

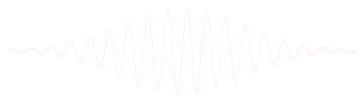
EEG Preprocessing

Importing data, rejecting data, and performing ICA decomposition

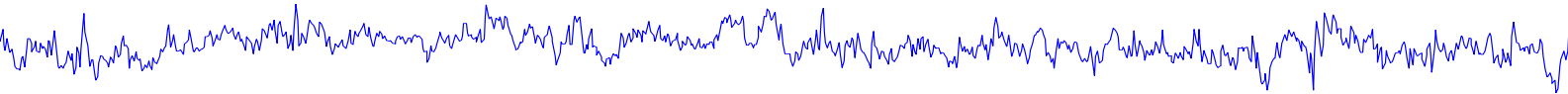
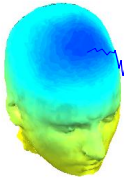
EEGLAB Workshop XXI

Santa Margherita Ligure, Italy

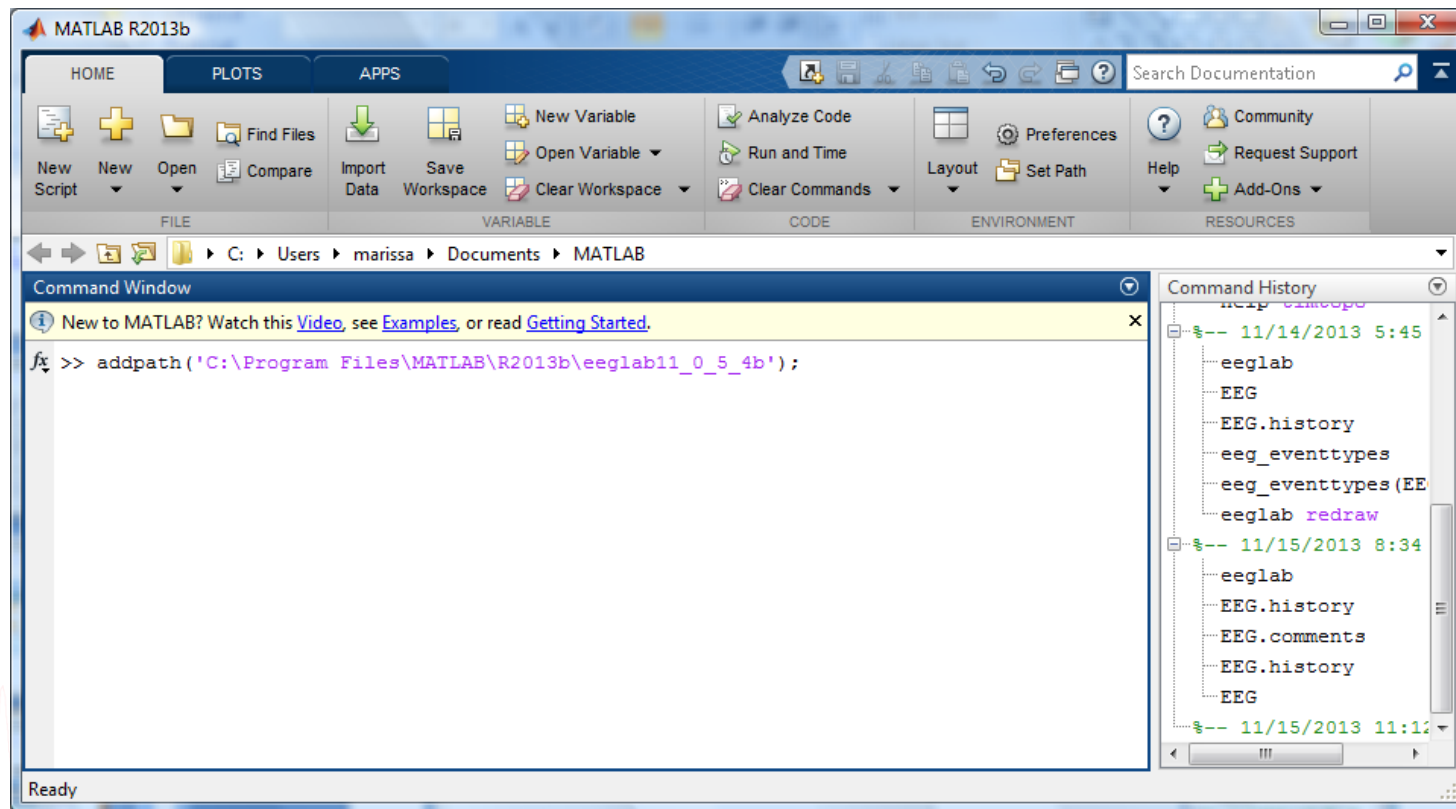
Day 1, 12:00-13:00



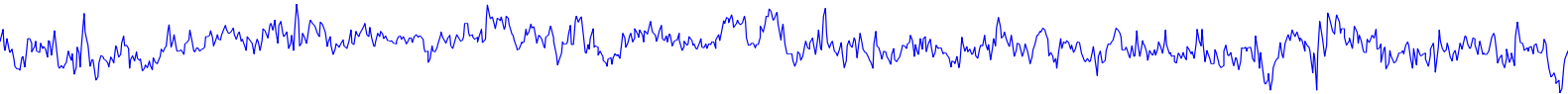
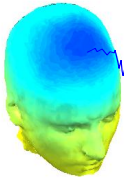
Installing EEGLAB and data folder



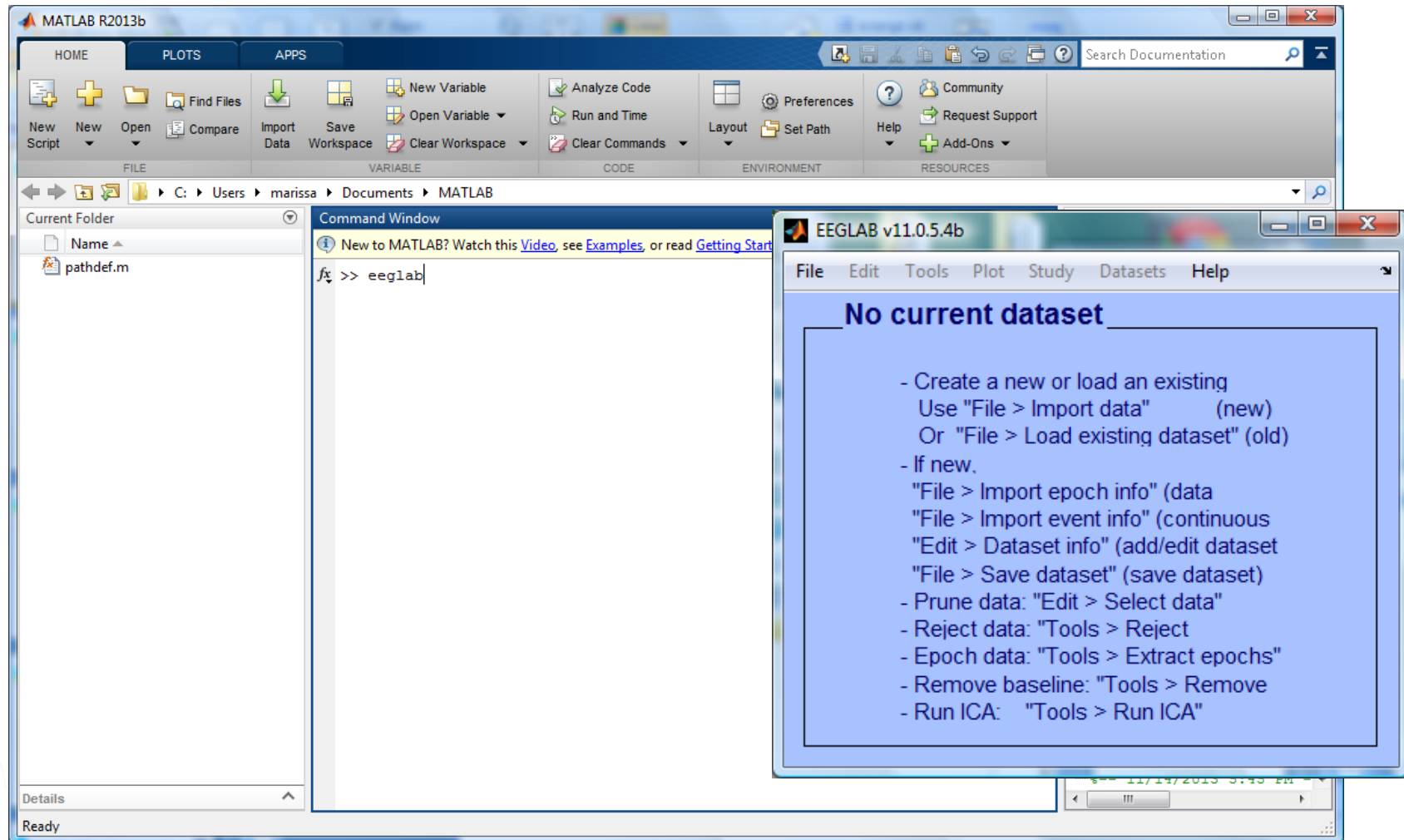
- Start Matlab
- Add the EEGLAB folder to your Matlab path:



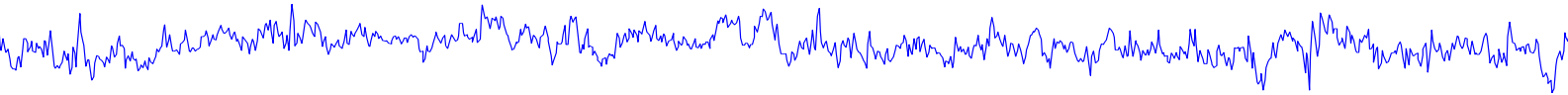
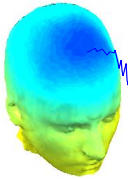
The EEGLAB Matlab software



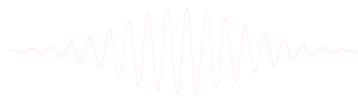
main graphic interface



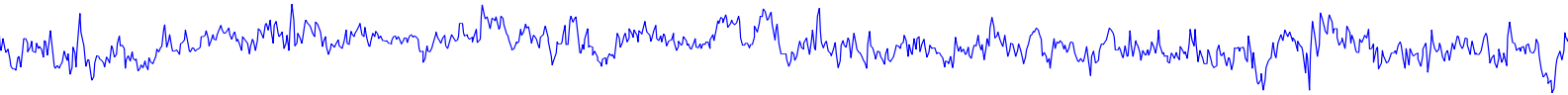
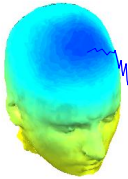
“Secrets” to a good ICA decomposition



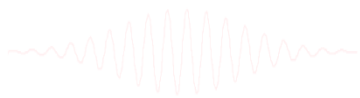
- Garbage in... garbage out (it's not magic)
- Remove large, non-stereotyped artifacts
- Do you have enough data? (based mostly on time, not frames)
- High-pass filter to remove slow drifts (no low-pass filter needed)
- Remove bad channels



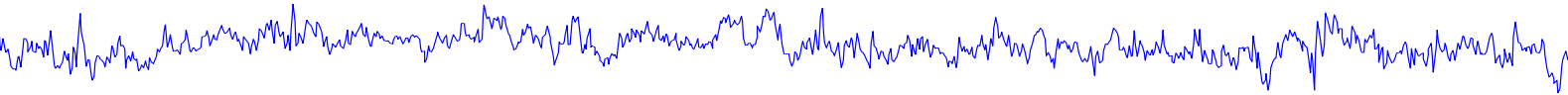
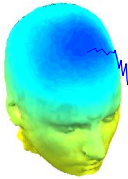
The Goal of Preprocessing



- Create a complete EEGLAB data set with
 - EEG
 - Channel Locations
 - Events
- Preprocess the EEG data to yield optimal ICA decompositions
 - Re-referencing
 - High Pass Filtering
 - Remove bad channels, noisy segments of data
- Run ICA decomposition



Many Preprocessing Variants



- Resources

- EEGLAB wiki “Quick Tutorial on Rejection”

- http://sccn.ucsd.edu/wiki/Quick_Rejection_Tutorial

- Makoto’s Preprocessing Pipeline

- http://sccn.ucsd.edu/wiki/Makoto%27s_preprocessing_pipeline

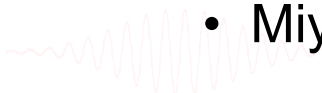
- Bigdely-Shamlo et al (2015): PREP Pipeline

- <http://dx.doi.org/10.3389/fninf.2015.00016>

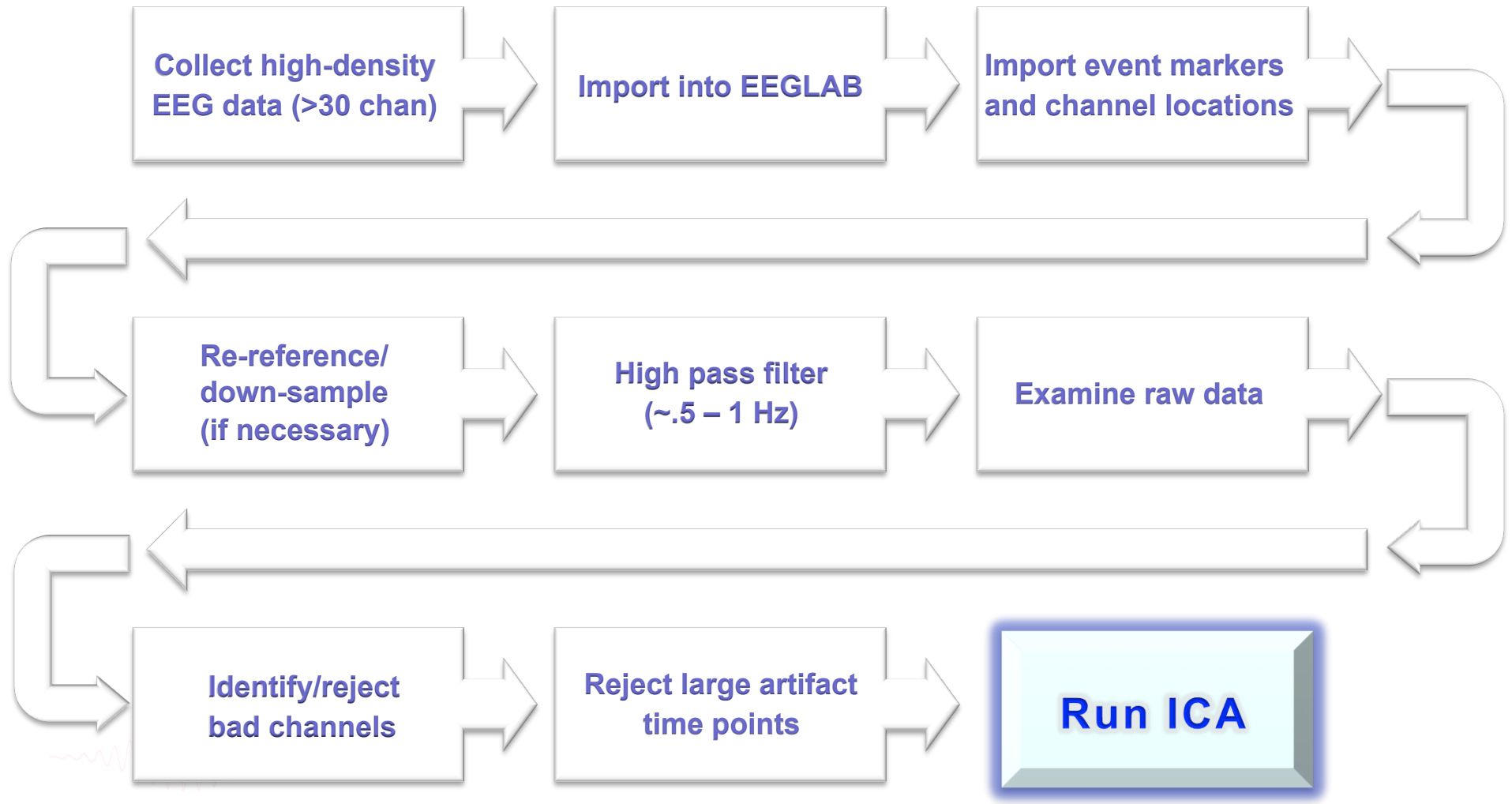
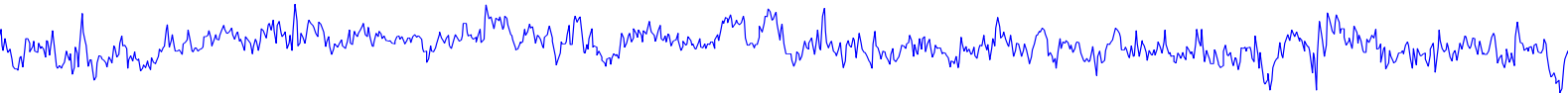
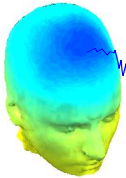
- EEGLAB Plugins

- Kothe’s clean_rawdata plugin

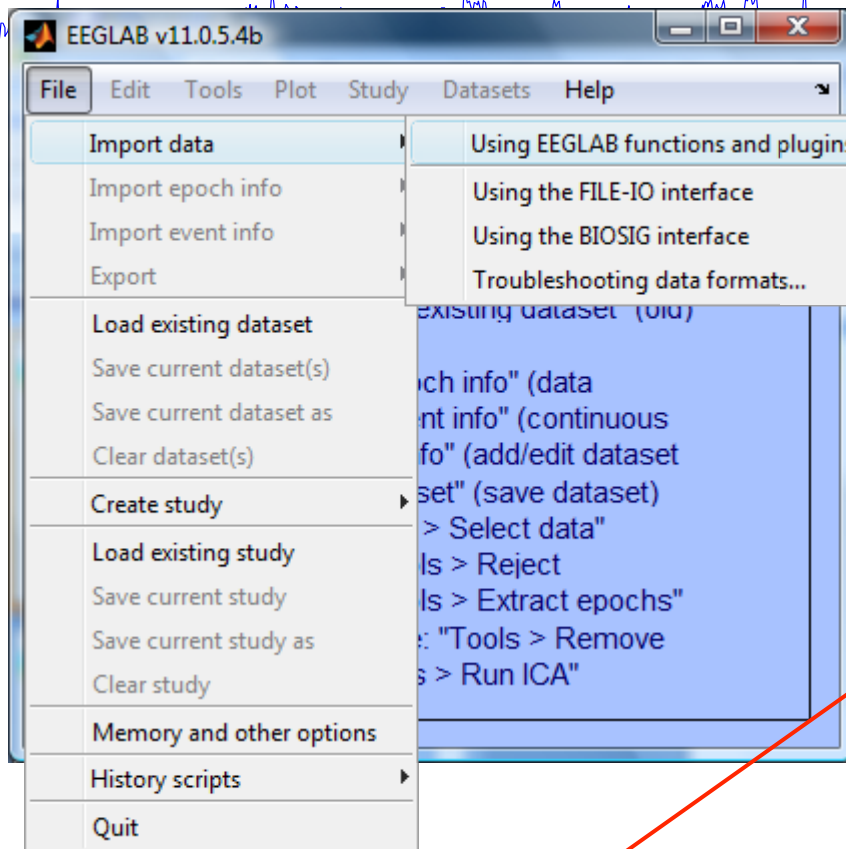
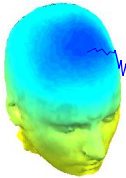
- Miyakoshi’s trimOutlier plugin



Pre-processing pipeline



Importing a dataset

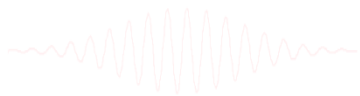
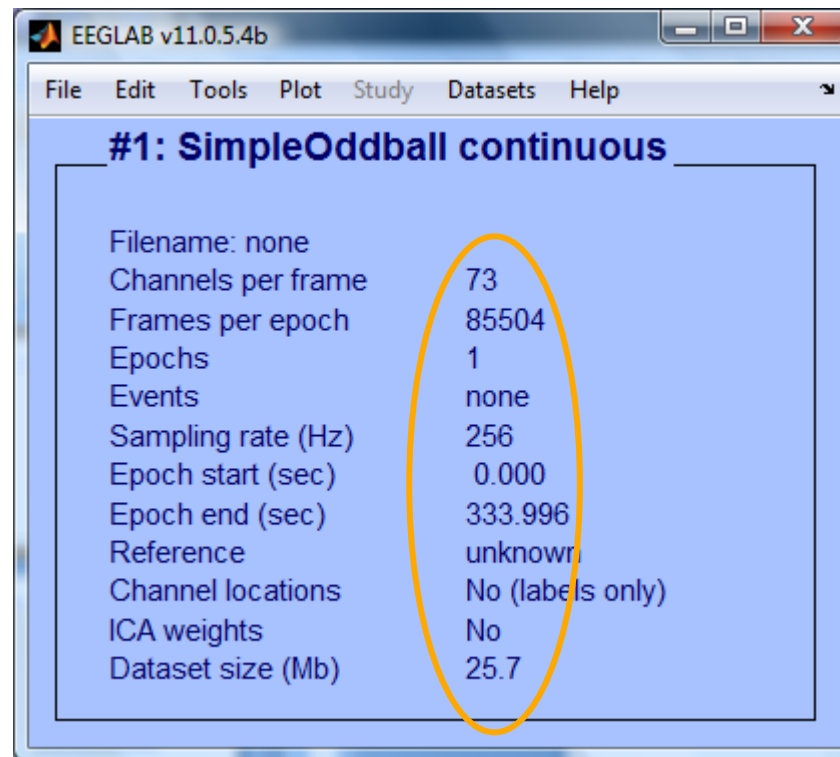
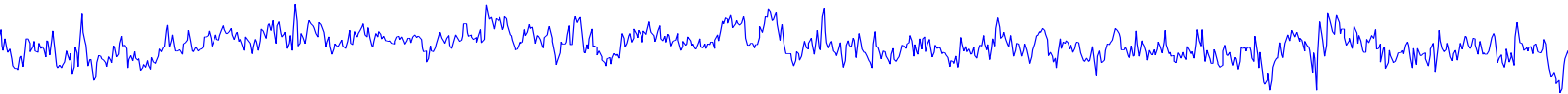
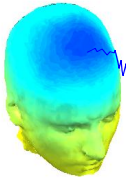


From ASCII/float file or Matlab array
From Netstation .mff (FILE-IO toolbox)
From Netstation binary simple file
From Multiple seg. Netstation files
From Netstation Matlab files
From BCI2000 ASCII file
From Snapmaster .SMA file
From Neuroscan .CNT file
From Neuroscan .EEG file
From Biosemi BDF file (BIOSIG toolbox)
From Biosemi BDF and EDF files (BDF plugin)
From EDF/EDF+/GDF files (BIOSIG toolbox)
From ANT EEProbe .CNT file
From ANT EEProbe .AVR file
From BCI2000 .DAT file
From BIOPAC MATLAB files
From Brain Vis. Rec. .vhdr file
From Brain Vis. Anal. Matlab file
From CTF folder (MEG)
From ERPSS .RAW or .RDF file
From INStep .ASC file
From 4D .m4d pdf file
From Procom Infinity Text File

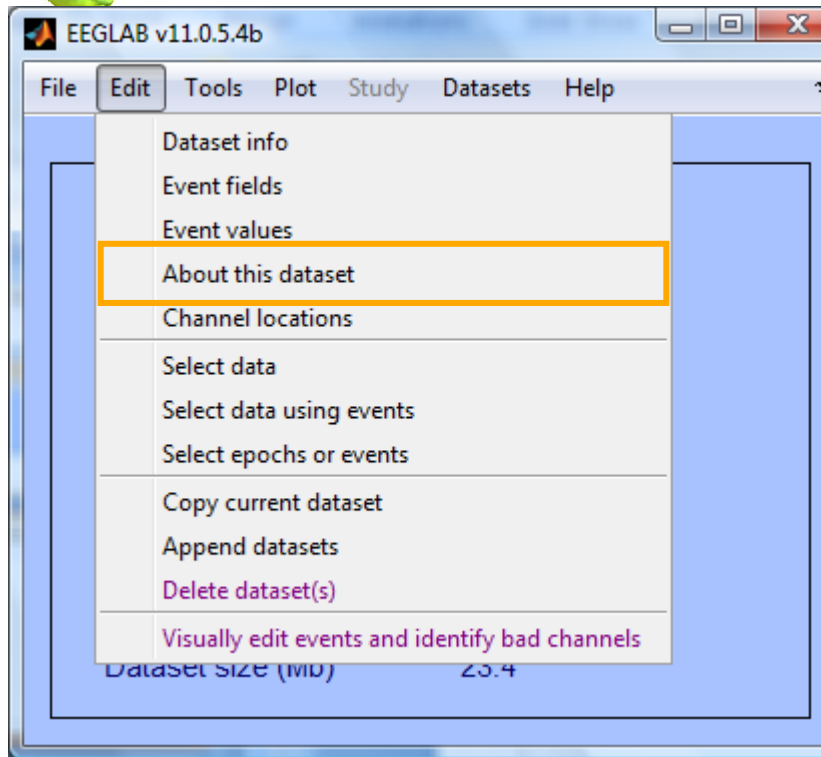
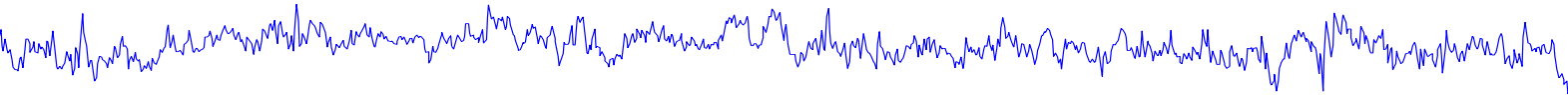
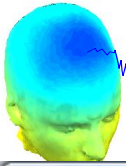
Tip for Biosemi users:
Use the 'BDF plugin' version
of the Biosemi BDF/EDF importer



Imported EEG data

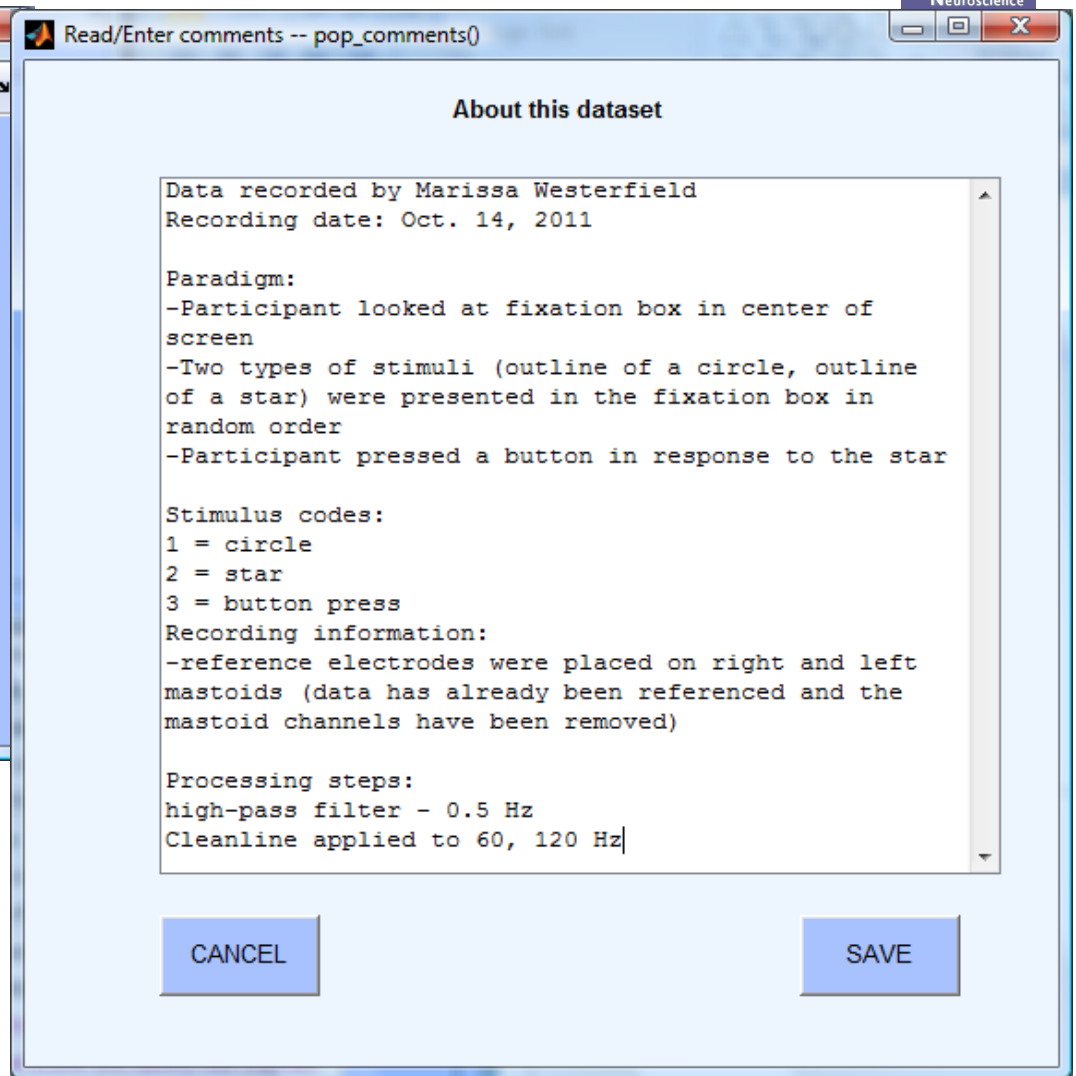


Comments and dataset history

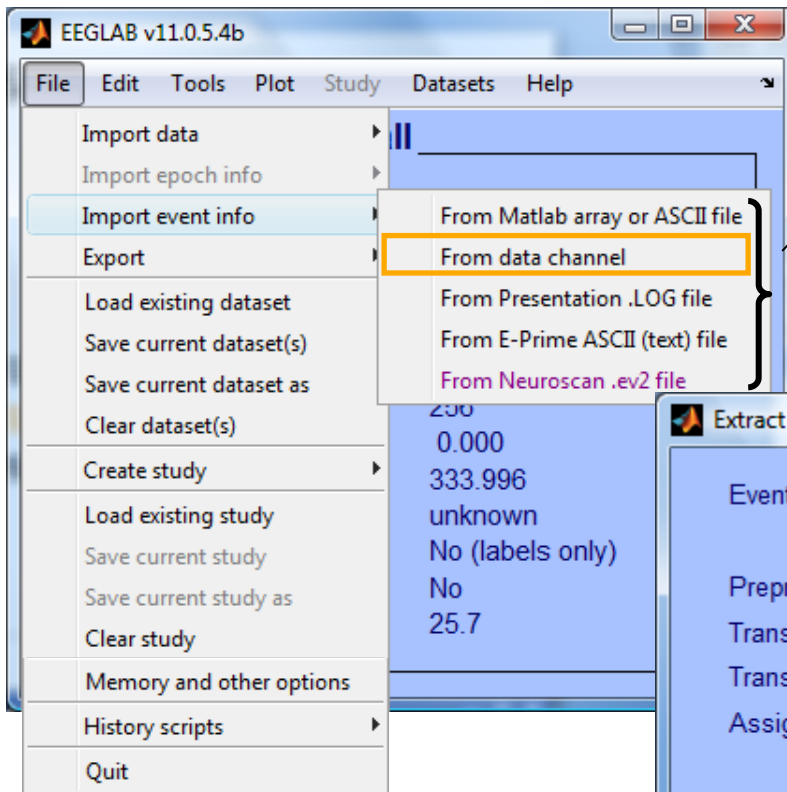
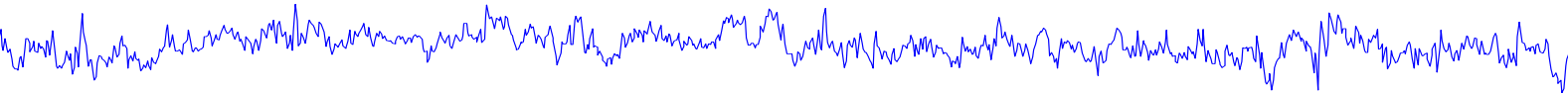
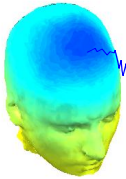


Also:
>> EEG.comments

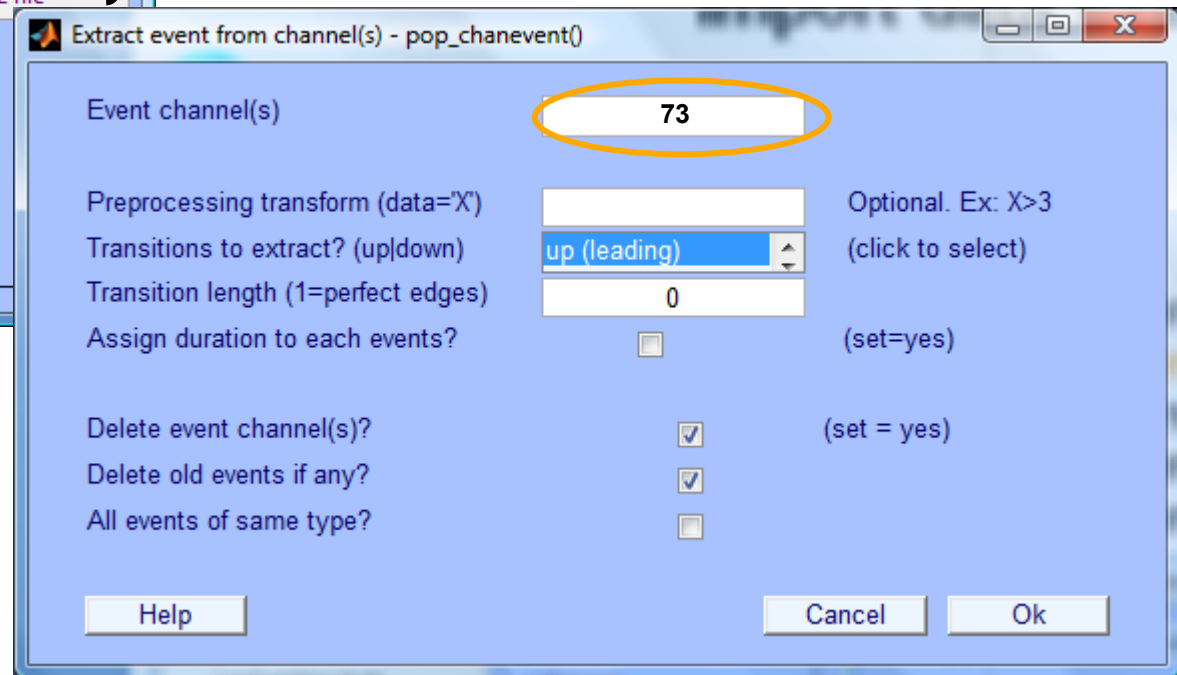
and
>> EEG.history



Import data events

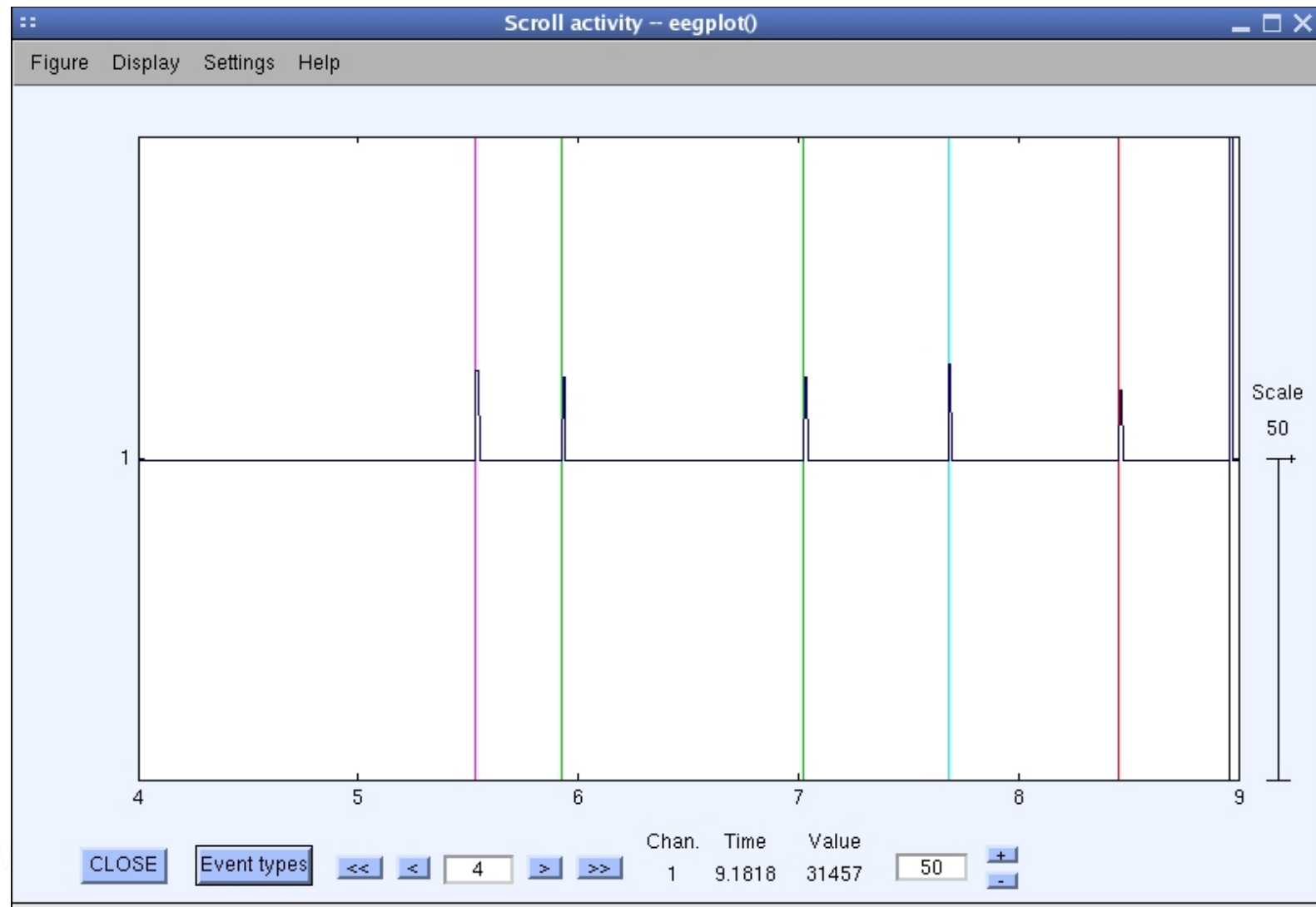
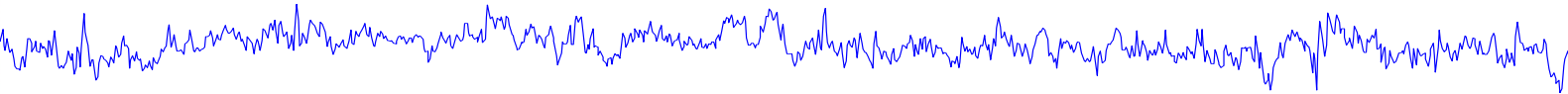
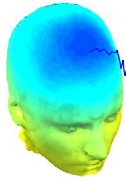


