



EEG Preprocessing in EEGLAB

EEGLAB

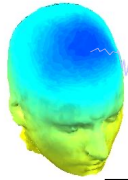
Ramon Martinez-Cancino, PhD

Arnaud Delorme, PhD

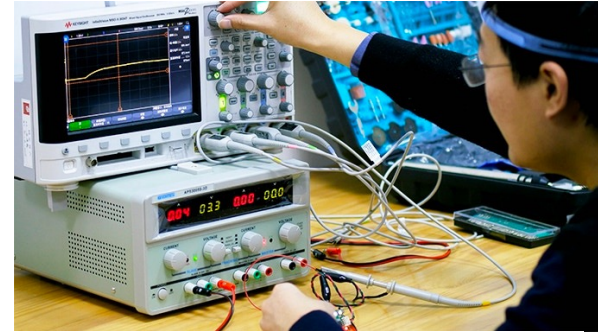
Johanna Wagner, PhD



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.

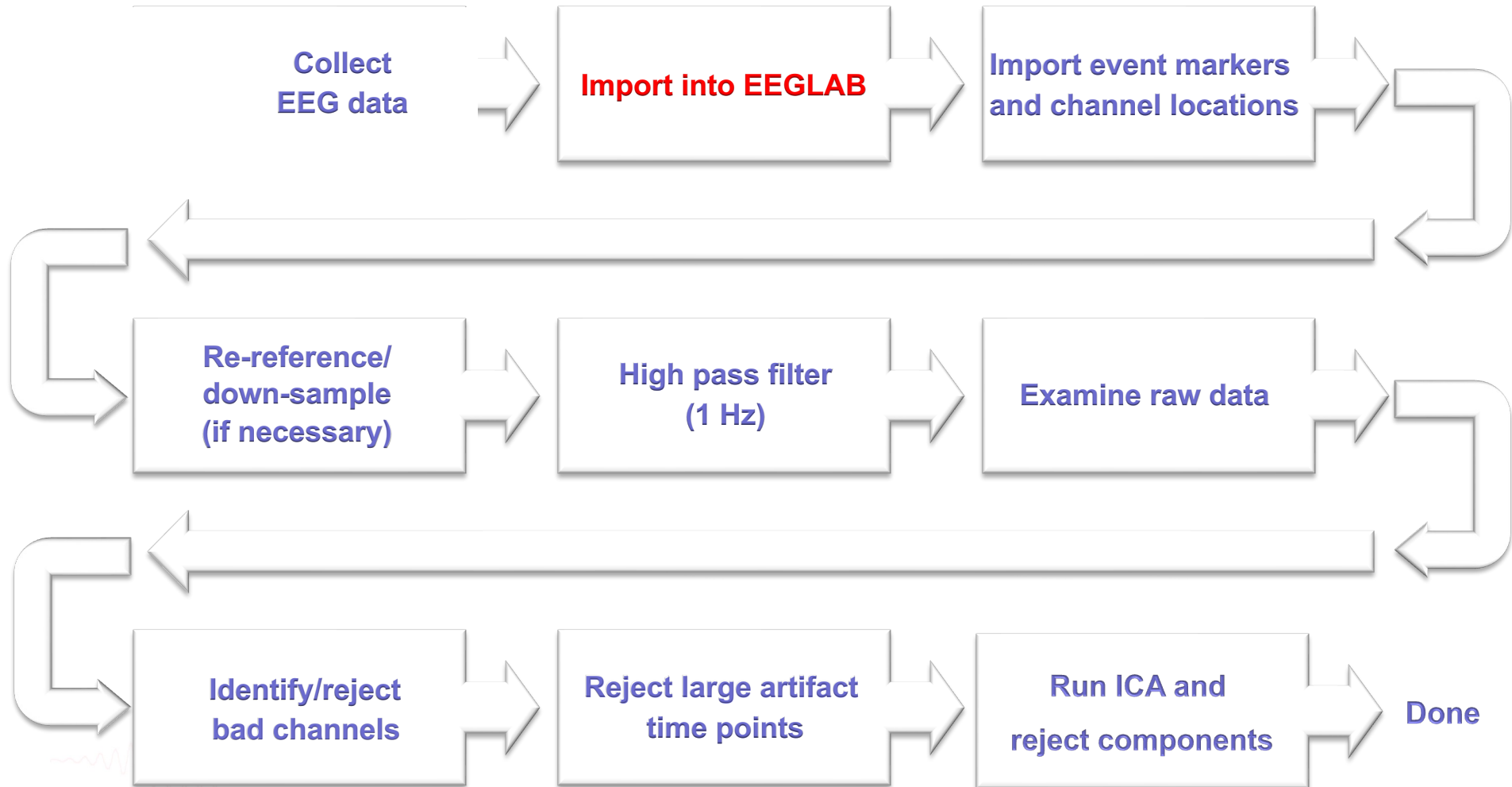
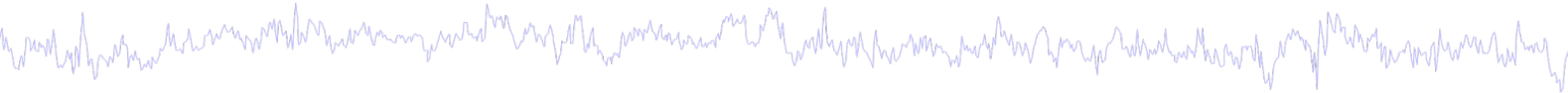
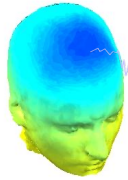


To make sense of the data, we need to:

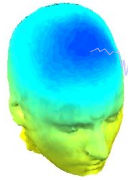
- Extract meaningful measures from it (such as brain oscillations; brain source activations)
- Compare brain data in different conditions
- Assess reliable changes due to external stimuli (event-related potentials)

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

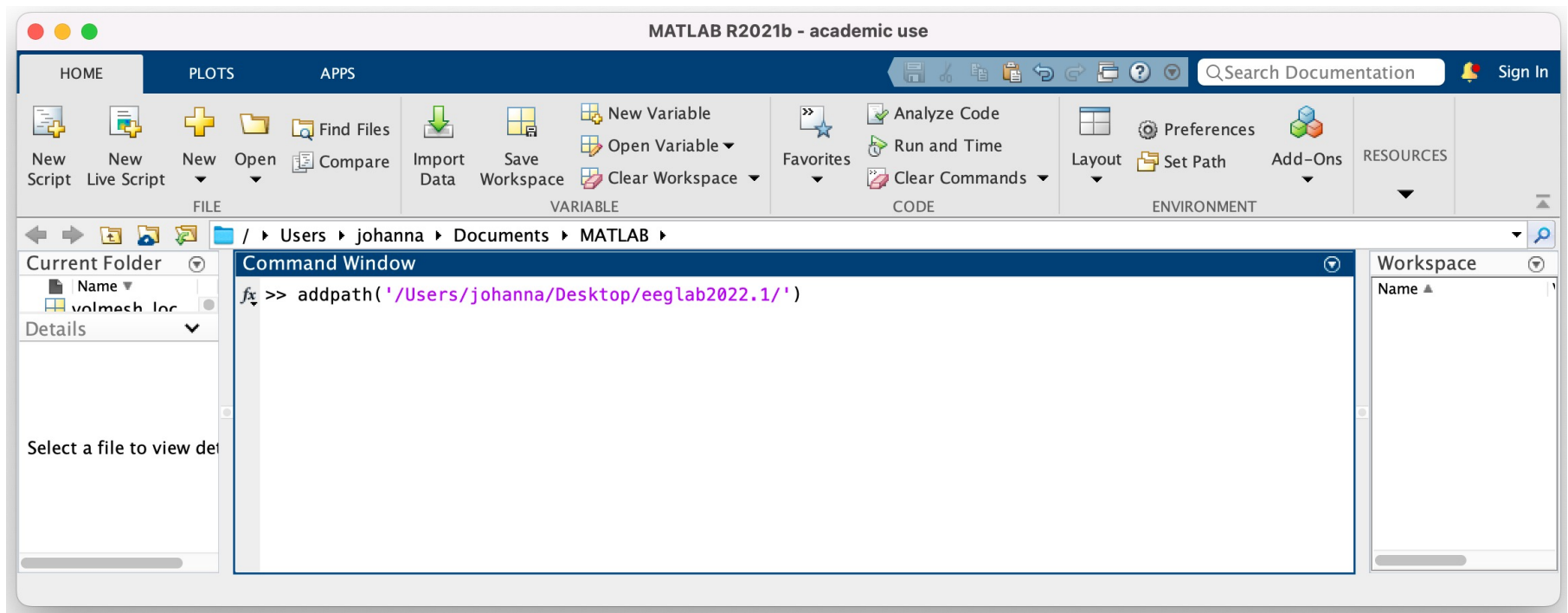
Pre-processing pipeline



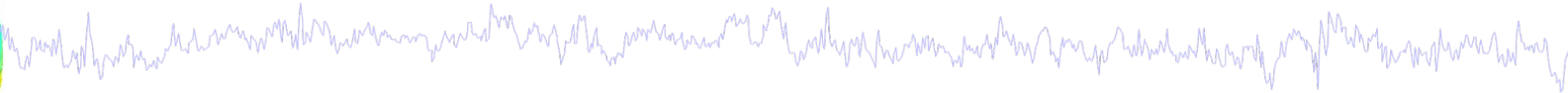
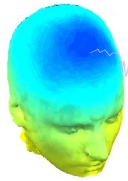
Installing EEGLAB and data folder



- Download and install Matlab (2016b or later)
- Download the latest version of EEGLAB (<http://www.sccn.ucsd.edu/eeglab>)
- Unzip EEGLAB
- Add the EEGLAB folder to your Matlab path:



The EEGLAB Matlab software

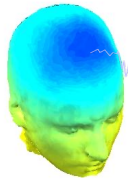


main graphic interface

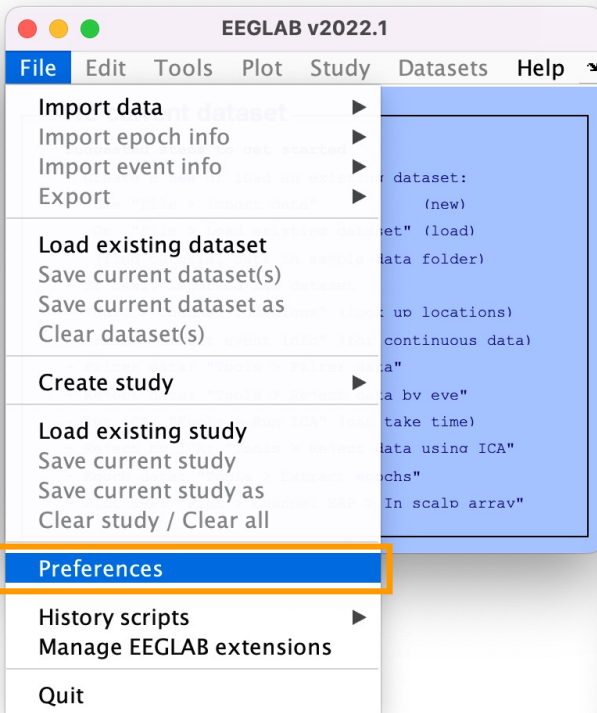
The screenshot shows the MATLAB R2021b academic use main window. The top menu bar includes HOME, PLOTS, and APPS. The toolbar contains icons for New Script, Live Script, New, Open, Compare, Import Data, Save Workspace, New Variable, Open Variable, Clear Workspace, Favorites, Analyze Code, Run and Time, Clear Commands, ENVIRONMENT, and RESOURCES. The Command Window shows the command `fx >> eeglab`. The EEGLAB v2022.1 window is open, displaying a "No current dataset" message and a list of suggested steps to get started:

- Create a new or load an existing dataset:
 - Use "File > Import data" (new)
 - Or "File > Load existing dataset" (load)
 - (find tutorial data in sample data folder)
- If newly imported raw dataset
 - "Edit > Channel locations" (look up locations)
 - "File > Import event info" (for continuous data)
- Filter data: "Tools > Filter data"
- Reject data: "Tools > Reject data by eve"
- Run ICA: "Tools > Run ICA" (can take time)
- Reject by ICA: "Tools > Reject data using ICA"
- Epoch data: "Tools > Extract epochs"
- Plot ERP: "Plot > Channel ERP > In scalp array"

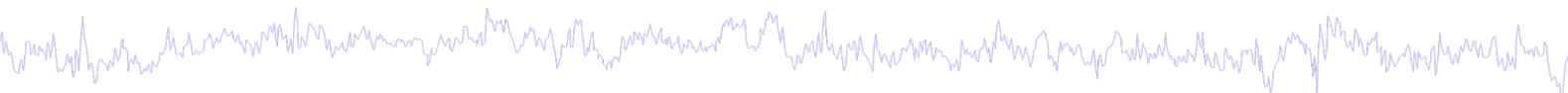
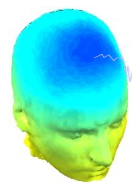
Adjust preferences (keep more than one dataset in memory)



uncheck

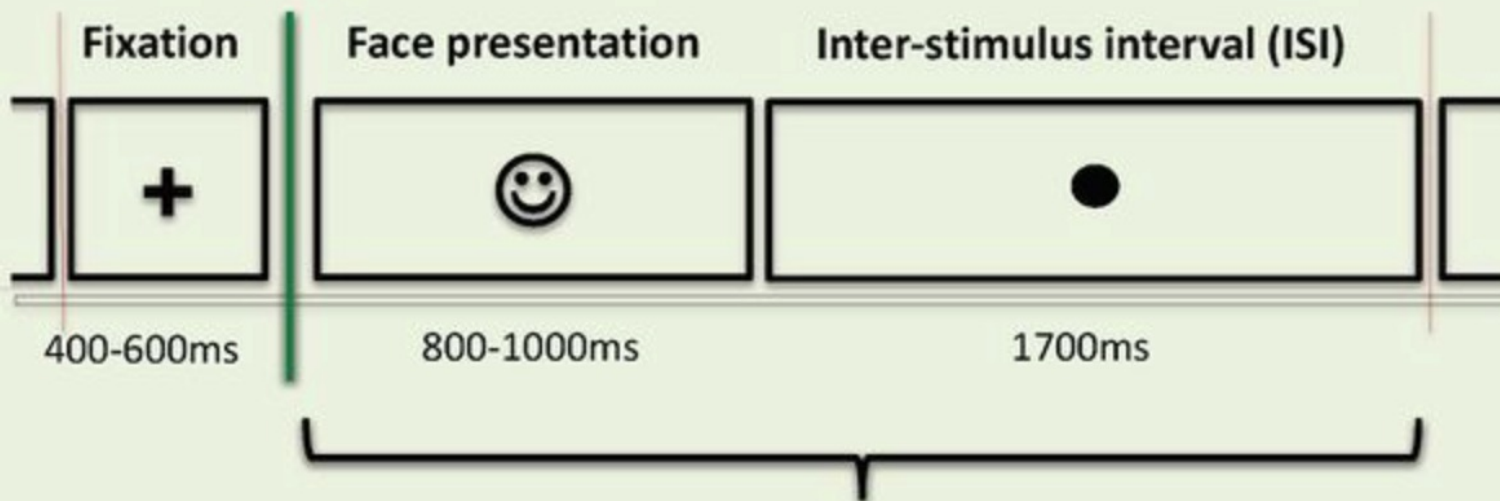


Sample data: Wakeman-Henson data



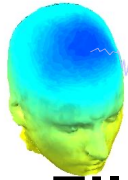
- 3 stimulus types:
- Scrambled Faces
 - Familiar Faces
 - Unfamiliar Faces

Trial structure



Participants were asked to press one of two keys based on how symmetric they regarded each image, 'more' or 'less symmetric than average'

Sample data: Wakeman-Henson data



File

Path: derivatives/meg_derivatives/sub-01/ses-meg/meg/

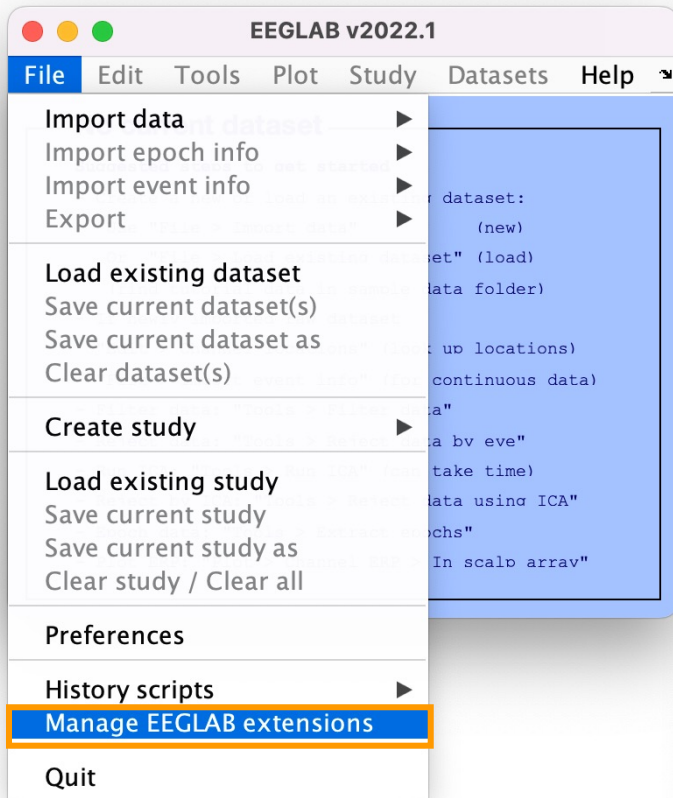
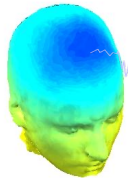
File: **sub-01_ses-meg_task-facerecognition_run-01_proc-sss_meg.fif**

Data

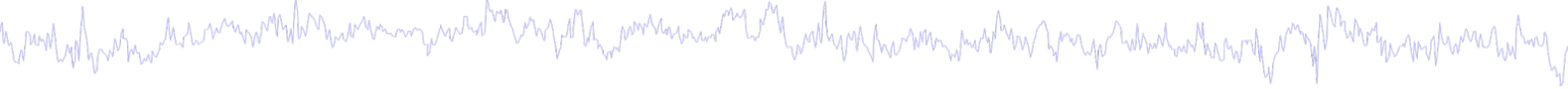
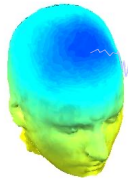
- 70 channel EEG,
- 2 EOG, 2 ECG
- 3D locations of EEG electrodes
- 1100 Hz sampling rate,
- recorded with Elekta Neuromag Vectorview 306 system,
- 306 MEG channels



Install extension for importing data files



Supported data formats



EEGLAB tutorial: https://sccn.ucsd.edu/wiki/A01:_Importing_Continuous_and_Epoched_Data

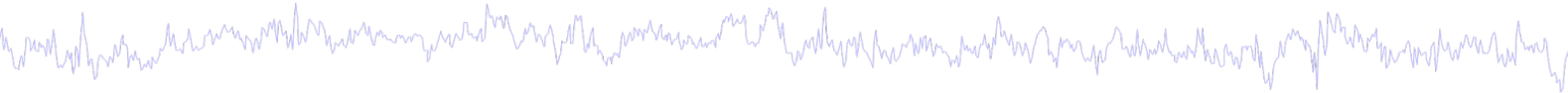
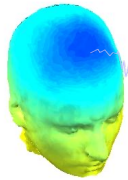
Supported Data Formats

File Format	File Extension	File type	Events	Channel Labels	EEGLAB	Biosig	File IO	Support
ANT EEProbe	.avr	--	--	--	--	--	--	Comments
ANT EEProbe	.cnt	--	--	--	y	y	y	Comments
ASCII	.bt	--	--	--	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	.cf	--	--	--	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
Neuromag	.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 Kohden	.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: <https://www.fieldtriptoolbox.org/development/module/fileio/>

Importing the Wakeman-Henson data



EEGLAB v2022.1

File Edit Tools Plot Study Datasets Help

- Import data
 - Using EEGLAB functions and plugins
 - Using the FILE-IO interface**
 - Using the BIOSIG interface
 - Troubleshooting data formats...
- 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
- Preferences
- History scripts
- Manage EEGLAB extensions
- Quit

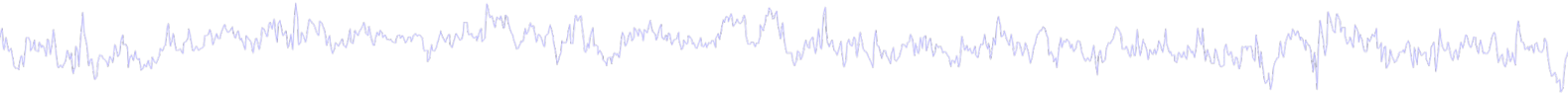
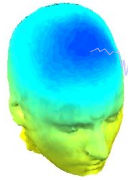
FILE-IO import

Do you want to import a file or a folder?

