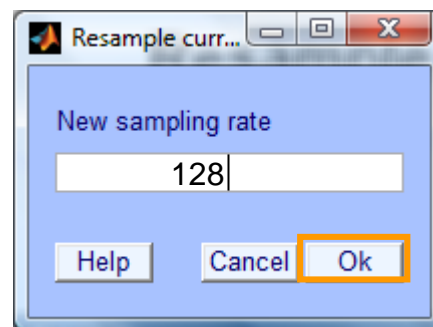
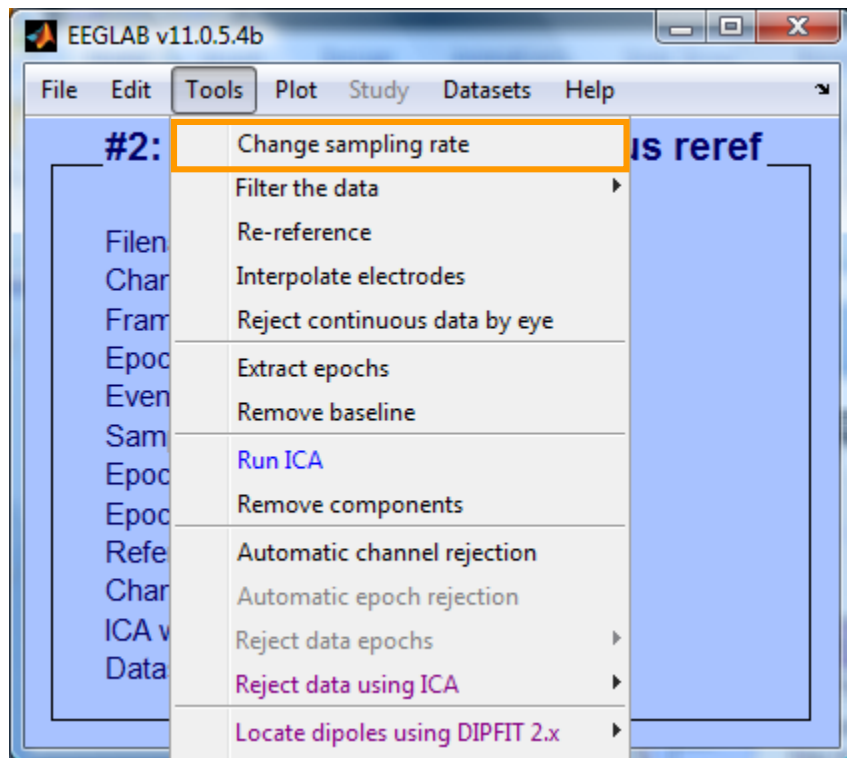


**OR, re-reference to
(i.e.) 'linked mastoids'**

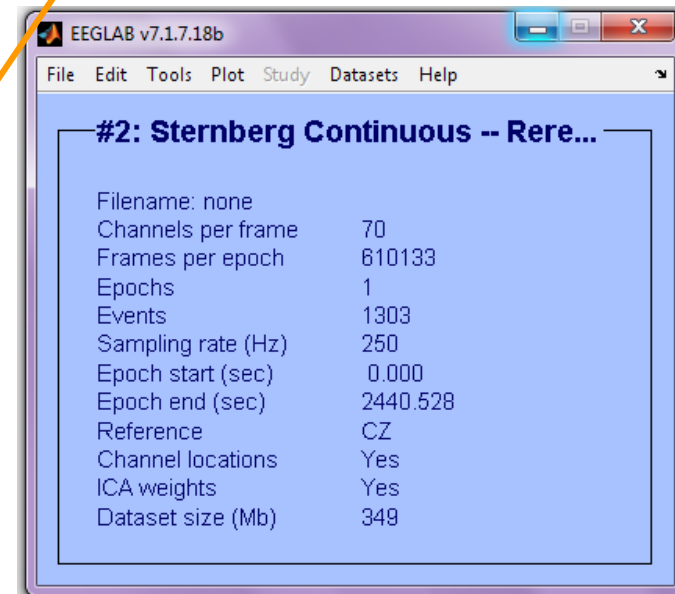
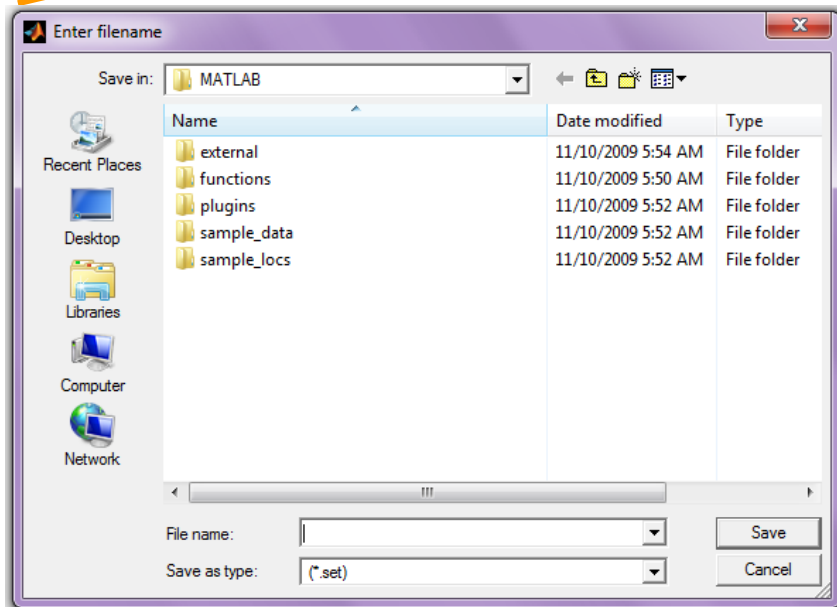
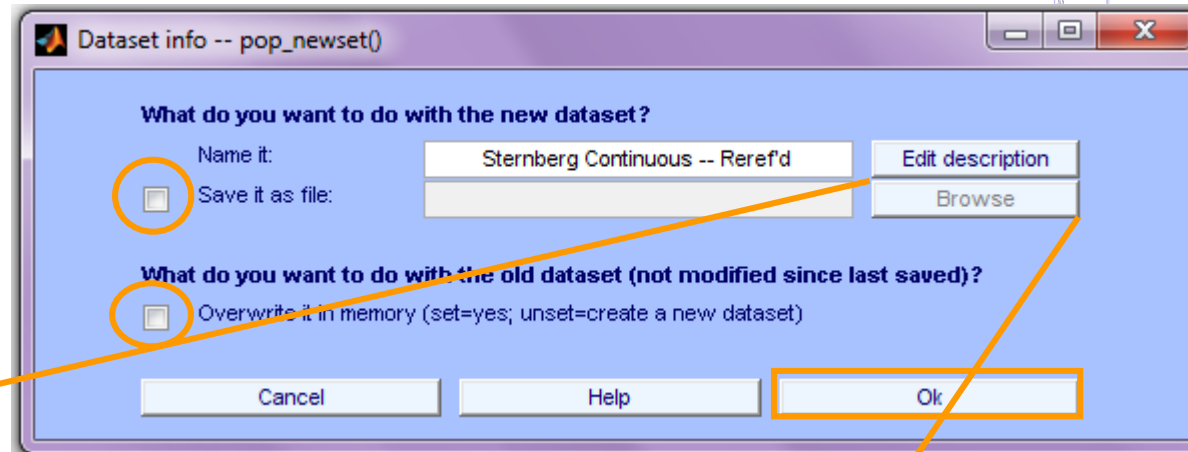
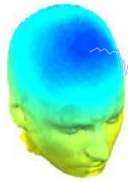


```
EEG = pop_reref( EEG, 39);
```

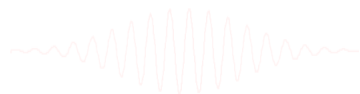
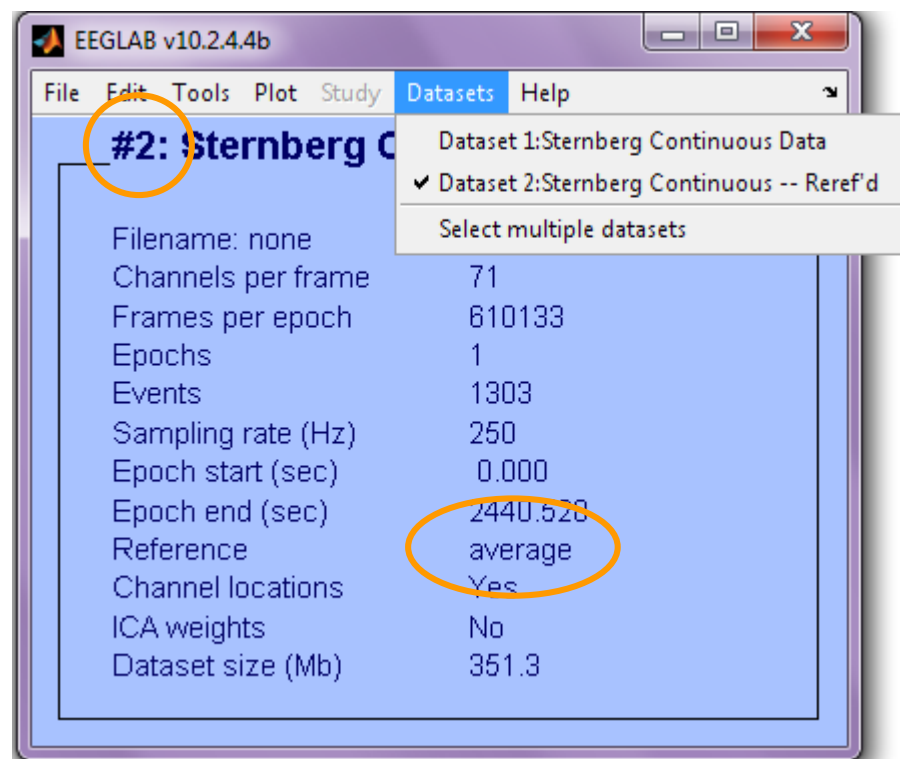
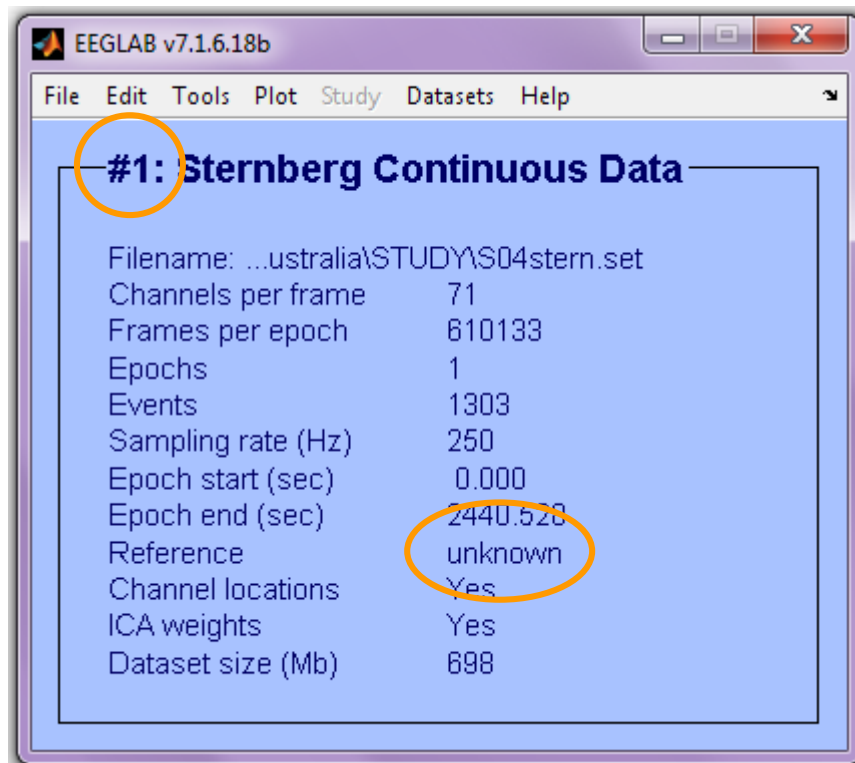
Resample data (if necessary)



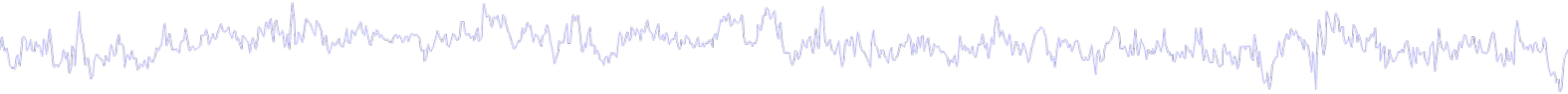
Save new dataset, keep old one



Multiple active datasets (ALLEEG)



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

**Identify/reject
bad channels**

**Reject large artifact
time points**

Plot

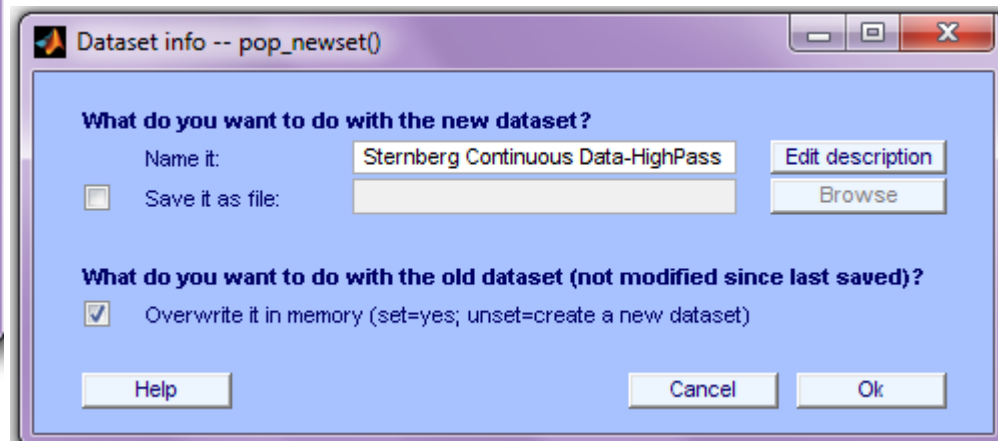
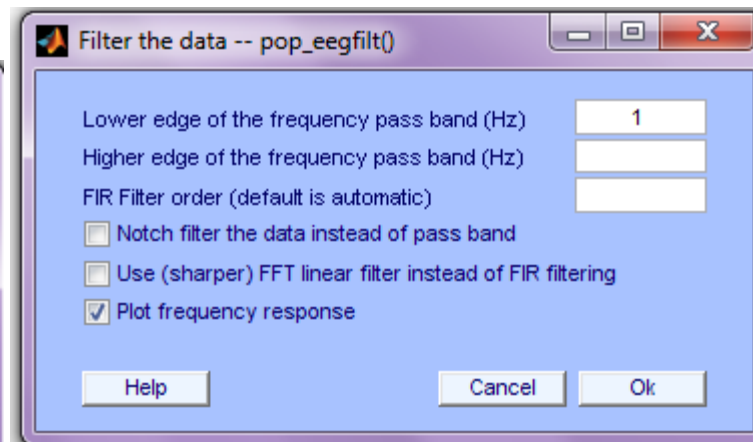
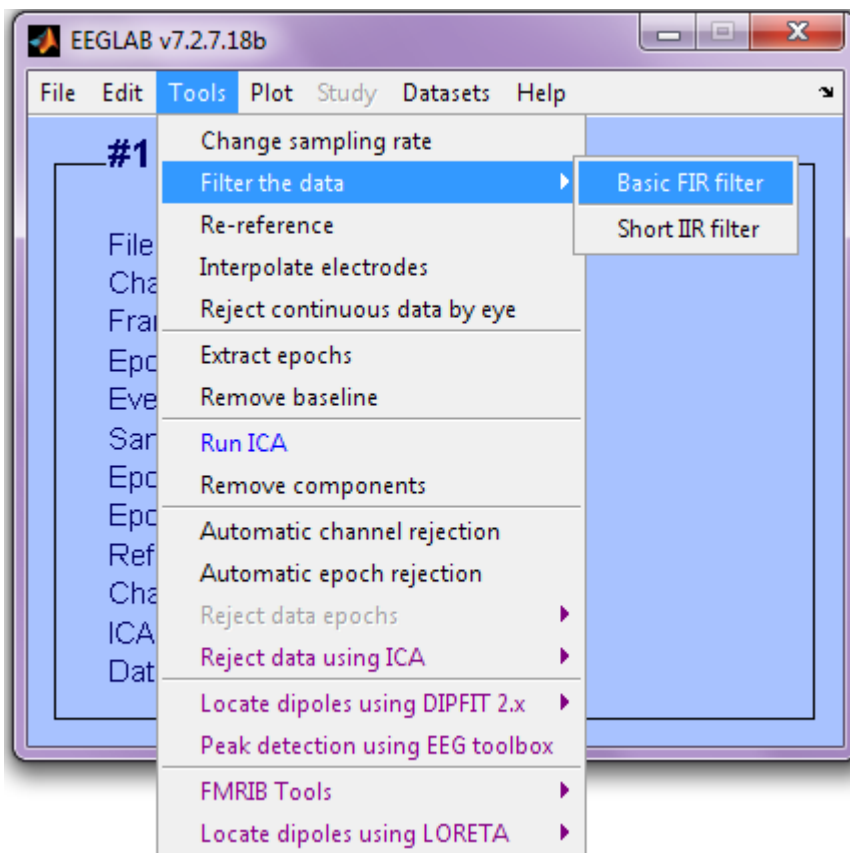


Filter the data (if necessary/desired)

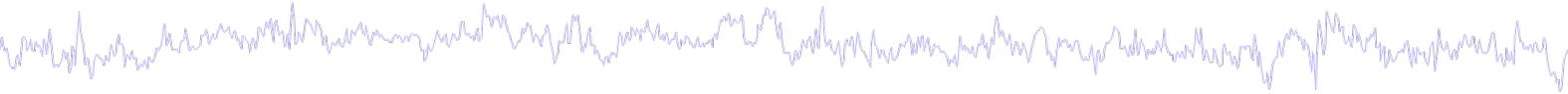


Lower cut off frequencies require longer stretches of continuous data

**High-pass
needed
for ICA**



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

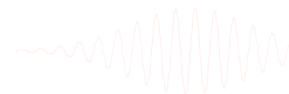
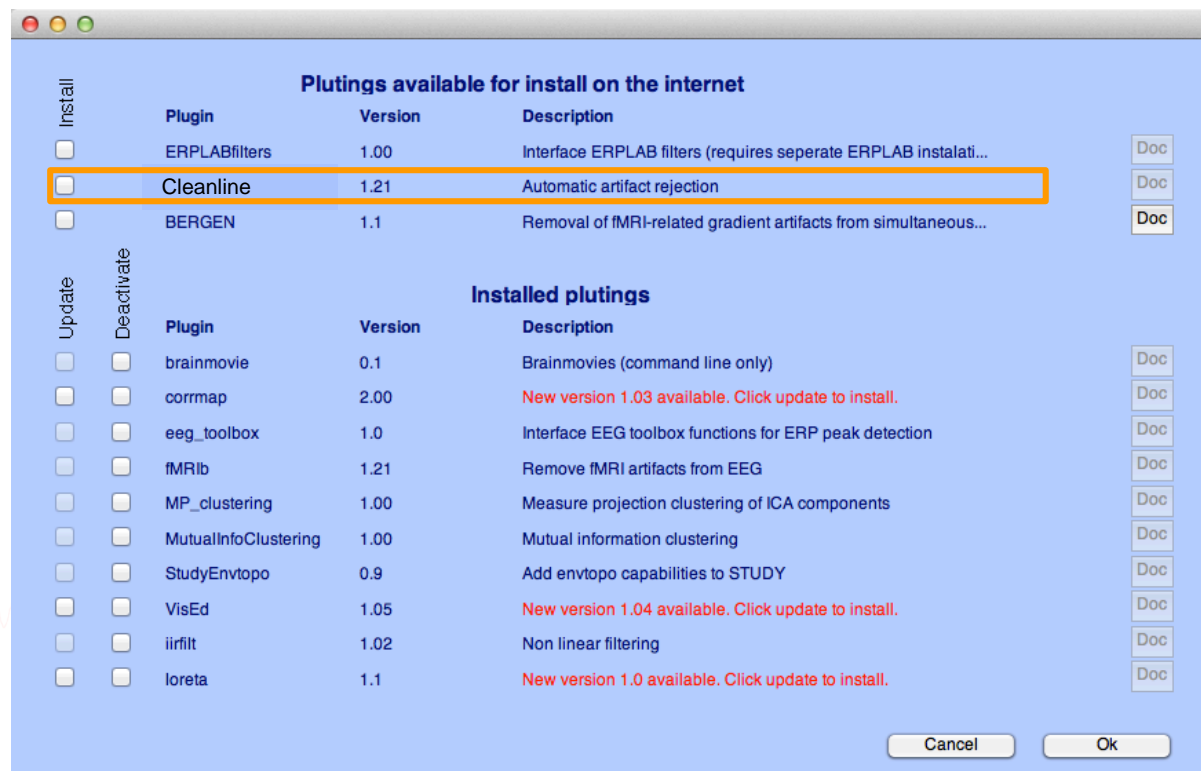
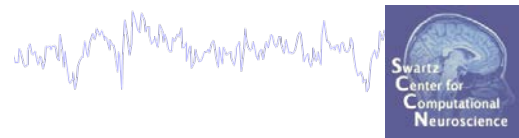
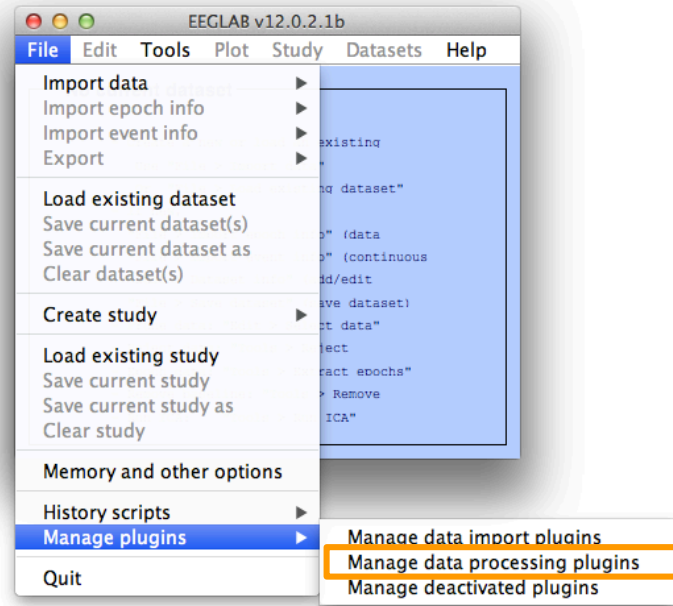
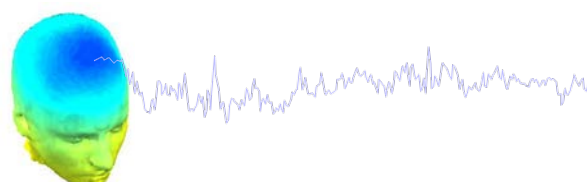
**Remove line noise
(if necessary)**

