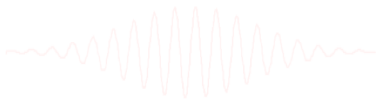
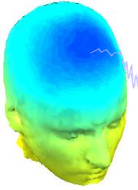


EEG Preprocessing in EEGLAB

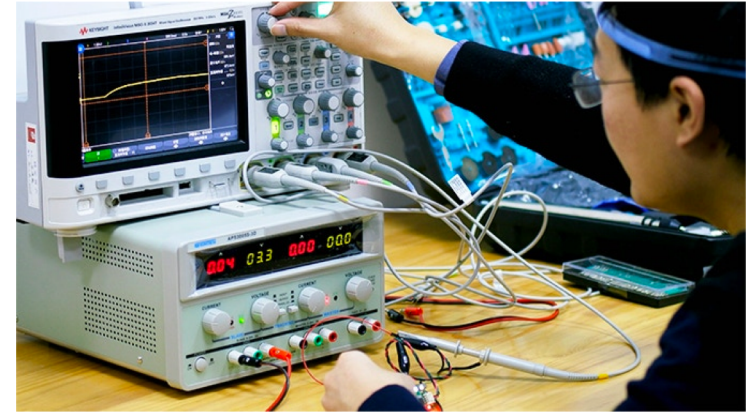
Arnaud Delorme



Why preprocess data?



EEG data out of the recording device is a continuous unprocessed signal. It is like measuring a difference of potential on an oscilloscope.

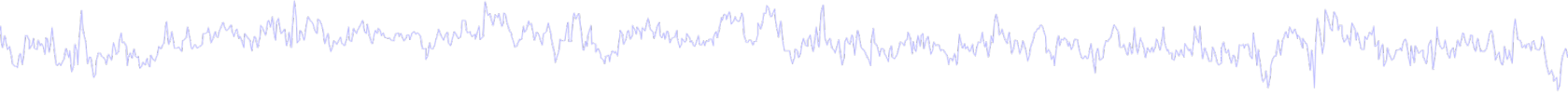
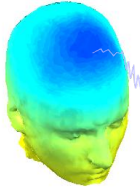


To make sense of the data, we need to:

- Extract meaningful measures from it (such as brain oscillations; brain source activations)
- Compare brain data in different conditions
- Assess reliable changes due to external stimuli (event-related potentials)

Before we do all that, we apply a series of transformation to the data.

Pre-processing pipeline



Collect EEG data

Import into EEGLAB

Import event markers and channel locations

Re-reference/down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

Examine raw data

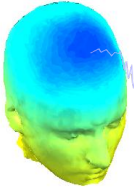
Identify/reject bad channels

Reject large artifact time points

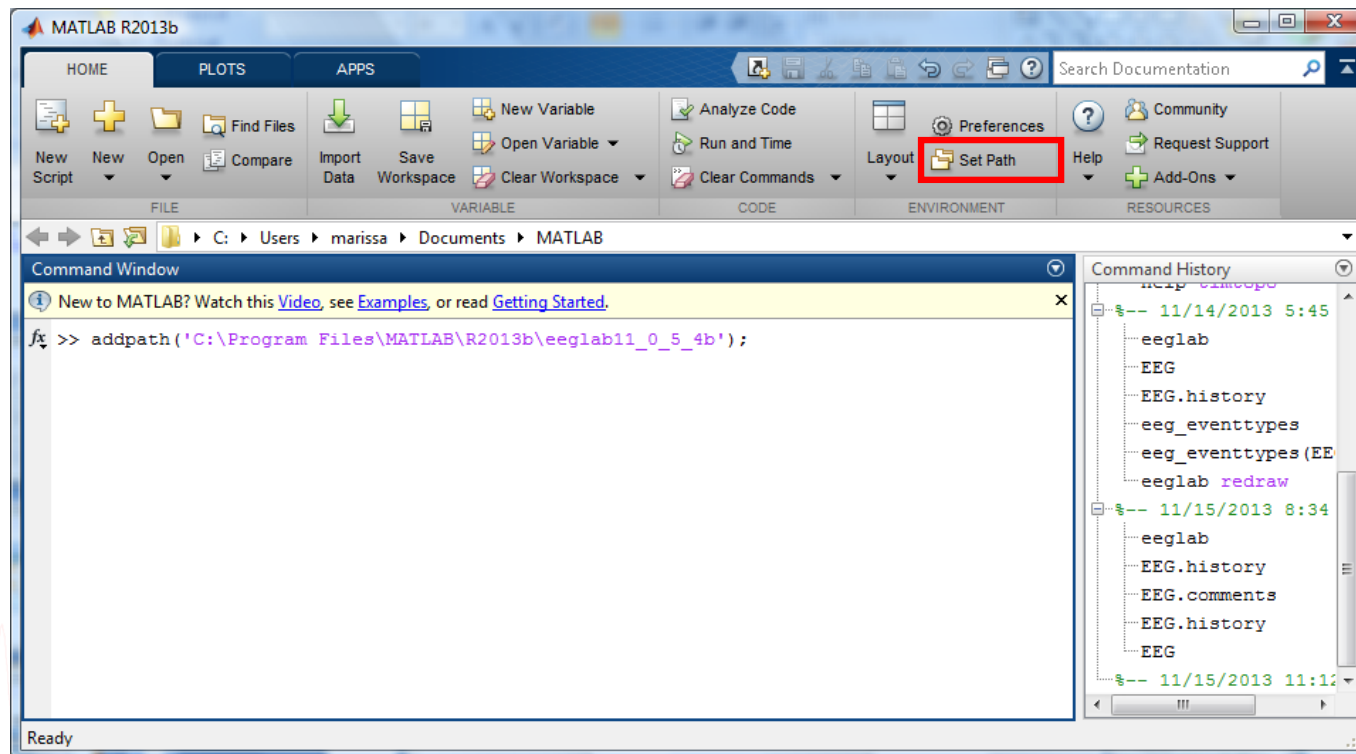
Run ICA and reject components

Done

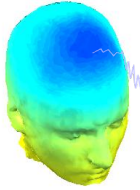
Installing EEGLAB and data folder



- Download and install Matlab (2008b or later)
- Download EEGLAB (<http://www.sccn.ucsd.edu/eeglab>)
- Unzip EEGLAB
- Add the EEGLAB folder to your Matlab path:



The EEGLAB Matlab software



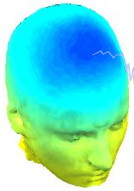
main graphic interface

The screenshot shows the MATLAB R2013b environment. The Command Window contains the command `eeqlab`. The EEGLAB v11.0.5.4b window is open, displaying the following instructions:

No current dataset

- Create a new or load an existing
Use "File > Import data" (new)
Or "File > Load existing dataset" (old)
- If new,
"File > Import epoch info" (data)
"File > Import event info" (continuous)
"Edit > Dataset info" (add/edit dataset)
"File > Save dataset" (save dataset)
- Prune data: "Edit > Select data"
- Reject data: "Tools > Reject"
- Epoch data: "Tools > Extract epochs"
- Remove baseline: "Tools > Remove"
- Run ICA: "Tools > Run ICA"

Importing a dataset



EEGLAB v11.0.5.4b

File Edit Tools Plot Study Datasets Help

Import data
Import epoch info
Import event info
Export

Load existing dataset
Save current dataset(s)
Save current dataset as
Clear dataset(s)

Create study
Load existing study
Save current study
Save current study as
Clear study

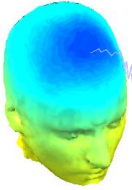
Memory and other options
History scripts
Quit

Using EEGLAB functions and plugins
Using the FILE-IO interface
Using the BIOSIG interface
Troubleshooting data formats...

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



Install extension for importing data files



EEGLAB development head

File Edit Tools Plot Study Datasets Help

- Import data
 - Import epoch info
 - Import event info
 - Export
- Load existing dataset
- Save current dataset(s)
- Save current dataset as
- Clear dataset(s)

Create study

Load existing study

Save current study

Save current study as

Clear study / Clear all

Memory and other options

History scripts

Manage EEGLAB extensions

- Data import extensions**
- Data processing extensions

Quit

Extensions available for install on the internet

Install	Plugin	Vers.	Score	Description	
<input type="checkbox"/>	BDFimport	1.10	1920	Import BDF data files	Doc
<input type="checkbox"/>	ANTEepimport	1.13	1436	Import ANT .cnt data and trigger files	Doc
<input type="checkbox"/>	MFFimport	2.1	978	Import MFF files from the EGI company	Doc
<input type="checkbox"/>	BCI2000import	0.36	861	Import BCI2000 data files	Doc
<input type="checkbox"/>	biopac	1.00	771	Import BIOPAC data files	Doc
<input type="checkbox"/>	loadcurry	2.0	623	Import Neuroscan Curry 6, 7 and 8 data files	Doc
<input type="checkbox"/>	erpssimport	1.01	611	Import ERPSS data files	Doc
<input type="checkbox"/>	NihonKoden	1.01	585	Import Nihon Koden M00 files	Doc
<input type="checkbox"/>	loadhdf5	1.1	534	Load hdf5 files recorded with g.recorder	Doc
<input type="checkbox"/>	neuroimaging4d	1.00	528	Import Neuroimaging4d data files	Doc
<input type="checkbox"/>	INSTEPascimport	1.00	526	Import INSTEP ASCII data files	Doc

Update

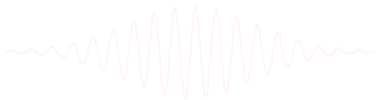
Deactivate

Installed extensions

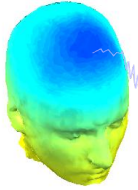
Update	Deactivate	Plugin	Vers.	Score	Description	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Biosig	3.3.0	22642	Import multiple data files formats	Doc
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Fileio	170623	9130	Import multiple data files formats	Doc
<input type="checkbox"/>	<input checked="" type="checkbox"/>	bva-io	1.5.13	4299	Import Brain Vision Analyser data files	Doc
<input type="checkbox"/>	<input checked="" type="checkbox"/>	xdfimport	1.13	879	Import files in XDF format	Doc

< Prev. page Next page >

Cancel Ok



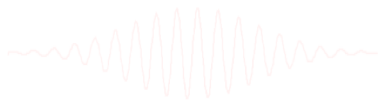
Supported data formats



EEGLAB tutorial: <https://sccn.ucsd.edu/wiki/A01: Importing Continuous and Epoched Data>

Supported Data Formats

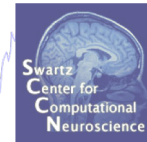
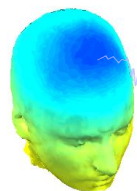
File Format	File Extension	File type	Events	Channel Labels	EEGLAB	Biosig	File IO	Support
ANT EEPProbe	.avr	-	-	-	-	-	-	Comments
ANT EEPProbe	.cnt	-	-	-	y	y	y	Comments
ASCII	.txt	-	-	-	y	y	-	Comments
BCI2000	.bci2000	continuous	-	-	p	-	-	Comments
BCI2000	.gdf	continuous	-	-	p	-	-	Comments
Biologic	.eeg	-	-	-	-	-	-	Comments
Biopac	.mat/acq	-	-	-	p (see comments)	-	-	Comments
Biosemi	.bdf	continuous	Channel	-	y	y	y	Comments
Blackrock	.NEV .NSx	-	-	-	see comments	-	-	Comments
Brain Vision Analyzer	.mat	continuous & segmented	Embedded	-	y	y	n	Comments
Brain Vision Analyzer	.vhdr	-	file	-	y	y	n	Comments
BrainStorm	.vsm	-	-	-	-	-	-	Comments
Cogniscan	-	-	-	-	p	-	-	Comments
Compumedics Profusion	.raw	-	-	-	see comments	-	-	Comments
CTF/BrainStorm	.ctf	-	-	-	y	y	y	Comments
EGI/Netstation	.RAW	continuous & segmented	Channel	-	y	y	y	Comments
Elektra (MEG)	.fif	-	-	-	n (see comments)	y	n	Comments
Emotiv	.edf	-	-	-	y (see comments)	y (see comments)	y (see comments)	Comments
ERPSS	.raw	-	-	-	y	n	n	Comments
ERPSS	.rdf	-	-	-	y	n	n	Comments
European Data Format (16-bit)	.edf	-	Channel	-	y	y	n	Comments
EDF+	.edf	-	Channel	-	y	y	n	Comments
INSTEP	.asc	-	-	-	y	n	n	Comments
Matlab Array	.mat	-	Channel	-	y	y	n	Comments
Micromed	-	-	-	-	p	-	-	Comments
Neuroimaging4D	.m4d	-	-	-	y	n	n	Comments
Neuroimag	.fif	-	-	-	see comments	n	see comments	Comments
Neuroscan	.avg	-	-	-	-	-	-	Comments
Neuroscan	.CNT	-	Embedded (see comments)	-	y	y	y	Comments
Neuroscan	.eeg	continuous	-	-	y	y	y	Comments
Nihon Kodhen	.eeg	continuous	-	-	-	y (see comments)	-	Comments
Profusion	.slp	-	-	-	-	-	-	Comments
Snapmaster	.SMA	-	Channel	-	y	y	n	Comments
Spike2	.mat	-	-	-	y (see comments)	n	n	Comments
Tucker-Davis Technology	.tdt	-	-	-	p	-	-	Comments



BIOSIG: <http://pub.ist.ac.at/~schloegl/biosig/TESTED>

File-IO: <http://www.fieldtriptoolbox.org/development/fileio>

Sample data: basic P300 paradigm



File

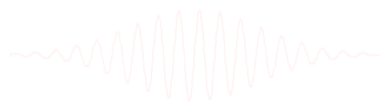
SimpleOddball.set

Data

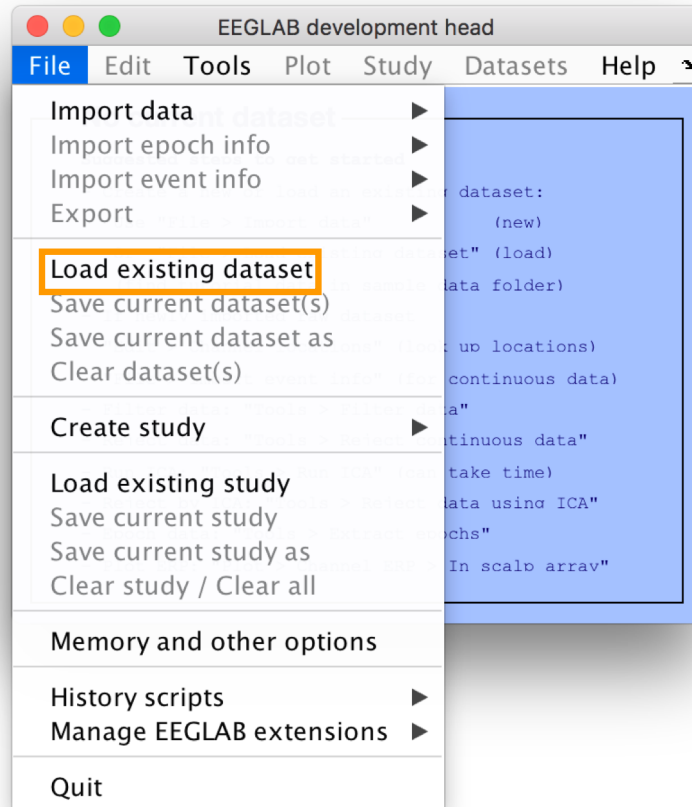
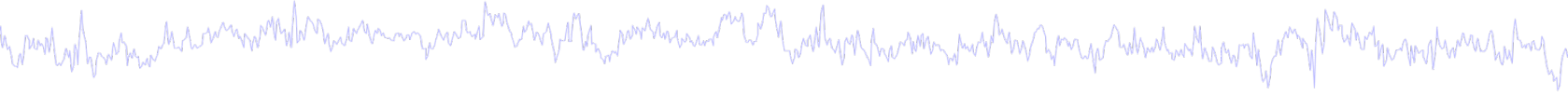
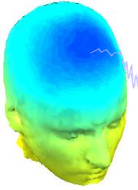
68 channel EEG, 256 Hz sampling rate, Biosemi system, re-referenced during import to averaged left and right mastoid electrodes

Task

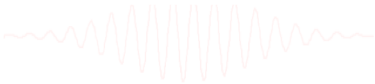
speeded button press response to star shape (no response to circle shape), 100 ms presentation duration, 200 trials



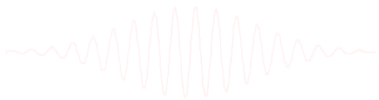
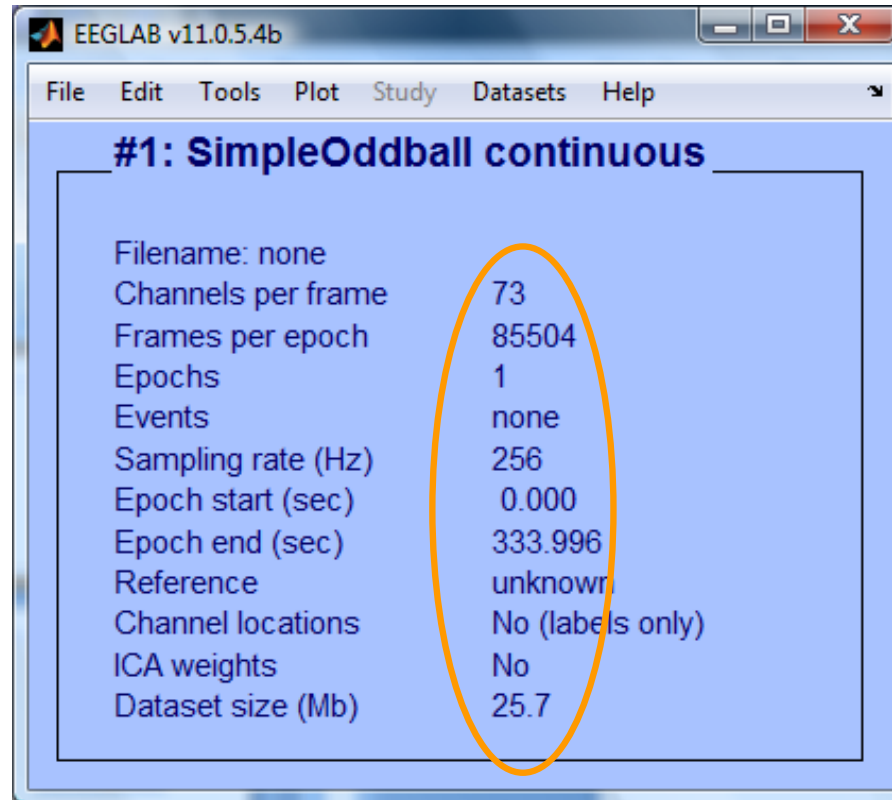
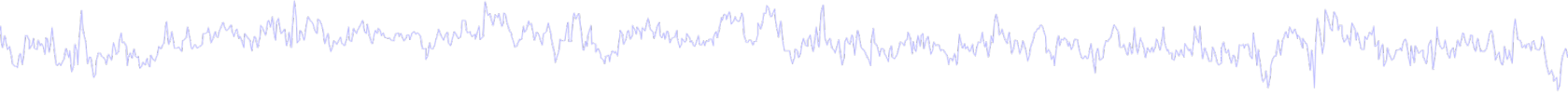
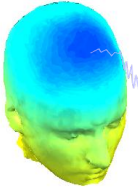
Load a dataset



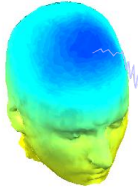
Load "SimpleOddball.set"



Imported EEG data



Pre-processing pipeline



Collect EEG data

Import into EEGLAB

Import event markers and channel locations

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

**High pass filter
(~.5 – 1 Hz)**

Examine raw data

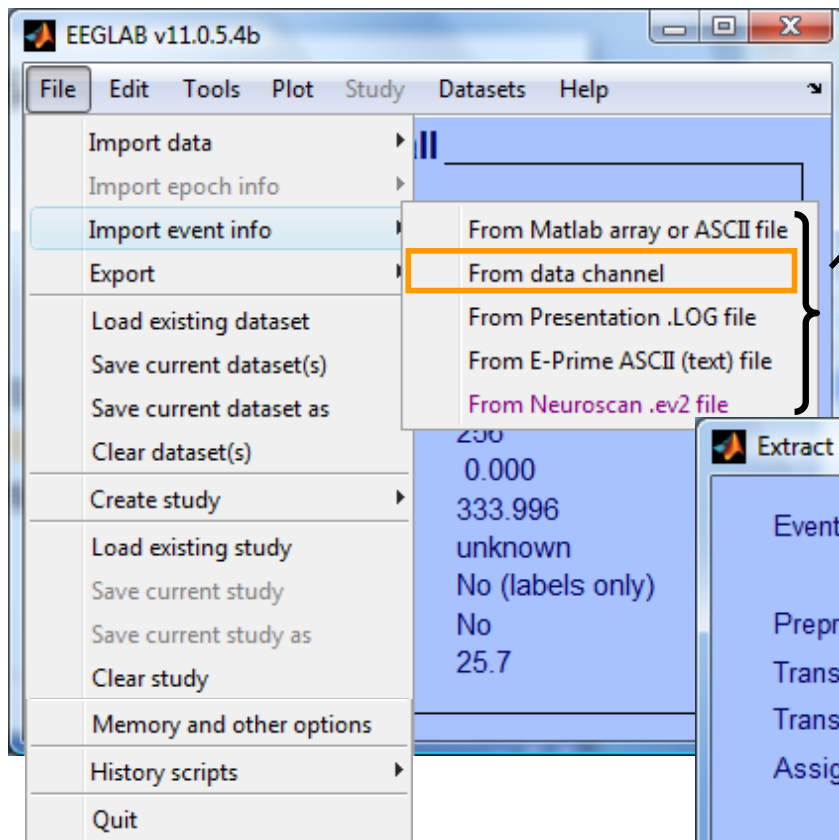
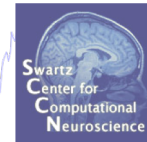
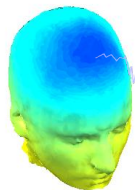
**Identify/reject
bad channels**

**Reject large artifact
time points**

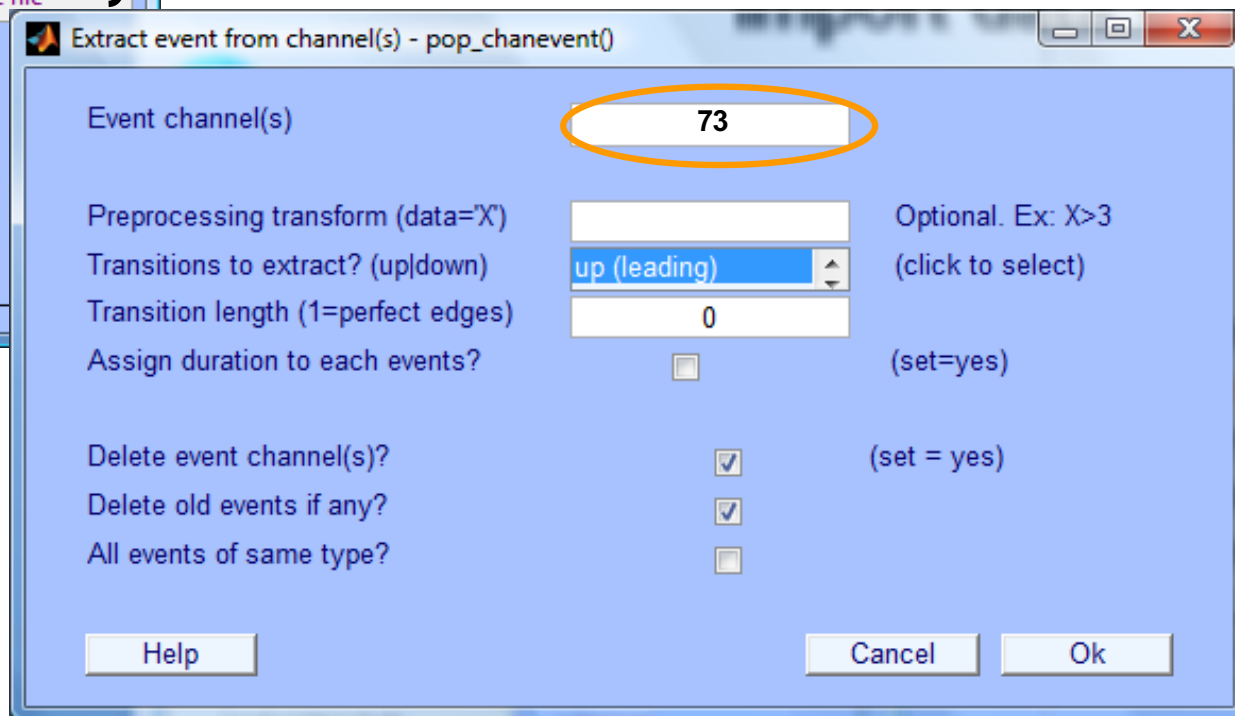
**Run ICA and
reject components**

Done

Import data events

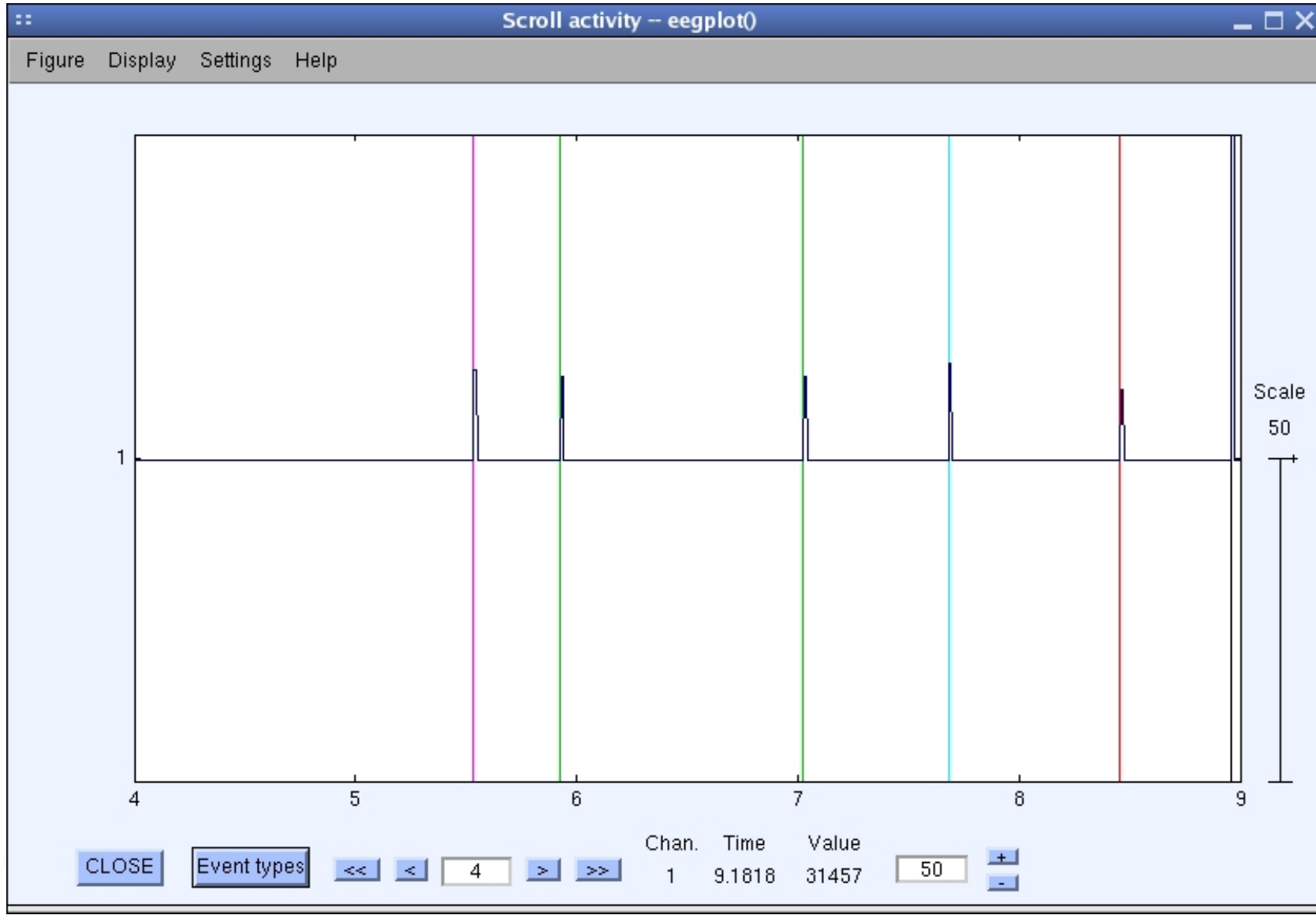
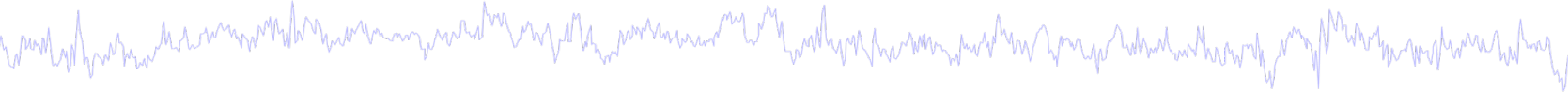
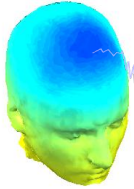