Folder File

Import: **sub-01_ses-meg_task-facerecognition_run-01_proc-sss_meg.fif**

Importing the Wakeman-Henson data



```
% Step 1: Importing data with FileIO
```

```
EEG = pop_fileio(fullfile(path2data, filename));
```

```
% Adjust some fields
```

```
EEG.filename = 'sub-01_ses-meg_task-facerecognition_run-01_proc-sss_meg.fif';
```

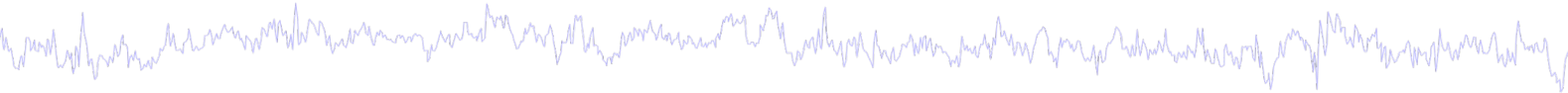
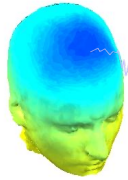
```
EEG.setname = 'sub-01_ses-meg_task-facerecognition_run-01_proc-sss_meg';
```

```
EEG.subject = 'sub-01';
```

```
eeglab redraw
```



Imported EEG data



EEGLAB v2022.1

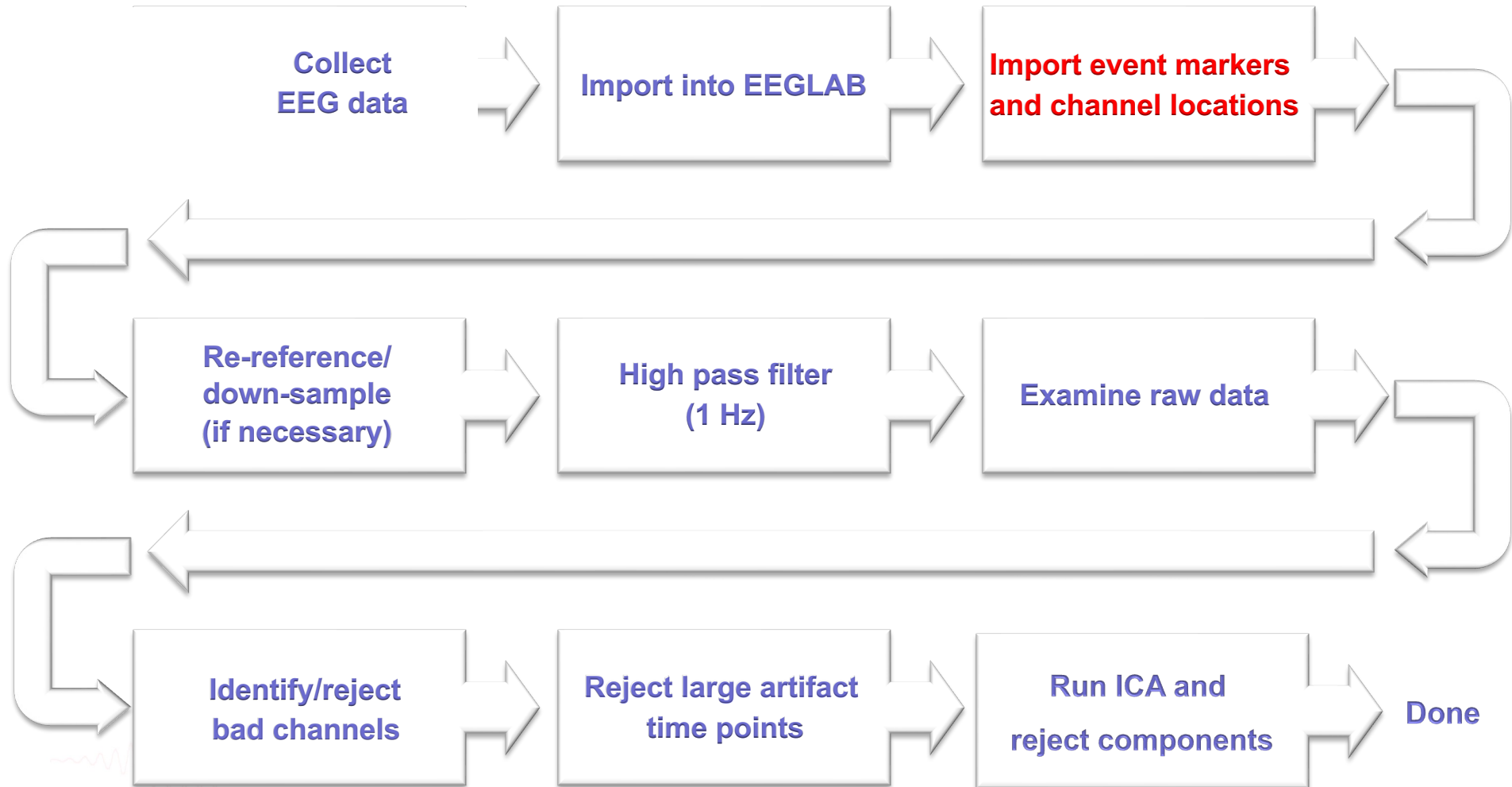
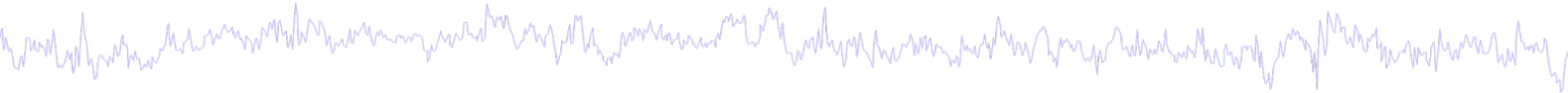
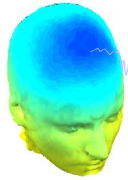
File Edit Tools Plot Study Datasets Help

#1: S1Wakeman-Henson

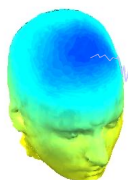
Filename:	none
Channels per frame	404
Frames per epoch	540100
Epochs	1
Events	264
Sampling rate (Hz)	1100
Epoch start (sec)	-0.000
Epoch end (sec)	490.999
Reference	unknown
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	877.8



Pre-processing pipeline



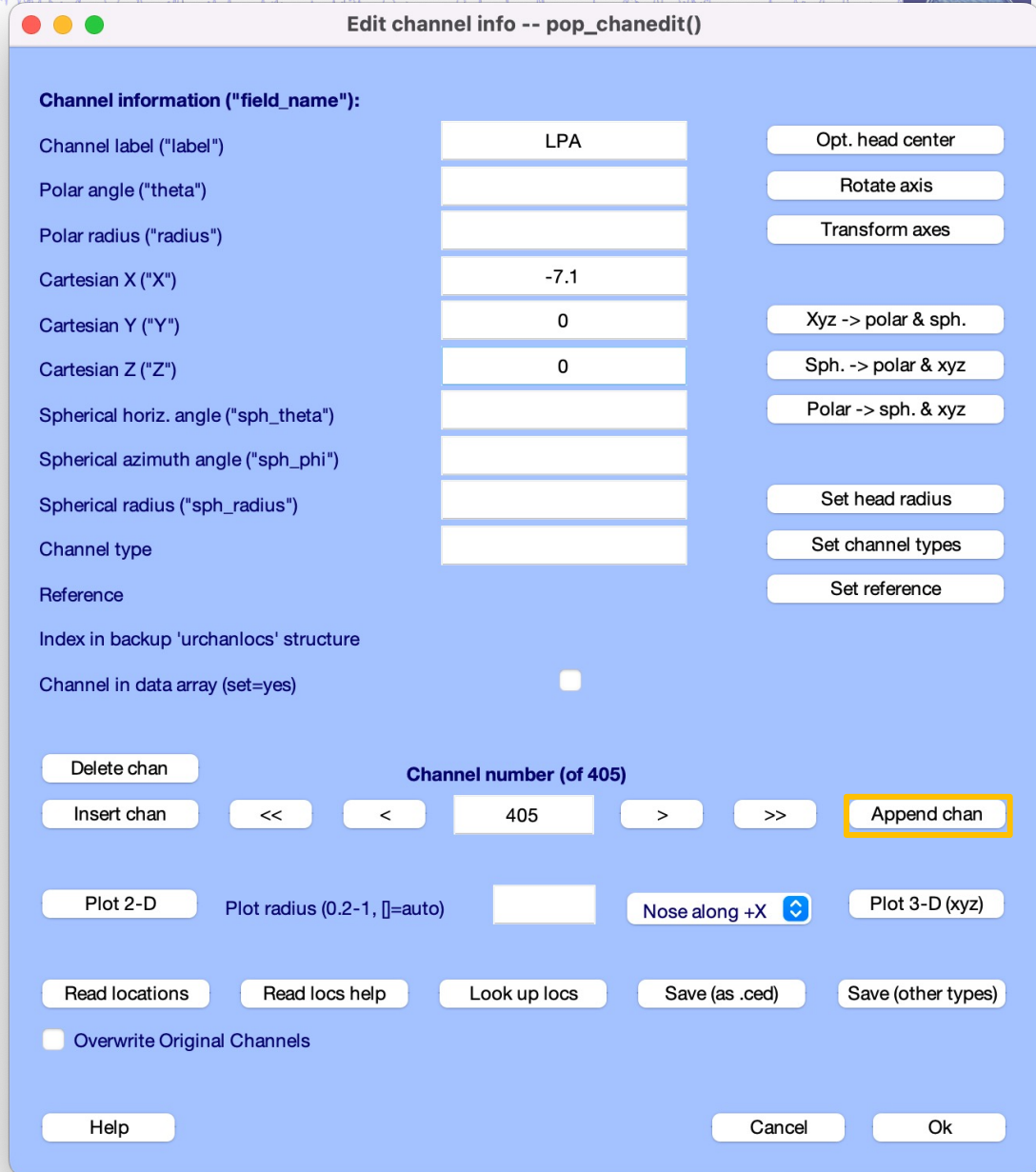
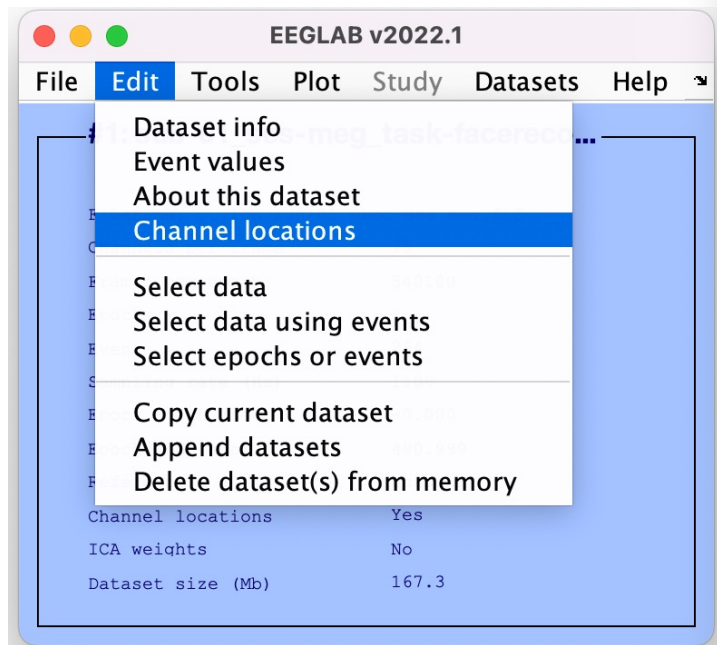
Adding fiducials



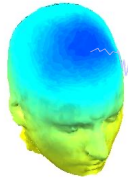
LPA = [-7.1, 0, 0];

RPA = [7.756, 0, 0];

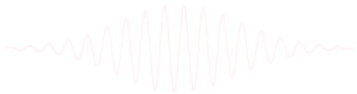
Nz = [0, 10.636, 0];



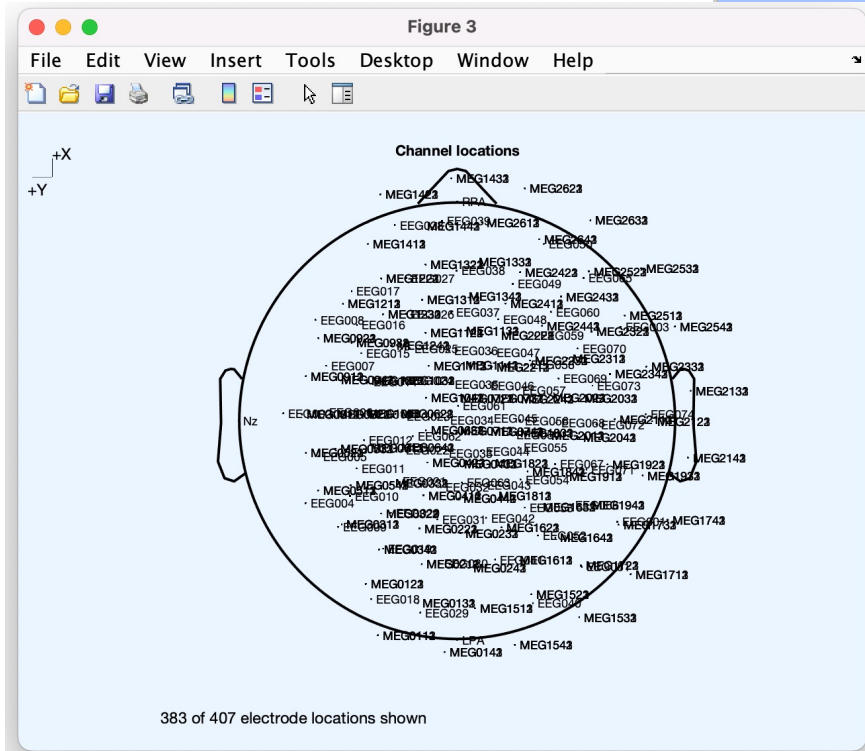
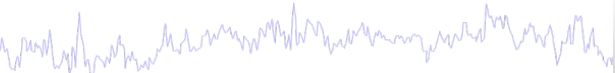
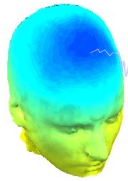
Adding fiducials



```
EEG=pop_chanedit(EEG,...  
'changefield',{n+0,'labels','LPA'},...  
'changefield',{n+0,'X','-7.1'}, 'changefield',{n+0,'Y','0'}, 'changefield',{n+0,'Z','0'},...  
'changefield',{n+1,'labels','RPA'},...  
'changefield',{n+1,'X','7.756'}, 'changefield',{n+1,'Y','0'}, 'changefield',{n+1,'Z','0'},...  
'changefield',{n+2,'labels','Nz'},...  
'changefield',{n+2,'Y','10.636'}, 'changefield',{n+2,'X','0'}, 'changefield',{n+2,'Z','0'});
```



Plot / check channel locations



Edit channel info -- pop_chanedit()

Channel information ("field_name"): Channel label ("label"): MEG0113

theta): -69.6752

"radius"): 0.52229

X"): 3.9316

'Y"): 10.6145

Z"): -0.7941

iz. angle ("sph_theta"): 69.6752

muth angle ("sph_phi"): -4.013

ius ("sph_radius"): 11.347

megplanar

up 'urchanlocs' structure

ata array (set=yes)

Channel number (of 407): 1

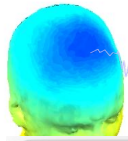
Plot 2-D Plot radius (0.2-1, []=auto) Nose along +X Plot 3-D (xyz)

Read locations Read locs help Look up locs Save (as .ced) Save (other types)

Overwrite Original Channels

Help Cancel Ok

Change nose direction of channels



Edit channel info -- pop_chanedit()

Channel information ("field_name"):

Channel label ("label")	MEG0113	Opt. head center
Polar angle ("theta")	-159.6752	Rotate axis
Polar radius ("radius")	0.52229	Transform axes
Cartesian X ("X")	-10.6145	XYZ -> polar & sph
Cartesian Y ("Y")	3.9316	Sph. -> polar & xyz
Cartesian Z ("Z")	-0.7941	Polar -> sph. & xyz
Spherical horiz. angle ("sph_theta")	159.6752	Set head radius
Spherical azimuth angle ("sph_phi")	-4.013	Set channel types
Spherical radius ("sph_radius")	11.347	Set reference
Channel type	megplanar	
Reference		
Index in backup 'urchanlocs' structure		
Channel in data array (set=yes)	<input checked="" type="checkbox"/>	

Delete chan **Channel number (of 407)** Append chan

Insert chan << < 1 > >> Append chan

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

Read locations Read locs help Look up locs Save (other types)

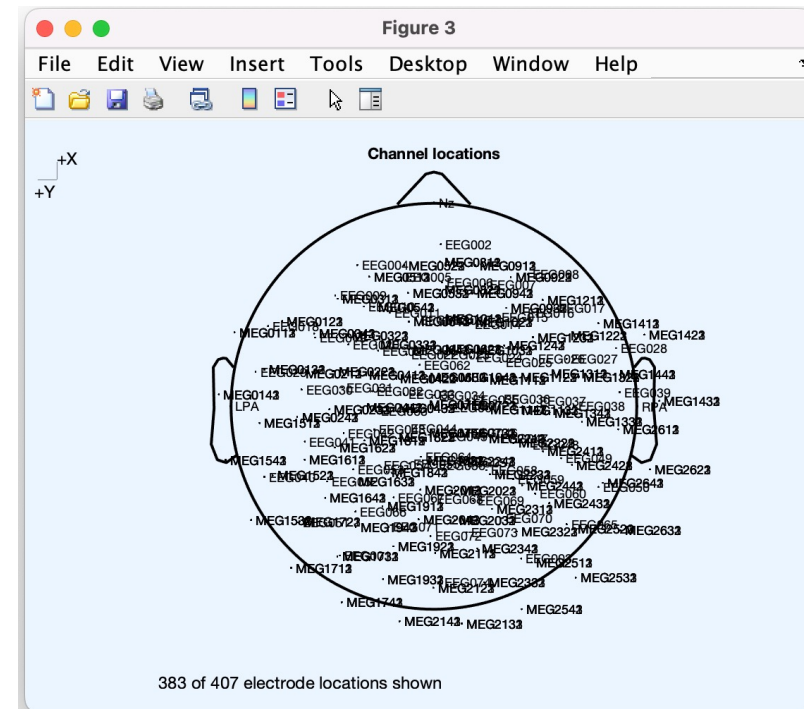
Overwrite Original Channels

Help Cancel Ok

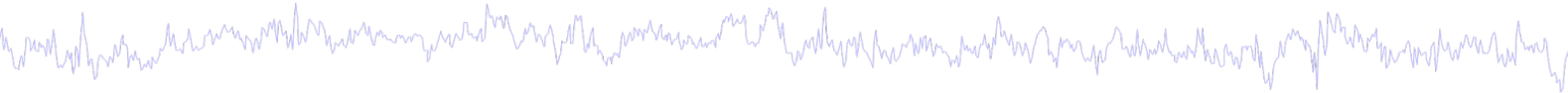
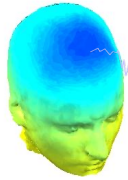
My Warn Dialog

Changing the nose direction will force EEGLAB to physically rotate electrodes, so next time you call this interface, nose direction will be +X. If your electrodes are currently aligned with a specific head model, you will have to rotate them in the model coregistration interface to realign them with the model.

Ok



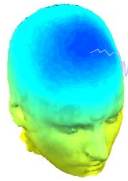
Change nose direction of channels



```
EEG = pop_chanedit(EEG, 'nosedir', '+Y');
```



Changing Channel types and removing channel locations for EOG and ECG



Edit channel info -- pop_chanedit()

Channel information ("field_name"):

Channel label ("label")	<input type="text" value="eeg061"/>	<input type="button" value="Opt. head center"/>
Polar angle ("theta")	<input type="text"/>	<input type="button" value="Rotate axis"/>
Polar radius ("radius")	<input type="text"/>	<input type="button" value="Transform axes"/>
Cartesian X ("X")	<input type="text"/>	
Cartesian Y ("Y")	<input type="text"/>	<input type="button" value="Xyz -> polar & sph."/>
Cartesian Z ("Z")	<input type="text"/>	<input type="button" value="Sph. -> polar & xyz"/>
Spherical horiz. angle ("sph_theta")	<input type="text"/>	<input type="button" value="Polar -> sph. & xyz"/>
Spherical azimuth angle ("sph_phi")	<input type="text"/>	
Spherical radius ("sph_radius")	<input type="text"/>	<input type="button" value="Set head radius"/>
Channel type	<input type="text" value="HEOG"/>	<input type="button" value="Set channel types"/>
Reference		<input type="button" value="Set reference"/>

Index in backup 'urchanlocs' structure

Channel in data array (set=yes)

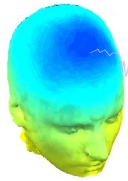
Channel number (of 78)

<< < > >>

Plot radius (0.2-1, []=auto)

Overwrite Original Channels

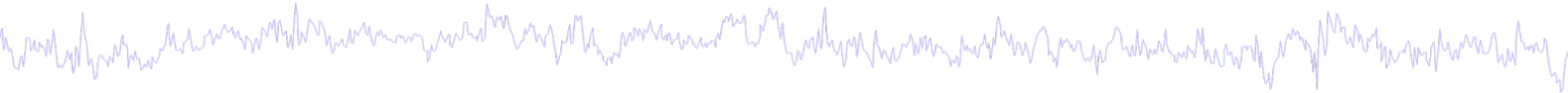
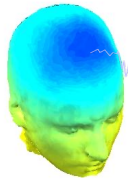
Changing Channel types and removing channel locations for EOG and ECG



```
EEG = pop_chanedit(EEG,...  
'chanefield',{...  
61 ... % channel number  
'type' 'HEOG'... % channel type  
'X' []... % channel locations  
'Y' []...  
'Z' []...  
'theta' []...  
'radius' []...  
'sph_theta' []...  
'sph_phi' []...  
'sph_radius' []});
```



Import data events



EEGLAB v2022.1

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
- Preferences
- History scripts
- Manage EEGLAB extensions
- Quit

facereco...

- From Matlab array or ASCII file
- From data channel
- From Presentation .LOG file
- From E-Prime ASCII (text) file
- From ERPLAB text files

Extract event from channel(s) - pop_chanevent()

Event channel(s) 381

Preprocessing transform (data='X') 'double(bitand

Transitions to extract? (up|down) up (leading)

Transition length (1=perfect edges) 1

Assign duration to each events? (set=yes)

Delete event channel(s)? (set = yes)

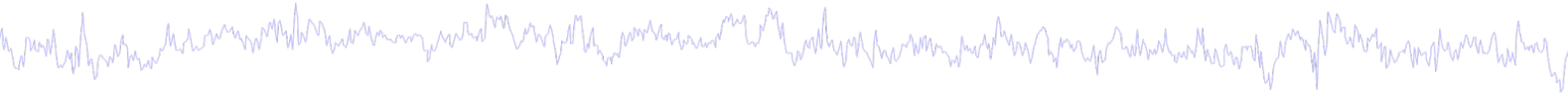
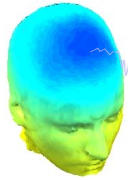
Delete old events if any?

All events of same type?

