

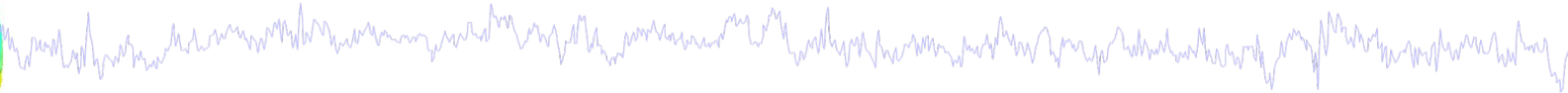
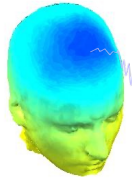
EEG Preprocessing in EEGLAB (cont.)

EEGLAB

Ramon Martinez-Cancino, PhD

Arnaud Delorme, PhD

Johanna Wagner, PhD

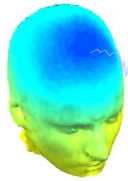


Data Cleaning for ICA

Variant 1: Continuous Data



Reject continuous data



Equivalent



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

EEGLAB v2022.1

File Edit Tools **Plot** Study Datasets Help

#7: sub 01 pre

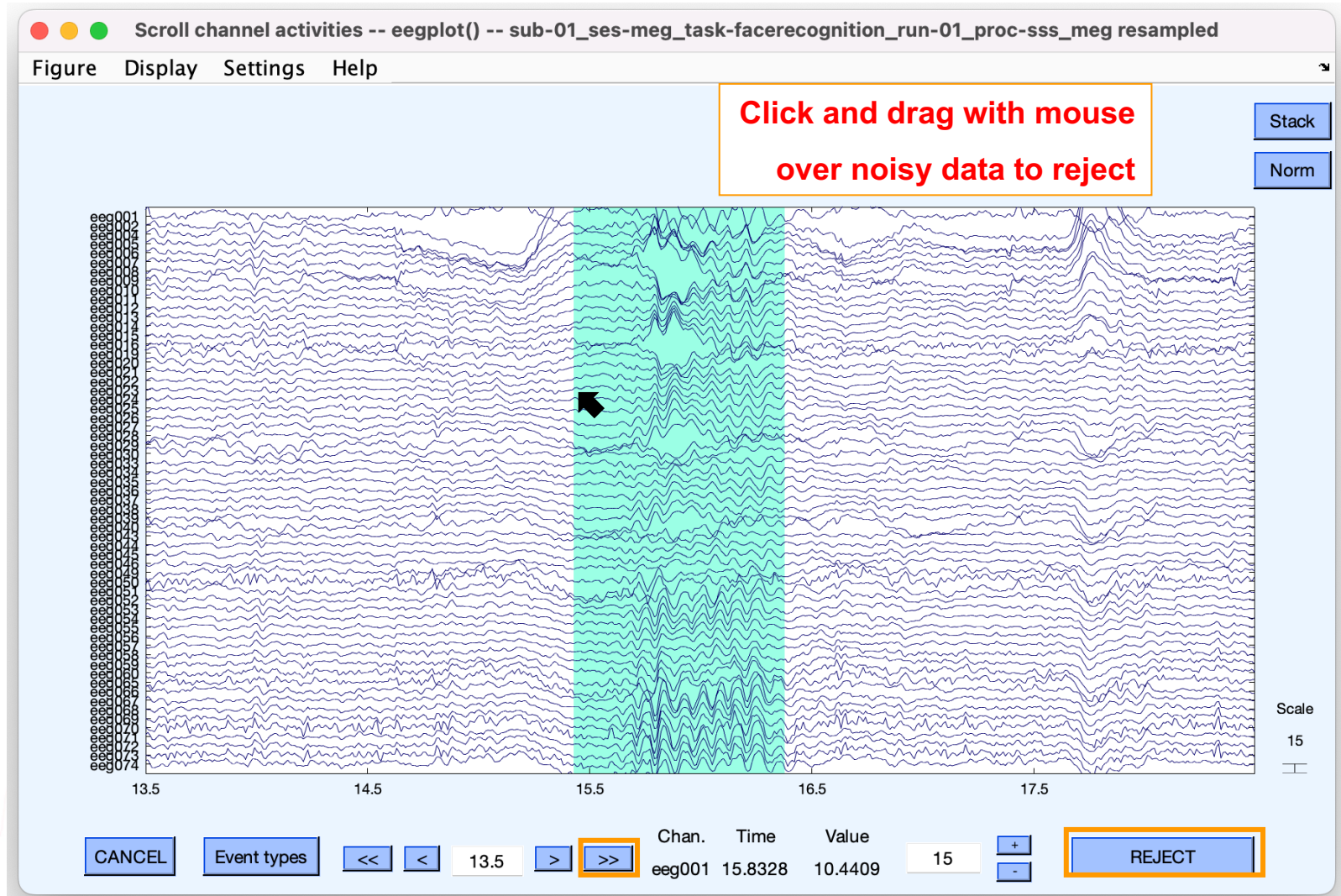
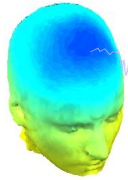
- Channel locations
- Channel data (scroll)**
- Channel spectra and maps
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Channel time-frequency
- Component activations (scroll)
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component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

Warning

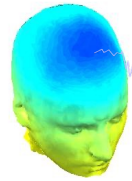
Mark stretches of continuous data for rejection by dragging the left mouse button. Click on marked stretches to unmark. When done, press "REJECT" to excise marked stretches (Note: Leaves rejection boundary markers in the event table).

Cancel Continue

Reject continuous data



Rejecting data for ICA



To prepare data for ICA:

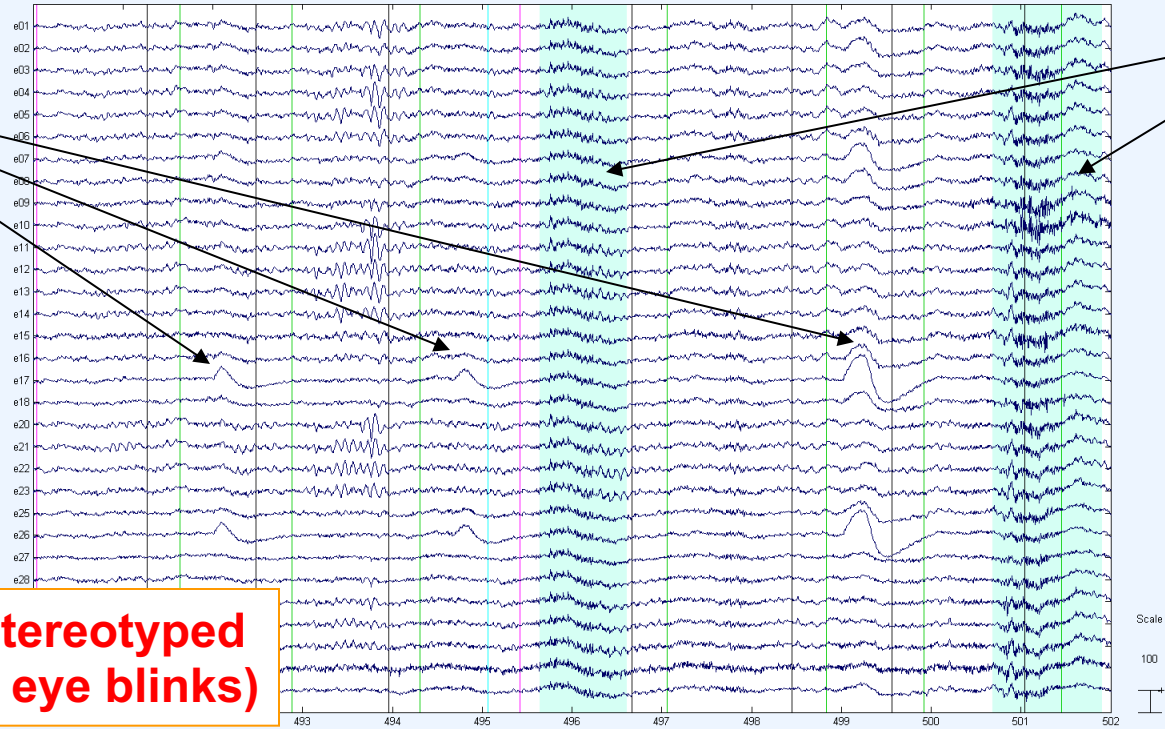
Reject large muscle or otherwise strange events...