- Import events from Matlab array or ASCII file
- **Import events from data channel**
- Import from Presentation event file
- Import events from E-Prime event file
- Import events from Neuroscan event file

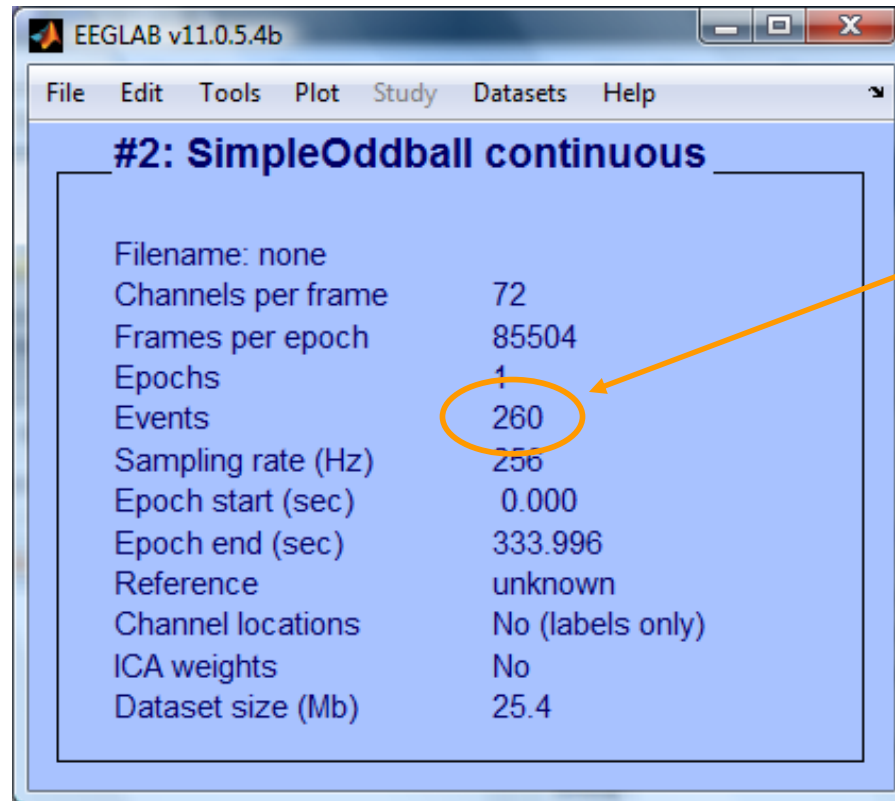
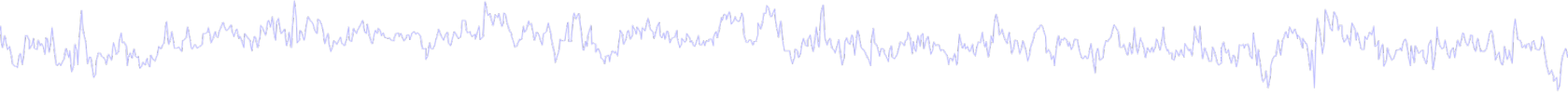
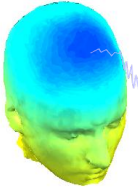


(Often imported automatically
during data import)

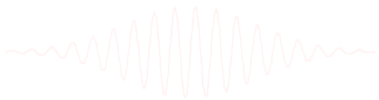
Appearance of an event channel in raw data



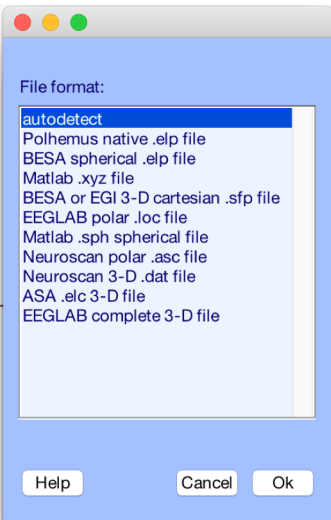
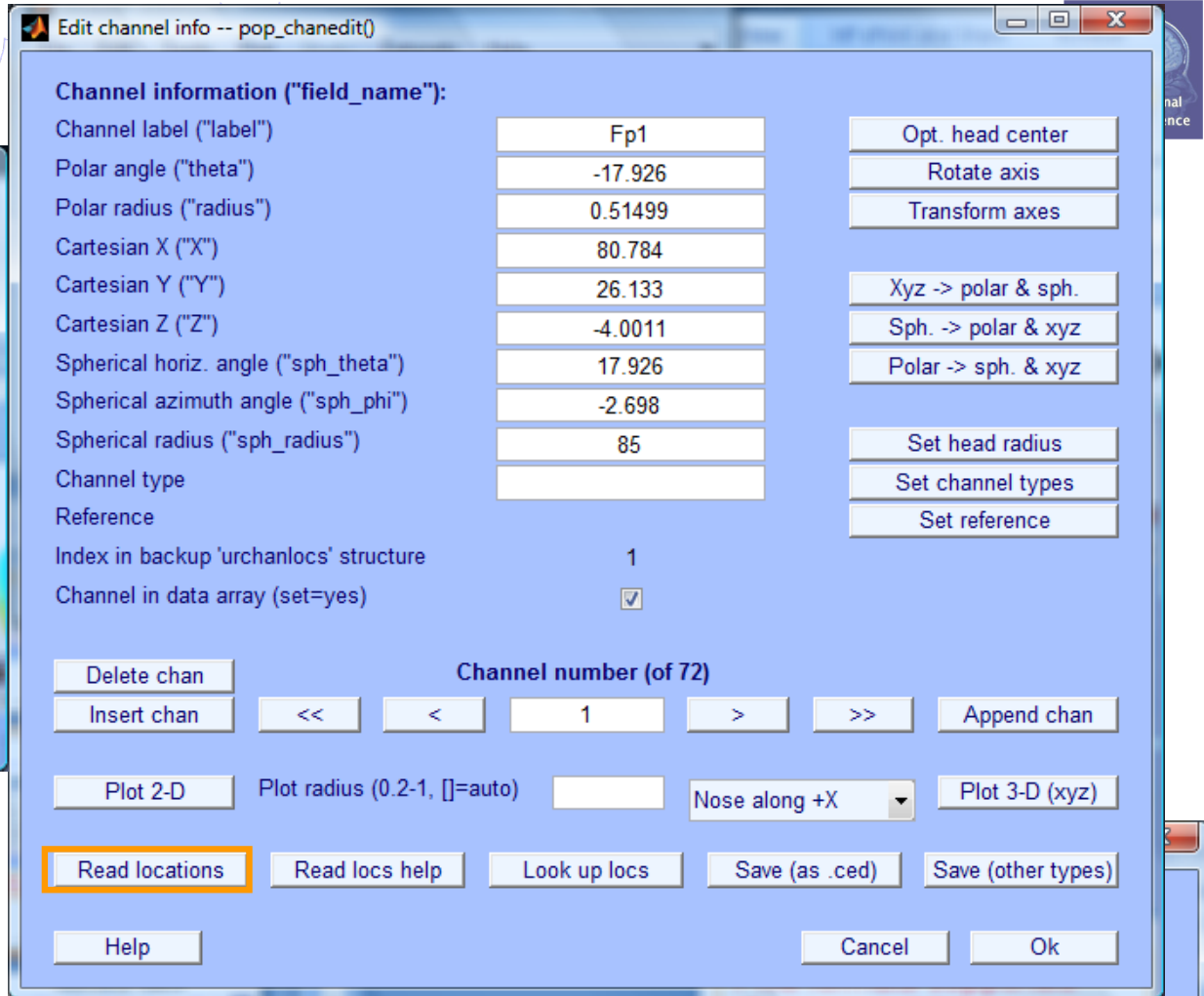
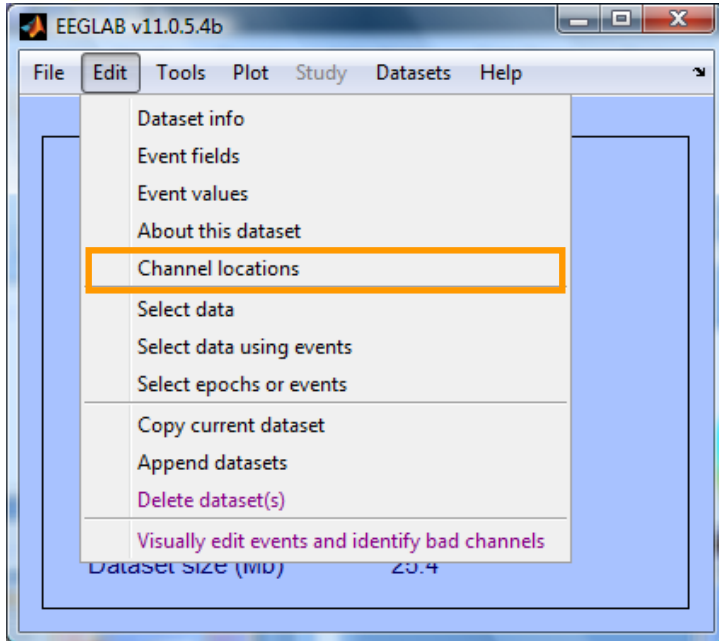
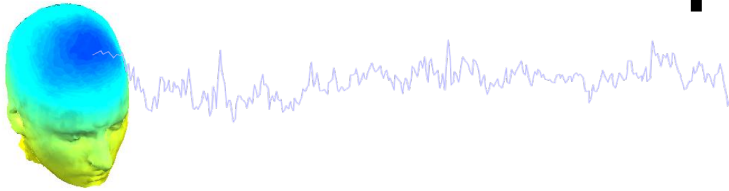
Imported data events



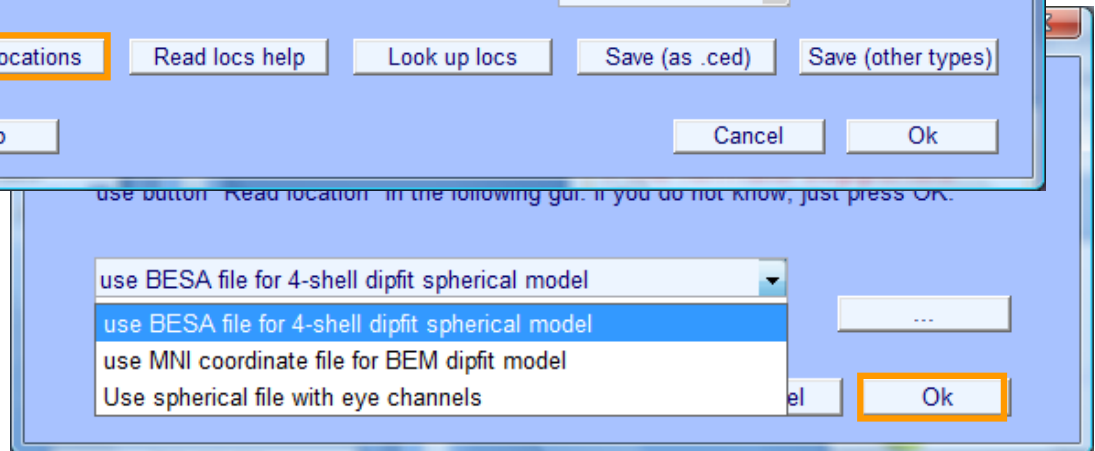
If event import was successful, you will see an appropriate number here

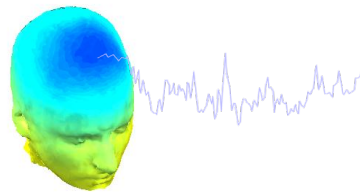


Import channel locations



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





Edit channel info -- pop_chanedit()

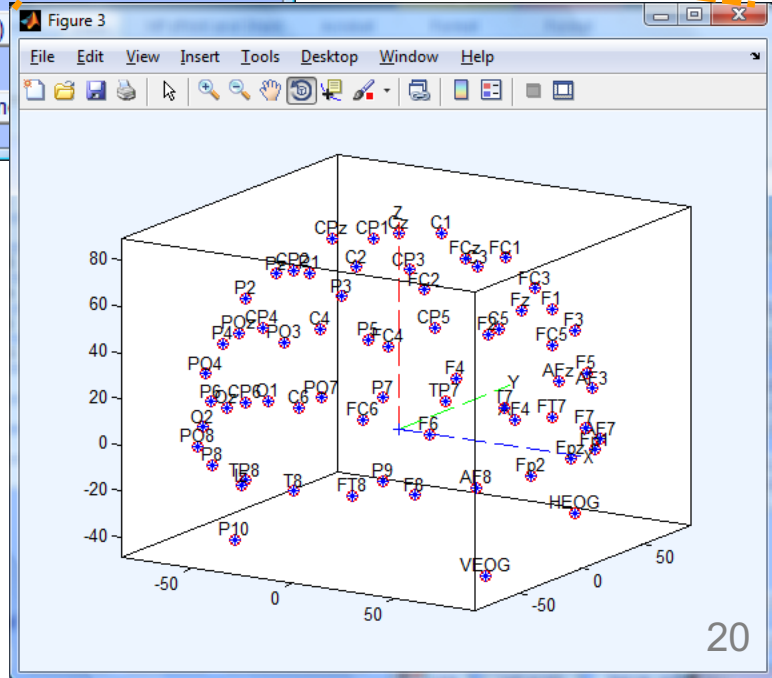
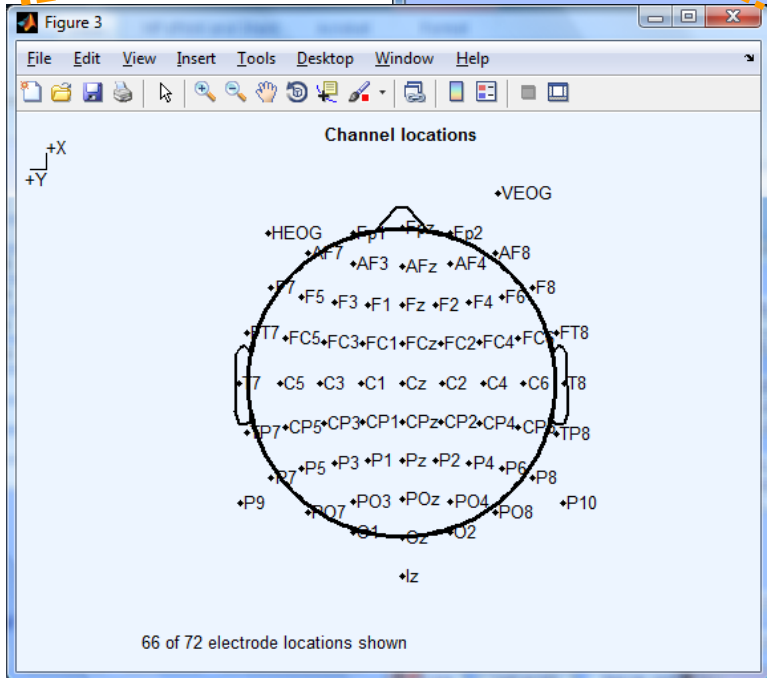
Channel information ("field_name"):

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

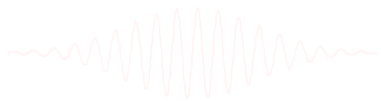
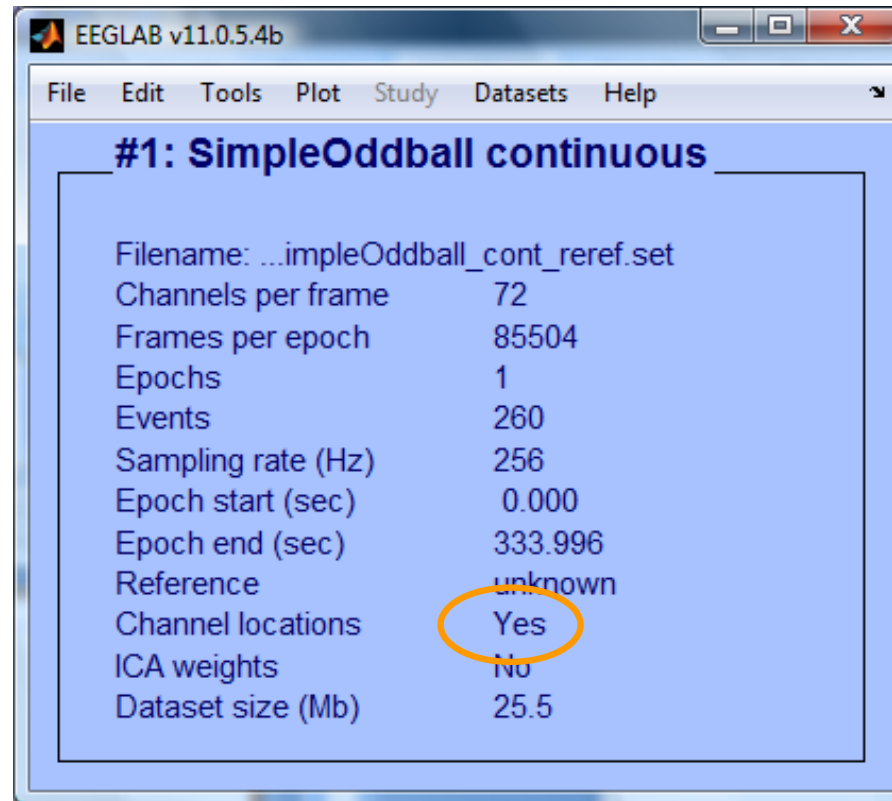
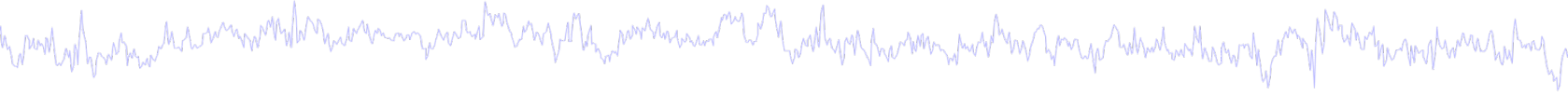
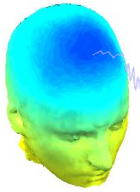
Channel number (of 72): 68

Buttons: Delete chan, Insert chan, <<, <, >, >>, Append chan

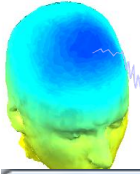
Plot 2-D Plot radius (0.2-1, [=auto]) Nose along +X Plot 3-D (xyz)



Imported channel locations



Comments and dataset history



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 dataset(s)
- Visually edit events and identify bad channels

Dataset size (MB) 23.4

Read/Enter comments -- pop_comments()

About this dataset

Data recorded by Marissa Westerfield
Recording date: Oct. 14, 2011

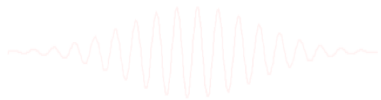
Paradigm:
-Participant looked at fixation box in center of screen
-Two types of stimuli (outline of a circle, outline of a star) were presented in the fixation box in random order
-Participant pressed a button in response to the star

Stimulus codes:
1 = circle
2 = star
3 = button press

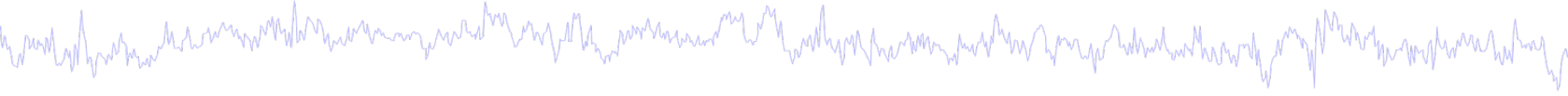
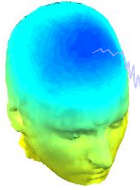
Recording information:
-reference electrodes were placed on right and left mastoids (data has already been referenced and the mastoid channels have been removed)

Processing steps:
high-pass filter - 0.5 Hz
Cleanline applied to 60, 120 Hz

CANCEL SAVE



Pre-processing pipeline



**Collect
EEG data**

Import into EEGLAB

**Import event markers
and channel locations**

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

**High pass filter
(~.5 – 1 Hz)**

Examine raw data

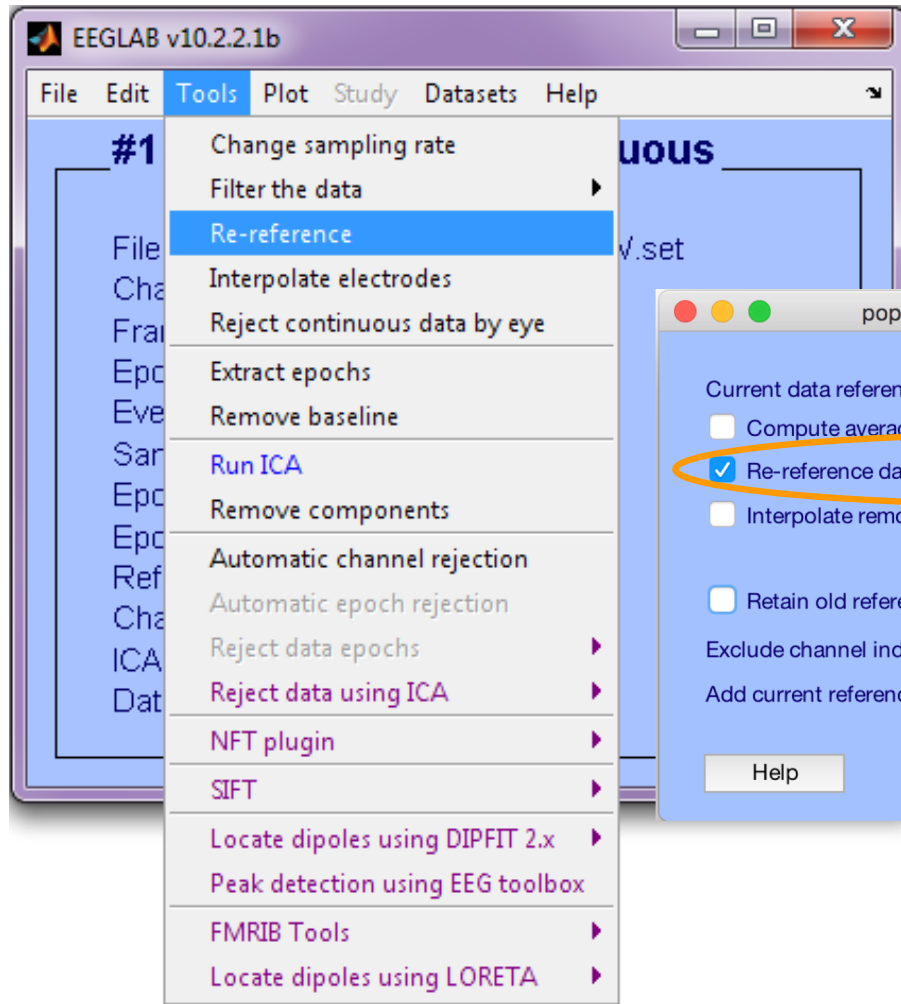
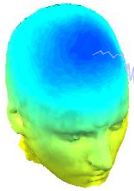
**Identify/reject
bad channels**