Help Cancel Ok

'double(bitand(int32(X),31))'

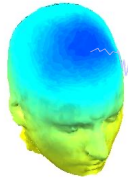
Import data events



```
edgelenval = 1;
EEG = pop_chanevent(EEG, 381, ...
'edge', 'leading', ... % extract events when value goes up
'edgelen', edgelenval, ... % maximum edge length
'delevent', 'on', ...
'delchan', 'off', ...
'oper', 'double(bitand(int32(X), 31))'); % first 5 bits
% prior to extracting edges, preprocess data
```



Plot raw data channel



EEGLAB v2022.1

File Edit Tools **Plot** Study Datasets Help

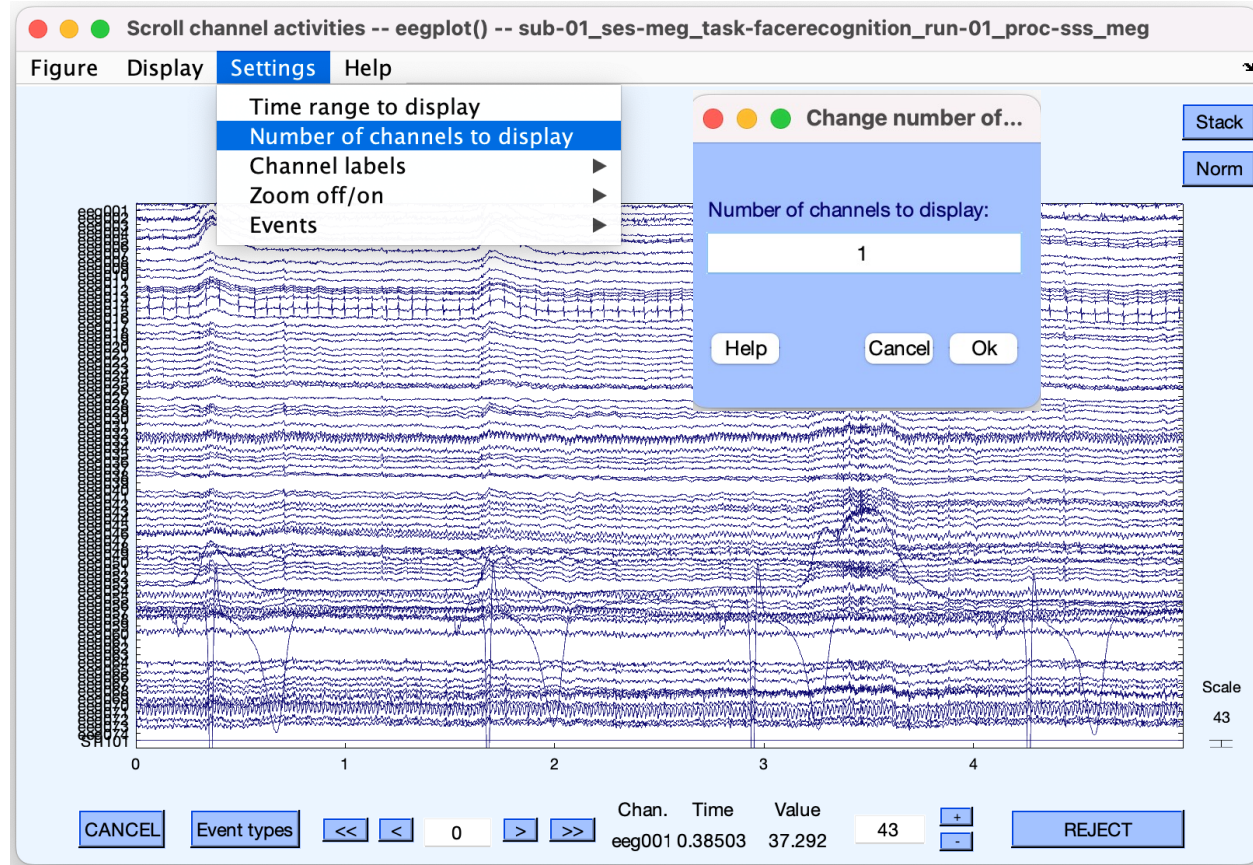
#1: sub-01_se

- Channel locations
- Channel data (scroll)**
- Channel spectra and maps
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Channel time-frequency

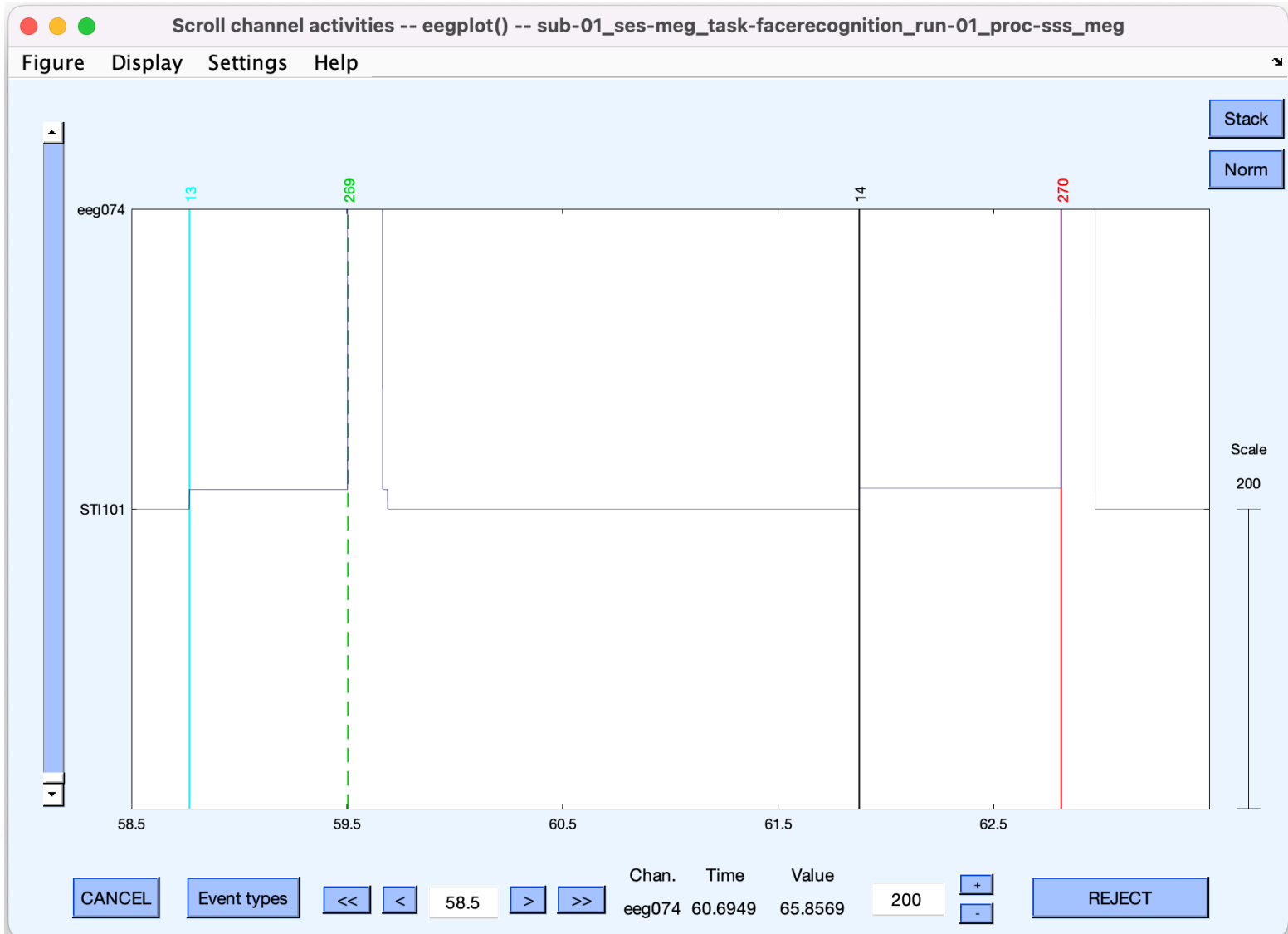
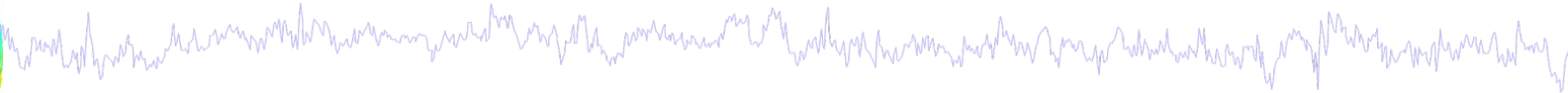
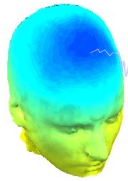
Component activations (scroll)

- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Component time-frequency

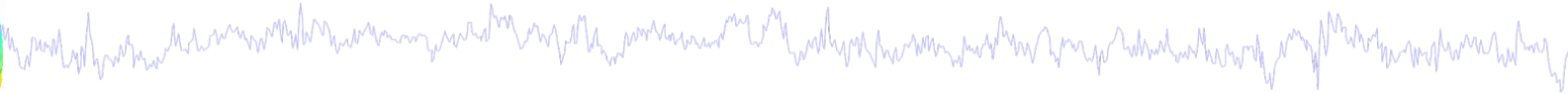
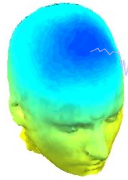
Filename: ...ion
Channels per fram
Frames per epoch
Epochs
Events
Sampling rate (Hz)
Epoch start (sec)
Epoch end (sec)
Reference
Channel locations
ICA weights
Dataset size (Mb)



Appearance of an event channel in raw data



Imported data events



```
>> EEG.event
```

```
ans =
```

```
1×259 struct array with fields:
```

```
    latency  
    type  
    urevent
```

```
>> {EEG.event.type}
```

```
ans =
```

```
1×259 cell array
```

```
Columns 1 through 8
```

```
    {'Unfamiliar'}    {'left_nonsym'}    {'Unfamiliar'}    {'left_nonsym'}    {'Unfamiliar'}    {'Unfamiliar'}    {'Famous'}    {'r
```

```
Columns 9 through 17
```

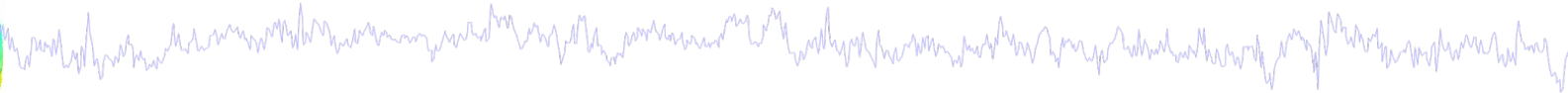
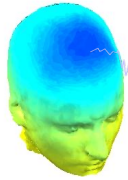
```
    {'Unfamiliar'}    {'Famous'}    {'right_sym'}    {'Scrambled'}    {'Unfamiliar'}    {'Famous'}    {'right_sym'}    {'Unfamiliar
```

```
Columns 18 through 26
```

```
    {'left_nonsym'}    {'Unfamiliar'}    {'left_nonsym'}    {'Famous'}    {'right_sym'}    {'Famous'}    {'right_sym'}    {'Unfamil
```

```
Columns 27 through 35
```

Adjust event latencies



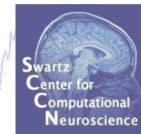
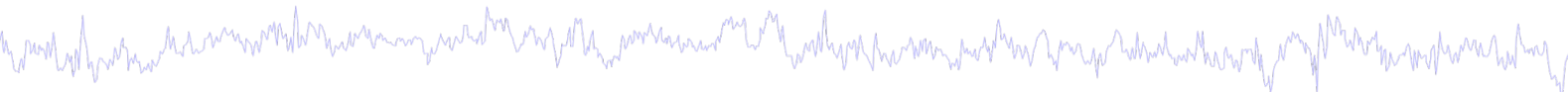
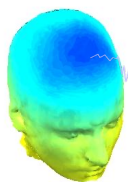
```
EEG = pop_adjustevents(EEG, 'addms', 34);
```

Correcting event latencies

-> events have a shift of 34 ms as per the authors



Imported data events

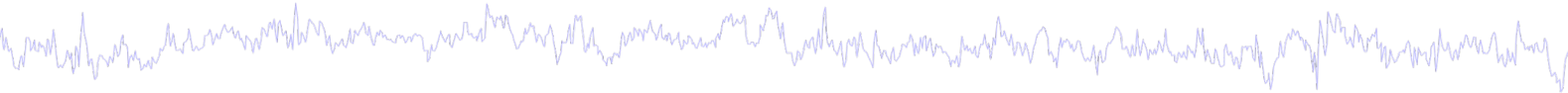
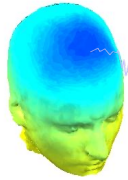


```
EEGLAB v2022.1
File Edit Tools Plot Study Datasets Help
#1: sub-01_ses-meg_task-facereco...
Filename: ...ion run-01 proc-sss meg.fif
Channels per frame      74
Frames per epoch       540100
Epochs                 1
Events                 259
Sampling rate (Hz)     1100
Epoch start (sec)     -0.000
Epoch end (sec)       490.999
Reference               unknown
Channel locations       Yes
ICA weights            No
Dataset size (Mb)      165.1
```

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



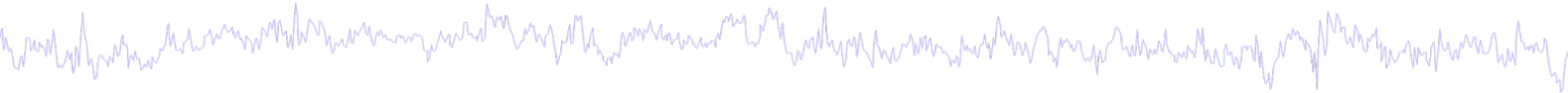
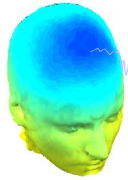
Select EEG channels



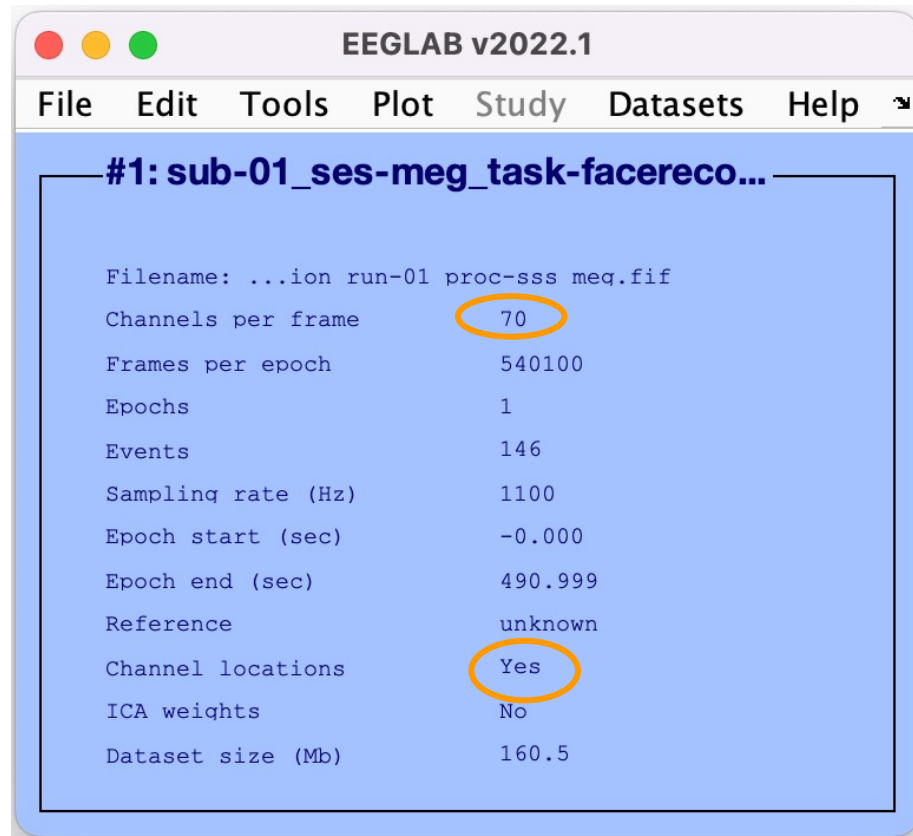
- EEG001-EEG060 and EEG065-EEG074 → EEG,
- EEG061-EEG064 → HEOG, VEOG and ECG.
- STI101 → event channel



Select EEG channels



```
EEG = pop_select(EEG, 'chantype', 'eeg');
```



Optimize headcenter



Edit channel info -- pop_chanedit()

Channel information ("field_name"):

Channel label ("label")	EEG001	Opt. head center
Polar angle ("theta")	-147.7955	Rotate axis
Polar radius ("radius")	0.43278	Transform axes
Cartesian X ("X")	-6.6155	
Cartesian Y ("Y")	4.1667	Xyz -> polar & sph.
Cartesian Z ("Z")	1.676	Sph. -> polar & xyz
Spherical horiz. angle ("sph_theta")	147.7955	Polar -> sph. & xyz
Spherical azimuth angle ("sph_phi")	12.0991	
Spherical radius ("sph_radius")	7.996	Set head radius
Channel type	eeg	Set channel types
Reference		Set reference
Index in backup 'urchanlocs' structure		
Channel in data array (set=yes)	<input checked="" type="checkbox"/>	

Delete chan Channel number (of 73)

Insert chan << < 1 > >>

Plot 2-D Plot radius (0.2-1, []=auto) N

Read locations Read locs help Look up locs

Overwrite Original Channels

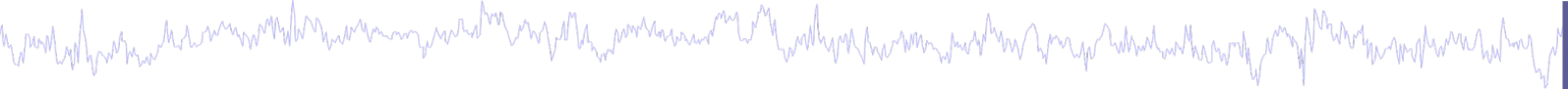
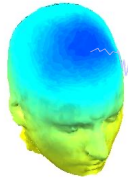
Help

Convert channel locations -- pop_chancenter()

Optimize center location or specify center

Channel indices to ignore for best-sphere matching

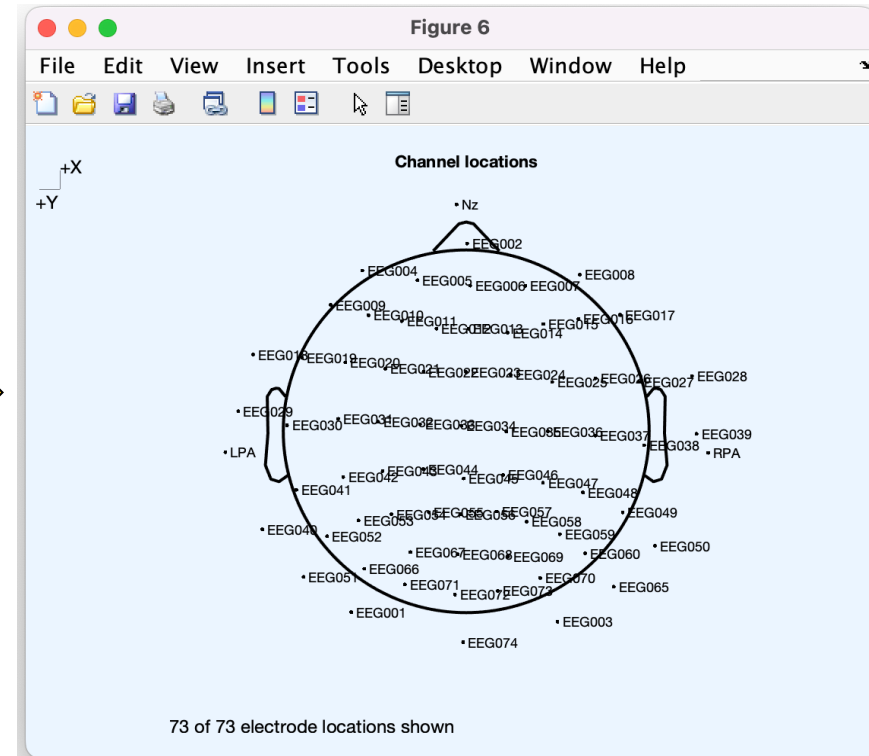
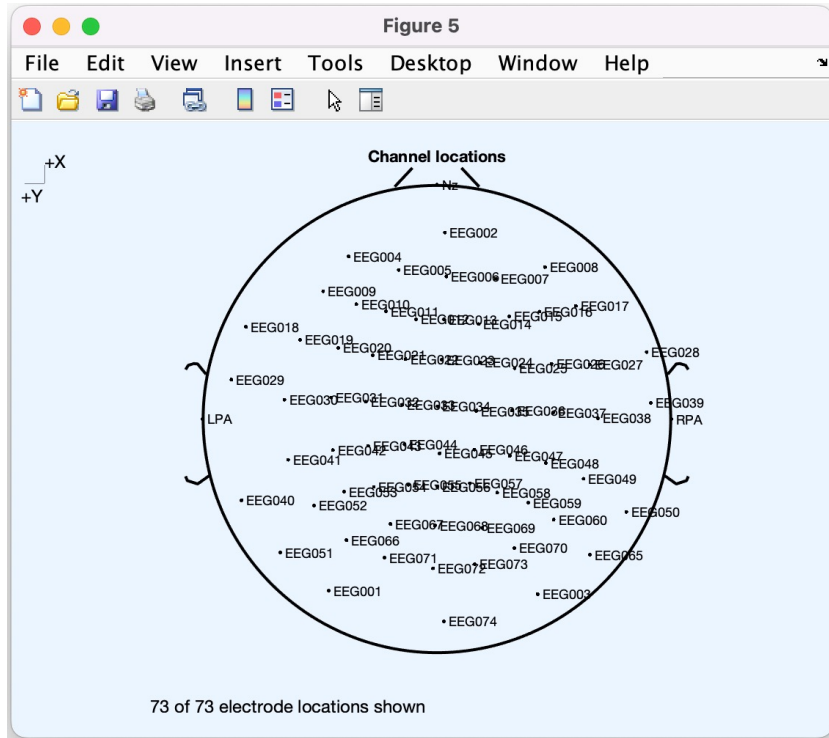
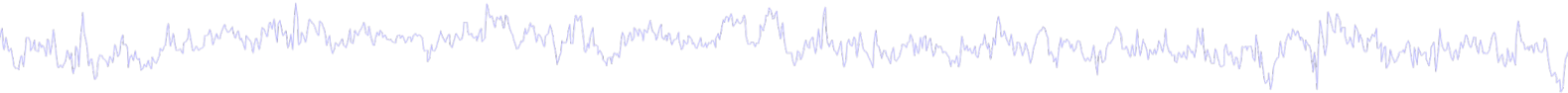
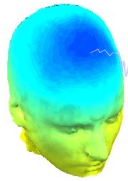
Optimize headcenter



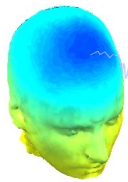
```
EEG = pop_chanedit(EEG,...  
'eval','chans = pop_chancenter( chans, [],[])');
```