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

Keep

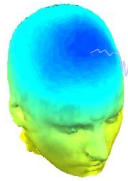
Reject

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

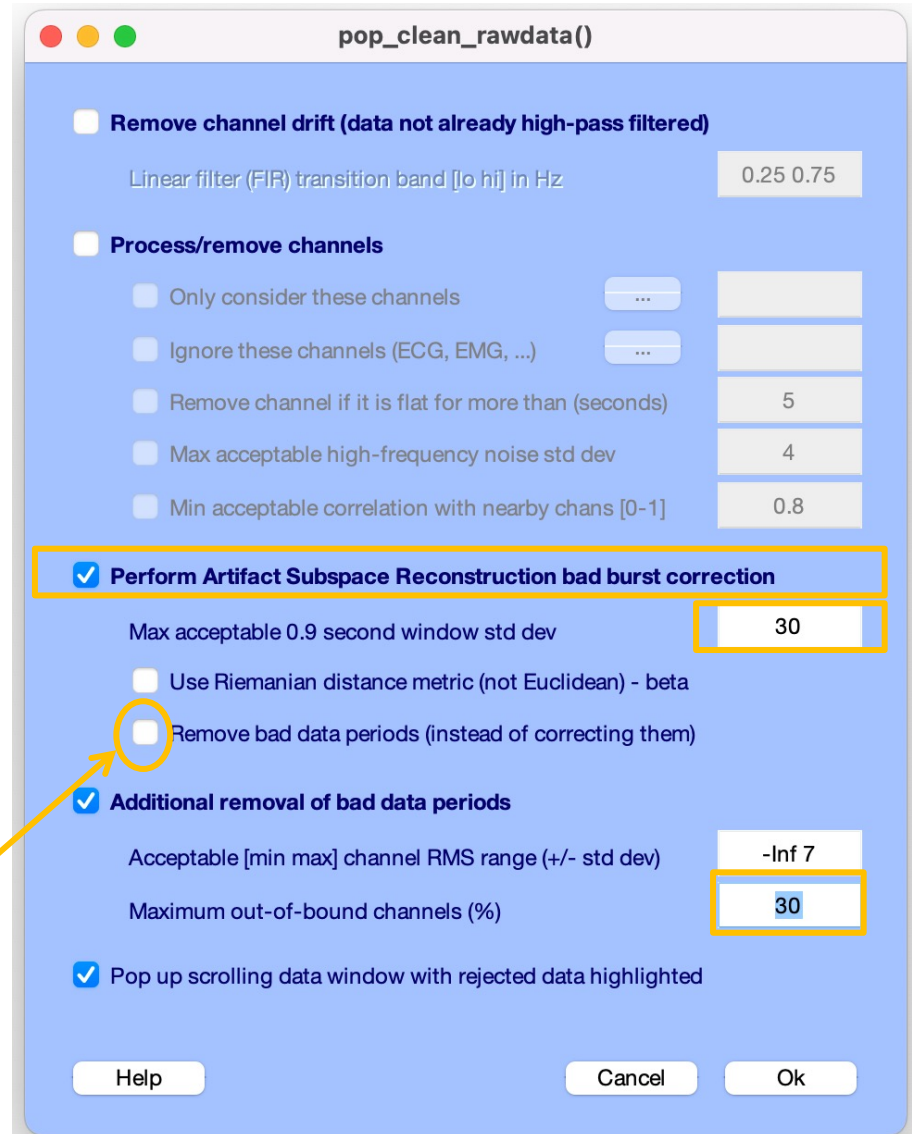
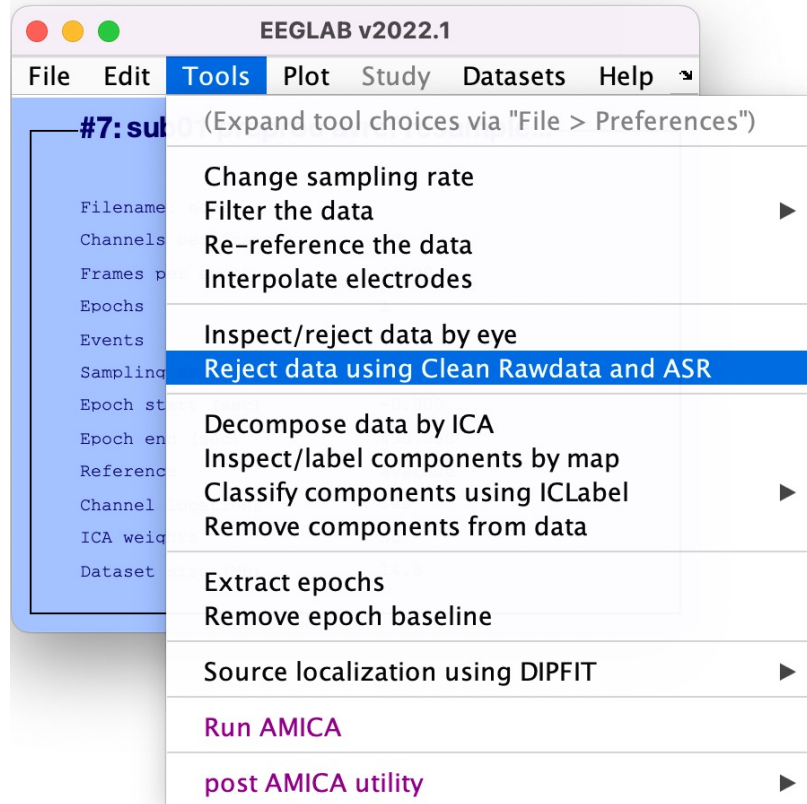


CANCEL Event types << < 490 > >> Chan. Time Value e01 502.3519 -9.7 100 REJECT

Automatic rejection of continuous data

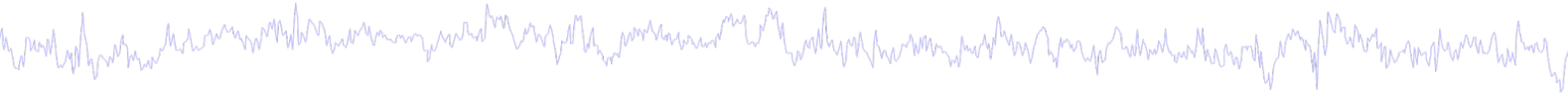
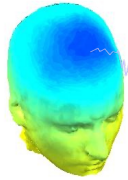


Clean_rawdata plugin of EEGLAB



uncheck

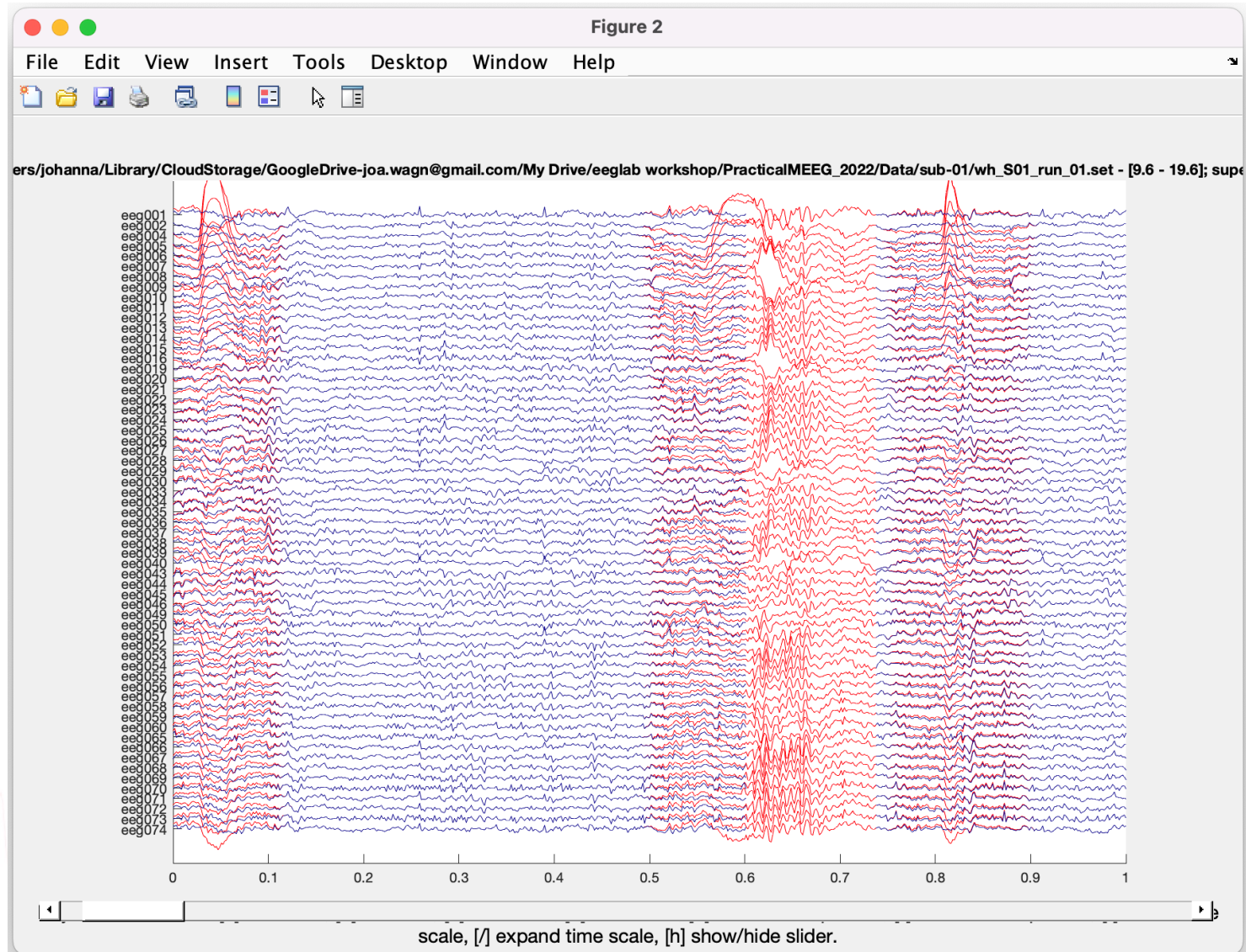
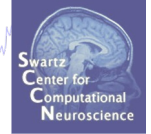
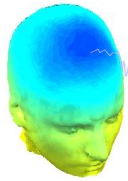
Automatic rejection of continuous data