- Import events from Matlab array or ASCII file
- **Import events from data channel**
- Import from Presentation event file
- Import events from E-Prime event file
- Import events from Neuroscan event file

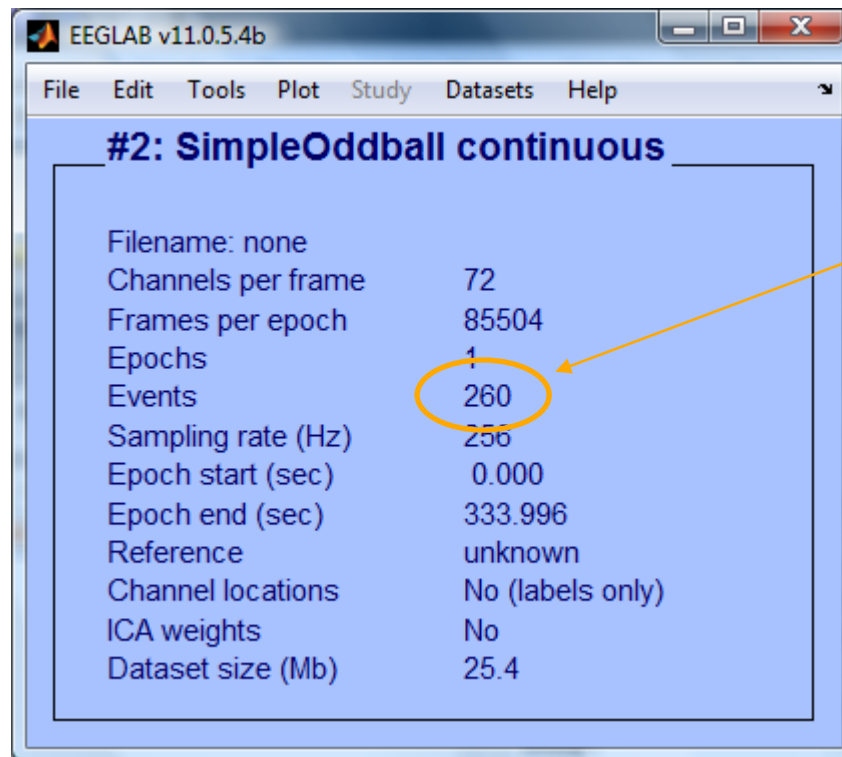
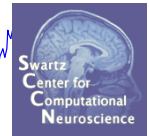
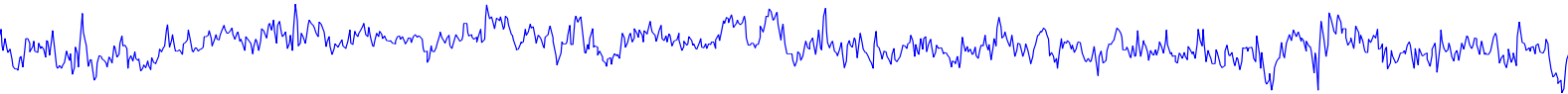
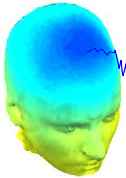


(Often imported automatically
during data import)

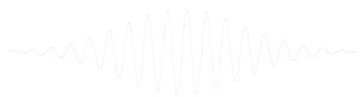
Appearance of an event channel in raw data



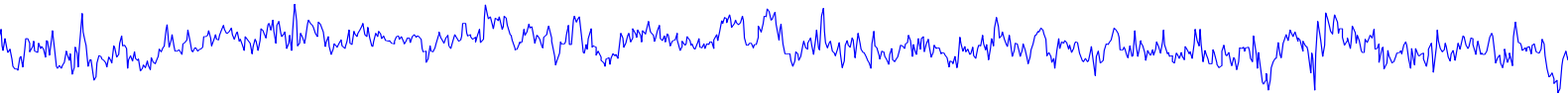
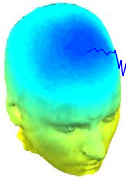
Imported data events



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



Sample data: basic P300 paradigm



File

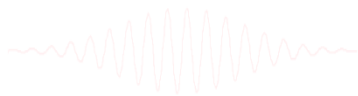
SimpleOddball.set

Data

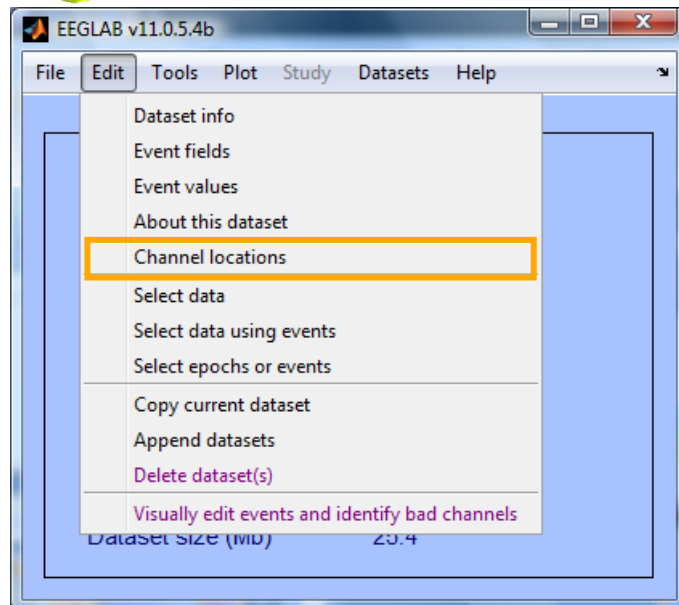
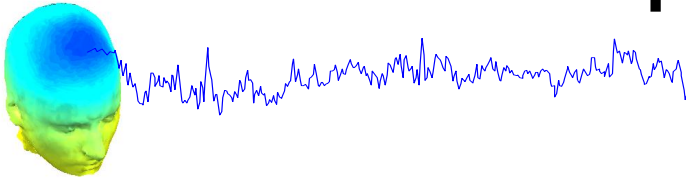
68 channel EEG, 256 Hz sampling rate, Biosemi system, re-referenced during import to averaged left and right mastoid electrodes

Task

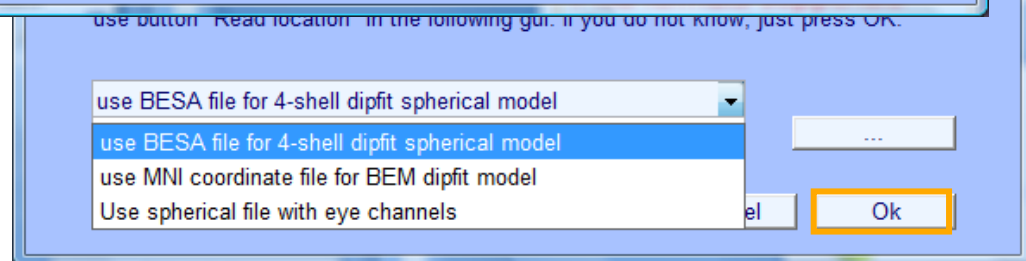
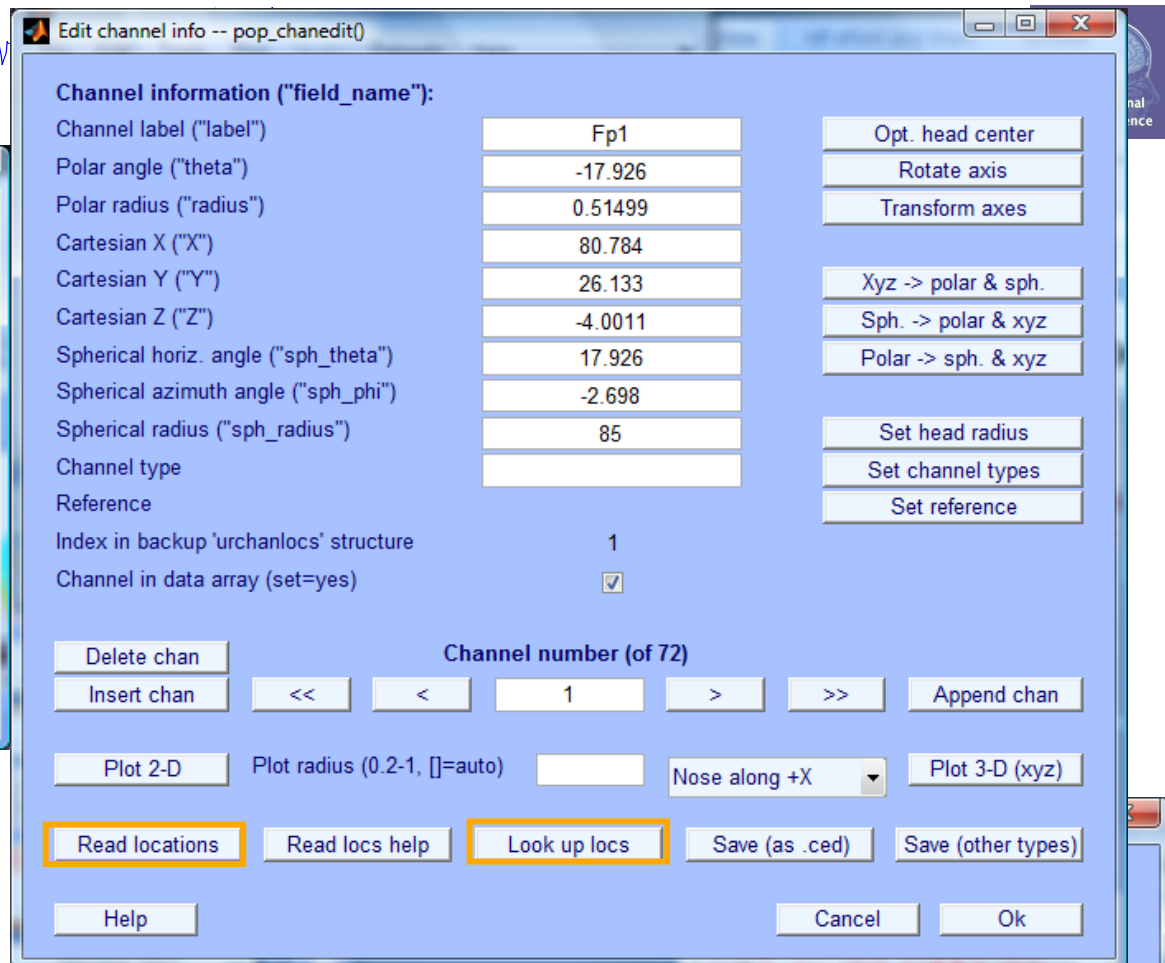
speeded button press response to star shape (no response to circle shape), 100 ms presentation duration, 200 trials



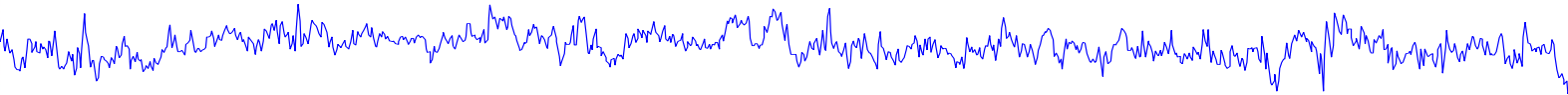
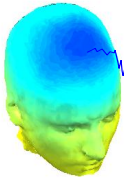
Import channel locations



7 file formats supported
(Polhemus, BESA, ...)



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)

1

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

Convert channel locations -- pop_chancenter()

Optimize center location ☒ or specify center 0 0 0

Channel indices to ignore for best-sphere matching

Buttons: Browse, Help, Cancel, Ok

Force electrode location -- forclocs()

X/Y value	Coordinate	Electrode list
0	X (rotate X-Z plane)	Cz

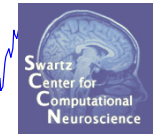
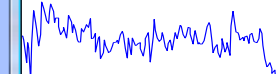
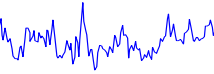
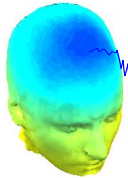
Buttons: Pick, Help, Cancel, Ok

Set channel ...

Channel indices 1:71

Type (e.g. EEG) EEG

Buttons: Help, Cancel, Ok



Edit channel info -- pop_chanedit()

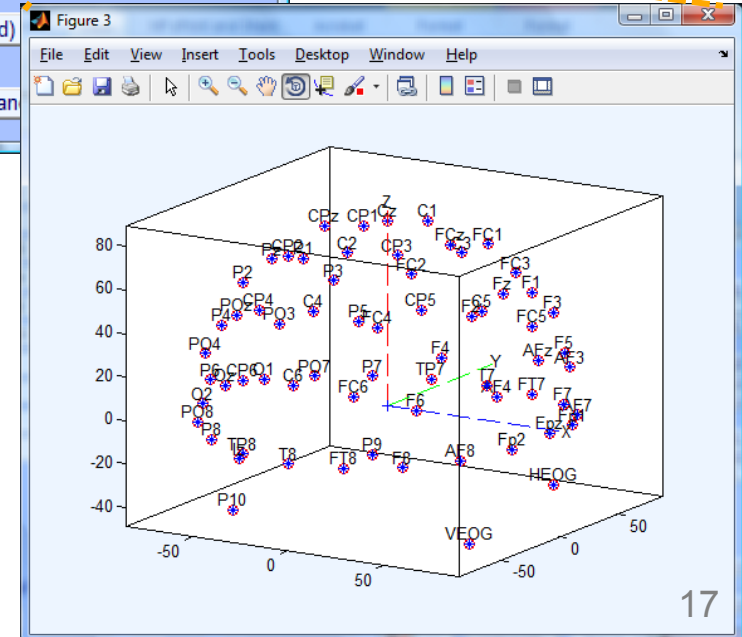
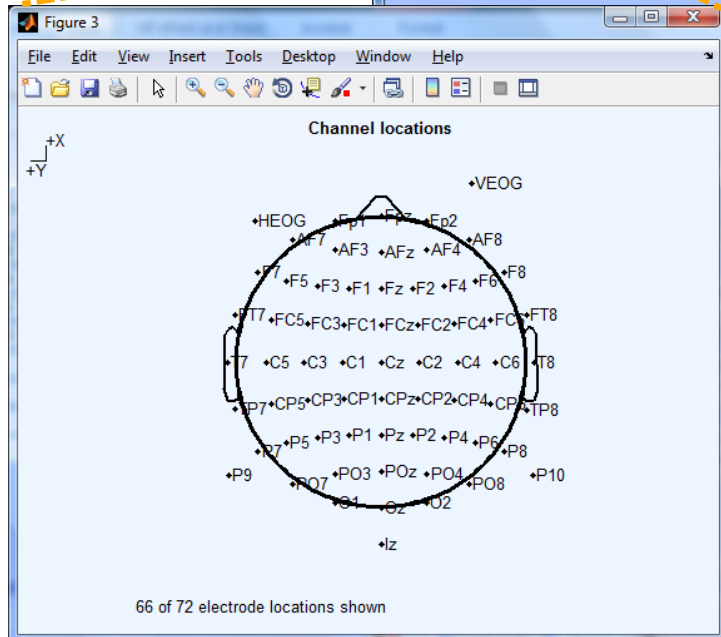
Channel information ("field_name"):

Channel label ("label")	HEOG	Opt. head center
Polar angle ("theta")	-42	Rotate axis
Polar radius ("radius")	0.65556	Transform axes
Cartesian X ("X")	55.7734	XYZ -> polar & sph.
Cartesian Y ("Y")	50.2186	Sph. -> polar & xyz
Cartesian Z ("Z")	-39.9051	Polar -> sph. & xyz
Spherical horiz. angle ("sph_theta")	42	Set head radius
Spherical azimuth angle ("sph_phi")	-28	Set channel types
Spherical radius ("sph_radius")	85	Set reference
Channel type		
Reference		
Index in backup 'urchanlocs' structure	68	
Channel in data array (set=yes)	<input checked="" type="checkbox"/>	

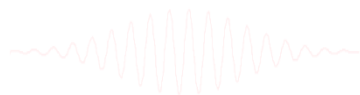
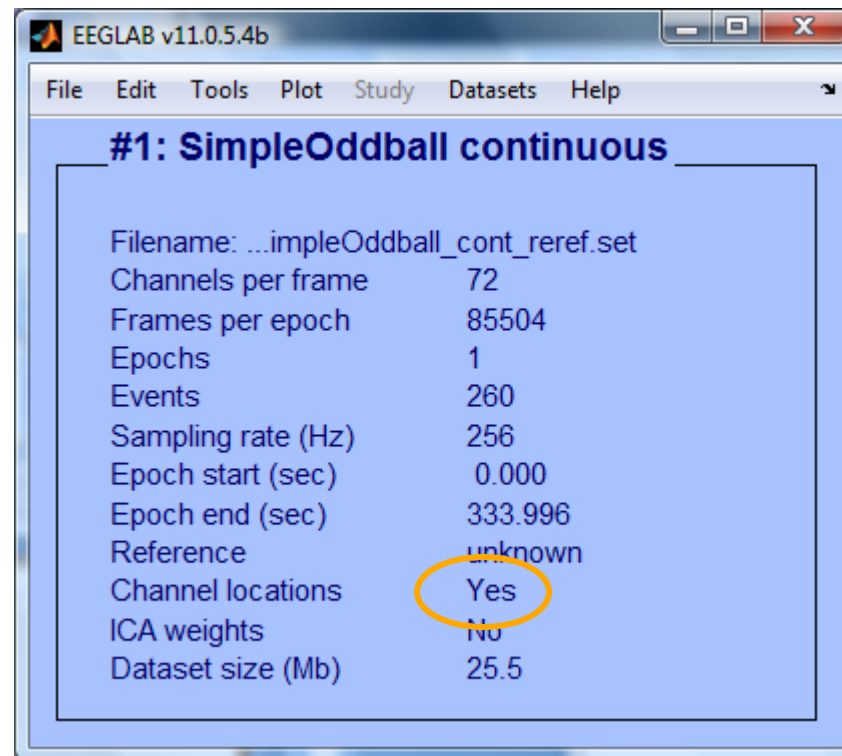
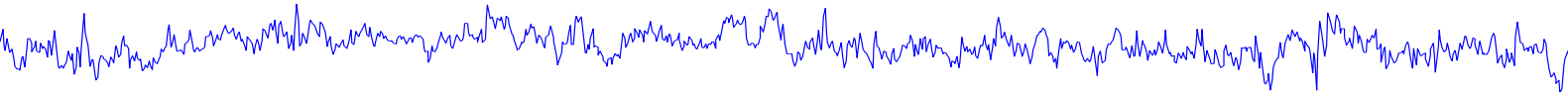
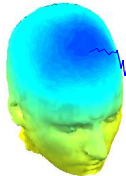
Channel number (of 72)

68

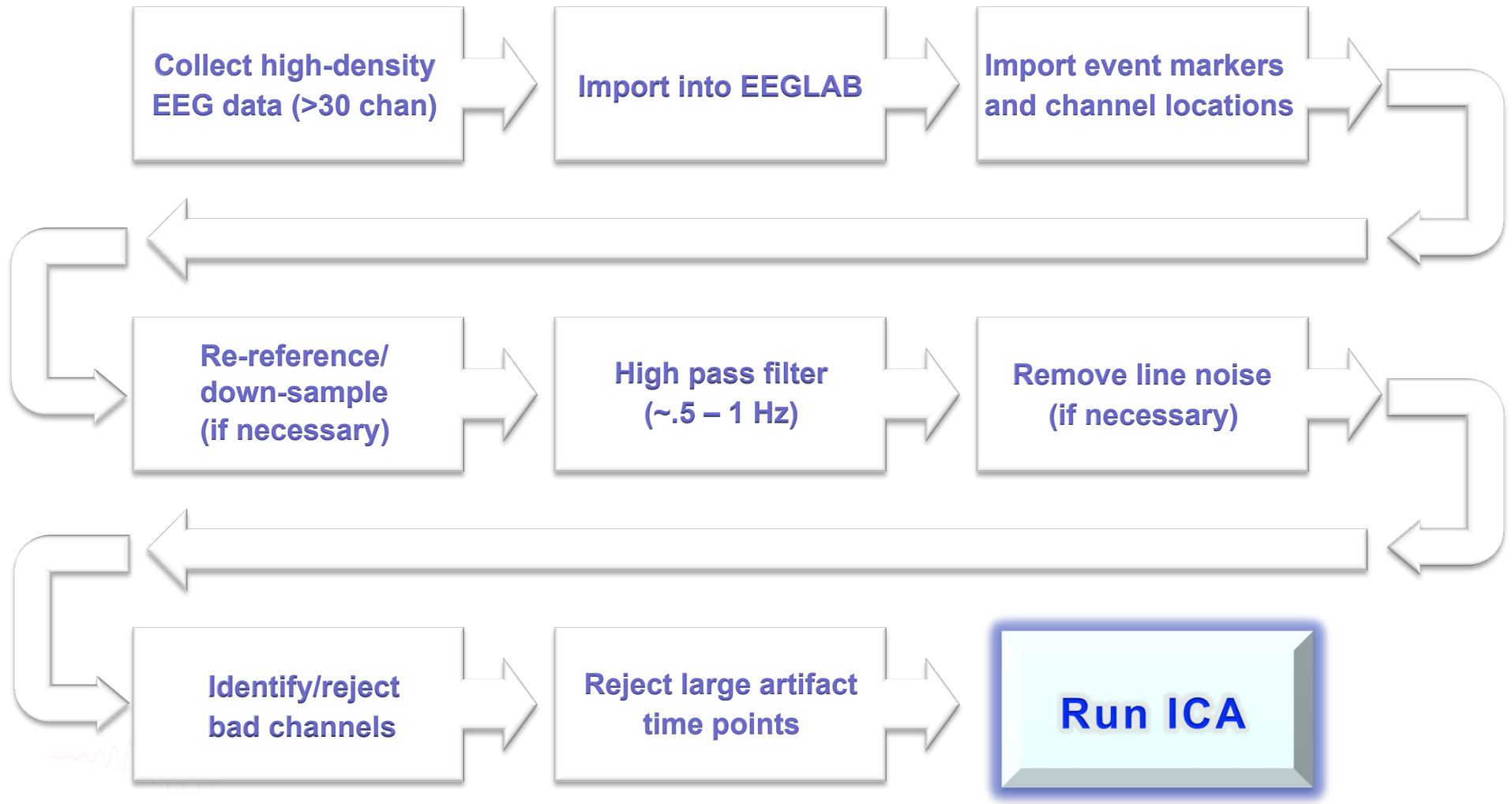
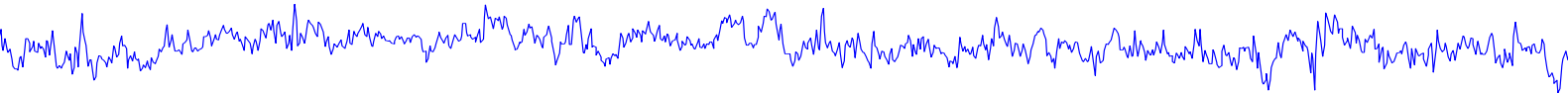
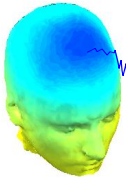
Plot 2-D Plot radius (0.2-1, []=auto) Nose along +X Plot 3-D (xyz)



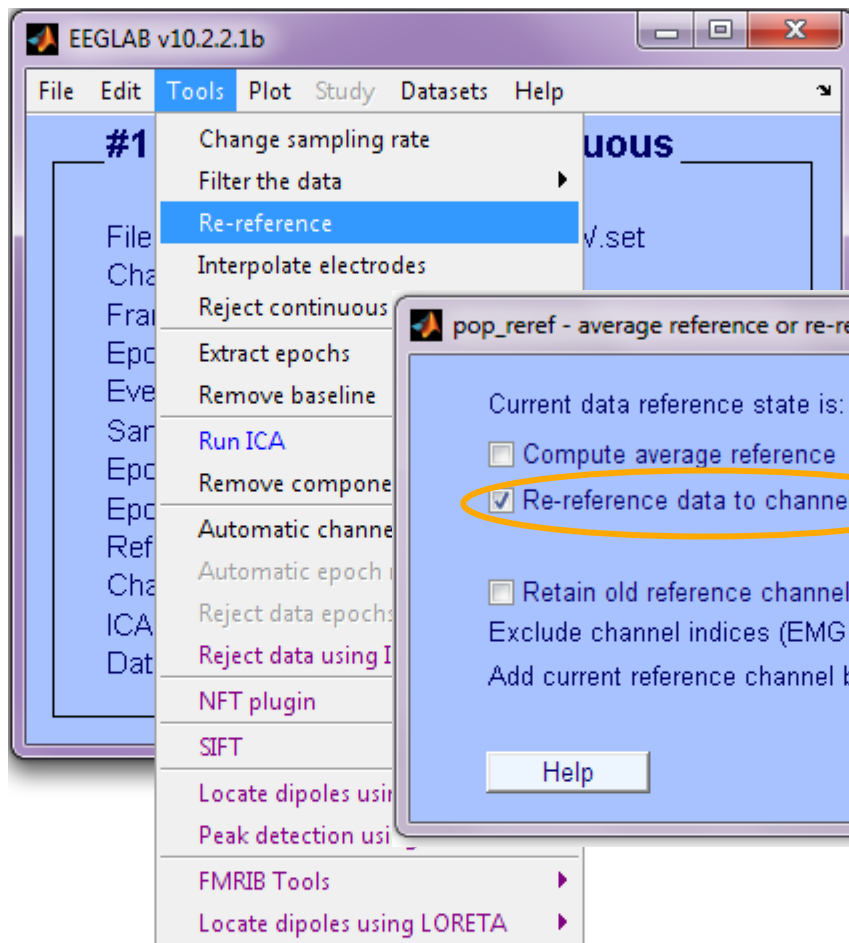
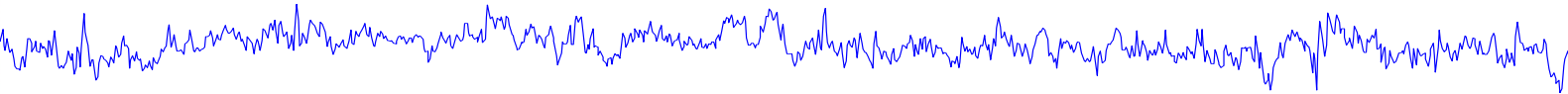
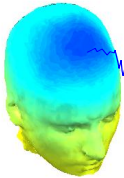
Imported channel locations



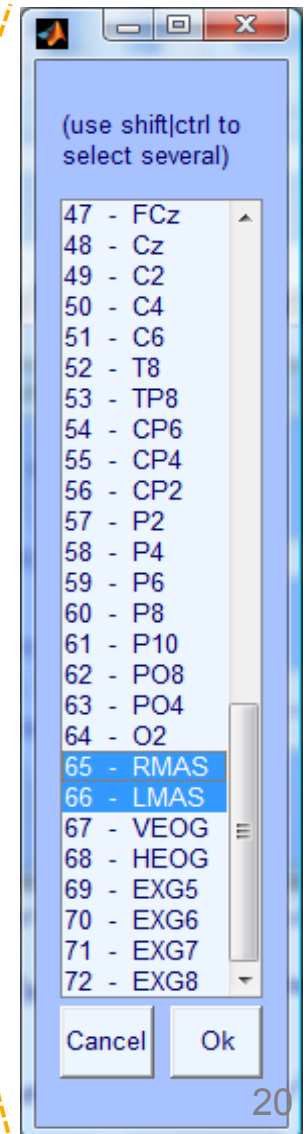
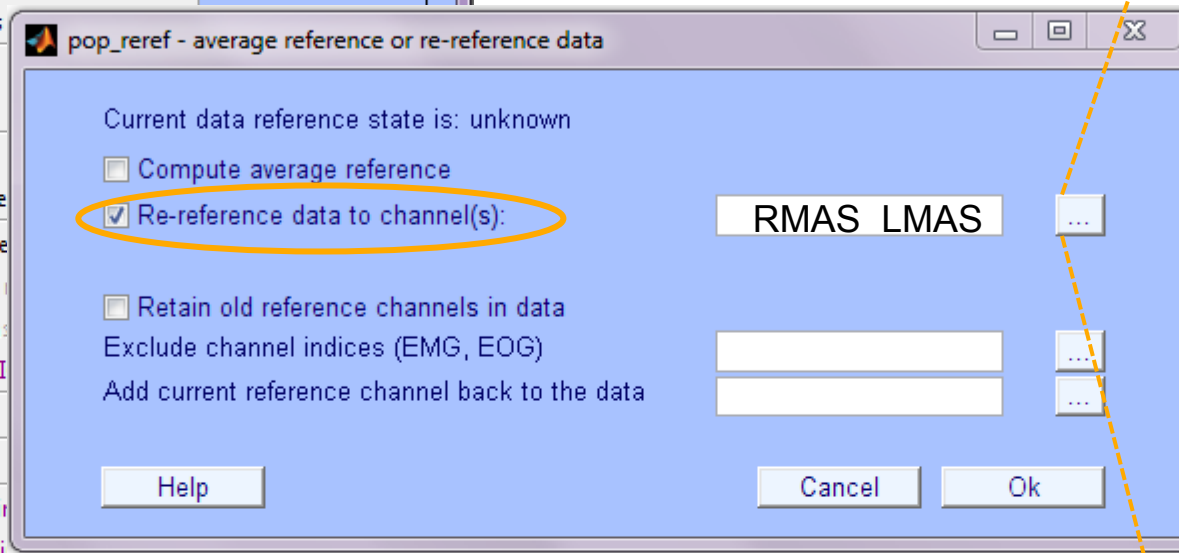
Pre-processing pipeline



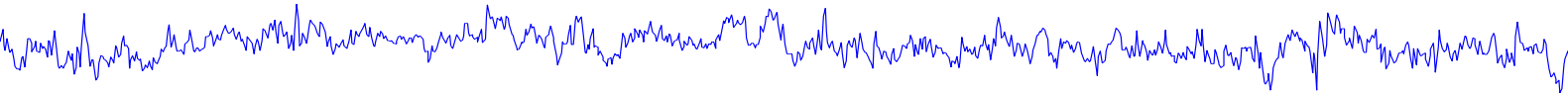
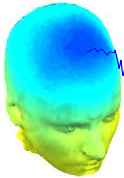
Re-reference data (if necessary/desired)