**Reject large artifact
time points**

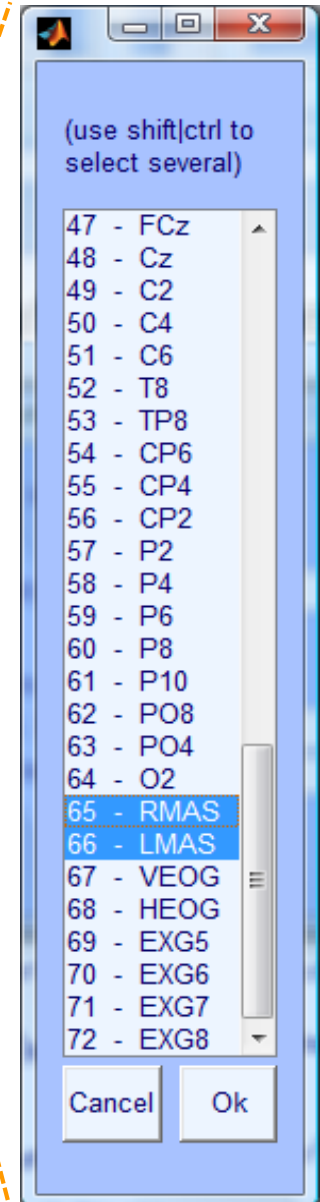
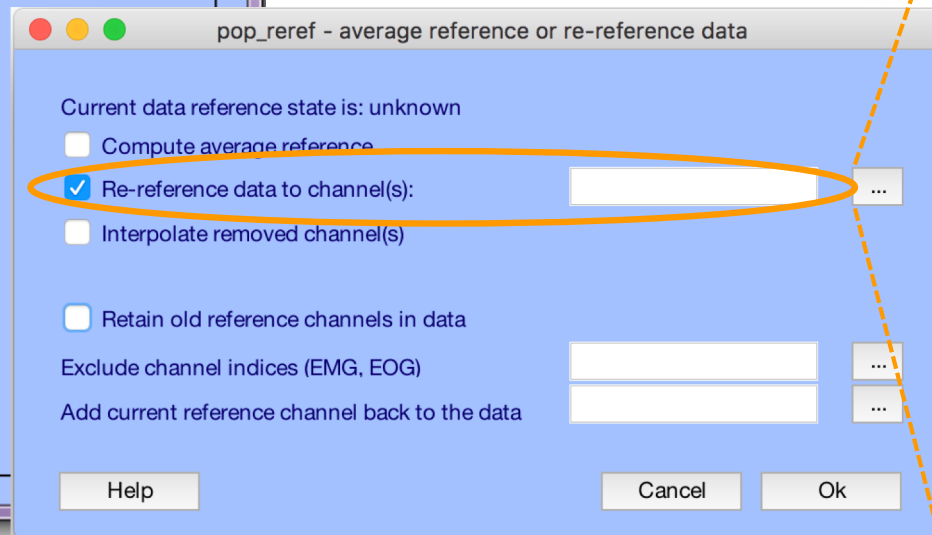
**Run ICA and
reject components**

Done

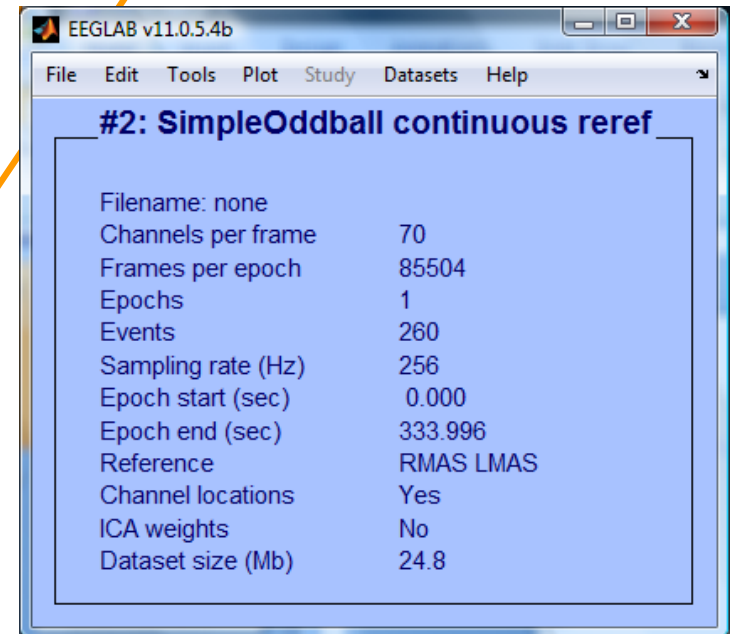
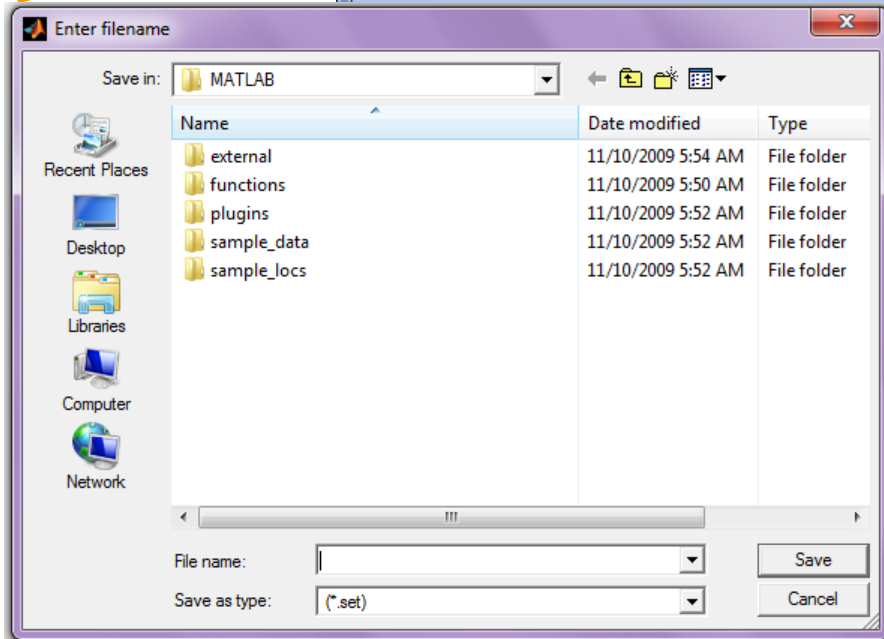
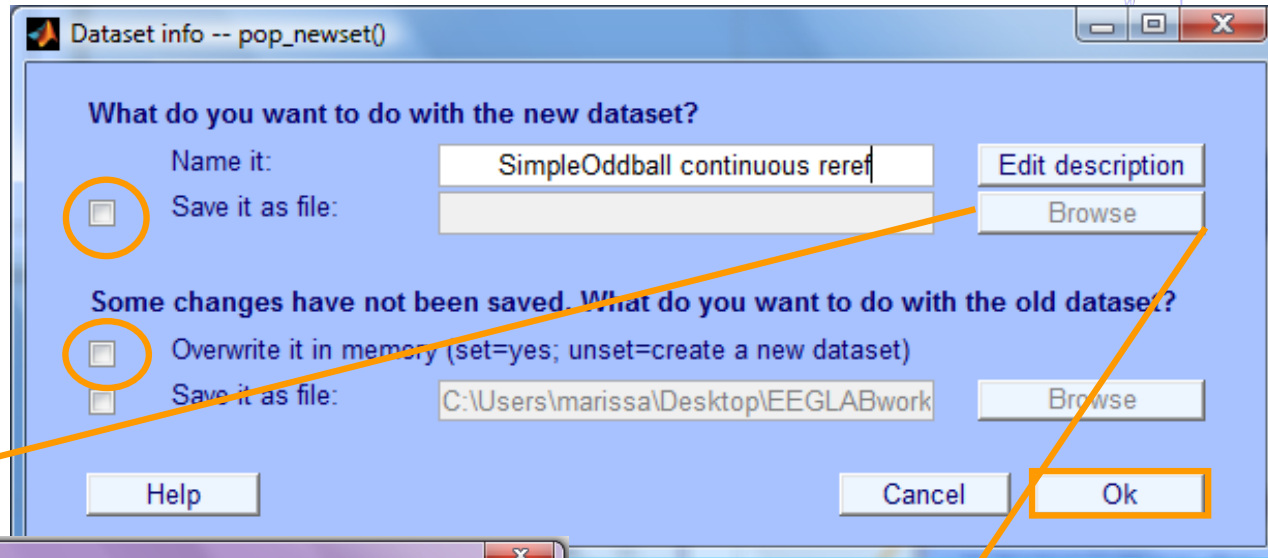
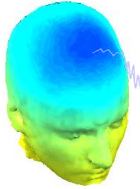
Re-reference data (if necessary/desired)



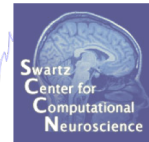
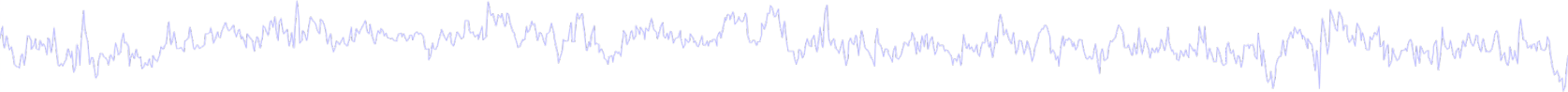
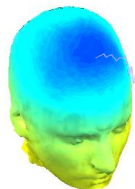
Re-reference to
(e.g.) 'linked mastoids'



Save new dataset, keep old one



Multiple active datasets



EEGLAB v11.0.5.4b

File Edit Tools Plot Study Datasets Help

#1: SimpleOddball continuous

Filename:	...impleOddball_cont_reref.set
Channels per frame	72
Frames per epoch	85504
Epochs	1
Events	260
Sampling rate (Hz)	256
Epoch start (sec)	0.000
Epoch end (sec)	333.996
Reference	unknown
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	25.5

EEGLAB v11.0.5.4b

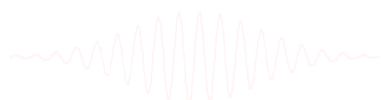
File Edit Tools Plot Study Datasets Help

#2: SimpleOddball

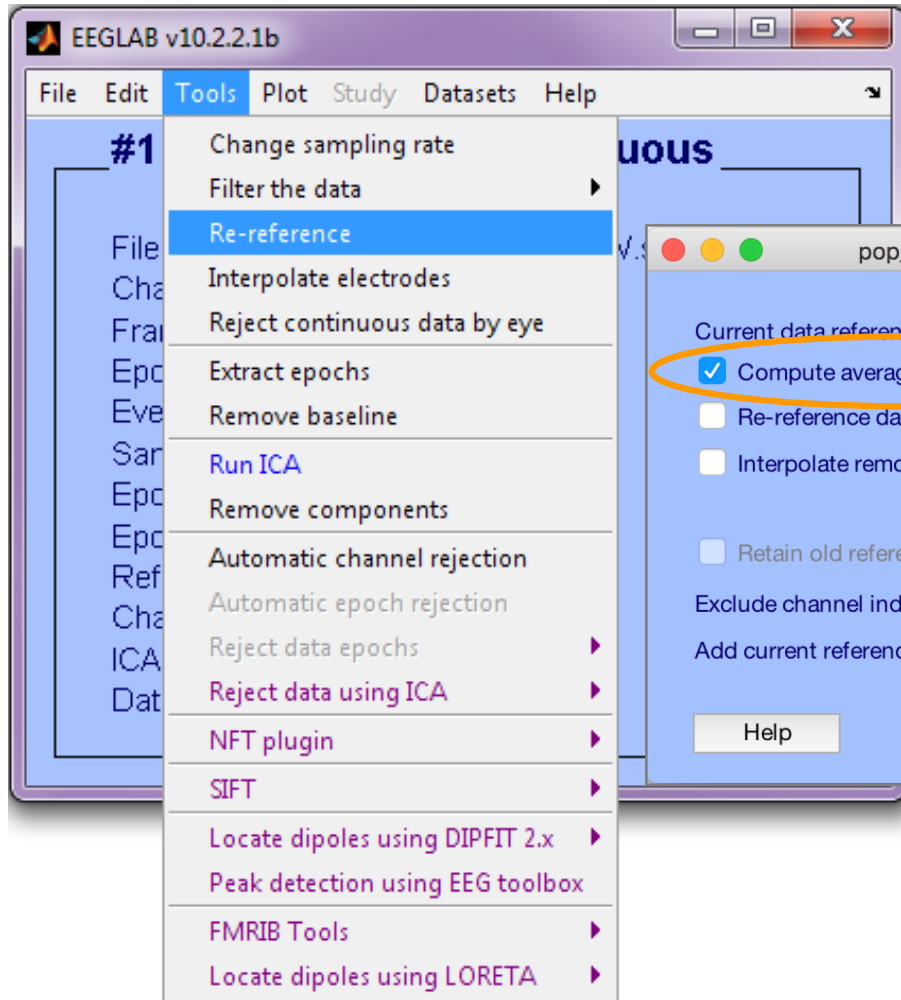
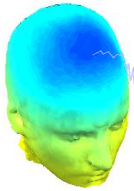
Filename:	none
Channels per frame	
Frames per epoch	85504
Epochs	1
Events	260
Sampling rate (Hz)	256
Epoch start (sec)	0.000
Epoch end (sec)	333.996
Reference	RMAS LMAS
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	24.8

Dataset 1: SimpleOddball continuo
 Dataset 2: SimpleOddball continuo

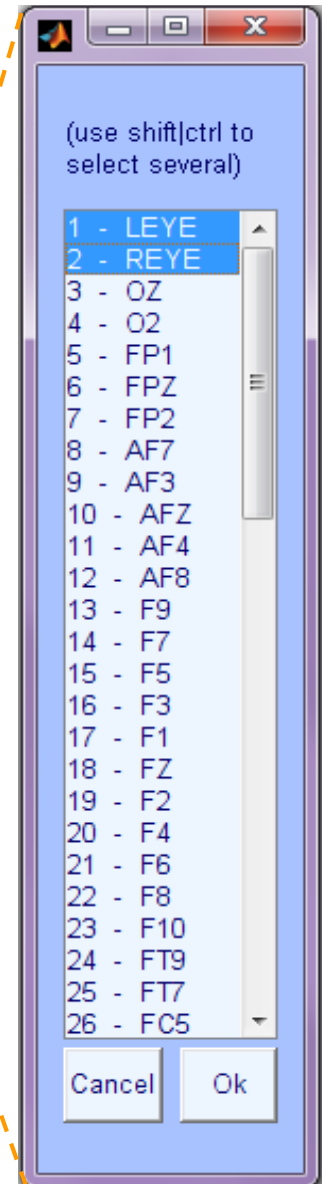
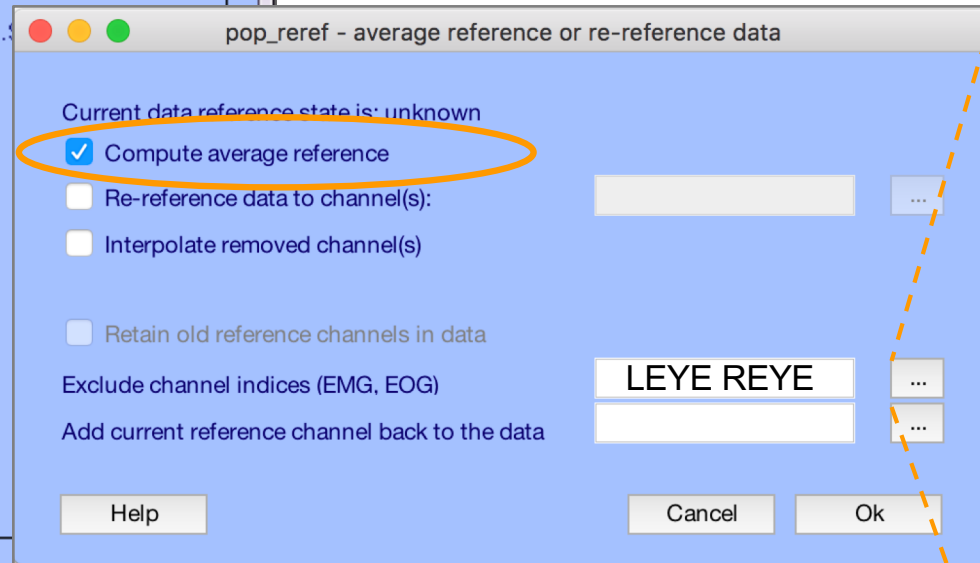
Select multiple datasets



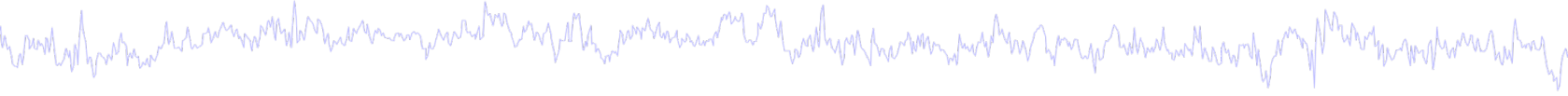
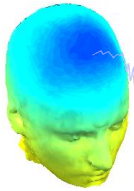
Re-reference data (if necessary/desired)



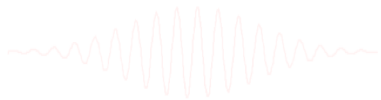
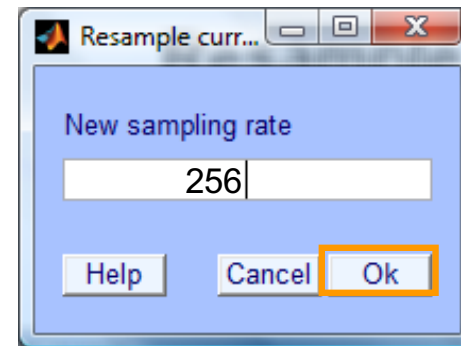
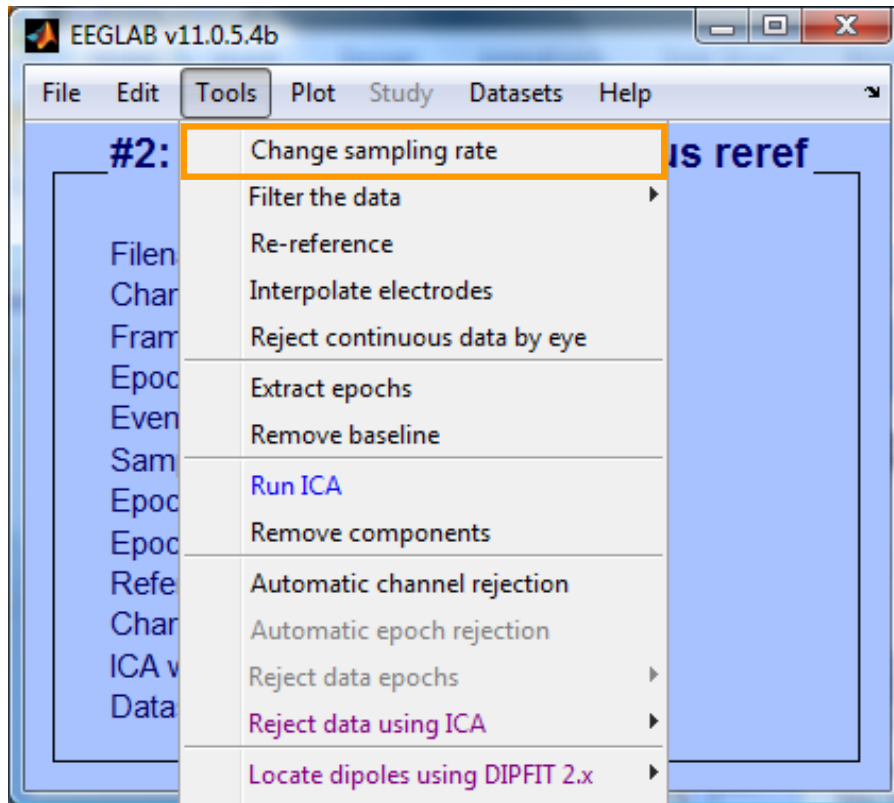
Or,
average reference



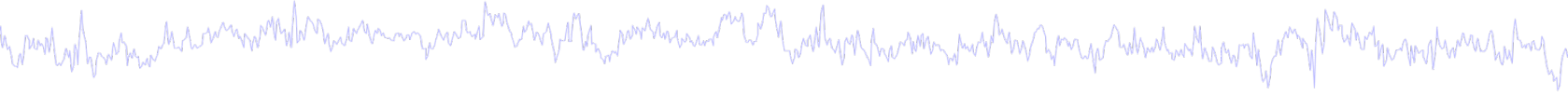
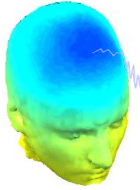
Resample data (if desired)



Reason: Reduce space, time.



Pre-processing pipeline



Collect EEG data

Import into EEGLAB

Import event markers and channel locations

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

**High pass filter
(~.5 – 1 Hz)**

Examine raw data

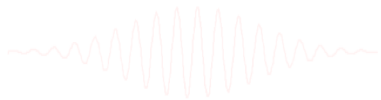
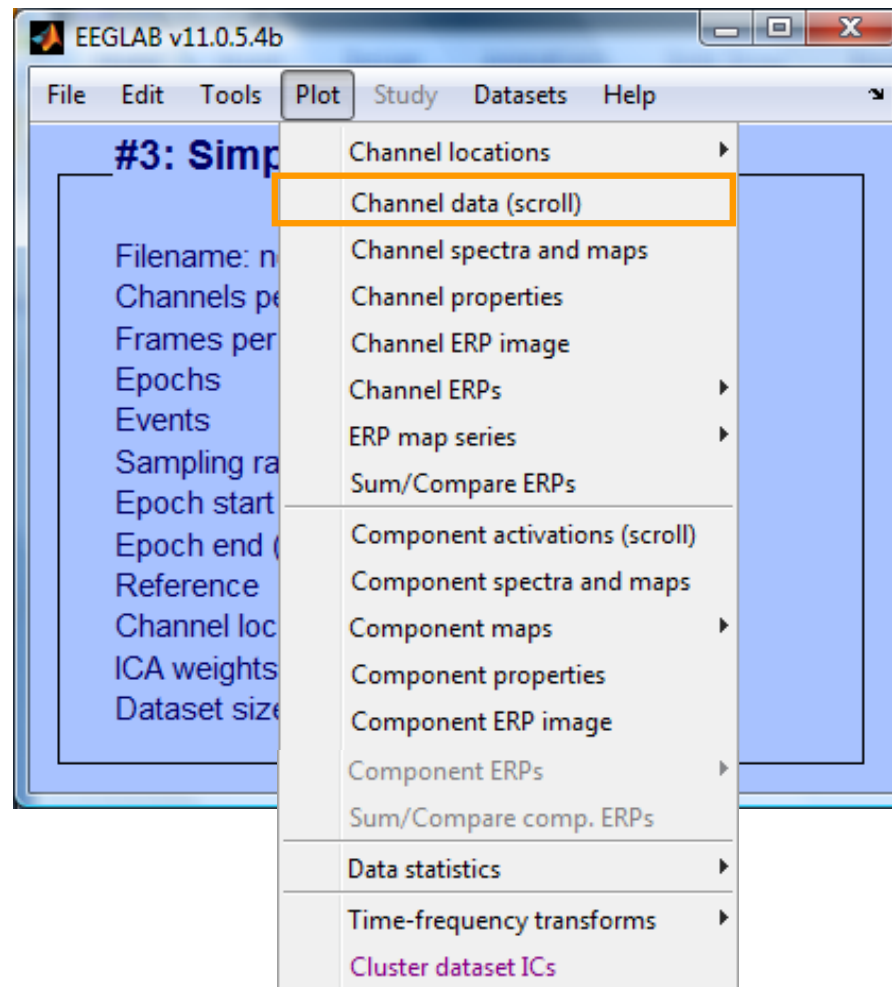
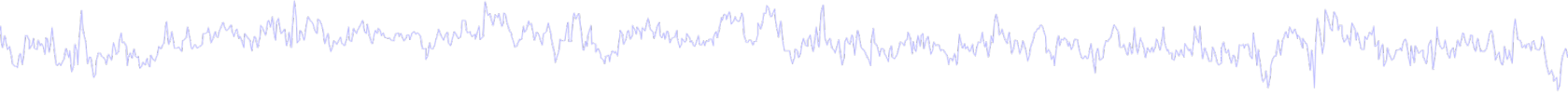
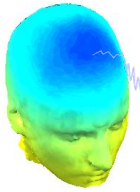
**Identify/reject
bad channels**