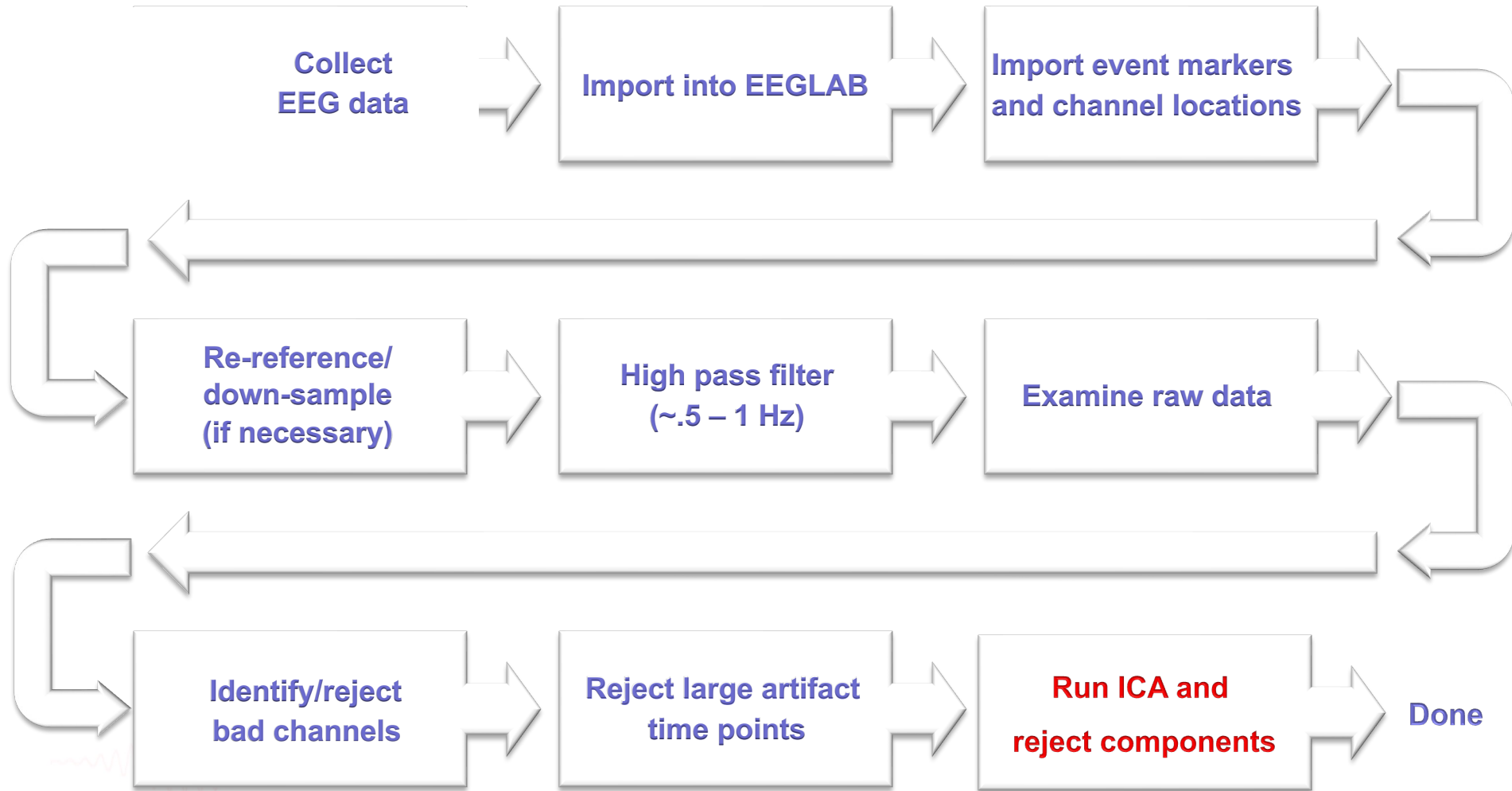
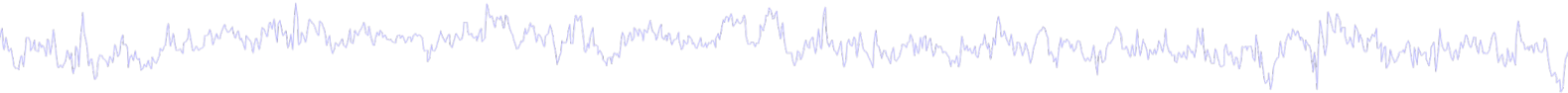
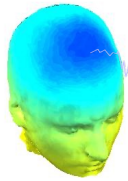
```
EEG = clean_artifacts( EEG, 'Highpass', 'off',...  
    'ChannelCriterion', 'off',...  
    'LineNoiseCriterion', 'off',...  
    'BurstCriterion', 30,...  
    'WindowCriterion', 0.3);
```



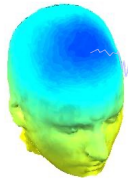
Automatic rejection of continuous data



Pre-processing pipeline



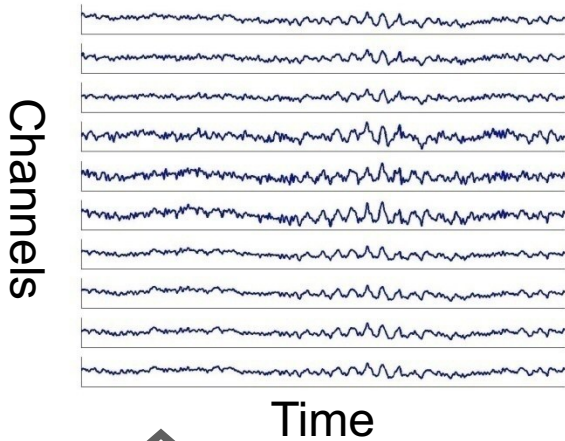
Independent Component Analysis



x = scalp EEG

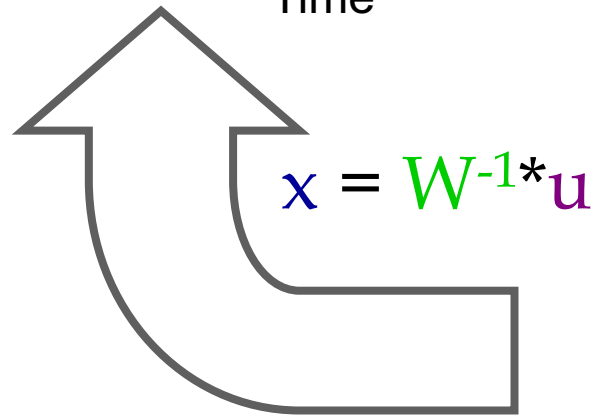
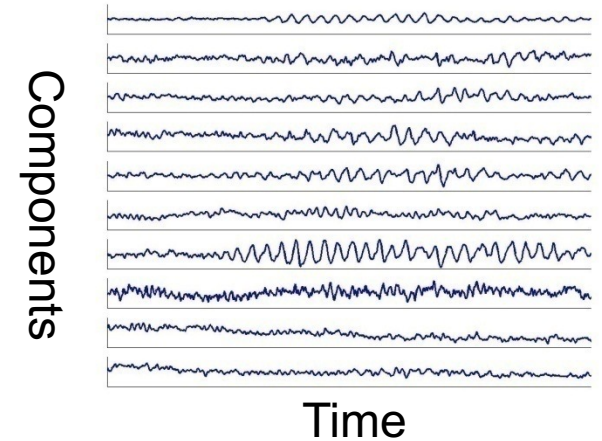
W = unmixing matrix