Optimize headcenter



Plot channel locations in 2D and 3 D



Edit channel info -- pop_chanedit()

Channel information ("field_name"): Channel label ("label") Polar angle ("theta")

EEG001	Opt. head center
-147.7896	Rotate axis
0.58748	
-7.2743	
4.5827	
-2.4242	
147.7896	
-15.7466	
8.9328	
eeg	

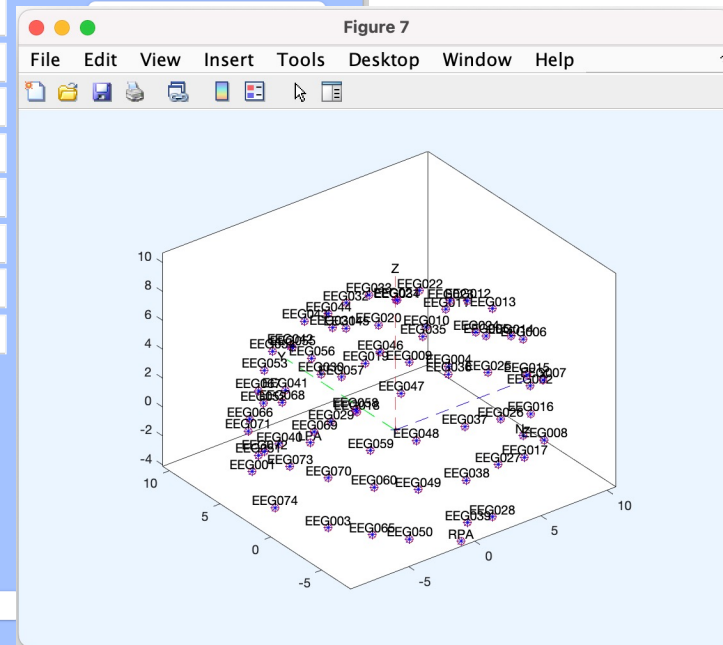
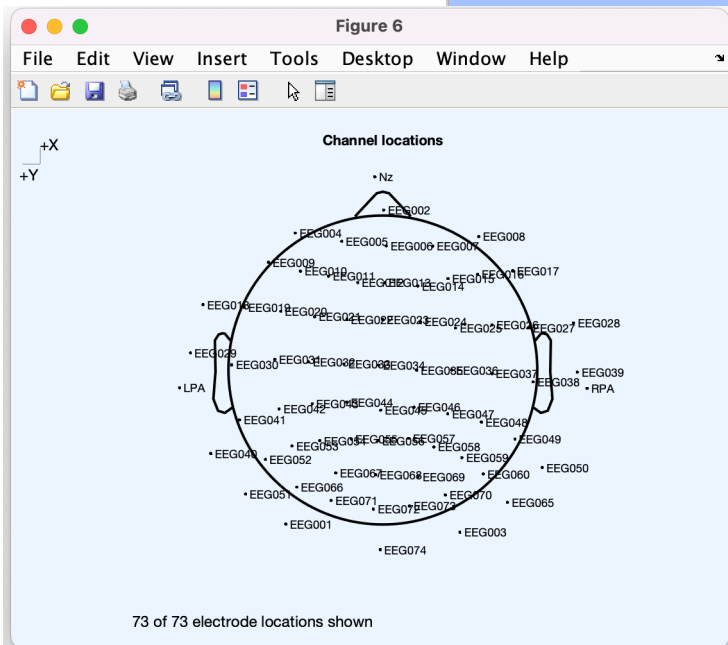
Channel number (of 73) 1

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

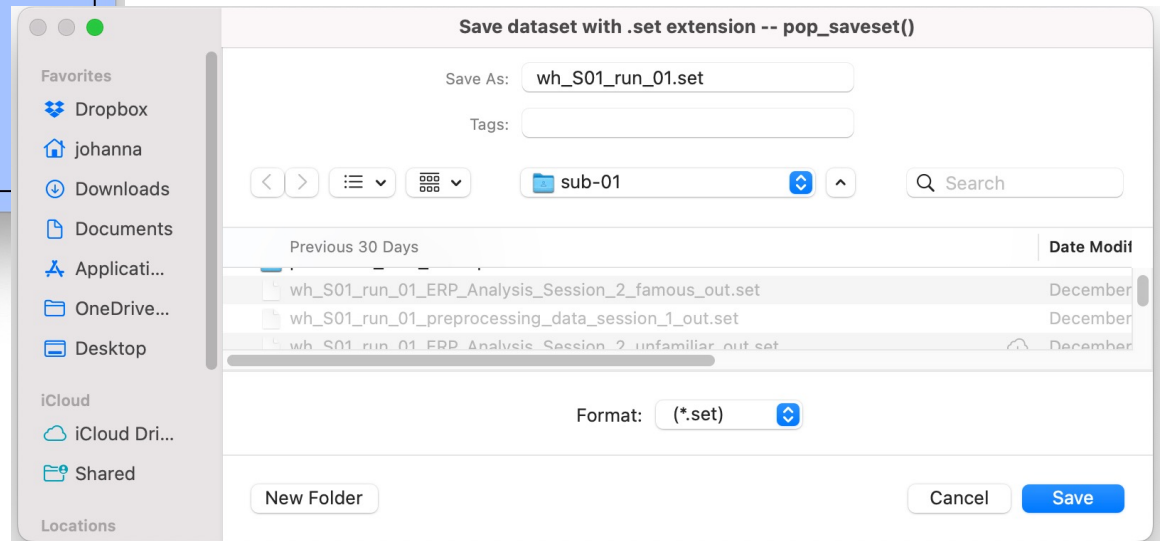
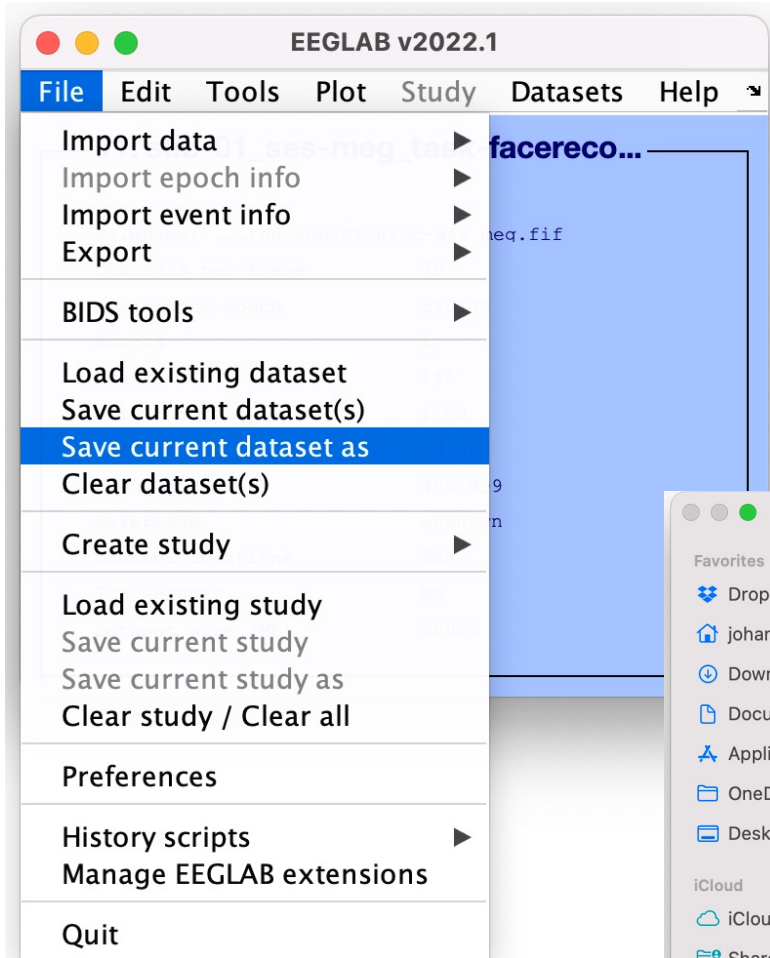
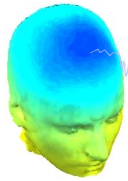
Read locations Read locs help Look up locs Save (as .ced) Save (other types)

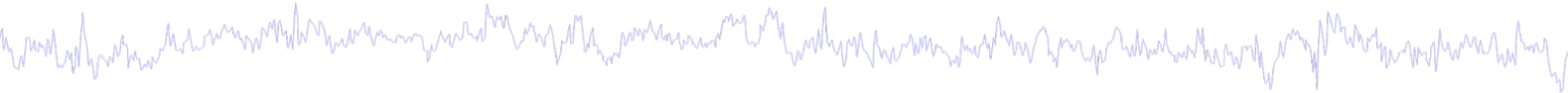
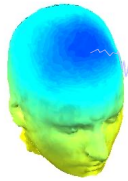
Overwrite Original Channels

Help Cancel OK



Save dataset





EEGLAB v2022.1

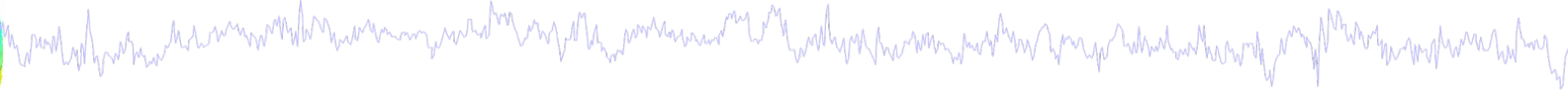
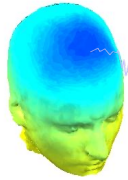
File Edit Tools Plot Study Datasets Help

#1: sub-01_ses-meg_task-facereco...

```
Filename: ...ta/sub-01/wh S01 run 01.set
Channels per frame      70
Frames per epoch       540100
Epochs                 1
Events                 146
Sampling rate (Hz)     1100
Epoch start (sec)     -0.000
Epoch end (sec)       490.999
Reference              unknown
Channel locations      Yes
ICA weights            No
Dataset size (Mb)      160.5
```



EEG structure



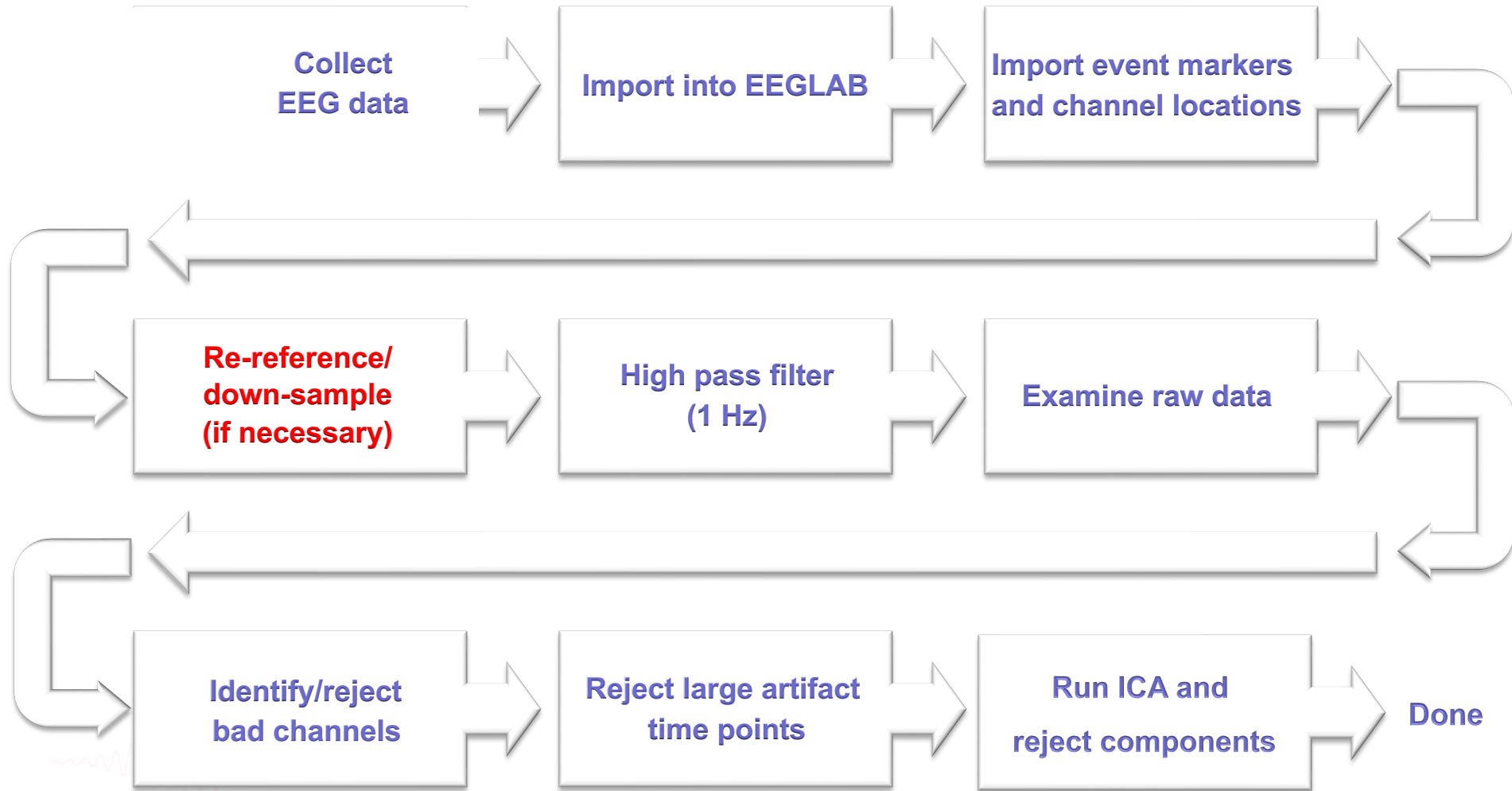
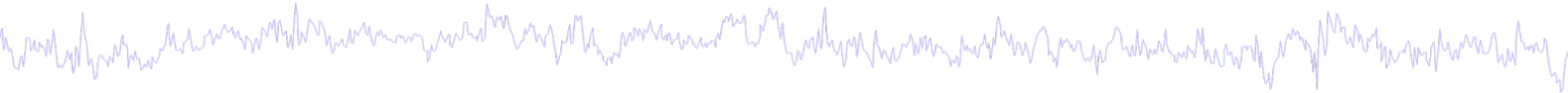
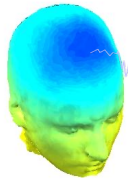
>> EEG

EEG =

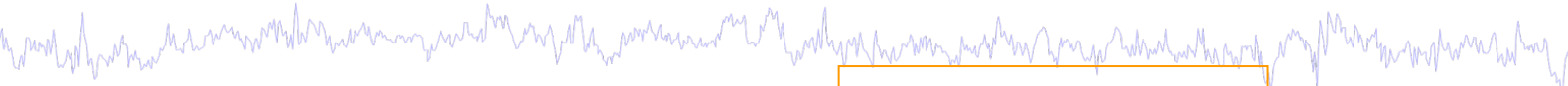
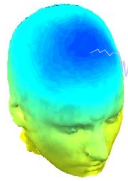
struct with fields:

```
setname: 'sub-01_ses-meg_task-facerecognition_run-01_proc-sss_meg'  
filename: 'wh_S01_run_01.set'  
filepath: '/Users/johanna/Library/CloudStorage/GoogleDrive-joa.wagn@gmail.com/My Drive/eeglab workshop/PracticalMEEG_2022/Data/sub-01/'  
subject: 'sub-01'  
group: ''  
condition: ''  
session: []  
comments: 'Original file: /Volumes/GoogleDrive/.shortcut-targets-by-id/1pfQX7Y9f6LSy69ZhRCWZ2e1pnUiSkHAj/PracticalMEEG_2022/Data/sub-01/sub-01_se  
nbchan: 74  
trials: 1  
  pnts: 540100  
  srate: 1100  
  xmin: 0  
  xmax: 490.9991  
  times: [0 0.9091 1.8182 2.7273 3.6364 4.5455 5.4545 6.3636 7.2727 8.1818 9.0909 10 10.9091 11.8182 12.7273 13.6364 14.5455 15.4545 ... ]  
  data: [74x540100 single]  
icaact: []  
icawinv: []  
icasphere: []  
icaweights: []  
icachansind: []  
  chanlocs: [74x1 struct]  
  urchanlocs: [74x1 struct]  
  chaninfo: [1x1 struct]  
    ref: 'common'  
  event: [1x259 struct]  
  urevent: [1x259 struct]  
eventdescription: {'' '' ''}  
  epoch: []  
epochdescription: {}  
  reject: [1x1 struct]  
  stats: [1x1 struct]  
specdata: []  
specicaact: []  
splinefile: ''  
icasplinefile: ''  
dipfit: []  
history: '←EEG.etc.eeglabvers = '2021.0'; % this tracks which version of EEGLAB is being used, you may ignore it←EEG.etc.eeglabvers = '2022.1';  
saved: 'yes'
```

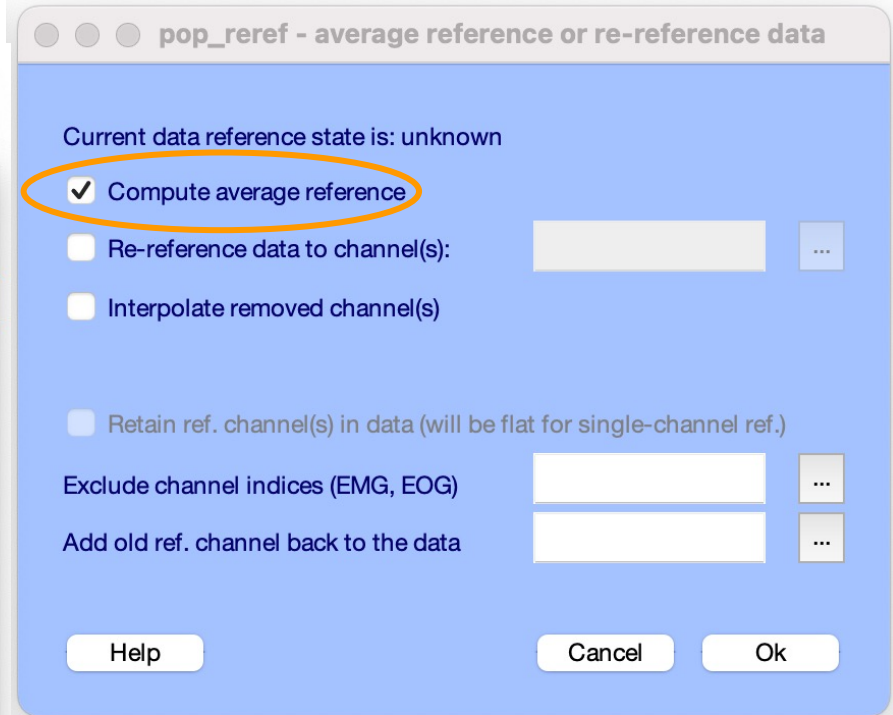
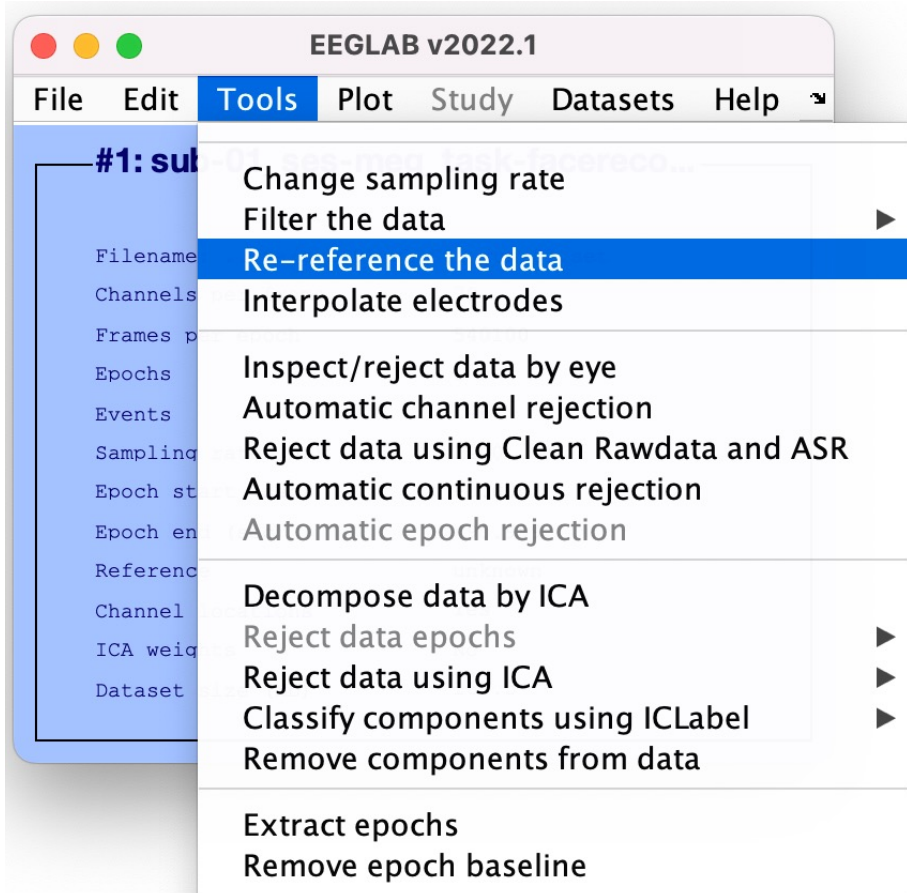
Pre-processing pipeline



Re-reference data (if necessary/desired)

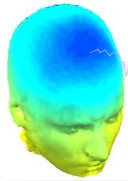


average reference



```
EEG = pop_reref(EEG,[]);
```

Create new dataset, keep old one



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. What do you want to do with the old dataset?

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

Save it as file:

EEGLAB v2022.1

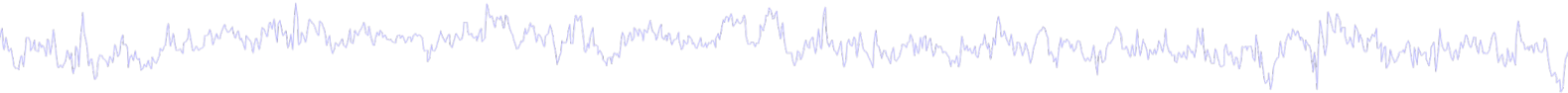
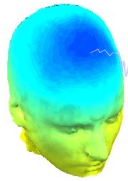
File Edit Tools Plot Study Datasets Help

#2: sub-01_avref

Filename:	none
Channels per frame	70
Frames per epoch	540100
Epochs	1
Events	146
Sampling rate (Hz)	1100
Epoch start (sec)	-0.000
Epoch end (sec)	490.999
Reference	average
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	160.5



Multiple active datasets



EEGLAB v2022.1

File Edit Tools Plot Study Datasets Help

#1: sub-01_ses-meg_task-facereco...