**Identify/reject
bad channels**

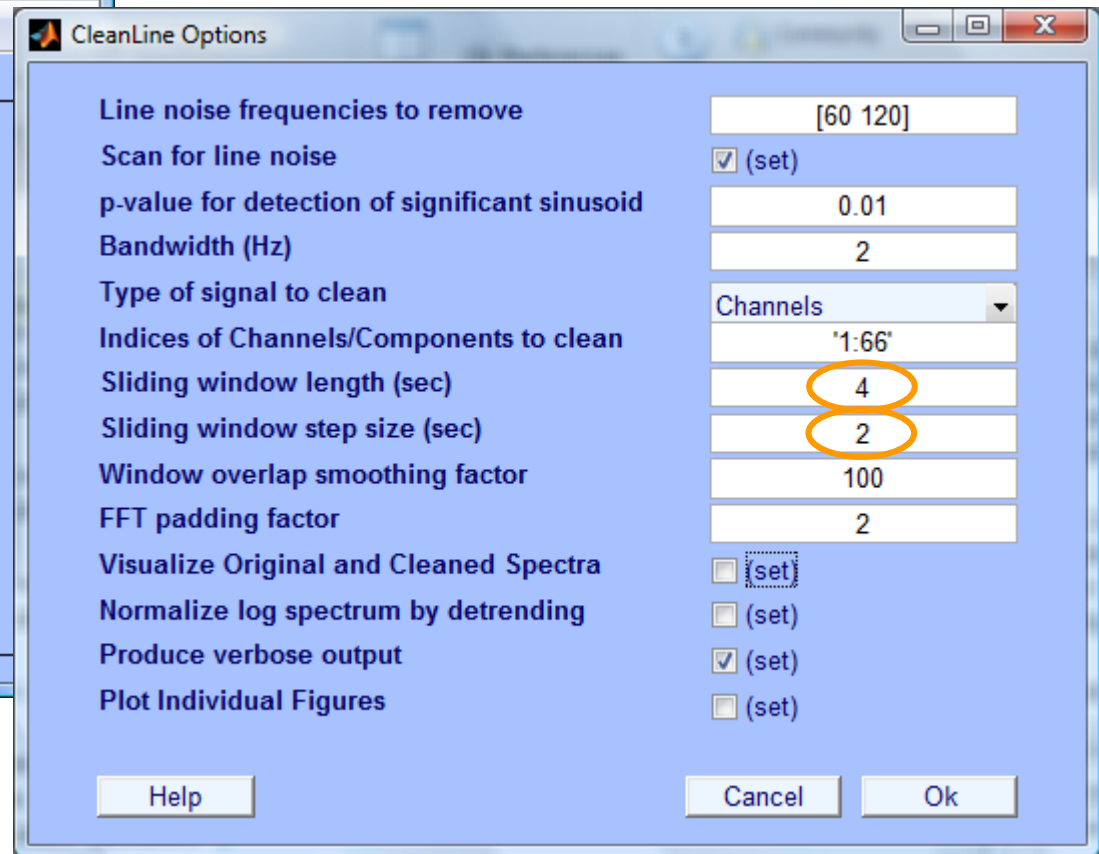
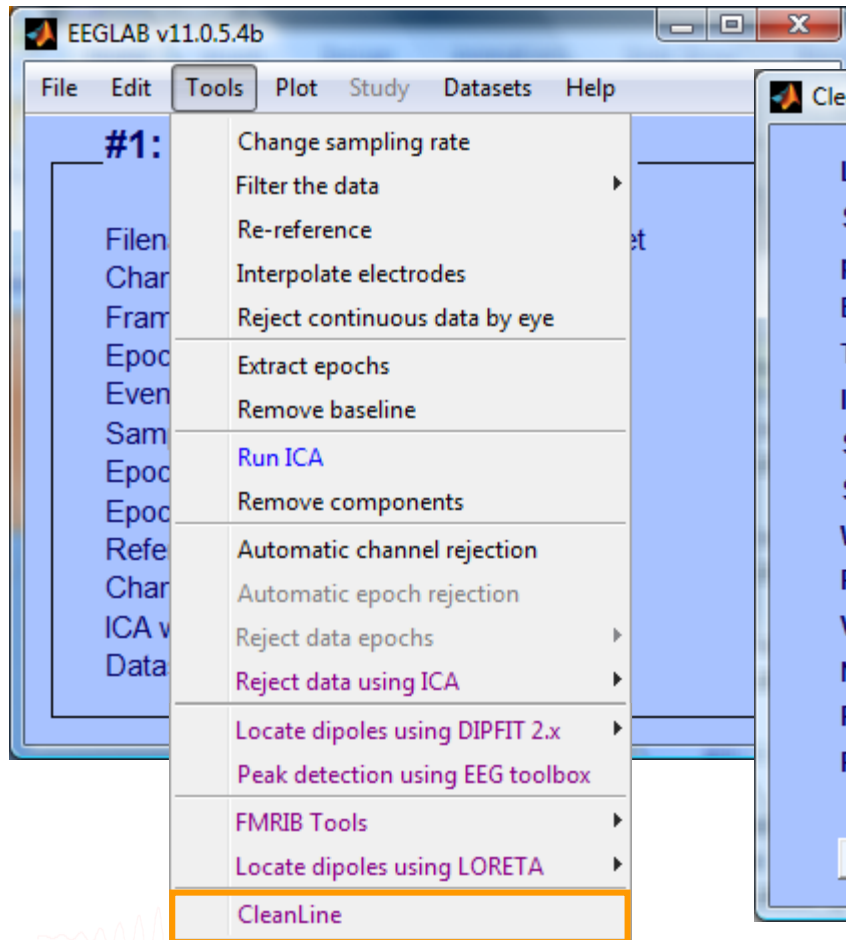
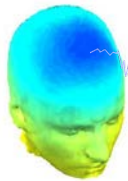
**Reject large artifact
time points**

Plot

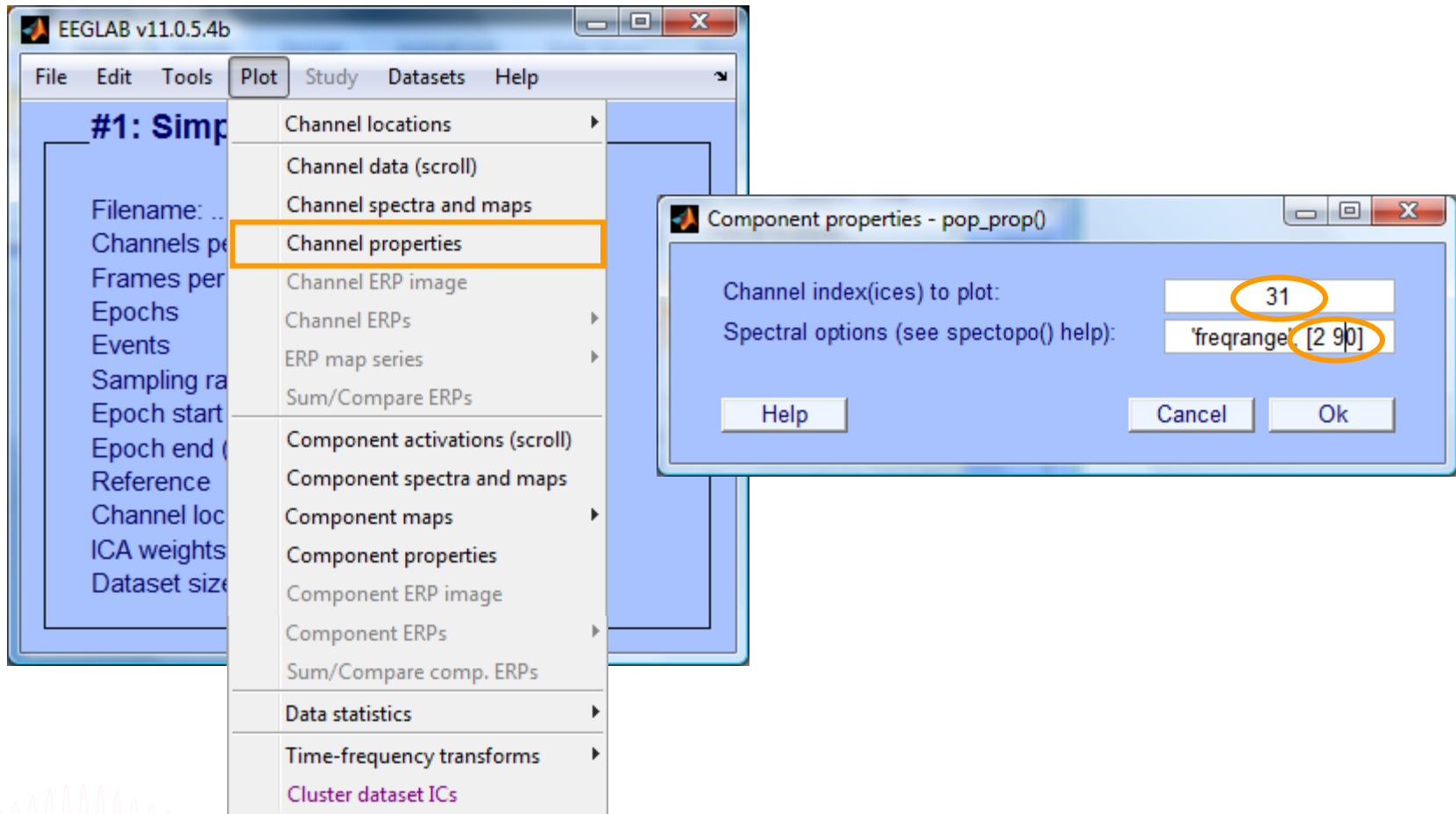




Remove line noise (Cleanline)



Plot channel spectra



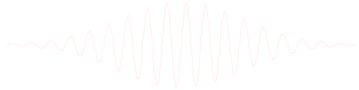
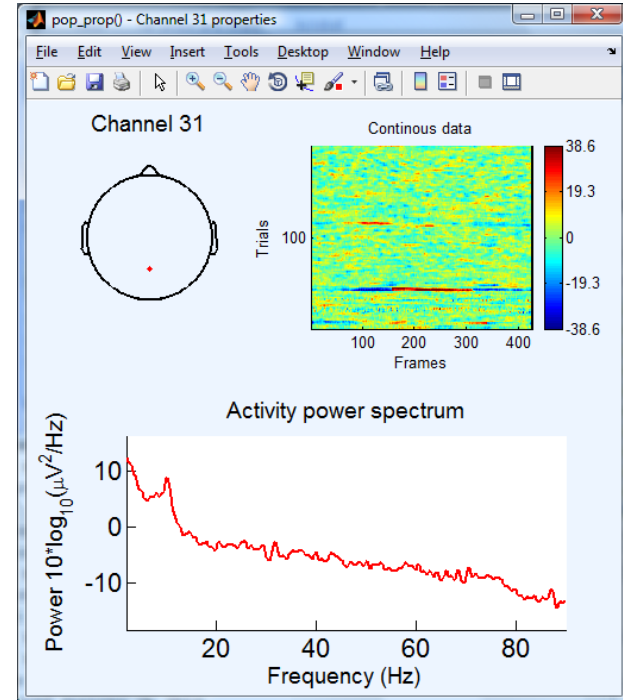
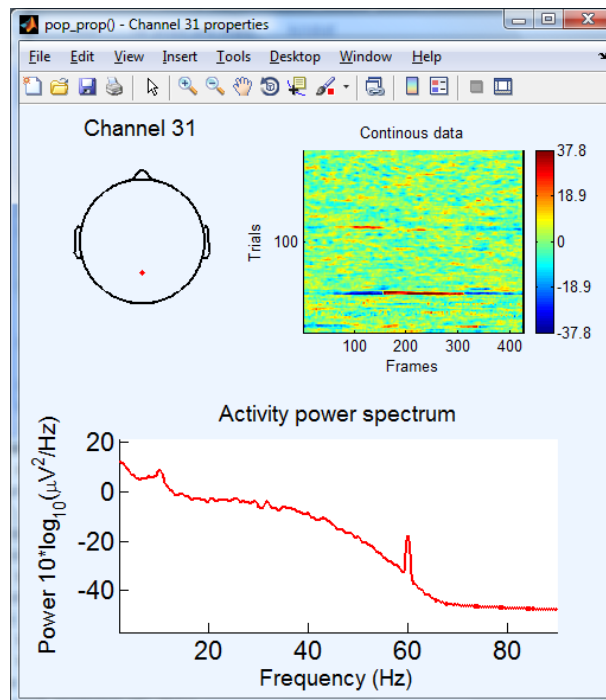
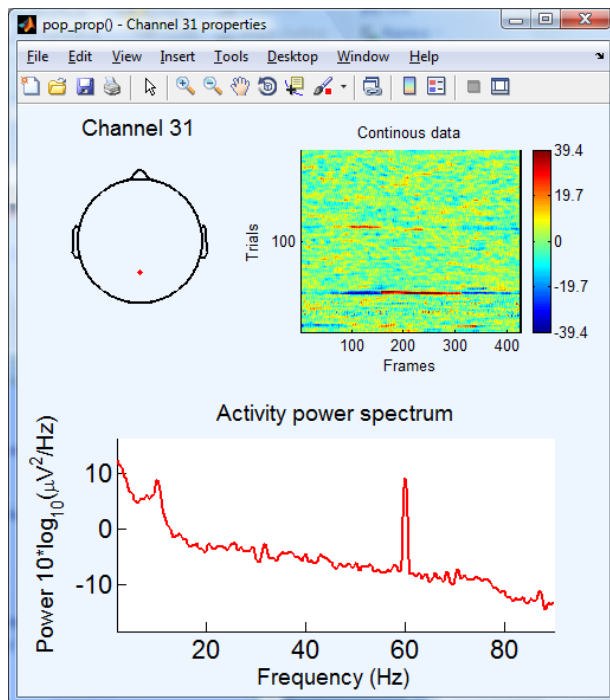
Filter comparisons



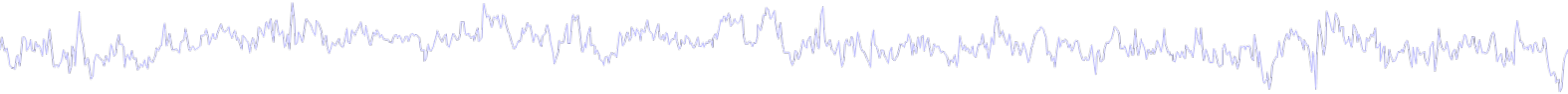
0.5 Hz high-pass filter

0.5 Hz high-pass filter
50 Hz low-pass filter

0.5 Hz high-pass filter
Cleanline: 60 Hz



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

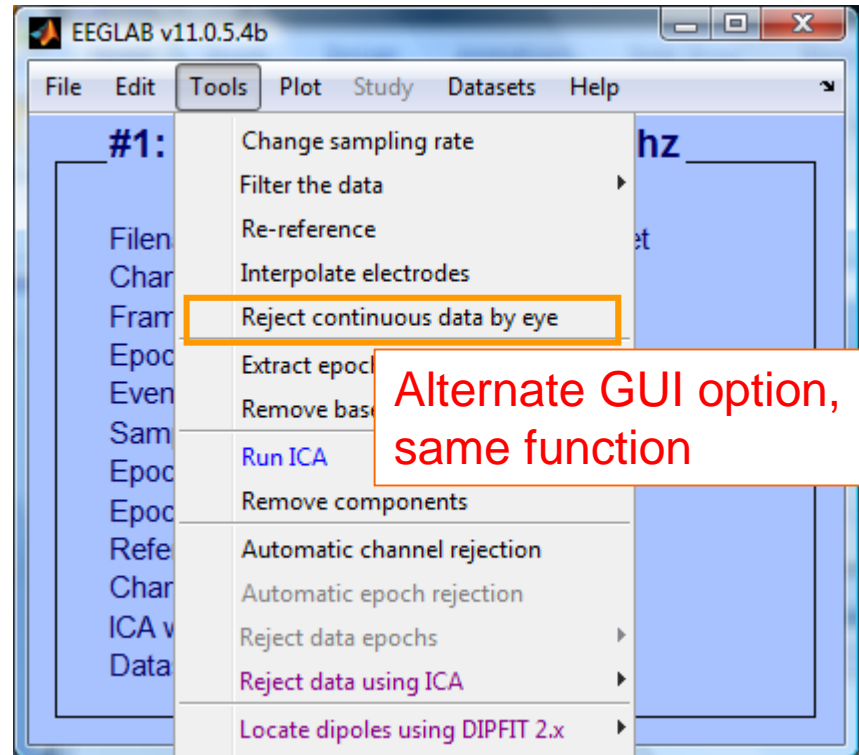
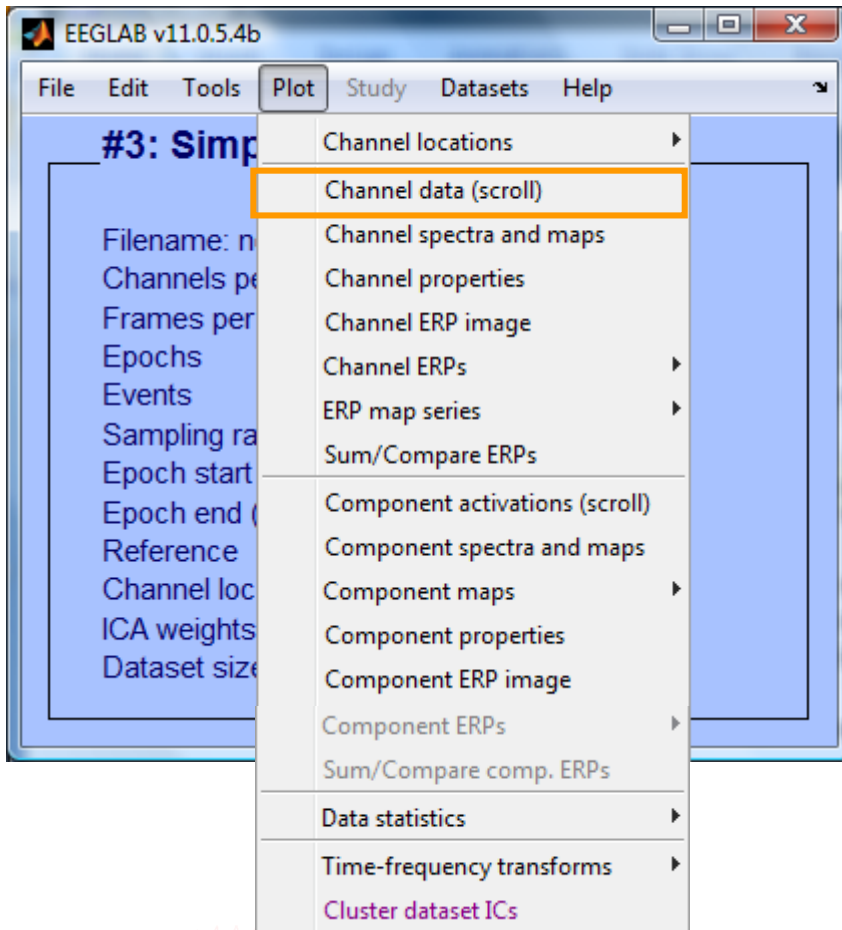
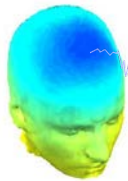
**Identify/reject
bad channels**