u = sources

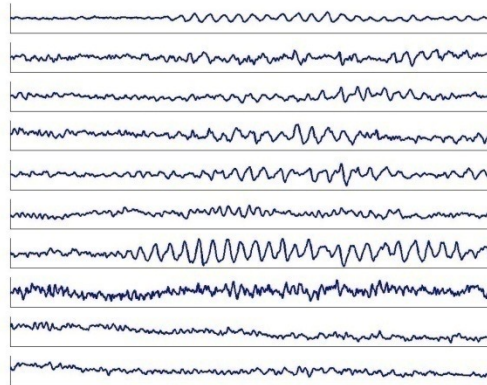


$$W^*x = u$$

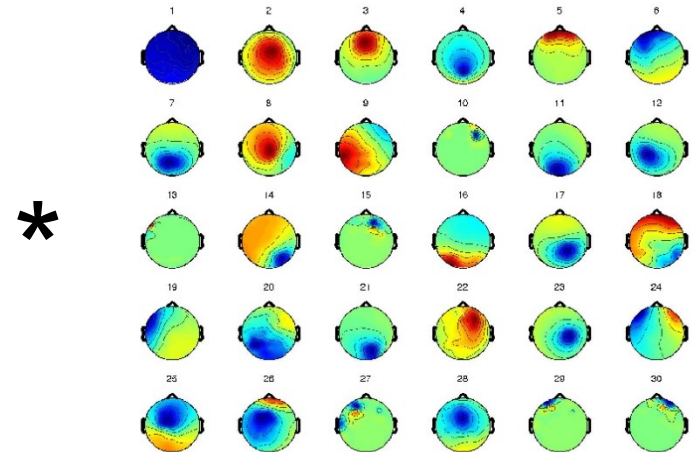
ICA

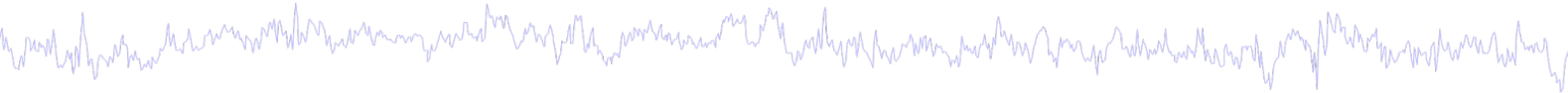
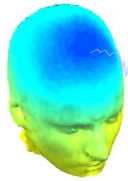


u = sources



W^{-1} (scalp projections)





Task 1

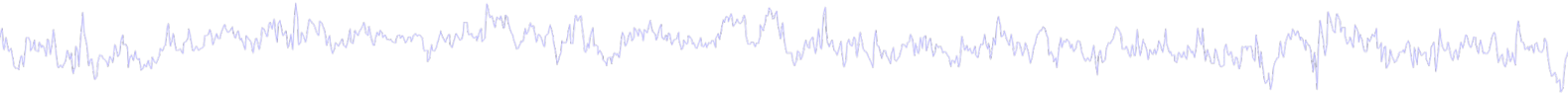
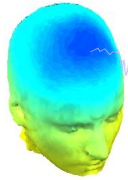
Run ICA

Task 2

Evaluating ICA Components



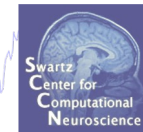
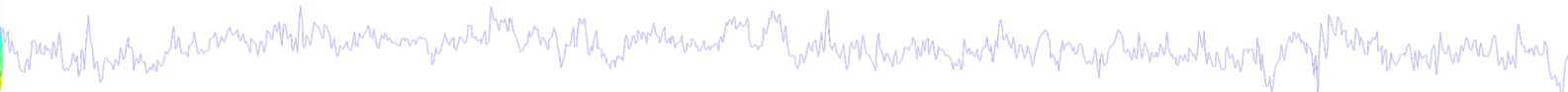
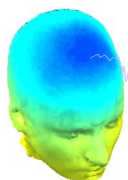
“Secrets” to a good ICA decomposition



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



Preprocessed Dataset



EEGLAB v2022.1

File Edit Tools Plot Study **Datasets** Help

#8: sub-01_avref resampled

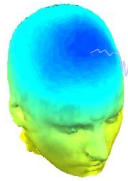
Filename:	none
Channels per frame	61
Frames per epoch	48094
Epochs	1
Events	153
Sampling rate (Hz)	100
Epoch start (sec)	-0.000
Epoch end (sec)	480.930
Reference	average
Channel locations	Yes
ICA weights	No
Dataset size (Mb)	18.1

- Dataset 1:sub-01_ses-meg_task-facerecognition_run-01_proc-sss_meg
- Dataset 2:sub-01_avref
- Dataset 3:sub-01_avref resampled
- Dataset 4:sub-01_avref resampled highfilt
- Dataset 5:sub-01_avref resampled highlowfilt
- Dataset 6:sub-01_avref resampled highlowfilt_ASRremchan
- Dataset 7:sub-01_avref resampled highlowfilt_ASRremchan_avref
- Dataset 8:sub-01_avref resampled highlowfilt_ASRremchan_avref_ASR

Select multiple datasets



ICA options



Option Default Comments

Option	Default	Comments
'extended'	0	1 is recommended to find sub-gaussians
'stop'	1e-7	final weight change → stop
'irate'	determined from data	too small → too long... too large → wts blow up
'maxsteps'	512	more channels → more steps
'pca'	0 or EEG.nbchan	Decompose only a principal data subspace

EEGLAB v2022.1

File Edit **Tools** Plot Study Datasets Help

#8: sul

- Change sampling rate
- Filter the data
- Re-reference the data
- Interpolate electrodes
- Inspect/reject data by eye
- Automatic channel rejection
- Reject data using Clean Rawdata and ASR
- Automatic continuous rejection
- Automatic epoch rejection
- Decompose data by ICA**
- Reject data epochs
- Reject data using ICA
- Classify components using ICLabel
- Remove components from data
- Extract epochs
- Remove epoch baseline
- Source localization using DIPFIT
- Scalp current density

Run ICA decomposition -- pop_runica()

ICA algorithm to use (click to select)

- Infomax runica.m (default)
- Infomax runica.m conservative (slow)
- Infomax picard.m
- FastICA picard.m (fastest)
- SOBI (sobi.m function)
- SOBI (accobica.m function)

Commandline options (See help messages)

'extended', 1, 'pca', 60

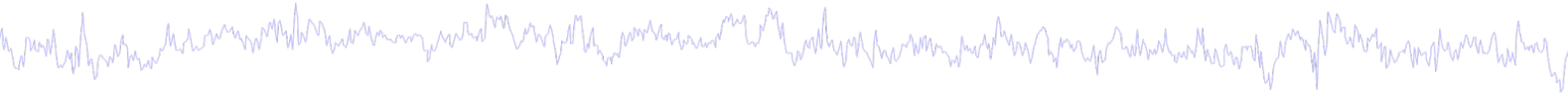
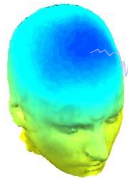
Reorder components by variance (if that's not already the case)

Use only channel type(s) or indices

... types ... channels

Help Cancel Ok

Faster ICA option



Run ICA decomposition -- pop_runica()

ICA algorithm to use (click to select)

- Infomax runica.m (default)
- Infomax runica.m conservative (slow)
- Infomax picard.m
- FastICA picard.m (fastest)
- SOBI (sobi.m function)
- SOBI (soscibic.m function)

Commandline options (See help messages)

'maxiter', 500, 'mode', 'standard', 'pca', 60

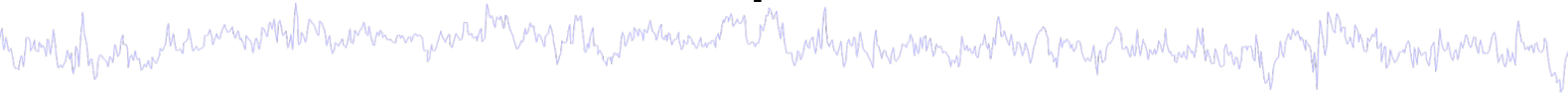
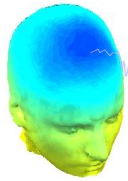
Reorder components by variance (if that's not already the case)

Use only channel type(s) or indices ... types ... channels

Help Cancel Ok



ICA options



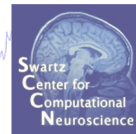
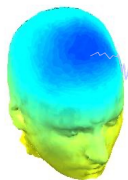
```
EEG = pop_runica( EEG , 'runica', 'extended', 1, 'pca', EEG.nbchan-1);
```

Faster option:

```
EEG = pop_runica( EEG , 'picard', 'maxiter', 500, 'pca', EEG.nbchan-1);
```



Runica progress...