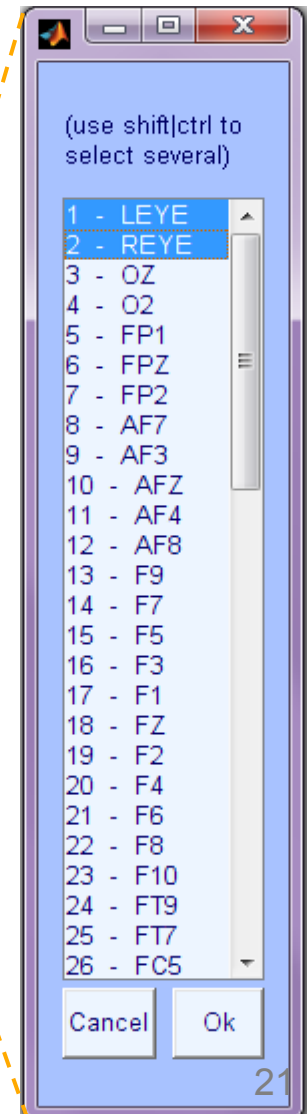
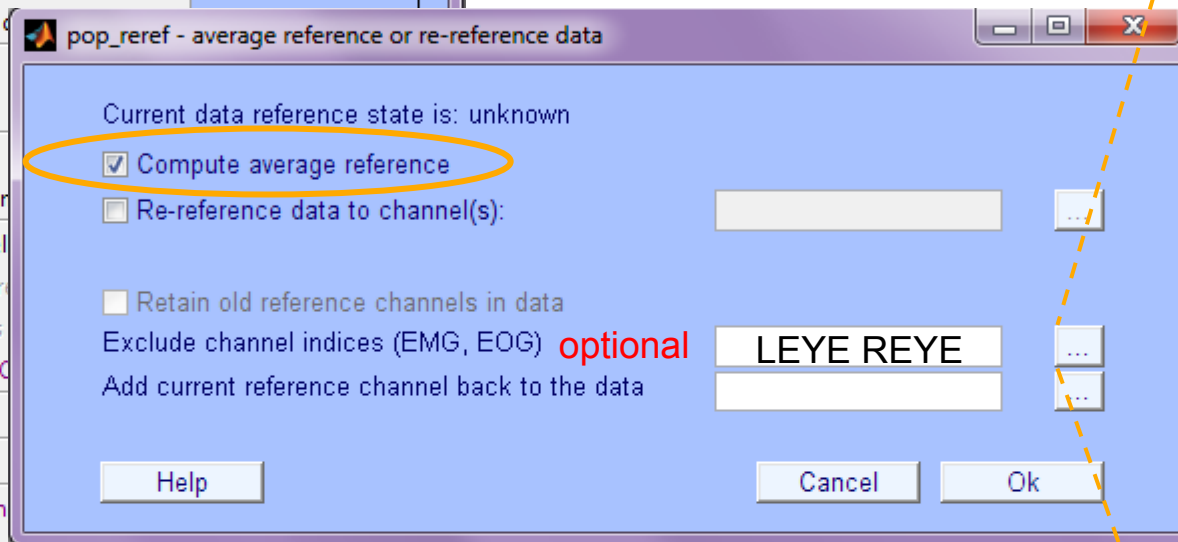
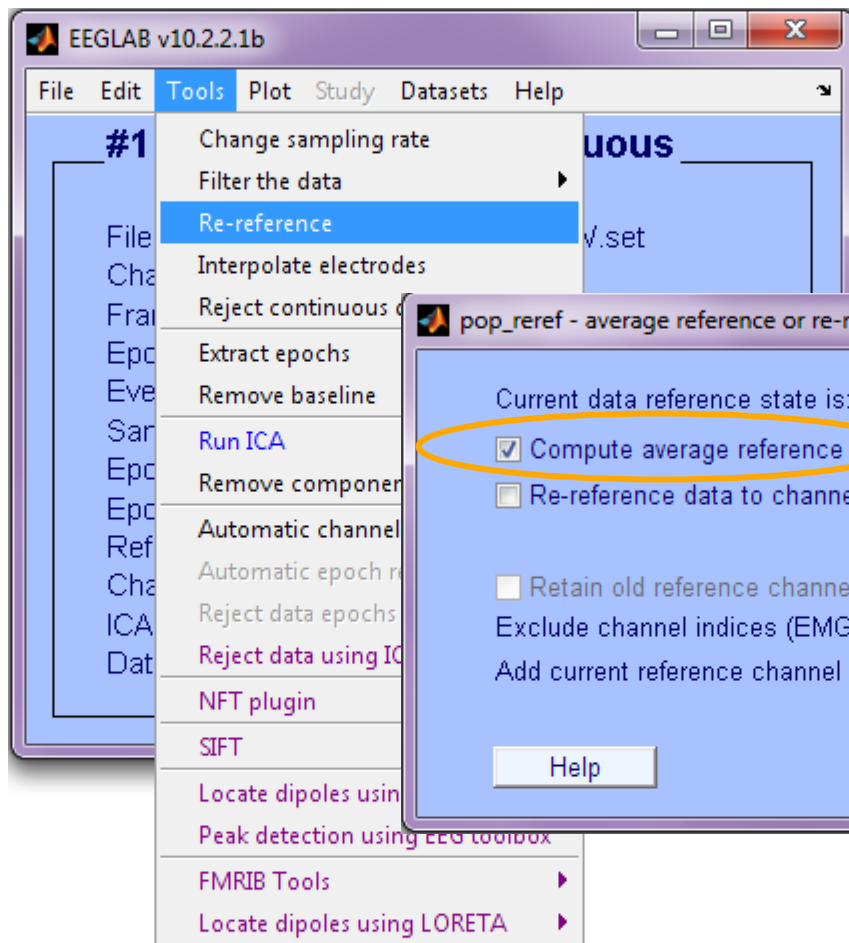
Re-reference to
(e.g.) 'linked mastoids'



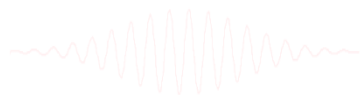
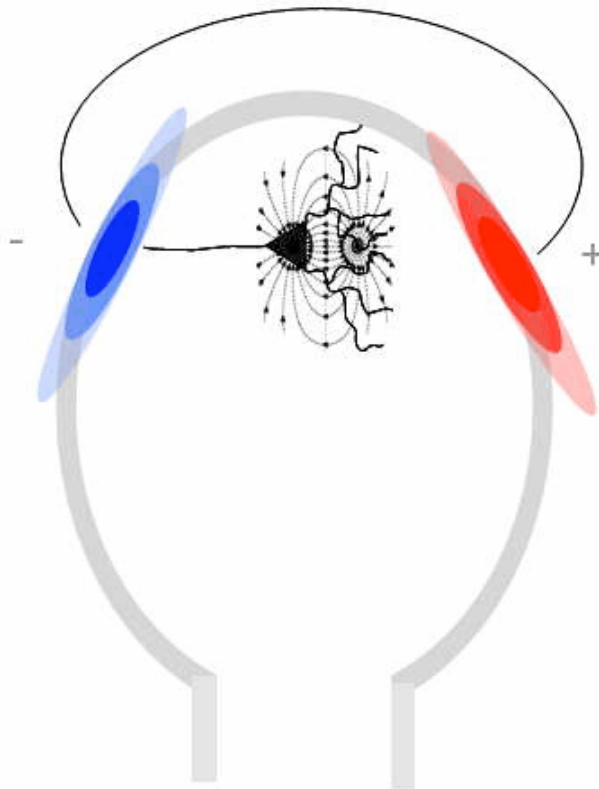
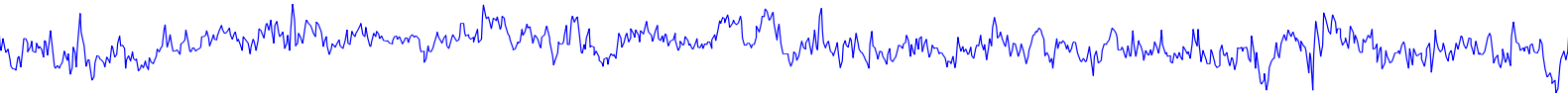
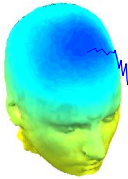
Re-reference data (if necessary/desired)



Or,
average reference



On Average Referencing

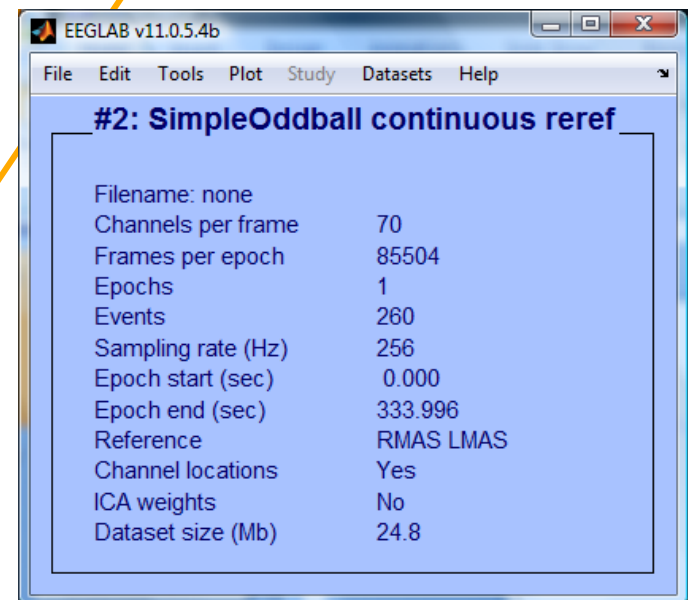
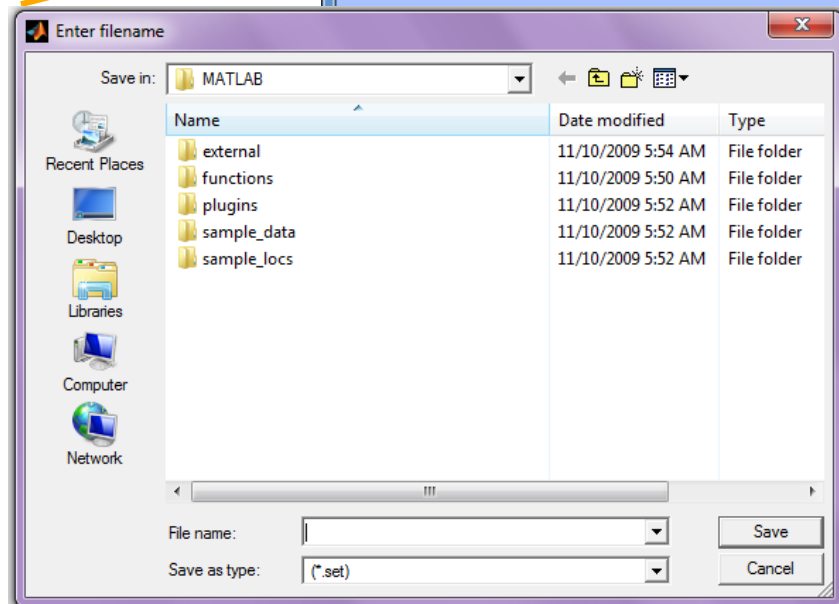
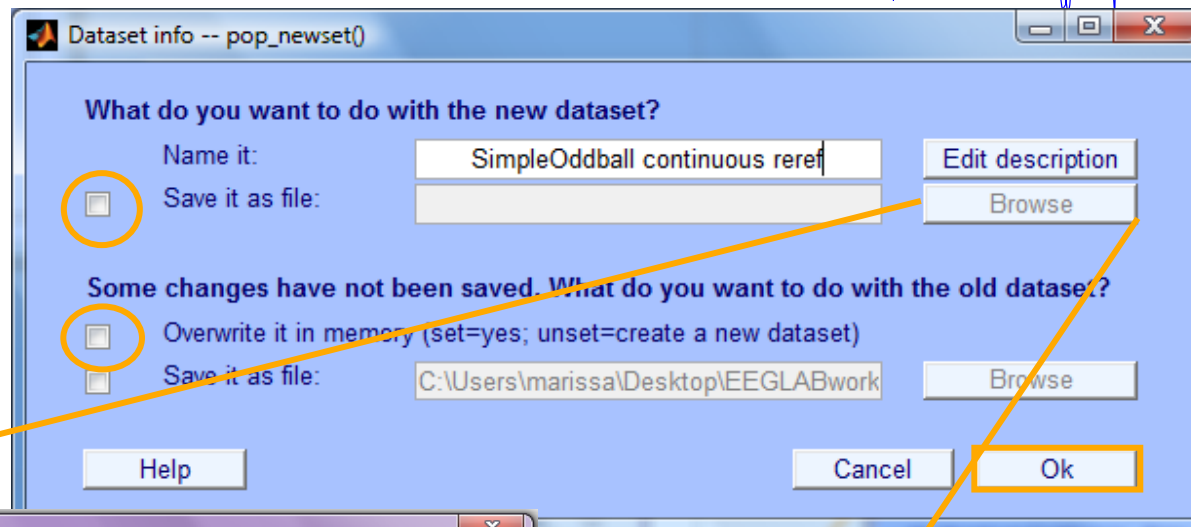
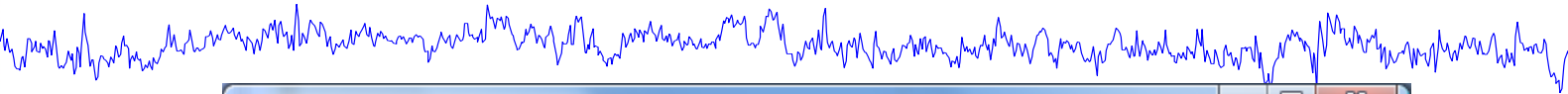
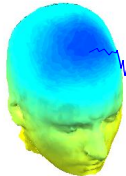


In theory, positive and negative current across entire head should balance—no net current source or sink: Average referencing enforces this.

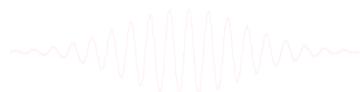
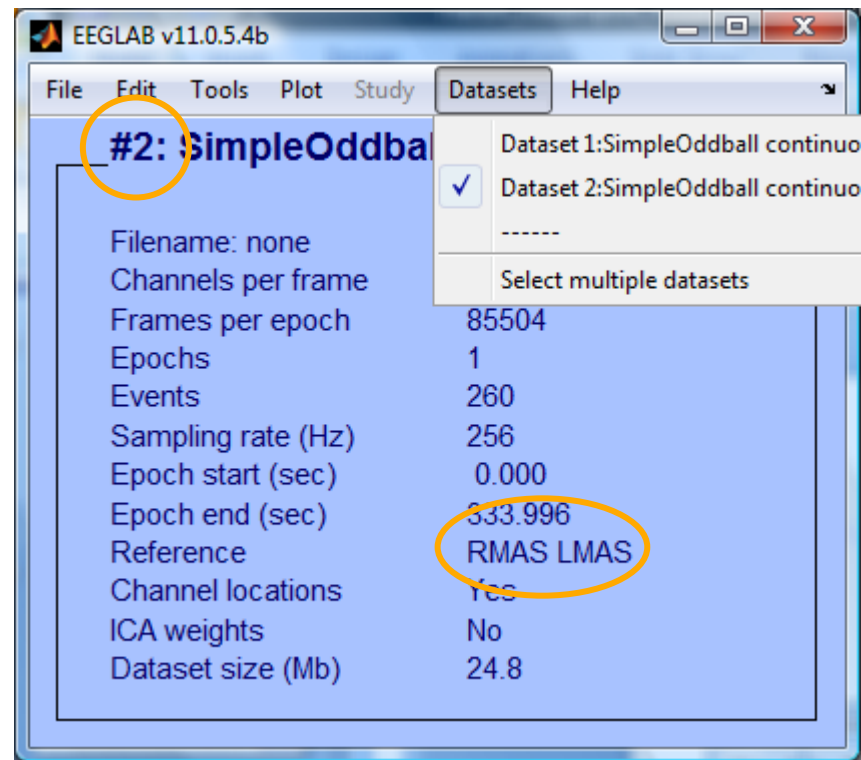
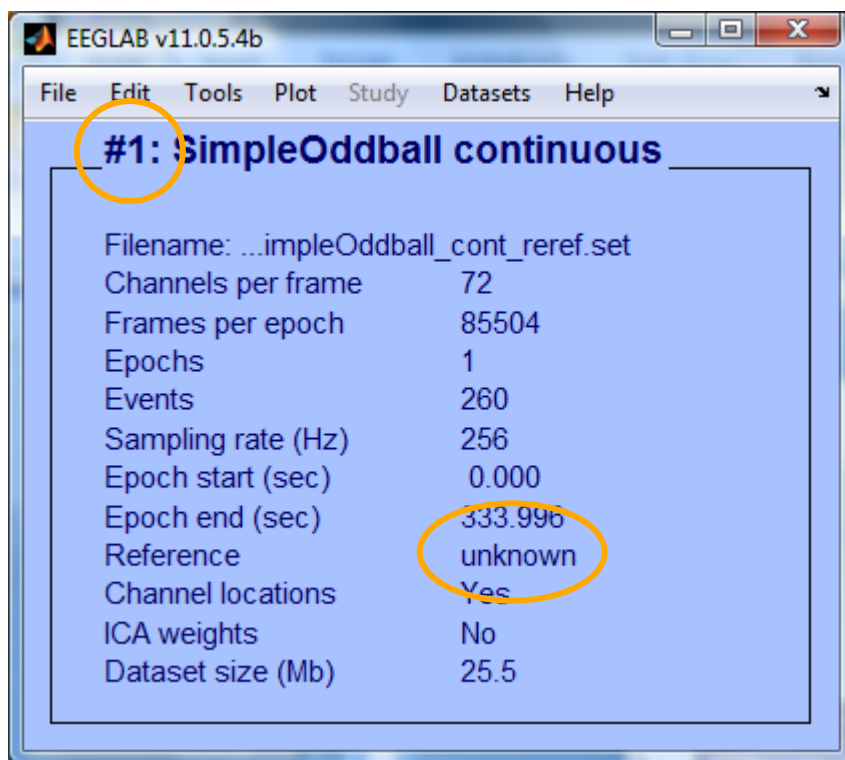
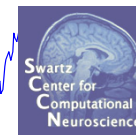
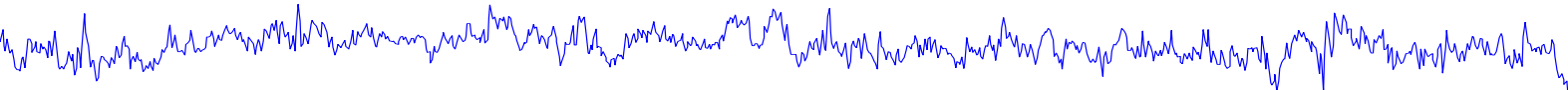
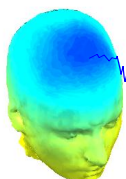
In practice, depends on distribution of electrodes.

Average referencing reduces data rank by 1, so you must remove one channel (Cz often)

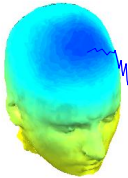
Save new dataset, keep old one



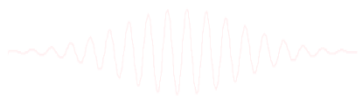
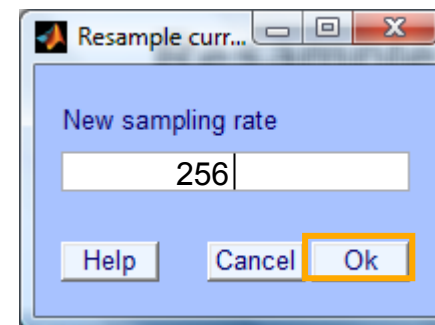
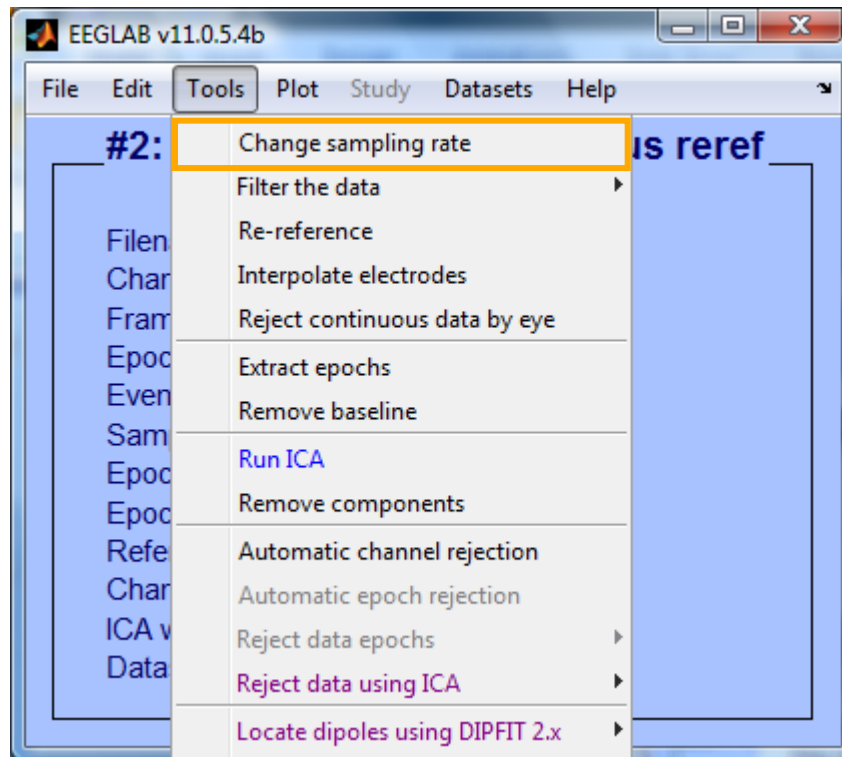
Multiple active datasets (ALLEEG)



Resample data (if desired)



Reason: Reduce space, time. But keep nyquist and ICA data length requirements in mind...



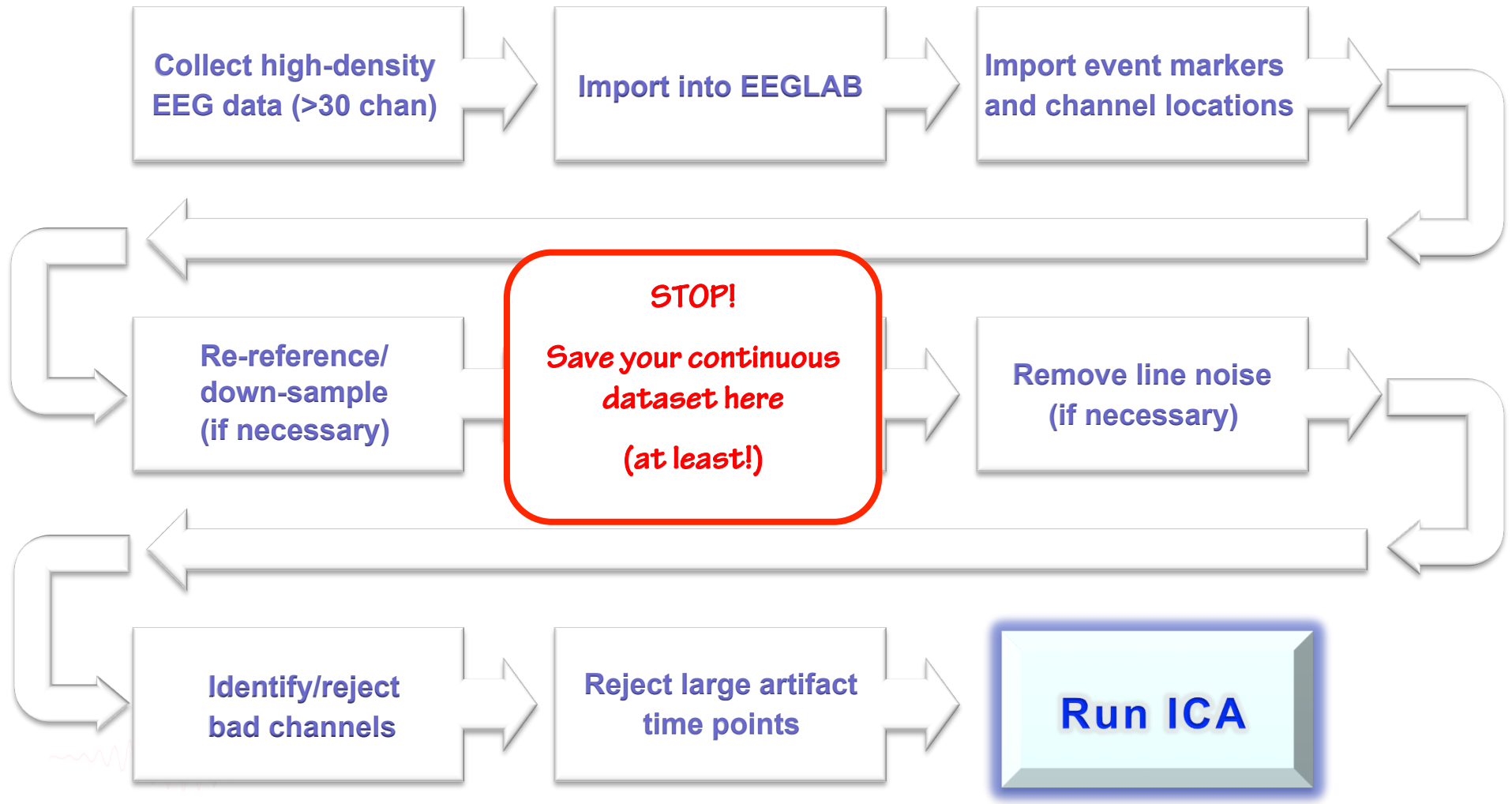
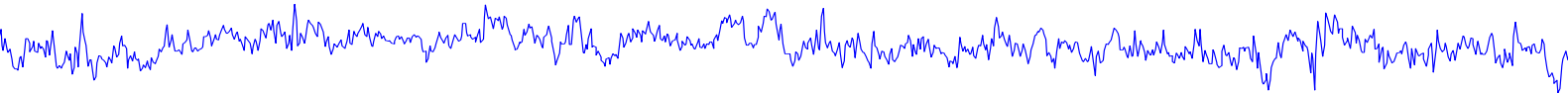
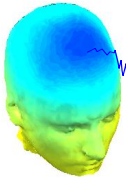
Remove unwanted channels

The diagram illustrates the steps to remove unwanted channels in EEGLAB. At the top, a topographic map of a head and a signal waveform are shown. Below them, three windows are displayed:

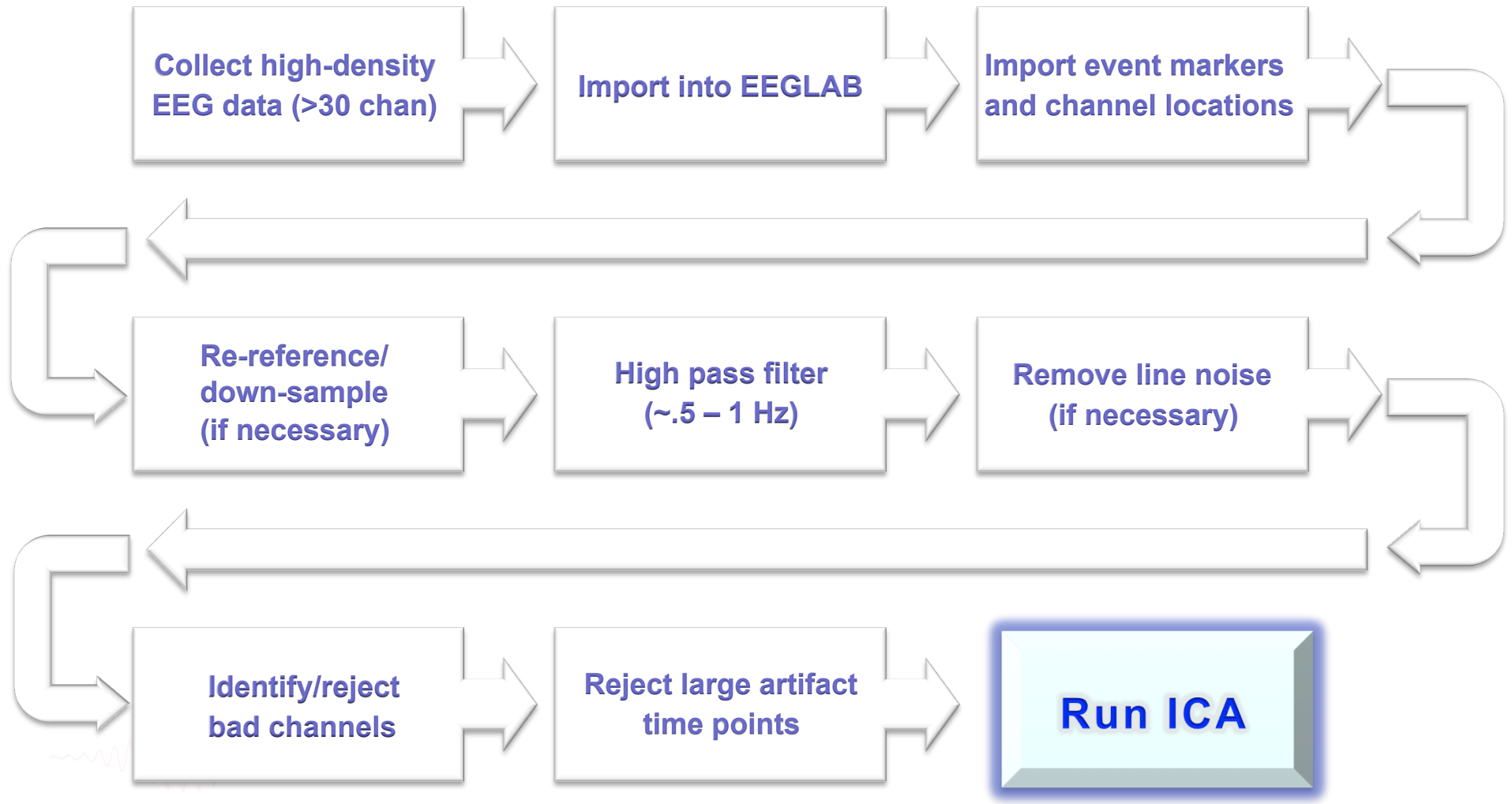
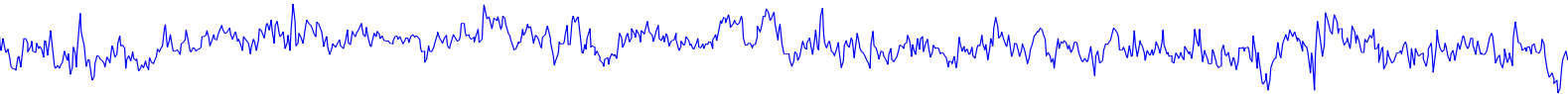
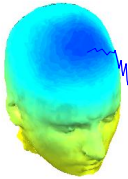
- EEGLAB v11.0.5.4b**: The main window with the 'Edit' menu open and 'Select data' highlighted.
- Select data -- pop_select()**: A dialog box with the following fields:
 - Select data in:** Time range [min max] (s), Point range (ex: [1 10]), Epoch range (ex: 3:2:10), Channel range.
 - Input desired range:** EXG5 EXG6 EXG7 EXG8.
 - on->remove these:** A list of channels with checkboxes. The checkbox for EXG5 is checked and circled in orange.
 - Buttons:** Help, Scroll dataset, Cancel, Ok.
- Channel locations**: A list of channels with their locations. The channels EXG5, EXG6, EXG7, and EXG8 are highlighted in blue. The 'Ok' button is highlighted in orange.

Orange arrows indicate the flow of the process: from the 'Select data' menu item to the 'Select data -- pop_select()' dialog, and from the 'on->remove these' list to the 'Channel locations' list.

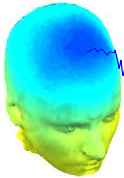
Pre-processing pipeline



Pre-processing pipeline



High-Pass Filter the data



Reason: remove slow, possibly large amplitude, drift



EEGLAB v11.0.5.4b

File Edit Tools Plot Study Datasets Help

#1: Change sampling rate
Filter the data
Re-reference
Interpolate electrodes
Reject continuous data by eye
Extract epochs
Remove baseline
Run ICA
Remove components
Automatic channel rejection
Automatic epoch rejection
Reject data epochs
Reject data using ICA
Locate dipoles using DIPFIT 2.x
Peak detection using EEG toolbox
FMRIB Tools
Locate dipoles using LORETA
CleanLine

Basic FIR filter
ERPLAB Butterworth
ERPLAB Polynomial
Short non-linear IIR

Filter the data -- pop_eegfilt()

Lower edge of the frequency pass band (Hz) 0.5
Higher edge of the frequency pass band (Hz)
FIR Filter order (default is automatic)
☐ Notch filter the data instead of pass band
☐ Use (sharper) FFT linear filter instead of FIR filtering (Use the option above if you do not have the Signal Processing Toolbox)
☐ Use causal filter (useful when performing causal analysis)
☐ Plot the filter frequency response
☒ Use fir1 (check, recommended) or firls (uncheck, legacy)

High-pass needed for ICA

Help Cancel Ok

Dataset info -- pop_newset()

What do you want to do with the new dataset?

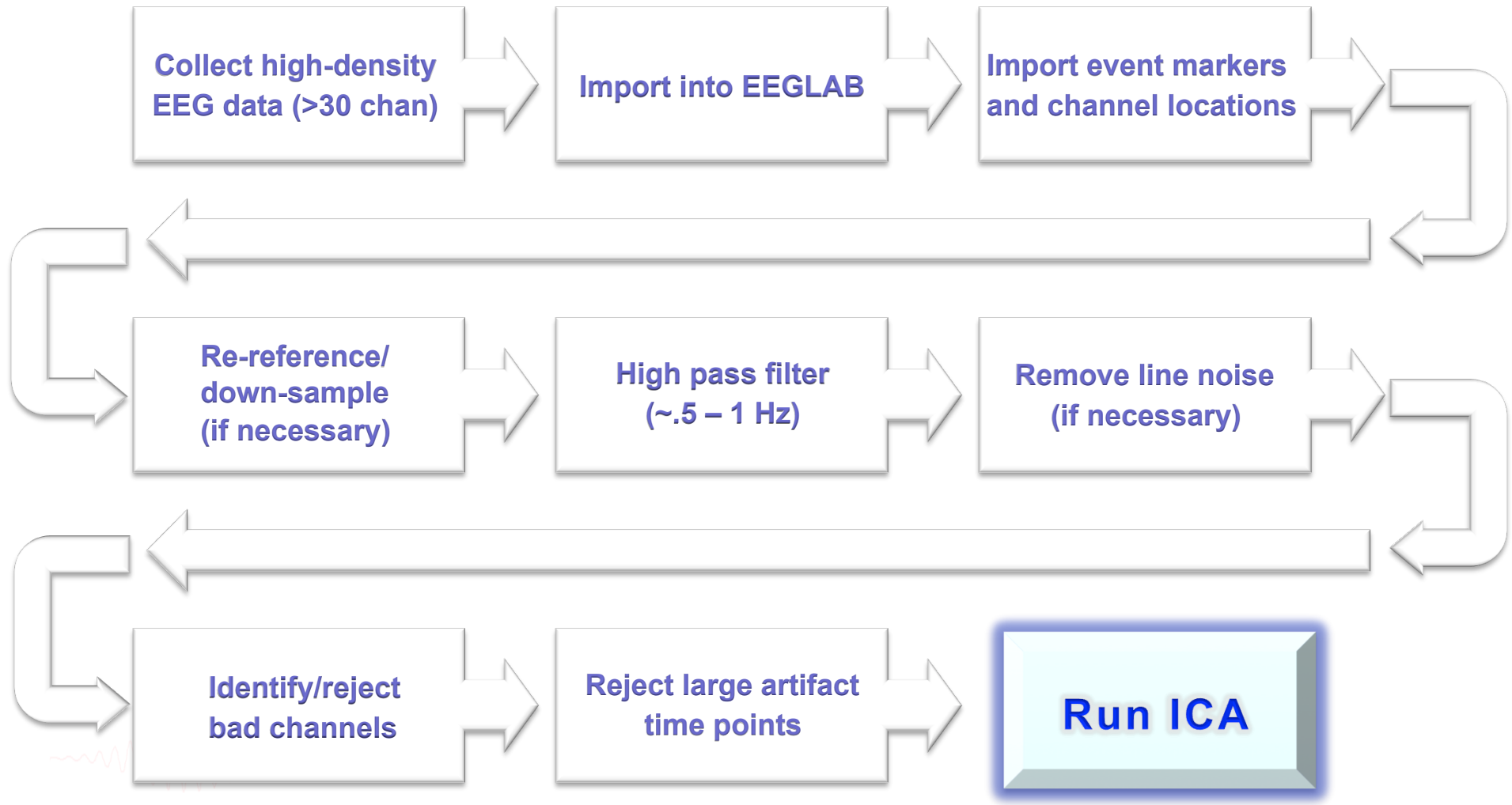
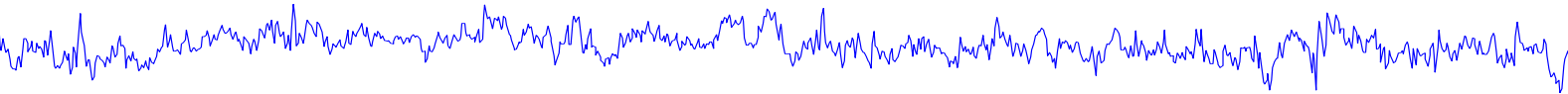
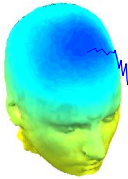
Name it: SimpleOddball hipass0.5 Edit description
☐ Save it as file: Browse

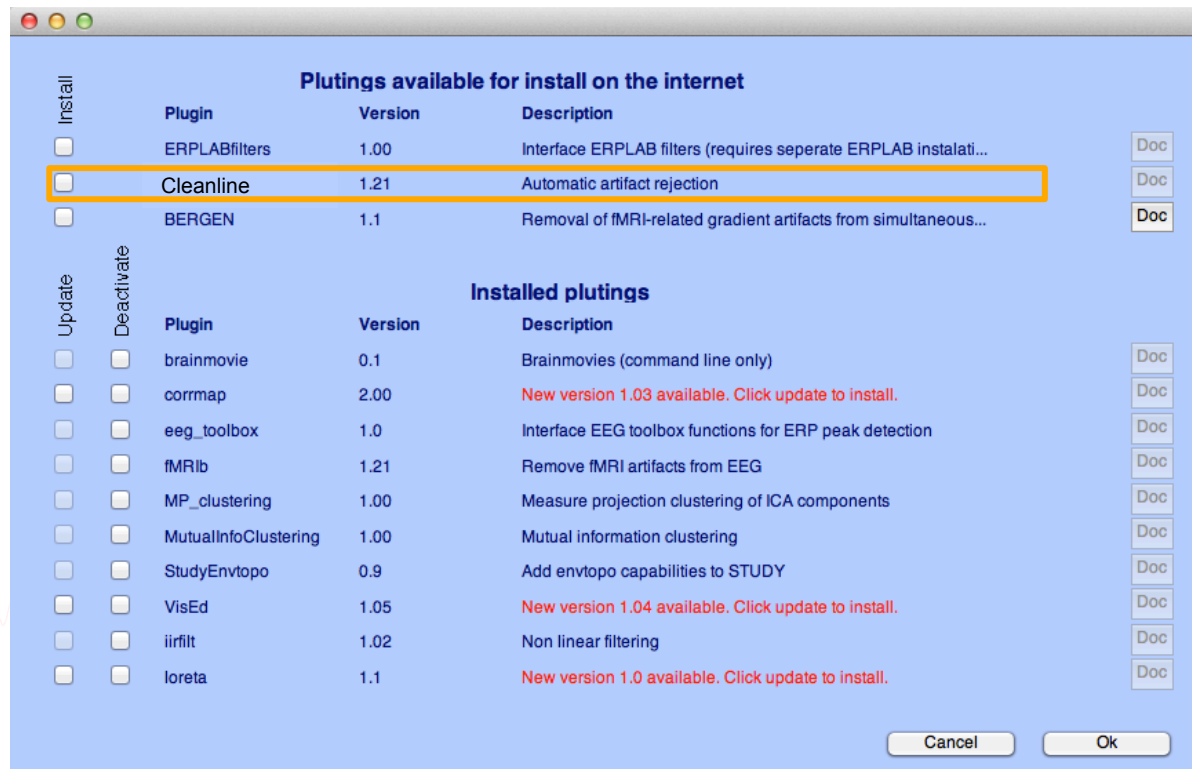
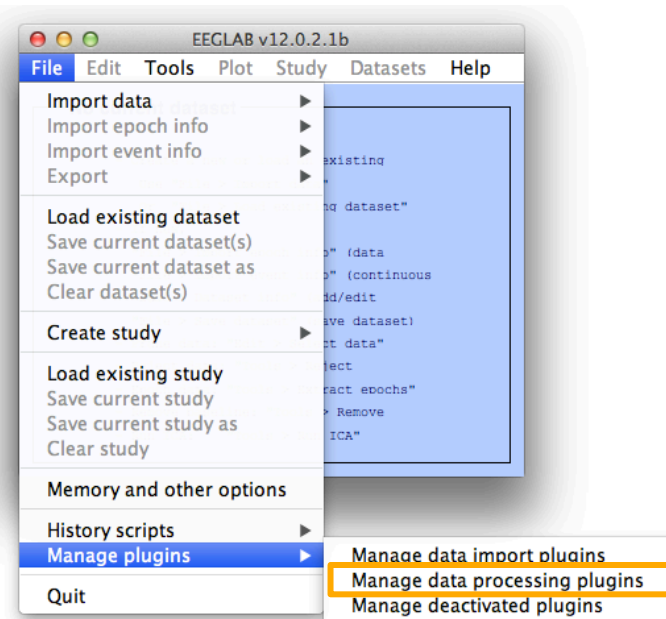
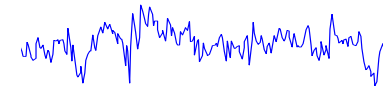
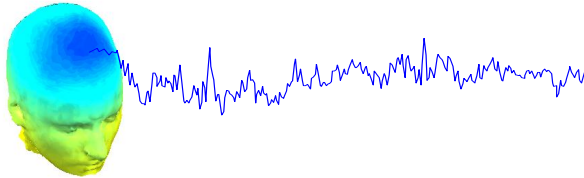
What do you want to do with the old dataset (not modified since last saved)?