**Reject large artifact
time points**

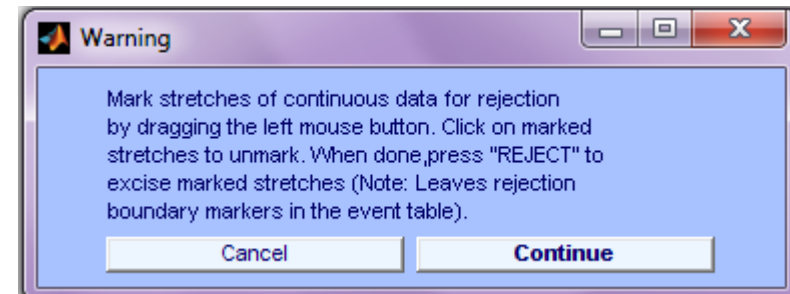
Plot



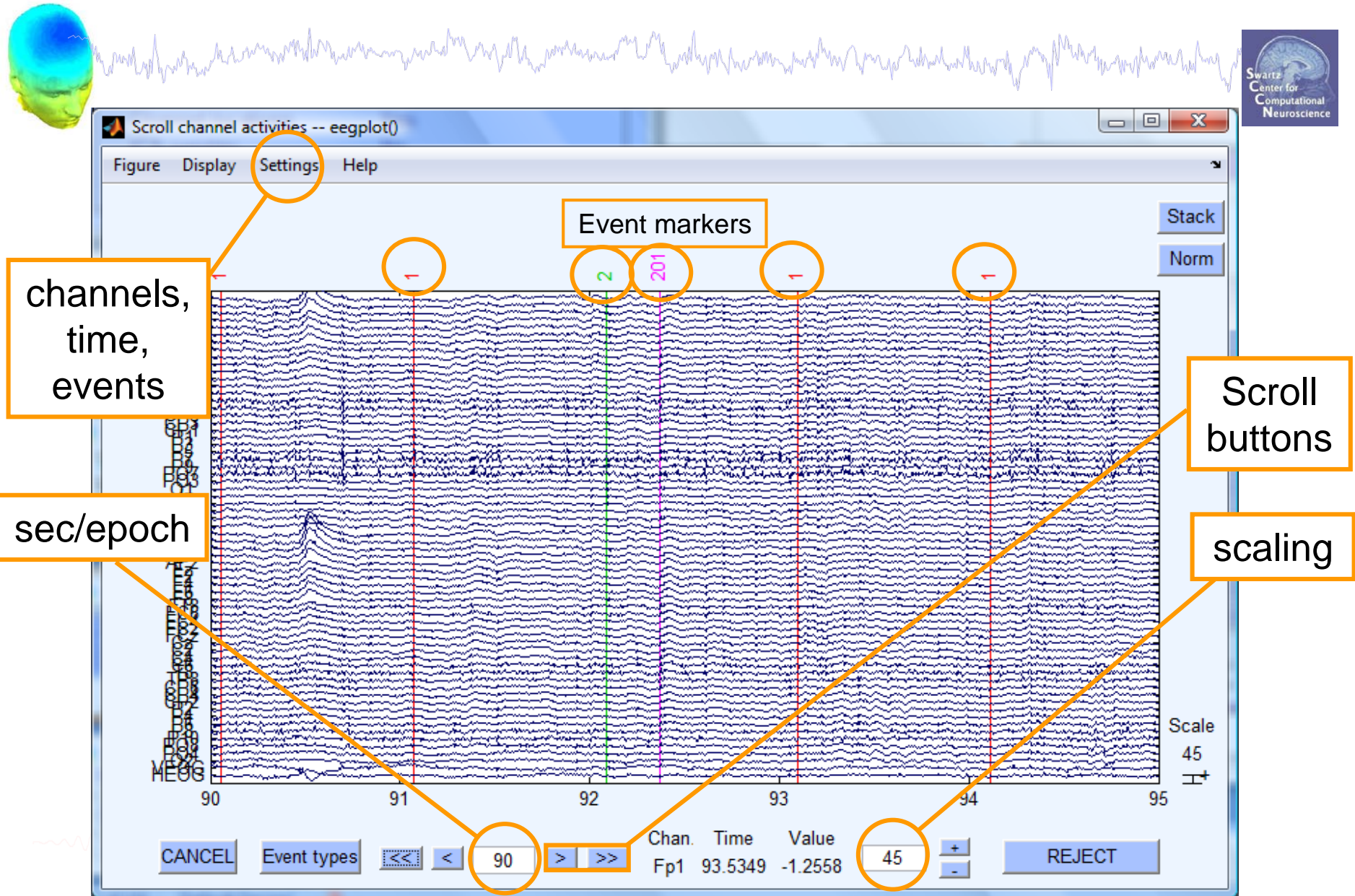
Scroll channel data



Alternate GUI option,
same function



Scroll channel data



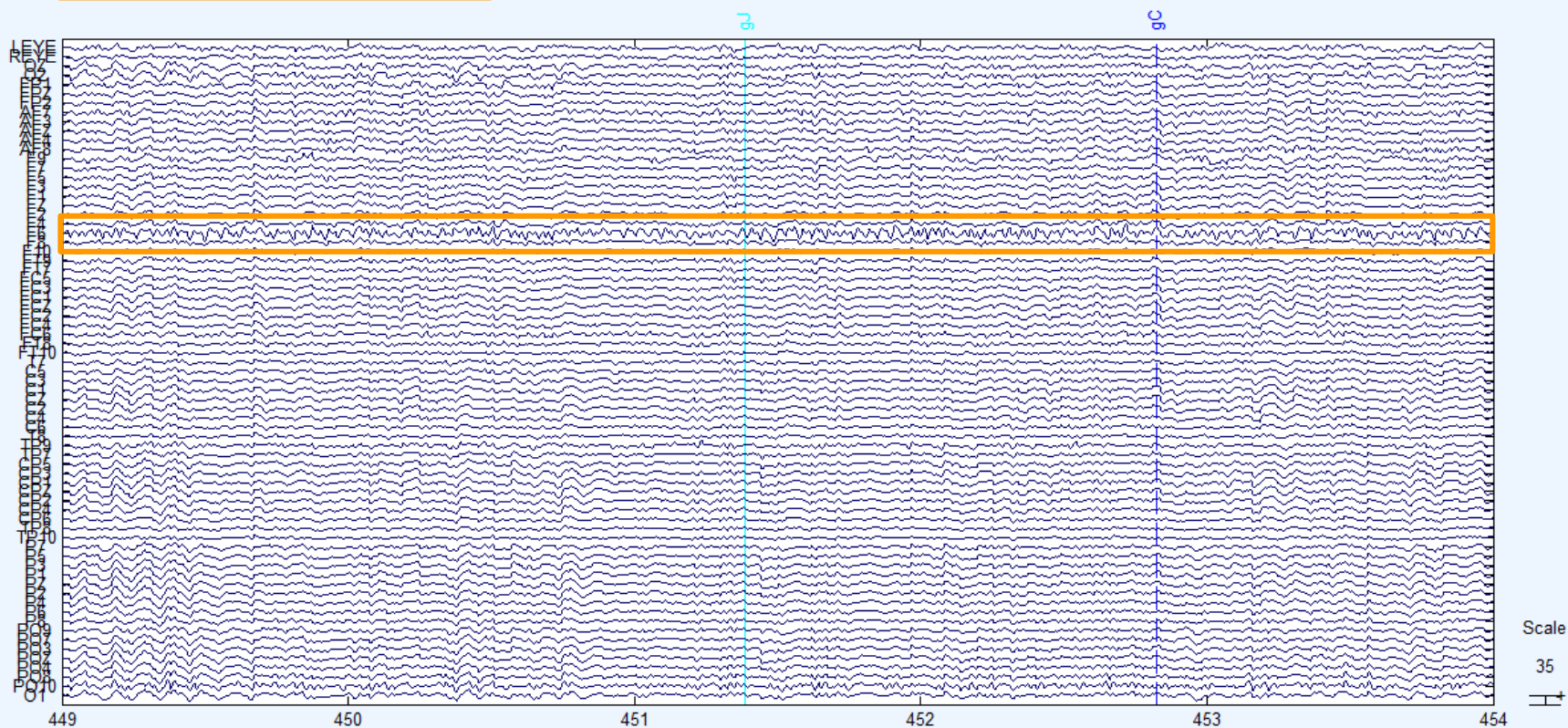
Manually identifying bad channels



Scroll channel activities -- eegplot()

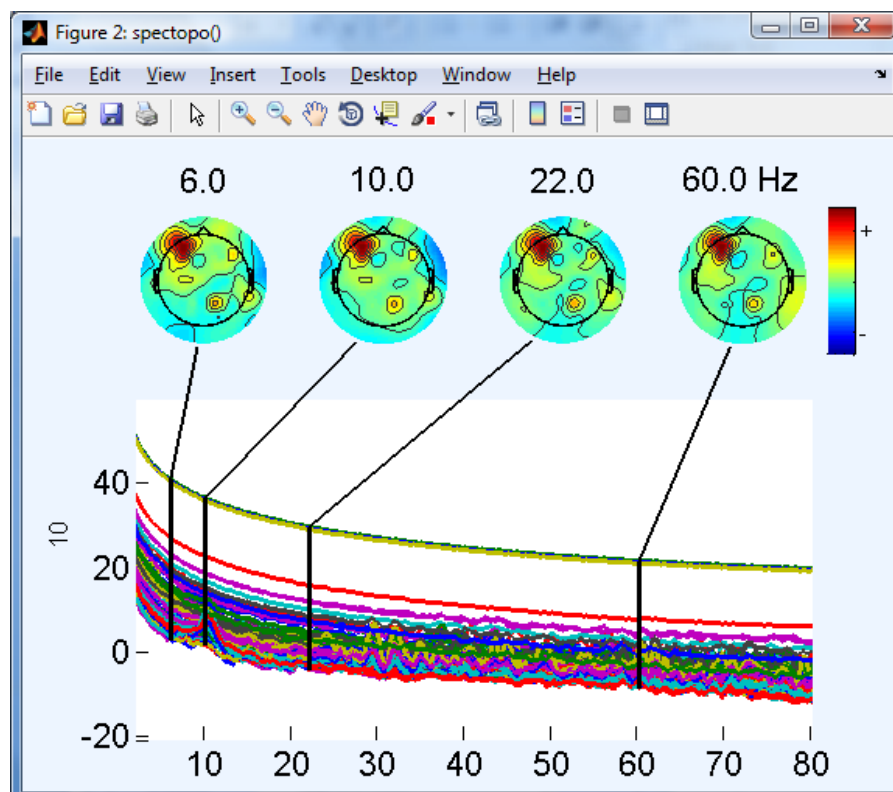
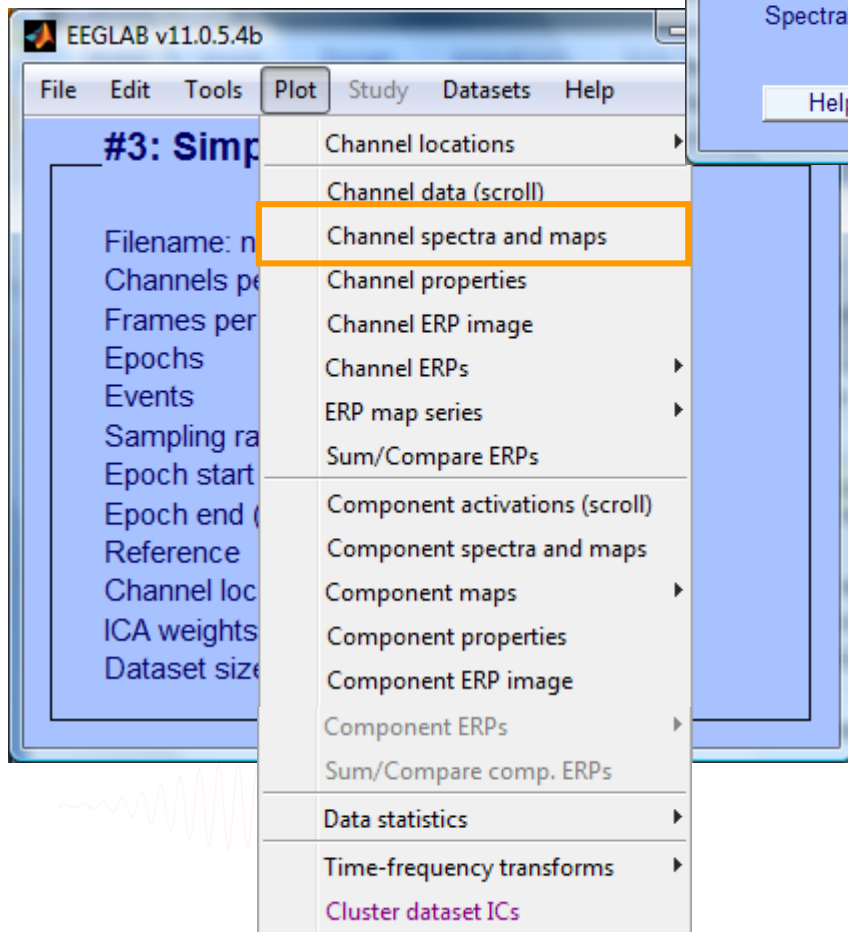
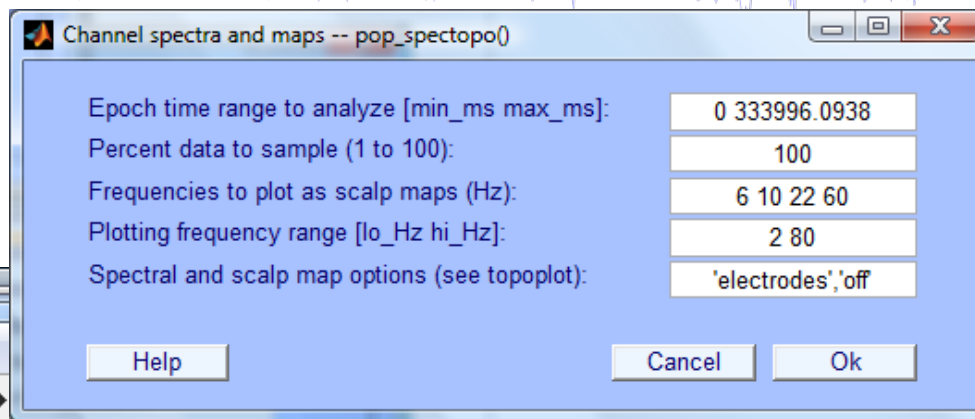
Figure Display Settings Help

Identify bad channel

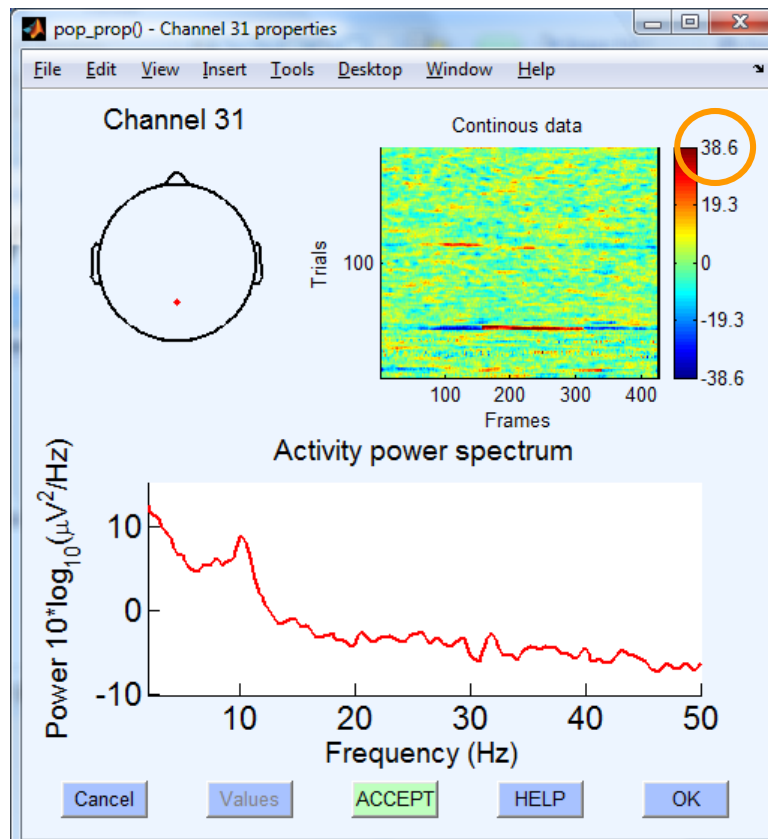
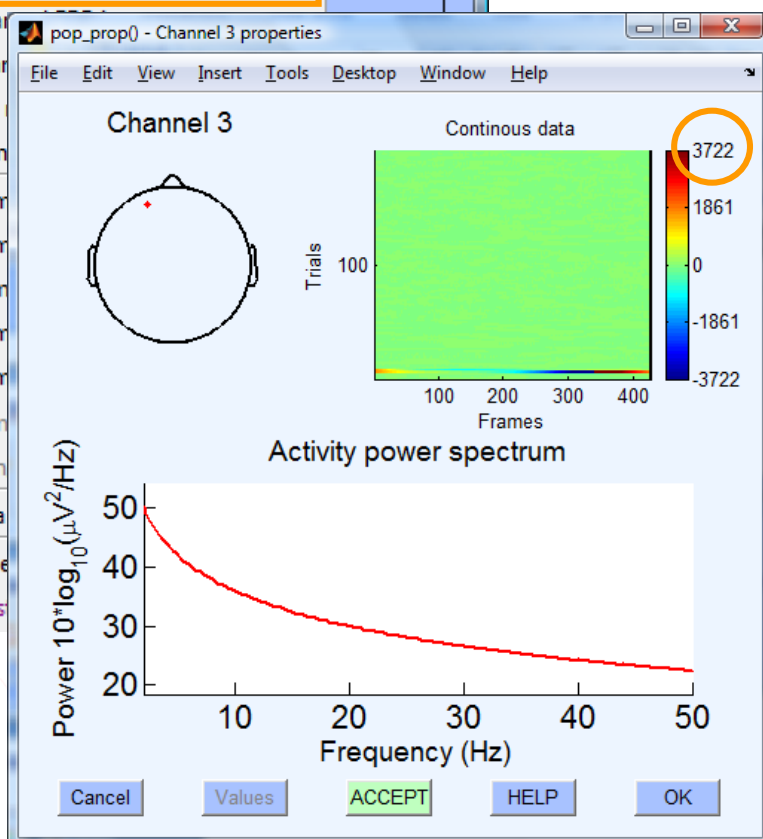
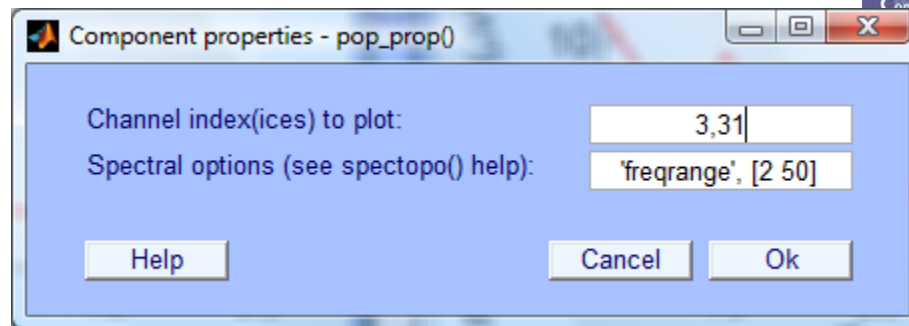
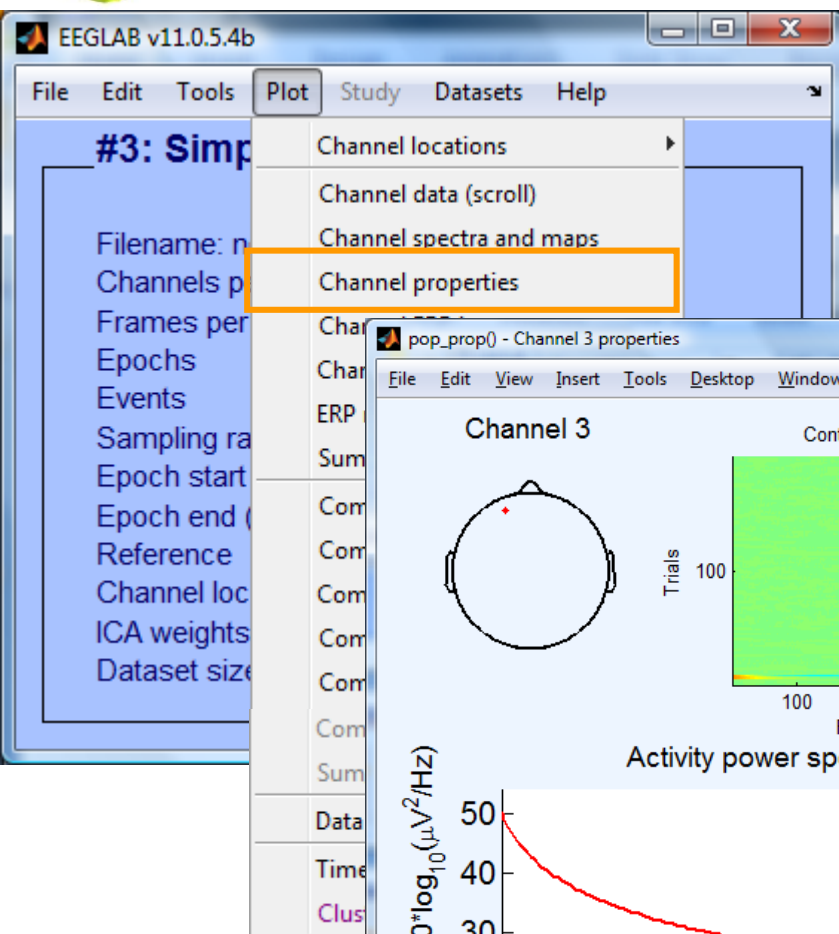
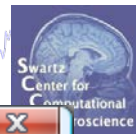