MATLAB R2021b - academic use

HOME PLOTS APPS

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New Script New Live Script New Open Find Files Import Data Save Workspace New Variable Open Variable Favorites Analyze Code Run and Time Clear Commands Preferences Set Path Add-Ons Help Community Request Support Learn MATLAB

FILE VARIABLE CODE ENVIRONMENT RESOURCES

Users > johanna > Library > CloudStorage > GoogleDrive-joa.wagn@gmail.com > My Drive > eeglab workshop > PracticalMEEG_2022 > MATLAB

Current Folder

- PracticalMEEG_Preprocess_Dat...
- PracticalMEEG_Importa Data.m
- PracticalMEEG_Import_Data_S...
- PracticalMEEG_ERP_Analysis_S...
- trash
- Figures

Command Window

```
>> EEG = pop_runica( EEG , 'runica', 'extended',1, 'pca', EEG.nbchan-1);

Saving current ICA decomposition in "EEG.etc.oldicaweights" (etc.).
Decomposition saved as entry 2.
Warning: you have used PCA to reduce dimensionality so ICA
is not modeling the entire data, only the PCA-reduced data.
Warning: fixing rank computation inconsistency (61 vs 60) most likely because running under Linux 64-bit Matlab
Attempting to convert data matrix to double precision for more accurate ICA results.

Input data size [60,47826] = 60 channels, 47826 frames/nAfter PCA dimension reduction,
finding 60 ICA components using extended ICA.
Kurtosis will be calculated initially every 1 blocks using 6000 data points.
Decomposing 13 frames per ICA weight ((3600)^2 = 47826 weights, Initial learning rate will be 0.001, block size 54.
Learning rate will be multiplied by 0.98 whenever angledelta >= 60 deg.
More than 32 channels: default stopping weight change 1E-7
Training will end when wchange < 1e-07 or after 512 steps.
Online bias adjustment will be used.
Removing mean of each channel ...
Final training data range: -40.6563 to 130.95
Reducing the data to 60 principal dimensions...
Computing the sphering matrix...
Starting weights are the identity matrix ...
Sphering the data ...
Beginning ICA training ... first training step may be slow ...
step 1 - lrate 0.001000, wchange 29.18269909, angledelta 0.0 deg
step 2 - lrate 0.001000, wchange 0.88232071, angledelta 0.0 deg
step 3 - lrate 0.001000, wchange 0.70743793, angledelta 80.8 deg
step 4 - lrate 0.000980, wchange 0.60157838, angledelta 93.3 deg
step 5 - lrate 0.000960, wchange 0.55077526, angledelta 99.2 deg
```

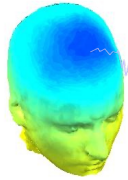
Press button to interrupt runica()

Interrupt

Select a file to view details

Busy

Results of ICA Decomposition in EEG struct



Command Window

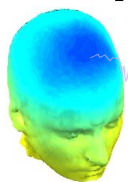
EEG =

struct with fields:

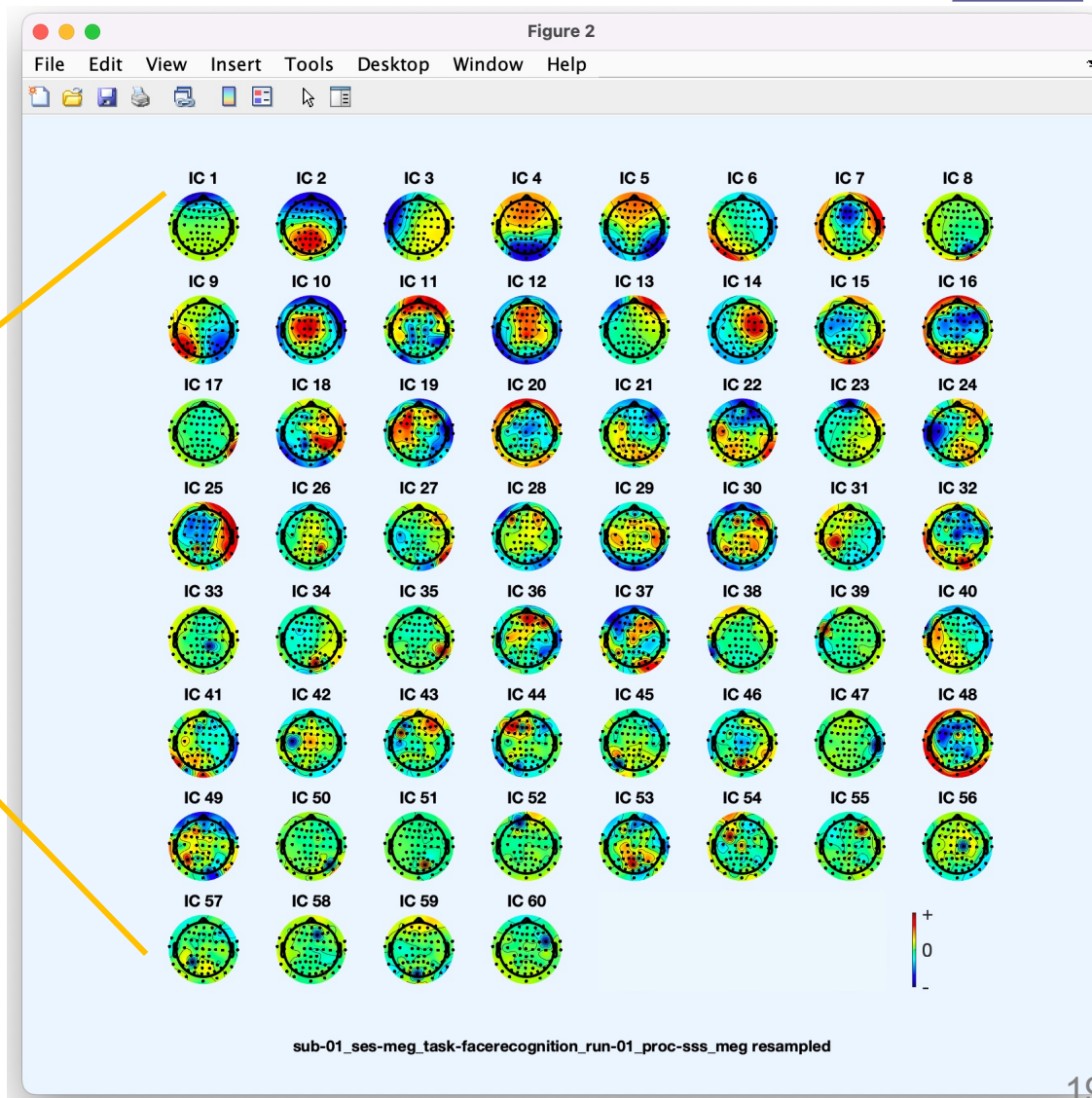
```
    setname: 'sub-01_ses-meg_task-facerecognit:'
    filename: 'wh_S01_run_01_preprocessing_data'
    filepath: '/Users/johanna/Library/CloudStor'
    subject: 'sub-01'
    group: ''
    condition: ''
    session: []
    comments: 'Original file: /Volumes/GoogleDr'
    nbchan: 61
    trials: 1
    pnts: 47826
    srate: 100
    xmin: 0
    xmax: 478.2503
    times: [0 10.0000 20.0000 30.0000 40.0000]
    data: [61x47826 single]
    icaact: [60x47826 single]
    icawinv: [61x60 double]
    icasphere: [61x61 double]
    icaweights: [60x61 double]
    icachansind: [1 2 3 4 5 6 7 8 9 10 11 12 13 14]
    chanlocs: [61x1 struct]
    urchanlocs: [74x1 struct]
    chaninfo: [1x1 struct]
        ref: 'average'
        event: [1x264 struct]
        urevent: [1x259 struct]
    eventdescription: {' ' ' ' ' '}
    epoch: []
    epochdescription: {}
        reject: [1x1 struct]
        stats: [1x1 struct]
    specdata: []
    specicaact: []
    splinefile: ''
    icasplinefile: ''
    dipfit: []
    history: 'EEG.etc.eeglabvers = '2021.0'; '
    saved: 'no'
    etc: [1x1 struct]
    run: []
    datfile: ''
```

icaact: [60x47826 single]
icawinv: [61x60 double]
icasphere: [61x61 double]
icaweights: [60x61 double]

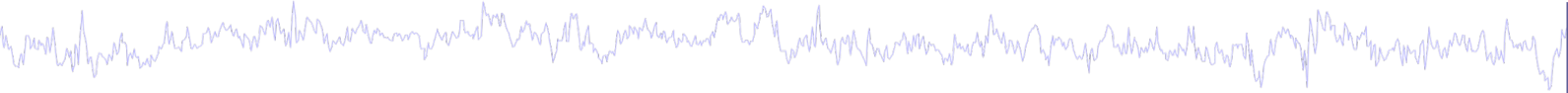
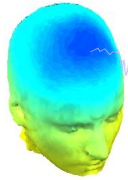
Results of ICA Decomposition in EEG struct



```
icaact: [60x47826 single]  
icawinv: [61x60 double]  
icasphere: [61x61 double]  
icaweights: [60x61 double]
```



English → MATLAB



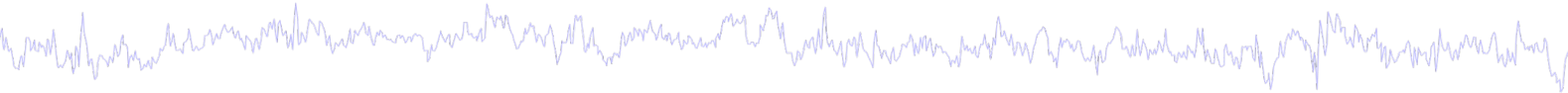
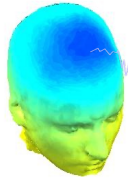
Source activation = **unmixing** * Channel data

Channel data = **mixing (topo)** * Source activation

EEG.icaact = (**EEG.icaweights*****EEG.icasphere**) * **EEG.data**

 **EEG.data** = **EEG.icawinv** * **EEG.icaact**

Running ICA



Task 1

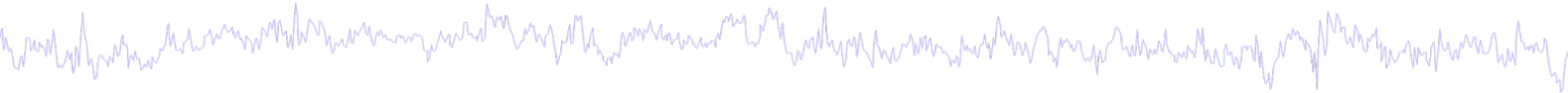
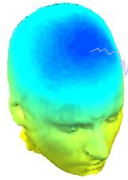
Run ICA

Task 2

Evaluating ICA Components



Now what...?