☒ Overwrite it in memory (set=yes; unset=create a new dataset)

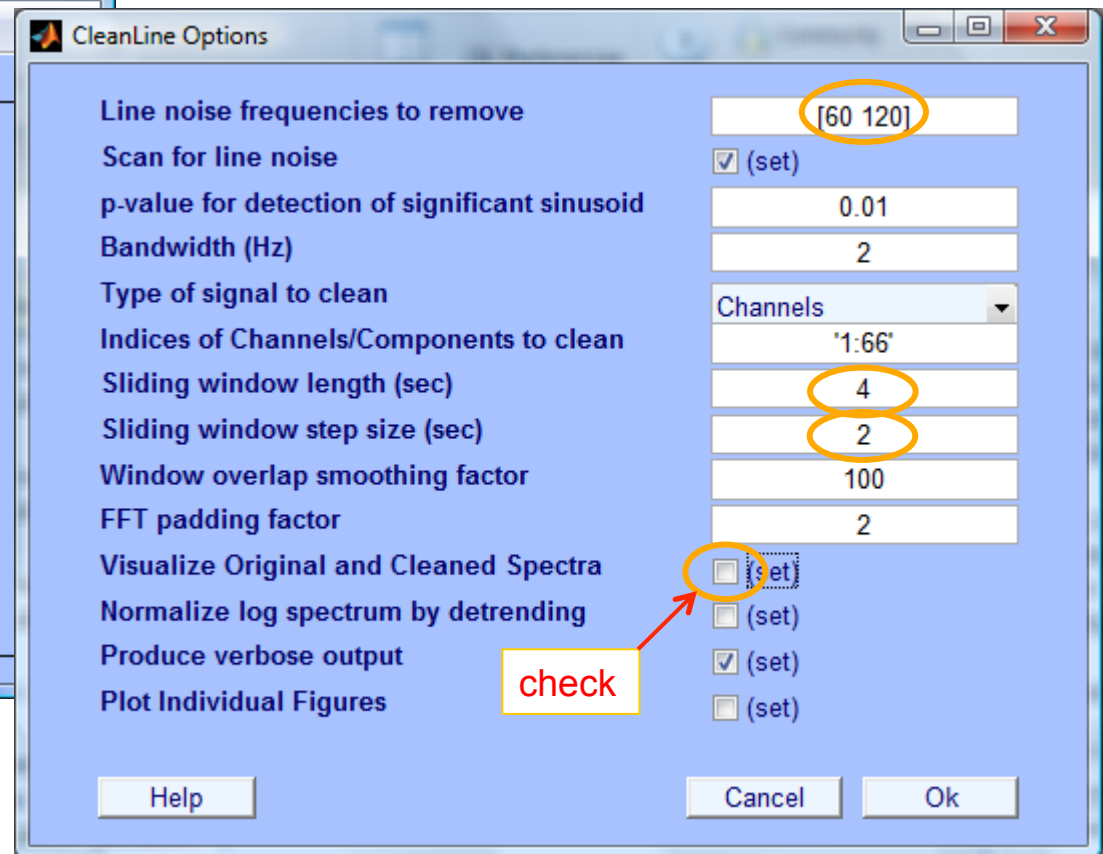
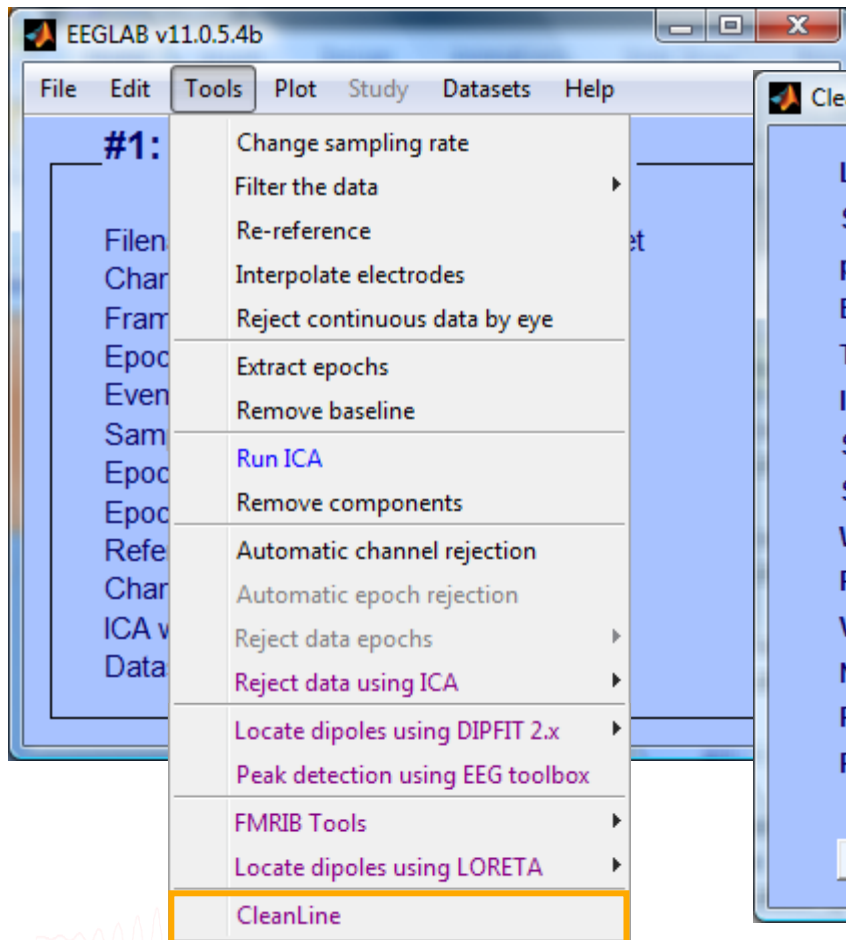
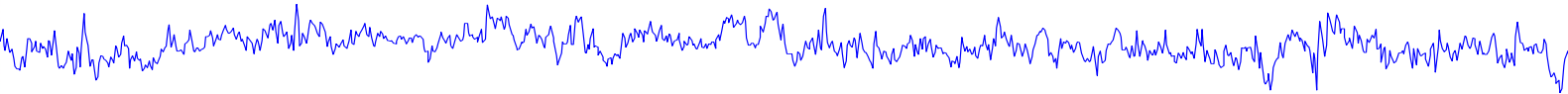
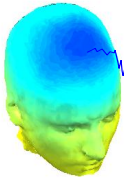
Help Cancel Ok

Pre-processing pipeline

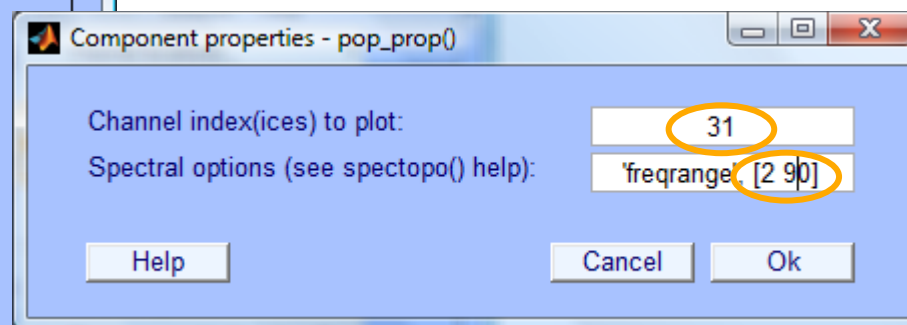
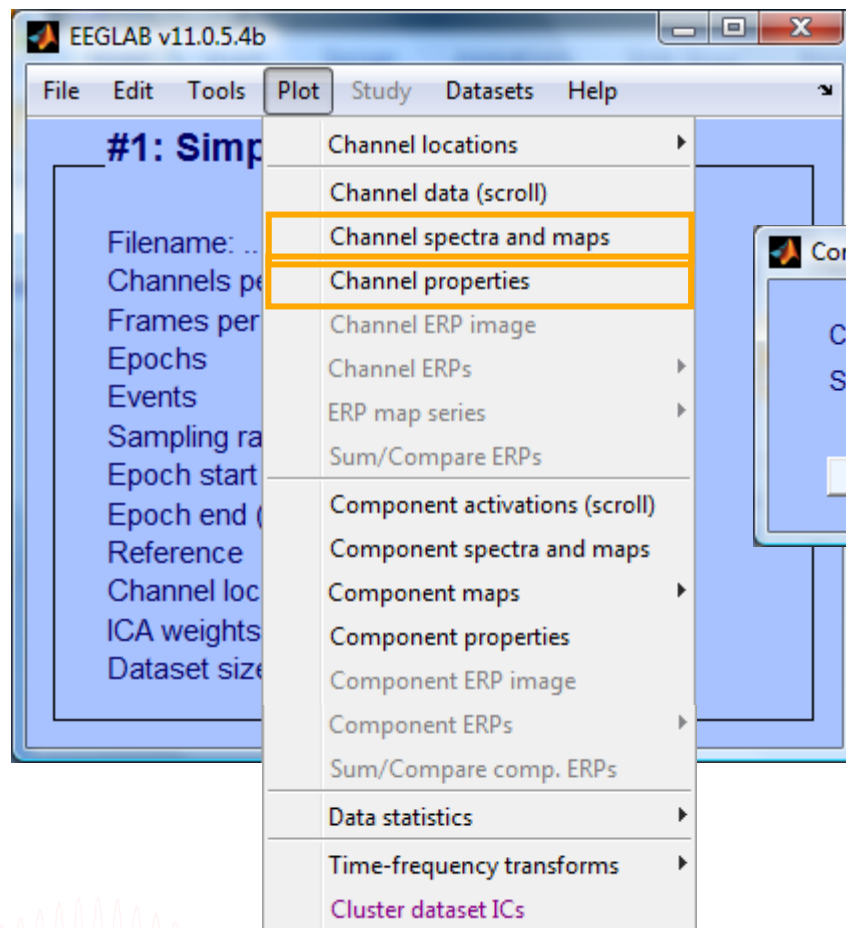
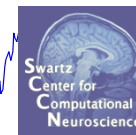
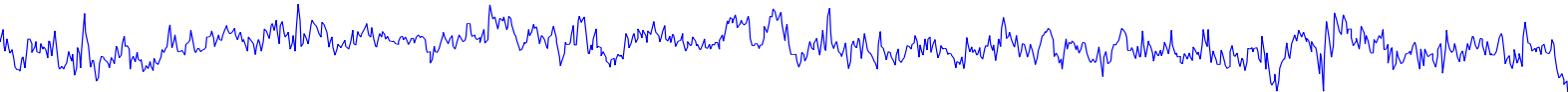
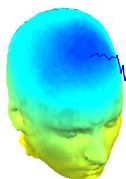




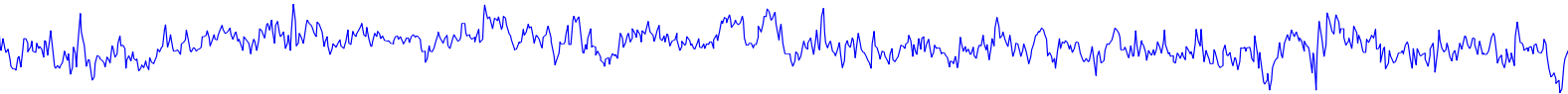
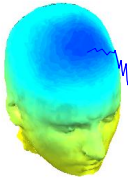
Remove line noise (Cleanline)



Plot channel spectra



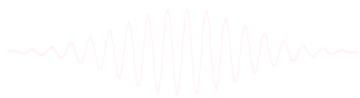
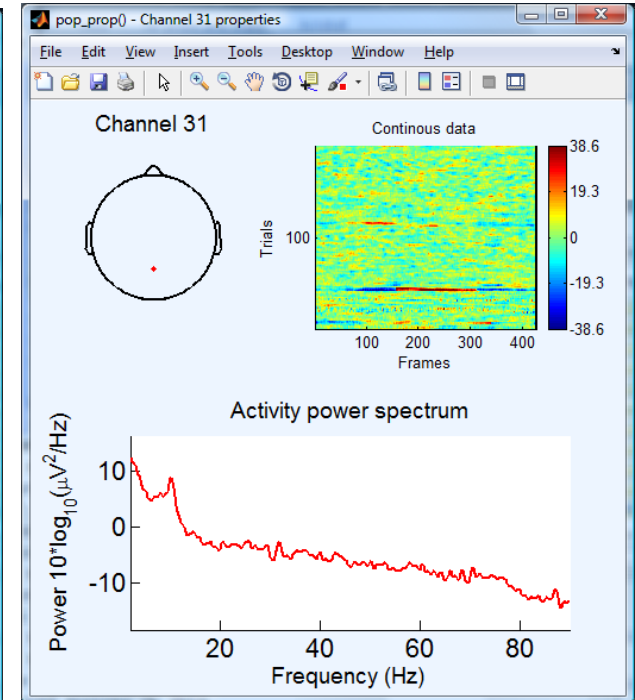
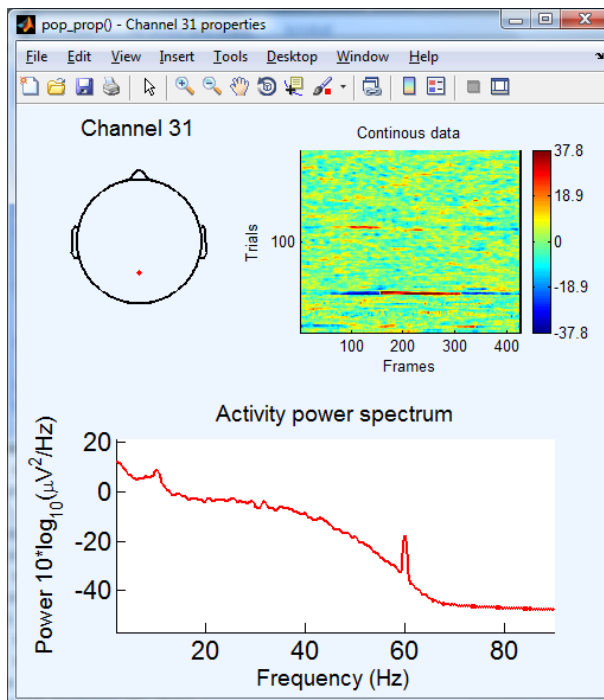
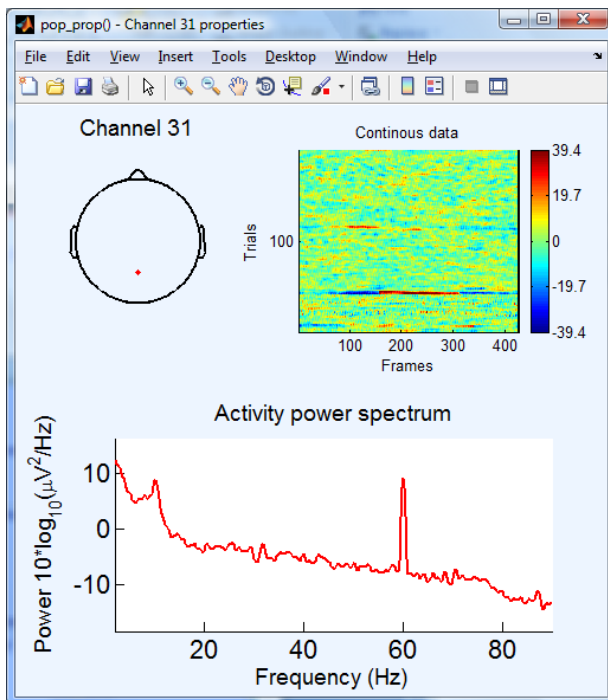
Filter comparisons



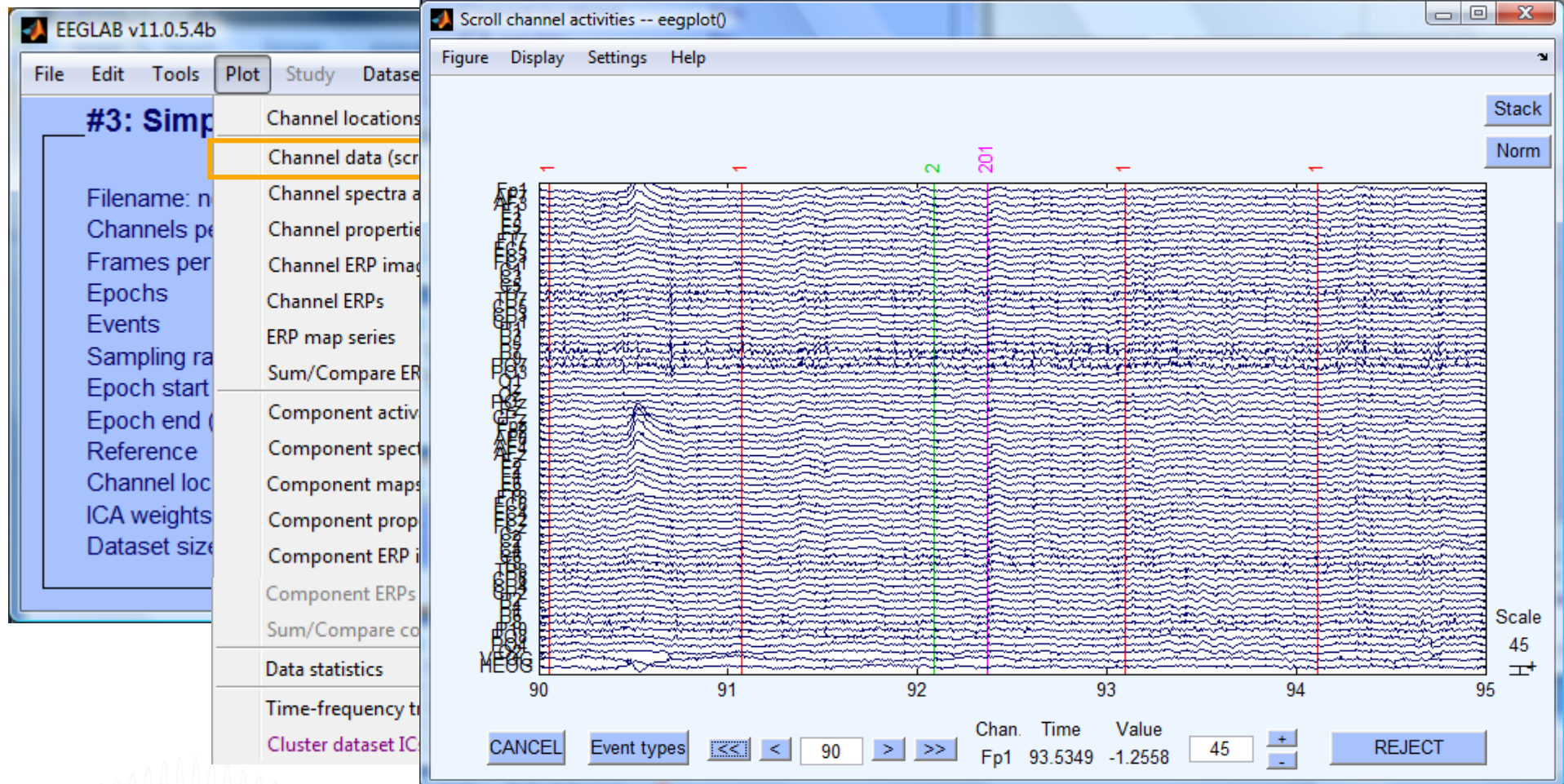
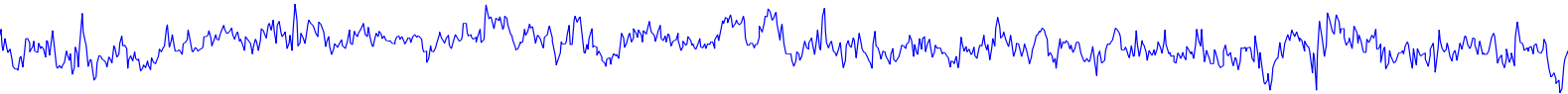
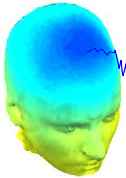
0.5 Hz high-pass filter

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

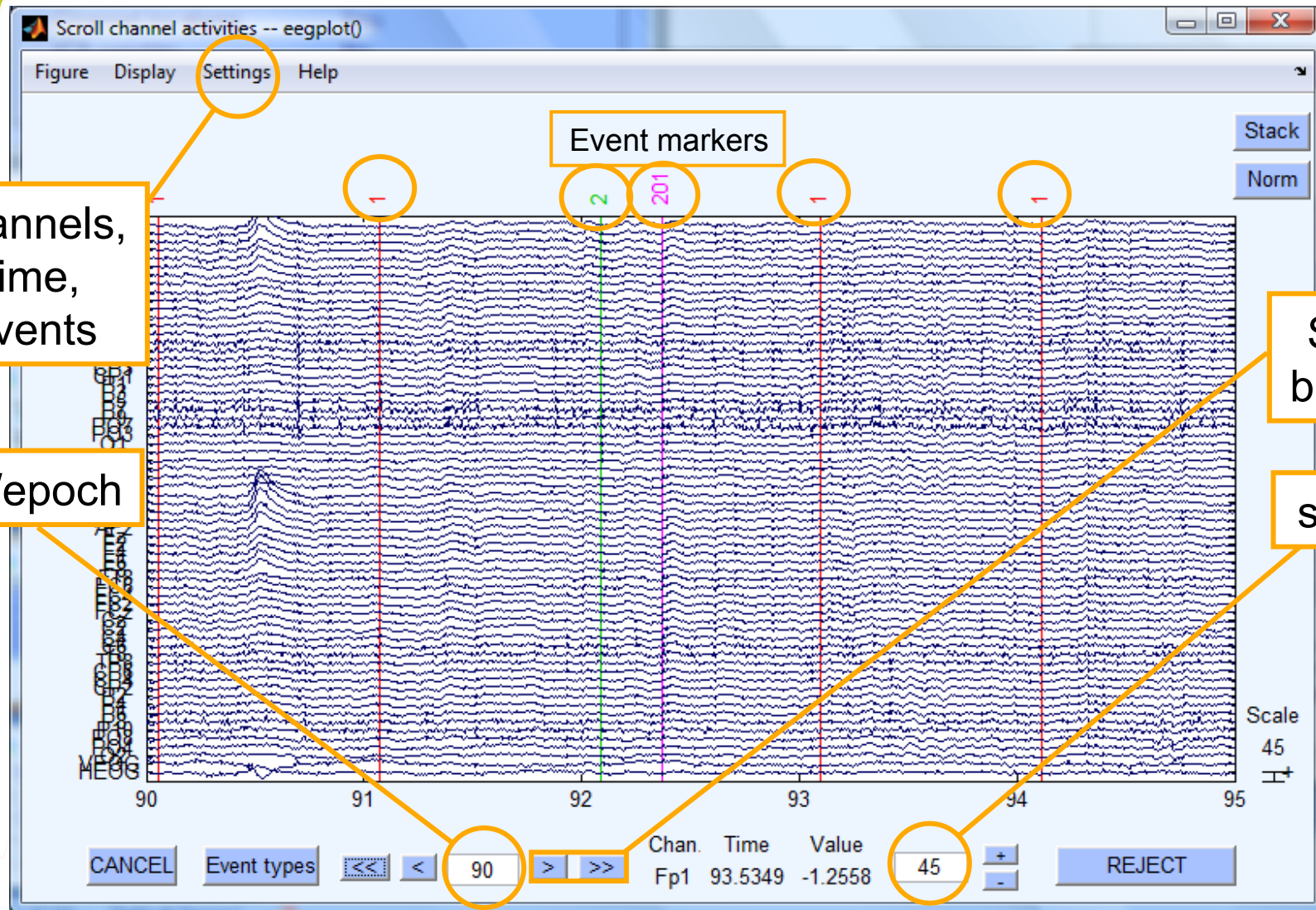
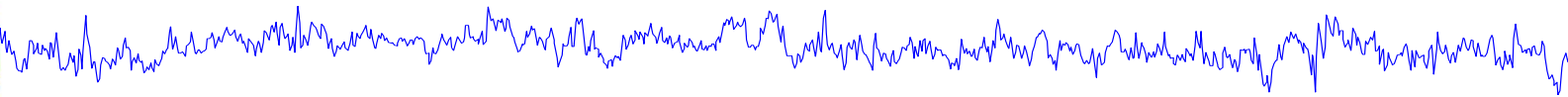
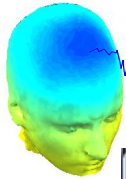
0.5 Hz high-pass filter
Cleanline



Scroll channel data



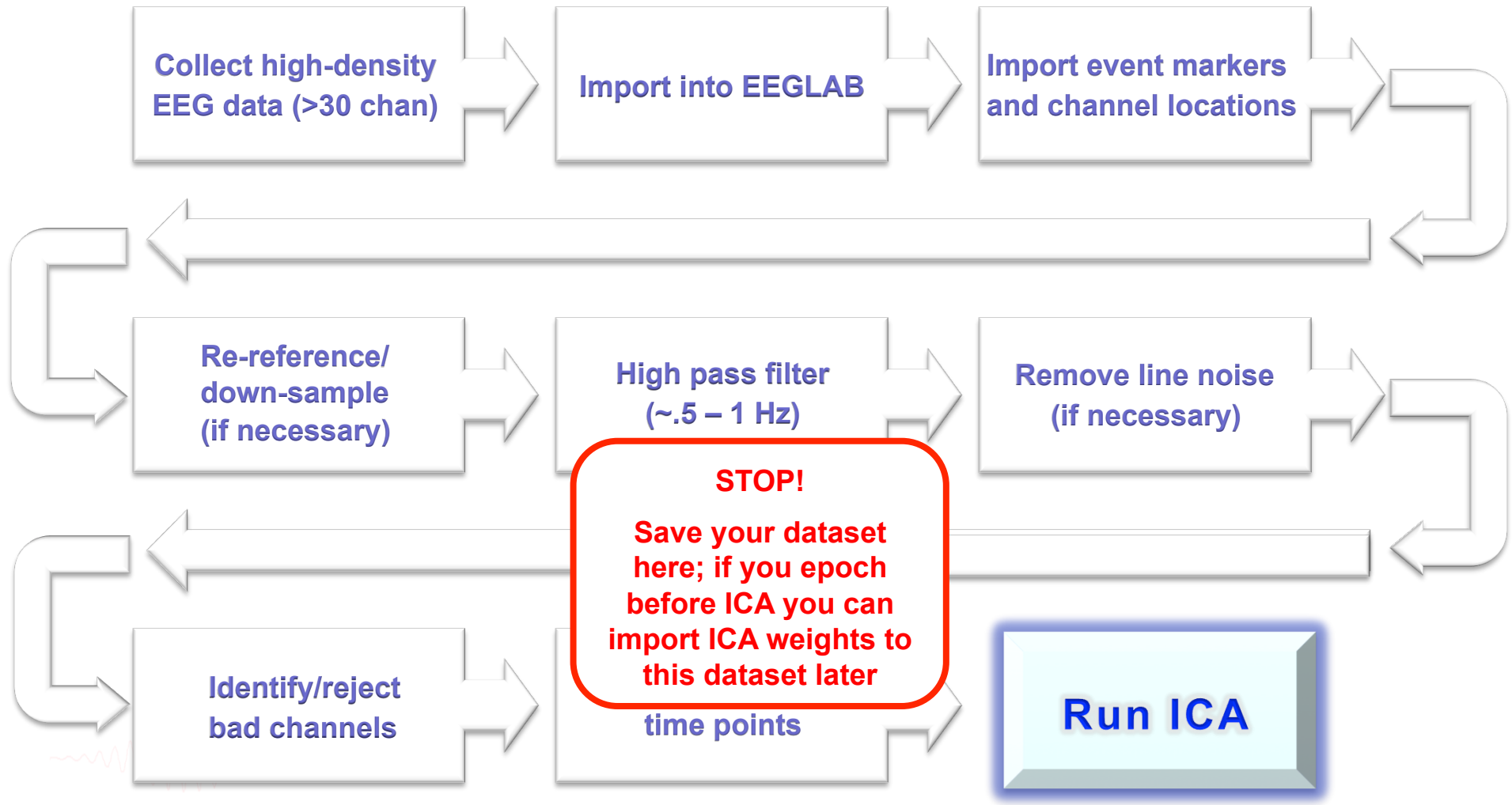
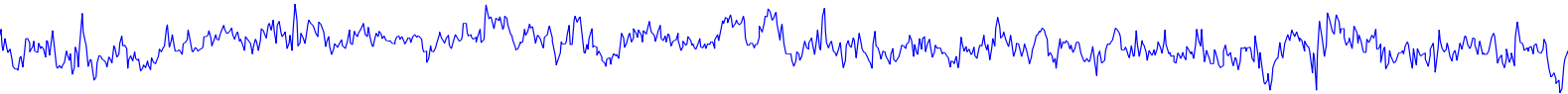
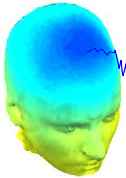
Scroll channel data

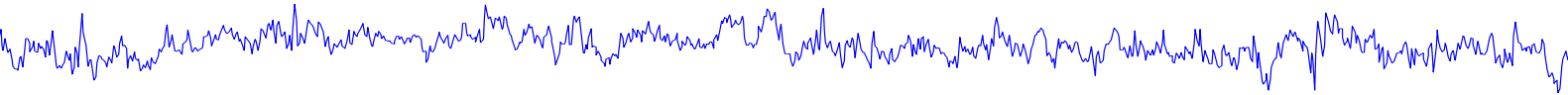
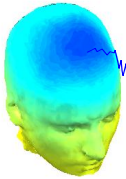