Filename:	...ta/sub-01/wh S01 run 01.set
Channels per frame	70
Frames per epoch	540100
Epochs	1
Events	146
Sampling rate (Hz)	1100
Epoch start (sec)	-0.000
Epoch end (sec)	490.999
Reference	unknown
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	160.5

EEGLAB v2022.1

File Edit Tools Plot Study **Datasets** Help

#2: sub-01_avref

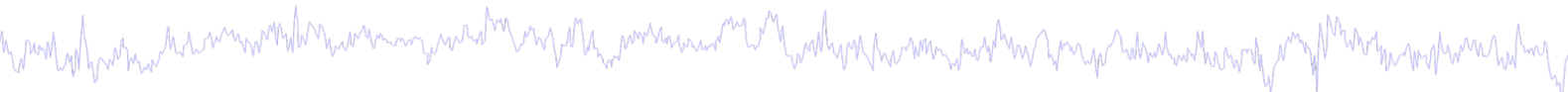
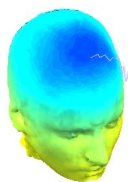
Filename:	none
Channels per frame	70
Frames per epoch	540100
Epochs	1
Events	146
Sampling rate (Hz)	1100
Epoch start (sec)	-0.000
Epoch end (sec)	490.999
Reference	average
Channel locations	yes
ICA weights	No
Dataset size (Mb)	160.5

Dataset 1:sub-01_ses-meg_task-facereco...
✓ Dataset 2:sub-01_avref

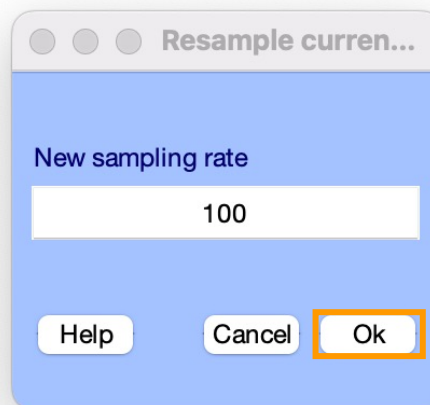
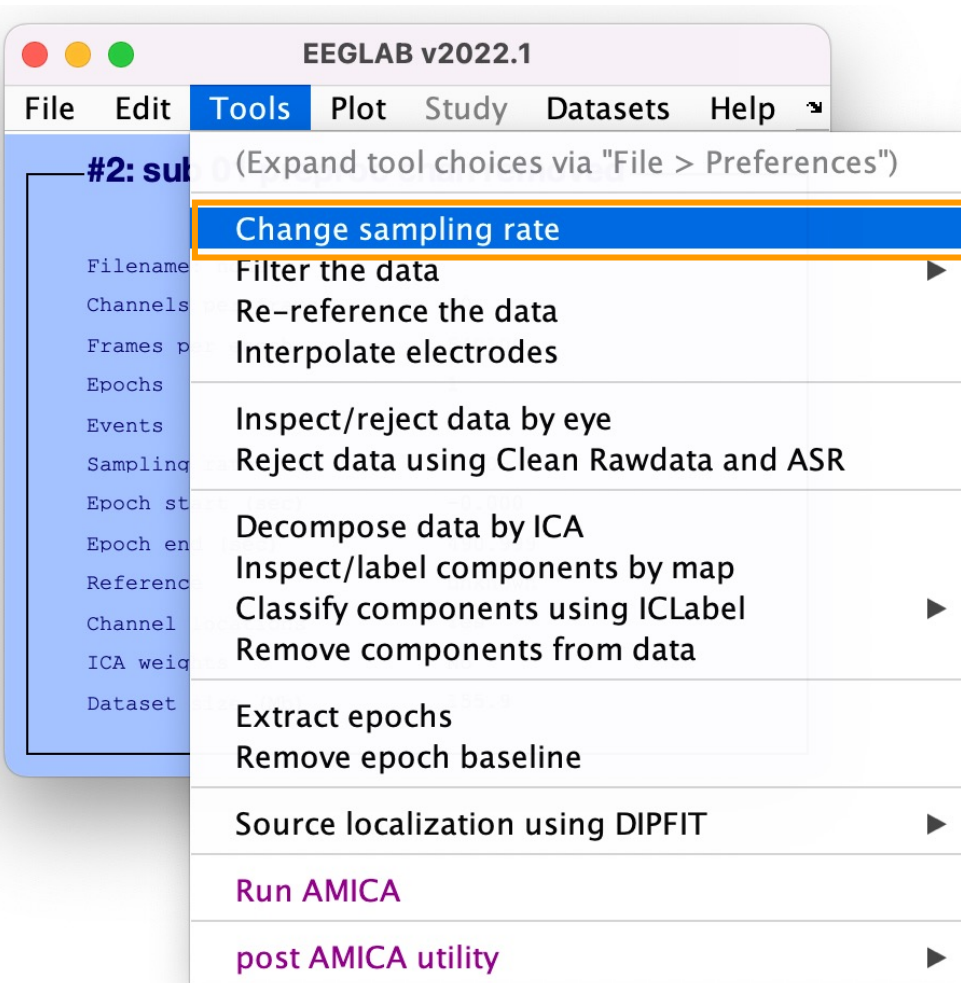
Select multiple datasets



Resample data (if desired)

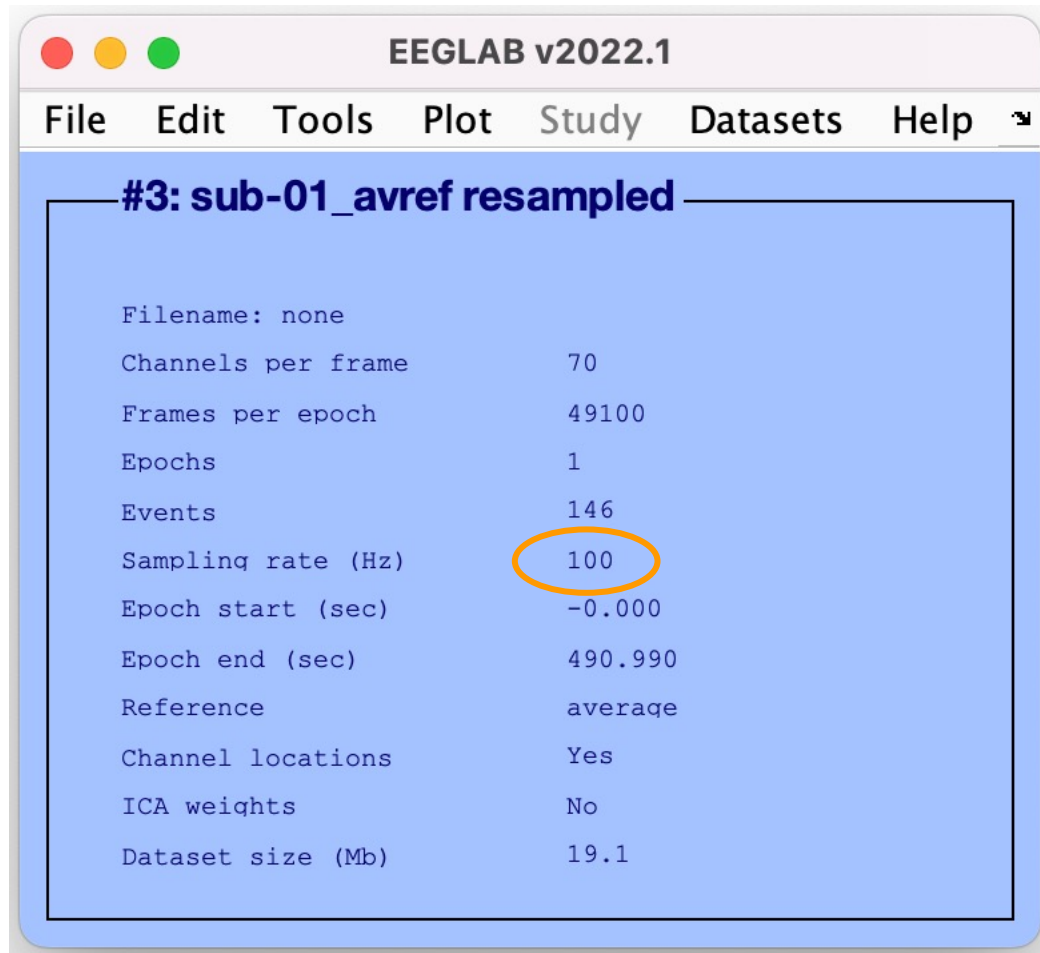
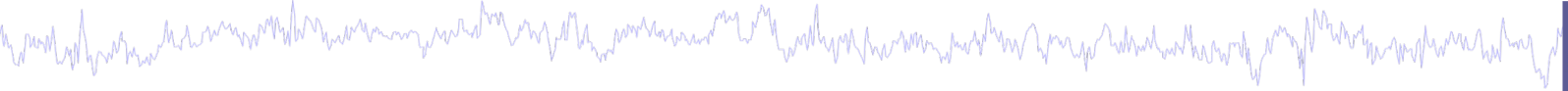
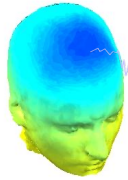


Reason: Reduce space, time.

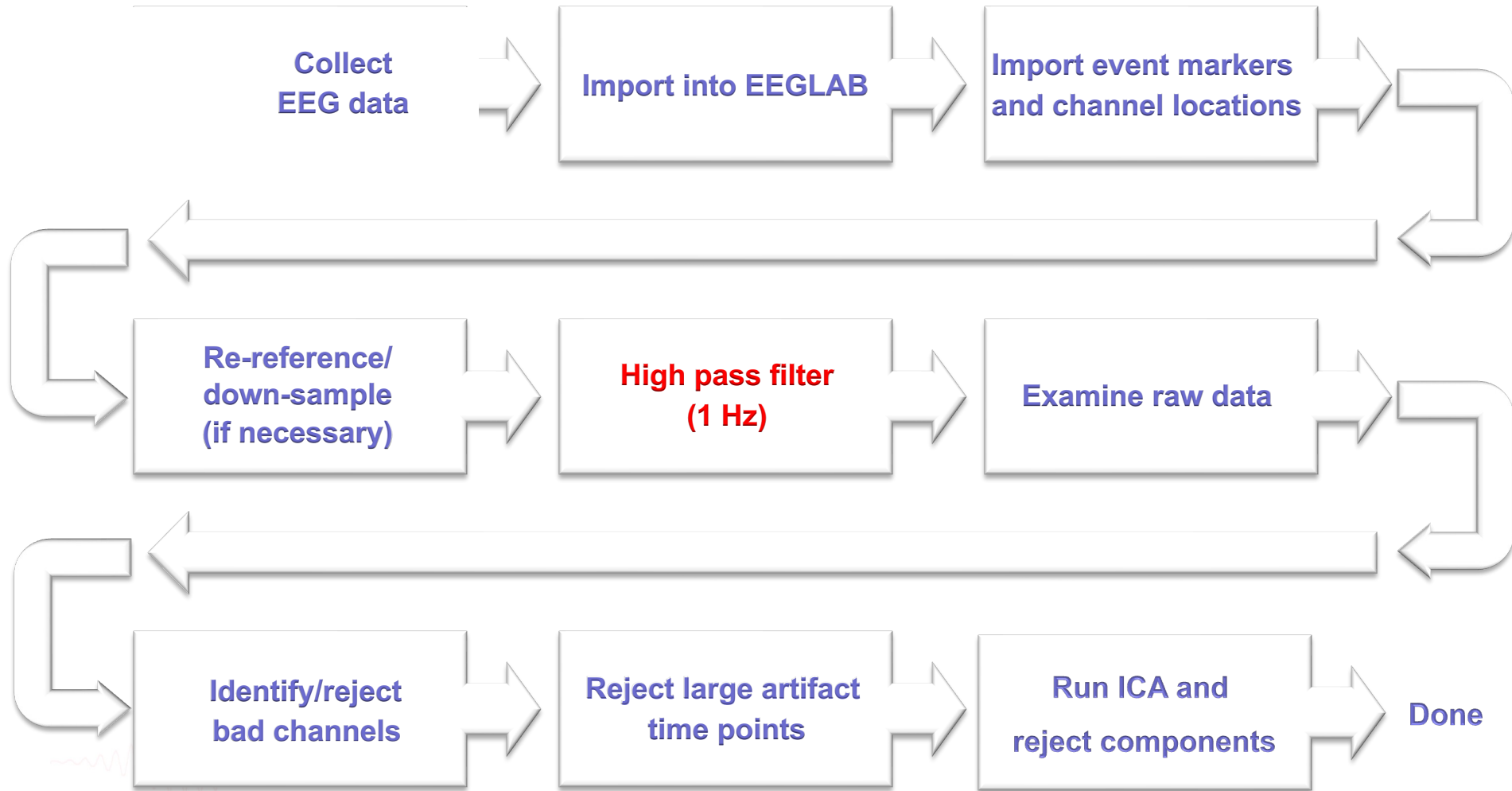
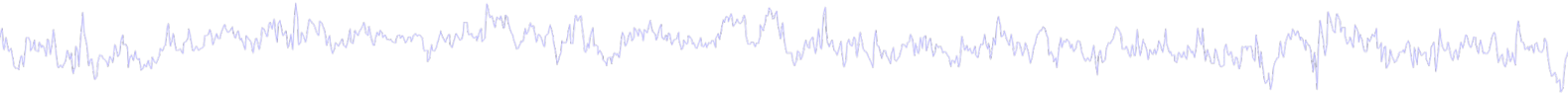
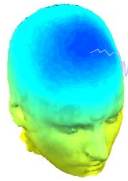


```
EEG = pop_resample(EEG, 100);
```

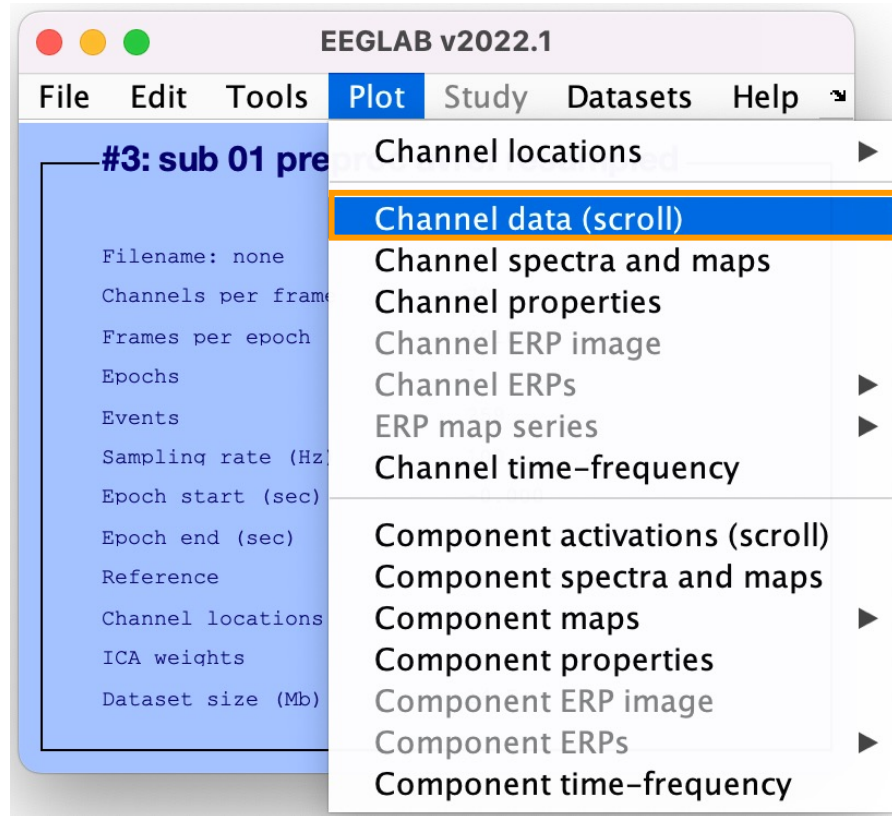
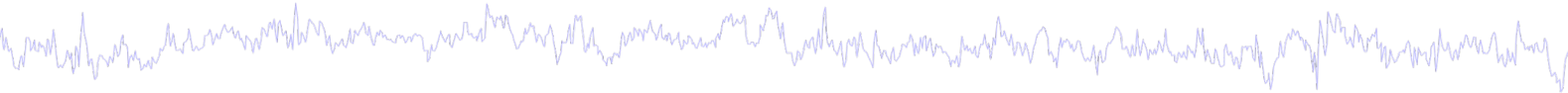
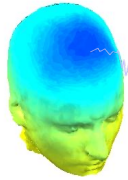
Resample data



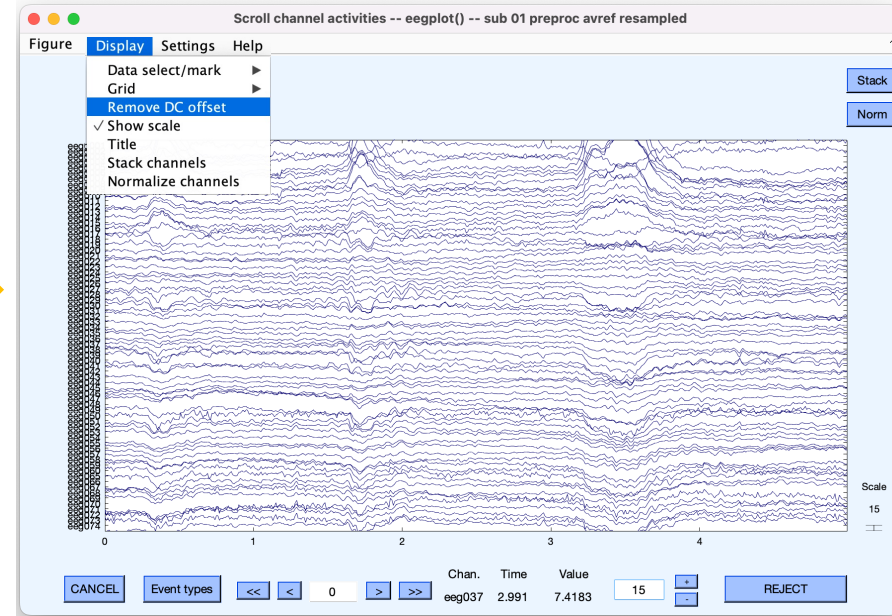
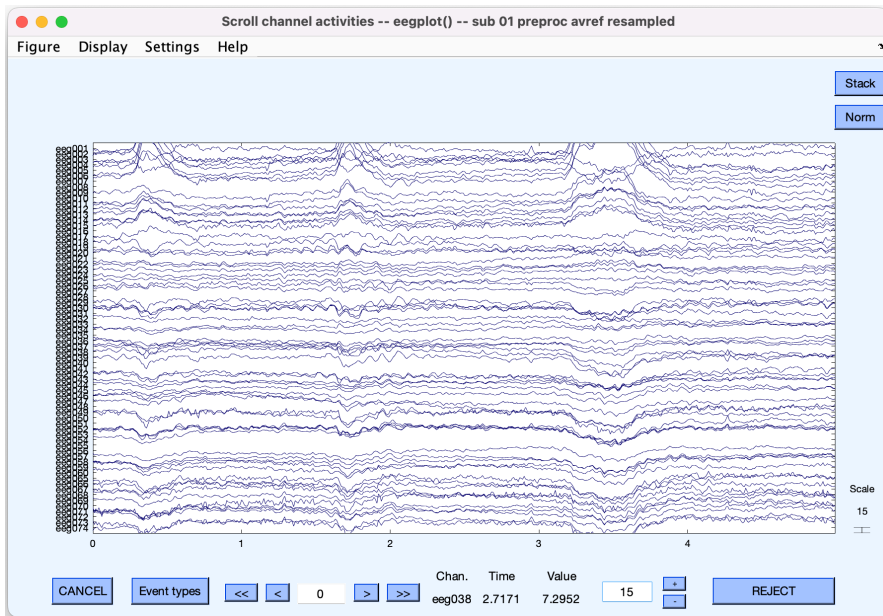
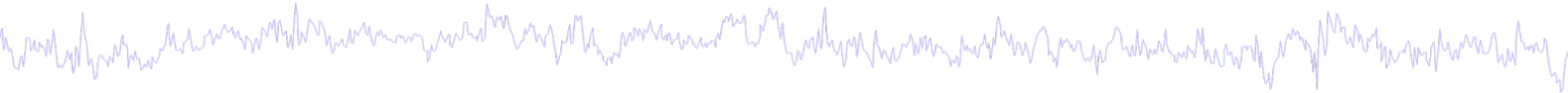
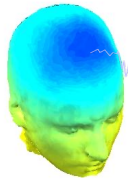
Pre-processing pipeline



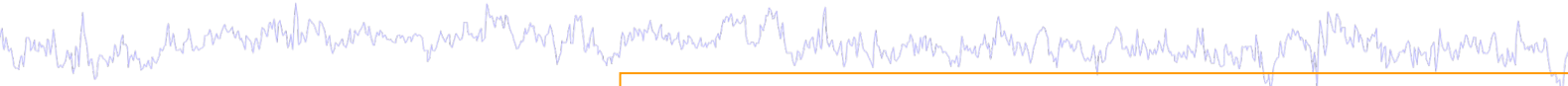
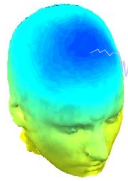
Scroll channel data



Scroll channel data



High-Pass Filter the data



Reason: remove slow, possibly large amplitude, drift

EEGLAB v2022.1

File Edit **Tools** Plot Study Datasets Help

#3: sul (Expand tool choices via "File > Preferences")

- Change sampling rate
- Filter the data** ▶
 - Basic FIR filter (new, default)**
 - Windowed sinc FIR filter
 - Parks-McClellan (equiripple) FIR filter
 - Moving average FIR filter
 - Basic FIR filter (legacy)
- Re-reference the data
- Interpolate electrodes
- Inspect/reject data by eye
- Reject data using Clean Rawdata and ASR
- Decompose data by ICA
 - Inspect/label components by map
 - Classify components using ICLabel ▶
 - Remove components from data
- Extract epochs
 - Remove epoch baseline
- Source localization using DIPFIT ▶
- Run AMICA
- post AMICA utility ▶

Filter the data -- pop_eegfiltnew()

Lower edge of the frequency pass band (Hz)

Higher edge of the frequency pass band (Hz)

FIR Filter order (Mandatory even. Default is automatic*)

*See help text for a description of the default filter order heuristic. Manual definition is recommended.