Part 1

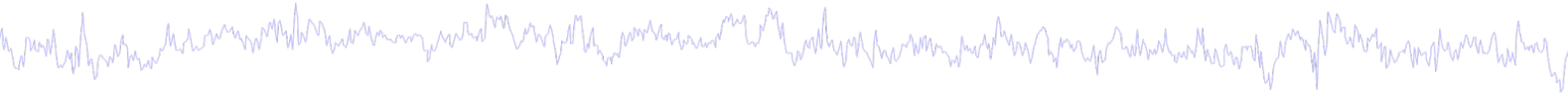
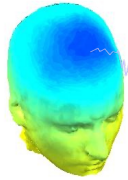
Getting an overview of your ICs

Part 2

Classifying/Evaluating ICs



Now what...?



Part 1

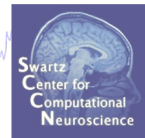
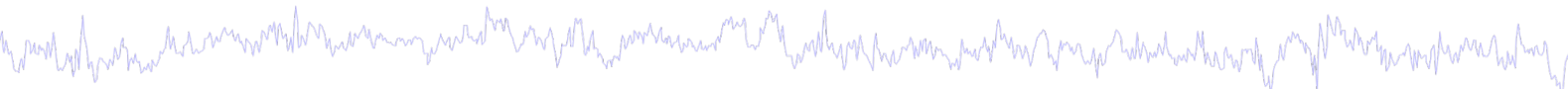
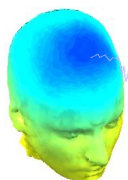
Getting an overview of your ICs

Part 2

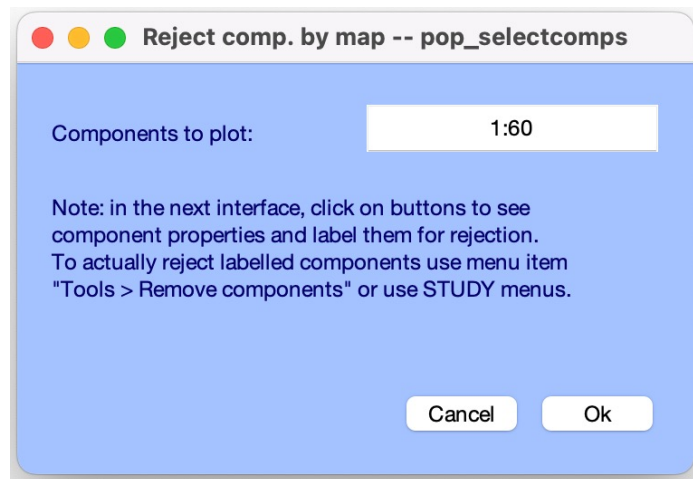
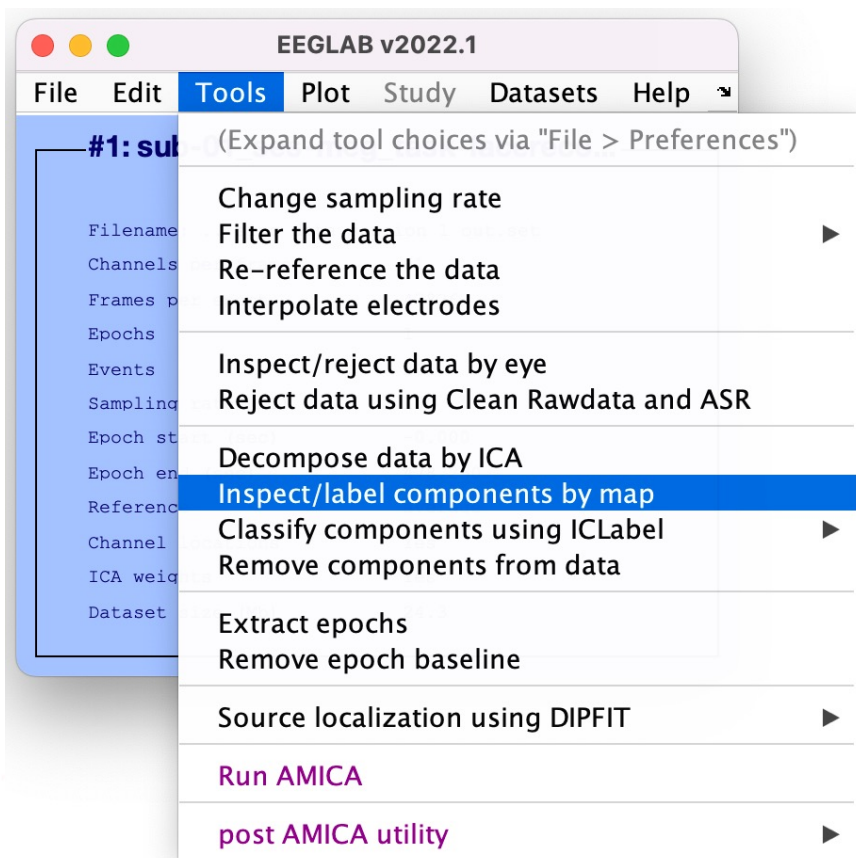
Classifying/Evaluating ICs



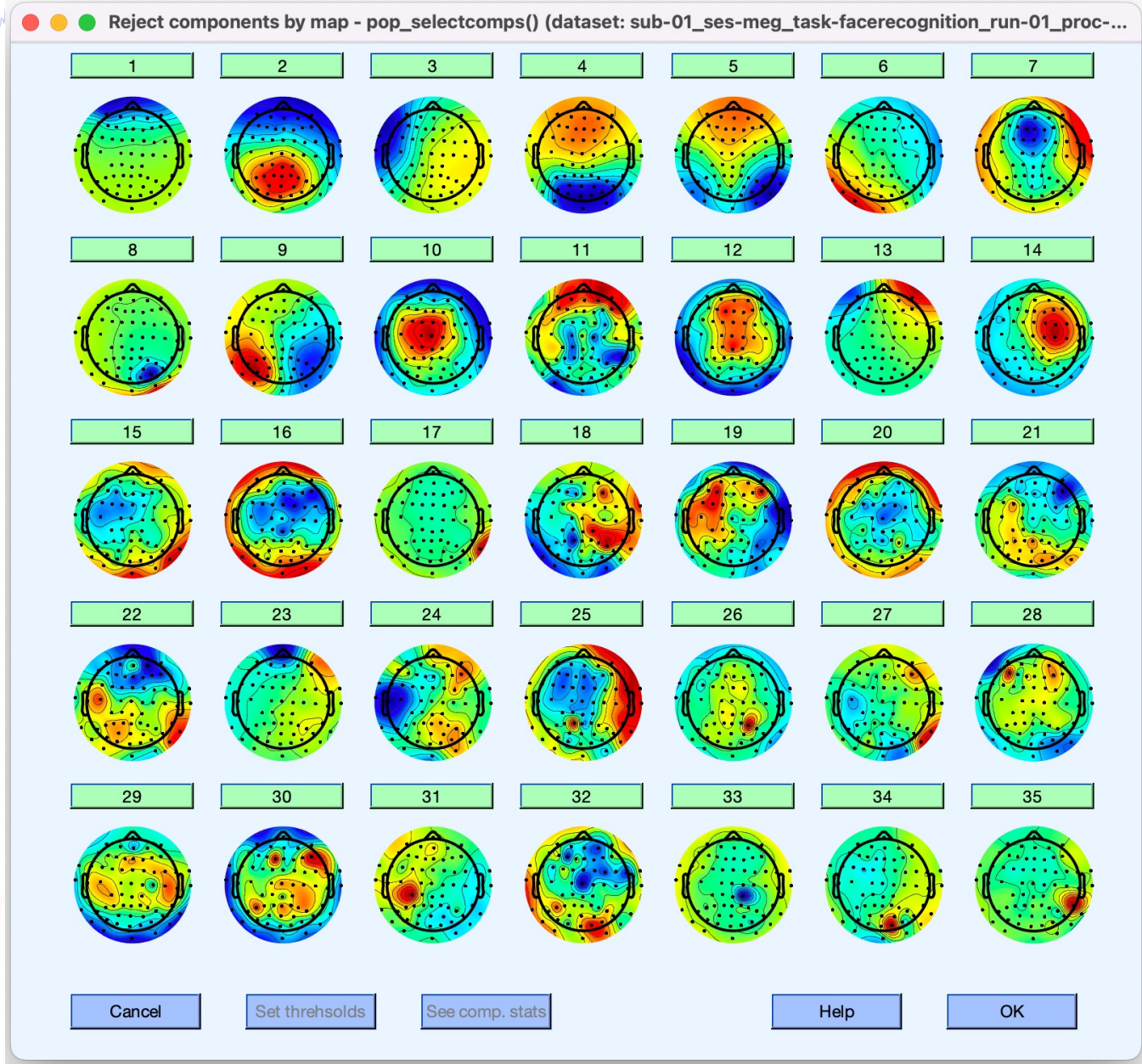
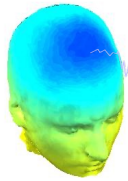
A convenient 'trick'...