Scroll buttons

scaling

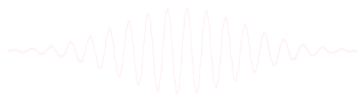
Pre-processing pipeline



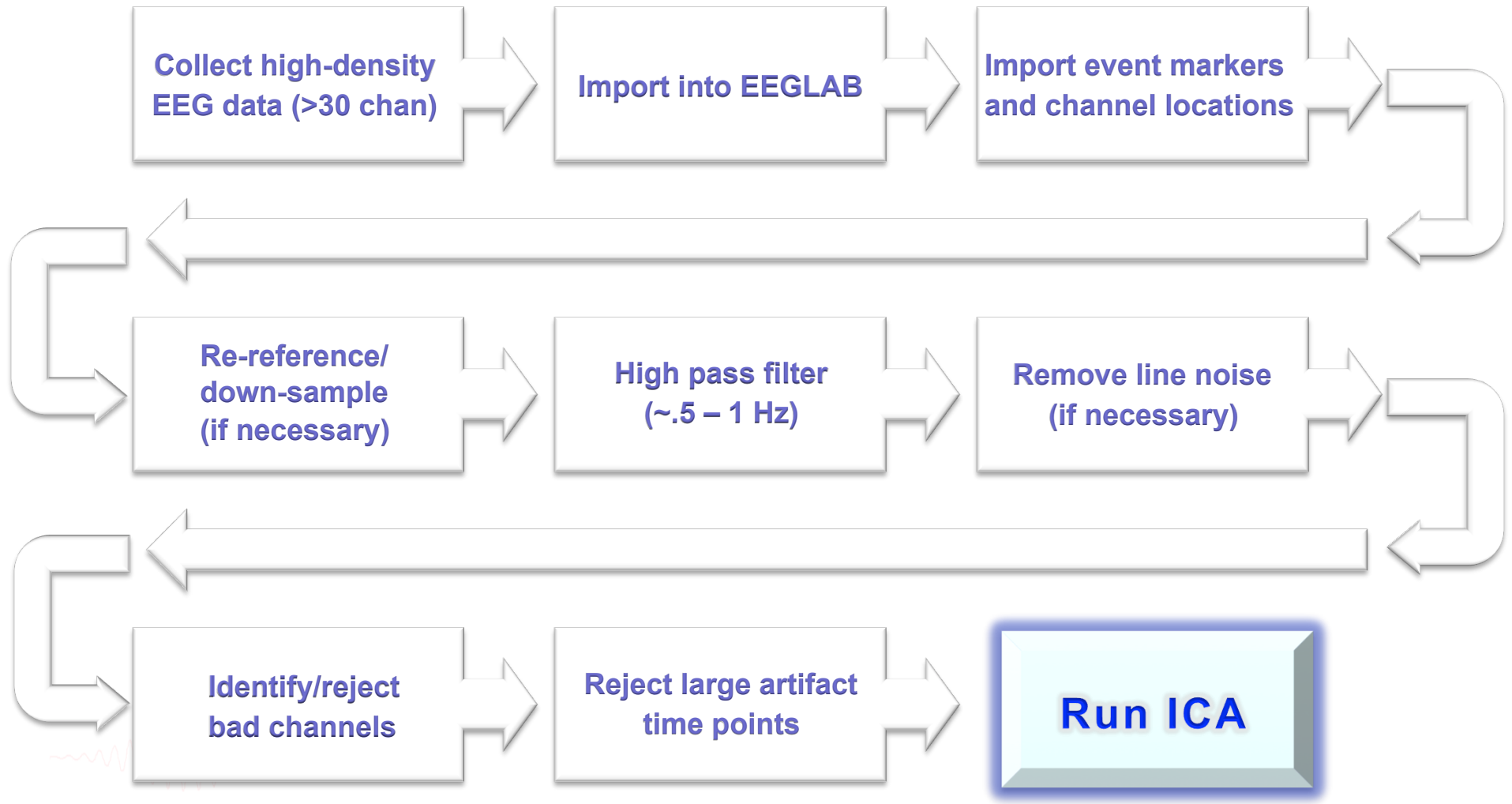
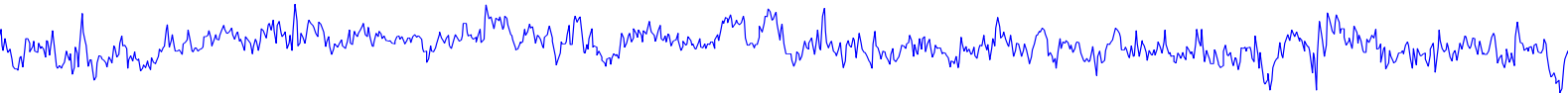
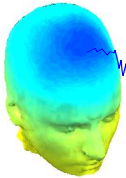


Data Cleaning for ICA

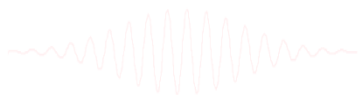
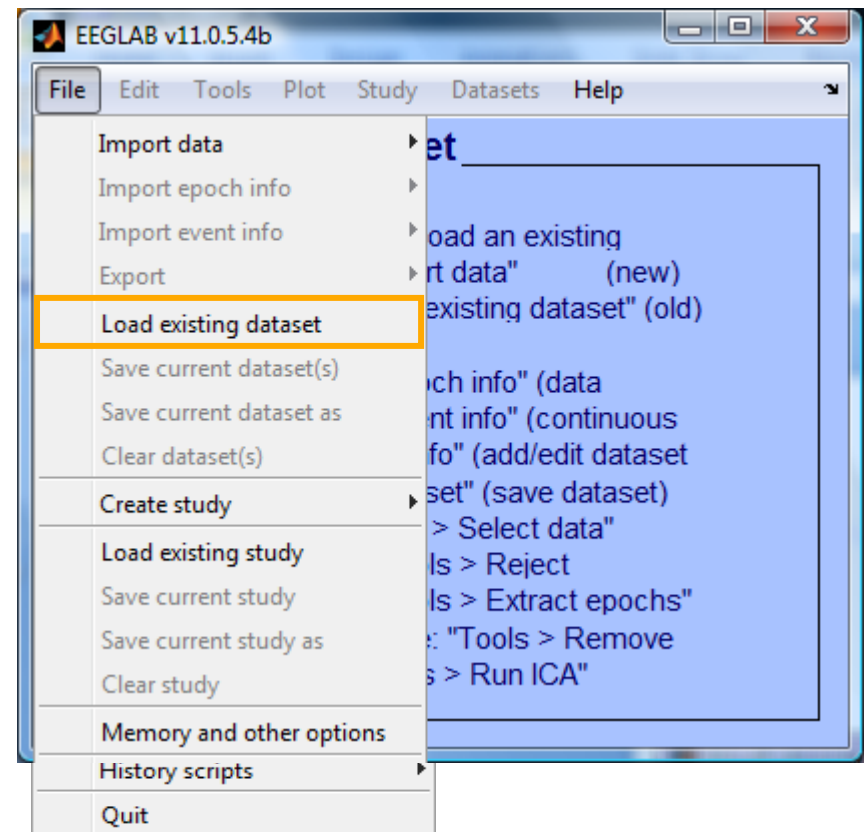
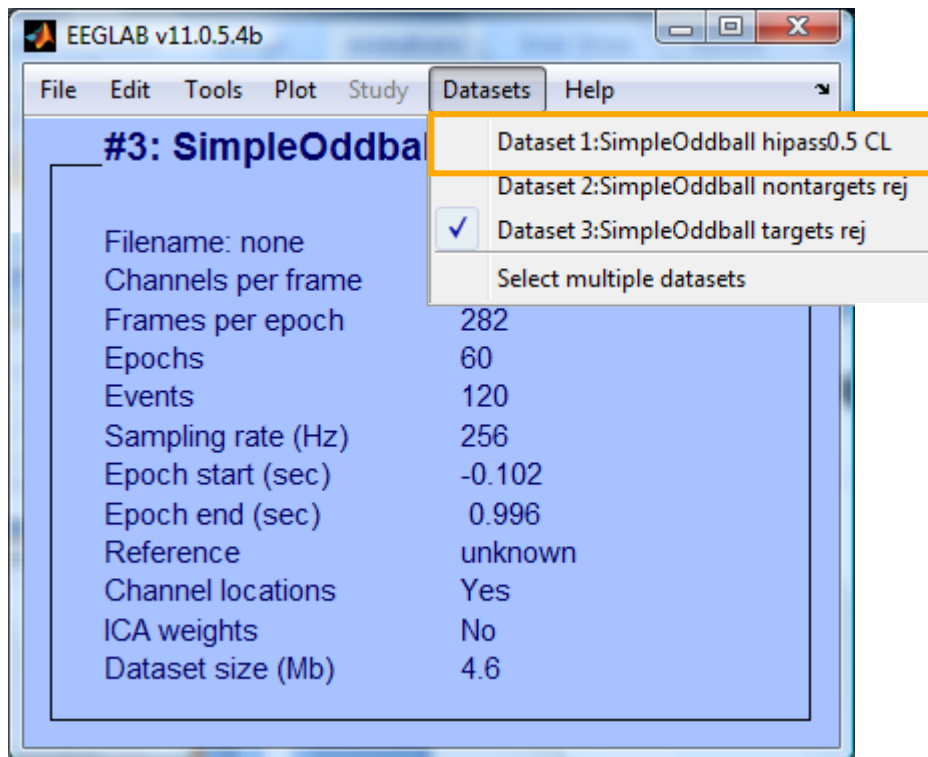
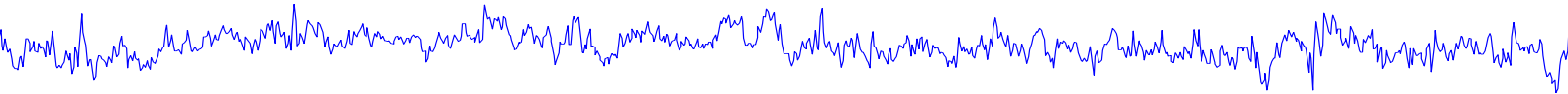
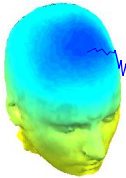
Variant 1: Continuous Data



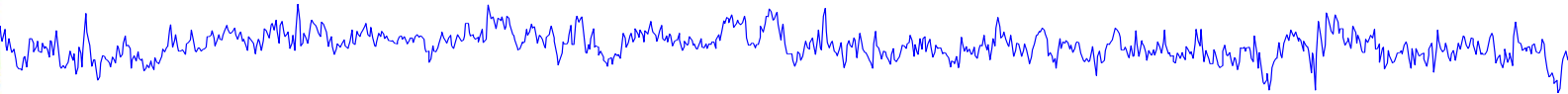
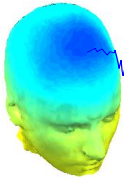
Pre-processing pipeline



Retrieve or reload continuous EEG dataset



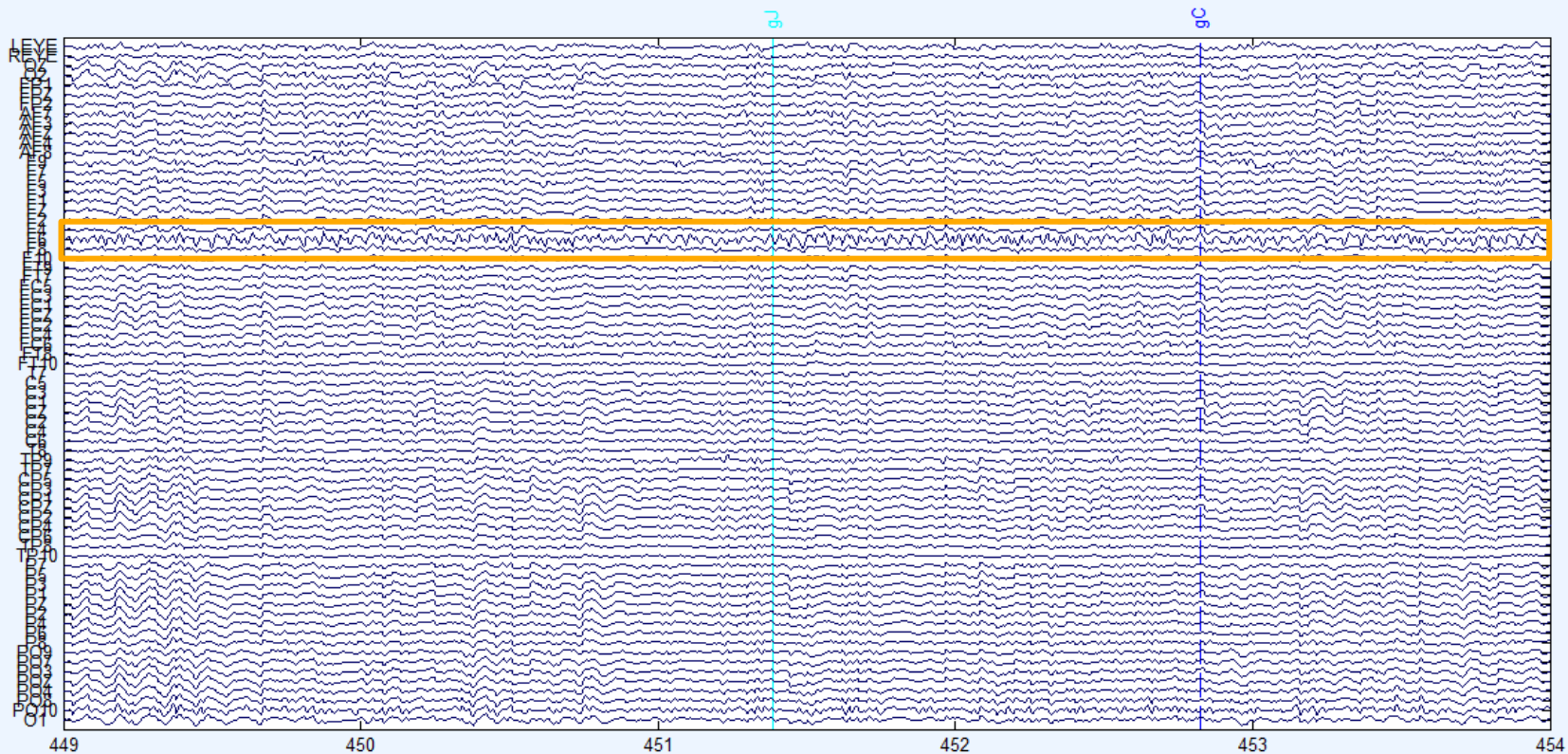
Manually identifying bad channels



Scroll channel activities -- eegplot()

Figure Display Settings Help

1) Identify bad channel



Scale
35
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CANCEL

Event types

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449

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Chan.

Time

Value

O1

451.0988

3.6619

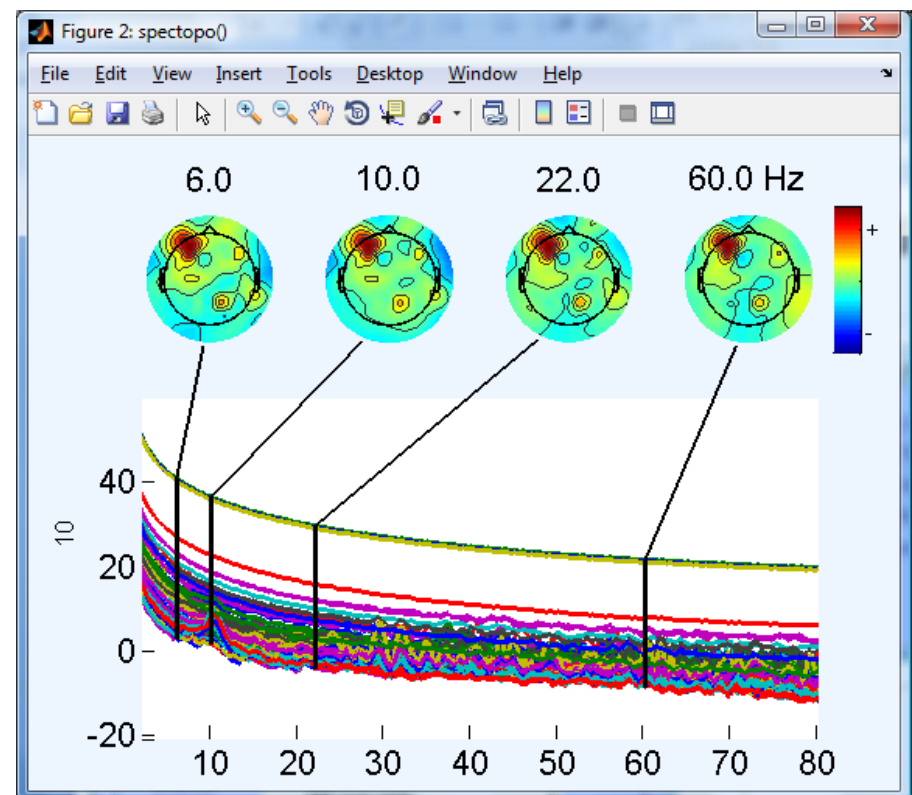
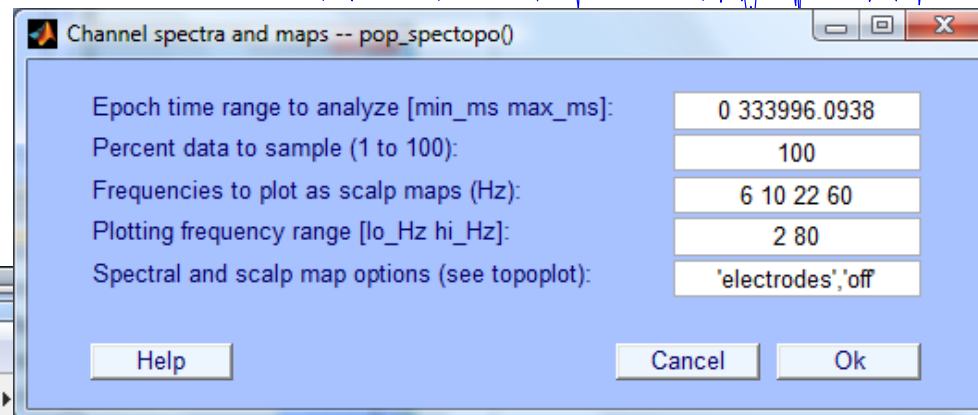
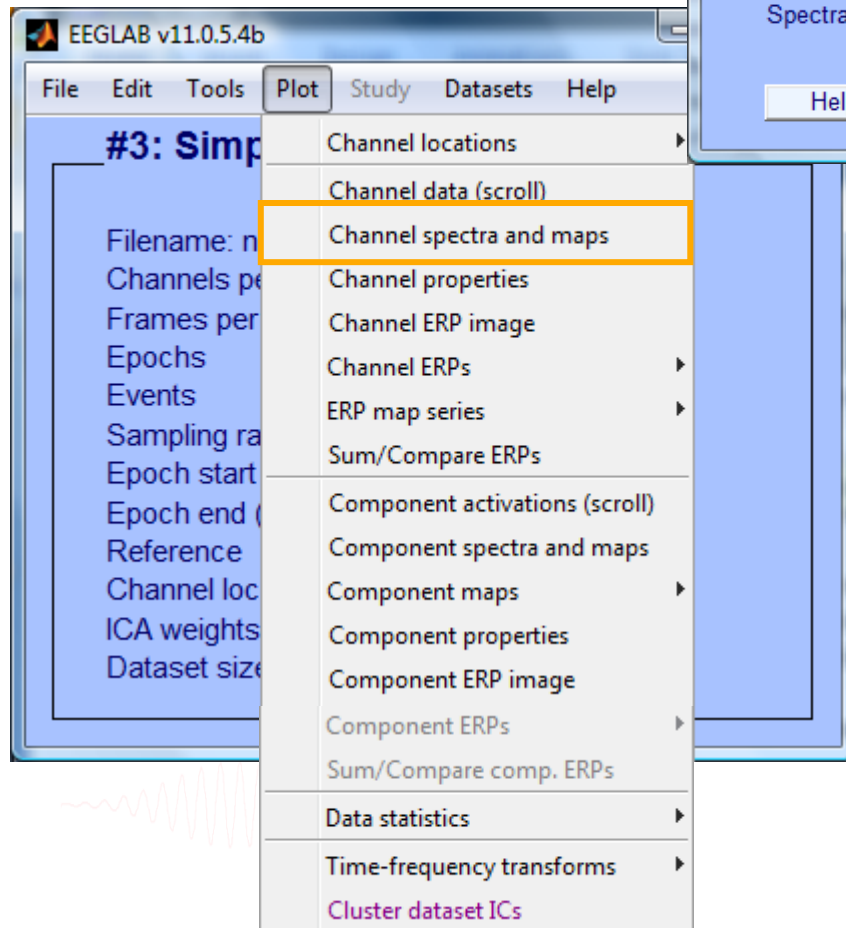
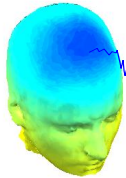
35

+

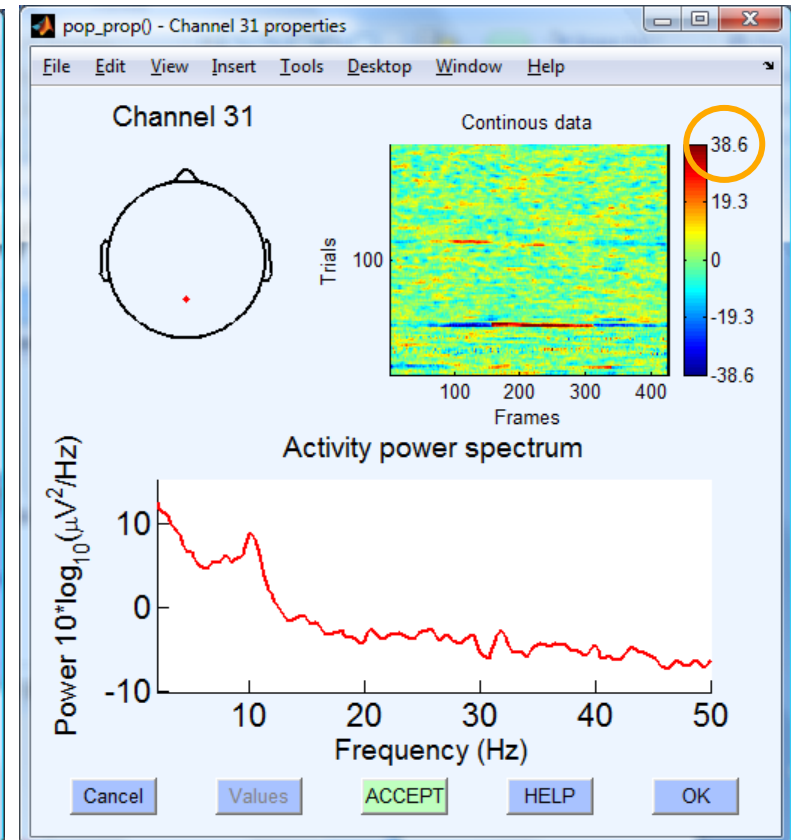
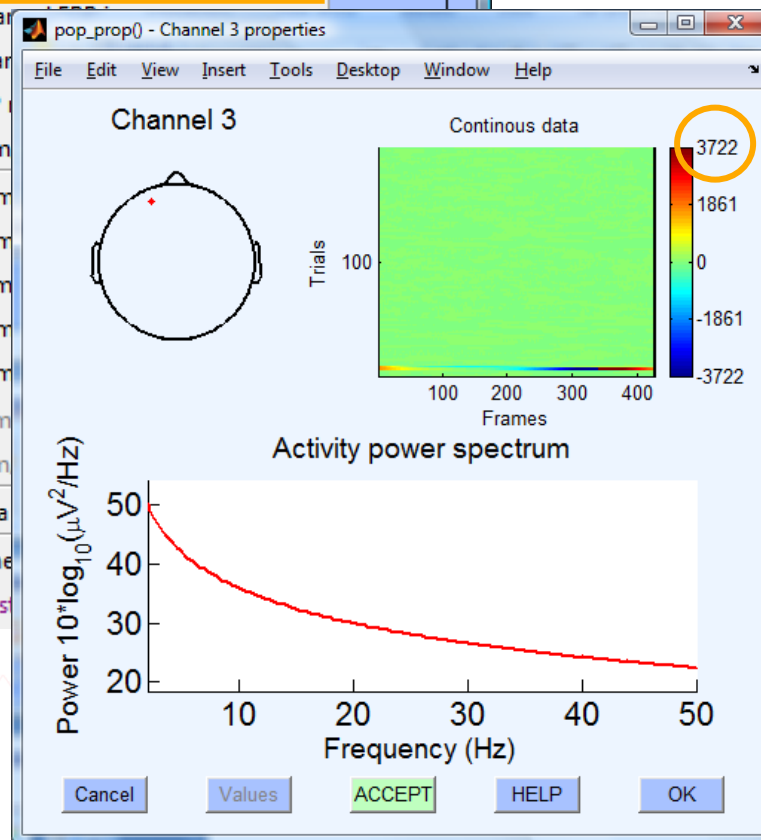
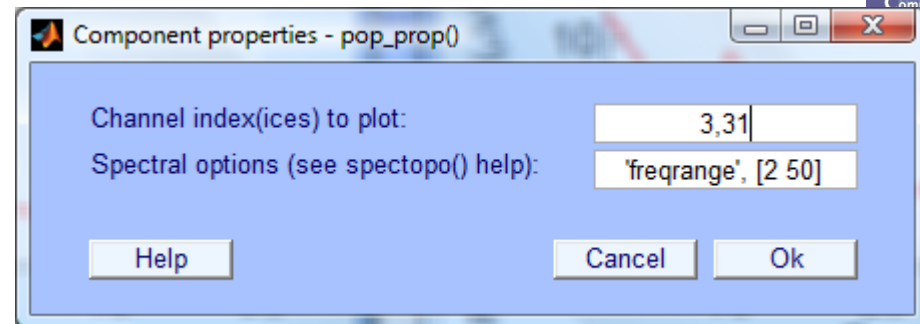
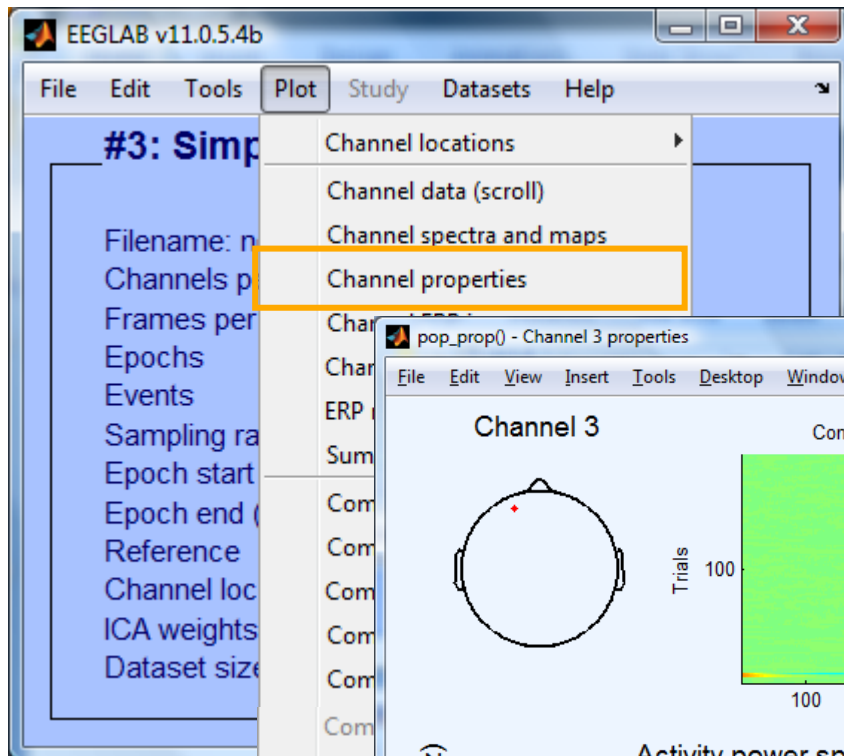
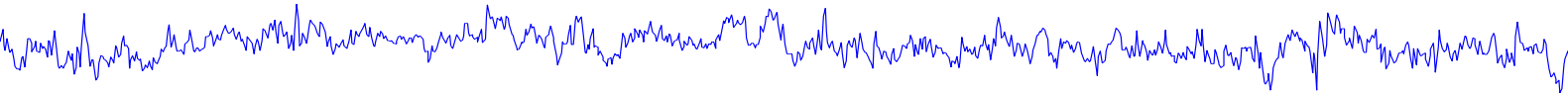
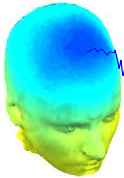
-

REJECT

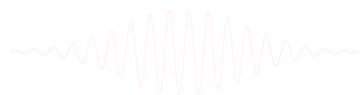
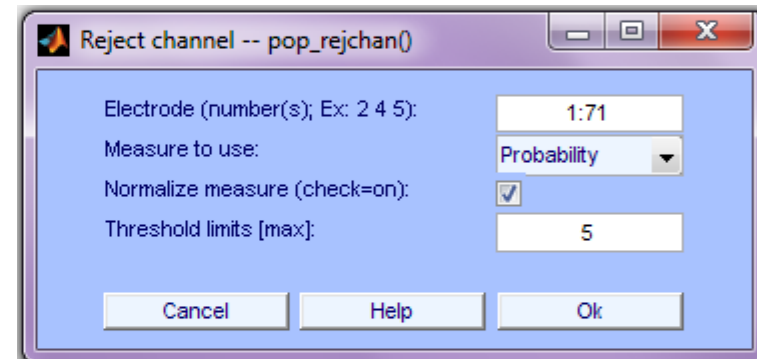
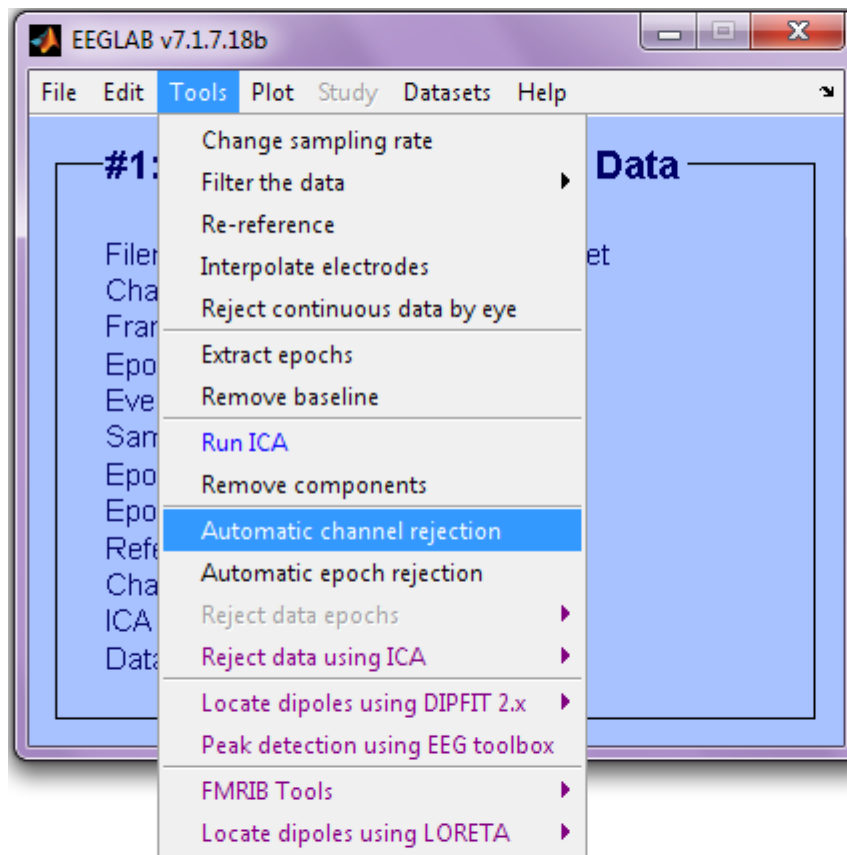
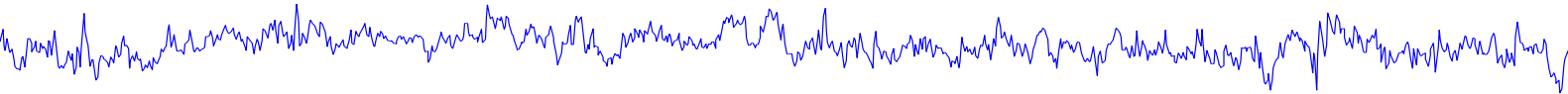
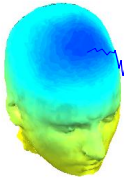
Manually identifying bad channels



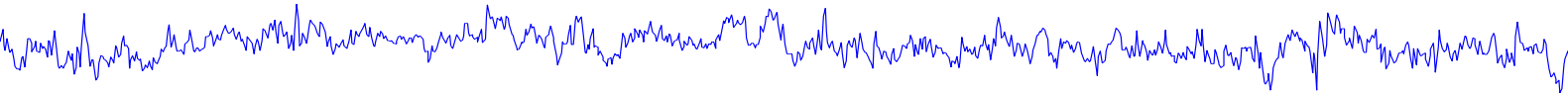
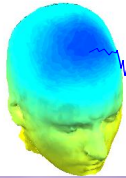
Manually identifying bad channels



Auto-detection of noisy channels

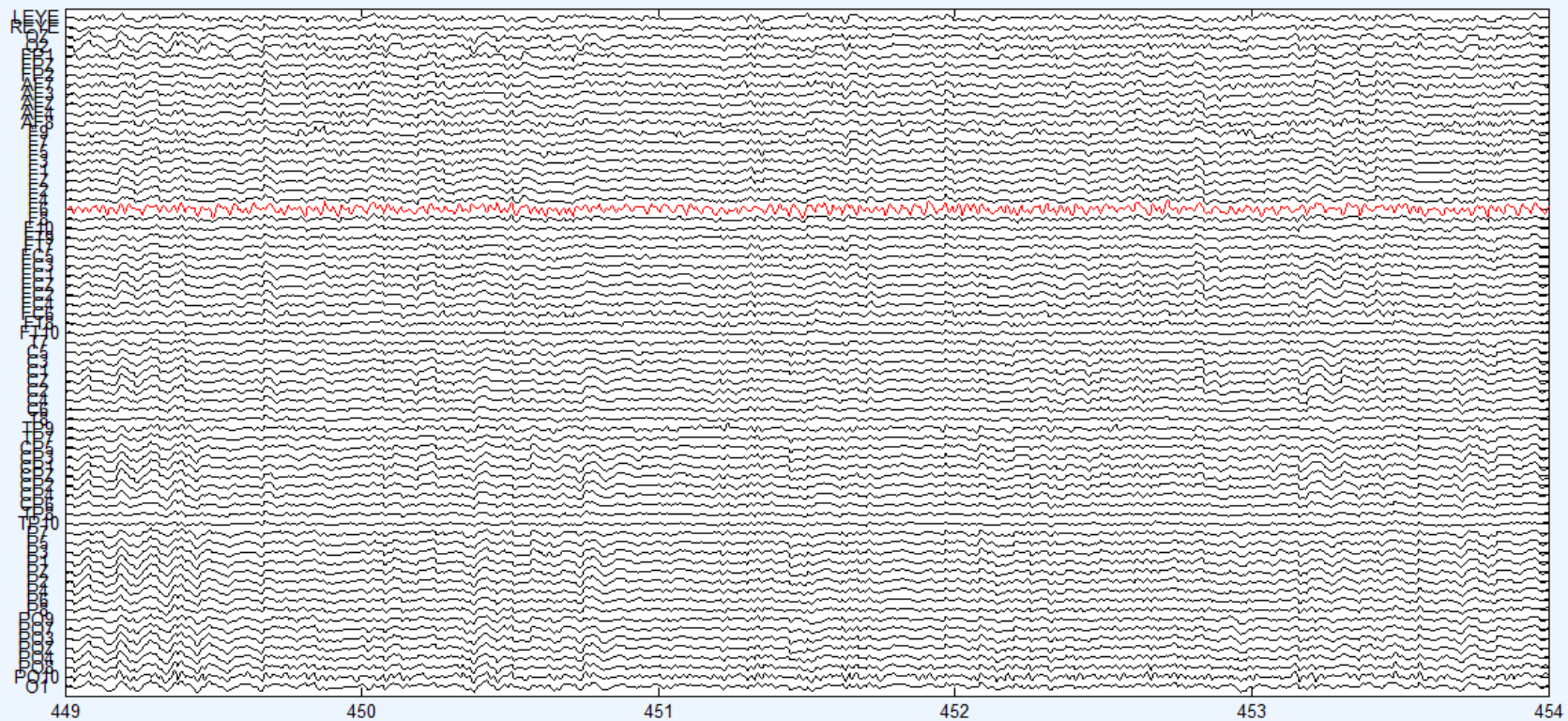


Auto-detected noisy channel



Scroll component activities -- eegplot()

Figure Display Settings Help



Scale
35
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CANCEL

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>>

Chan.