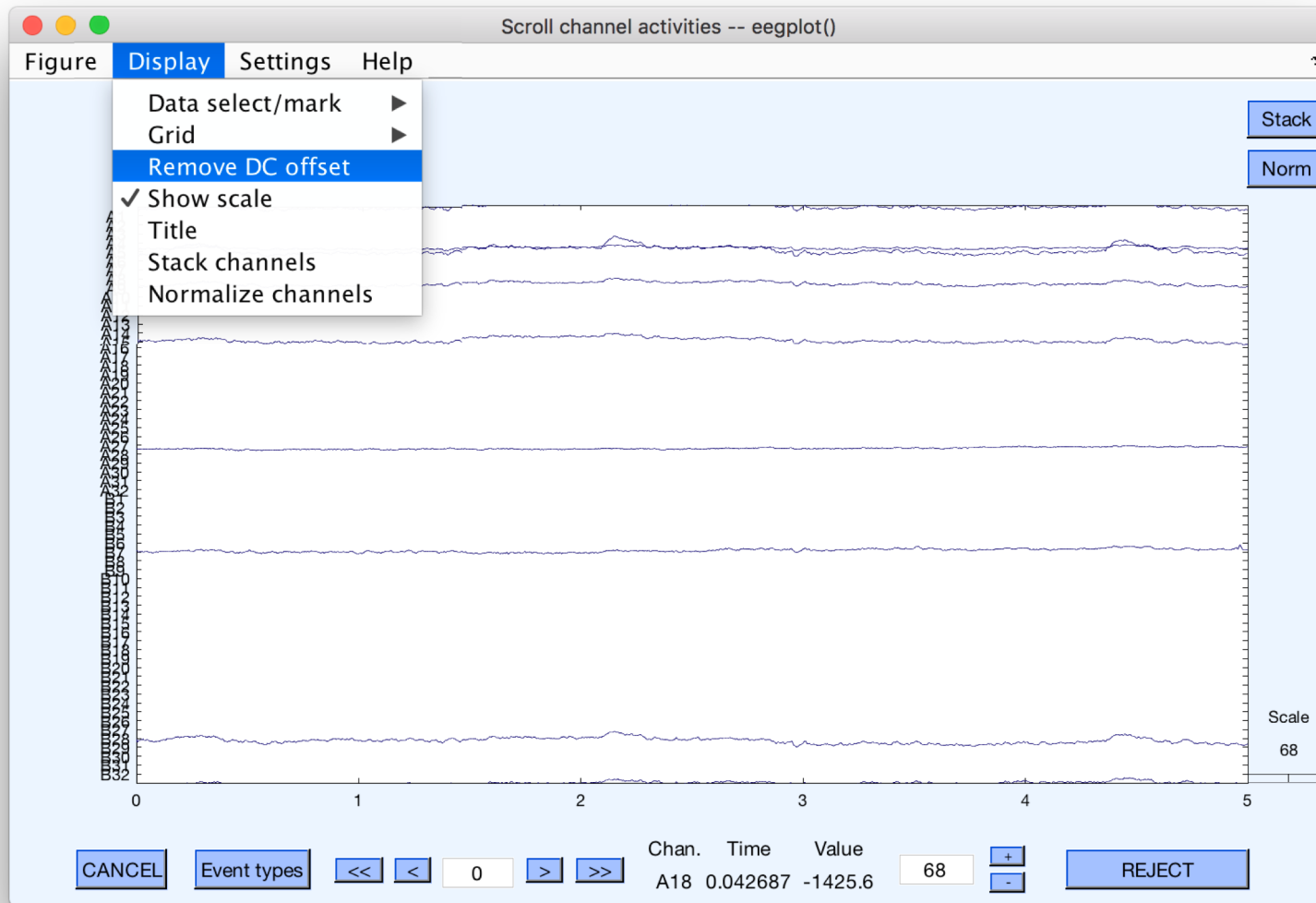
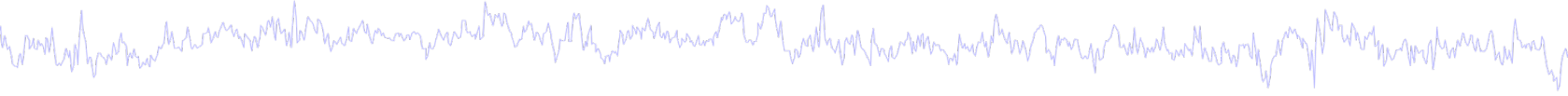
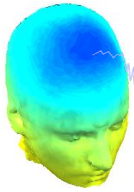
**Reject large artifact
time points**

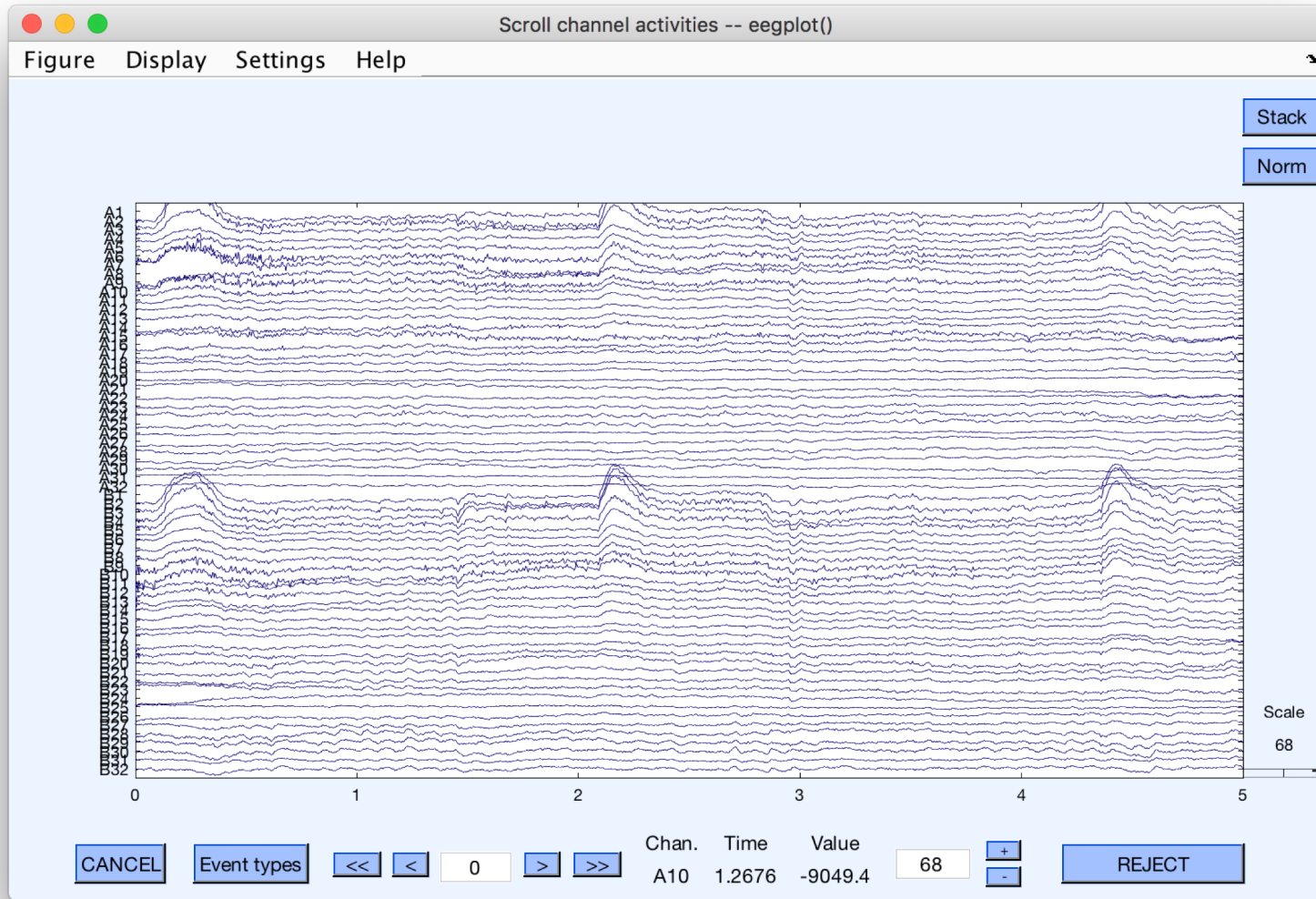
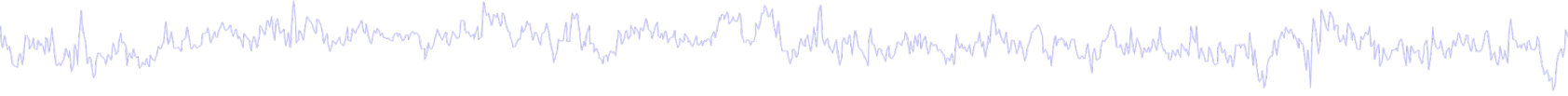
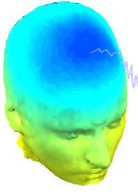
**Run ICA and
reject components**

Done

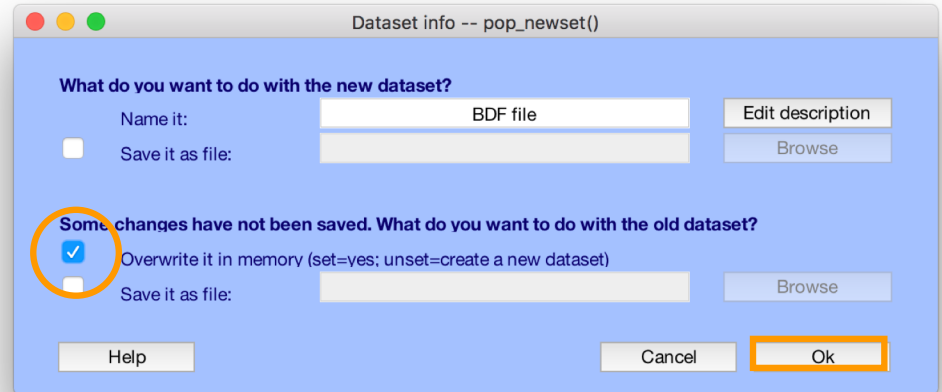
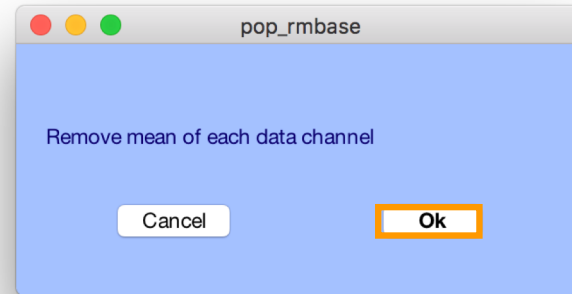
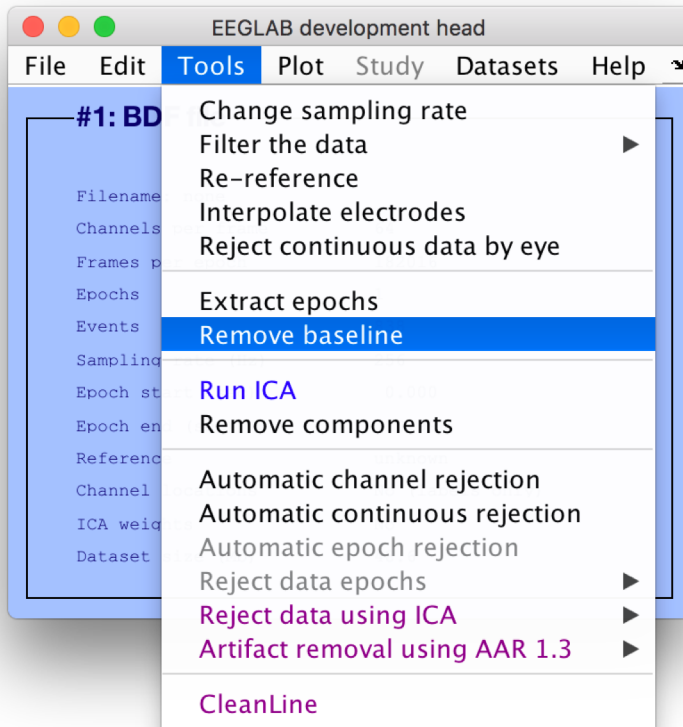
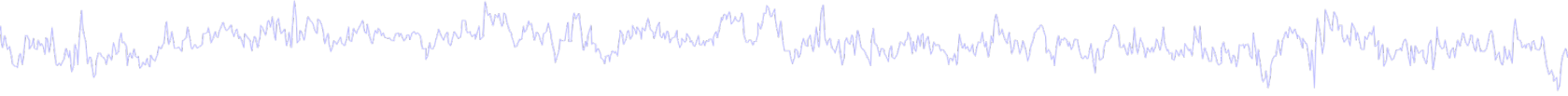
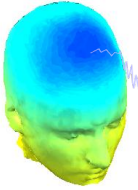
Scroll channel data





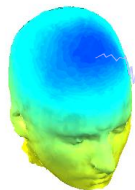


Remove DC offset

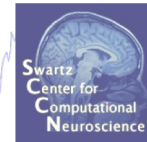


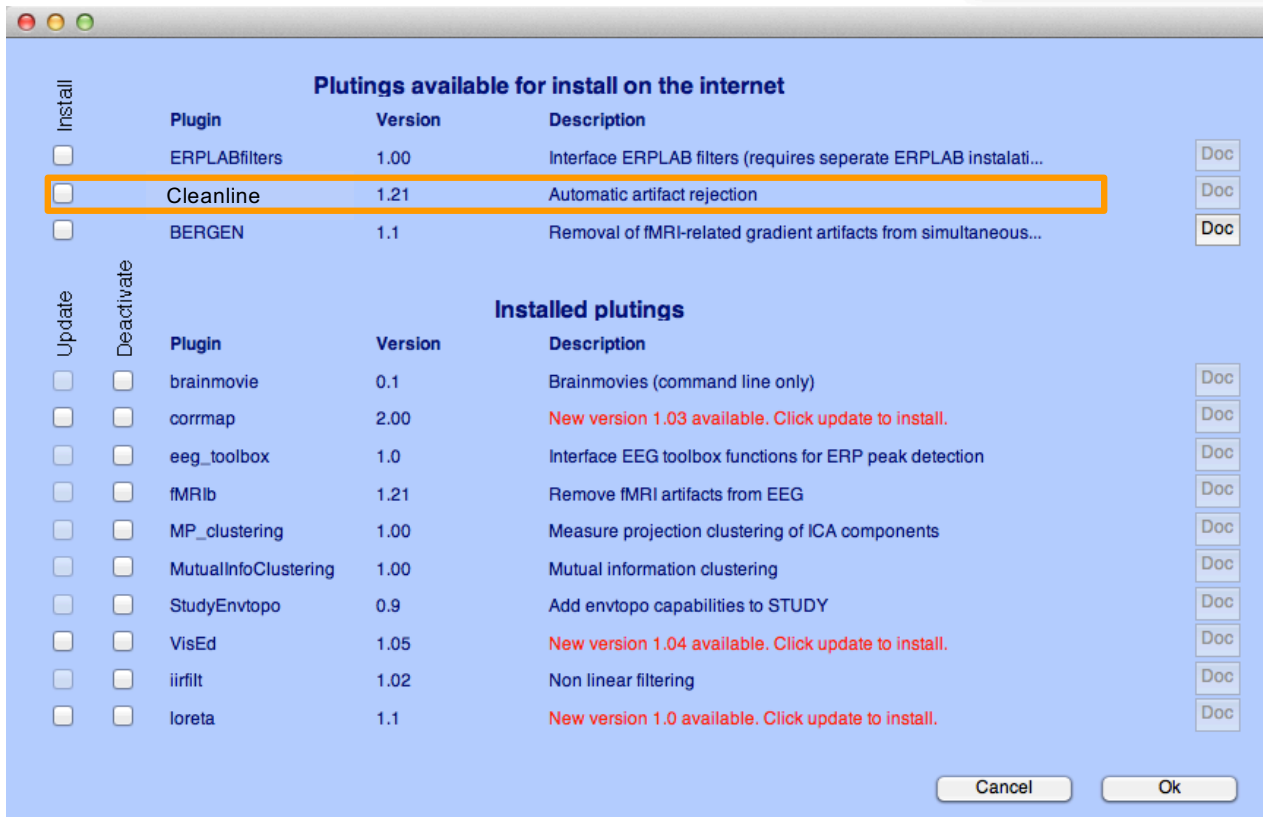
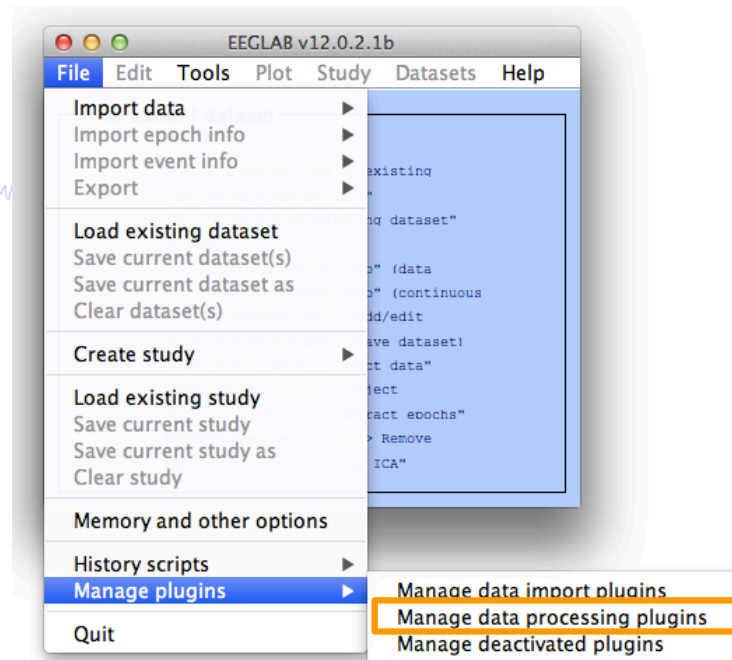
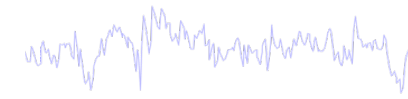
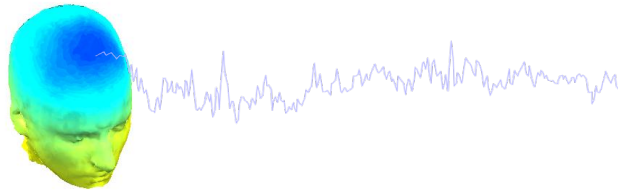
DC offsets introduce large filter artifact at signal boundaries, so it better to remove them prior to filter the signal.

High-Pass Filter the data



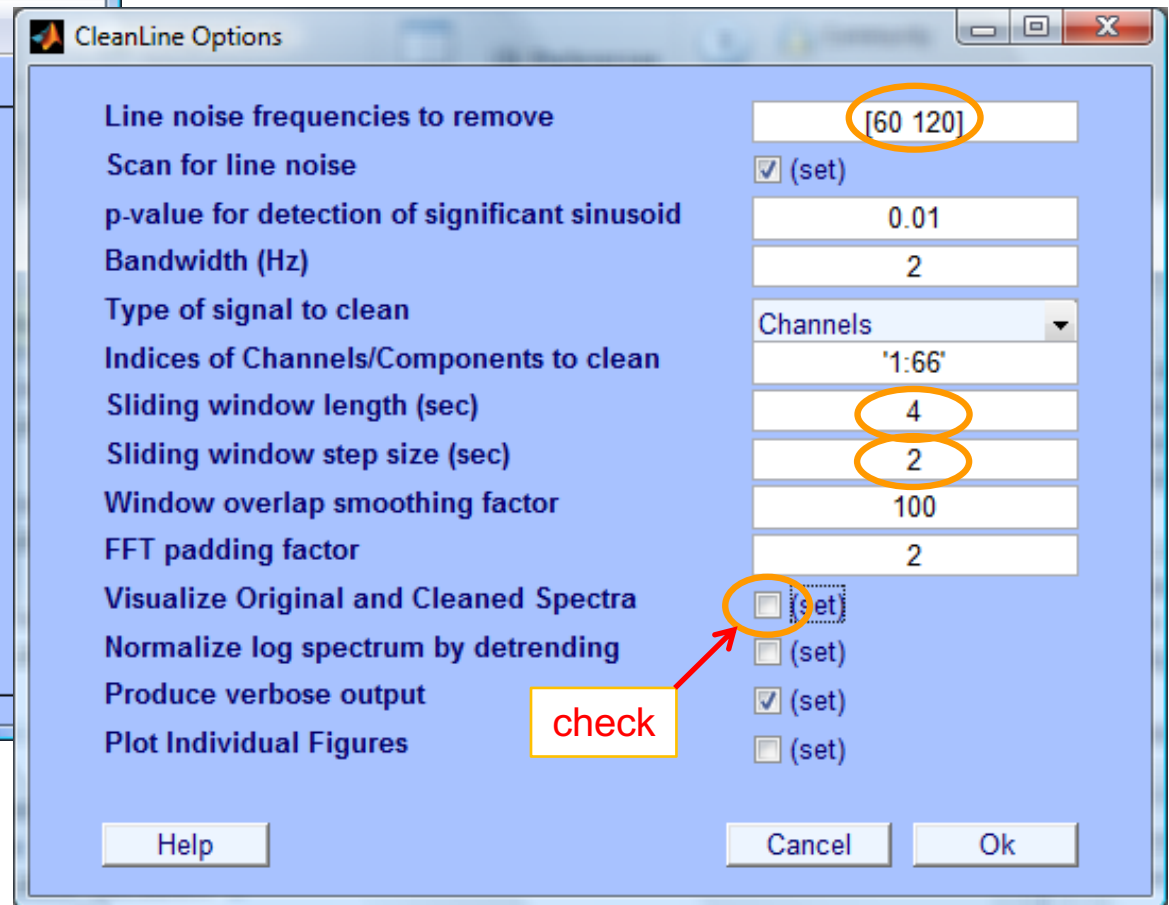
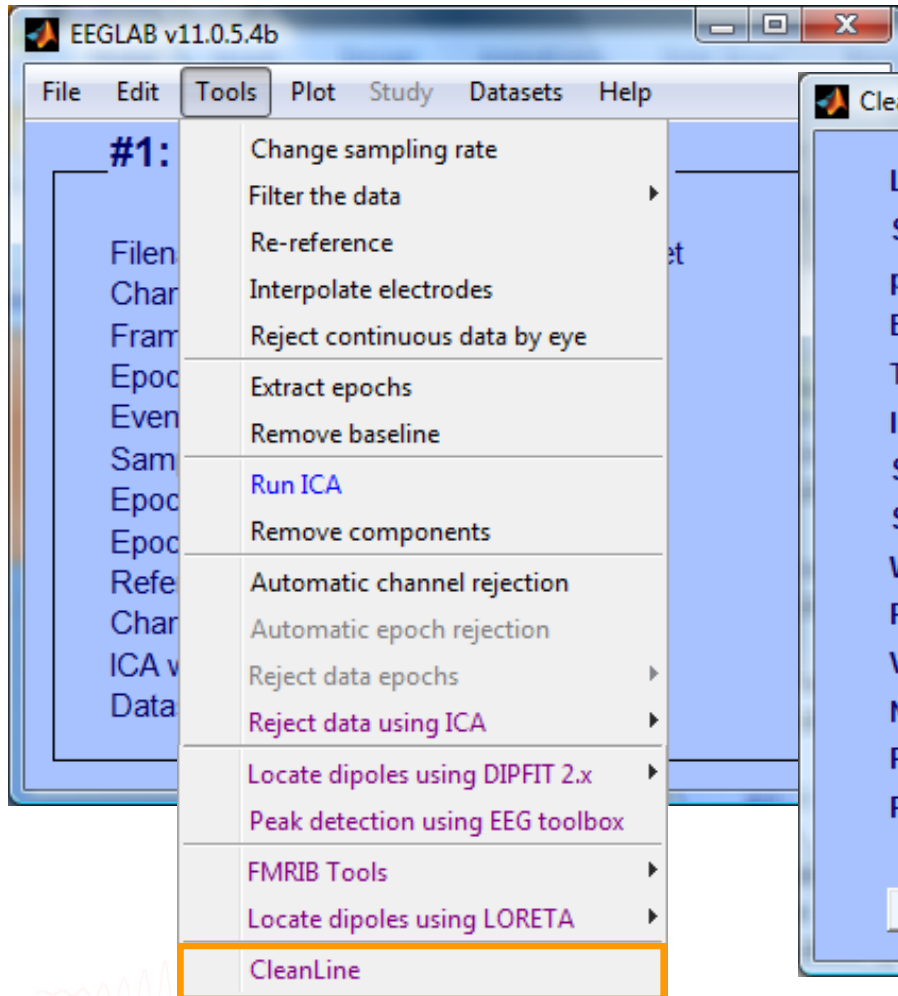
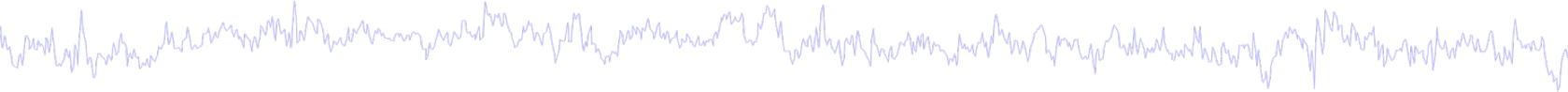
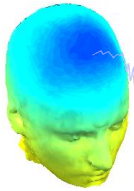
Reason: remove slow, possibly large amplitude, drift



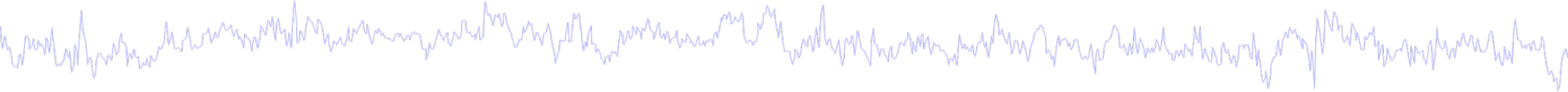
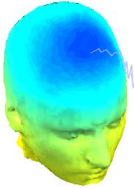


CleanLine uses an approach for line noise removal advocated by Partha Mitra and Hemant Bokil in "Observed Brain Dynamics" (2007), Chapter 7.3.4.

Remove line noise (Cleanline)



Plot channel properties



EEGLAB v11.0.5.4b

File Edit Tools **Plot** Study Datasets Help

#1: Simple

Filename: ...