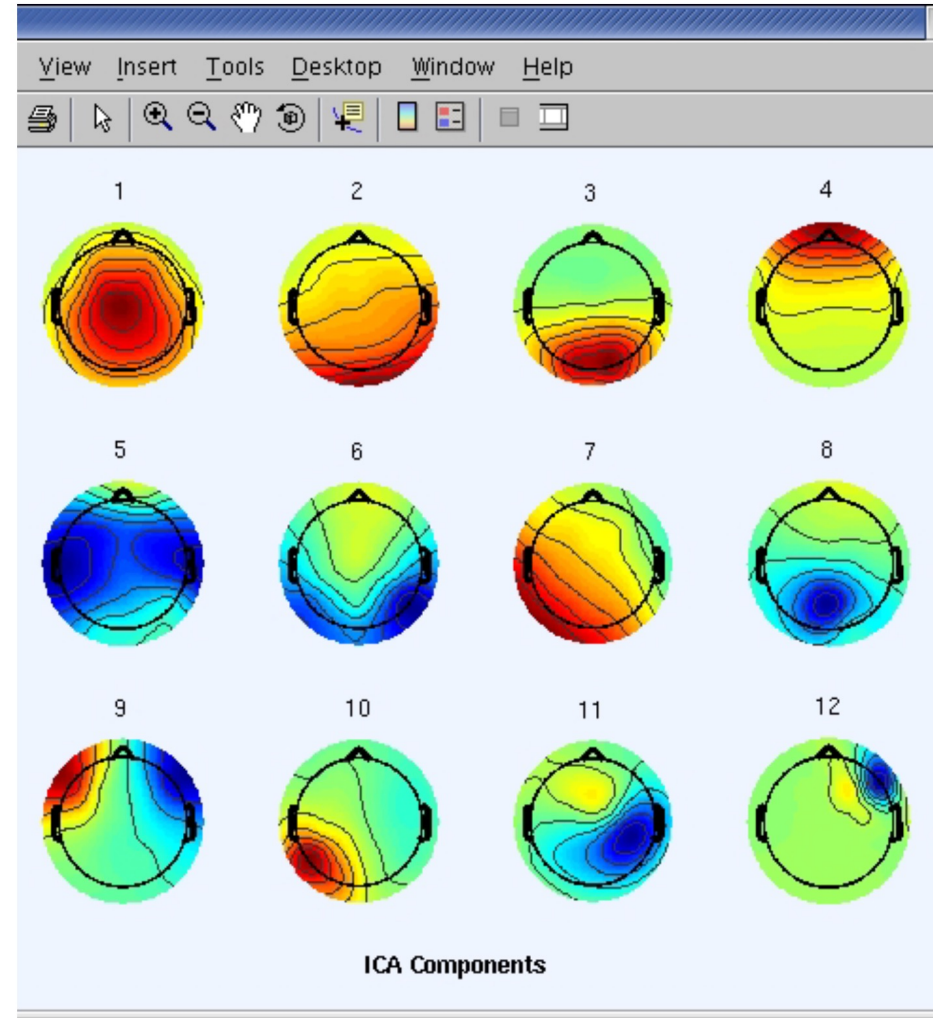
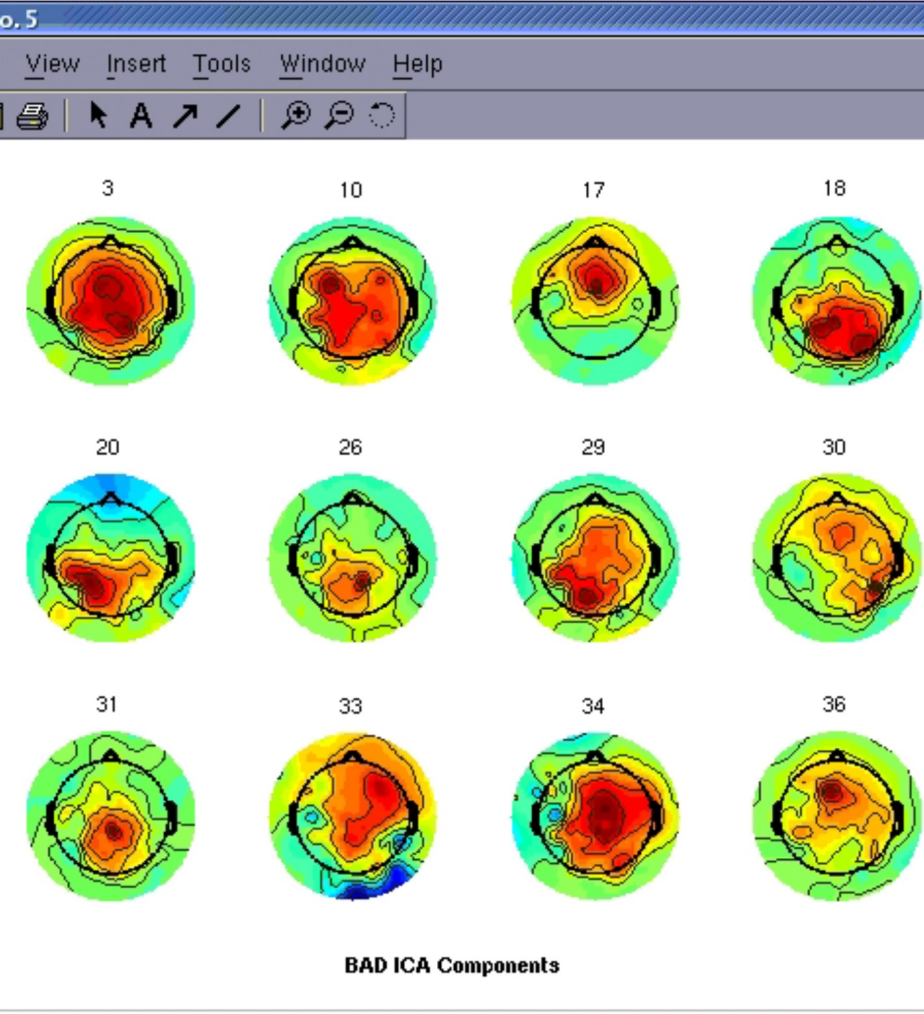
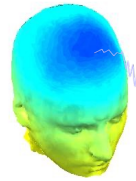
Use 'Inspect/label components by map'
to survey components