CANCEL		Event types		<<	<	449	>	>>	Chan.	Time	Value	35	+	REJECT	-
									O1	451.0988	3.6619				

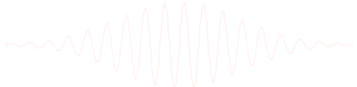
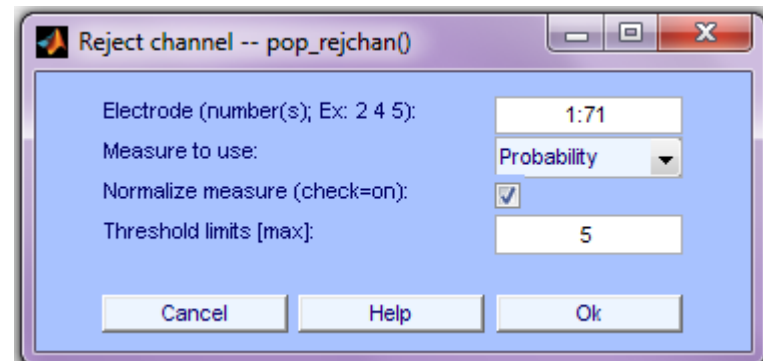
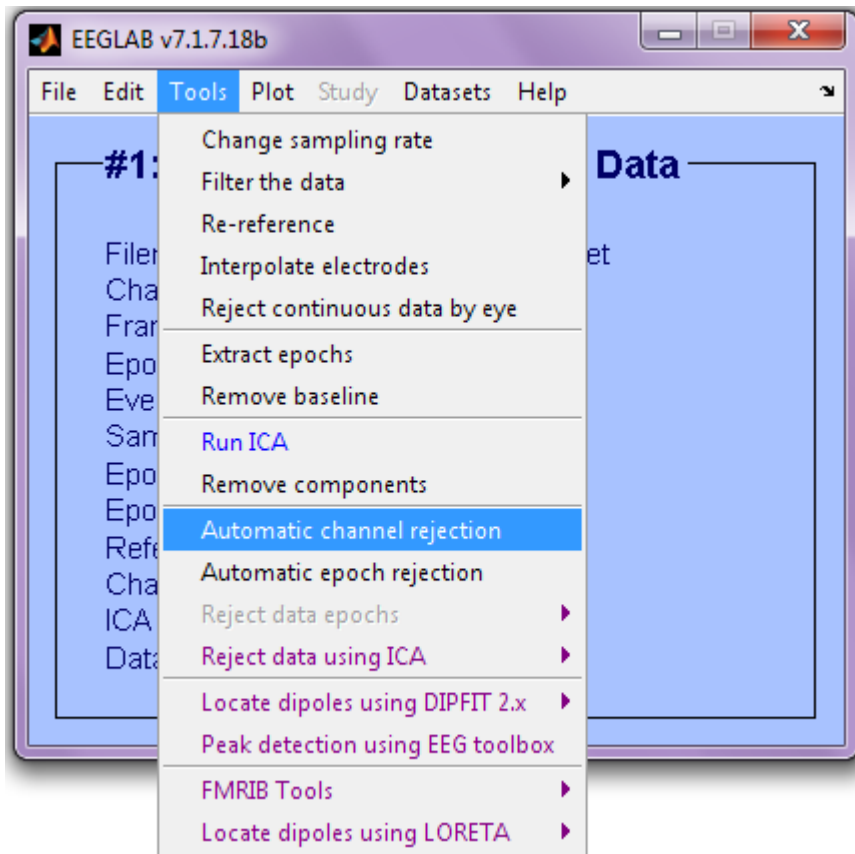
Manually identifying bad channels



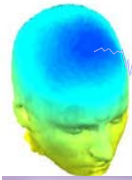
Manually identifying bad channels



Auto-detection of noisy channels

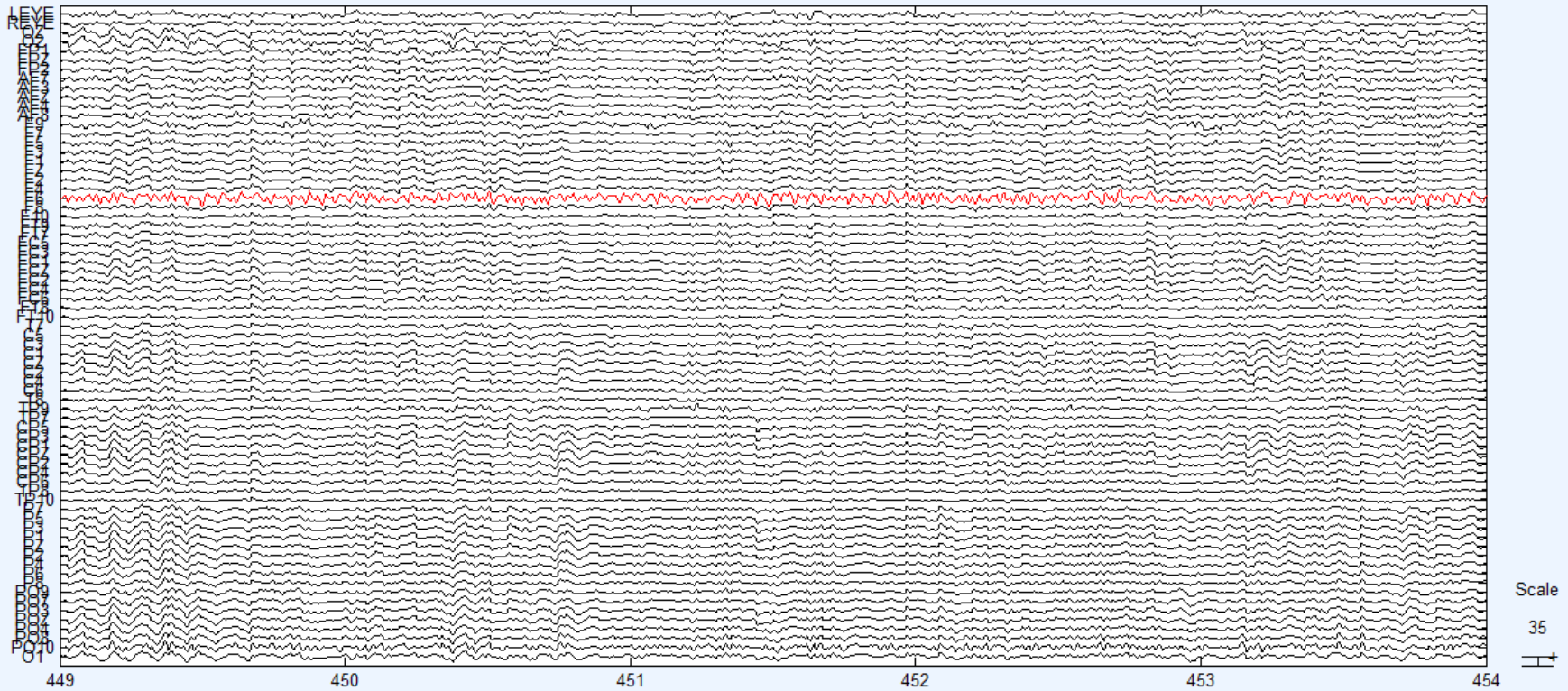


Auto-detected noisy channel



Scroll component activities -- eegplot()

Figure Display Settings Help



Scale
35

CANCEL

<<

<

449

>

>>

Chan.

Time

Value

TP8

452.1146

-2.6647

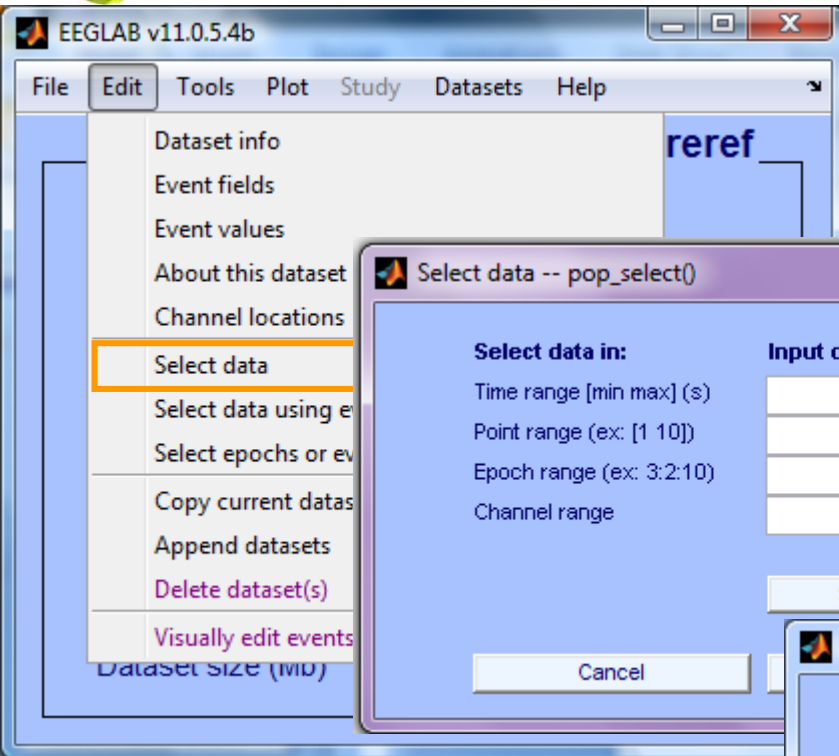
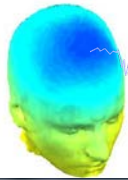
35

+

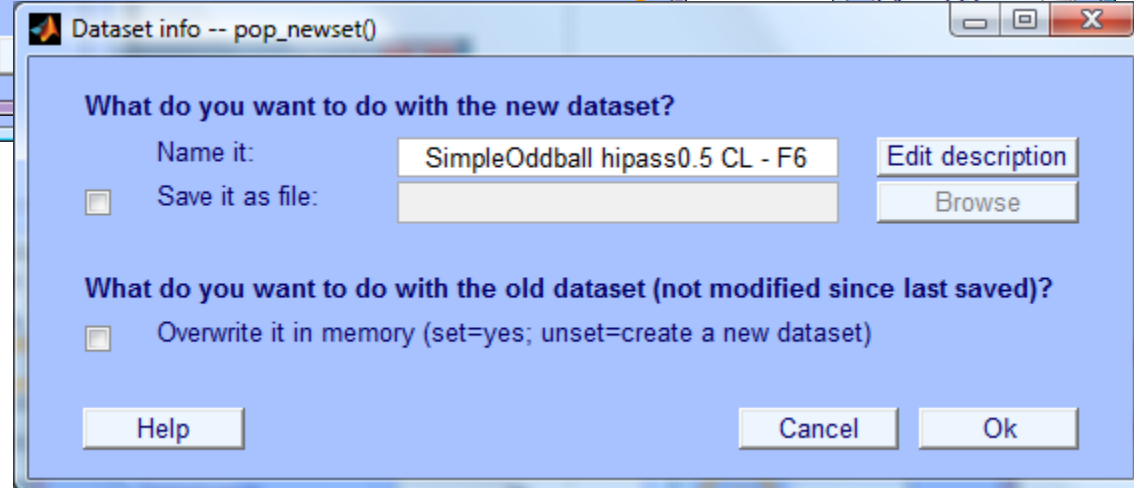
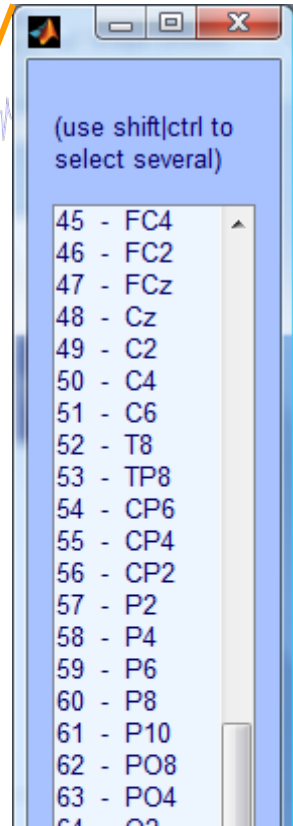
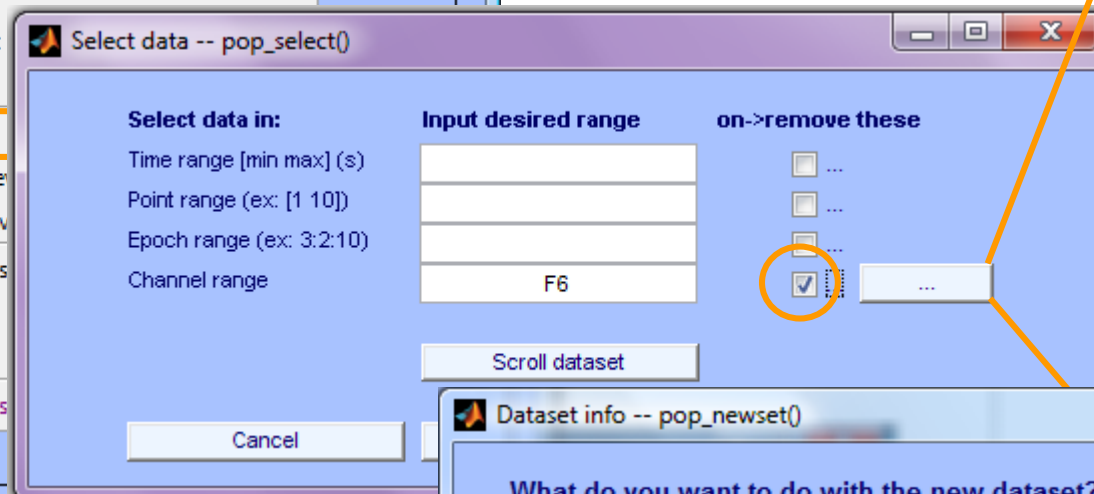
-

REJECT

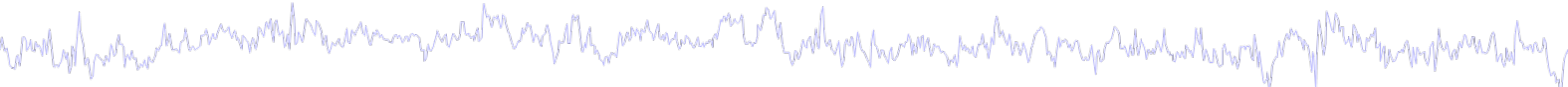
Removing channel(s)



If not checked, will result
in dataset with one channel



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

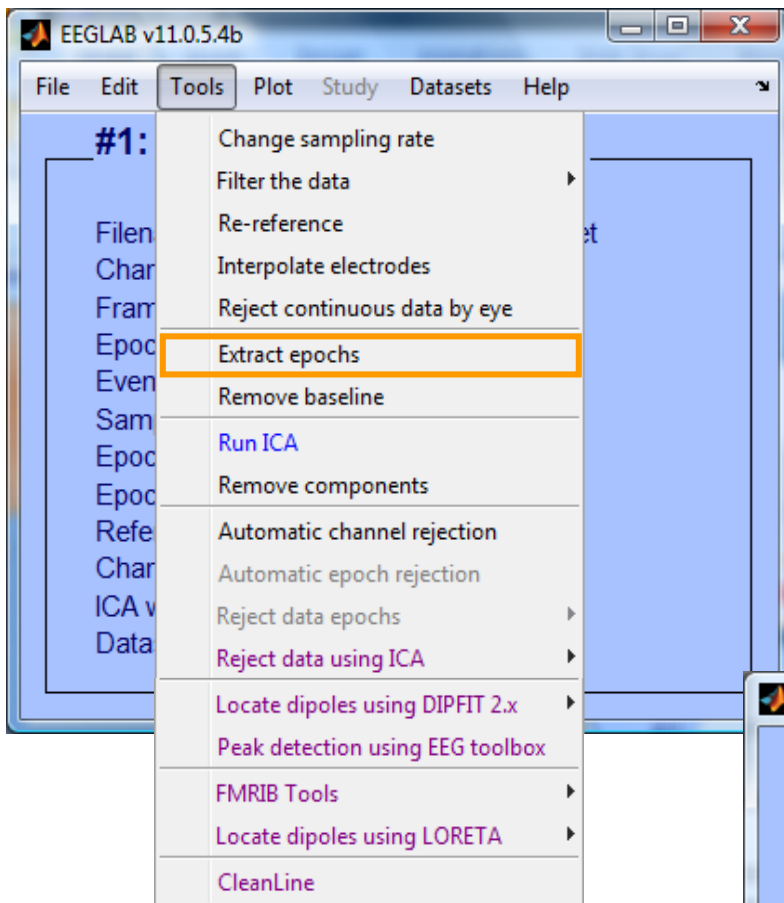
**Identify/reject
bad channels**

**Reject large artifact
time points**

Plot

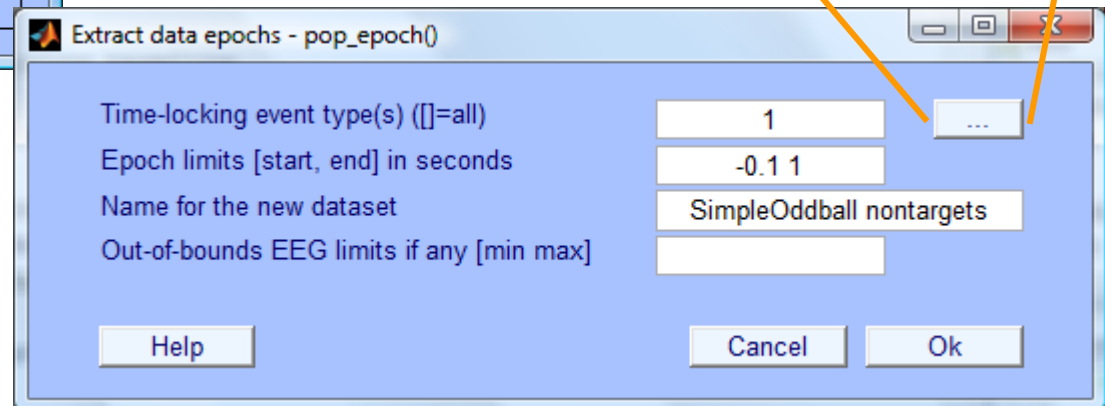
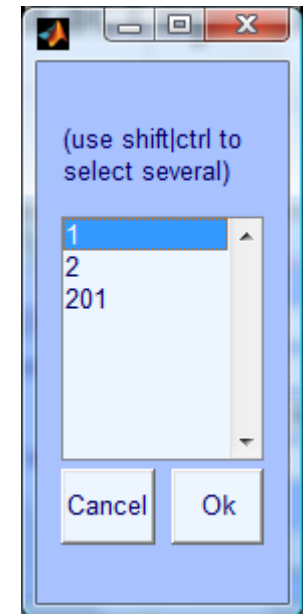


Extract epochs

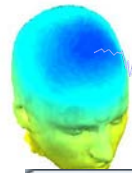


```
>> eeg_eventtypes (EEG)
```

1	140	star
2	60	circle
201	60	button press



Extract epochs



Dataset info -- pop_newset()

What do you want to do with the new dataset?

Name it: SimpleOddball nontargets Edit description

☐ Save it as file: Browse

Some changes have not been saved

☐ Overwrite it in memory (set=)

☐ Save it as file: C:\Us

Help

Epoch baseline removal -- pop_rmbase()

Baseline latency range (min_ms max_ms) ([] = whole epoch)

-101.5625 0

Else, baseline points vector (ex:1:56) ([] = whole epoch)
(overwritten by latency range above).