Notch filter the data instead of pass band

Use minimum-phase converted causal filter (non-linear!; beta)

Plot frequency response

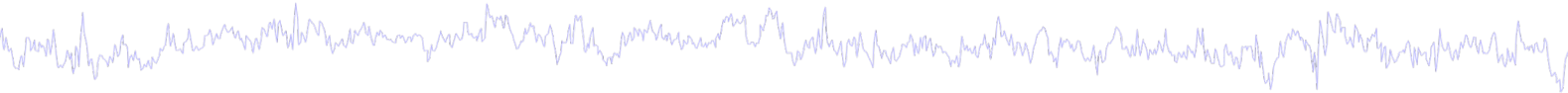
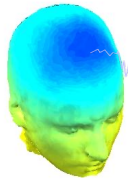
Channel type(s) ...

OR channel labels or indices ...

Help Cancel Ok

Highpass Filter for ICA

Low-Pass Filter the data



EEGLAB v2022.1

File Edit **Tools** Plot Study Datasets Help

#4: sul (Expand tool choices via "File > Preferences")

- Change sampling rate
- Filter the data**
- Re-reference the data
- Interpolate electrodes
- Inspect/reject data by eye
- Reject data using Clean Rawdata and ASR
- Decompose data by ICA
- Inspect/label components by map
- Classify components using ICLabel
- Remove components from data
- Extract epochs
- Remove epoch baseline
- Source localization using DIPFIT
- Run AMICA
- post AMICA utility

- Basic FIR filter (new, default)**
- Windowed sinc FIR filter
- Parks-McClellan (equiripple) FIR filter
- Moving average FIR filter
- Basic FIR filter (legacy)

Filter the data -- pop_eegfiltnew()

Lower edge of the frequency pass band (Hz)

Higher edge of the frequency pass band (Hz)

FIR Filter order (Mandatory even. Default is automatic*)

*See help text for a description of the default filter order heuristic. Manual definition is recommended.

Notch filter the data instead of pass band

Use minimum-phase converted causal filter (non-linear!; beta)

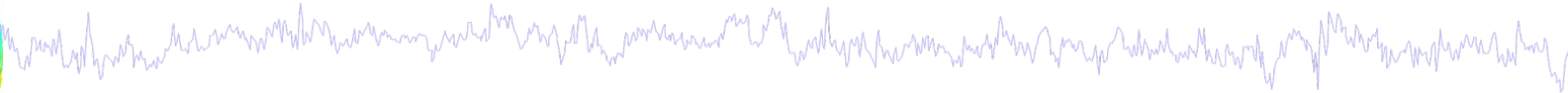
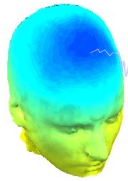
Plot frequency response

Channel type(s) ...

OR channel labels or indices ...

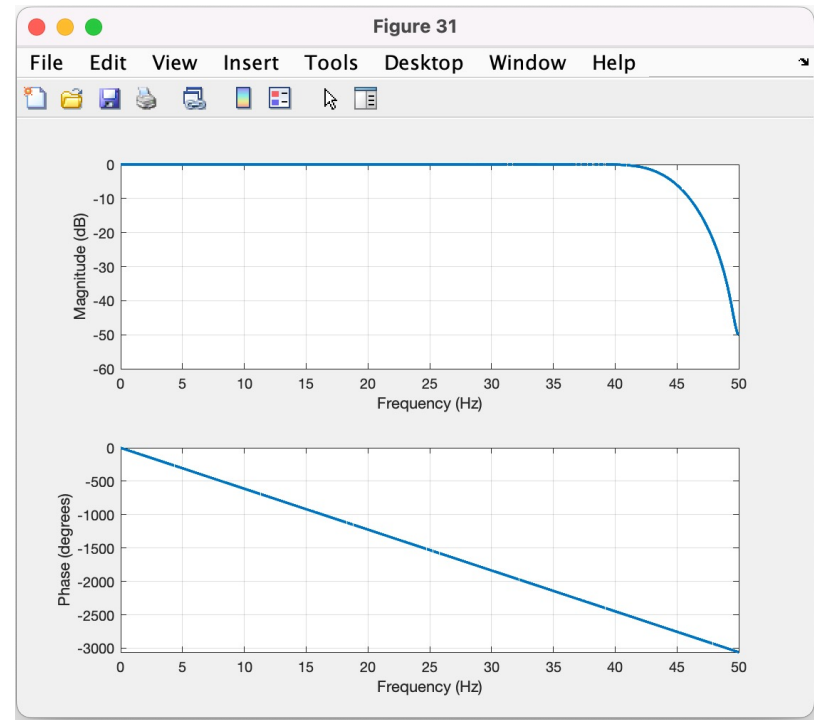
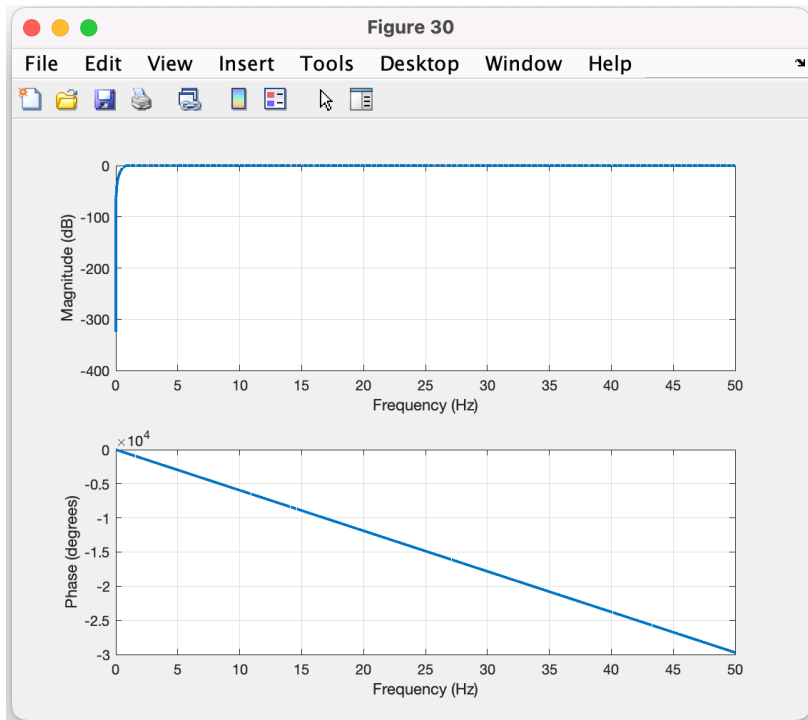
Help Cancel Ok

Filter the data

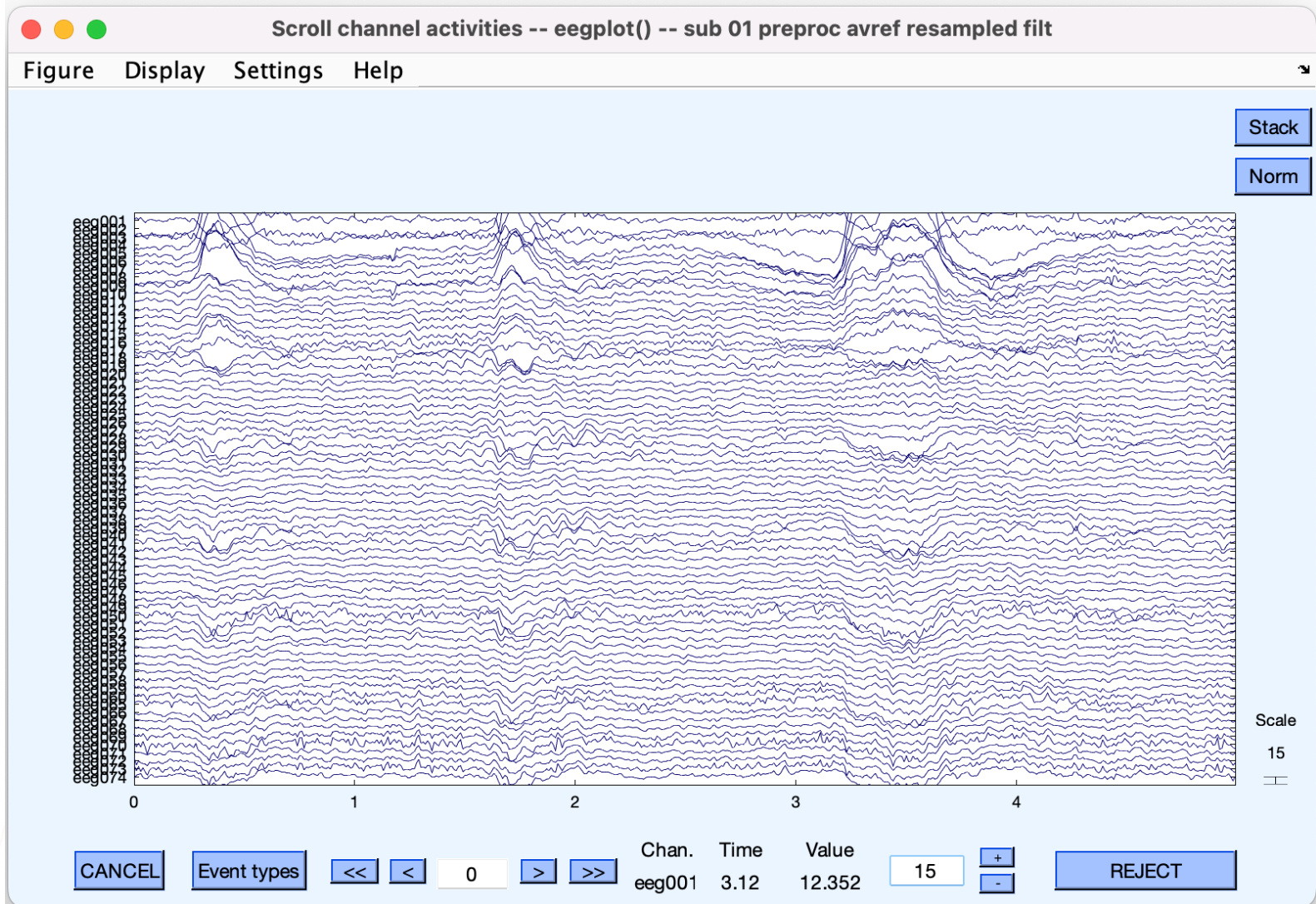
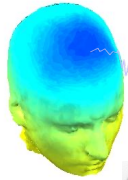


High pass (1 Hz)

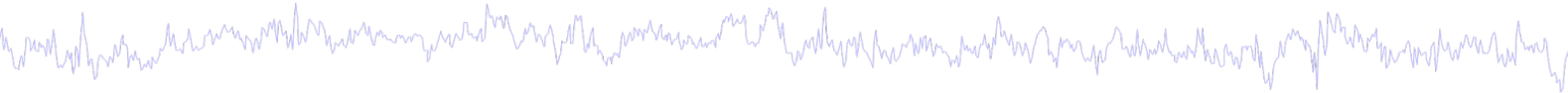
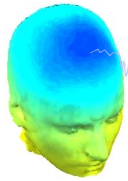
Low pass (40 Hz)



Scroll filtered channel data



Plot channel properties



EEGLAB v2022.1

File Edit Tools **Plot** Study Datasets Help

#5: sub 01 pre

- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties**
- Channel ERP image
- Channel ERPs
- ERP map series
- Channel time-frequency
- Component activations (scroll)
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Component time-frequency

Filename: none
Channels per frame
Frames per epoch
Epochs
Events
Sampling rate (Hz)
Epoch start (sec)
Epoch end (sec)
Reference
Channel locations
ICA weights
Dataset size (Mb)

Channel properties - pop_prop()

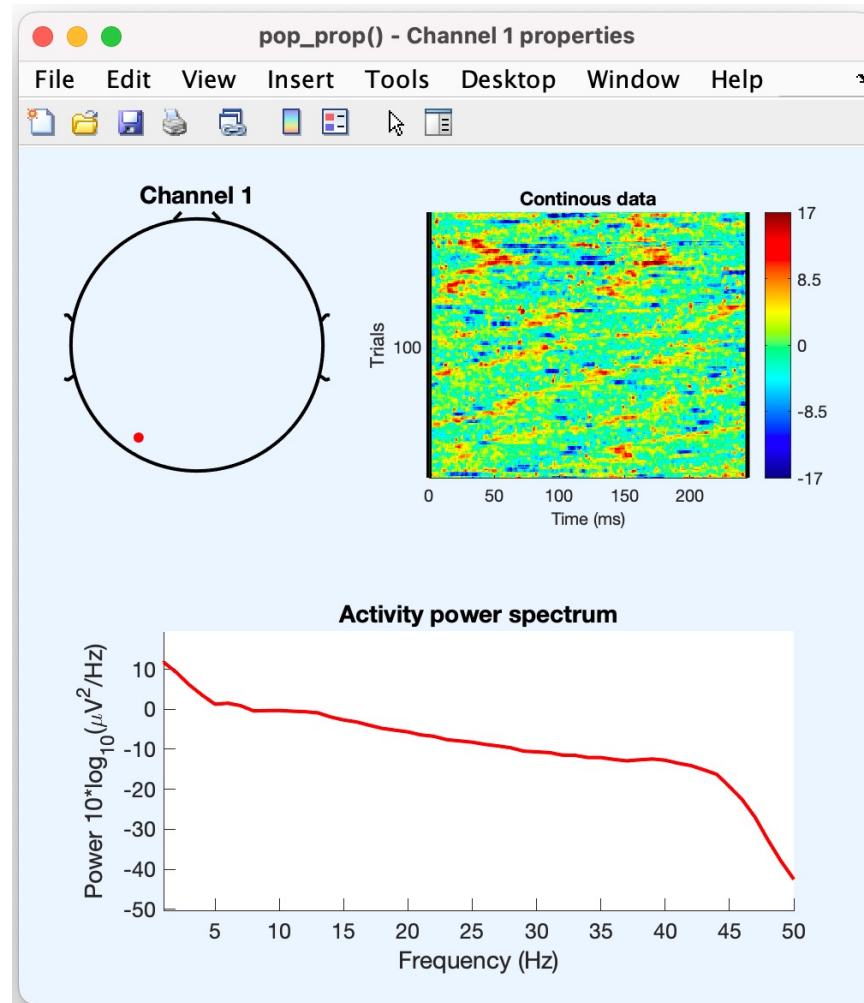
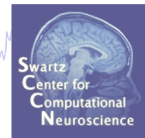
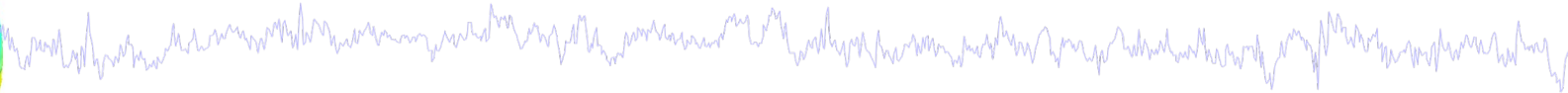
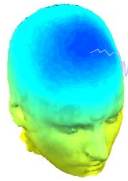
Channel index(ices) to plot: 1 ...

Spectral options (see spectopo() help): 'freqrange', [1 50]

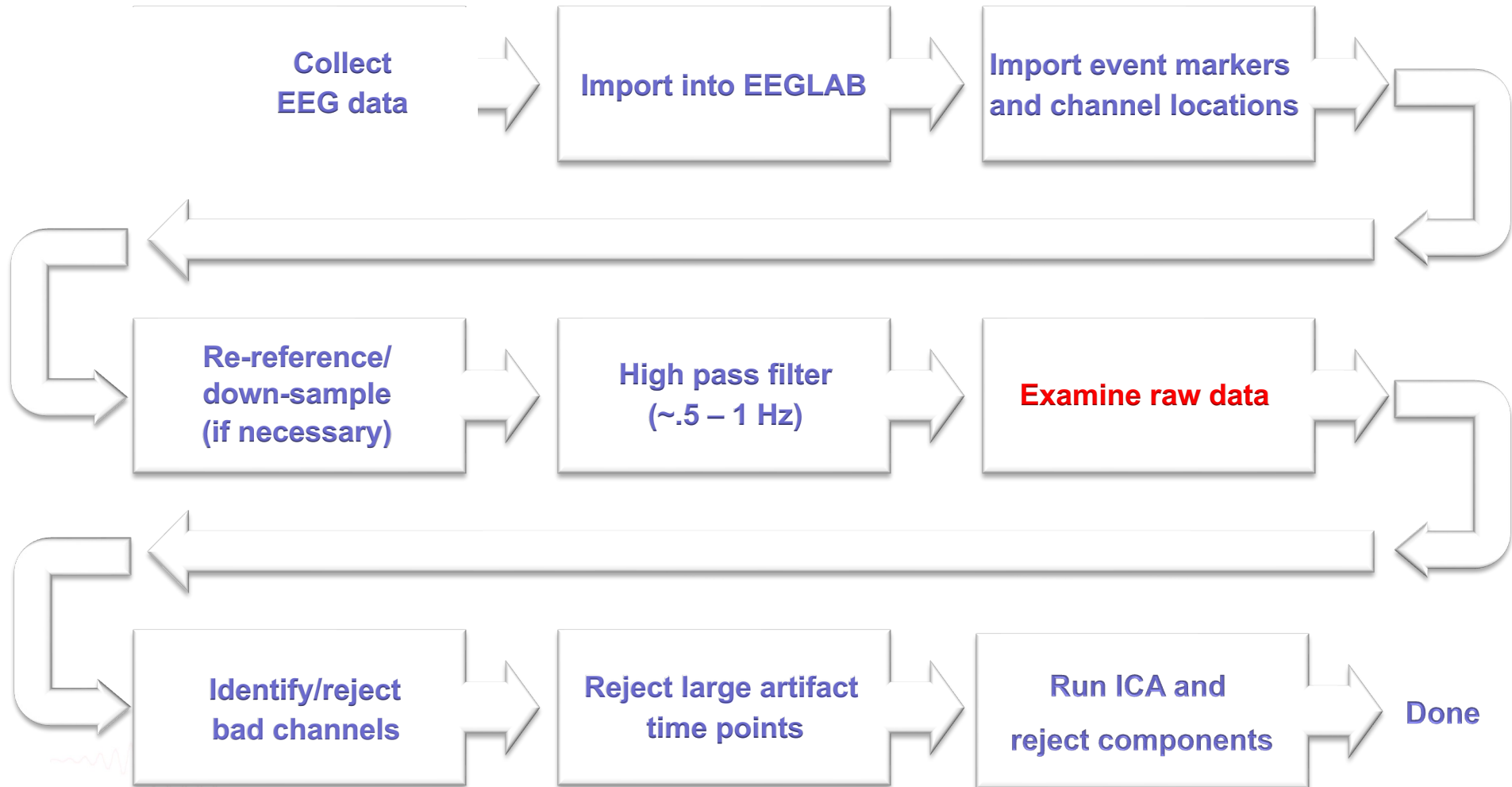
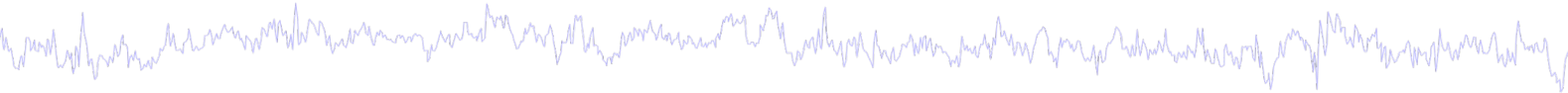
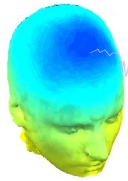
Help Cancel Ok



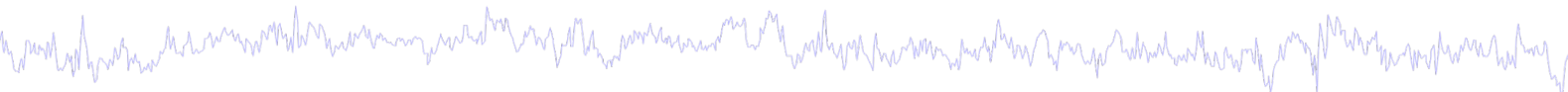
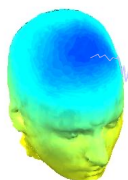
Plot channel properties