Channels per

Frames per

Epochs

Events

Sampling rate

Epoch start

Epoch end (

Reference

Channel loc

ICA weights

Dataset size

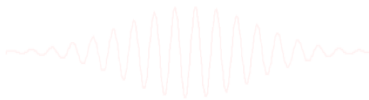
- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties**
- Channel ERP image
- Channel ERPs
- ERP map series
- Sum/Compare ERPs
- Component activations (scroll)
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Sum/Compare comp. ERPs
- Data statistics
- Time-frequency transforms
- Cluster dataset ICs

Component properties - pop_prop()

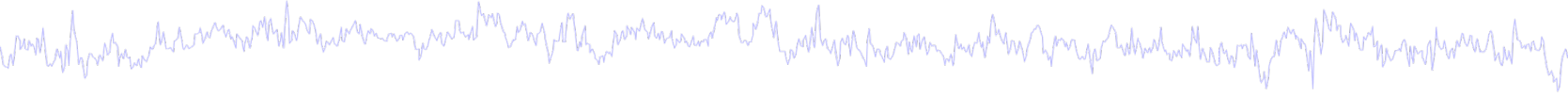
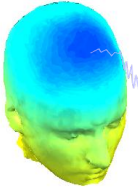
Channel index(ices) to plot:

Spectral options (see spectopo() help):

Help Cancel Ok



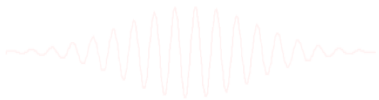
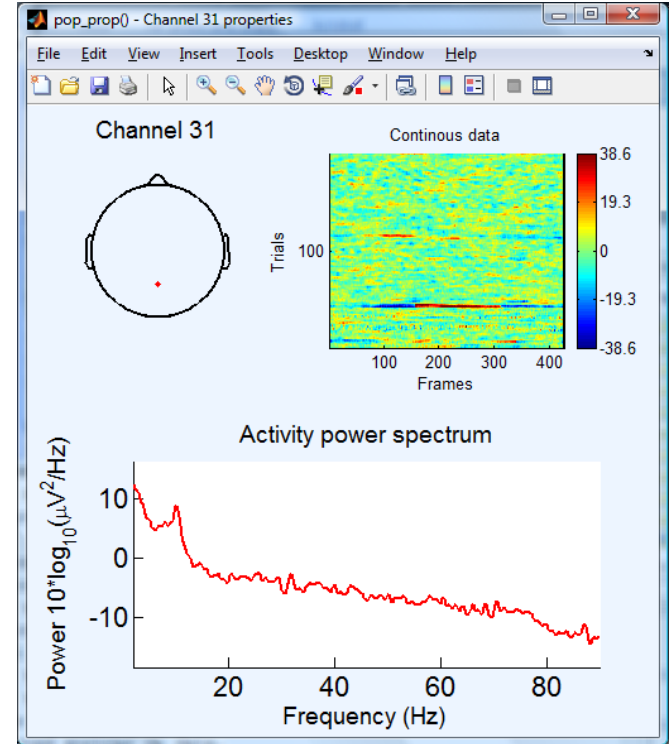
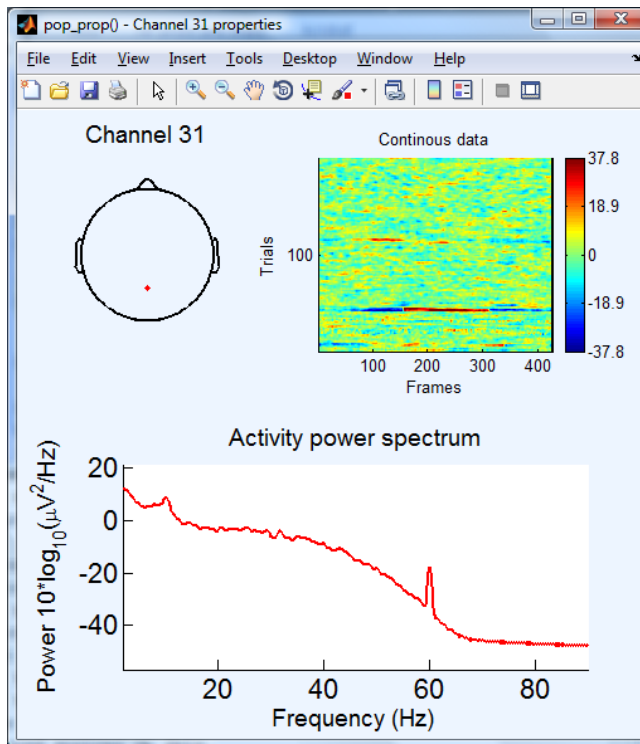
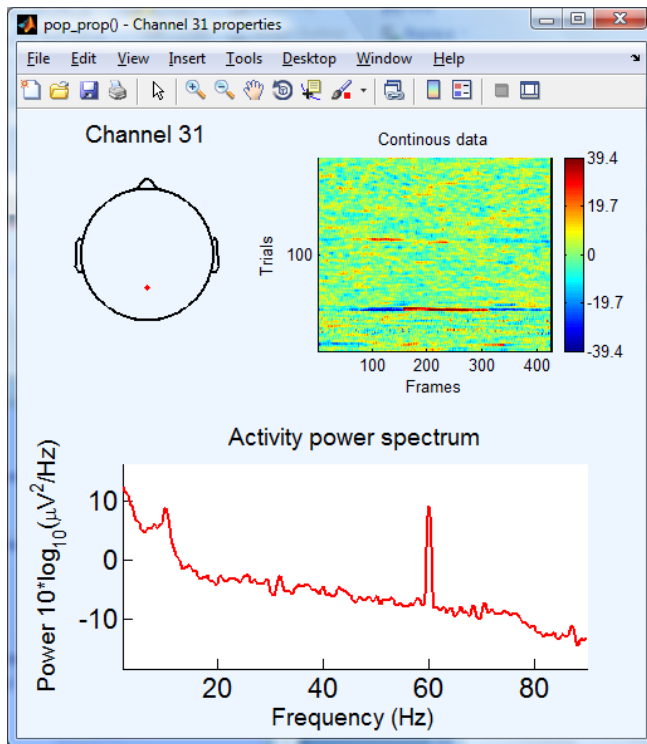
Filter comparisons



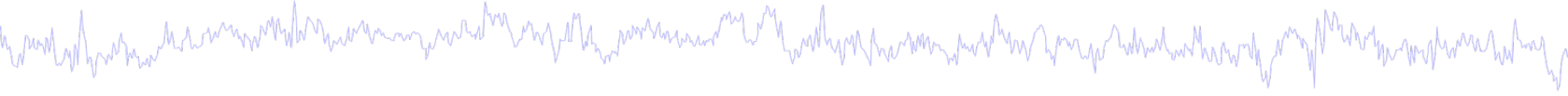
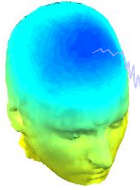
0.5 Hz high-pass filter

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

0.5 Hz high-pass filter
Cleanline



Pre-processing pipeline



**Collect
EEG data**

Import into EEGLAB

**Import event markers
and channel locations**

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

**High pass filter
(~.5 – 1 Hz)**

Examine raw data

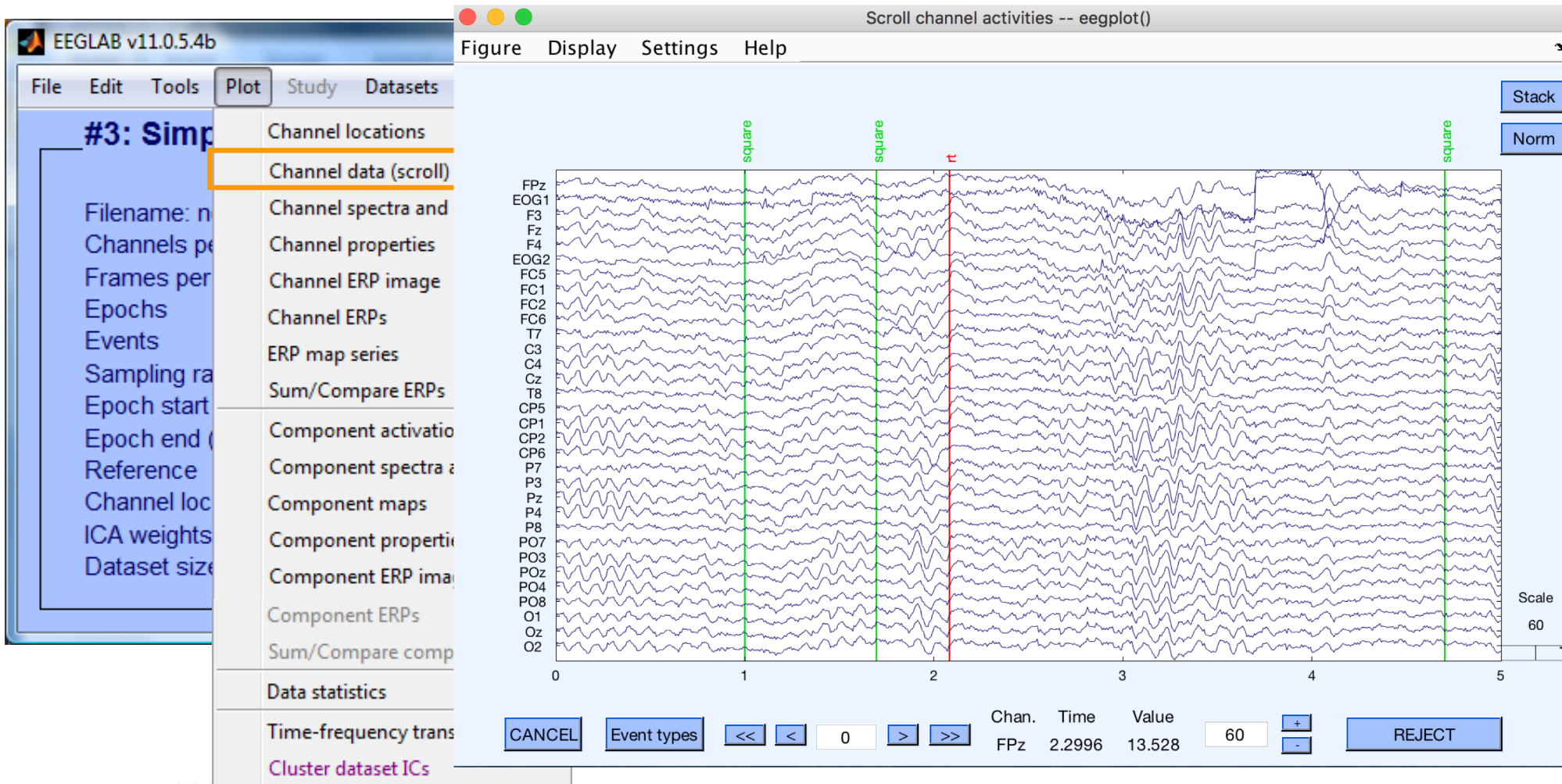
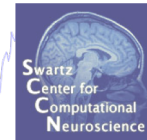
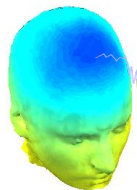
**Identify/reject
bad channels**

**Reject large artifact
time points**

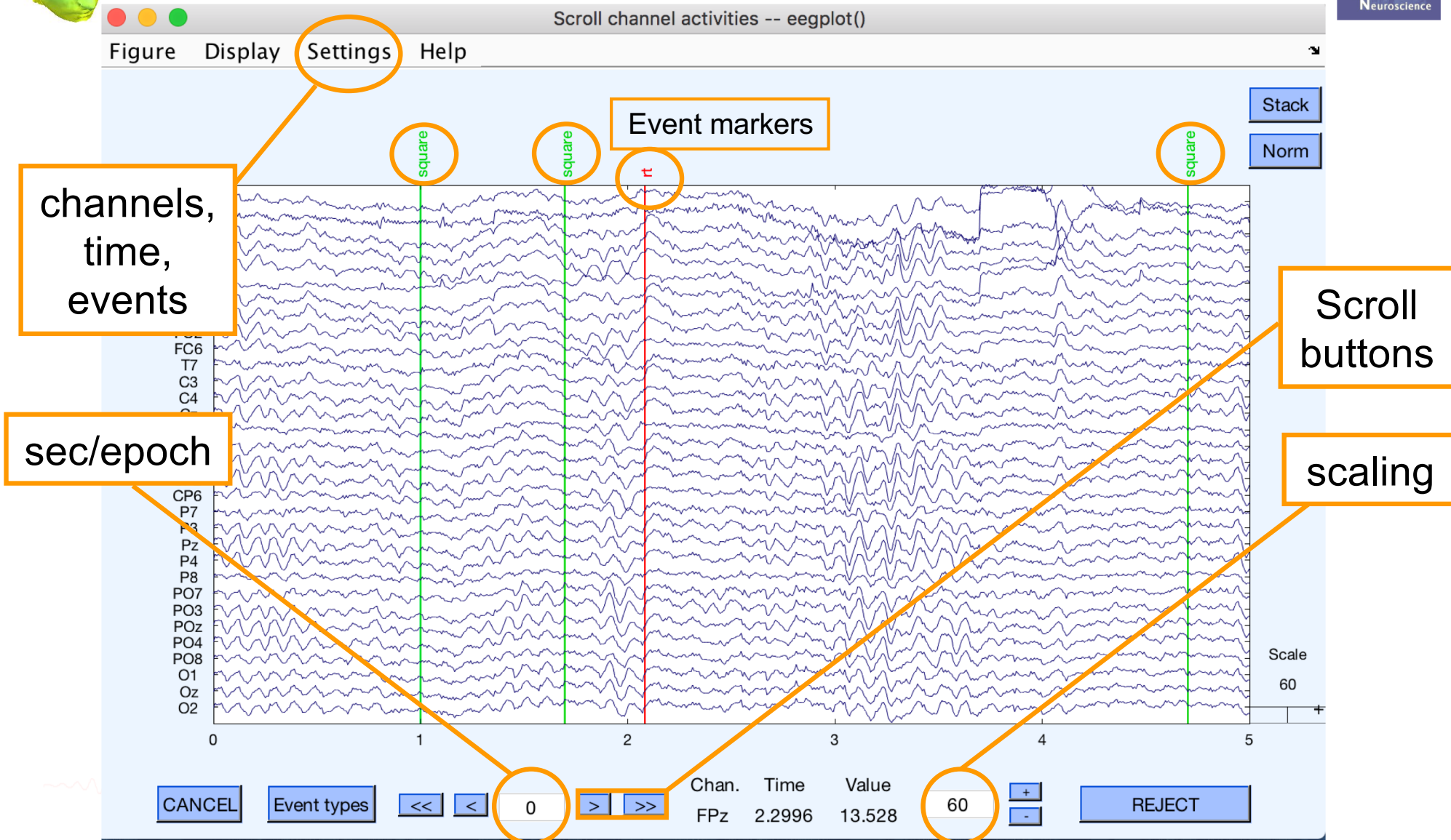
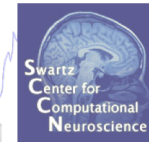
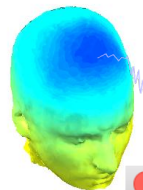
**Run ICA and
reject components**

Done

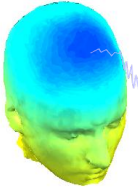
Scroll channel data



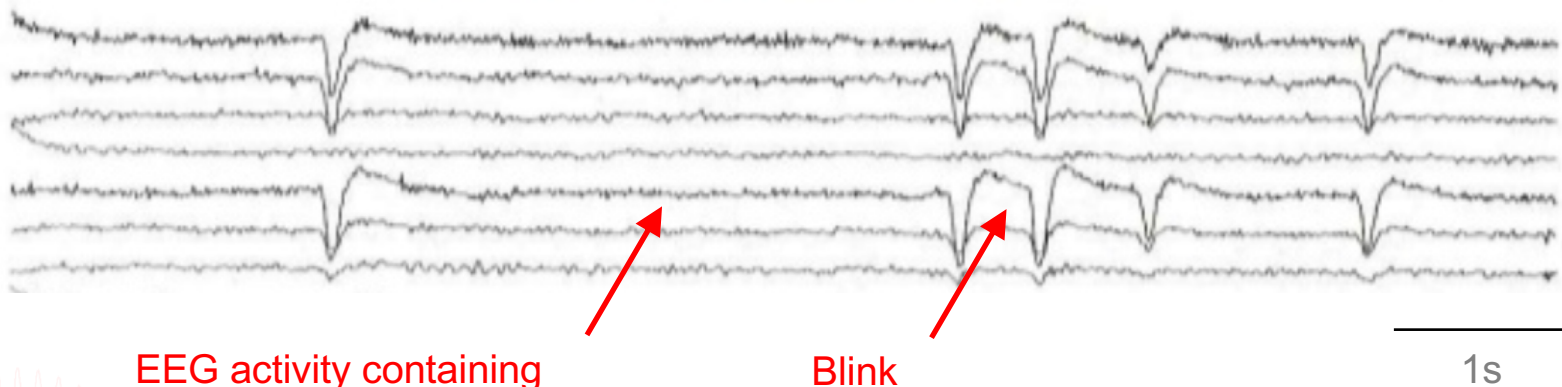
Scroll channel data



EEG artifacts

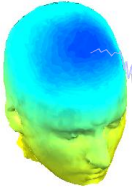


The amplitude of artifacts (such as eye movements) is often larger than the amplitude of brain data which potentially decrease signal/noise ratio, bias data analysis and potential results



EEG activity containing
potential brain data

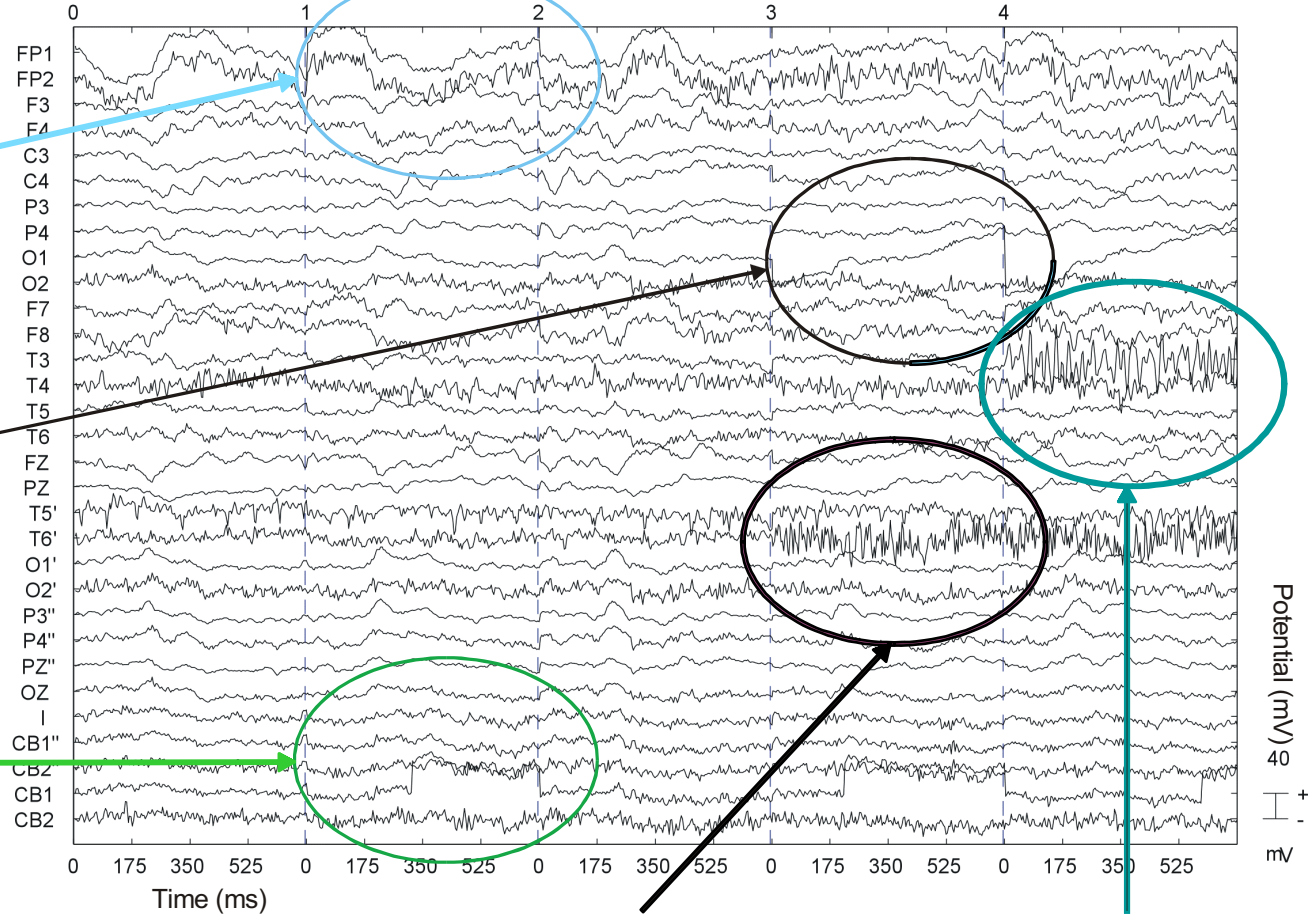
Type of artifacts



2 - Low frequency event (eye movements)

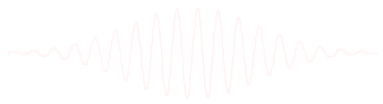
5 - Linear trend

3 - Discontinuity

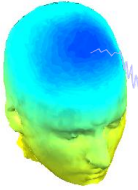


4 - High noise

1 - Transient high frequency event (muscle)

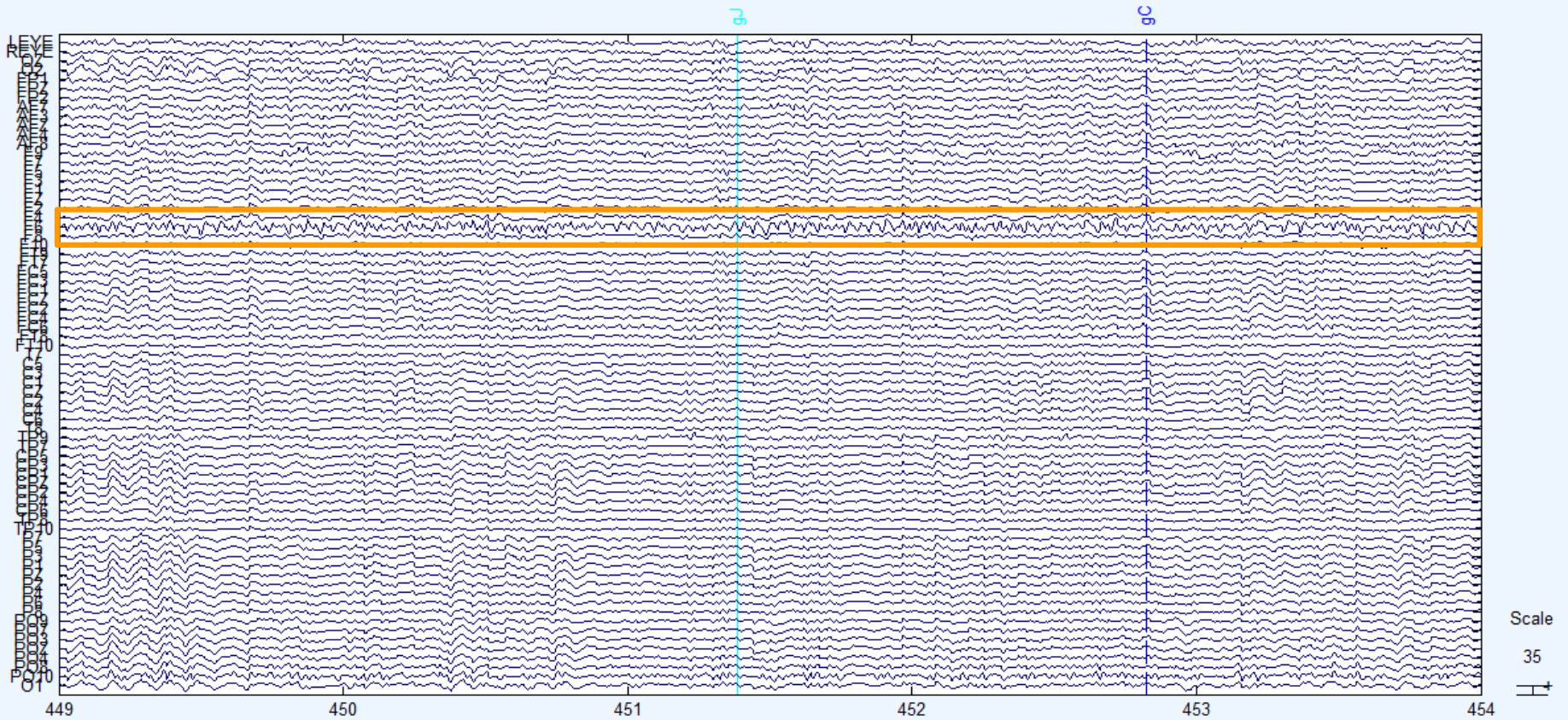


Looking for bad channels



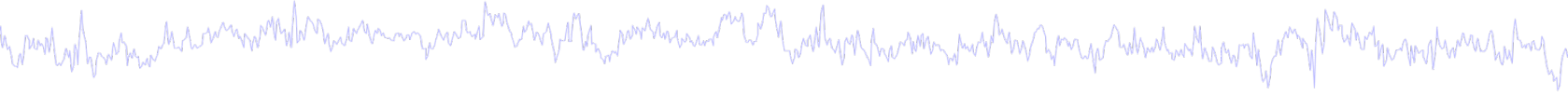
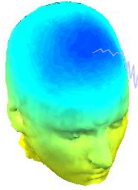
Scroll channel activities -- eegplot()

Figure Display Settings Help



CANCEL Event types << < 449 > >> Chan. Time Value 01 451.0988 3.6619 35 + - REJECT