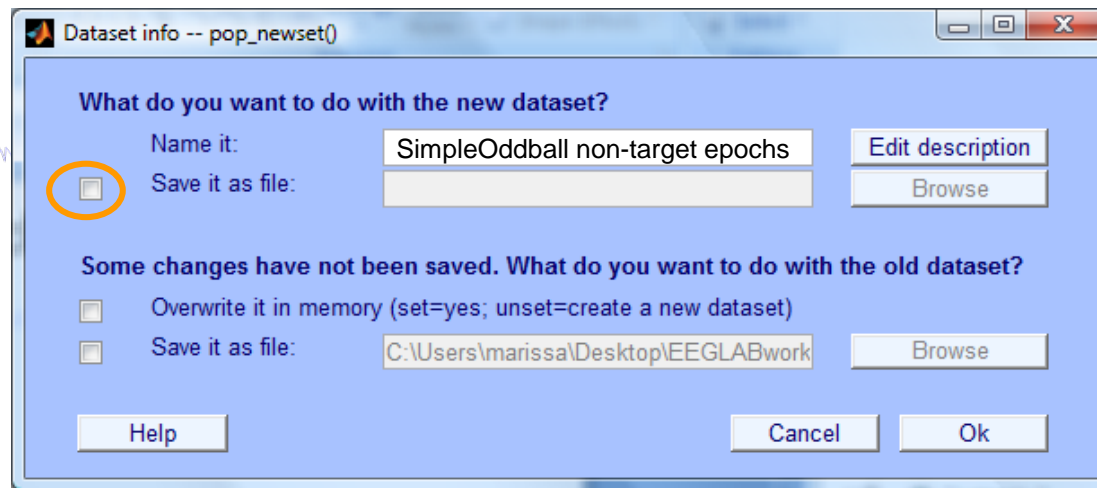
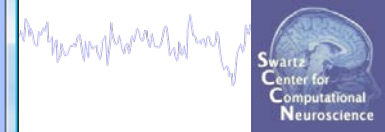
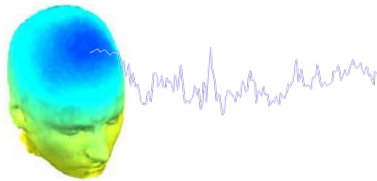
Help Cancel

EEGLAB v11.0.5.4b

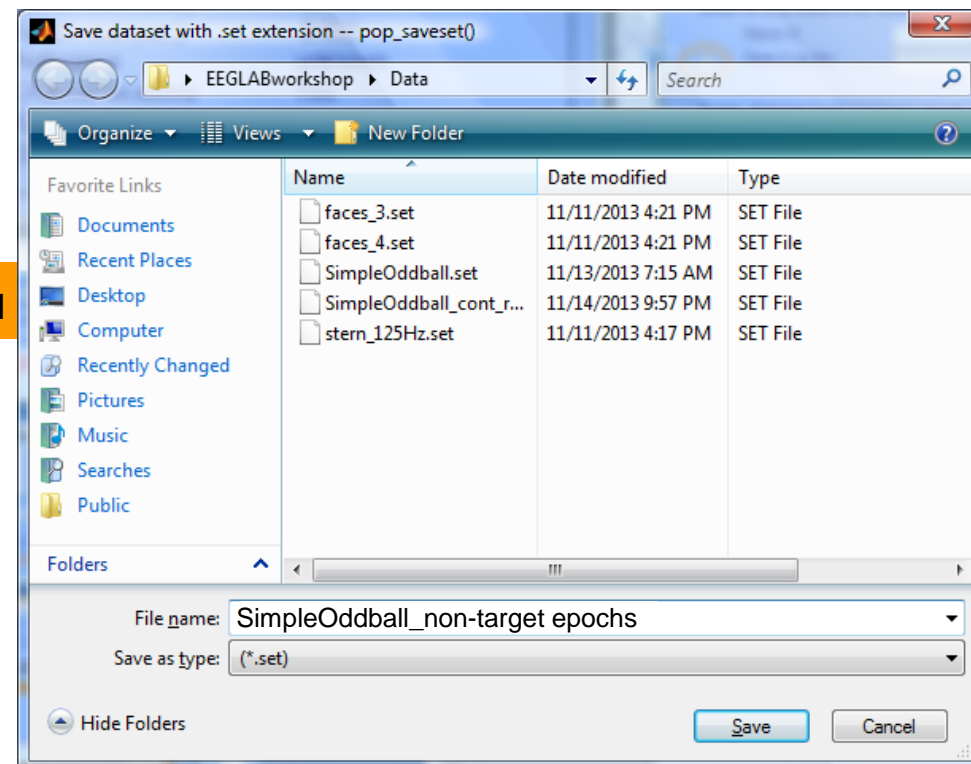
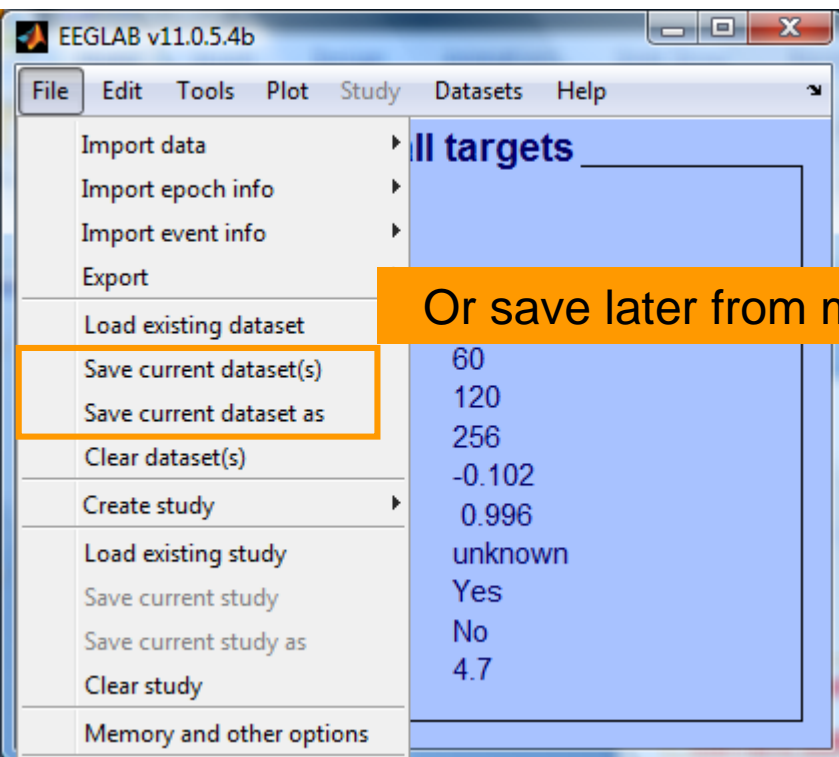
File Edit Tools Plot Study Datasets Help

#2: SimpleOddball nontargets

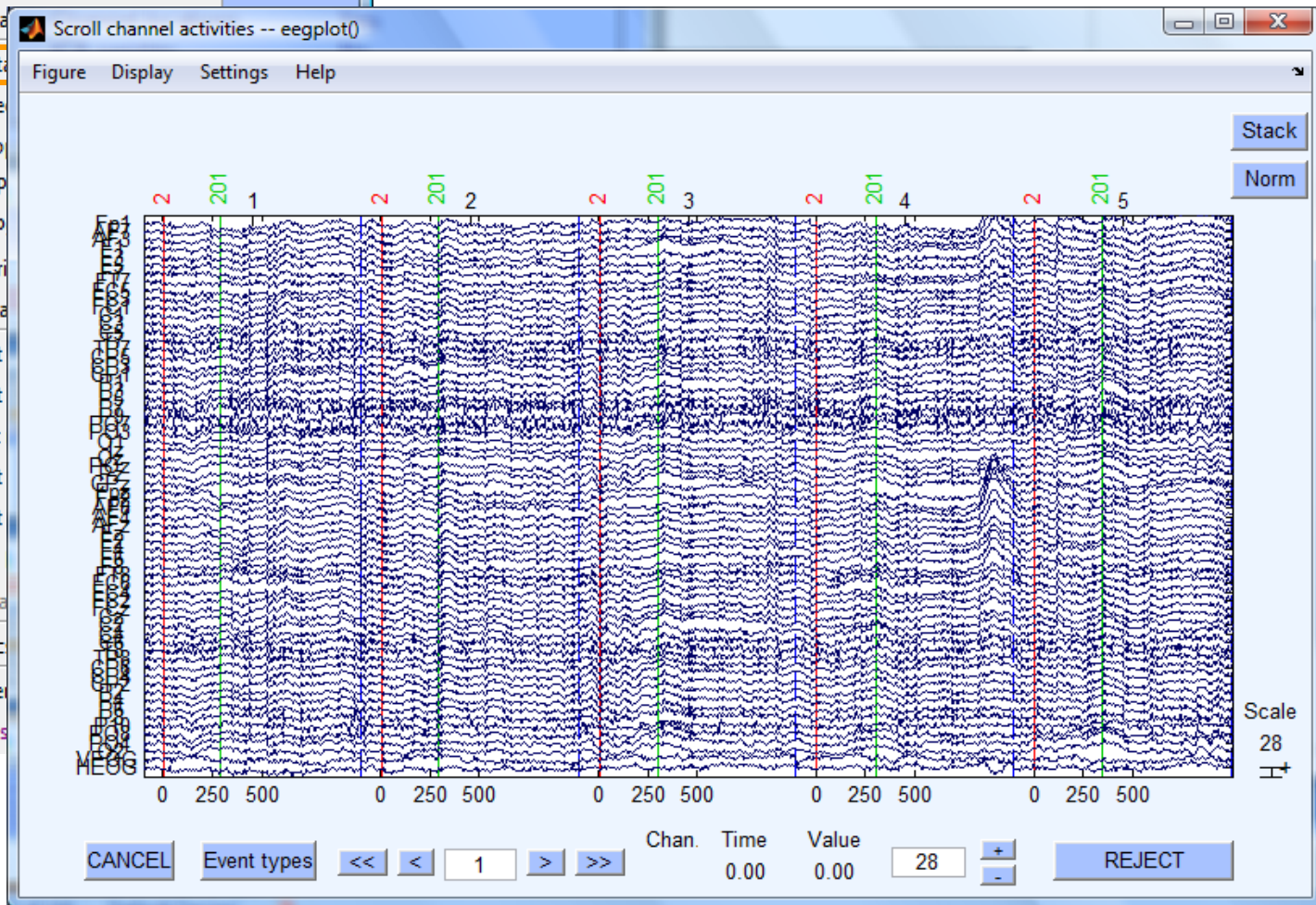
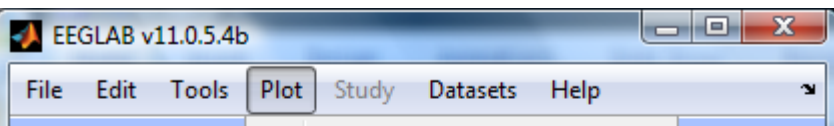
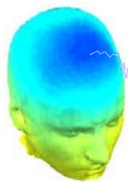
Filename:	none
Channels per frame	66
Frames per epoch	282
Epochs	140
Events	140
Sampling rate (Hz)	256
Epoch start (sec)	-0.102
Epoch end (sec)	0.996
Reference	unknown
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	10.6



Save dataset (optional)



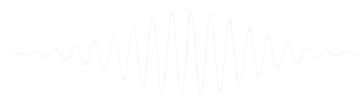
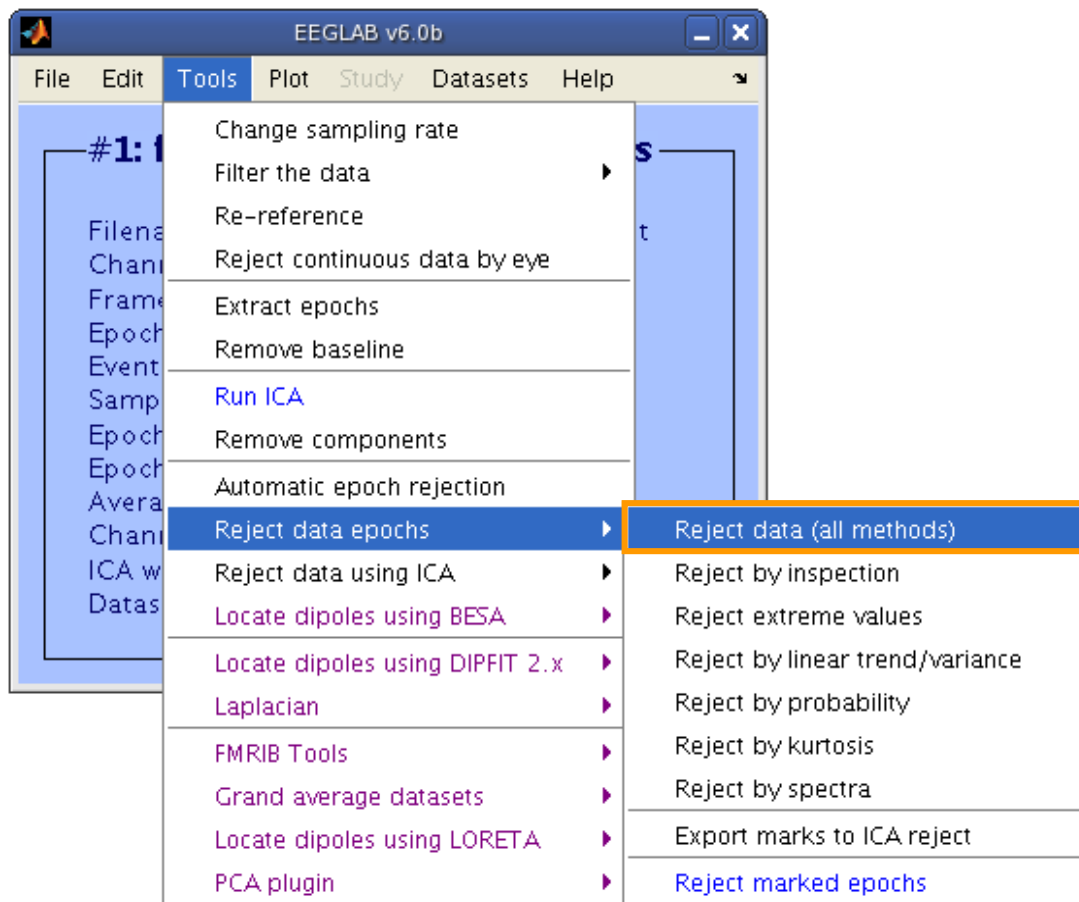
Scroll (epoched) channel data



Reject epochs with artifact



Reject data epochs



Reject data epochs



visual
inspection

Reject trials using data statistics - pop_rejmenu()

Mark trials by appearance ☐ Marked trials 0

Find abnormal values ☐

Upper limit(s) (uV)	25	Lower limit(s) (uV)	-25
Start time(s) (ms)	-1000	Ending time(s) (ms)	1996
Electrode(s)	1:31	Currently marked trials	0

Find abnormal trends ☐

Max slope (uV/epoch)	50	R-squared limit (0 to 1)	0.3
Electrode(s)	1:31	Currently marked trials	0

Find improbable data ☐

Single-channel limit (std. dev.)	5	All channels limit (std. dev.)	5
Electrode(s)	1:31	Currently marked trials	0

Find abnormal distributions ☐

Single-channel limit (std. dev.)	5	All channels limit (std. dev.)	5
Electrode(s)	1:31	Currently marked trials	0

Find abnormal spectra (slow) ☐

Upper limit(s) (dB)	25	Lower limit(s) (dB)	-25
Low frequency(s) (Hz)	0	High frequency(s) (Hz)	50
Electrode(s)	1:31	Currently marked trials	0

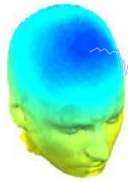
Plotting options

Show all trials marked for rejection by the measure selected above or checked below | /

<input checked="" type="checkbox"/> Abnormal appearance	<input checked="" type="checkbox"/> Abnormal values	<input checked="" type="checkbox"/> Abnormal trends
<input checked="" type="checkbox"/> Improbable epochs	<input checked="" type="checkbox"/> Abnormal distributions	<input checked="" type="checkbox"/> Abnormal spectra

probability

Reject data epochs



Reject trials using data statistics - pop_rejmenu()

Mark trials by appearance ☐ Marked trials 0

Find abnormal values ☐

Upper limit(s) (uV)	25	Lower limit(s) (uV)	-25
Start time(s) (ms)	-500	Ending time(s) (ms)	496
Electrode(s)	1:70	Currently marked trials	0

Find abnormal trends ☐

Max slope (uV/epoch)	50	R-squared limit (0 to 1)	0.3
Electrode(s)	1:70	Currently marked trials	0

Find improbable data ☐

Single-channel limit (std. dev.)	5	All channels limit (std. dev.)	5
Electrode(s)	1:70	Currently marked trials	32

Find abnormal distributions ☐

Single-channel limit (std. dev.)	5	All channels limit (std. dev.)	5
Electrode(s)	1:70	Currently marked trials	0

Find abnormal spectra (slow) ☐

Upper limit(s) (dB)	25	Lower limit(s) (dB)	-25
Low frequency(s) (Hz)	0	High frequency(s) (Hz)	50
Electrode(s)	1:70	Currently marked trials	0

Plotting options

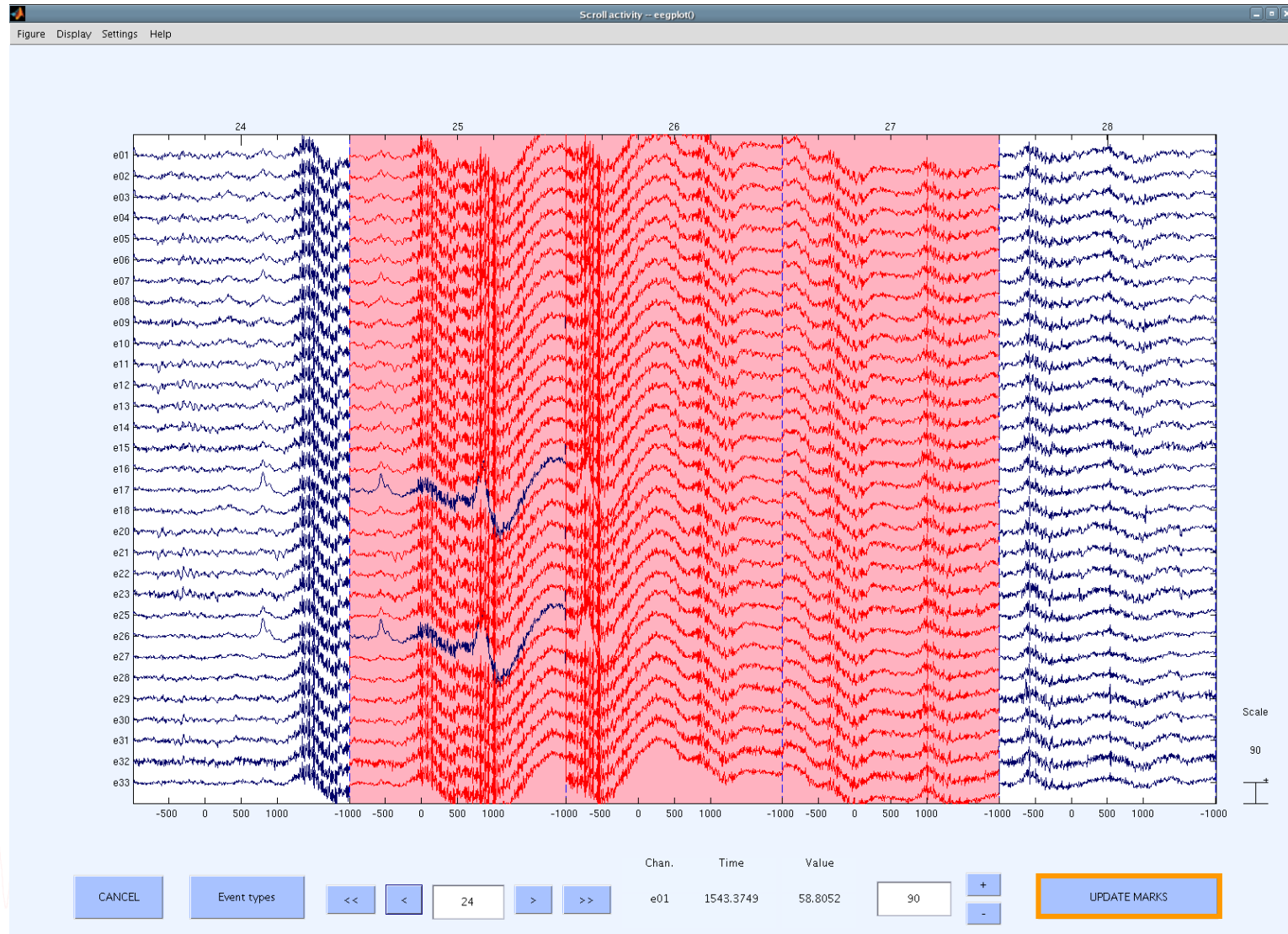
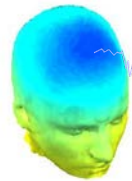
Show all trials marked for rejection by the measure selected above or checked below