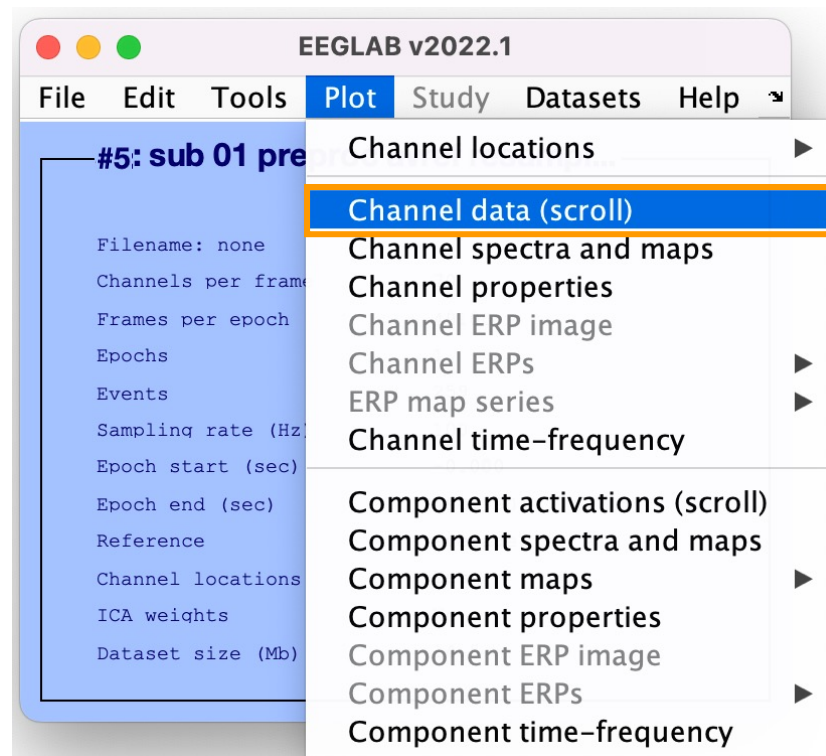
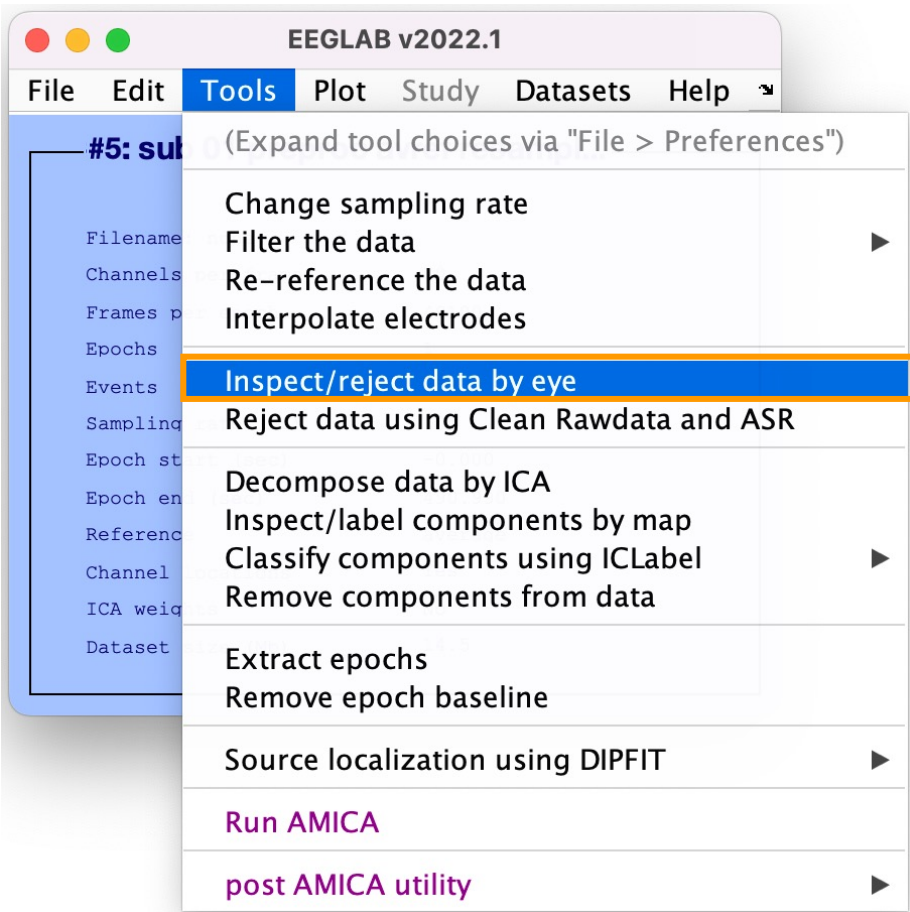
Pre-processing pipeline



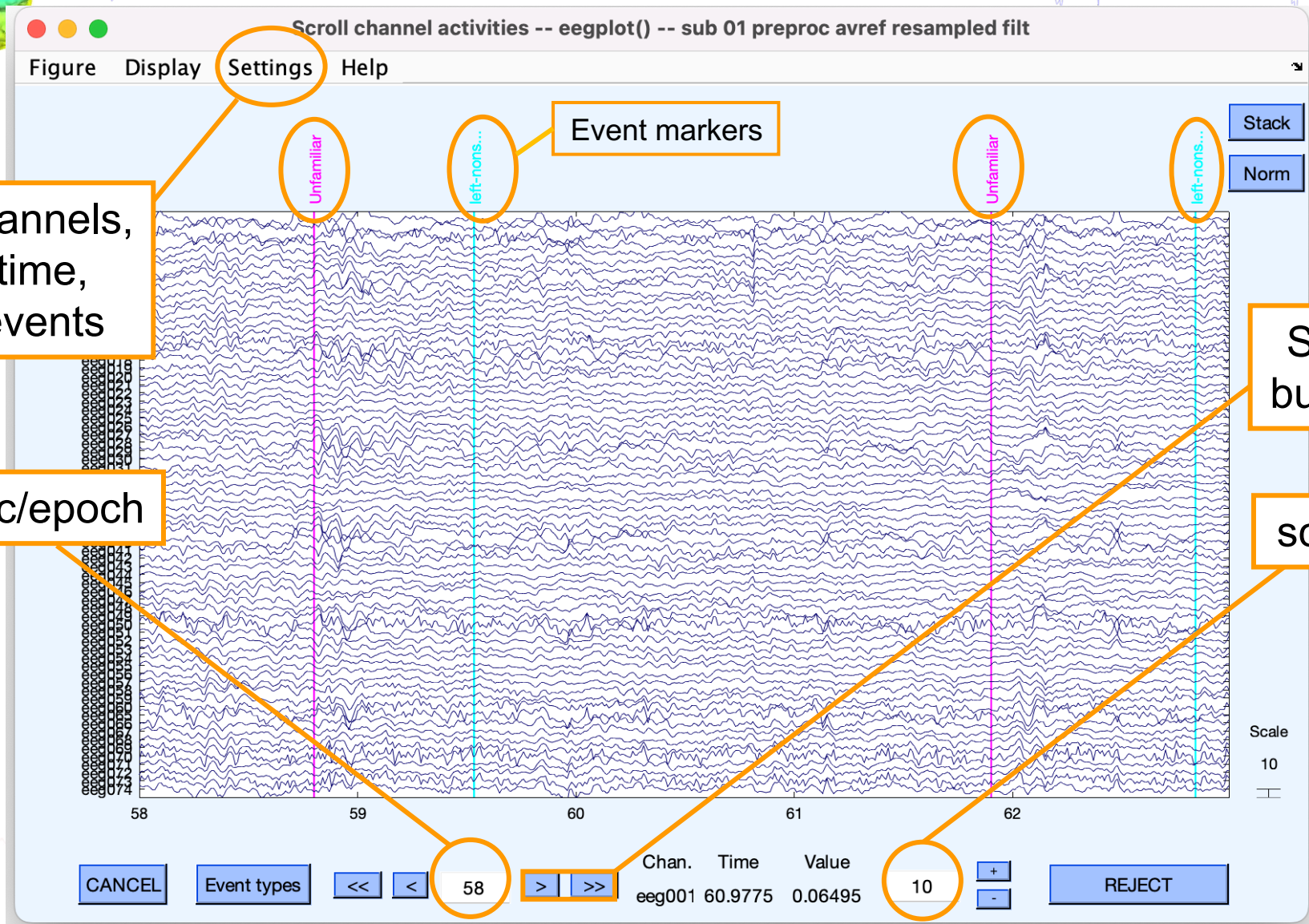
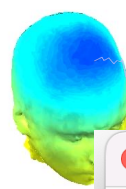
Scroll channel data



Alternate GUI option,
same function



Scroll channel data



channels,
time,
events

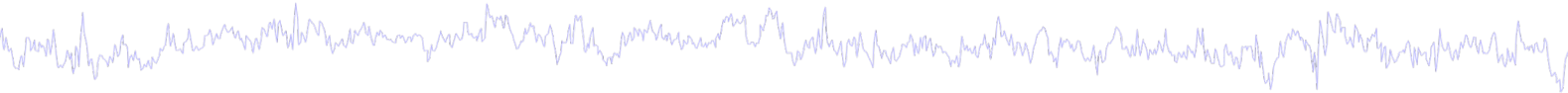
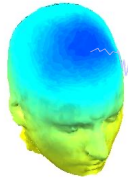
sec/epoch

Event markers

Scroll
buttons

scaling

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

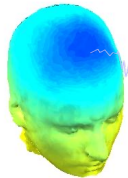


EEG activity containing
potential brain data

Blink

1s

Type of artifacts



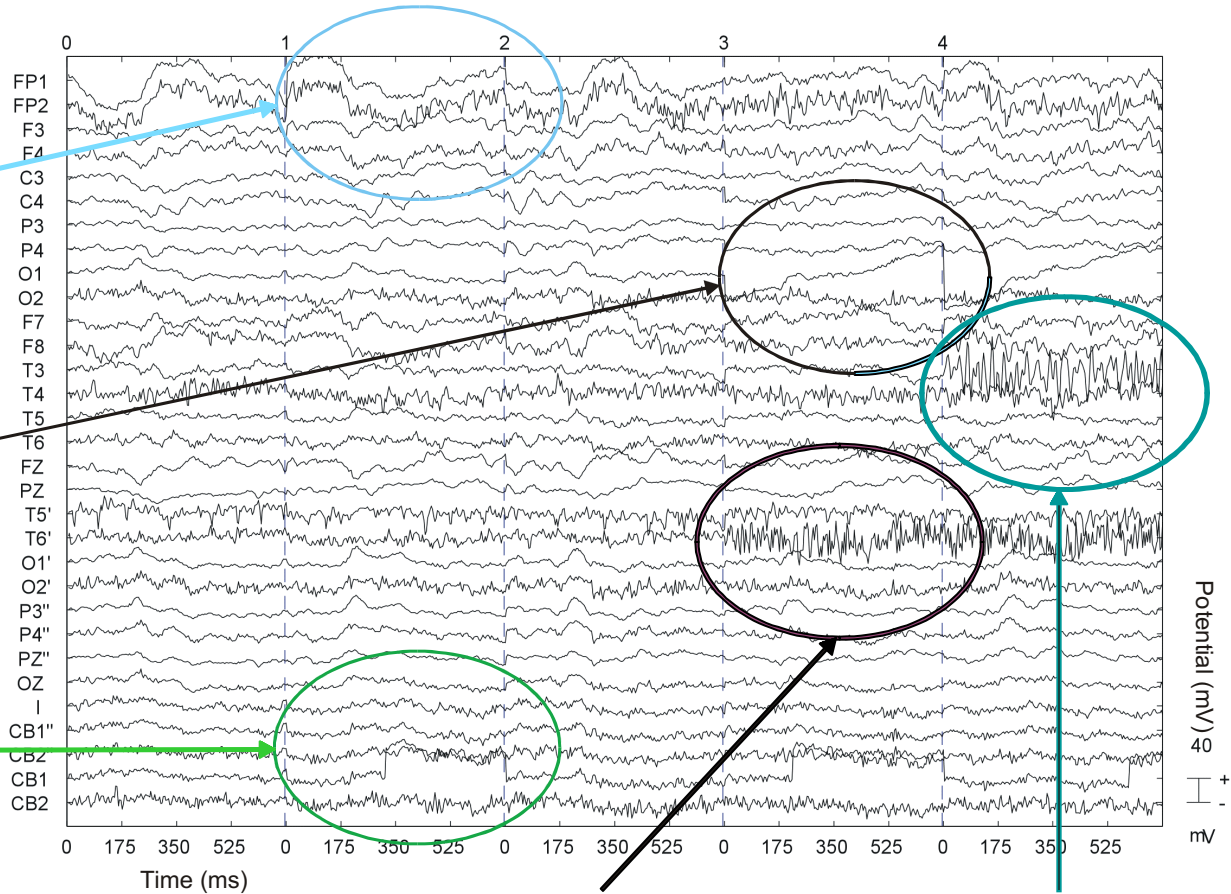
2 - Low frequency event (eye movements)

5 - Linear trend

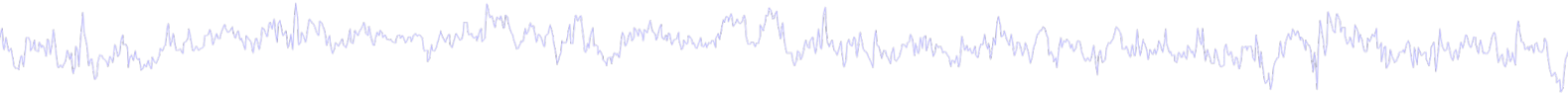
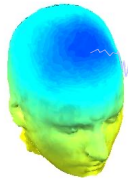
3 - Discontinuity

4 - High noise

1 - Transient high frequency event (muscle)



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

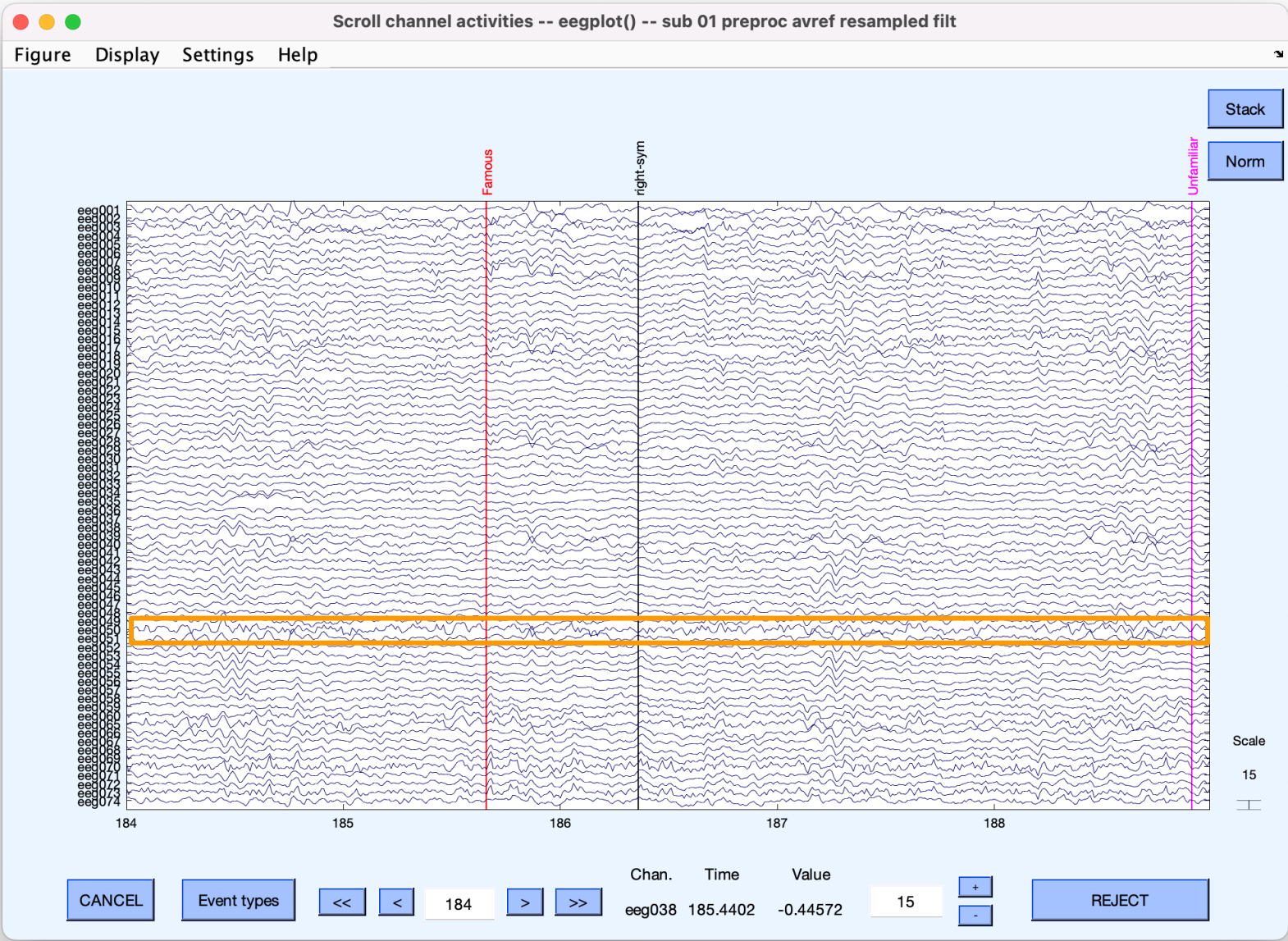
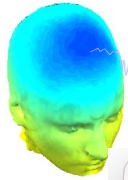
Identify/reject
bad channels

Reject large artifact
time points

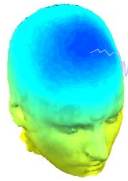
Run ICA and
reject components

Done

Looking for bad channels



Manually identifying bad channels



EEGLAB v2022.1

File Edit Tools **Plot** Study Datasets Help

#5: sub01 prep

- Channel locations
- Channel data (scroll)
- Channel spectra and maps**
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Channel time-frequency
- Component activations (scroll)
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Component time-frequency

Filename: none
Channels per frame
Frames per epoch
Epochs
Events
Sampling rate (Hz)
Epoch start (sec)
Epoch end (sec)
Reference
Channel locations
ICA weights
Dataset size (Mb)

Channel spectra and maps -- pop_spectopo()

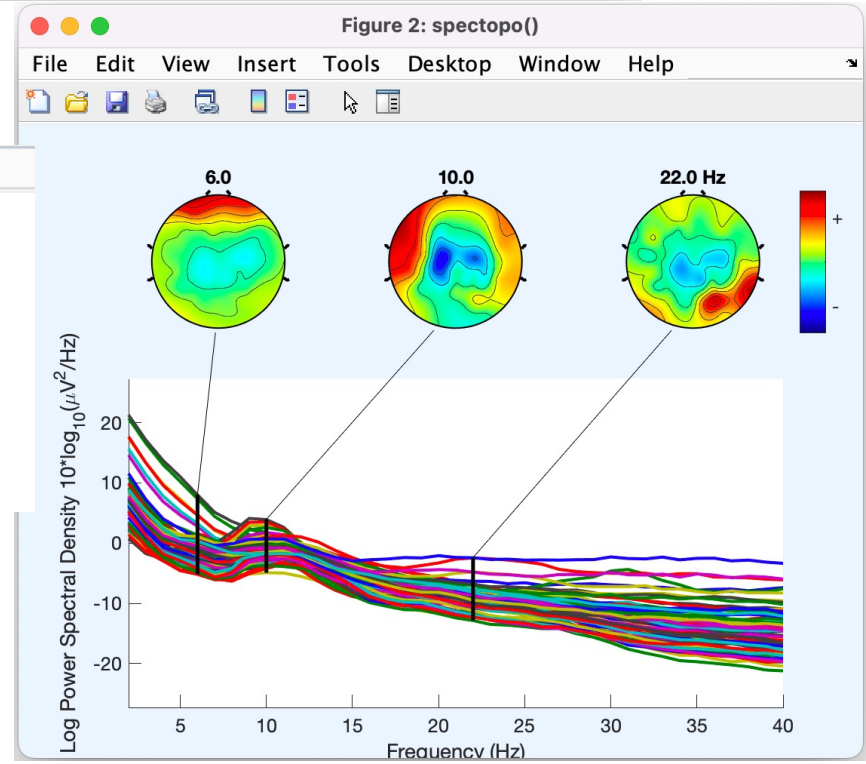
Epoch time range to analyze [min_ms max_ms]:	0 490990
Percent data to sample (1 to 100):	100
Frequencies to plot as scalp maps (Hz):	6 10 22
Plotting frequency range [lo_Hz hi_Hz]:	2 40
Spectral and scalp map options (see topoplot):	'electrodes','off'

Help Cancel Ok

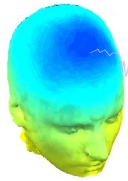
Command Window

```
Channel 18  
Channel 8  
Channel 50  
Channel 66  
Channel 16  
Channel 60  
fx >>
```

```
figure; pop_spectopo(EEG,1, [0 490990],...  
    'EEG' , 'freq', [6 10 22],...  
    'freqrange', [2 40], 'electrodes', 'off');
```



Manually identifying bad channels



EEGLAB v2022.1

File Edit Tools **Plot** Study Datasets Help

#5: sub01 pre

- Filename: none
- Channels per frame
- Frames per epoch
- Epochs
- Events
- Sampling rate (Hz)
- Epoch start (sec)
- Epoch end (sec)
- Reference
- Channel locations
- ICA weights
- Dataset size (Mb)

Channel locations
Channel data (scroll)
Channel spectra and maps
Channel properties
Channel ERP image
Channel ERPs
ERP map series
Channel time-frequency

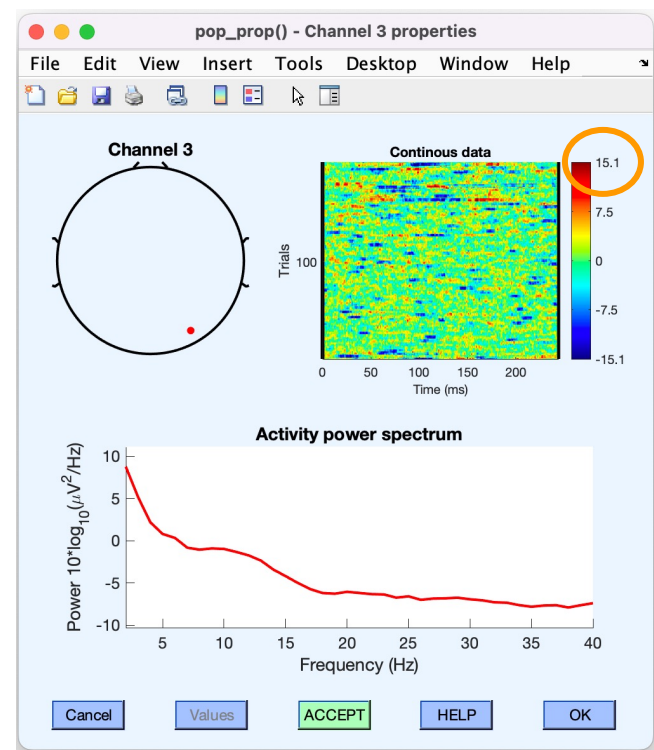
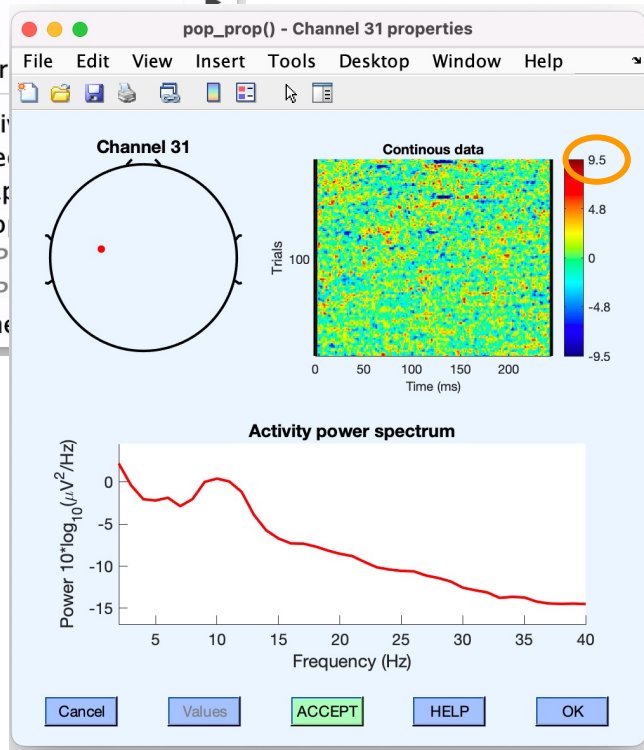
Component activation
Component spectra
Component maps
Component projections
Component ERPs
Component ERP images
Component time-frequency

Channel properties - pop_prop()

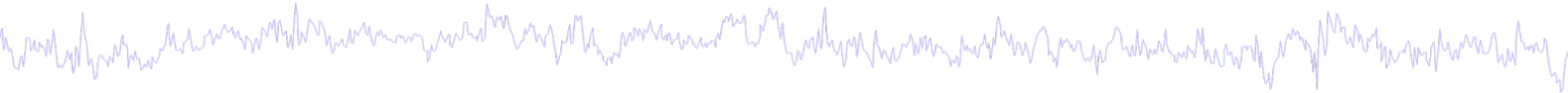
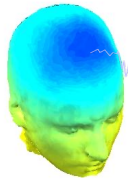
Channel index(ices) to plot: 3 31 ...