Pre-processing pipeline



Collect EEG data

Import into EEGLAB

Import event markers and channel locations

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

**High pass filter
(~.5 – 1 Hz)**

Examine raw data

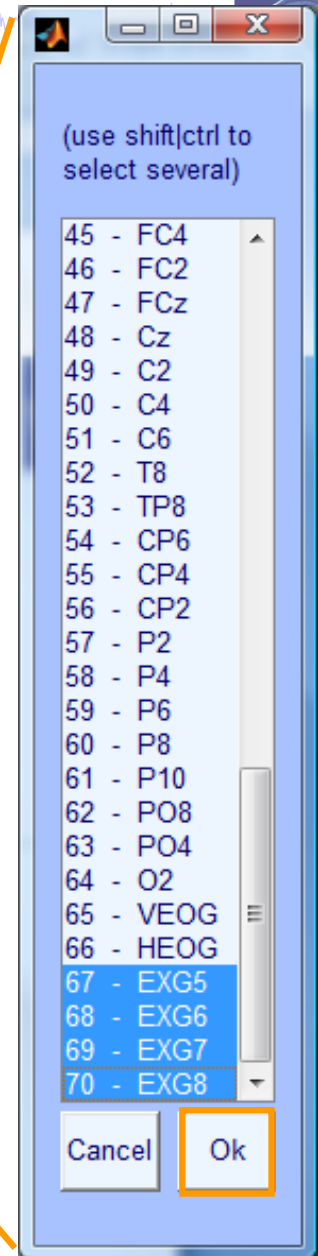
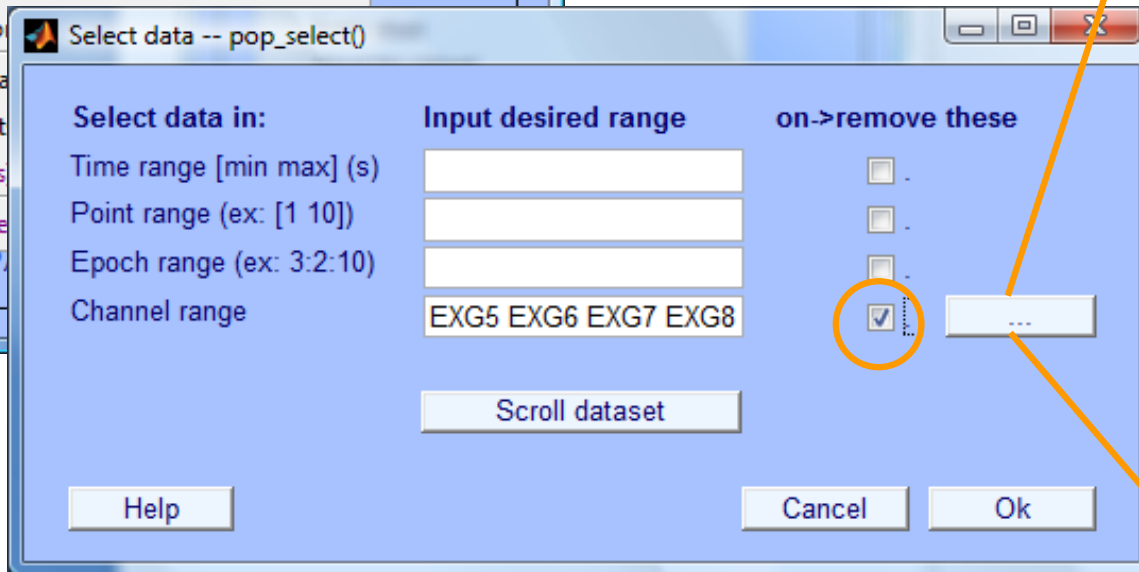
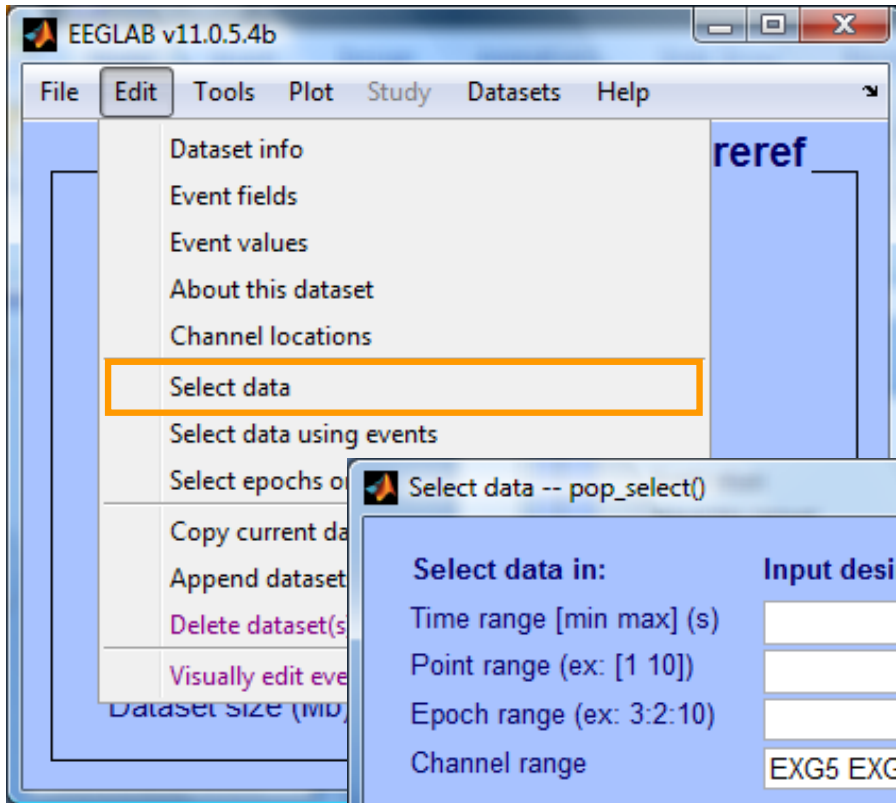
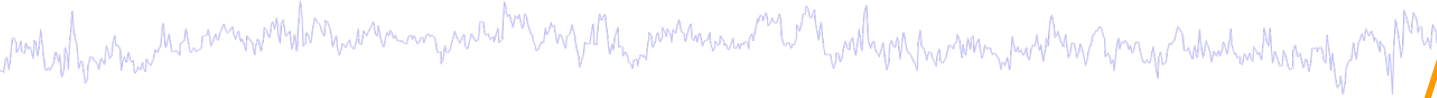
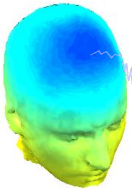
**Identify/reject
bad channels**

**Reject large artifact
time points**

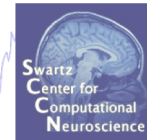
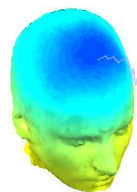
**Run ICA and
reject components**

Done

Remove unwanted channels



Manually identifying bad channels



EEGLAB v11.0.5.4b

File Edit Tools **Plot** Study Datasets Help

#3: Simp

Filename: n

Channels pe

Frames per

Epochs

Events

Sampling ra

Epoch start

Epoch end (

Reference

Channel loc

ICA weights

Dataset size

- Channel locations
- Channel data (scroll)
- Channel spectra and maps**
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Sum/Compare ERPs
- Component activations (scroll)
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Sum/Compare comp. ERPs
- Data statistics
- Time-frequency transforms
- Cluster dataset ICs

Channel spectra and maps -- pop_spectopo0

Epoch time range to analyze [min_ms max_ms]: 0 333996.0938

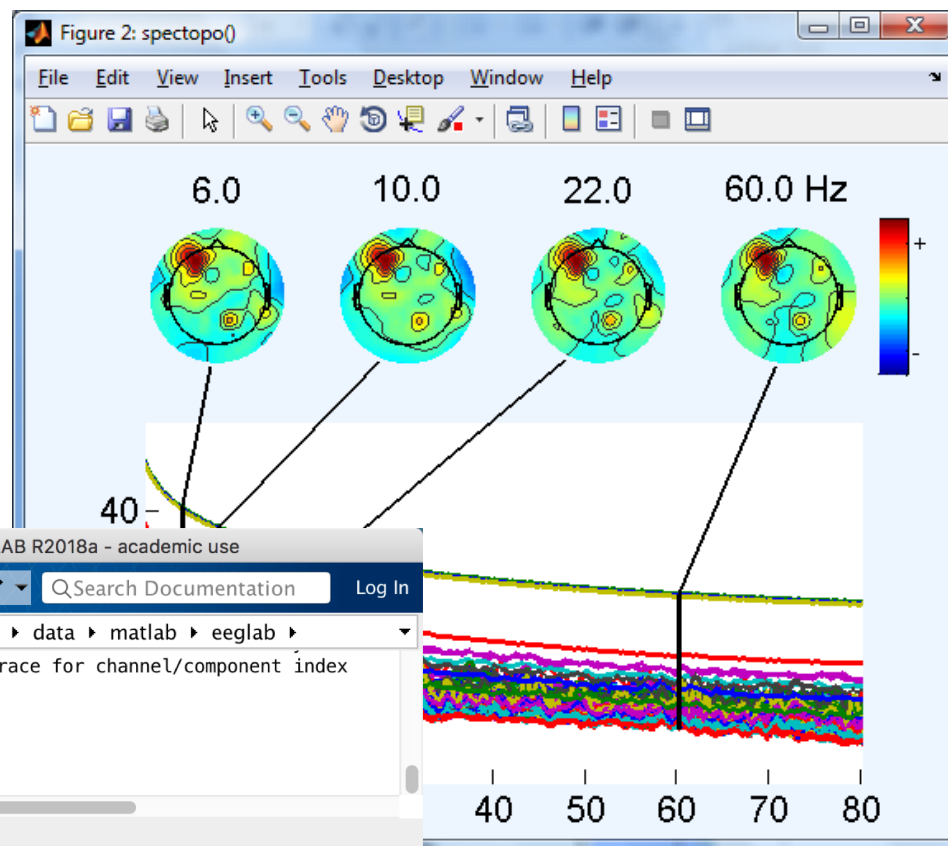
Percent data to sample (1 to 100): 100

Frequencies to plot as scalp maps (Hz): 6 10 22 60

Plotting frequency range [lo_Hz hi_Hz]: 2 80

Spectral and scalp map options (see topoplot): 'electrodes','off'

Help Cancel Ok



MATLAB R2018a - academic use

H... P... A... Q Search Documentation Log In

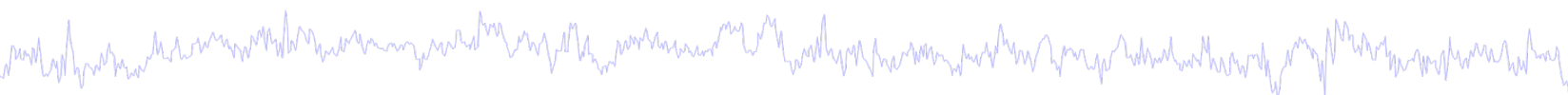
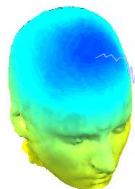
/ > data > matlab > eeglab >

Click on each trace for channel/component index

- Channel 24
- Channel 15
- Channel 32
- Channel 30

Command >>

Manually identifying bad channels



EEGLAB v11.0.5.4b

File Edit Tools **Plot** Study Datasets Help

#3: Simp

- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties**

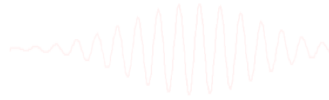
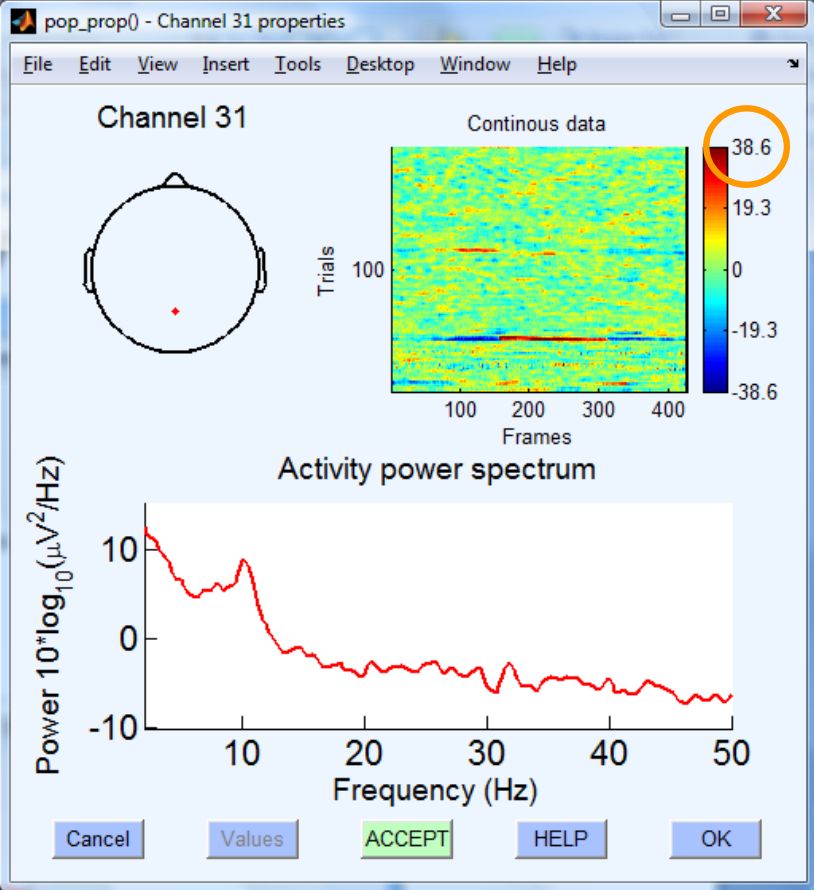
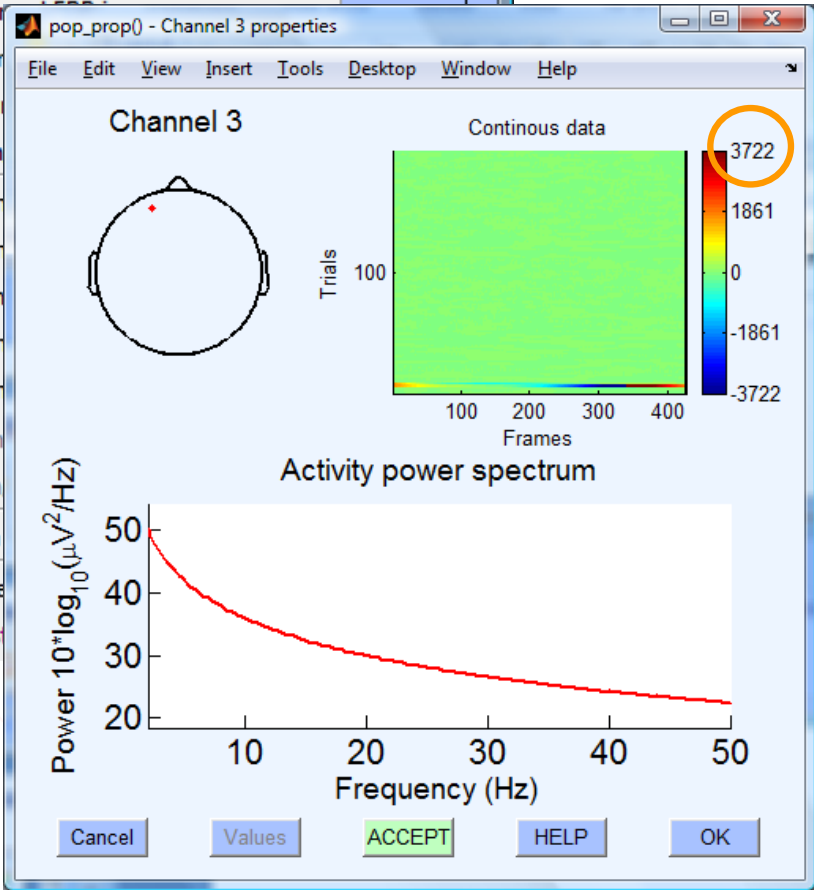
Filename: n
Channels p
Frames per
Epochs
Events
Sampling ra
Epoch start
Epoch end (r
Reference
Channel loc
ICA weights
Dataset size

Component properties - pop_prop()

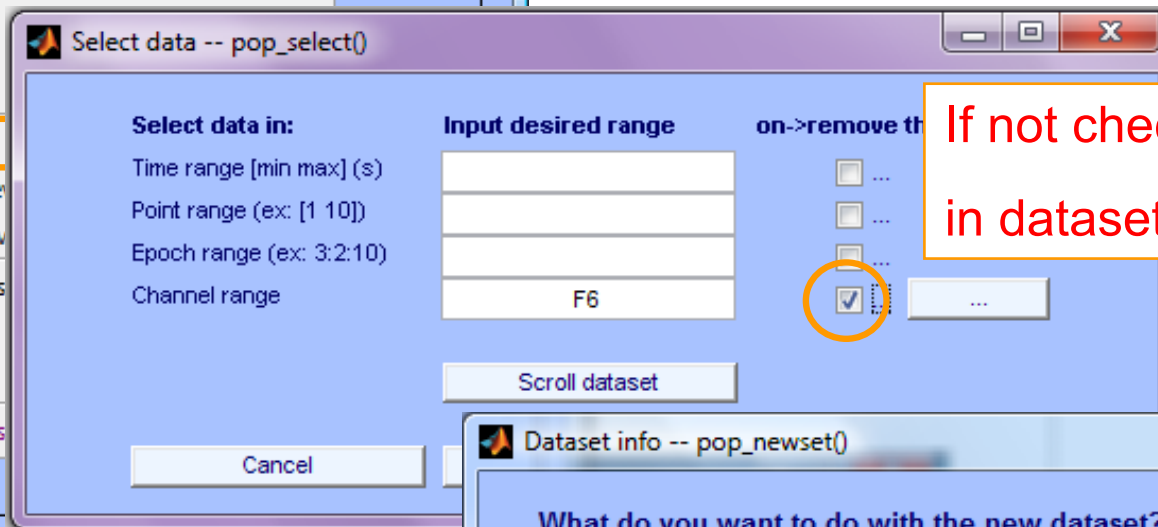
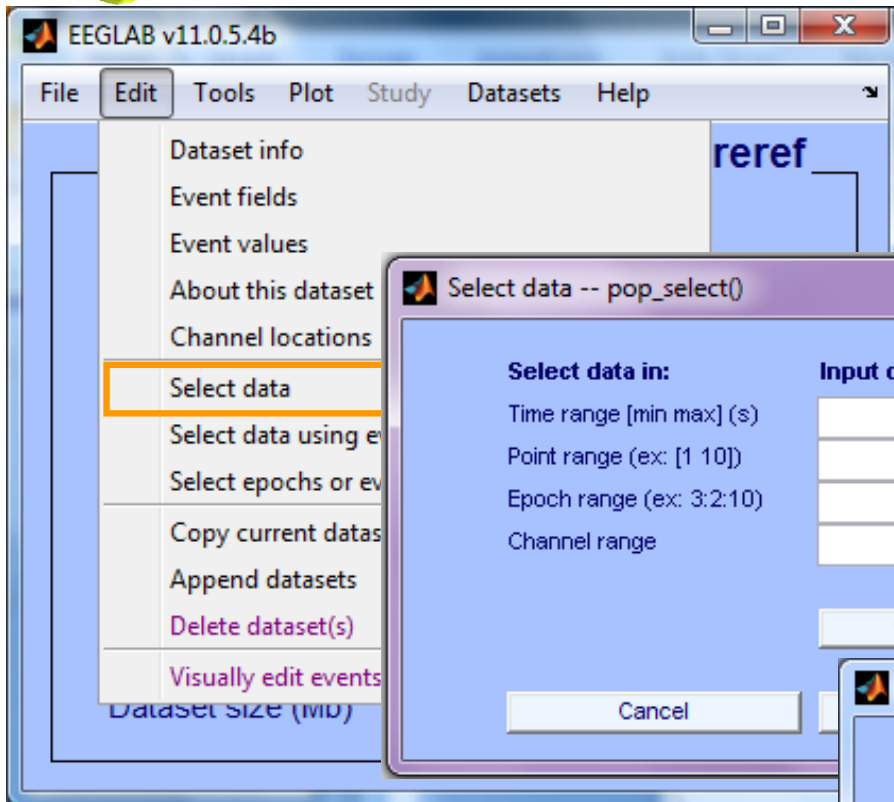
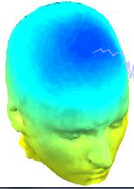
Channel index(ices) to plot:

Spectral options (see spectopo() help):

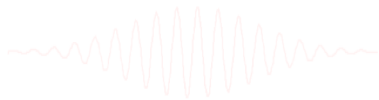
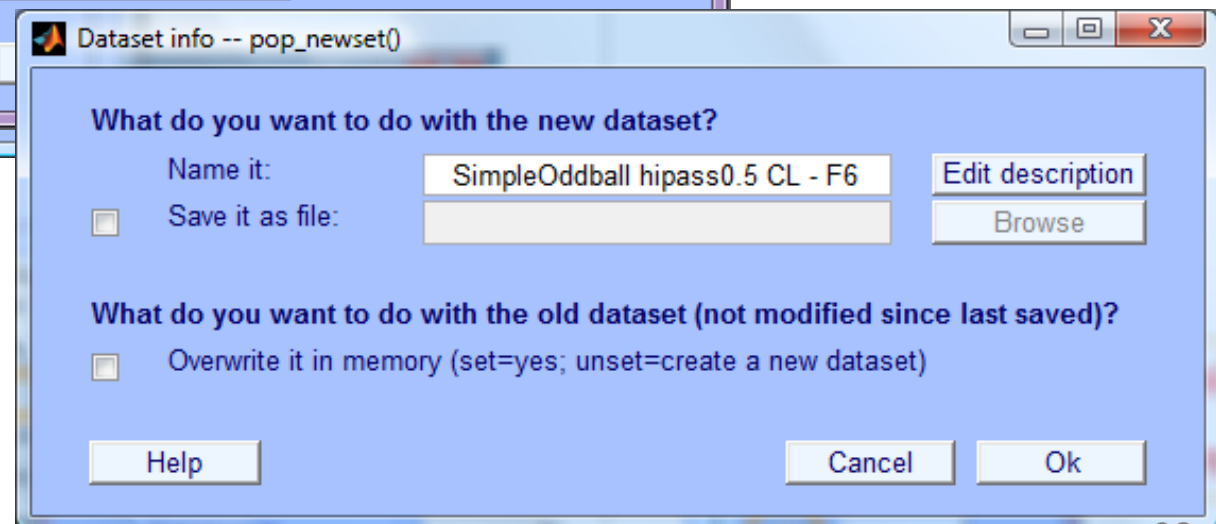
Help Cancel Ok



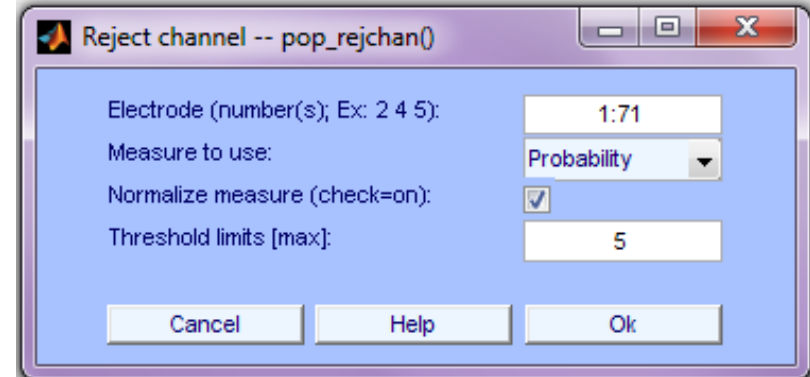
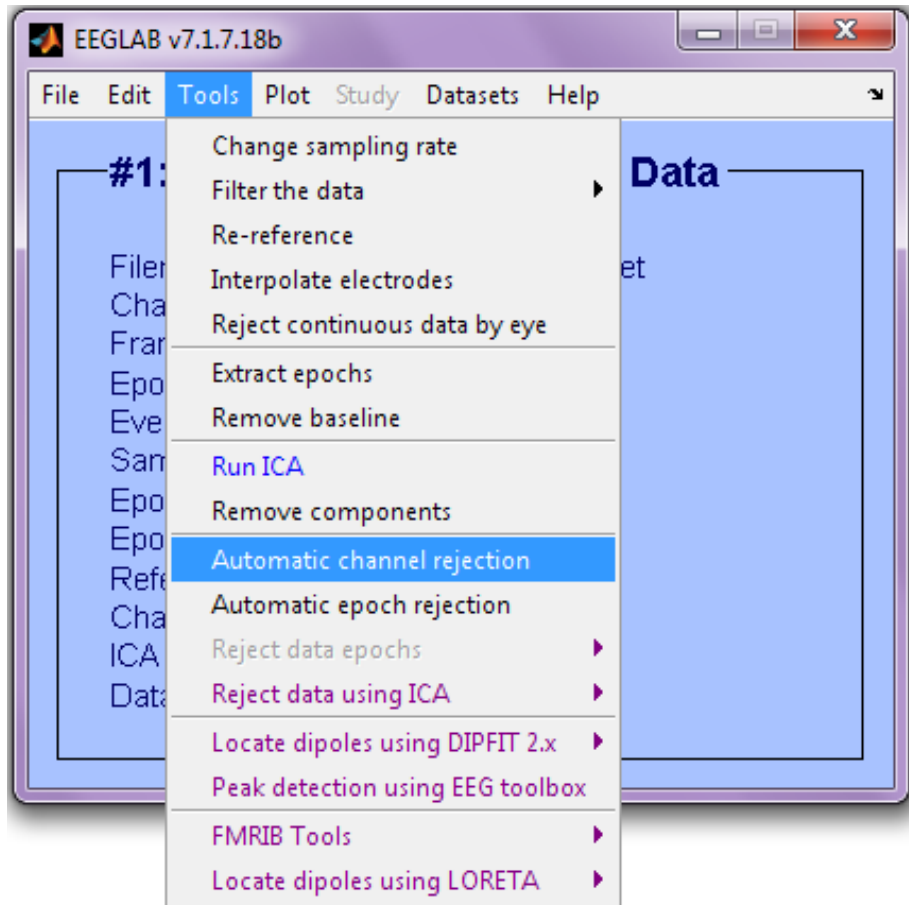
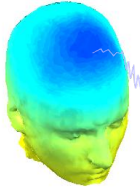
Removing channel(s)