Time

Value

TP8

452.1146

-2.6647

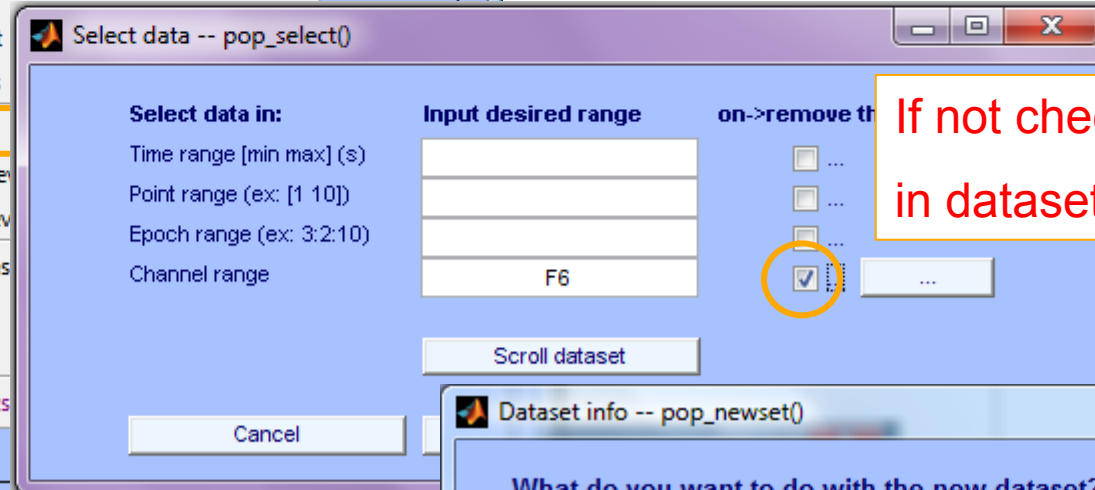
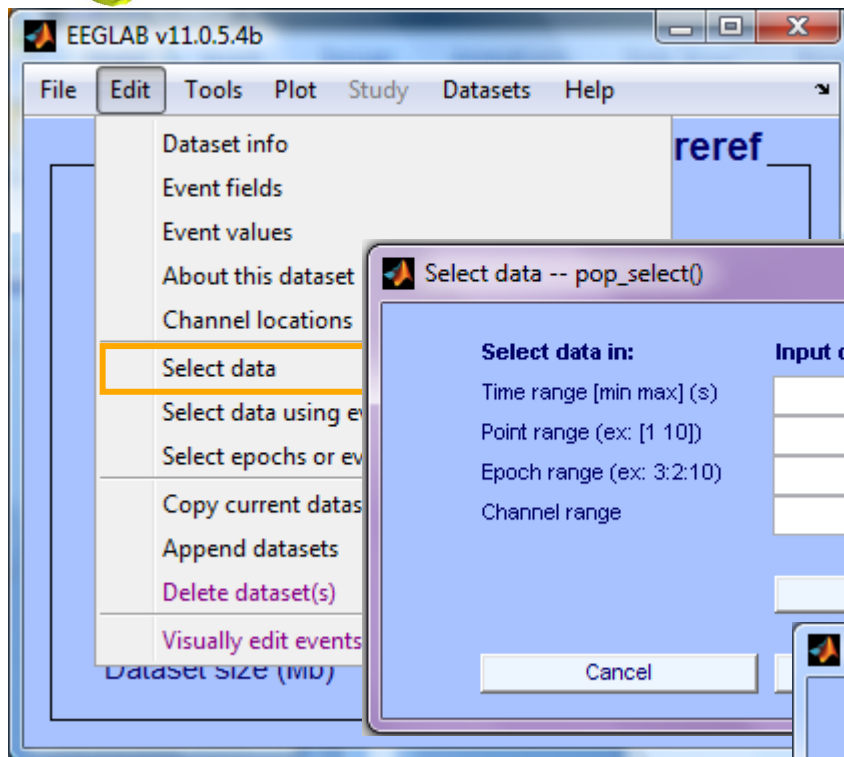
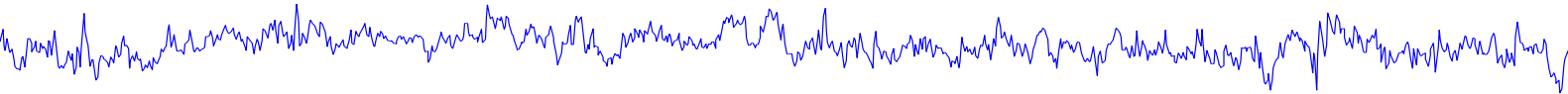
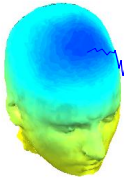
35

+

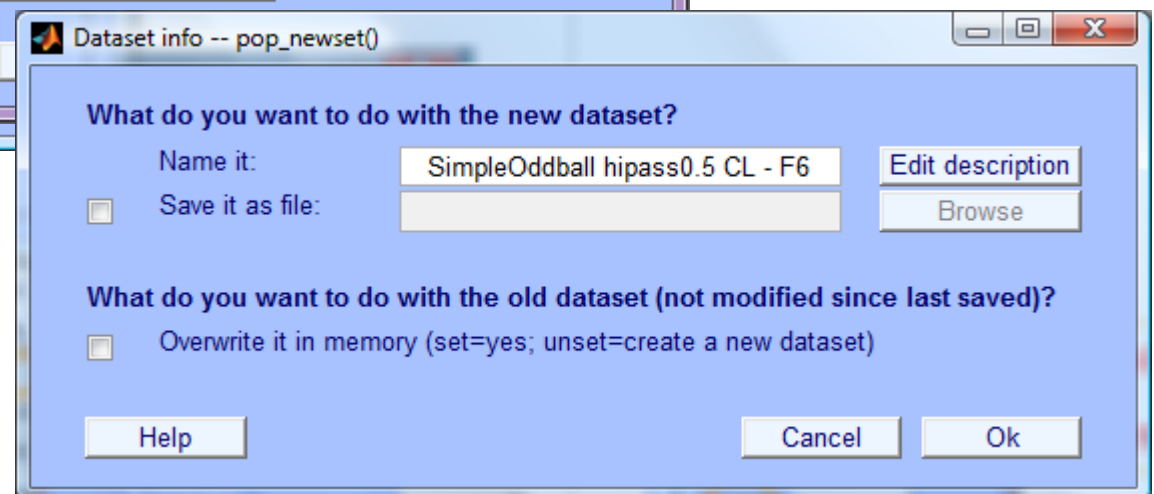
-

REJECT

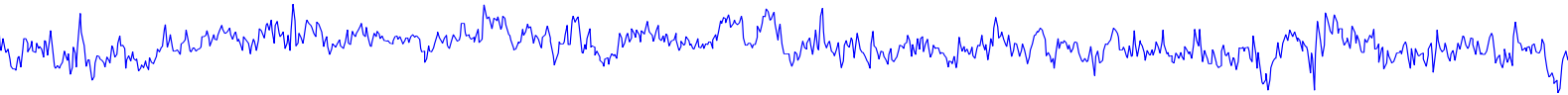
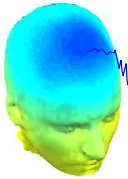
Removing channel(s)



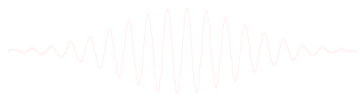
If not checked, will result
in dataset with one channel



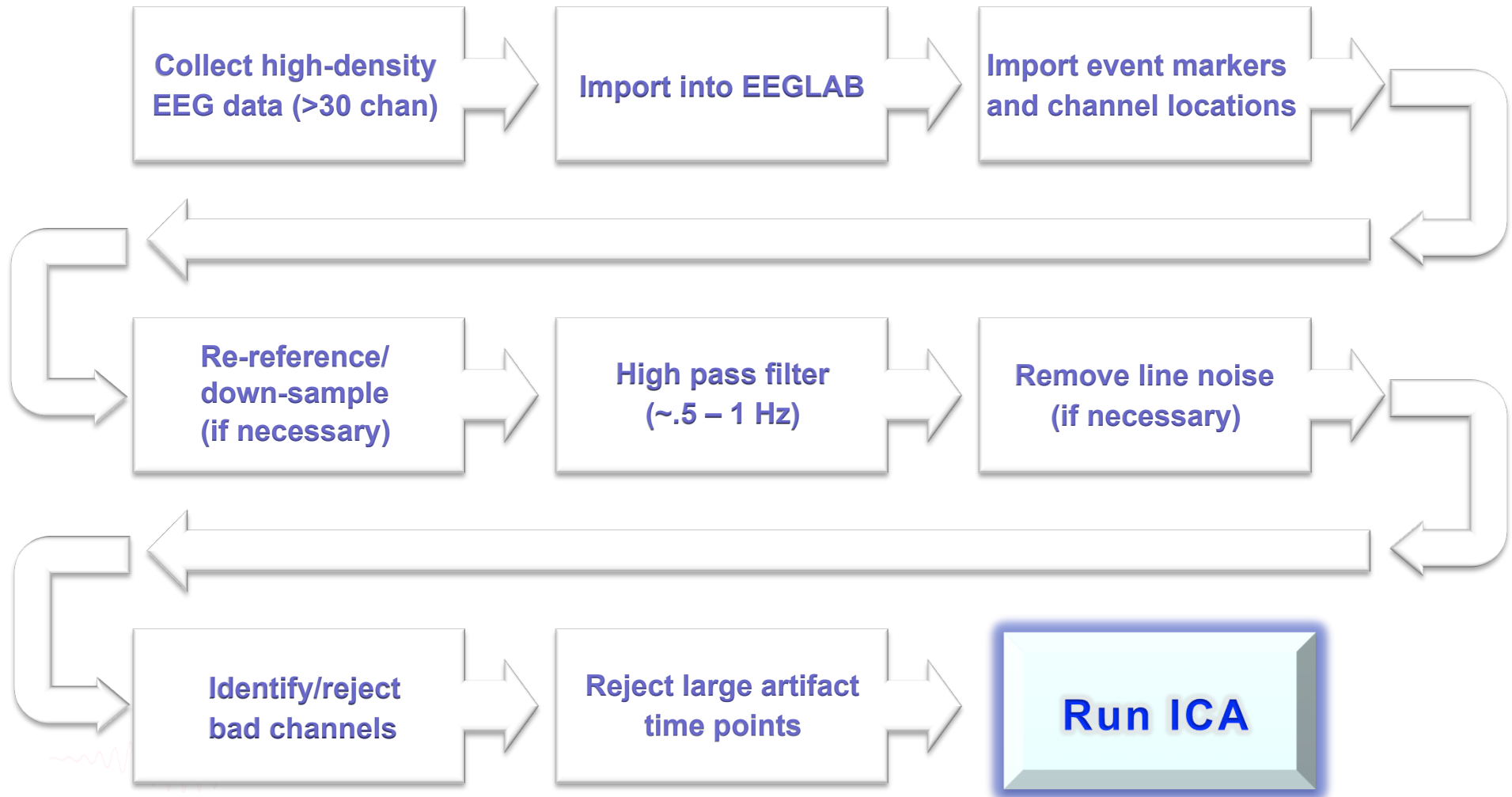
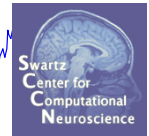
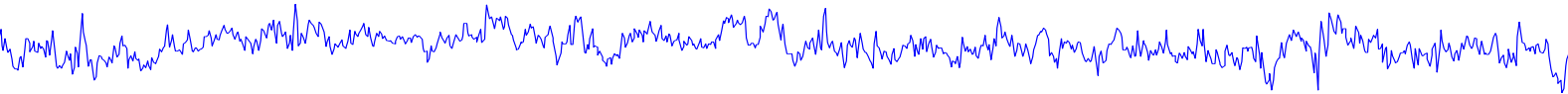
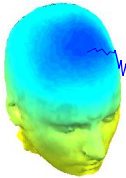
Removing channel(s)



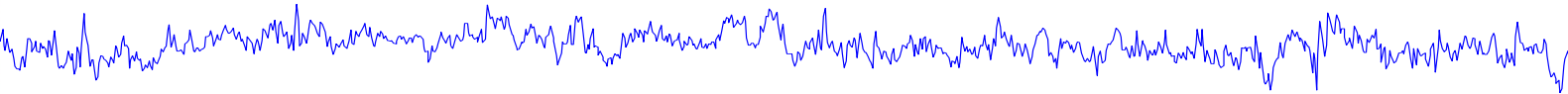
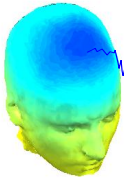
- You may want to interpolate bad channels rather than remove them altogether. Don't do this!
- The loss in dimensionality will affect the ICA decomposition
- Preferred solution:
 - **Delete** the bad channels before running ICA
 - STUDY tools will interpolate missing channels automatically



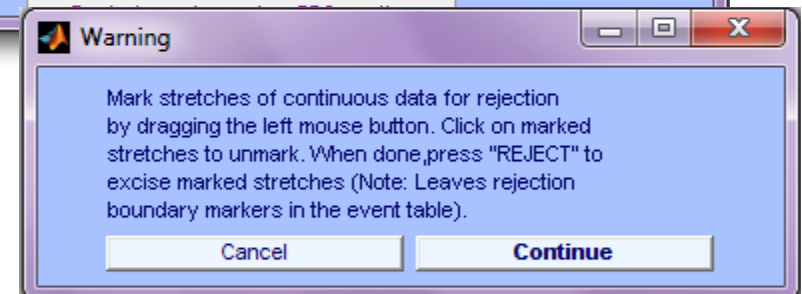
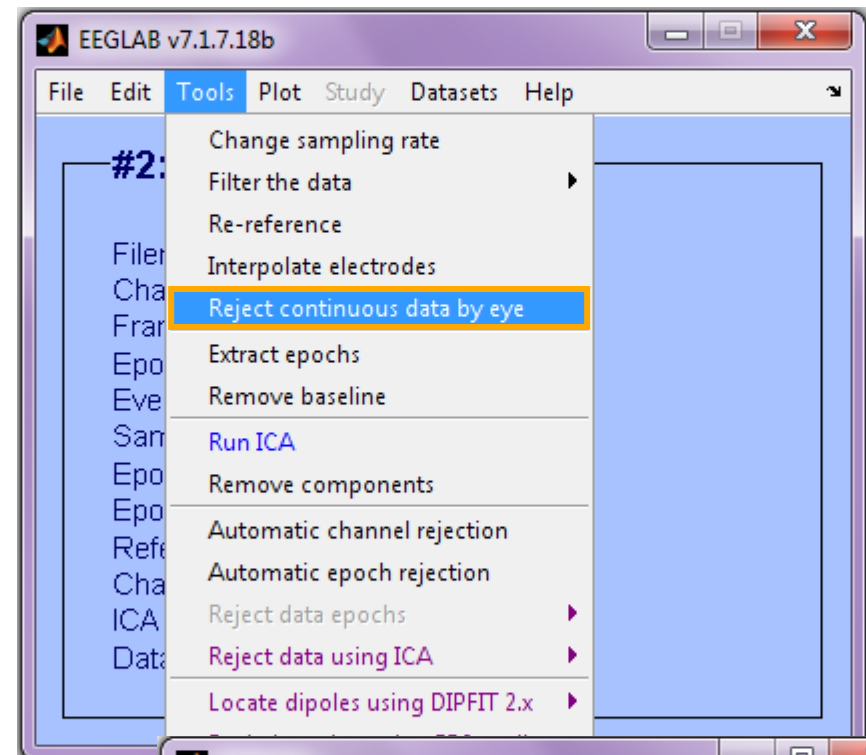
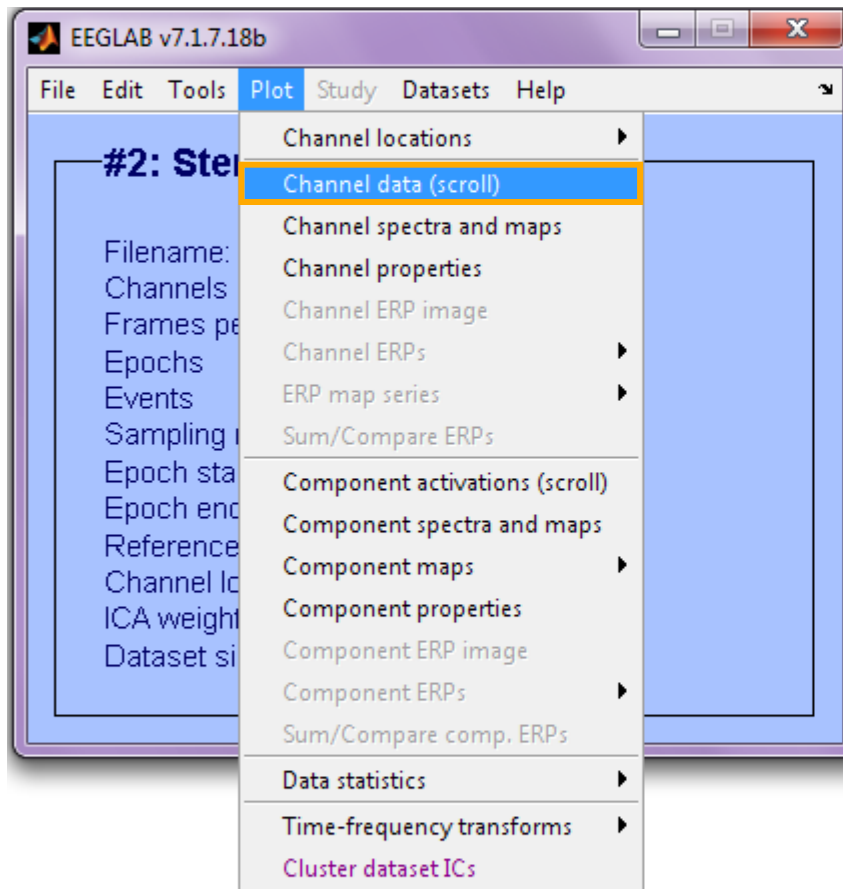
Pre-processing pipeline



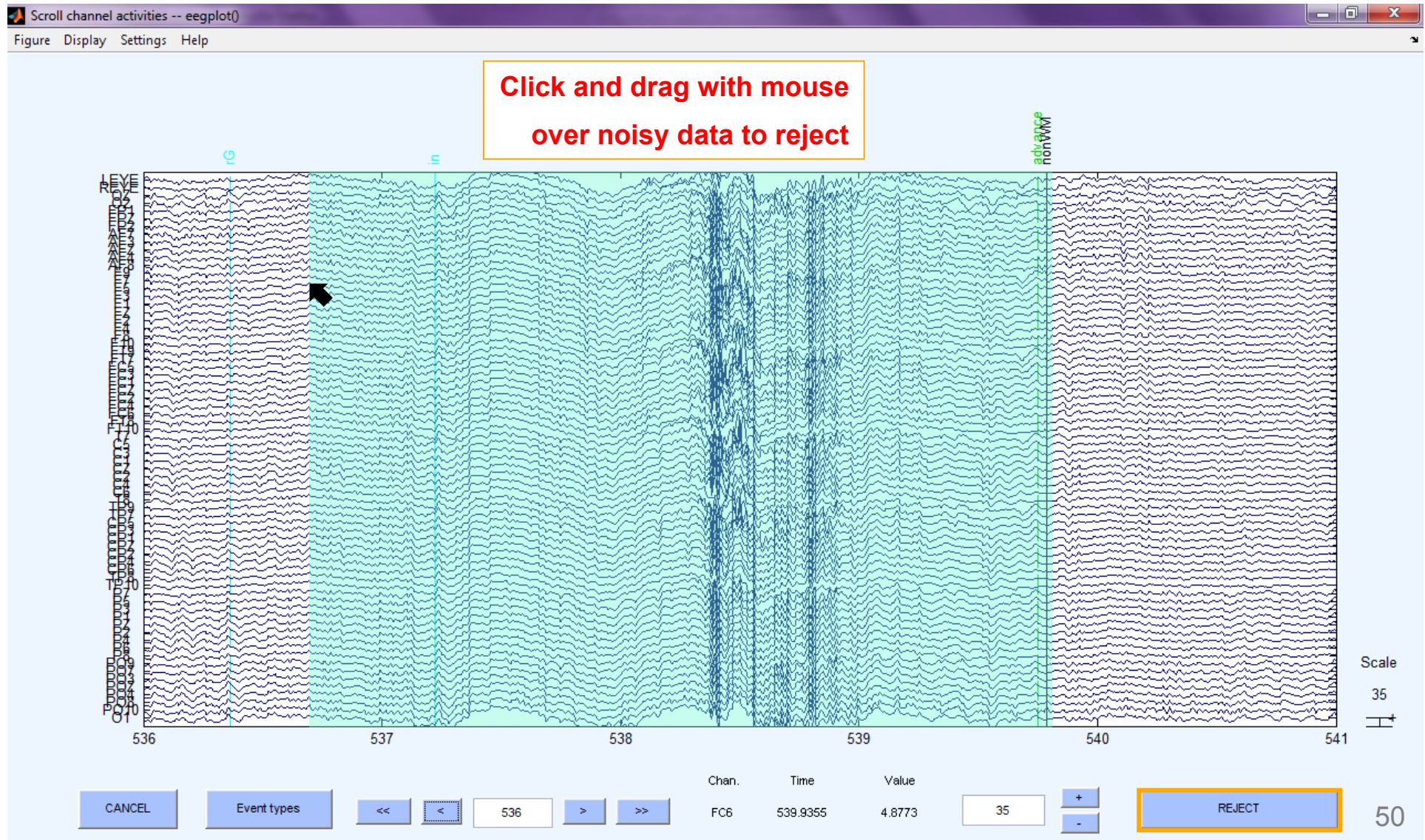
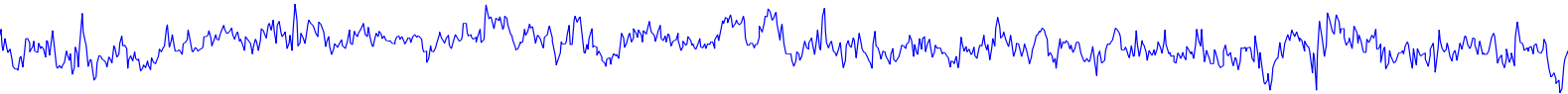
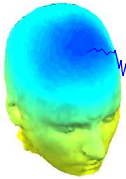
Reject continuous data



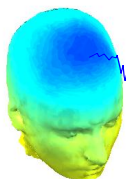
Equivalent



Reject continuous data



Rejecting data for ICA



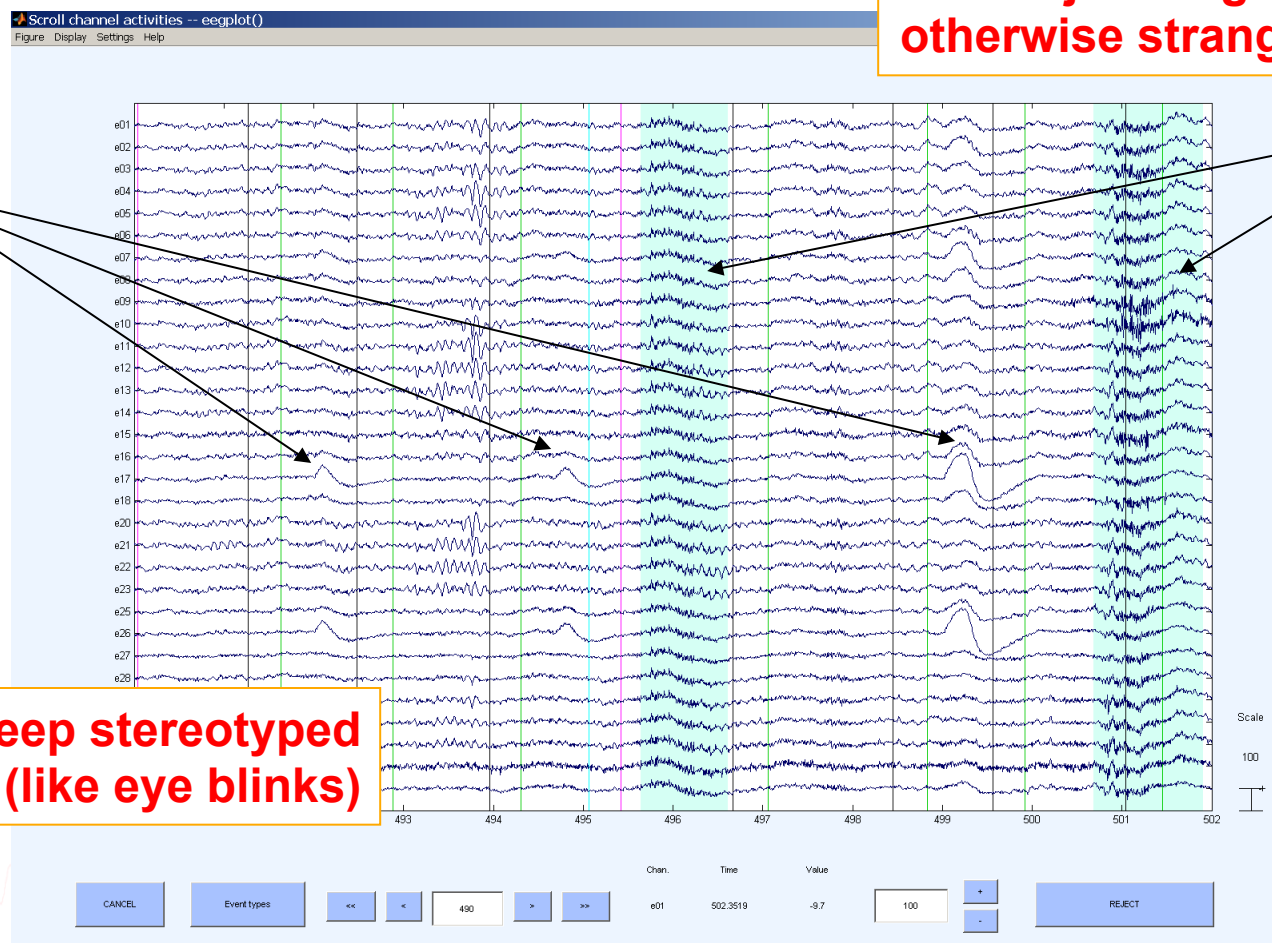
To prepare data for ICA:

Reject large muscle or otherwise strange events...

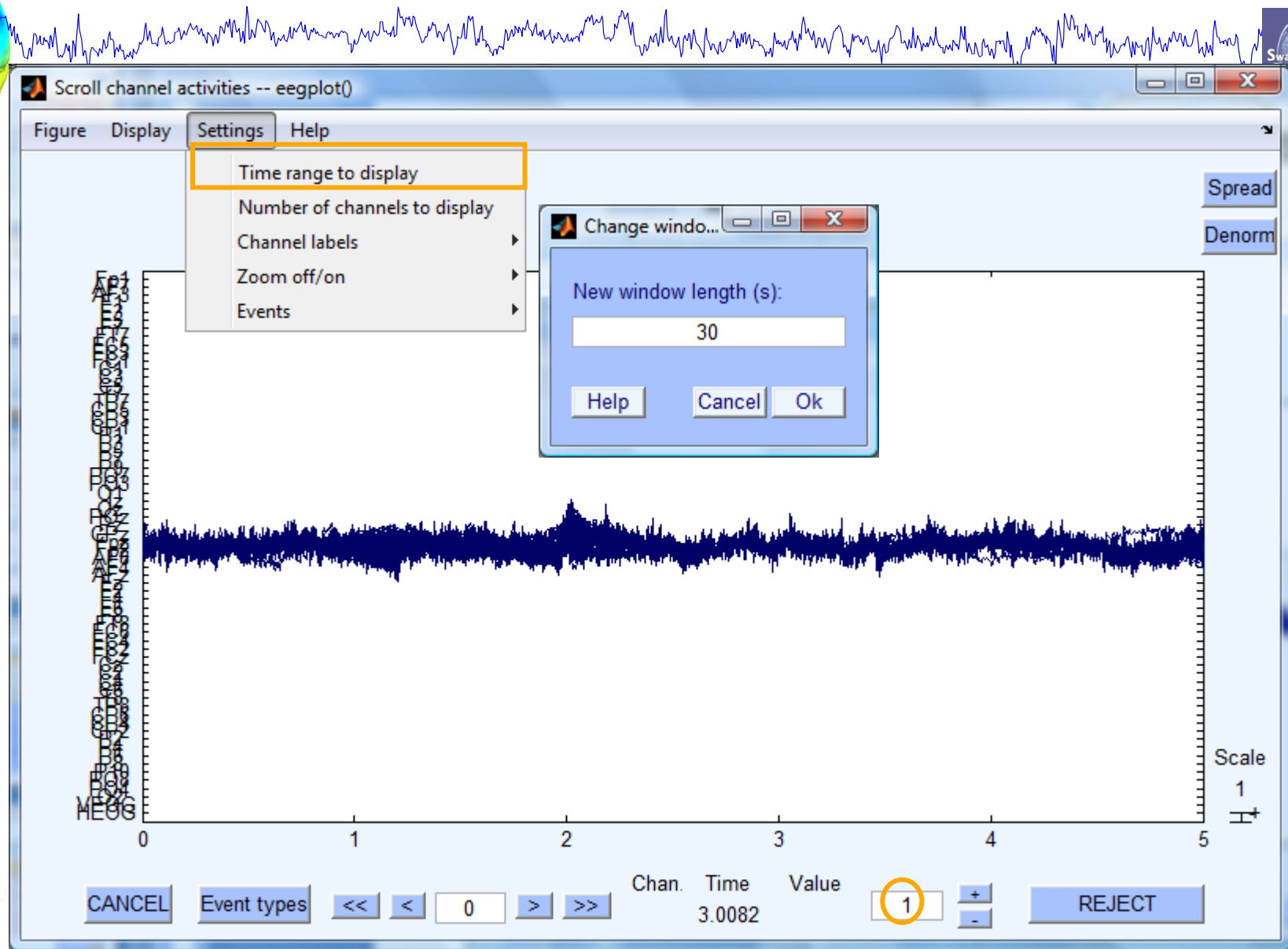
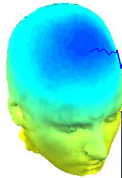
Keep

Reject

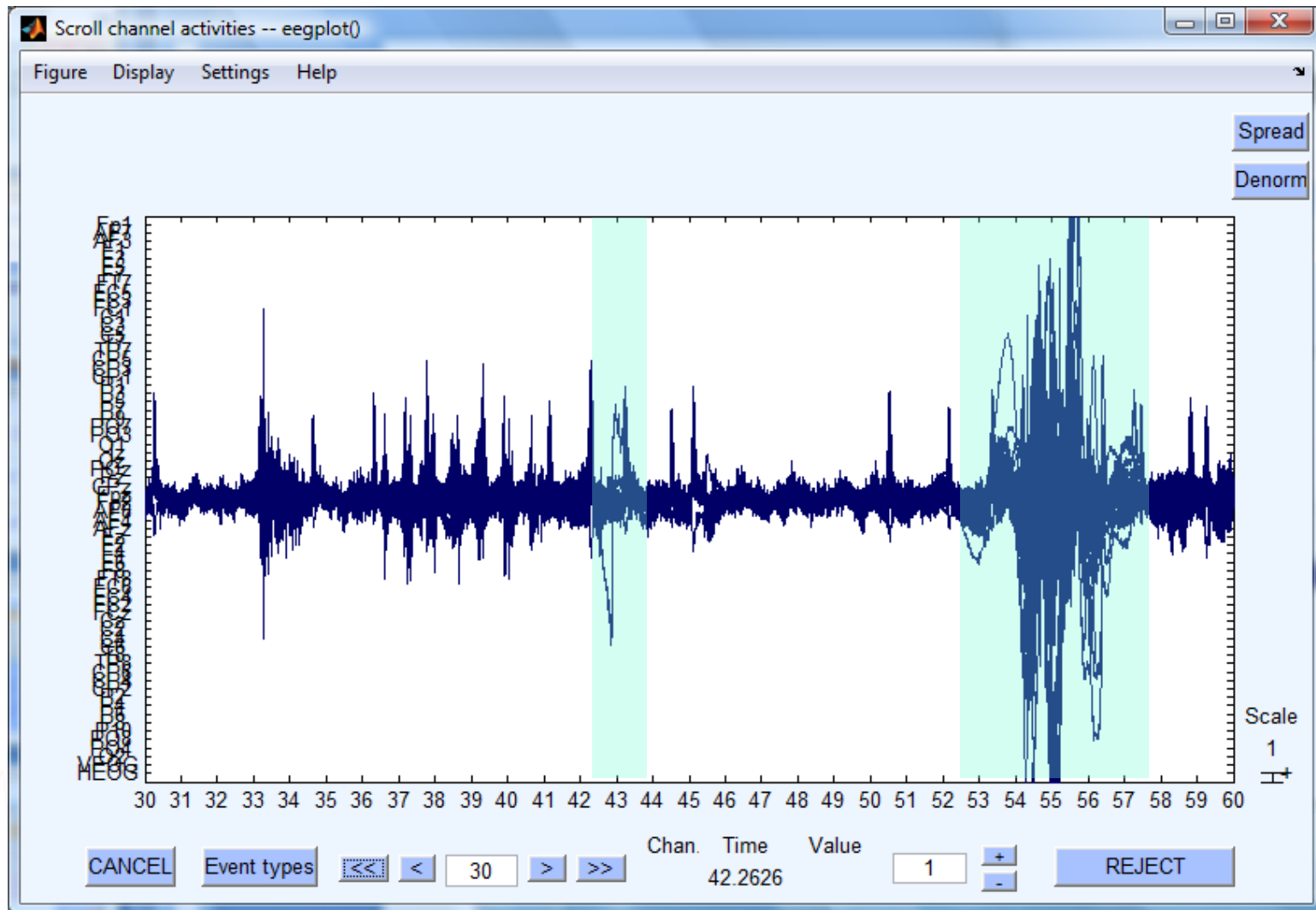
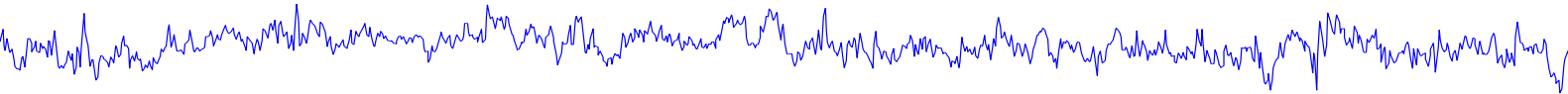
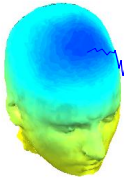
... but keep stereotyped artifacts (like eye blinks)

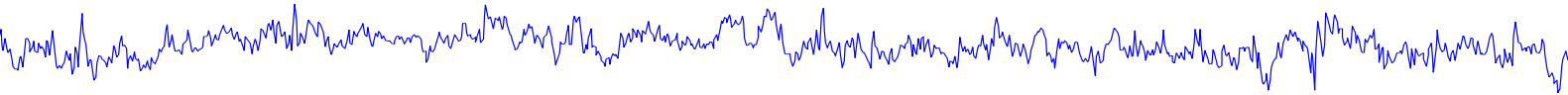
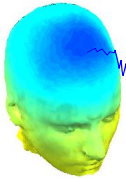


Fast (but sloppy) artifact rejection



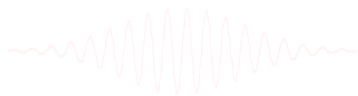
Fast (but sloppy) artifact rejection



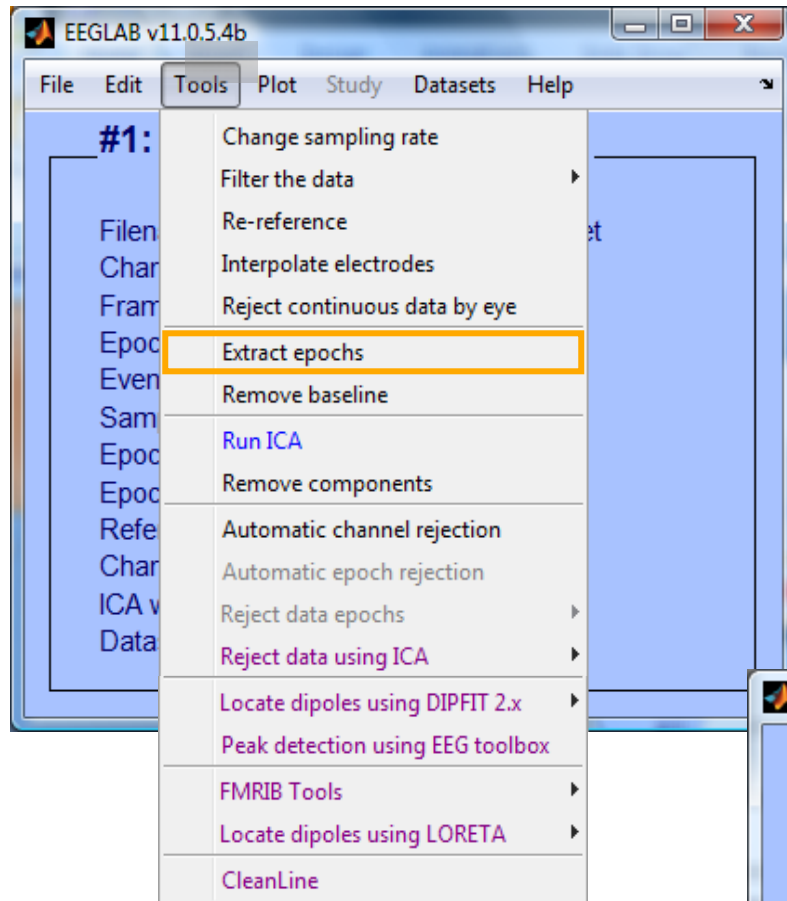
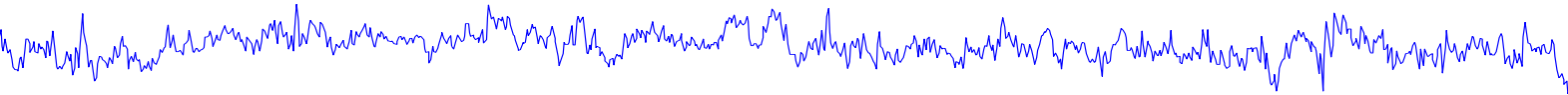
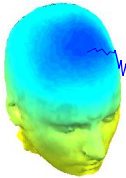


Data Cleaning for ICA

Variant 2: Epoched Data

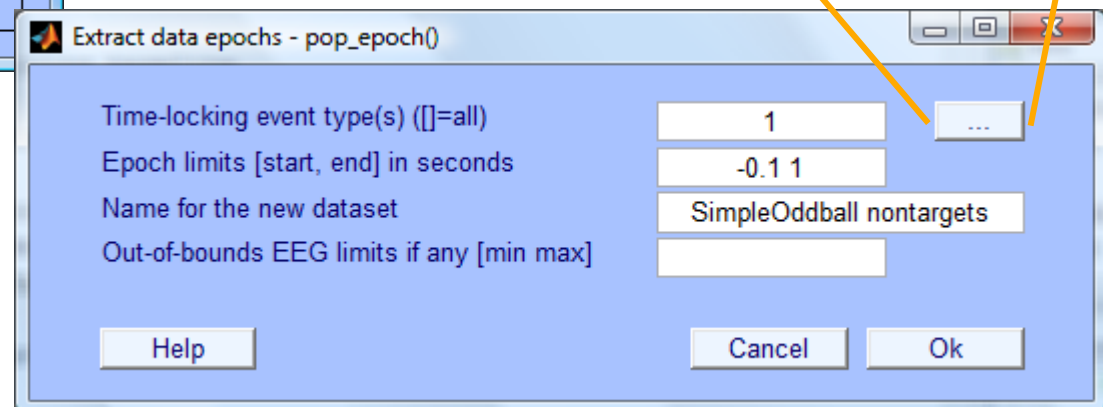
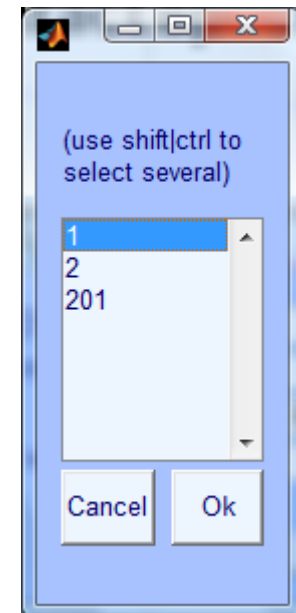


Extract epochs

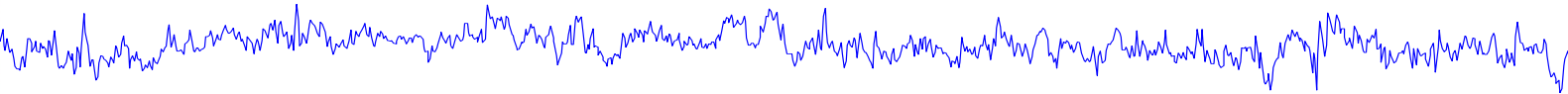
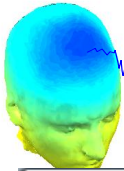


```
>> eeg_eventtypes (EEG)
```

1	140
2	60
201	60



Extract epochs



Dataset info -- pop_newset()

What do you want to do with the new dataset?