<input checked="" type="checkbox"/> Abnormal appearance	<input checked="" type="checkbox"/> Abnormal values	<input checked="" type="checkbox"/> Abnormal trends
<input checked="" type="checkbox"/> Improbable epochs	<input checked="" type="checkbox"/> Abnormal distributions	<input checked="" type="checkbox"/> Abnormal spectra

Start by clicking
Calculate:

Number of epochs
above threshold
indicated here

Reject data epochs



Reject data epochs



Reject trials using data statistics - pop_rejmenu()

Mark trials by appearance ☐ Scroll Data Marked trials 0

Find abnormal values ☐

Upper limit(s) (uV) Lower limit(s) (uV)
 Start time(s) (ms) Ending time(s) (ms)
 Electrode(s) Currently marked trials

Find abnormal trends ☐

Max slope (uV/epoch) R-squared limit (0 to 1)
 Electrode(s) Currently marked trials

Find improbable data ☐

Single-channel limit (std. dev.) All channels limit (std. dev.)
 Electrode(s) Currently marked trials

Find abnormal distributions ☐

Single-channel limit (std. dev.) All channels limit (std. dev.)
 Electrode(s) Currently marked trials

Find abnormal spectra (slow) ☐

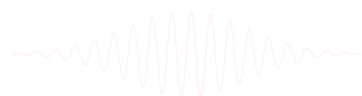
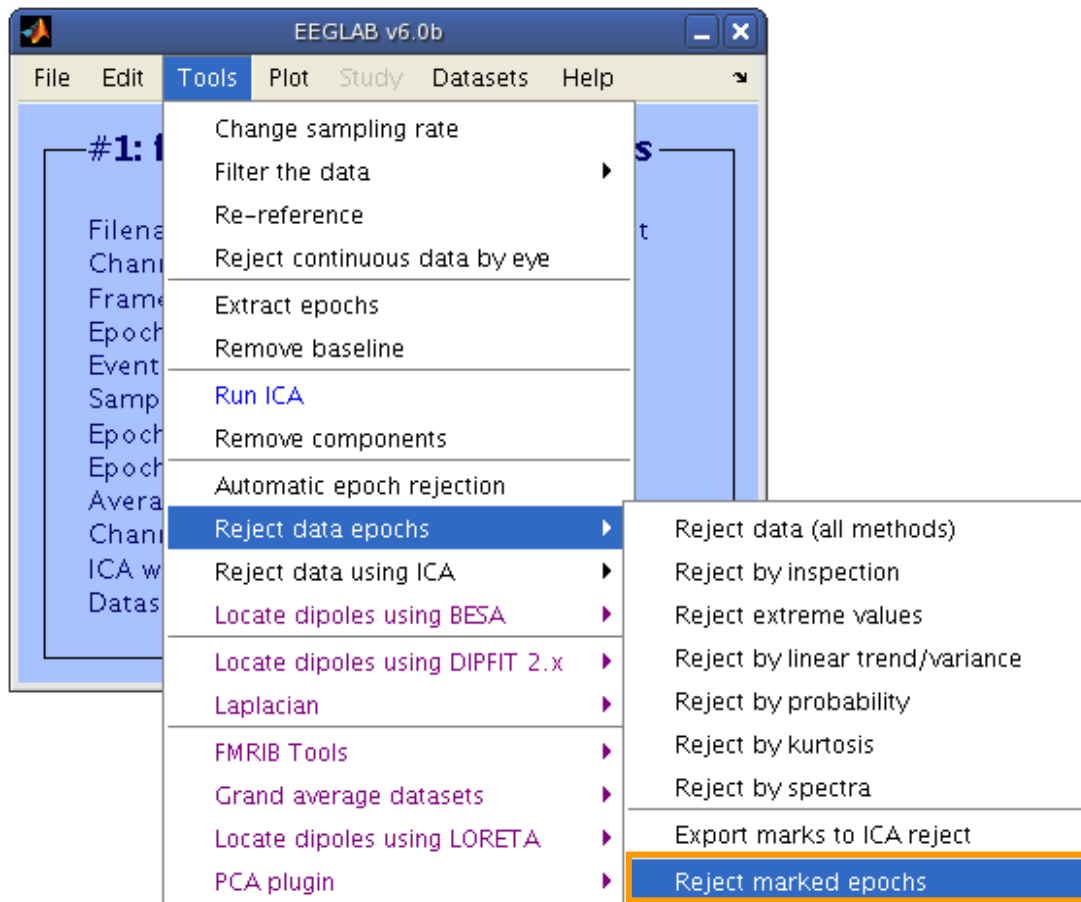
Upper limit(s) (dB) Lower limit(s) (dB)
 Low frequency(s) (Hz) High frequency(s) (Hz)
 Electrode(s) Currently marked trials

Plotting options

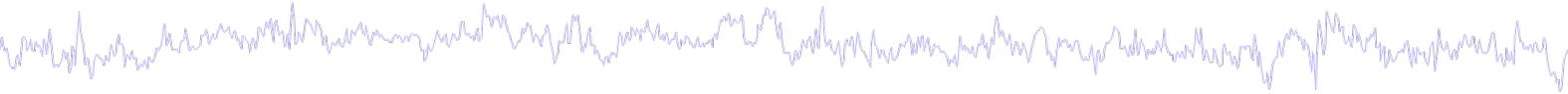
Show all trials marked for rejection by the measure selected above or checked below | /

☒ Abnormal appearance ☒ Abnormal values ☒ Abnormal trends
☒ Improbable epochs ☒ Abnormal distributions ☒ Abnormal spectra

Reject data epochs



Pre-processing pipeline



**Collect high-density
EEG data (>30 chan)**

Import into EEGLAB

**Import event markers
and channel locations**

**Re-reference/
down-sample
(if necessary)**

**High pass filter
(~.5 – 1 Hz)**

**Remove line noise
(if necessary)**

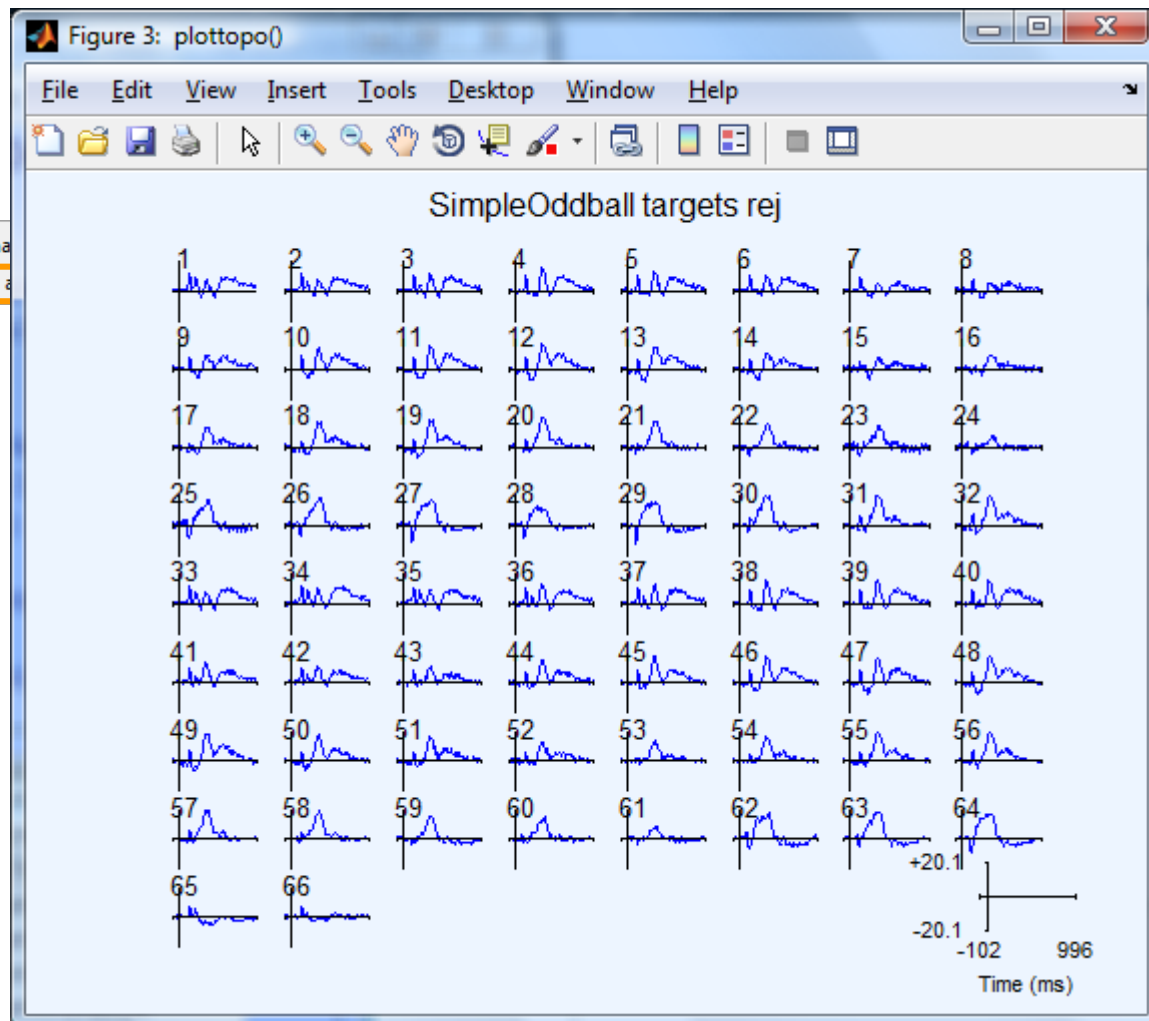
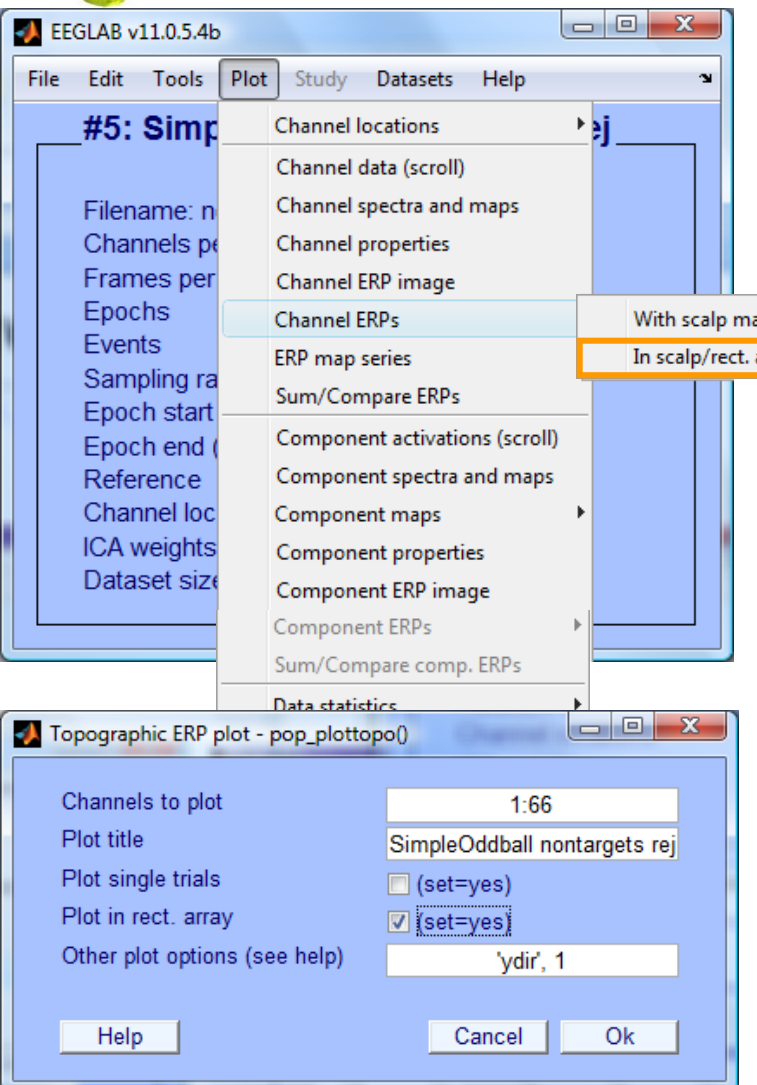
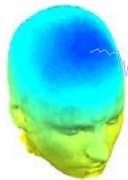
**Identify/reject
bad channels**

**Reject large artifact
time points**

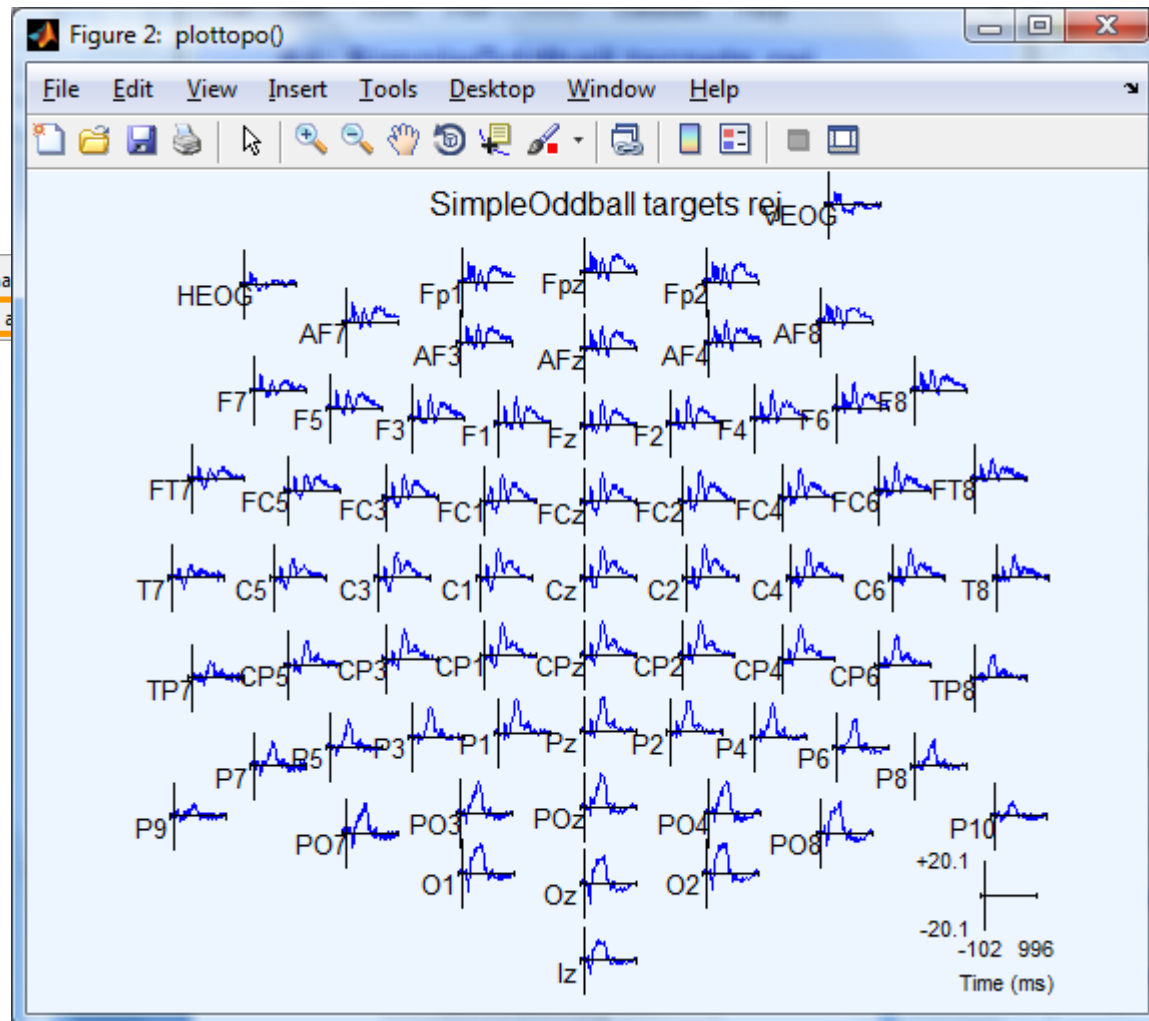
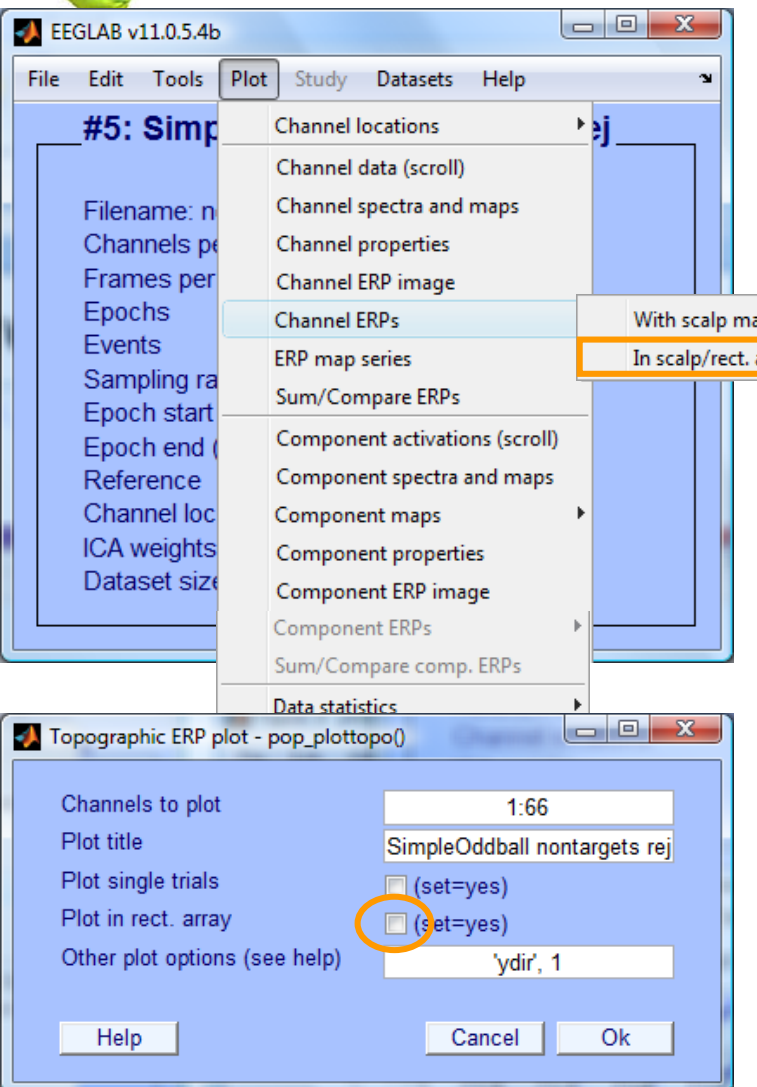
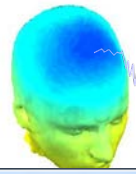
Plot