If not checked, will result in dataset with one channel

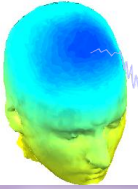


Auto-detection of noisy channels

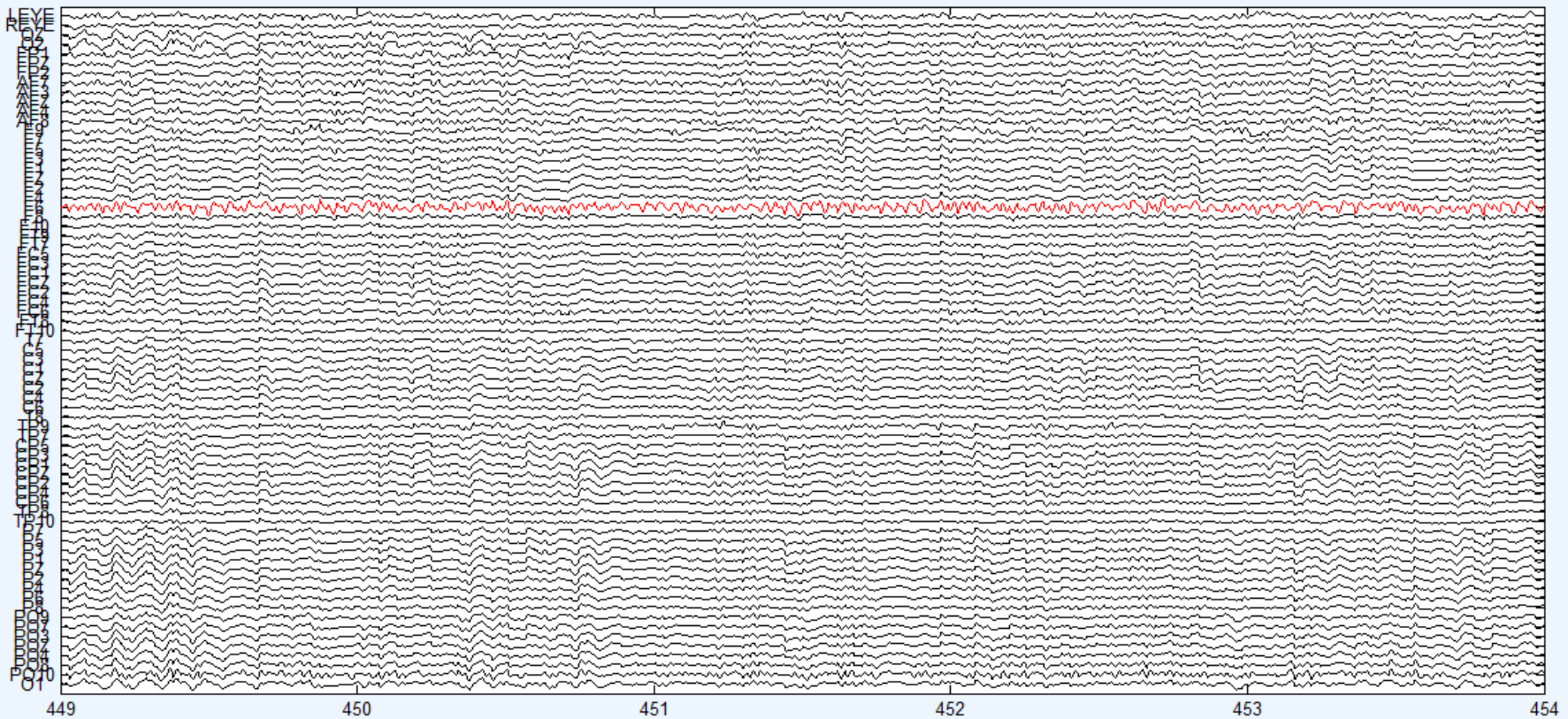


See also `clean_rawdata` plugin of EEGLAB

Auto-detected noisy channel



Scroll component activities -- eegplot() Figure Display Settings Help

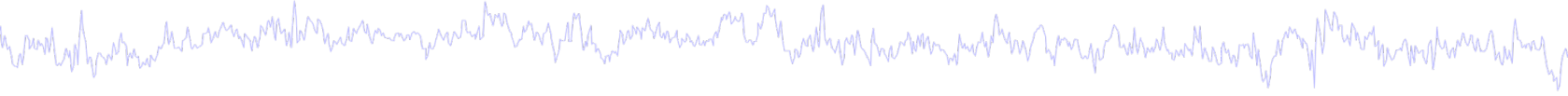
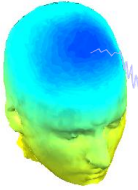


Scale 35

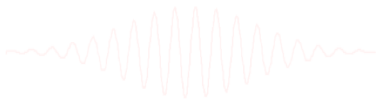
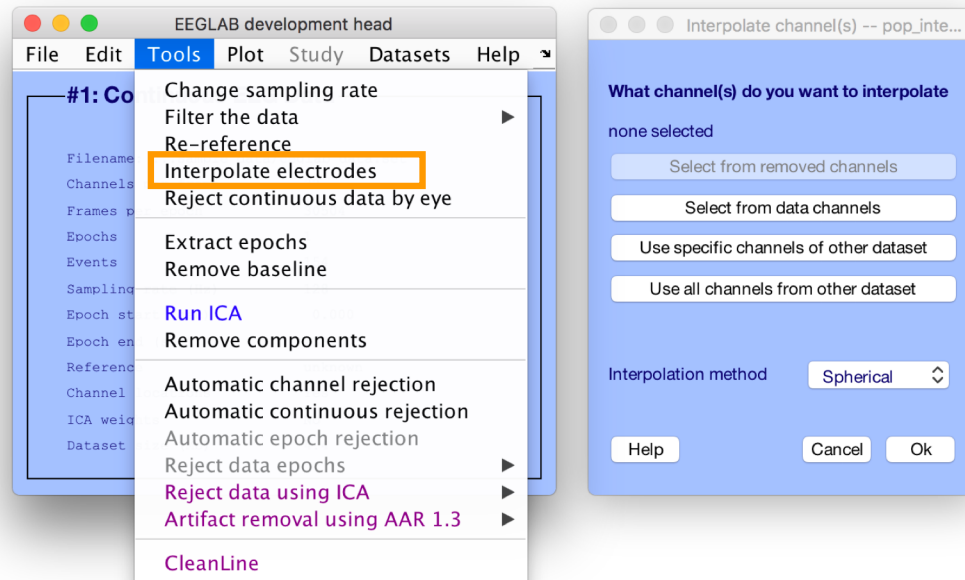
CANCEL << < 449 > >> Chan. Time Value 35 + - REJECT

Chan.	Time	Value
TP8	452.1146	-2.6647

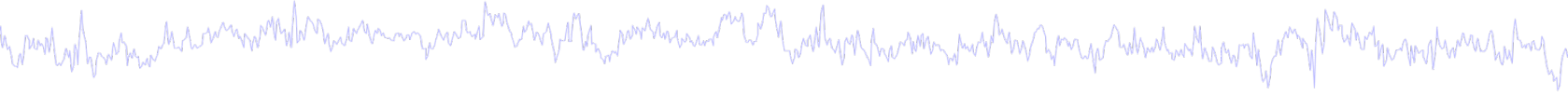
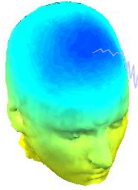
Removed channel(s)



- In EEGLAB, removed channels are not only labeled for rejection, they are actually removed from the data.
- Interpolating channels instead of removing them?



Pre-processing pipeline



**Collect
EEG data**

Import into EEGLAB

**Import event markers
and channel locations**

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

**High pass filter
(~.5 – 1 Hz)**

Examine raw data

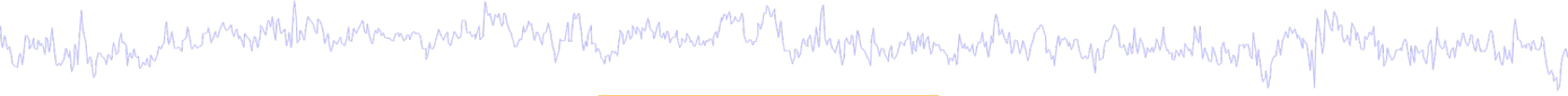
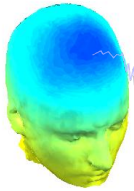
**Identify/reject
bad channels**

**Reject large artifact
time points**

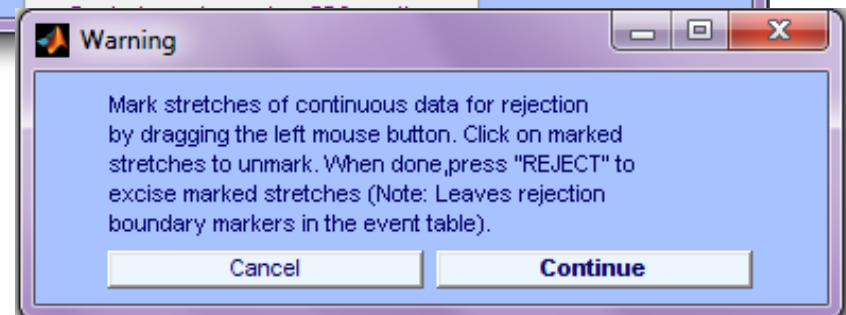
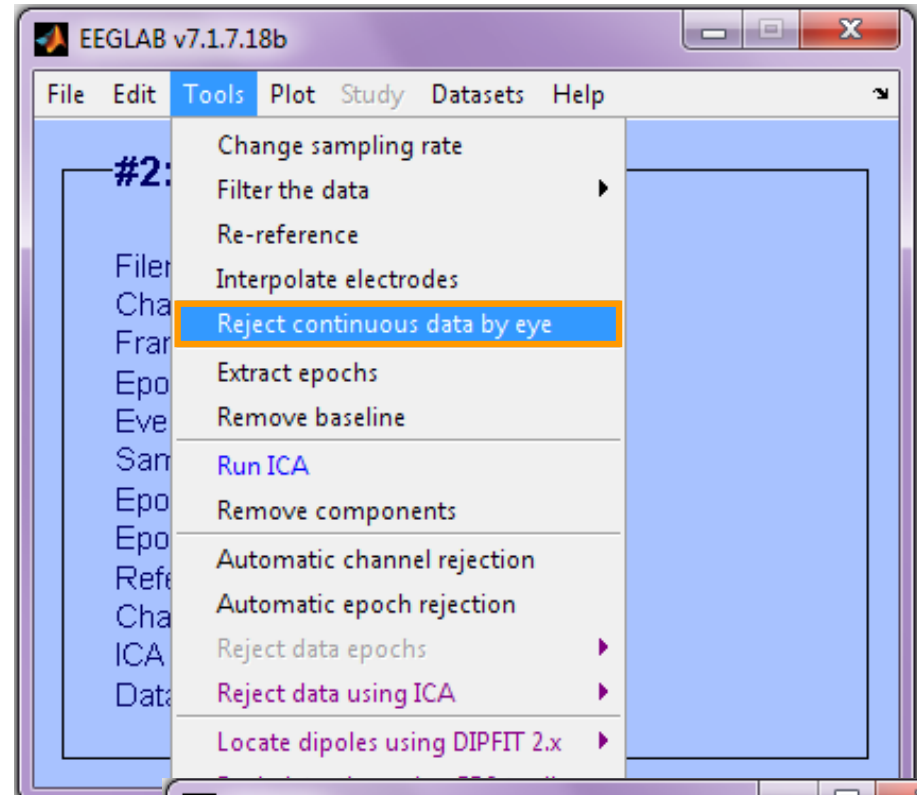
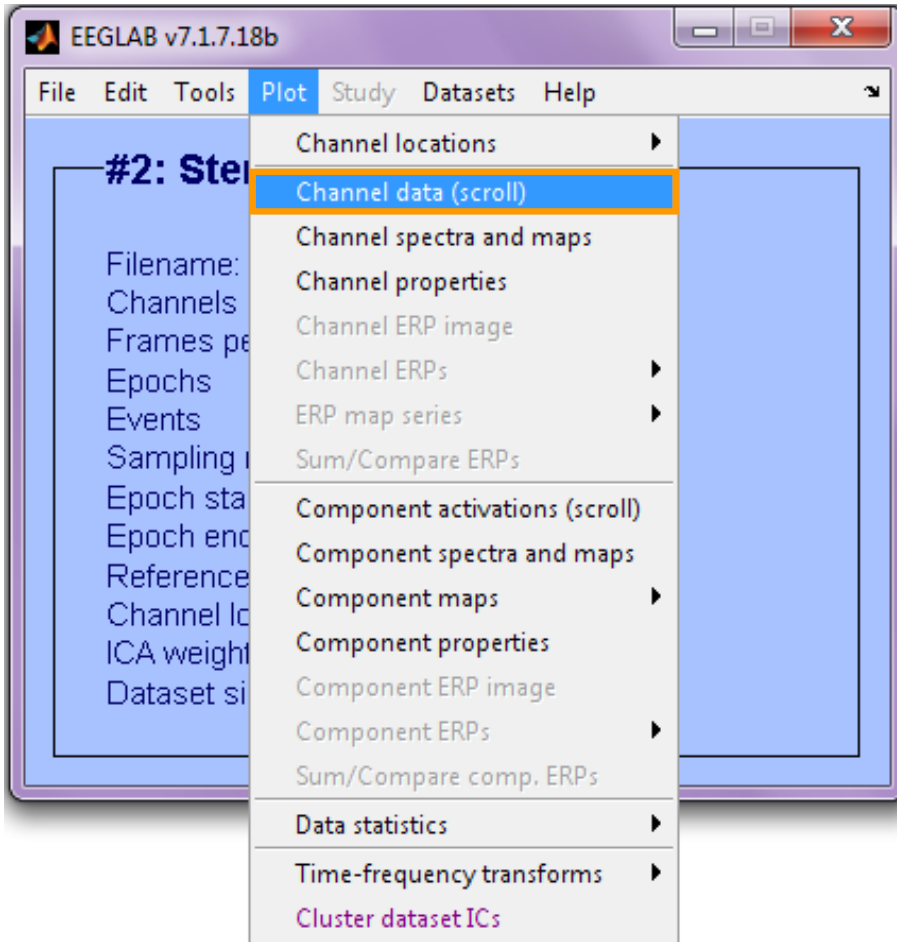
**Run ICA and
reject components**

Done

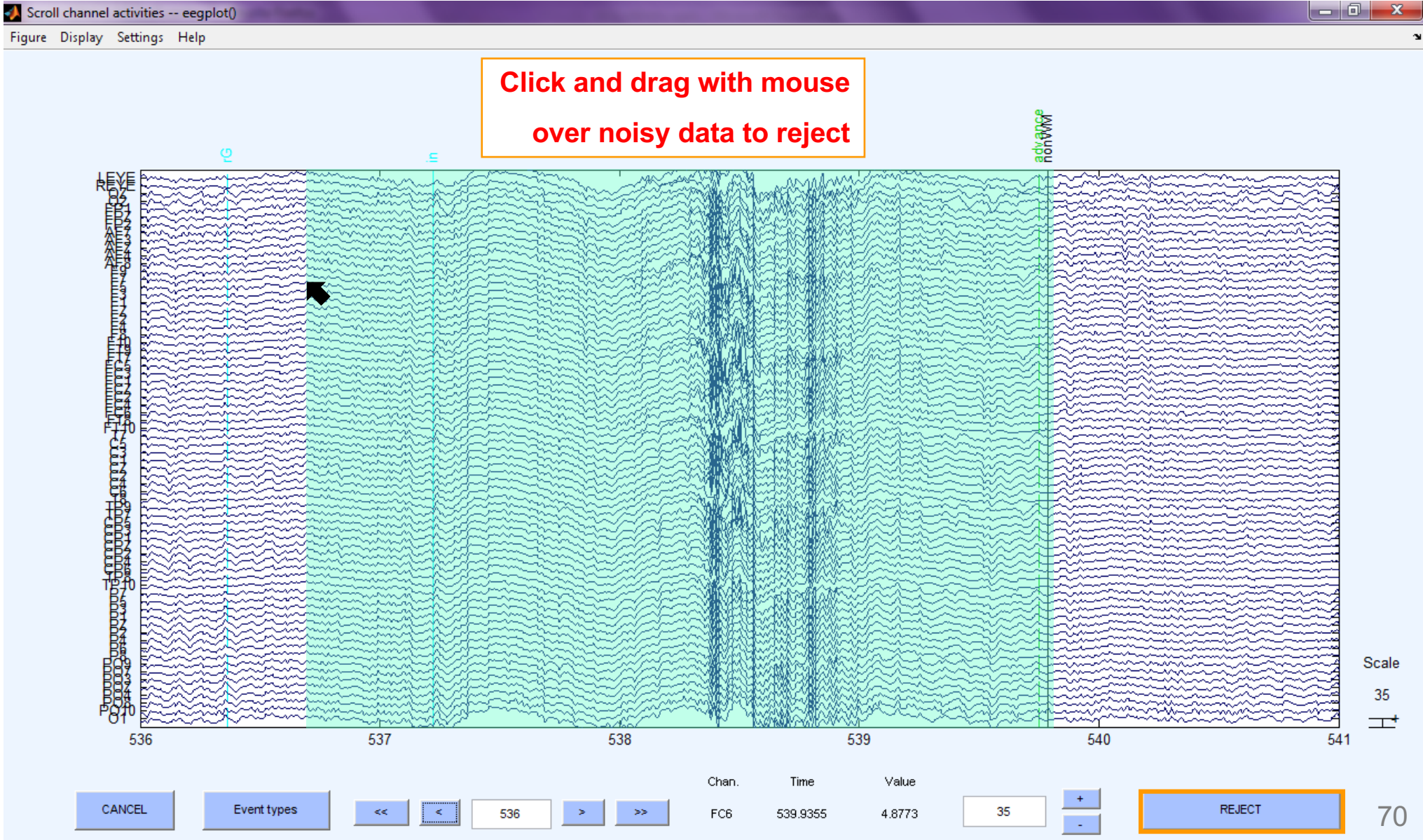
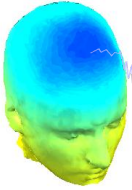
Reject continuous data



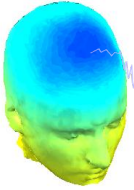
Equivalent



Reject continuous data



Rejecting data for ICA



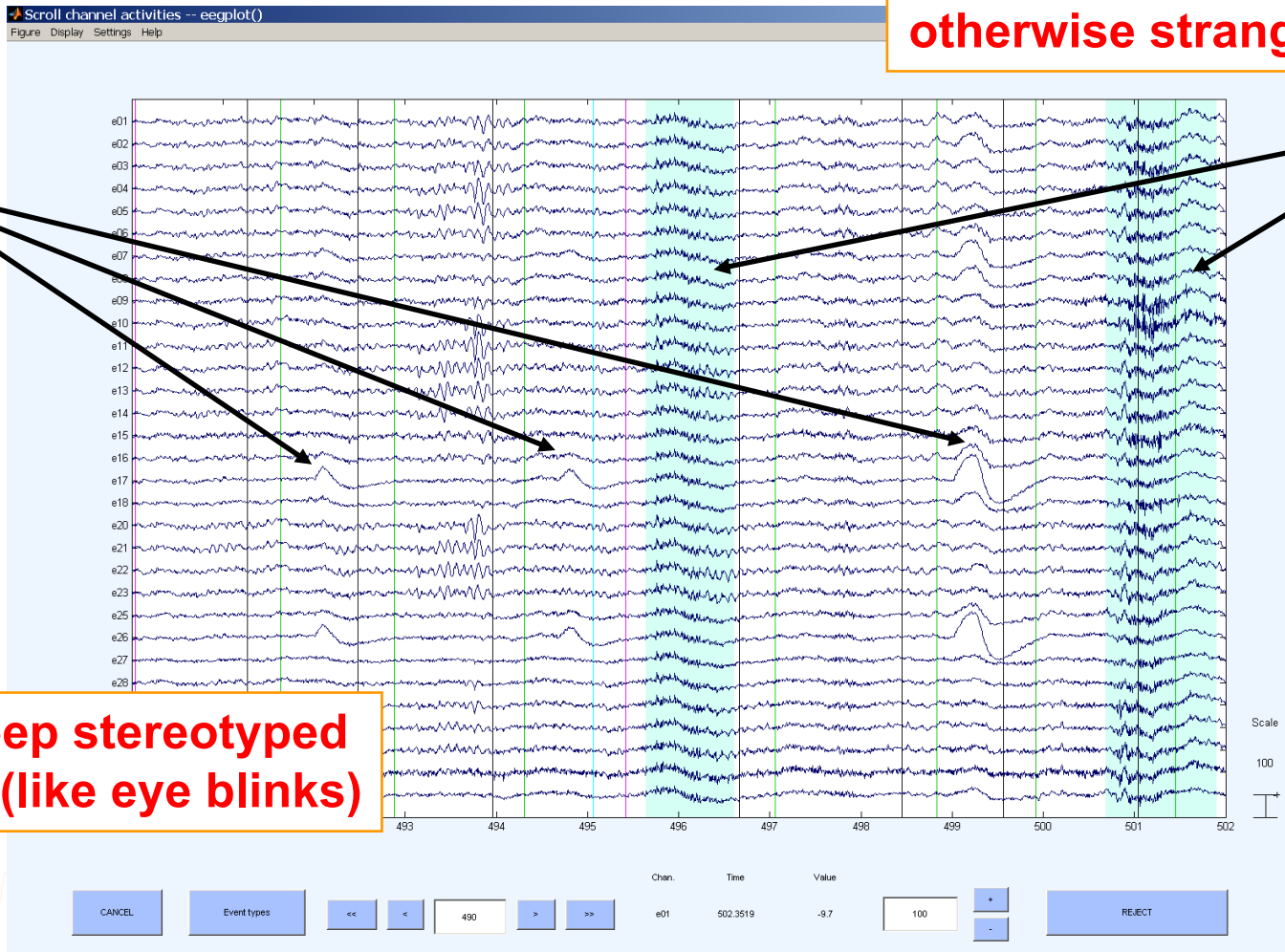
To prepare data for ICA:

Reject large muscle or otherwise strange events...

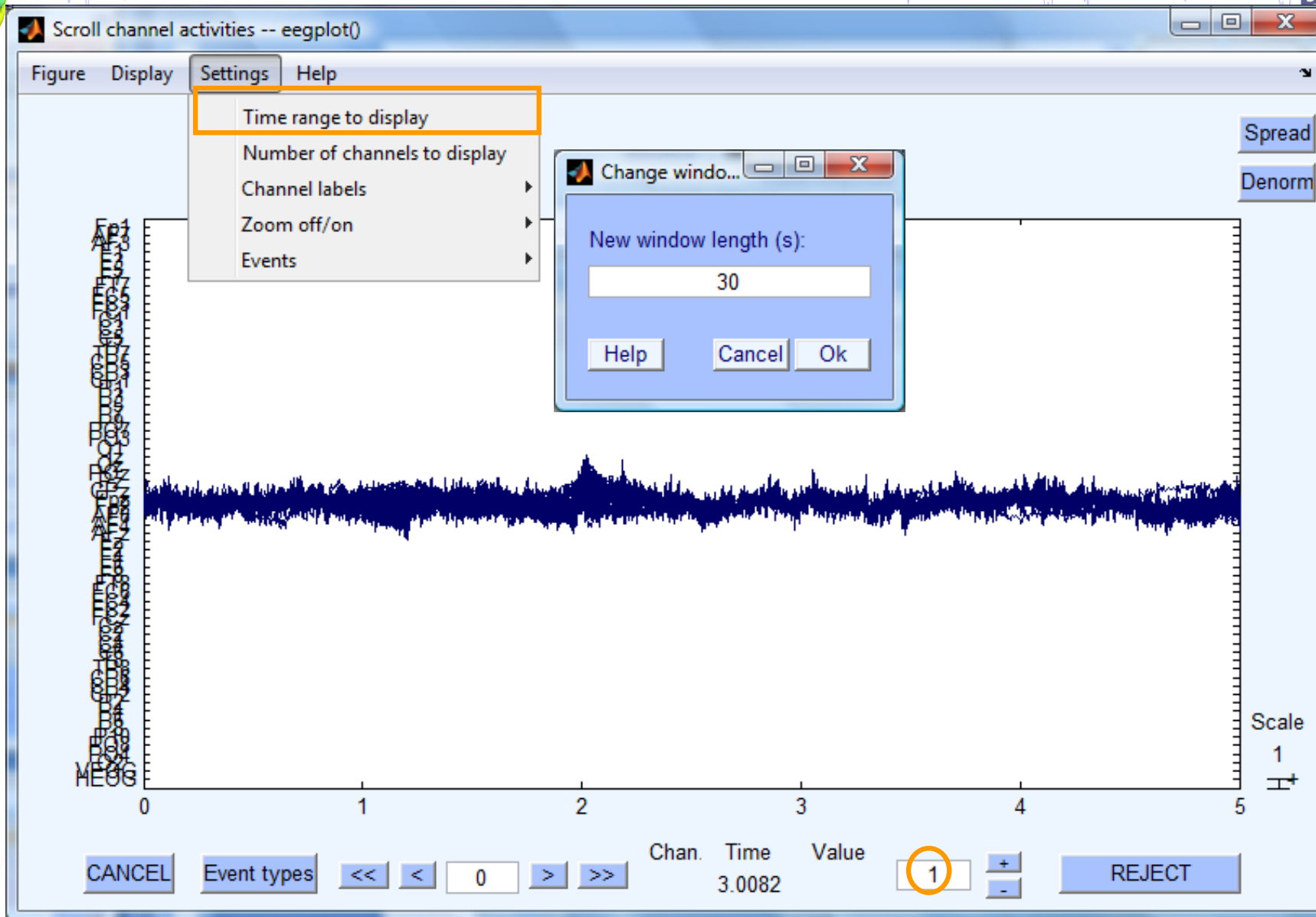
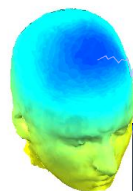
Reject