Name it:

☐ Save it as file:

Some changes have not been saved

☐ Overwrite it in memory (set=)

☐ Save it as file:

Epoch baseline removal -- pop_rmbase()

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

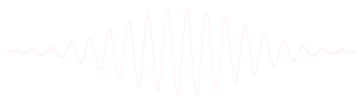
Else, baseline points vector (ex:1:56) ([] = whole) (overwritten by latency range above).

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



Select a subset of epochs

The image displays the EEGLAB v11.0.5.4b software interface. The 'Datasets' menu is open, with 'Select epochs or events' highlighted. A 'Confirmation' dialog box is shown, warning: 'Warning: delete 0 (out of 60) un-referenced epochs ?'. A red text box points to the '0' in the warning, stating: '0' because the subject did not miss any targets. The 'Select events -- pop_selectevent()' dialog box is also open, showing the 'Epoch selection' section with the checkbox 'Remove epochs not referenced by any selected event' checked. The 'Ok' button in the 'Select events' dialog is highlighted.

EEGLAB v11.0.5.4b

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
Visual
Datasets

Confirmation

Warning: delete 0 (out of 60) un-referenced epochs ?

Cancel Ok

Select events -- pop_selectevent()

Field		Selection		Set=NOT THESE
		min	max	
latency (ms)	No description			<input type="checkbox"/>
type	No description	201		<input type="checkbox"/>
epoch	No description			<input type="checkbox"/>
Event indices				<input type="checkbox"/>

Event selection

☐ Select all events NOT selected above (Set this button and "all BUT" buttons (above) for logical OR)

☐ Keep only selected events and remove all other events

Rename selected event type(s) as type:

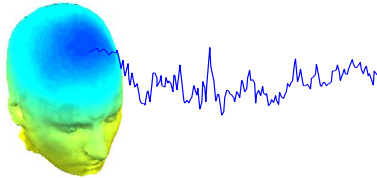
Retain old event type name(s) in (new) field named:

Epoch selection

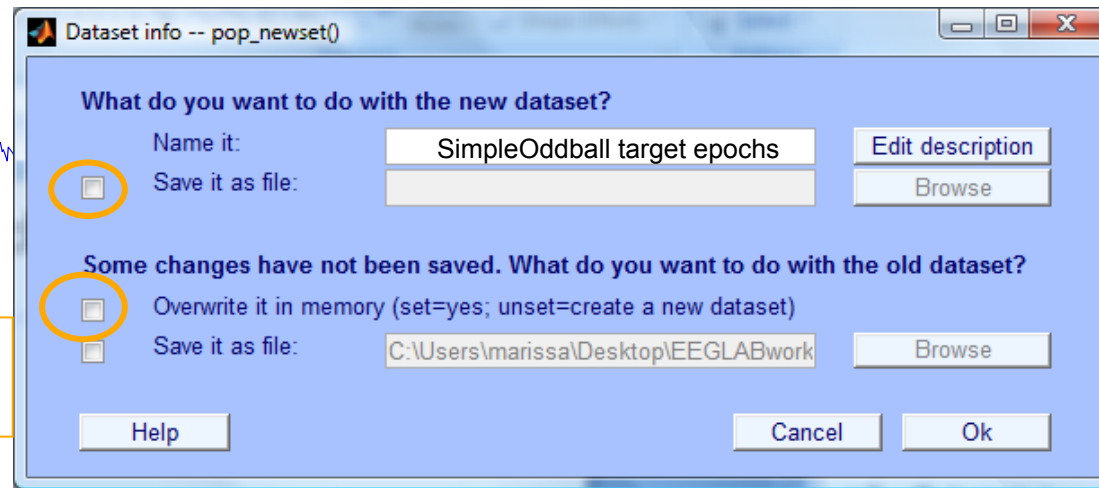
☒ Remove epochs not referenced by any selected event

☐ Invert epoch selection

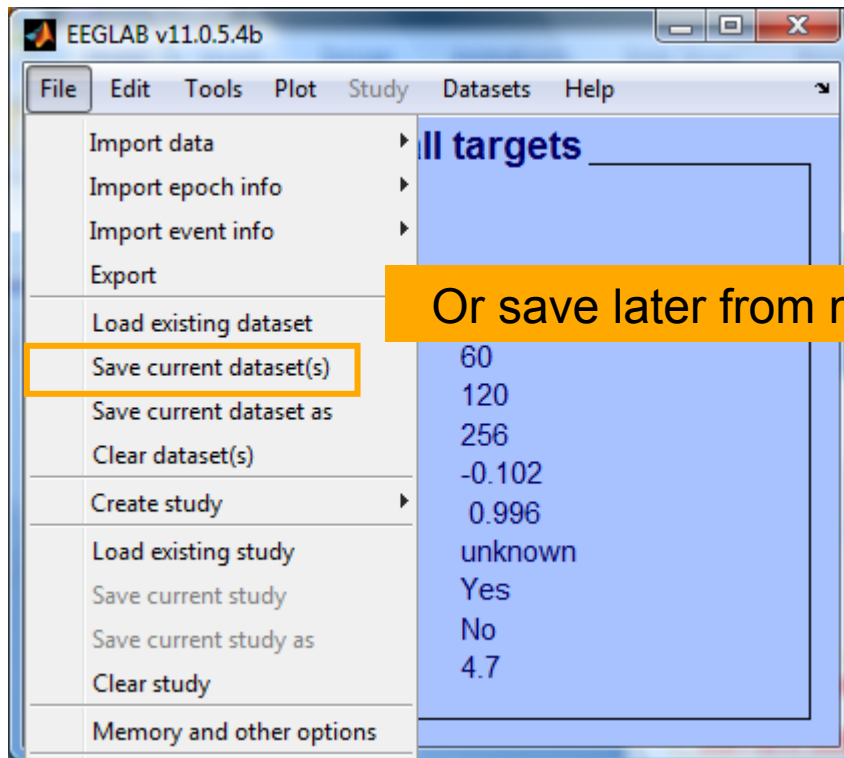
Help Cancel Ok



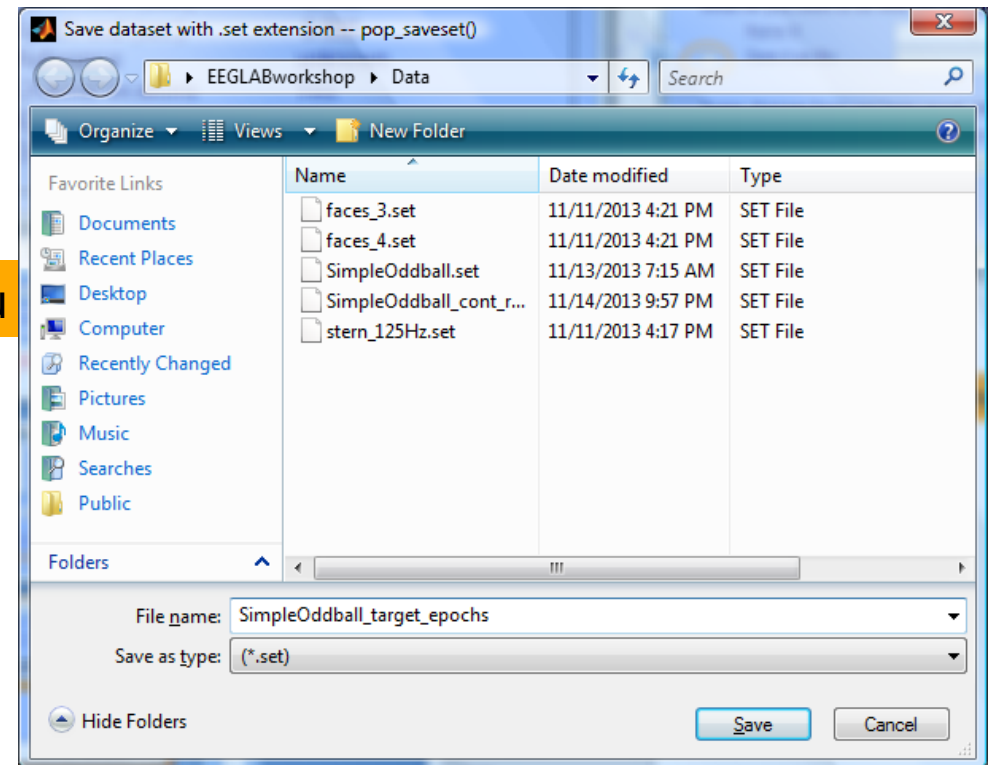
'Do not overwrite current dataset'



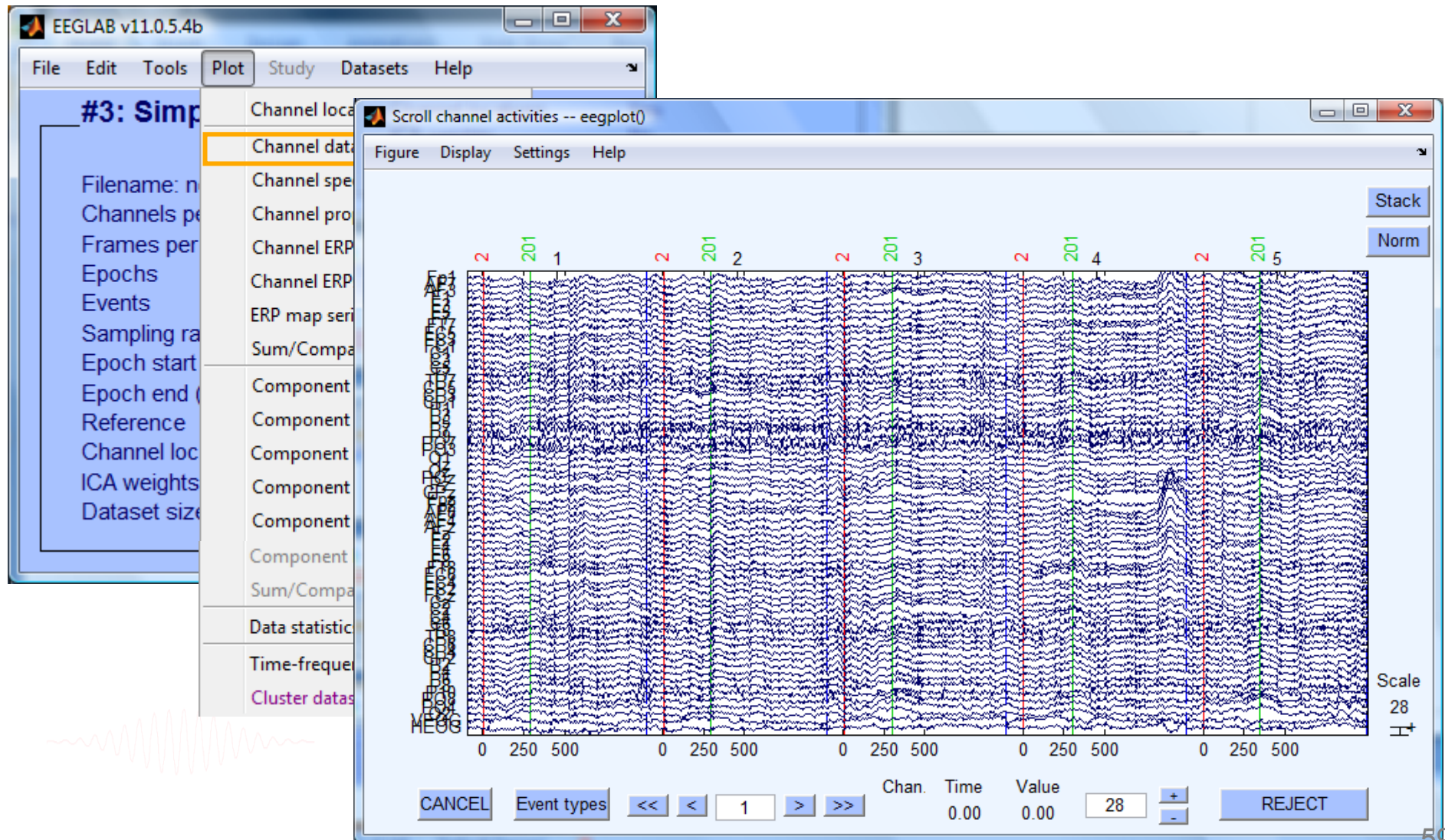
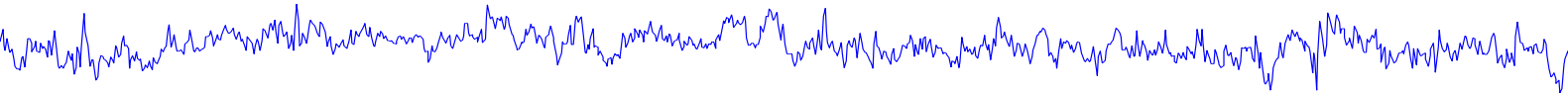
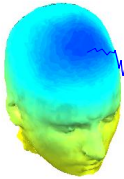
Save dataset (optional)



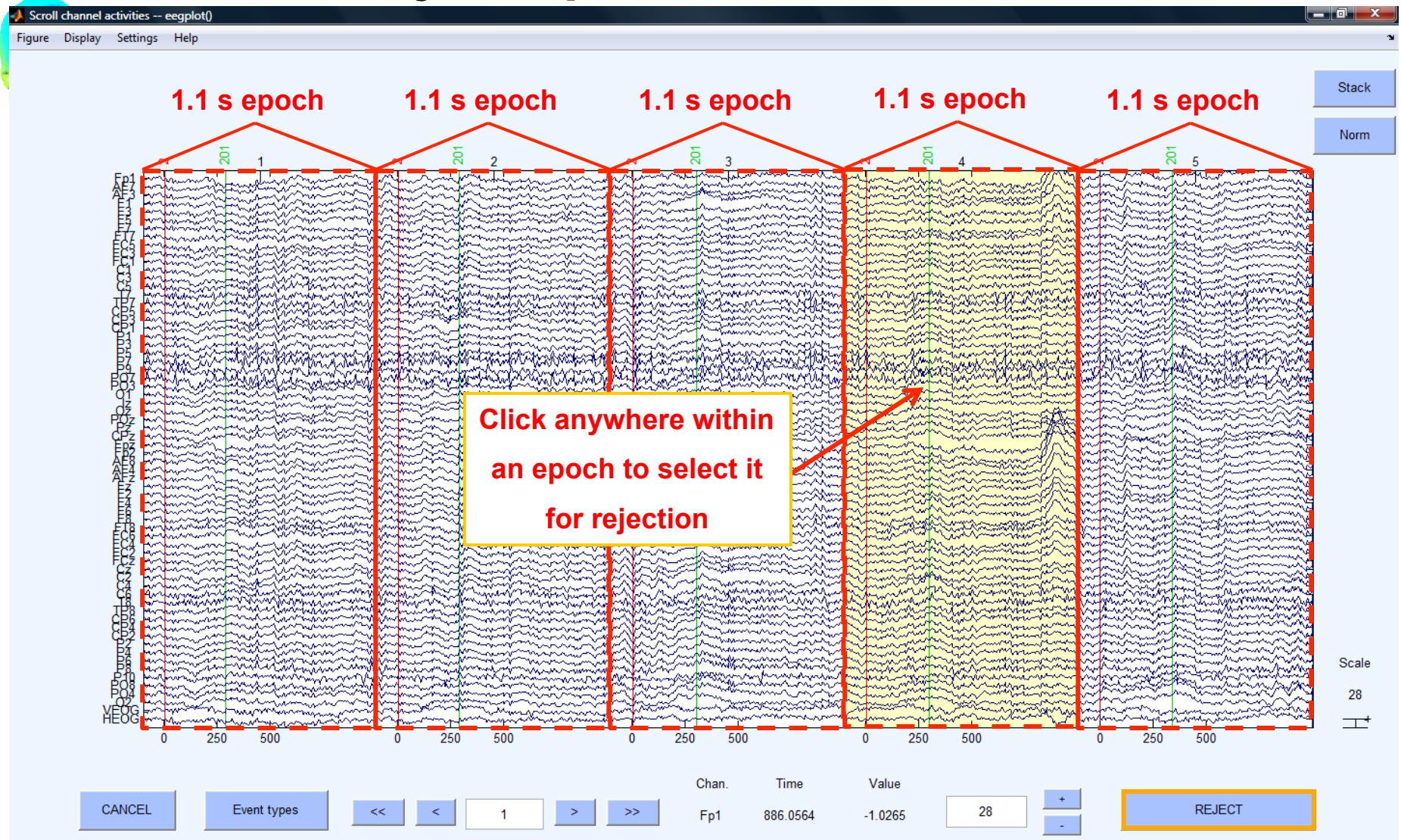
Or save later from menu



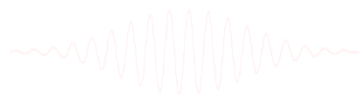
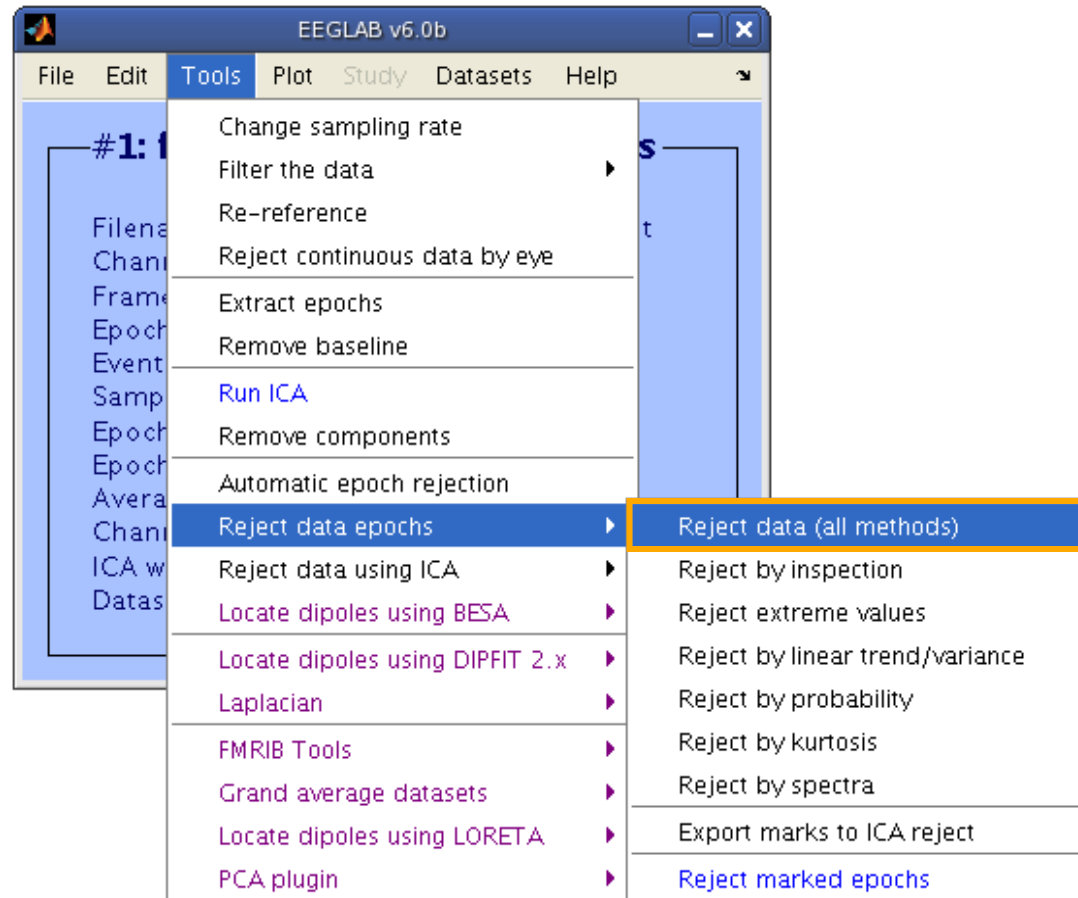
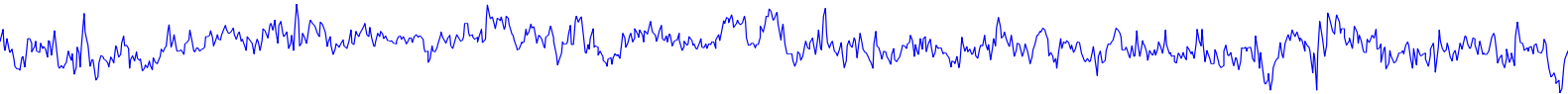
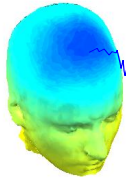
Scroll (epoched) channel data



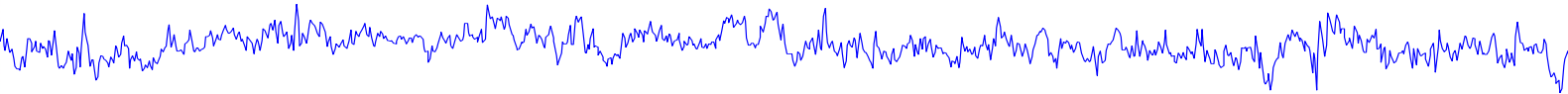
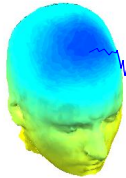
Reject epochs with artifact



Reject data epochs



Reject data epochs



visual
inspection

Reject trials using data statistics - pop_rejmenu()

Mark trials by appearance ☐ Scroll Data 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
 Calc / Plot Help

Find abnormal trends ☐

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

Find improbable data ☐

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

Find abnormal distributions ☐

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

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
 Calc / Plot Help

Plotting options

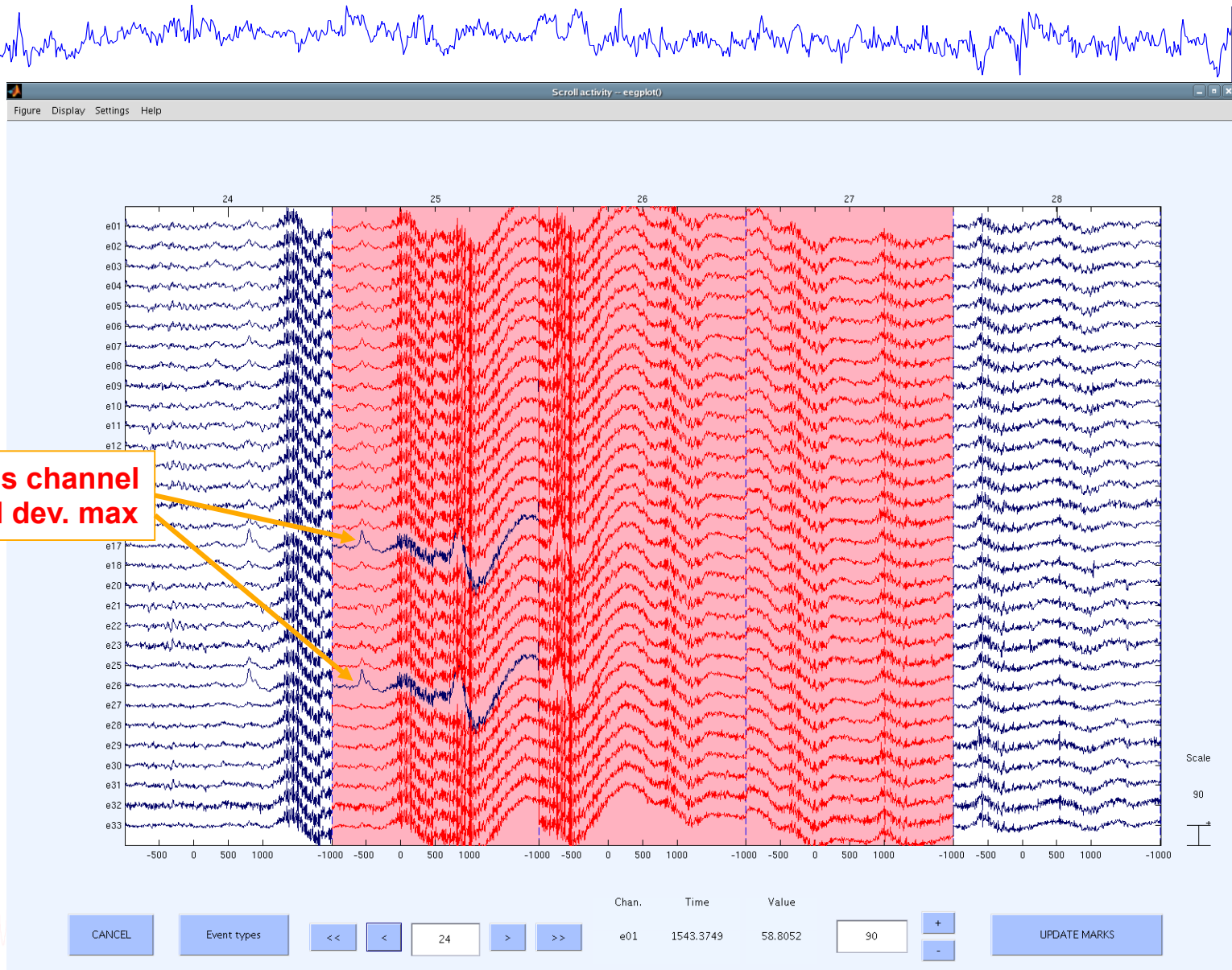
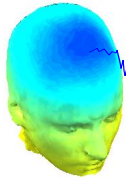
Show all trials marked for rejection by the measure selected above or checked below | /

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

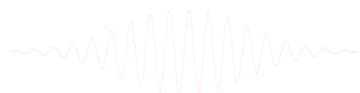
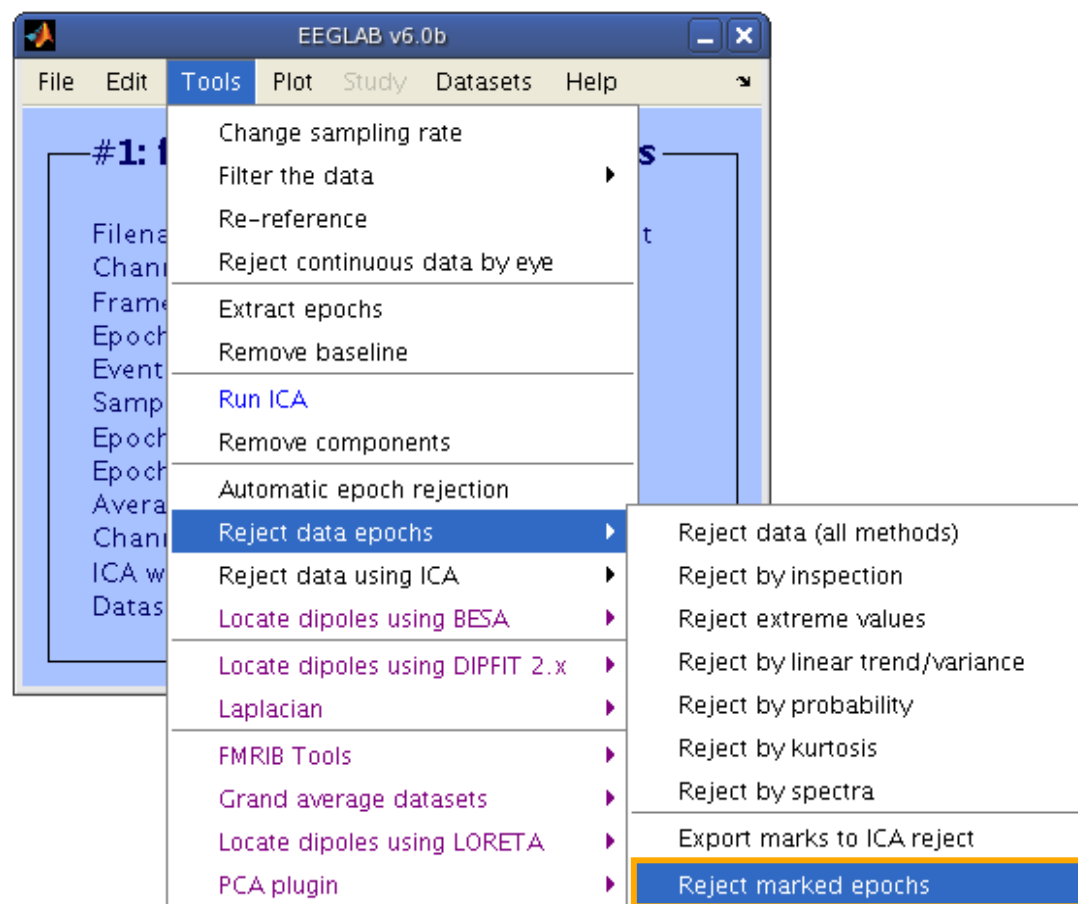
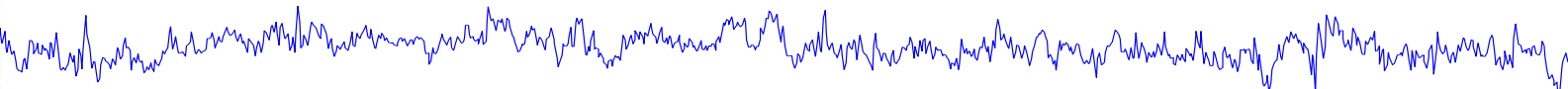
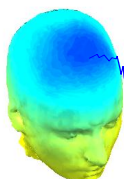
Close (keep marks) Clear all marks Reject marked trials

probability

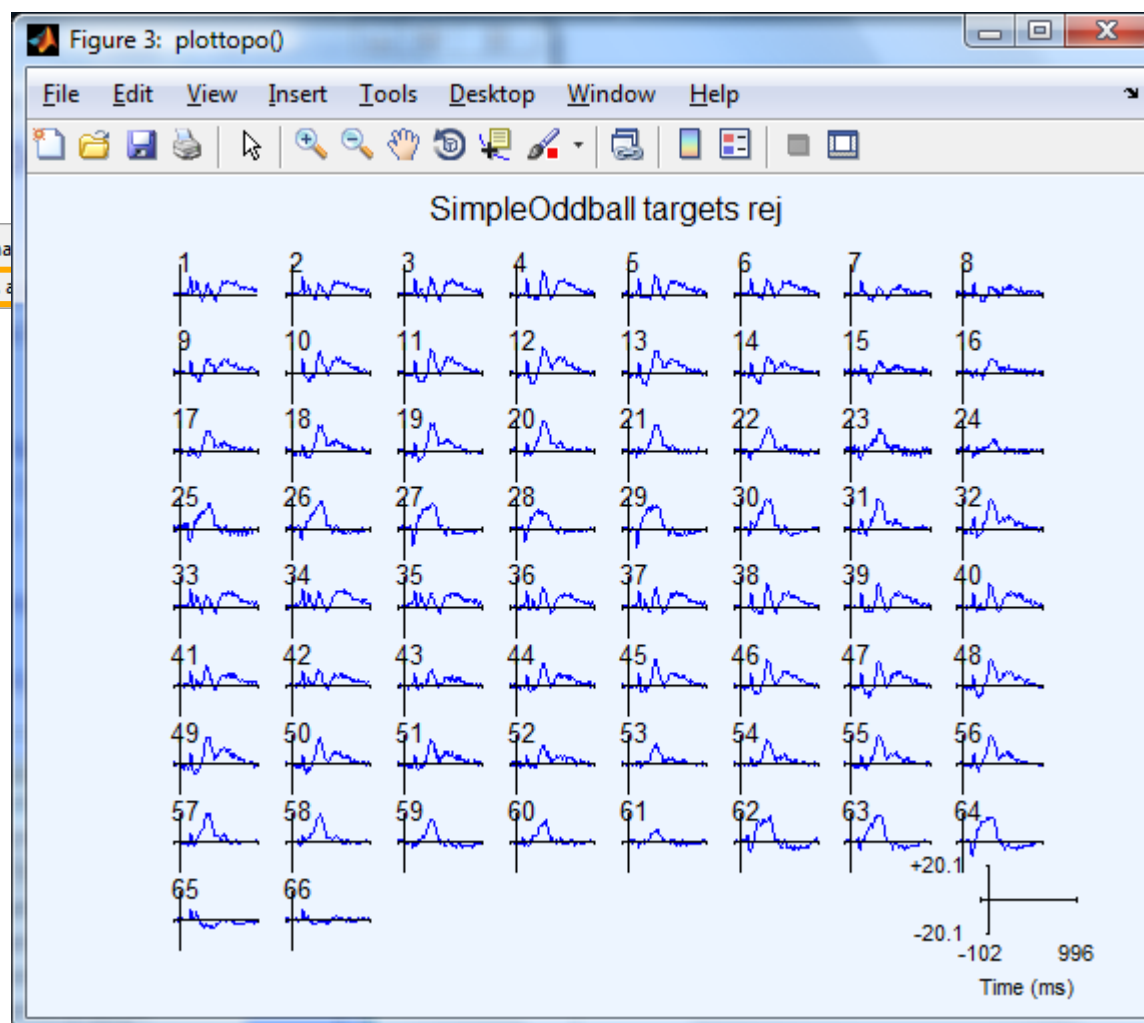
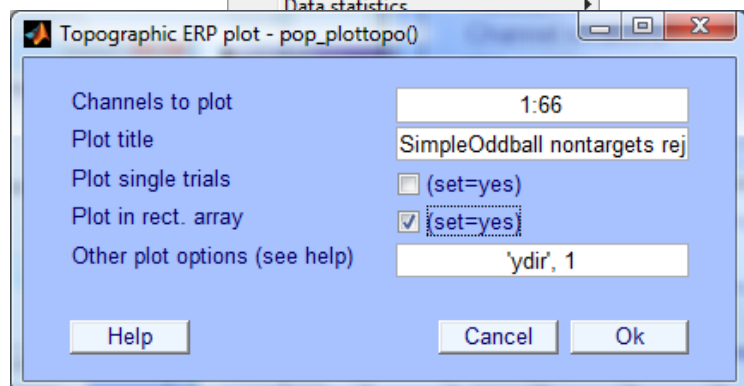
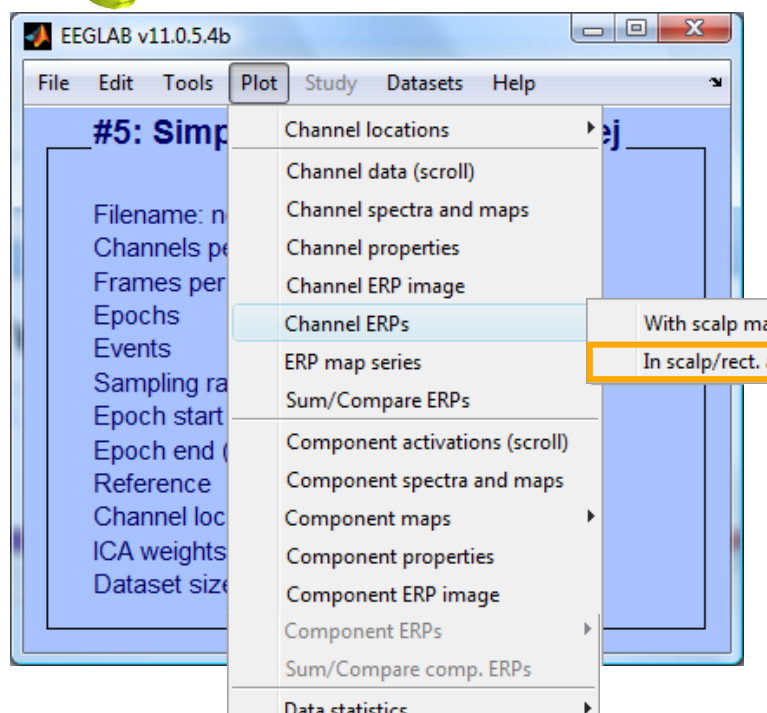
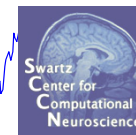
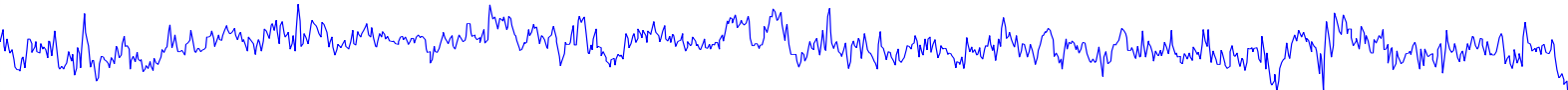
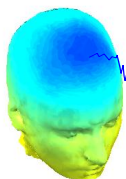
Reject data epochs