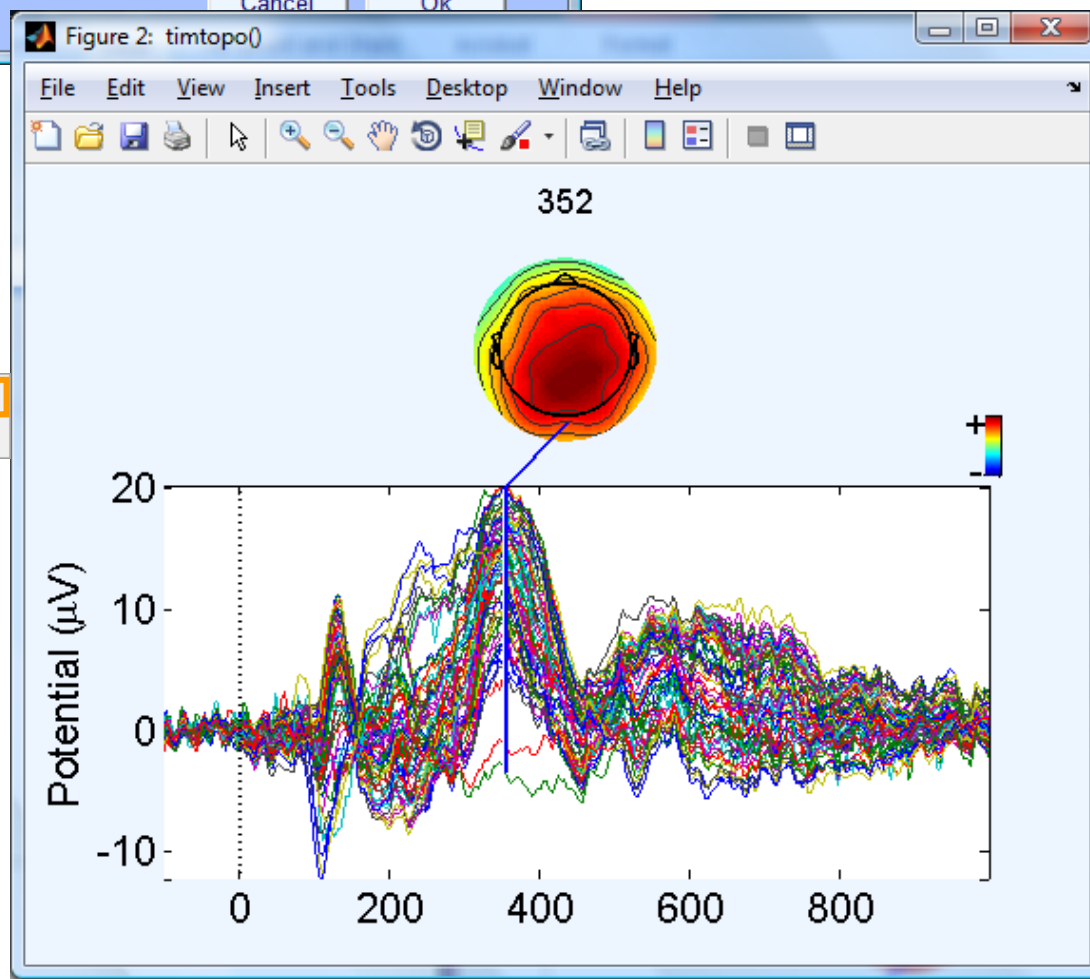
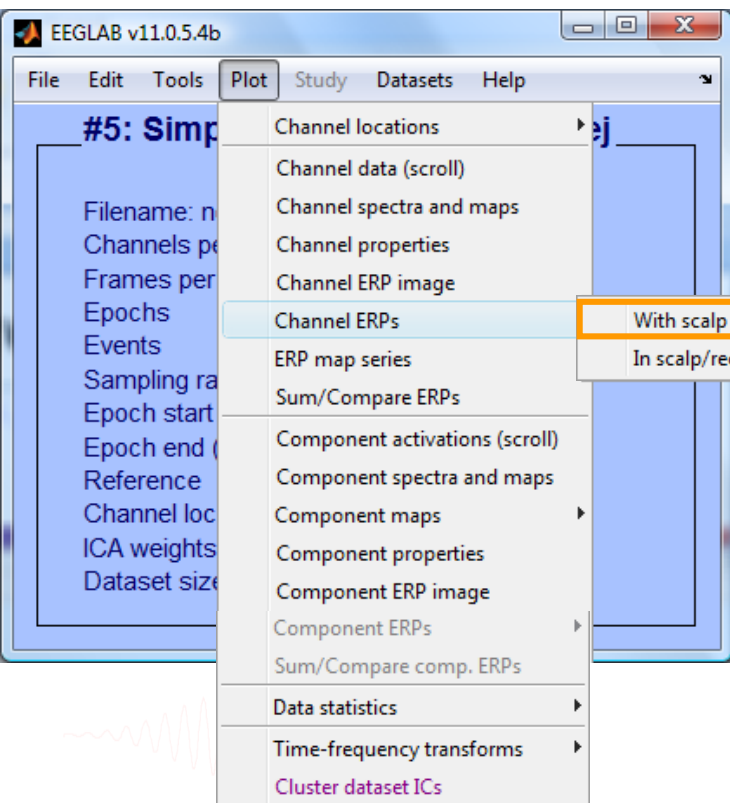
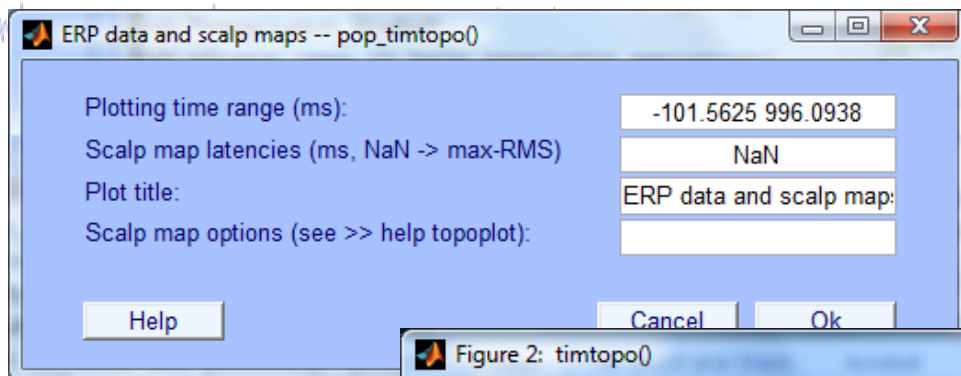
Visualize ERP in rectangular array



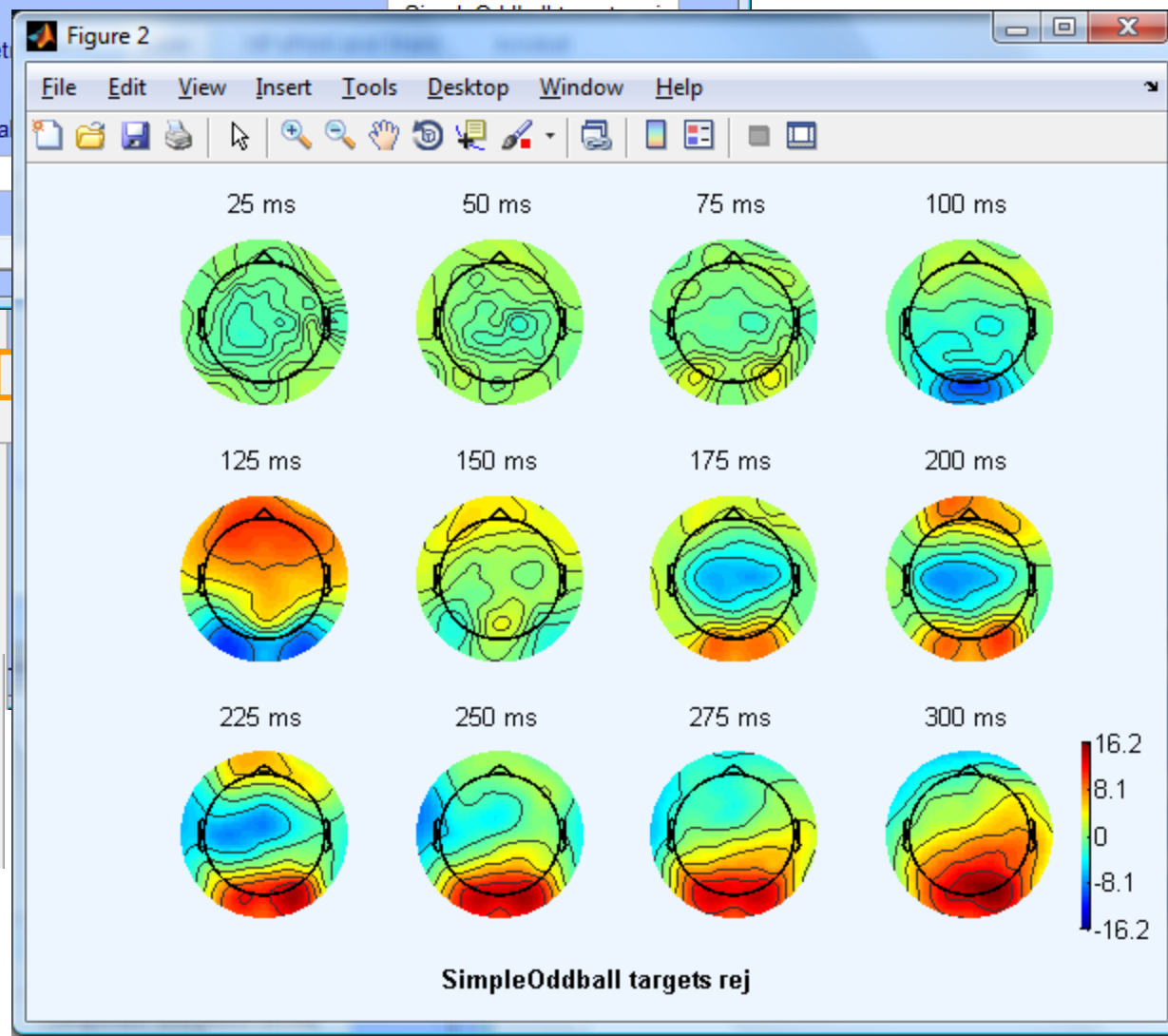
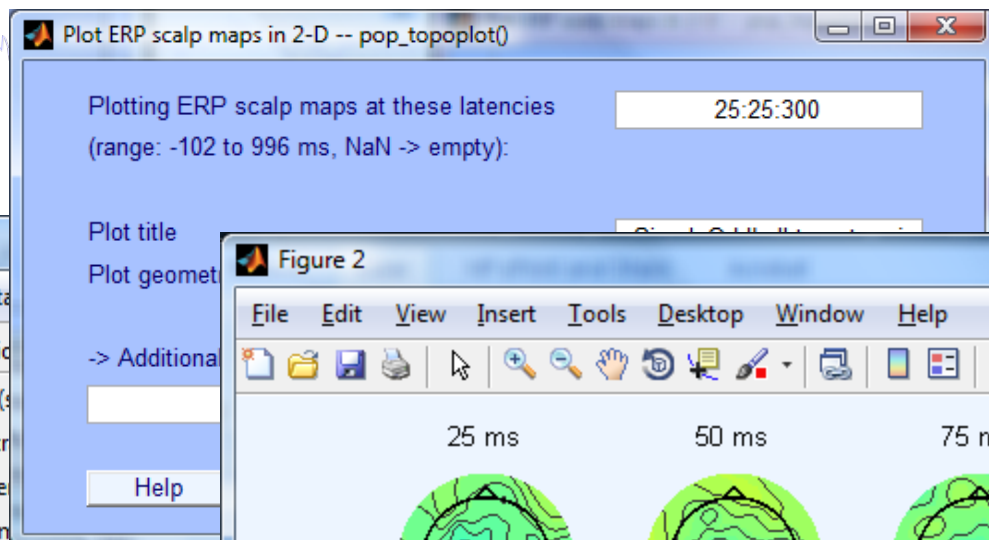
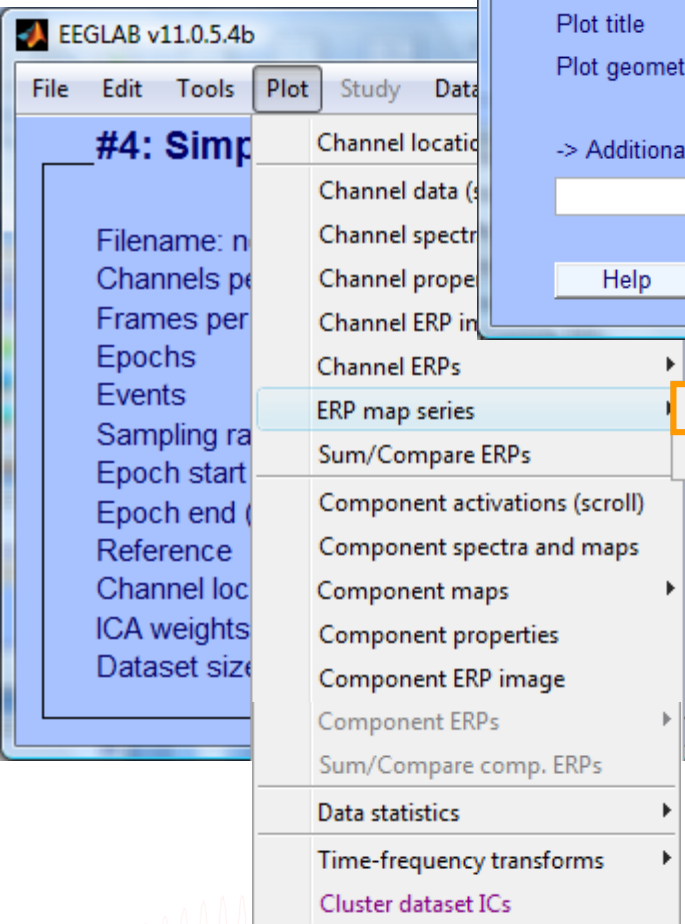
Visualize ERP in topographic array



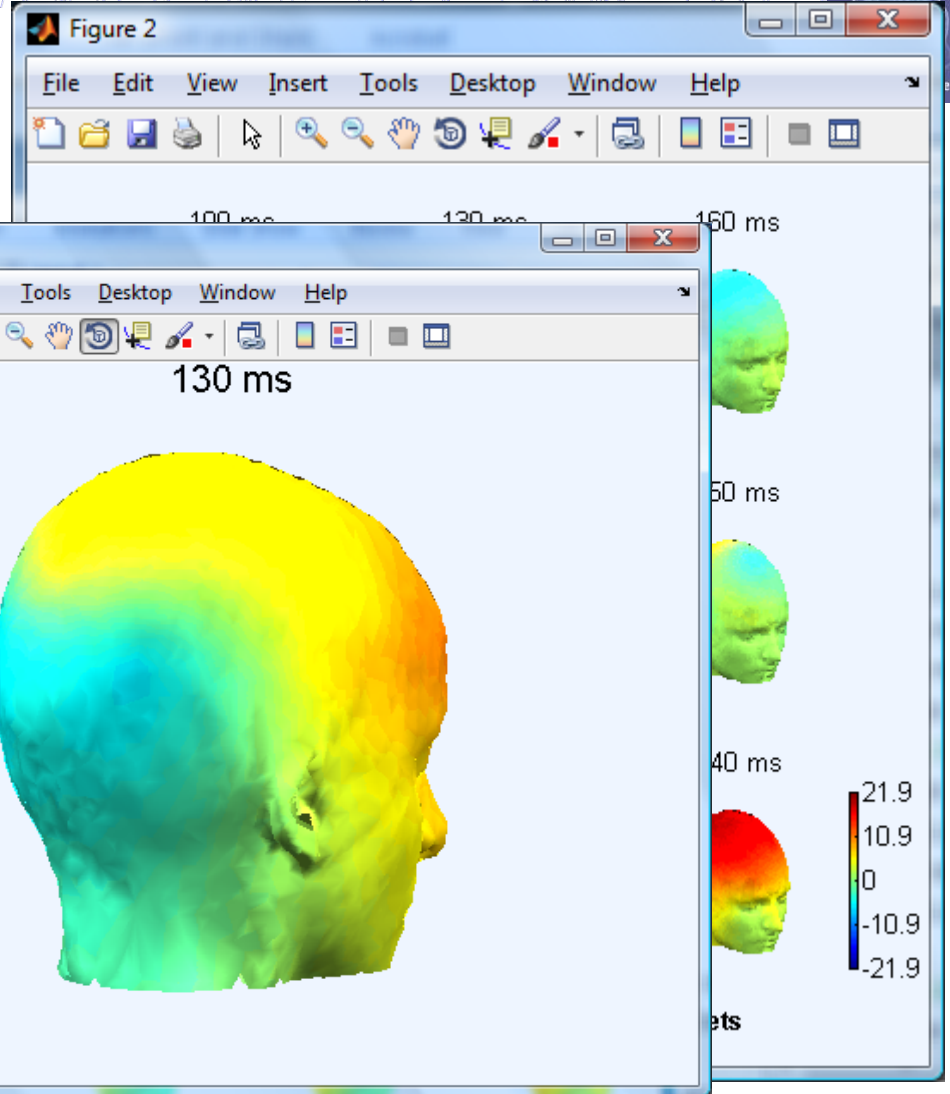
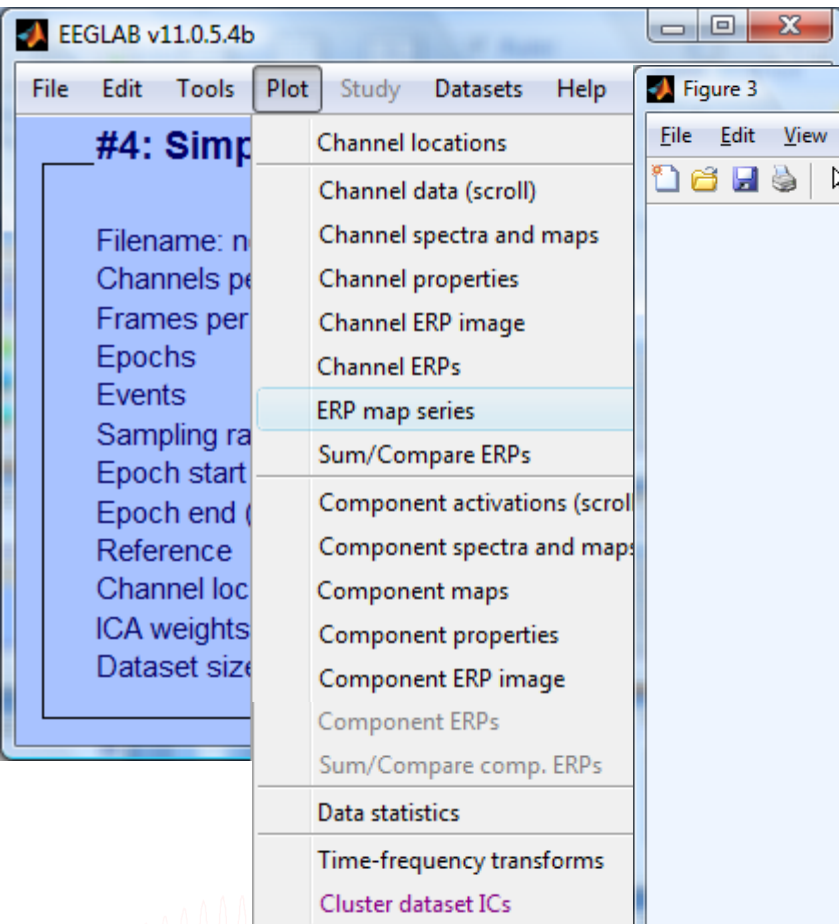
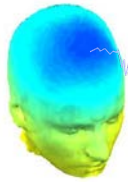
Visualize ERP scalp distribution



Visualize channel ERPs in 2D



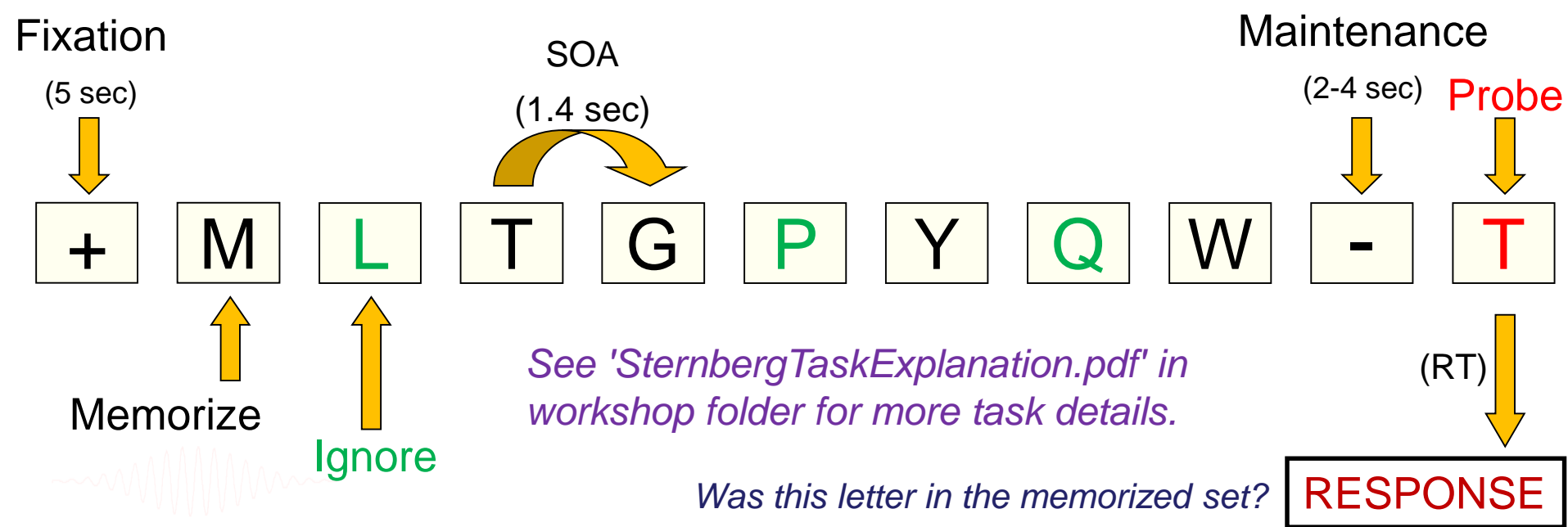
Visualize channel ERPs in 3D



Practice data set: Sternberg working memory



File .../SampleData/**stern.set**
Data Continuous data (not epoched), ref'd to right mastoid
Task between **3** and **7** letters to **memorize (colored black)**,
between **1** and **5** letters to **ignore (colored green)**,
8 letters presented during each trial
50% chance of **probe** letter being 'in-set'



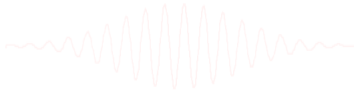
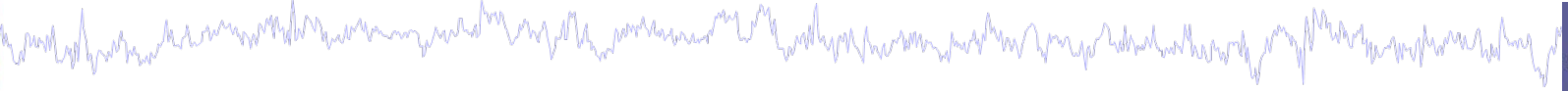
Exercise