Spectral options (see spectopo() help): 'freorange', [2 40]

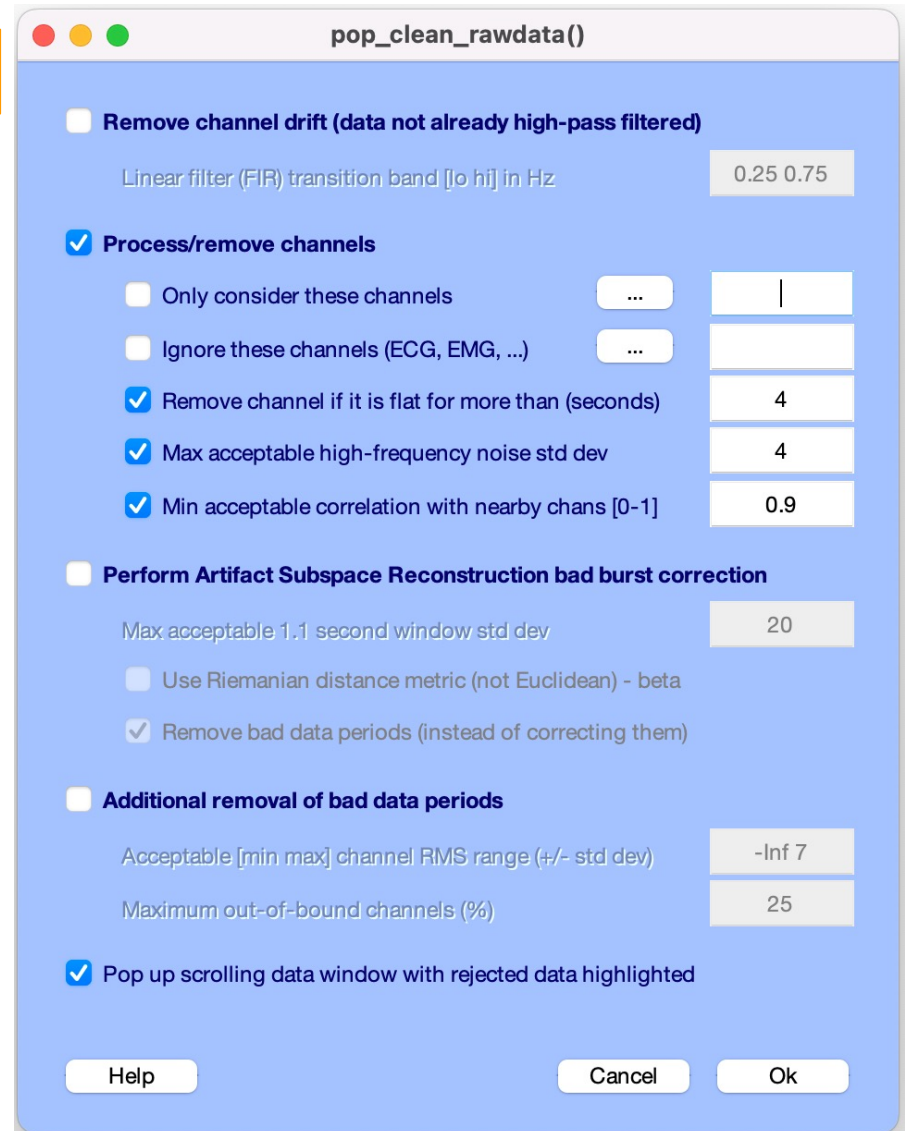
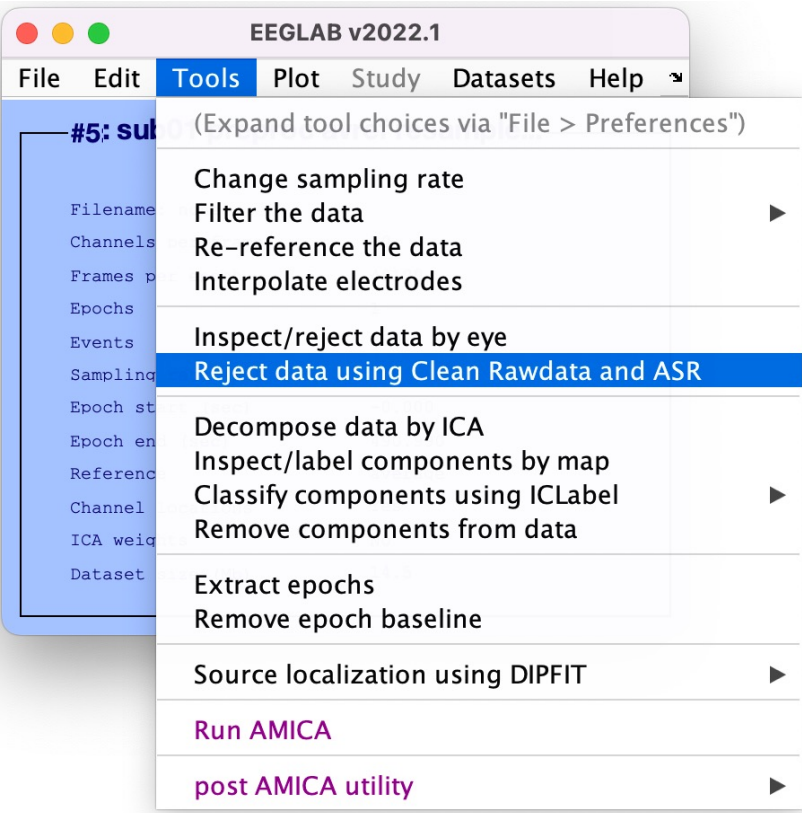
Help Cancel Ok



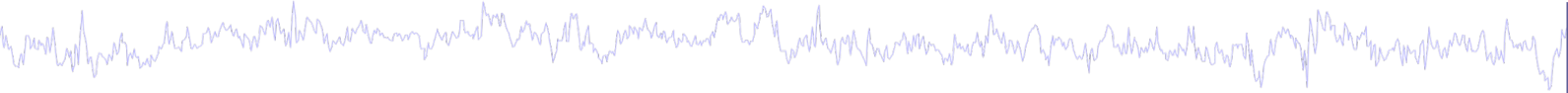
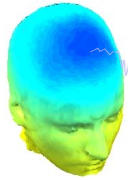
Auto-detection of noisy channels



Clean_rawdata plugin of EEGLAB



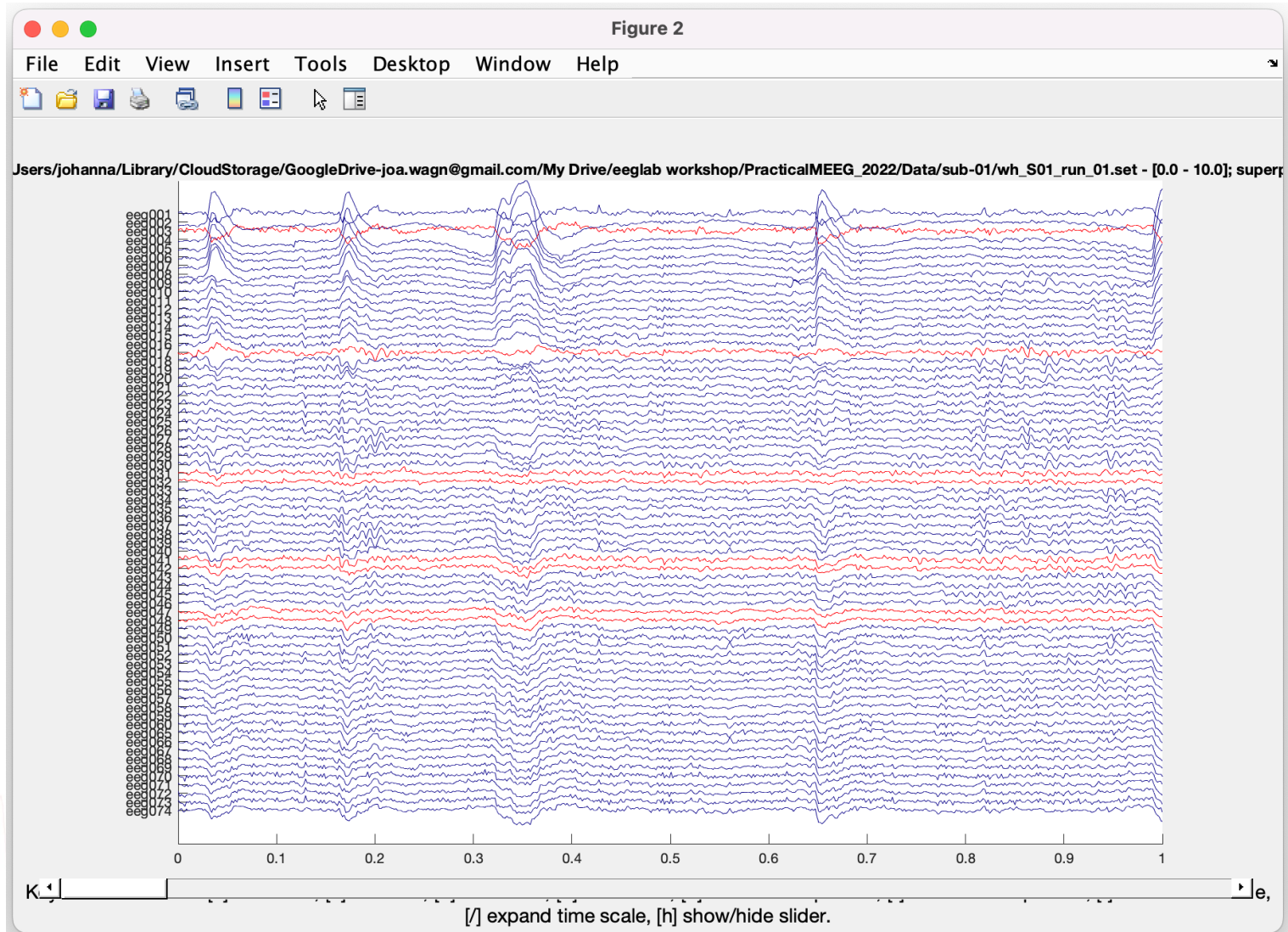
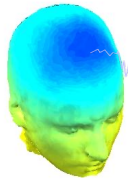
Auto-detection of noisy channels



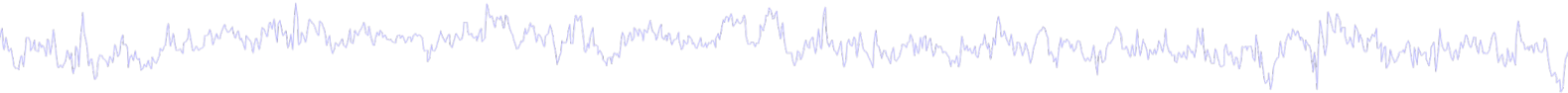
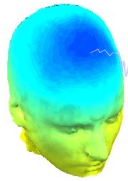
```
EEG = clean_artifacts(EEG, 'Highpass', 'off', ...  
    'ChannelCriterion', 0.9, ...  
    'ChannelCriterionMaxBadTime', 0.4, ...  
    'LineNoiseCriterion', 4, ...  
    'BurstCriterion', 'off', ...  
    'WindowCriterion', 'off' );
```



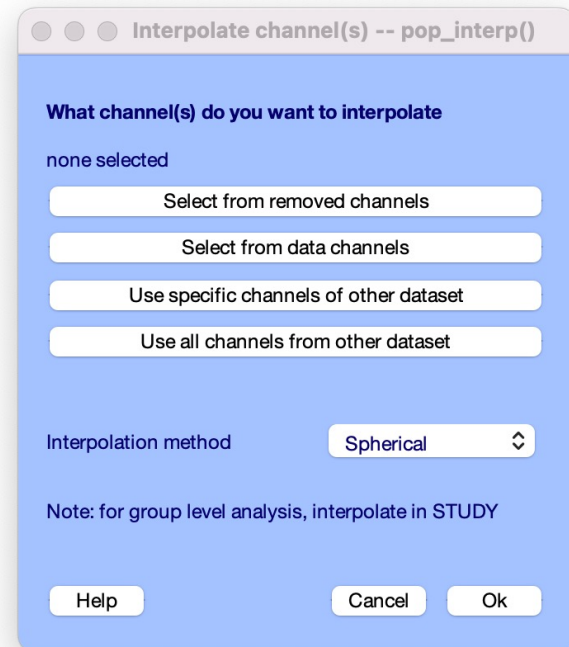
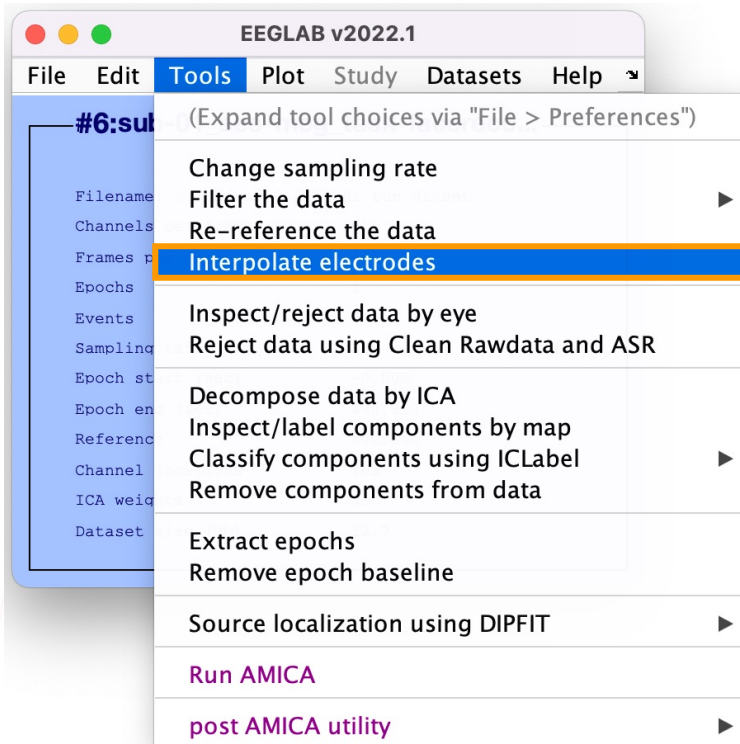
Auto-detected noisy channel



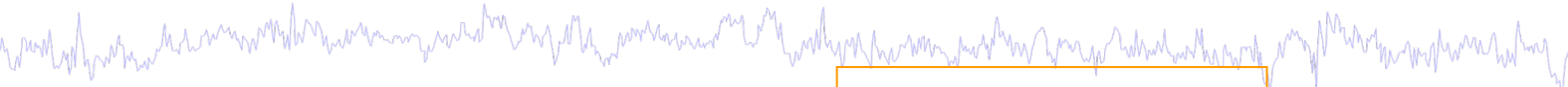
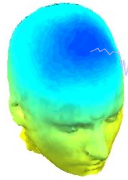
Removed channel(s)



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



Re-reference data (if necessary/desired)



average reference



EEGLAB v2022.1

File Edit **Tools** Plot Study Datasets Help

(Expand tool choices via "File > Preferences")

- Change sampling rate
- Filter the data
- Re-reference the data**
- Interpolate electrodes
- Inspect/reject data by eye
- Reject data using Clean Rawdata and ASR
- Decompose data by ICA
- Inspect/label components by map
- Classify components using ICLabel
- Remove components from data
- Extract epochs
- Remove epoch baseline
- Source localization using DIPFIT
- Run AMICA
- post AMICA utility

pop_reref - average reference or re-reference data

Current data reference state is: unknown

- Compute average reference
- Re-reference data to channel(s):
- Interpolate removed channel(s)
- Retain ref. channel(s) in data (will be flat for single-channel ref.)

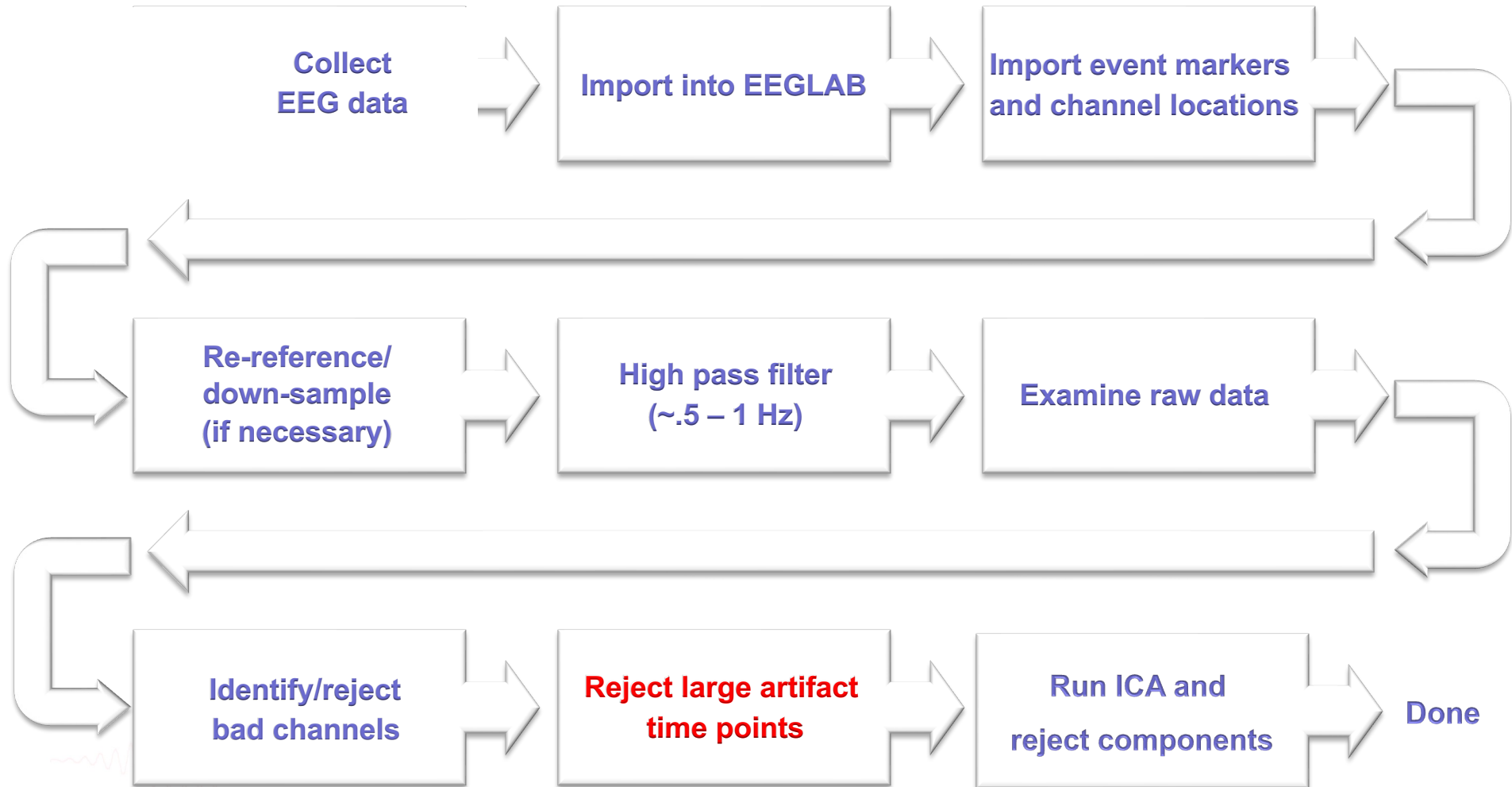
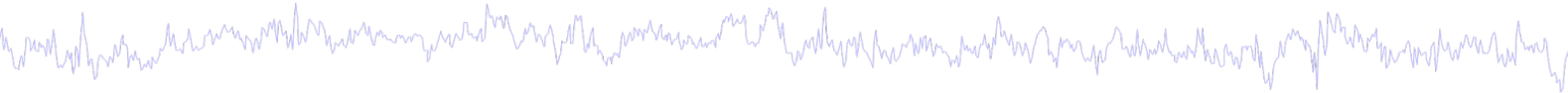
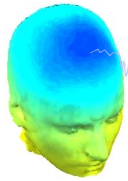
Exclude channel indices (EMG, EOG)

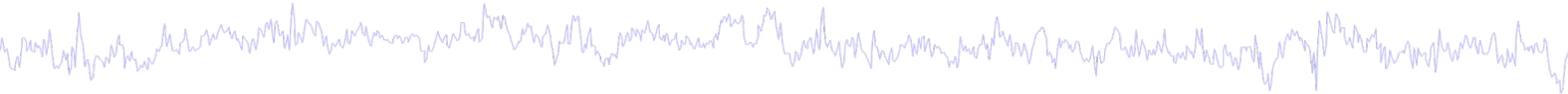
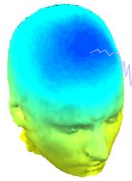
Add old ref. channel back to the data

Help Cancel Ok

```
EEG = pop_reref(EEG,[]);
```

Pre-processing pipeline





Thank You!