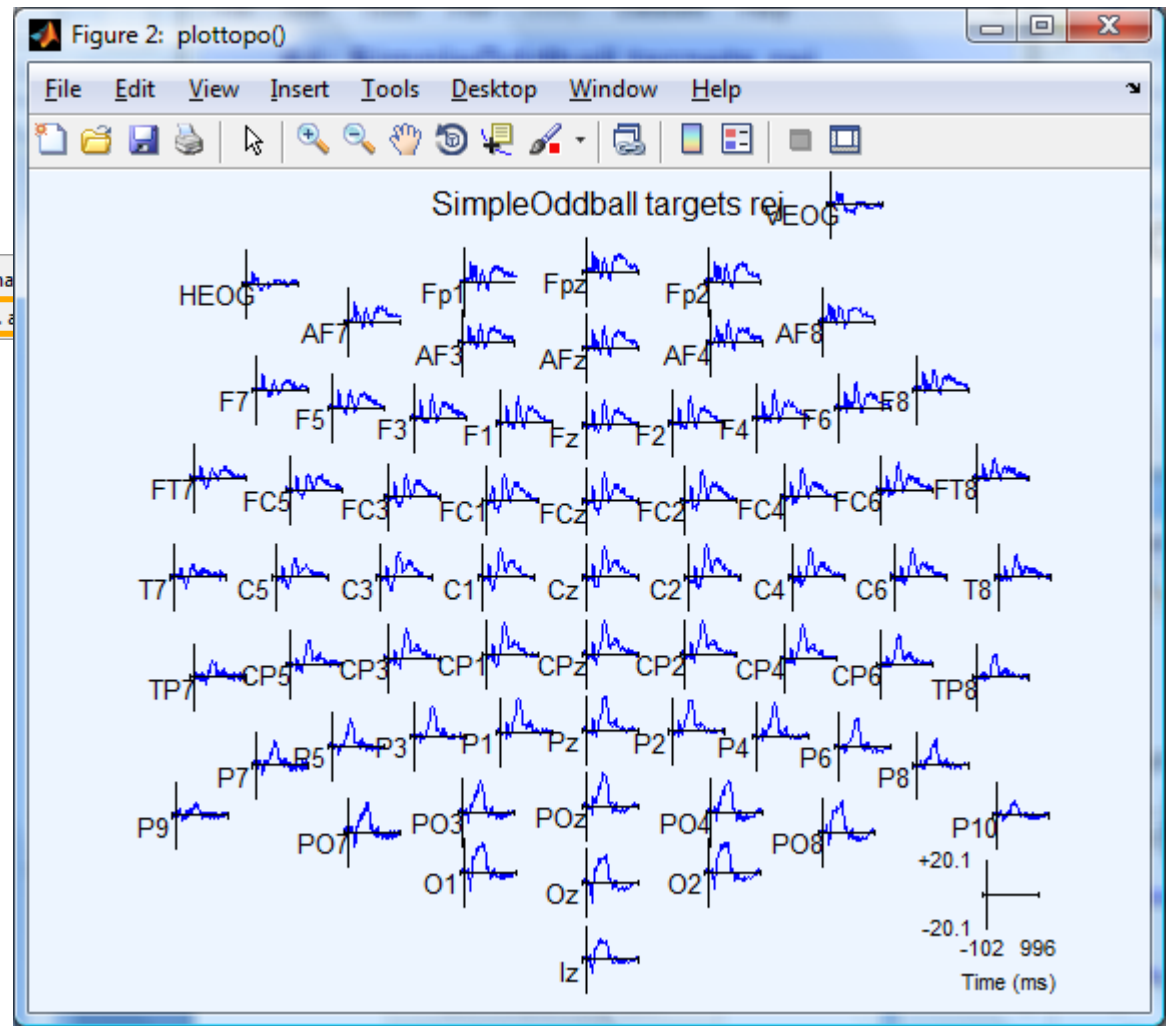
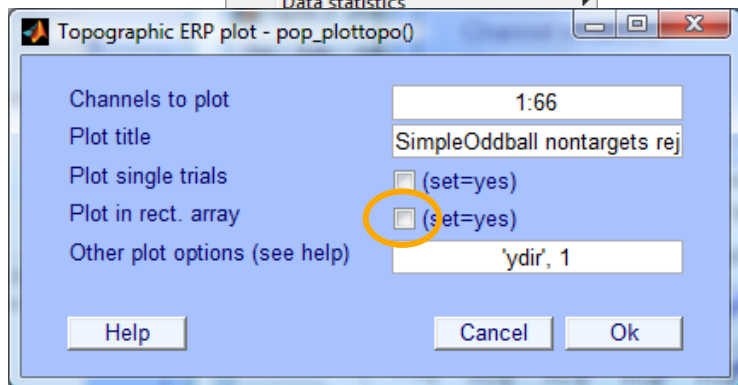
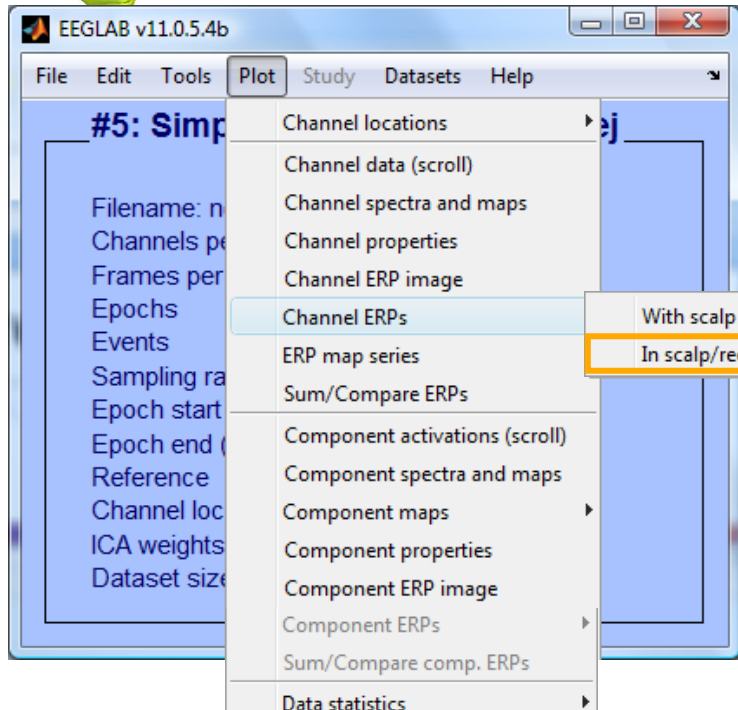
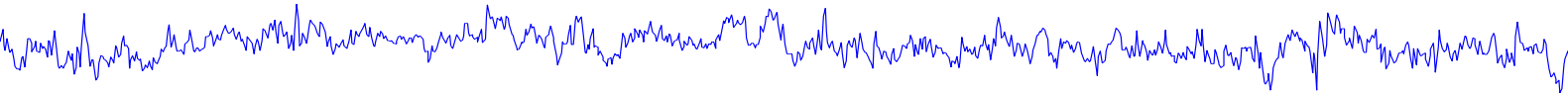
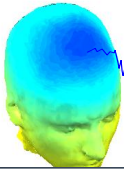
Reject data epochs



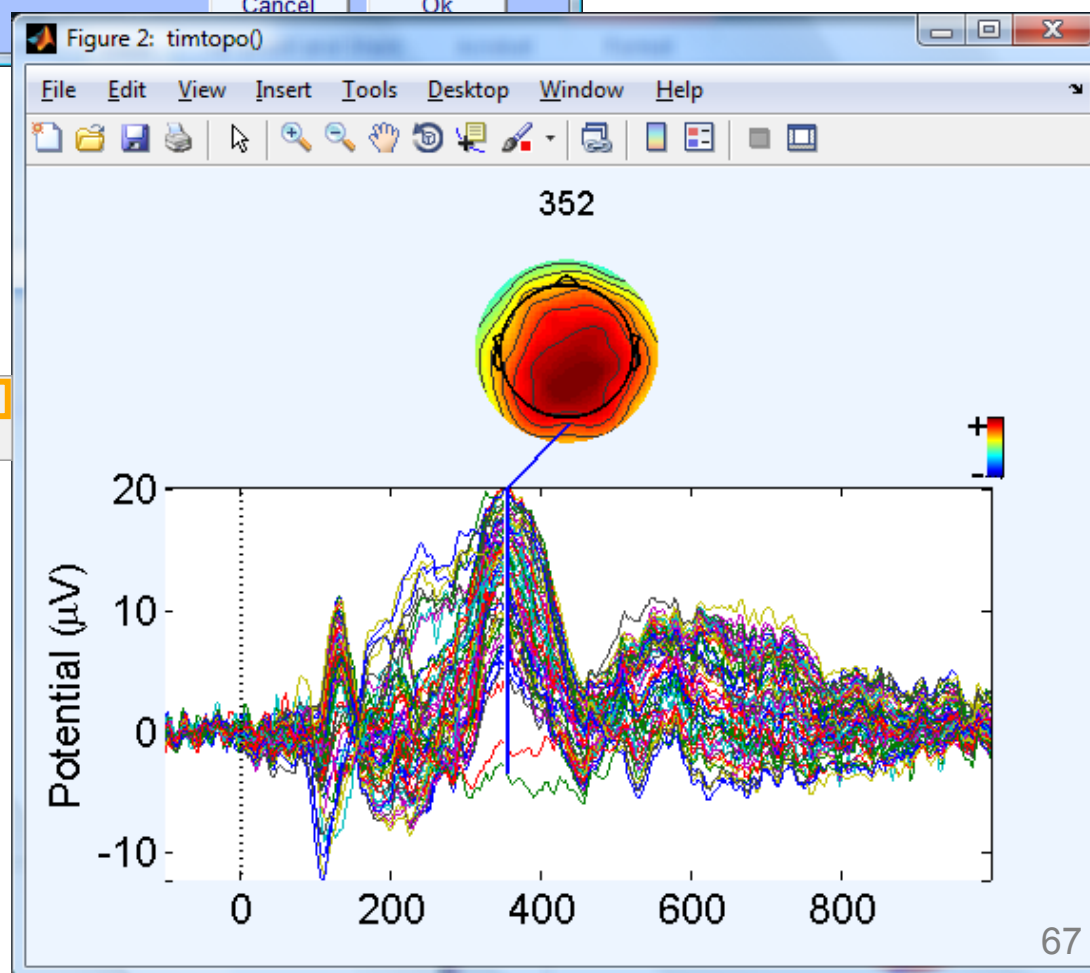
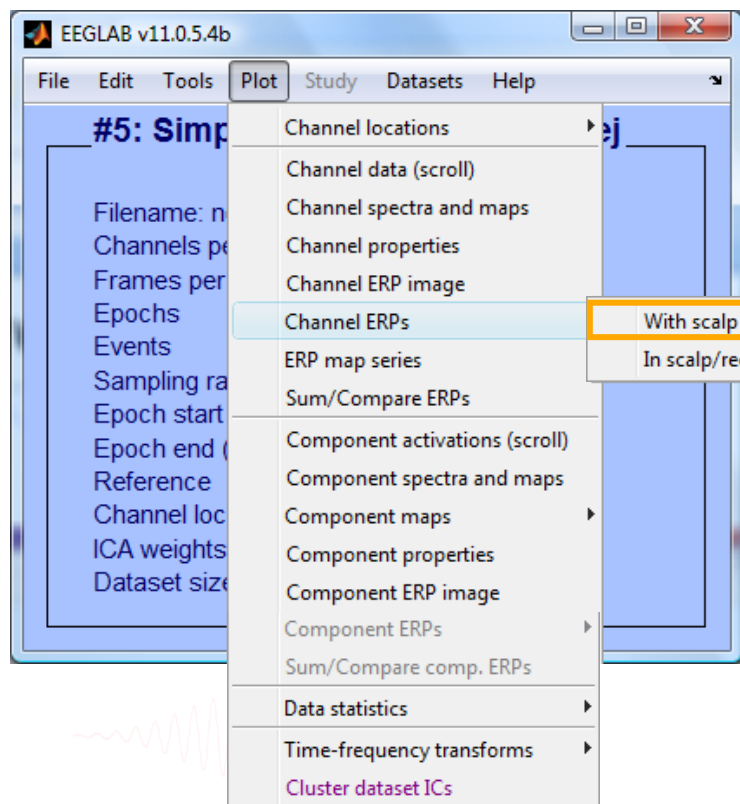
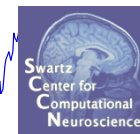
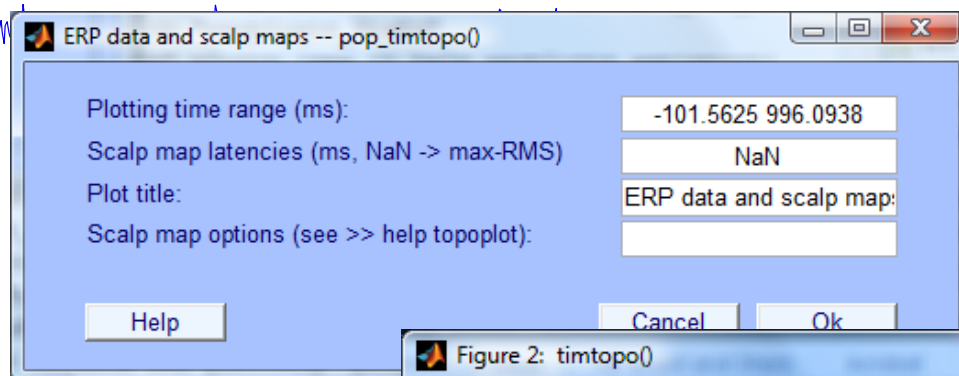
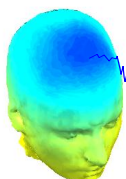
Visualize ERP in rectangular array



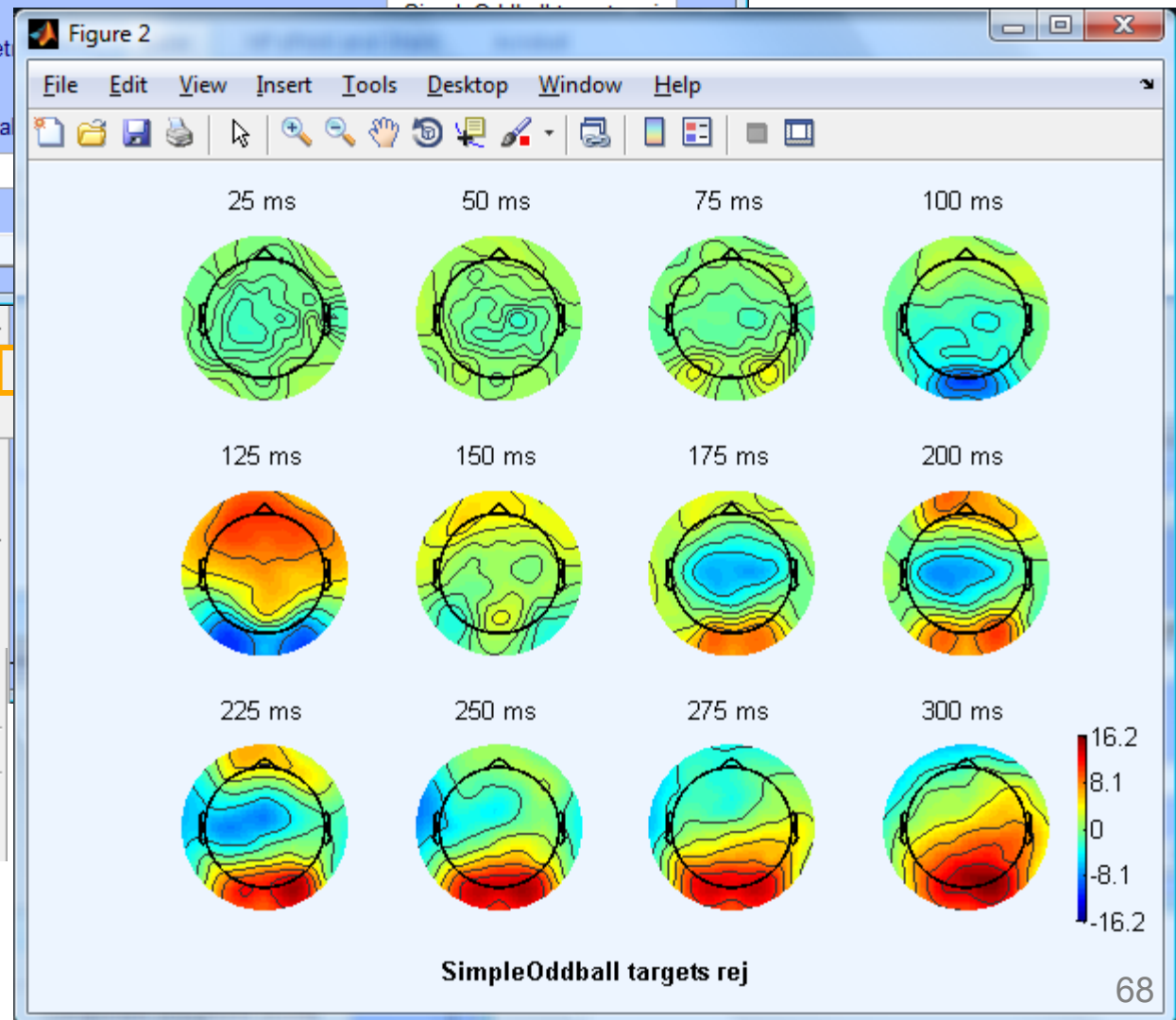
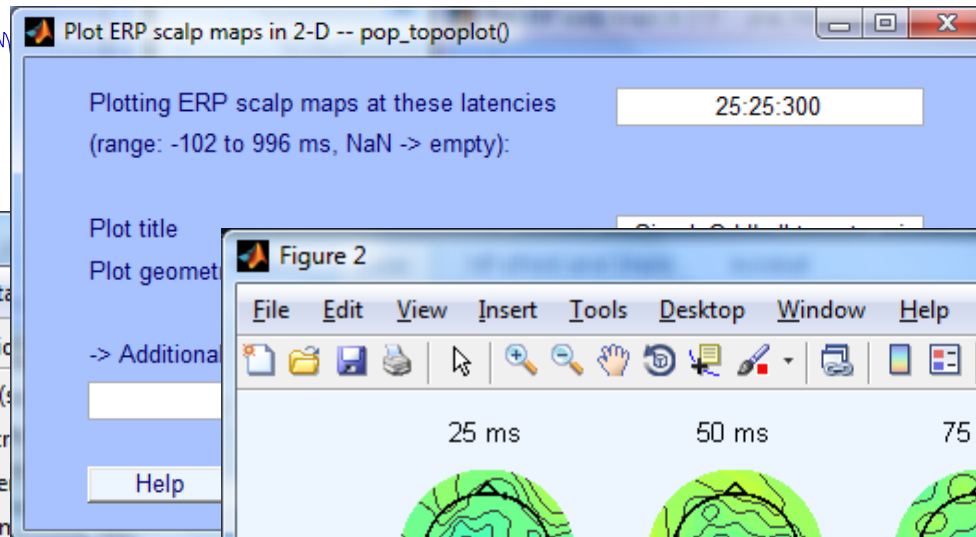
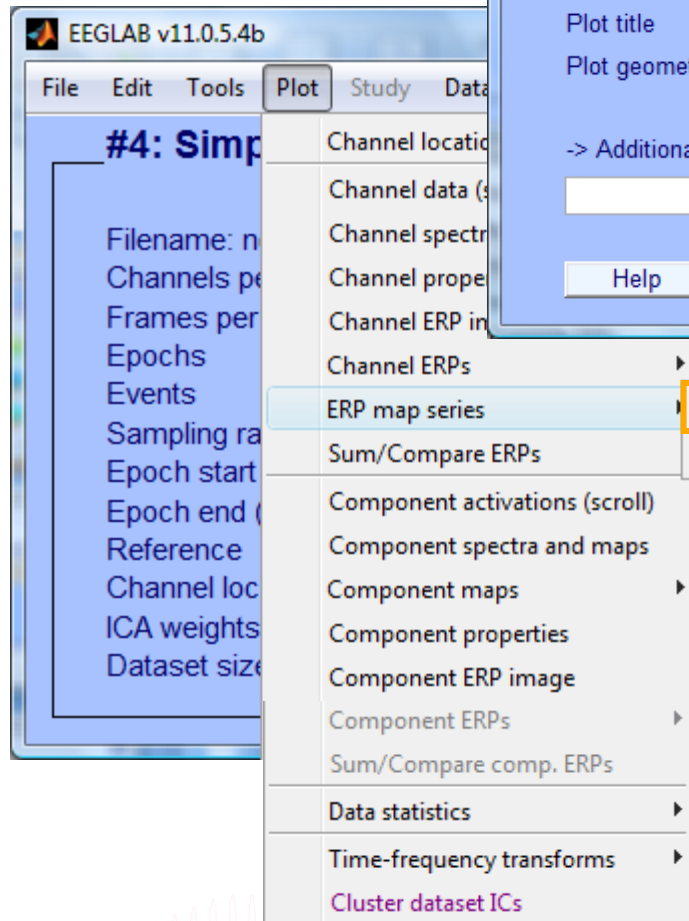
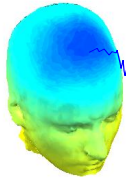
Visualize ERP in topographic array



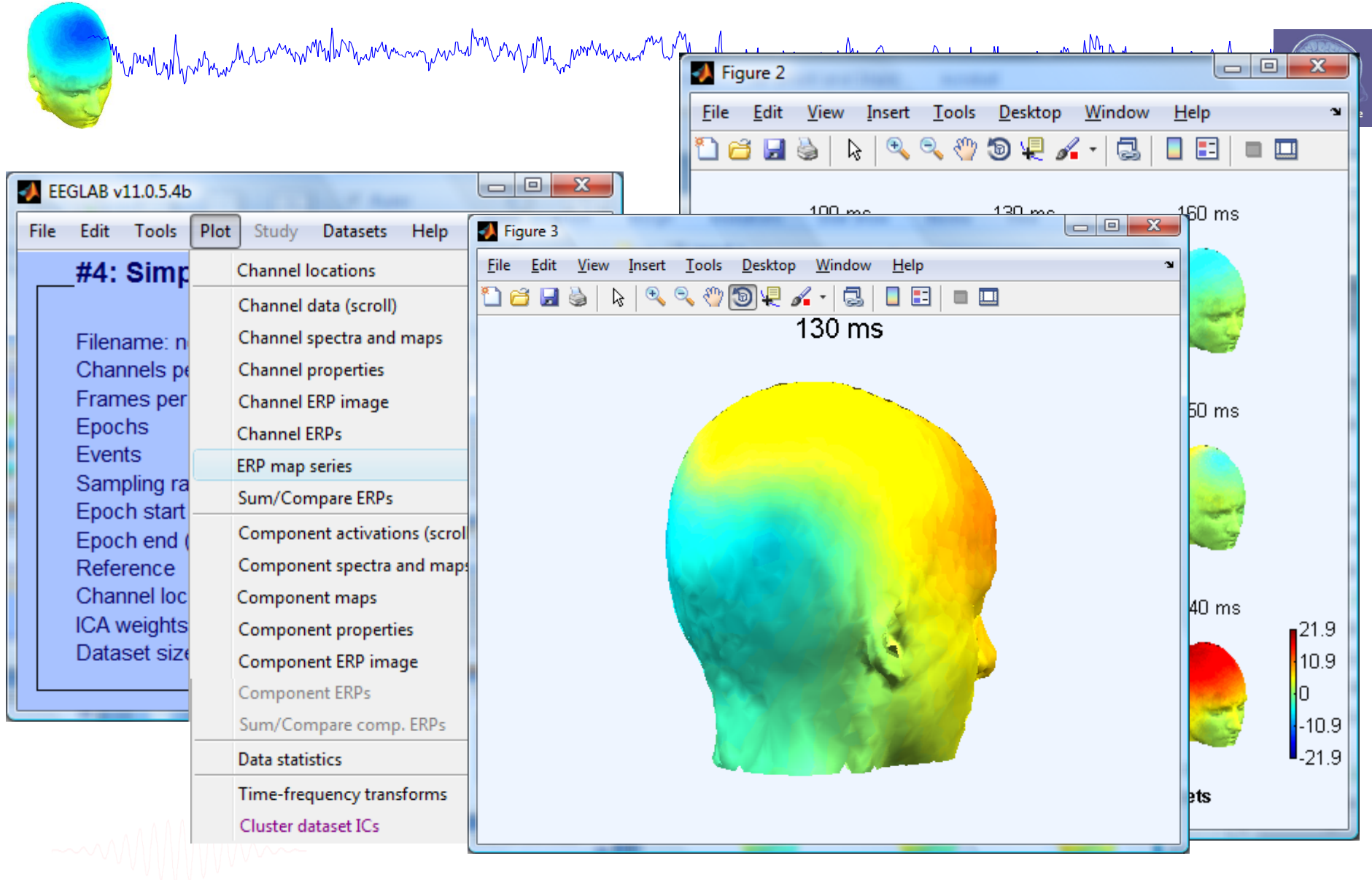
Visualize ERP scalp distribution



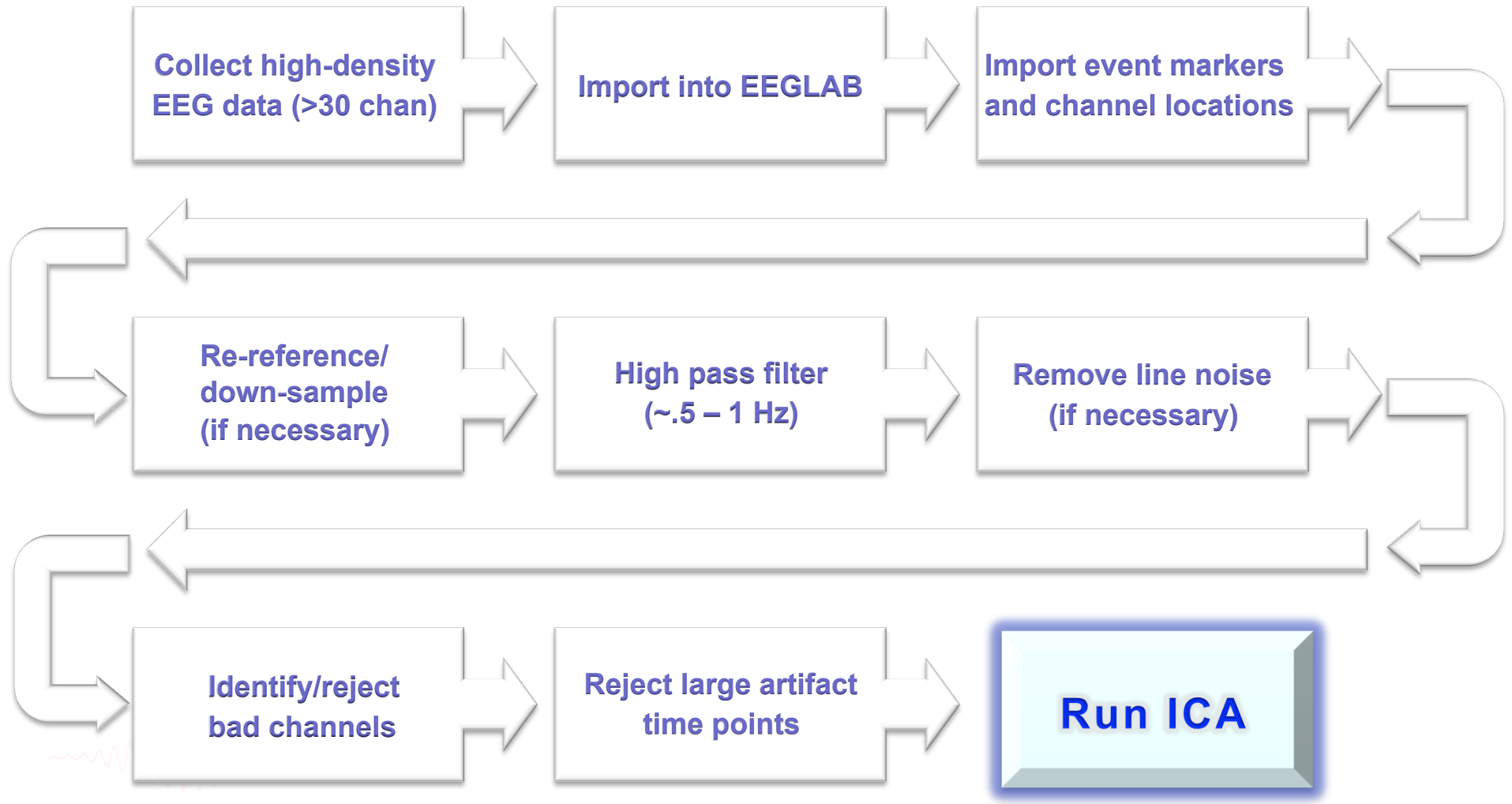
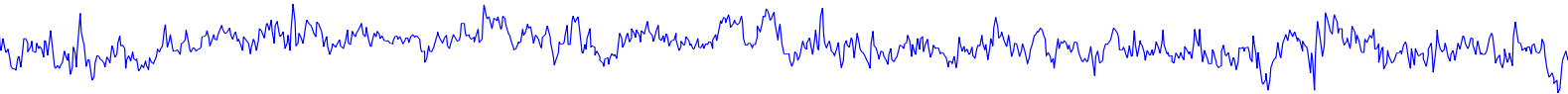
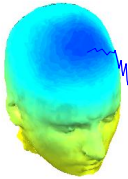
Visualize channel ERPs in 2D



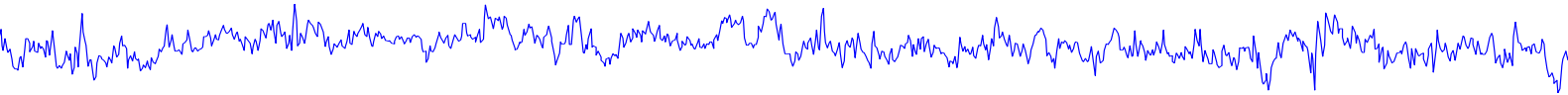
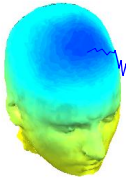
Visualize channel ERPs in 3D



Pre-processing pipeline



Exercises



- Preprocess data of your choice or load a previously filtered dataset e.g. faces_4.set
- Identify bad channel(s) using auto-detection tool; plot channel properties of flagged channels
- Identify and remove non-task portions of continuous data; see if the previously flagged channels are still identified as bad
- Epoch on event of interest. Scroll the epoched data and perform visual rejection of epochs
- Explore the automated artifact rejection tools
- Run ICA