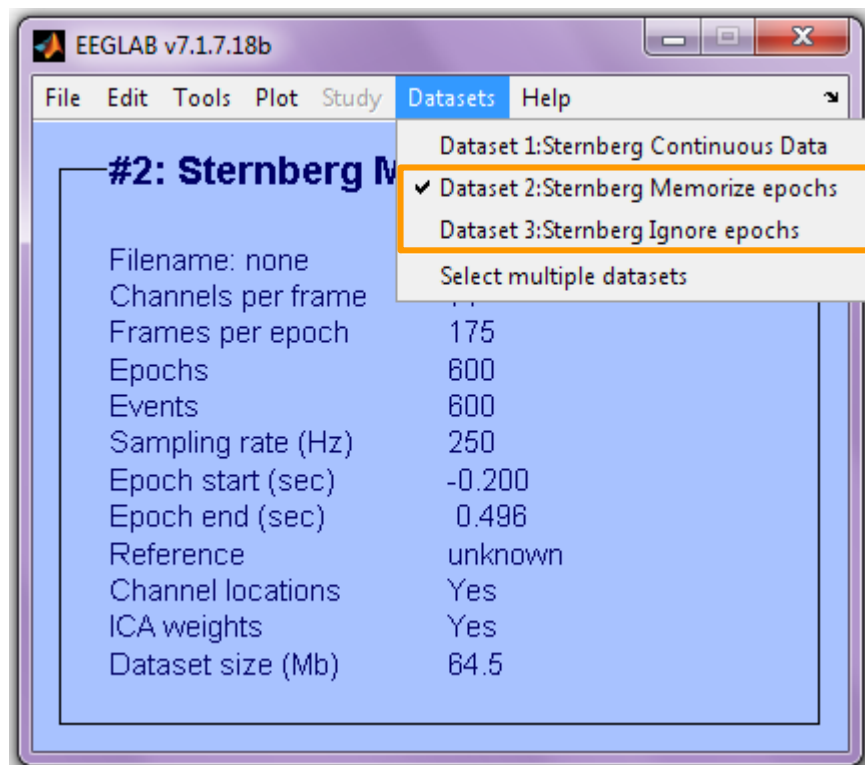
- **ALL**
 - Load stern_125Hz.set (continuous data)
 - Do not save your changes under the same filename!
- **Novice**
 - Scroll channel data and explore plotting options
 - Reject noisy time points and channels by visual inspection
 - Import standard channel locations
- **Intermediate**
 - Epoch the data and reject noisy epochs by auto rejection
 - Plot channel ERPs
 - Try different filter methods and cut-offs, compare results
- **Advanced** (requires supplementary material)
 - Compare channel ERPs across conditions



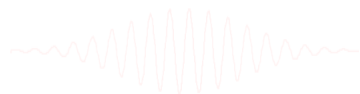
Supplementary lessons



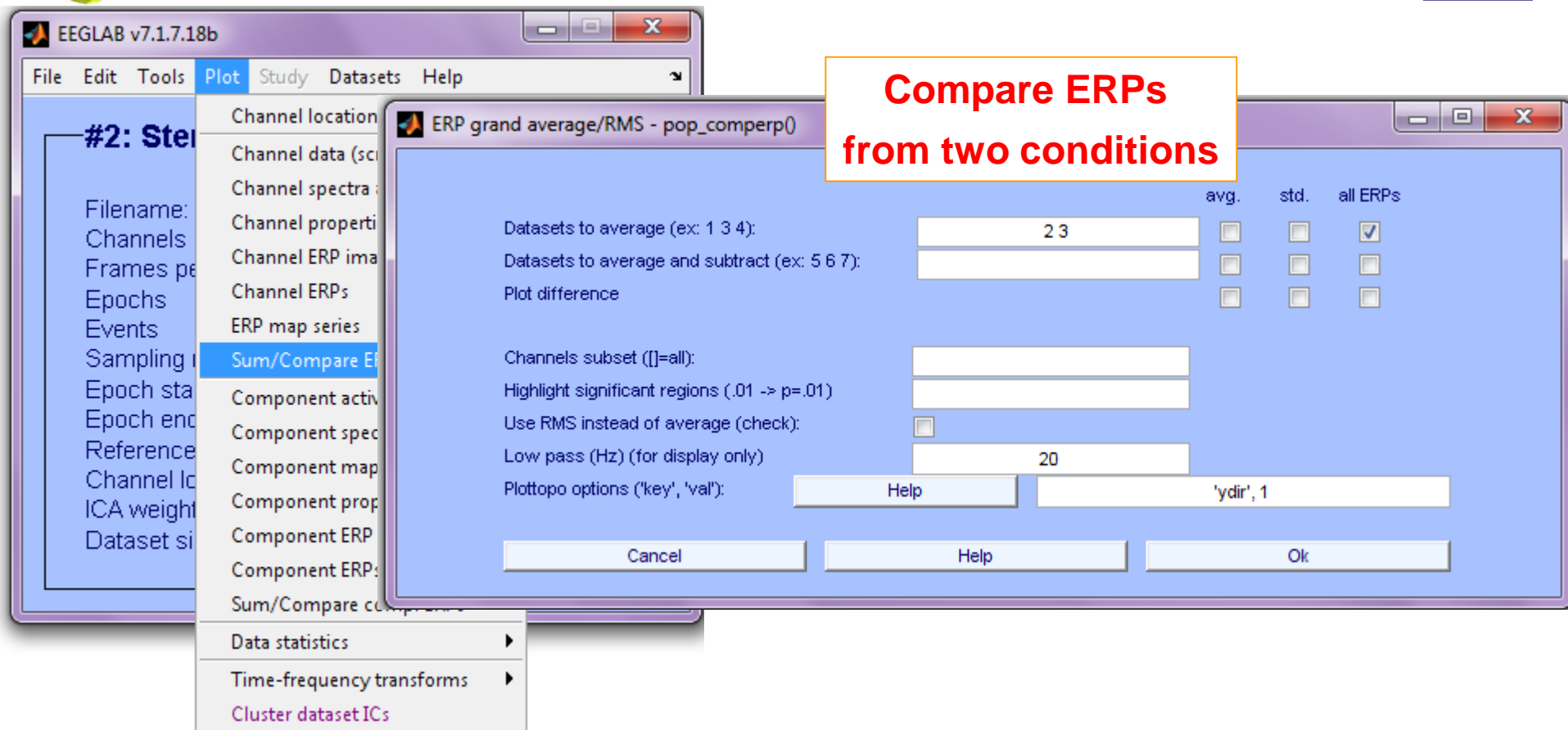
Compare ERPs across conditions



How do 'Memorize' and 'Ignore' ERPs differ?

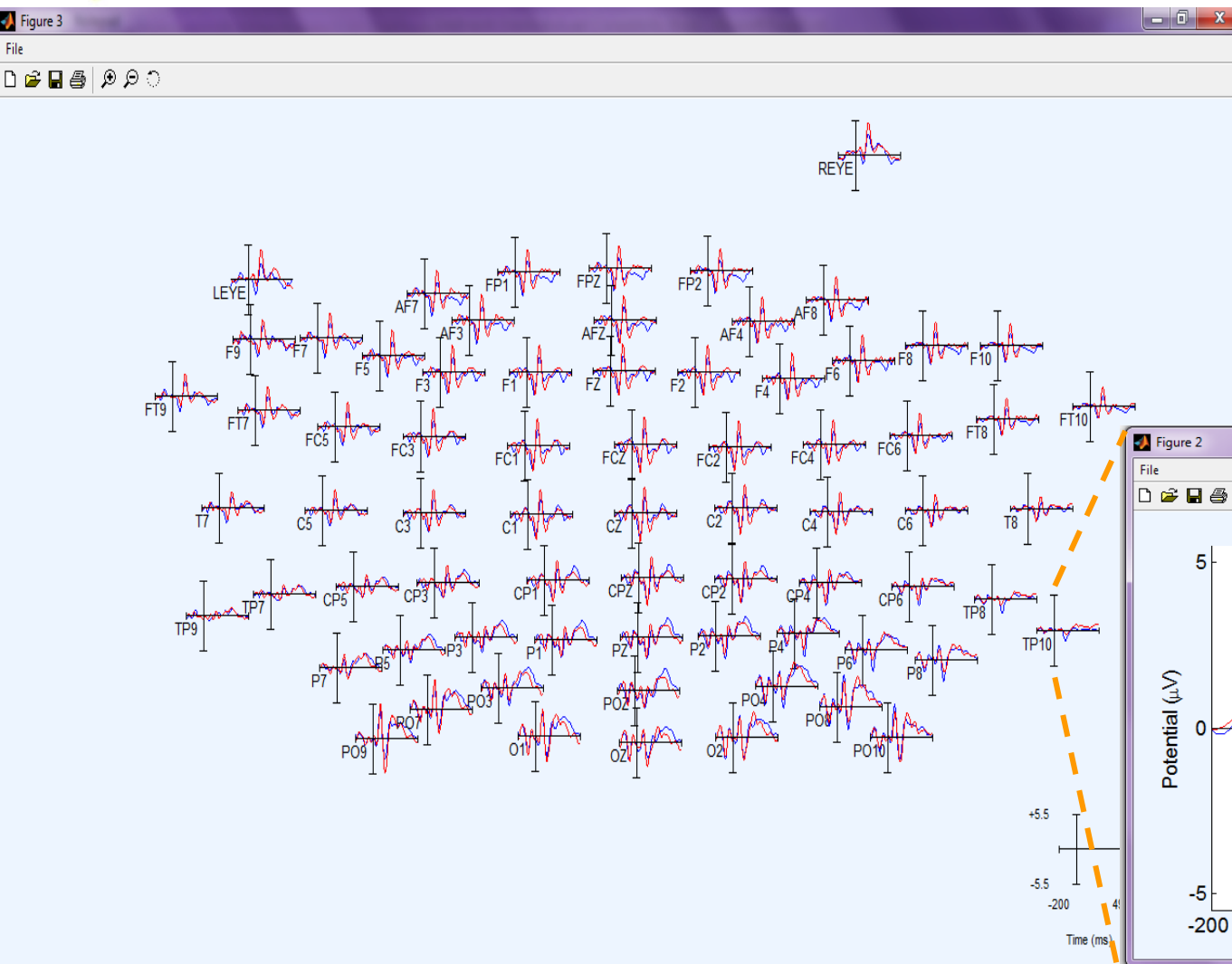
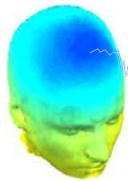


Compare ERPs across conditions

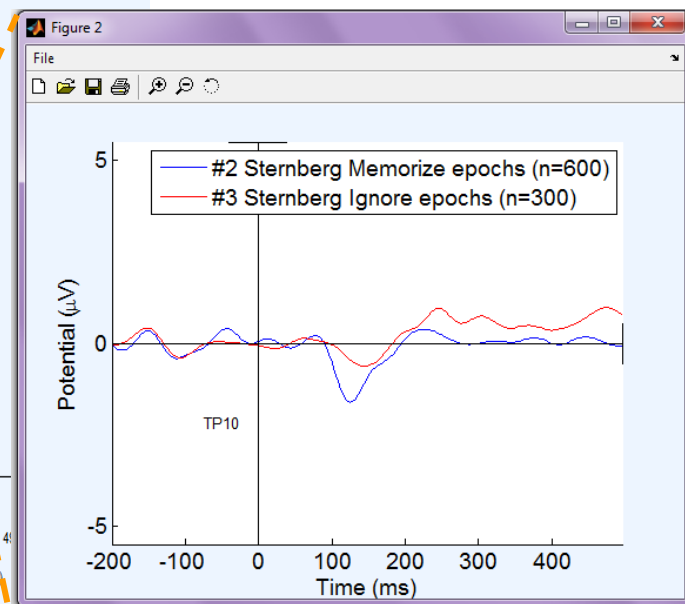


```
>>pop_comperp(ALLEEG,1,[2 3],[],'addavg','off','addstd','off', ...  
'addall','on','diffavg','off','diffstd','off','lowpass',20, ...  
'tplotopt',{'ydir',1});
```

Compare ERPs across conditions



**Click on an axis
to see larger image**



Analysis of ERP *differences*



**Plot *difference*
between two conditions**

ERP grand average/RMS - pop_compe

	avg.	std.	all ERPs
Datasets to average (ex: 1 3 4):	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Datasets to average and subtract (ex: 5 6 7):	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Plot difference	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Channels subset ([]=all):

Highlight significant regions (.01 -> p=.01)

Use RMS instead of average (check):

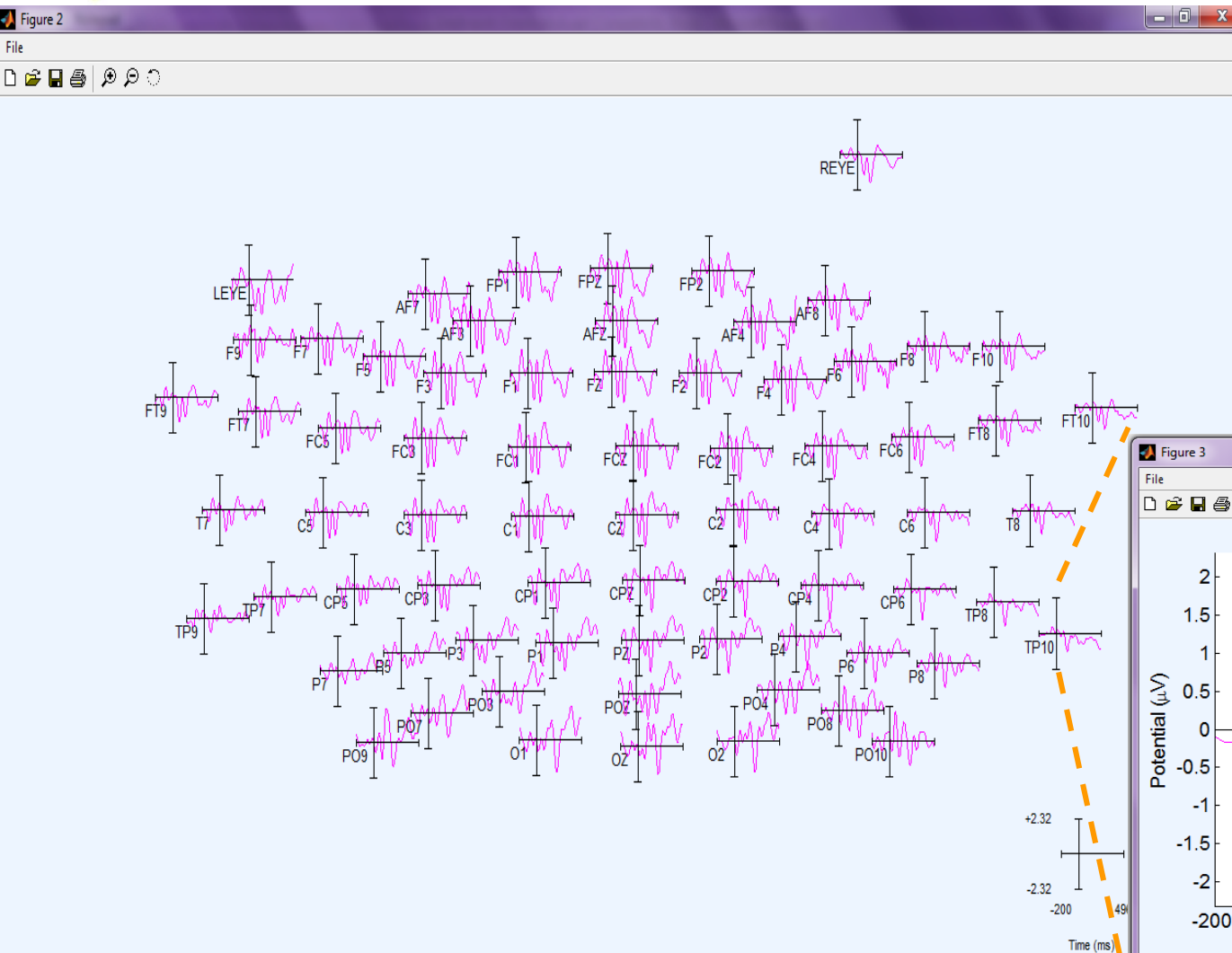
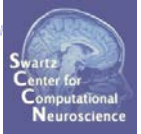
Low pass (Hz) (for display only)

Plottopo options ('key', 'val'):

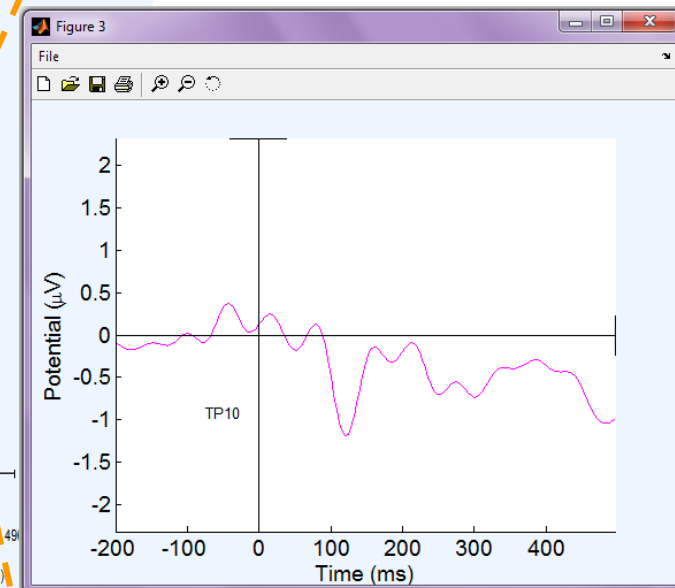
Cancel Help Ok

```
>> pop_comperp(ALLEEG,1, 2, 3,'addavg','off',...  
'addstd','off', 'diffavg','on','diffstd','off', ...  
'lowpass',20, 'tplotopt',{'ydir',1});
```

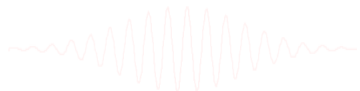
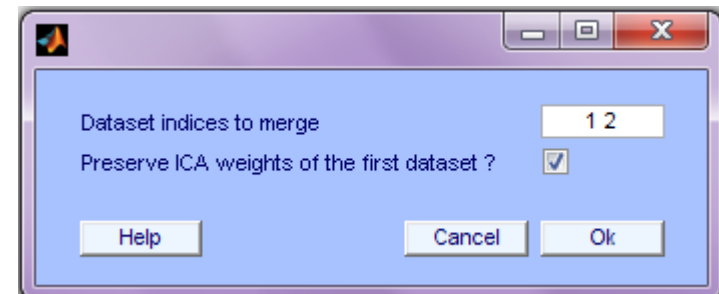
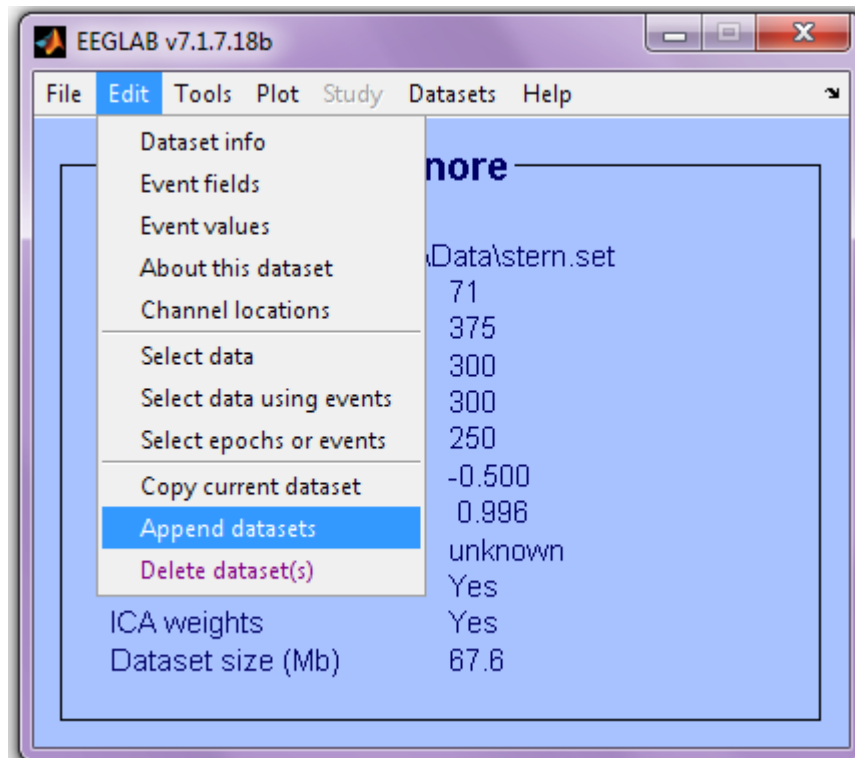
Analysis of ERP differences



**ERP
difference
between
2 conditions**



Merge (append) datasets



Merged datasets