Keep

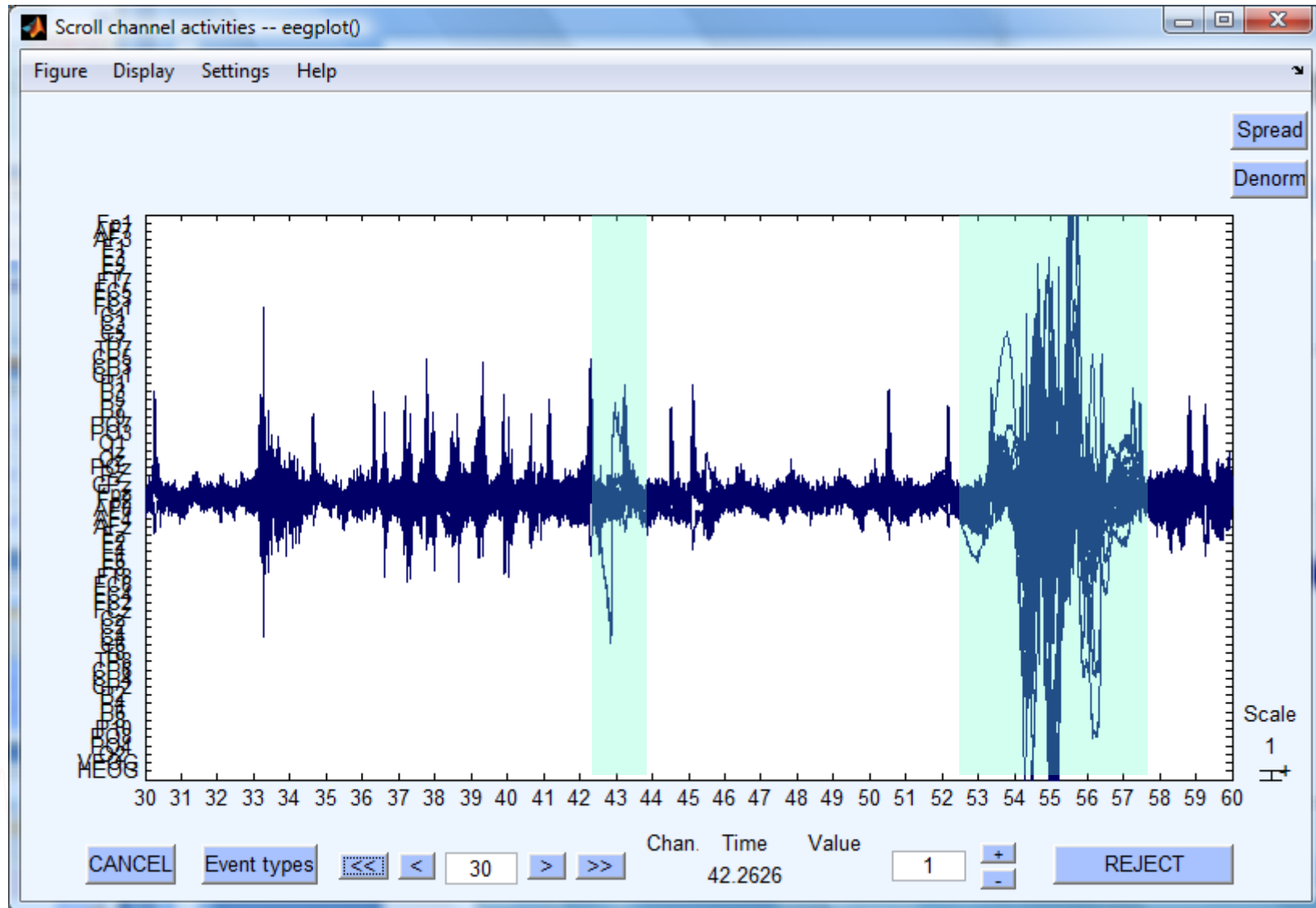
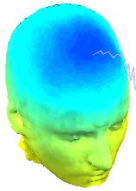
... but keep stereotyped artifacts (like eye blinks)



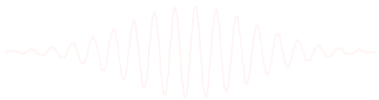
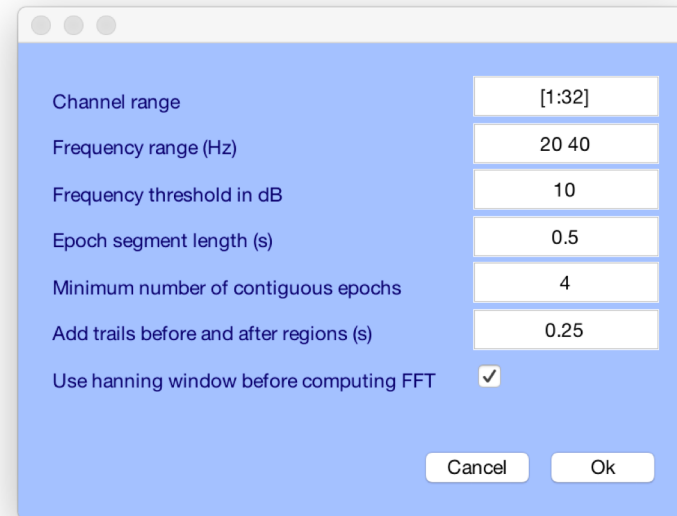
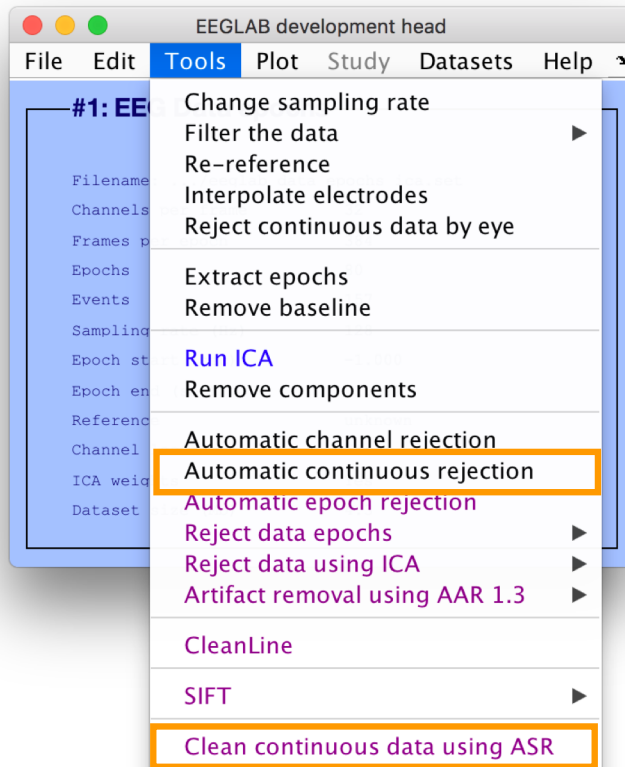
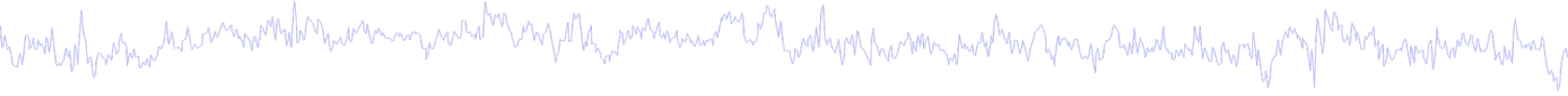
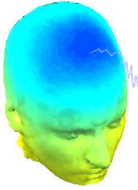
Fast manual artifact rejection



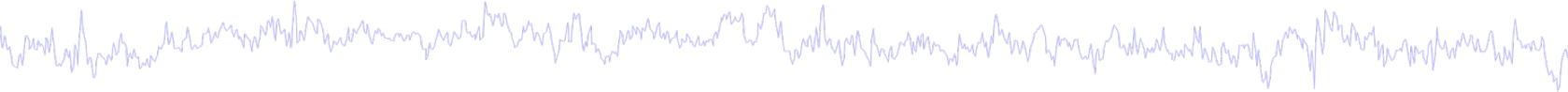
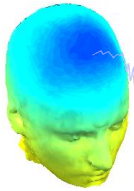
Fast manual artifact rejection



Automatic rejection of continuous data



Extract epochs



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

(use shift|ctrl to select several)

- 1
- 2
- 201

Cancel Ok

Extract data epochs - pop_epoch()

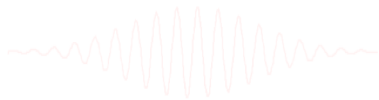
Time-locking event type(s) ([]) = all: 1 ...

Epoch limits [start, end] in seconds: -0.1 1

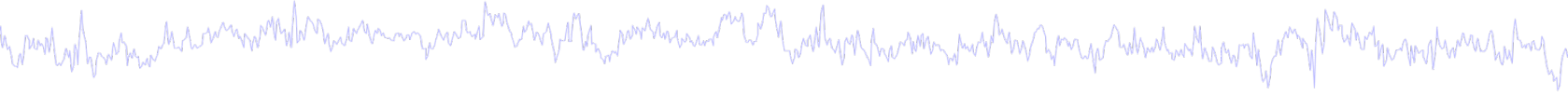
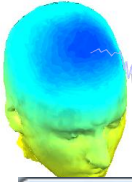
Name for the new dataset: SimpleOddball nontargets

Out-of-bounds EEG limits if any [min max]:

Help Cancel Ok



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)

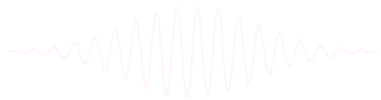
Else, baseline points vector (ex:1:56) ([] = whole) (overwritten by latency range above).

EEGLAB v11.0.5.4b

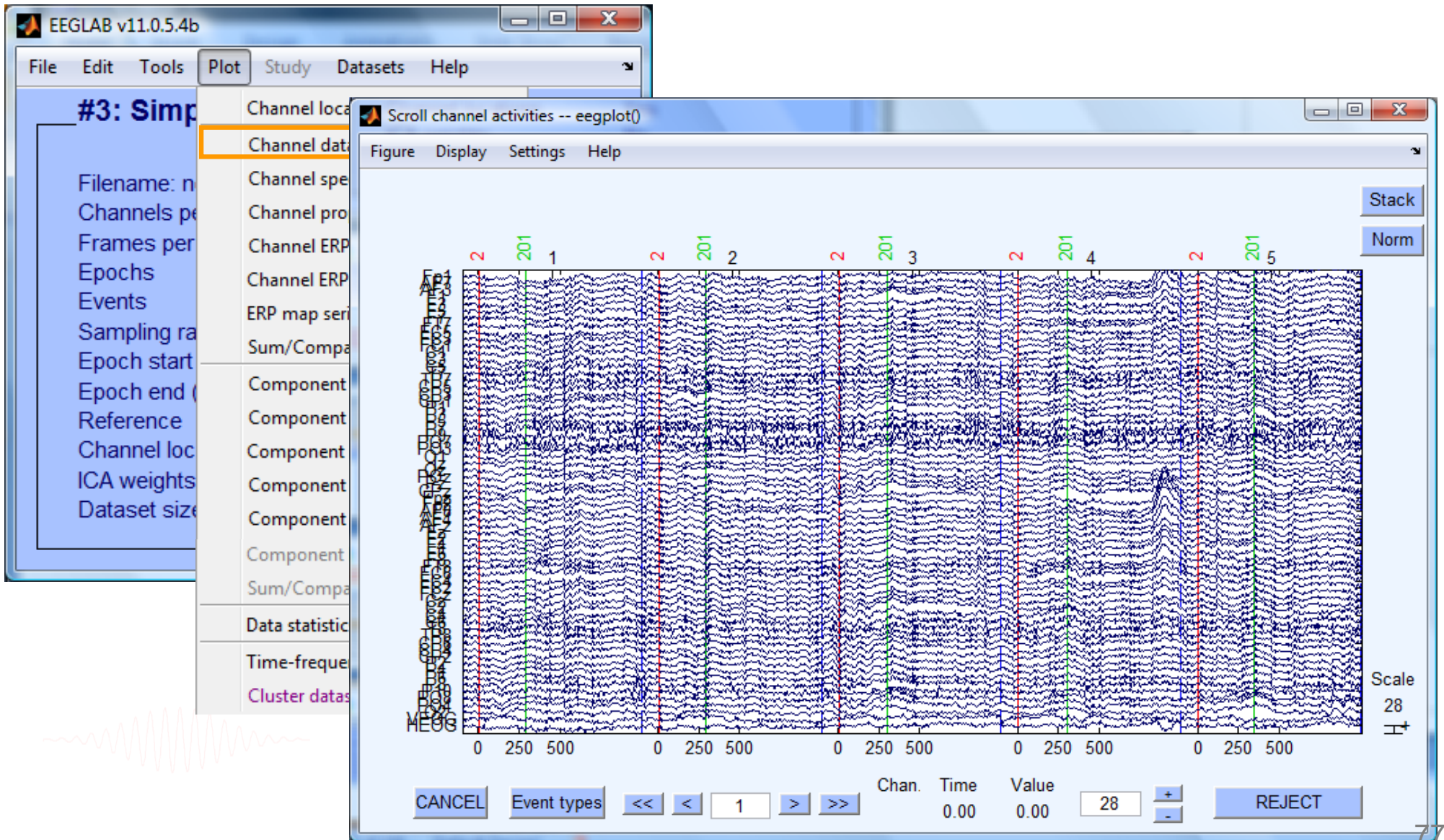
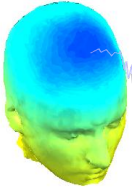
File Edit Tools Plot Study Datasets Help

#2: SimpleOddball nontargets

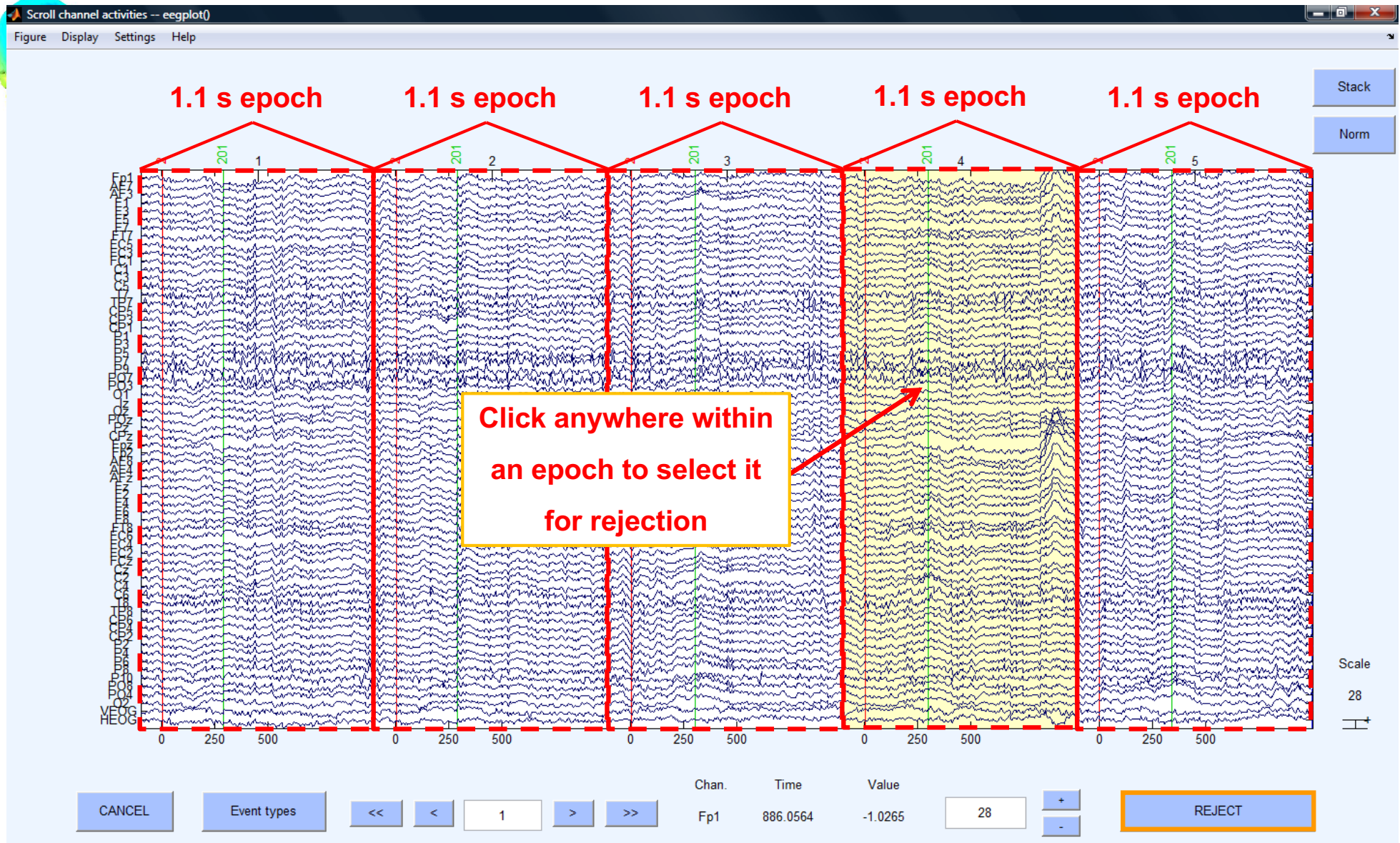
Filename:	none
Channels per frame	66
Frames per epoch	282
Epochs	140
Events	140
Sampling rate (Hz)	256
Epoch start (sec)	-0.102
Epoch end (sec)	0.996
Reference	unknown
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	10.6



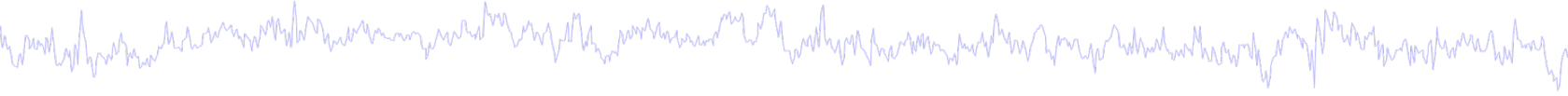
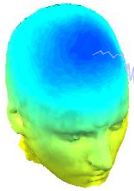
Scroll (epoched) channel data



Reject epochs with artifact



Reject data epochs



EEGLAB v6.0b

File Edit **Tools** Plot Study Datasets Help

- #1: f
- File name
- Change
- Frame
- Epoch
- Event
- Samp
- Epoch
- Epoch
- Avera
- Chan
- ICA w
- Datas

Change sampling rate

Filter the data

Re-reference

Reject continuous data by eye

Extract epochs

Remove baseline

Run ICA

Remove components

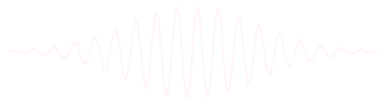
Automatic epoch rejection

Reject data epochs

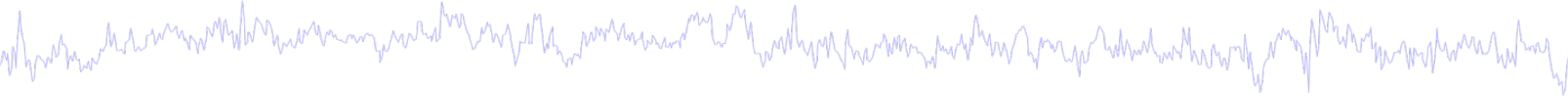
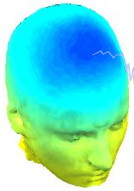
- Reject data using ICA
- Locate dipoles using BESA
- Locate dipoles using DIPFIT 2.x
- Laplacian
- FMRIB Tools
- Grand average datasets
- Locate dipoles using LORETA
- PCA plugin

Reject data (all methods)

- Reject by inspection
- Reject extreme values
- Reject by linear trend/variance
- Reject by probability
- Reject by kurtosis
- Reject by spectra
- Export marks to ICA reject
- Reject marked 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

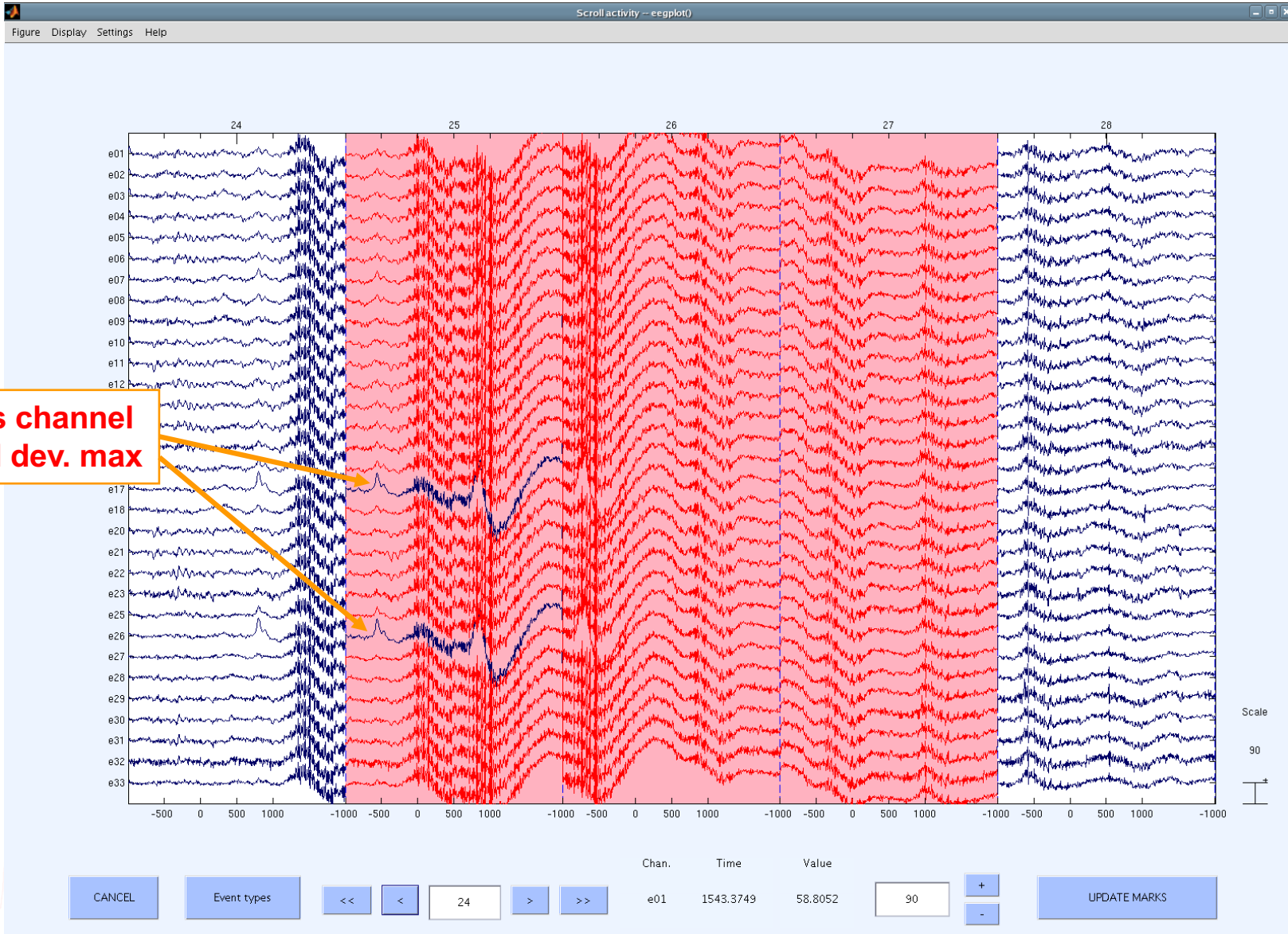
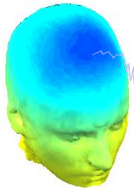
Show all trials marked for rejection by the measure selected above or checked below | /

<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

Close (keep marks) Clear all marks Reject marked trials

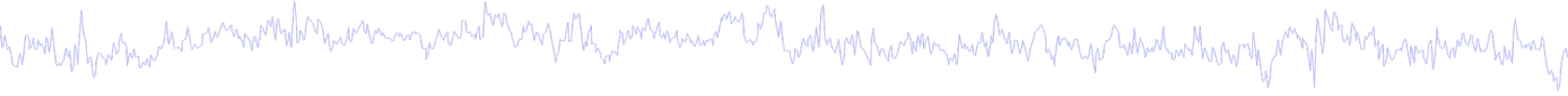
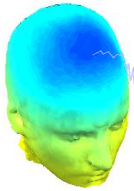
probability

Reject data epochs



Exceeds channel standard dev. max

Reject data epochs



EEGLAB v6.0b

File Edit **Tools** Plot Study Datasets Help

- #1: f
- File name
- Channel names
- Frame numbers
- Epoch numbers
- Event markers
- Sampling rate
- Epoch duration
- Epoch start time
- Average
- Channel weights
- ICA weights
- Datasets

Change sampling rate

Filter the data

Re-reference

Reject continuous data by eye

Extract epochs

Remove baseline

Run ICA

Remove components

Automatic epoch rejection

Reject data epochs

Reject data using ICA

Locate dipoles using BESA

Locate dipoles using DIPFIT 2.x

Laplacian

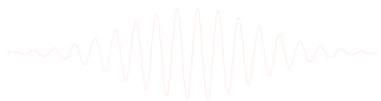
FMRIB Tools

Grand average datasets

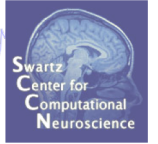
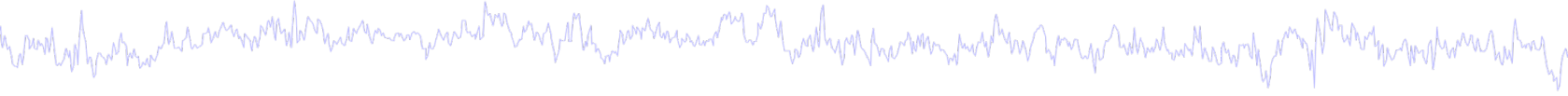
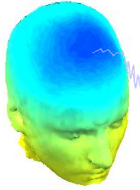
Locate dipoles using LORETA

PCA plugin

- Reject data (all methods)
- Reject by inspection
- Reject extreme values
- Reject by linear trend/variance
- Reject by probability
- Reject by kurtosis
- Reject by spectra
- Export marks to ICA reject
- Reject marked epochs**



Pre-processing pipeline



Collect EEG data

Import into EEGLAB

Import event markers and channel locations

Re-reference/down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

Examine raw data

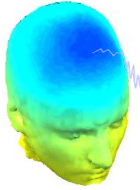
Identify/reject bad channels

Reject large artifact time points

Run ICA and reject components

Done

Acknowledgements



Scott Makeig



Julie Onton



Marissa Westerfield



Ramon Martinez

Makoto Miyakoshi

Luca Pion-Tonachini

Tzyy Ping Jung

Tim Mullen

Christian Kothe

Nima Bigdely Shamlo

Zeynep Akalin

Cyril Pernet

Clement Lee

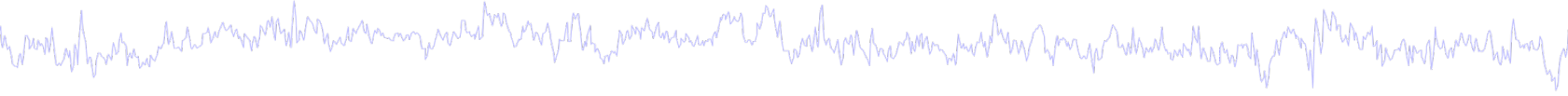
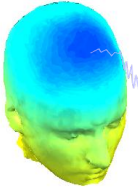
John Iversen

Johanna Wagner

Jason Palmer



Exercises



- Load time SimpleOddball.set dataset
- 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