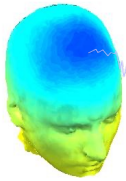
An interactive overview of ICs



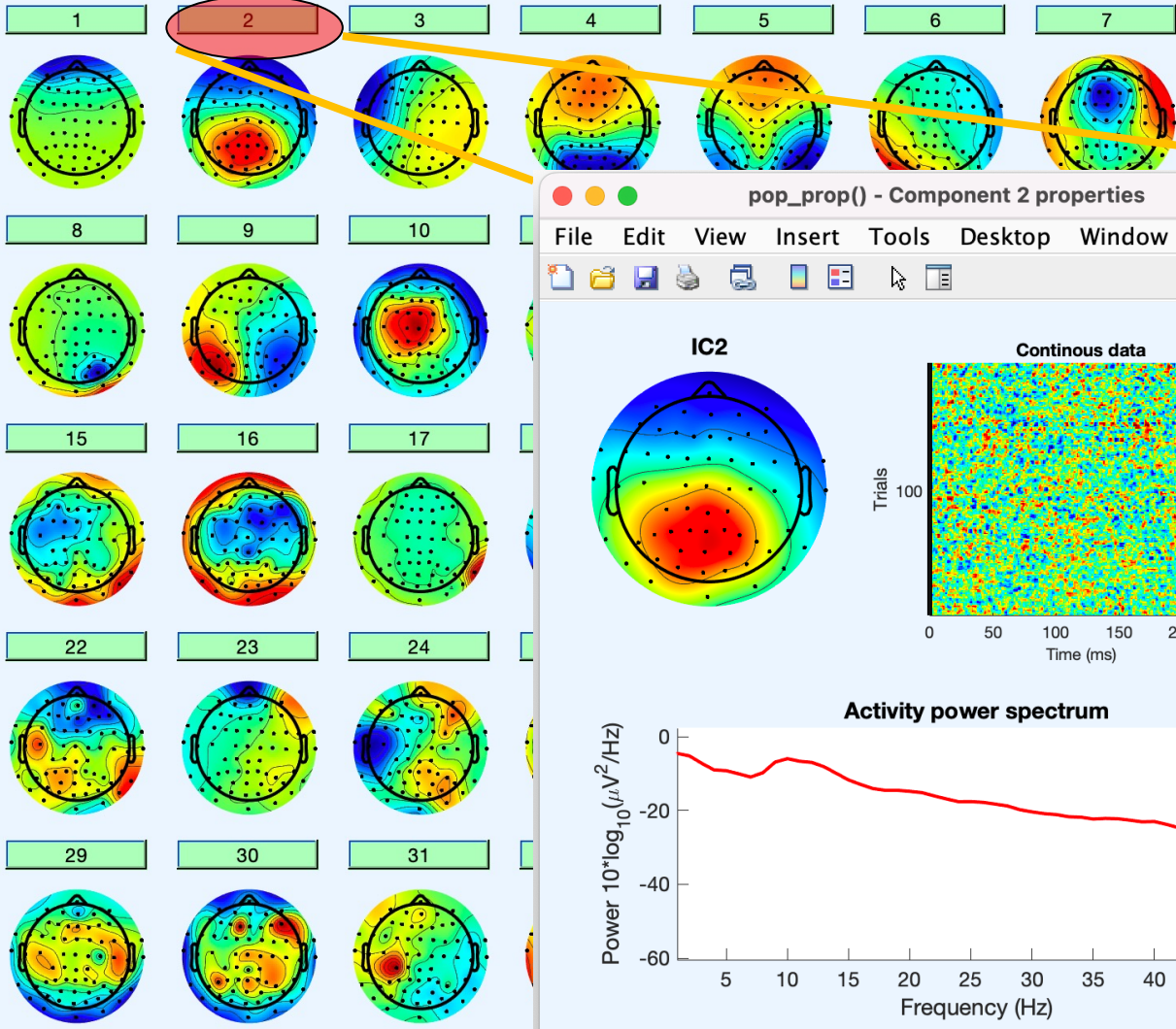
Step 0: Quality of Decomposition



Examining IC Properties

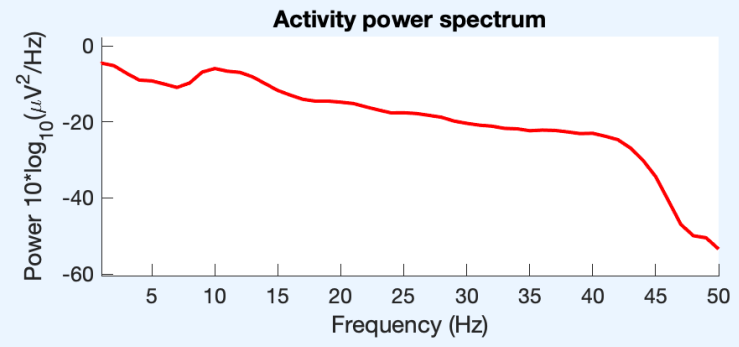
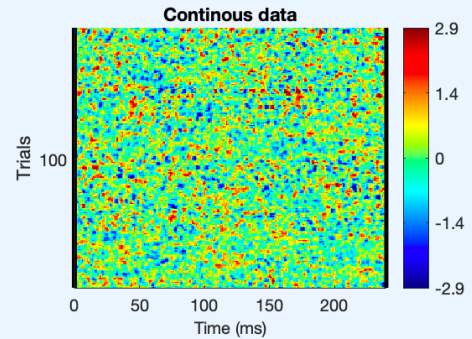
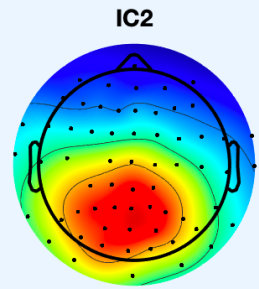


Reject components by map - pop_selectcomps() (dataset: sub-01_ses-meg_task-facerecognition_run-01_proc-...)



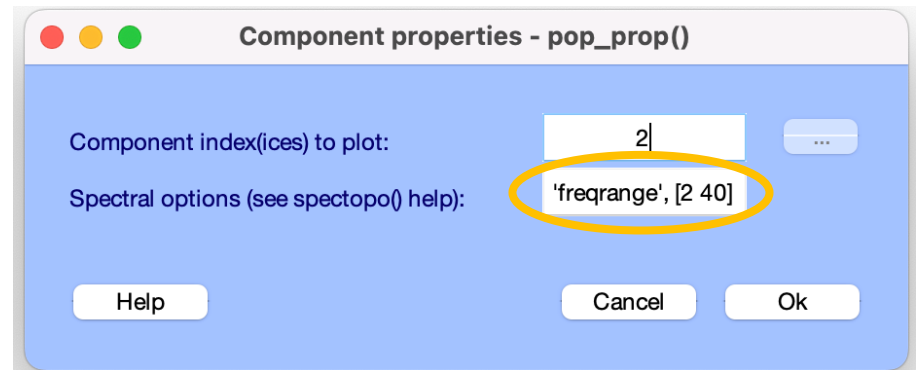
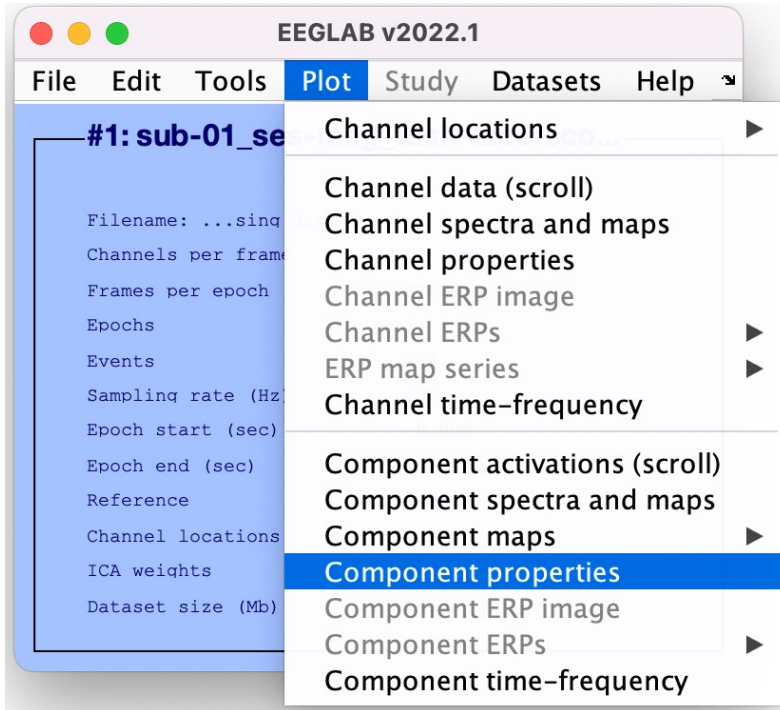
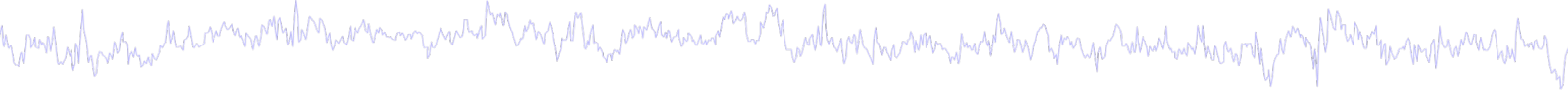
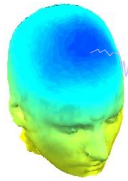
pop_prop() - Component 2 properties

File Edit View Insert Tools Desktop Window Help

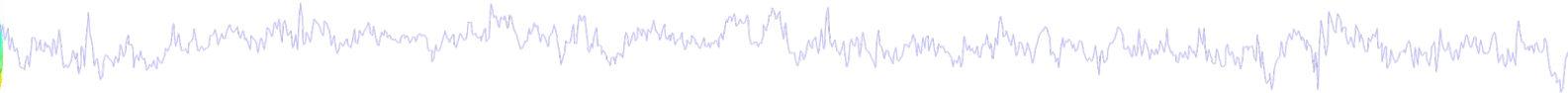
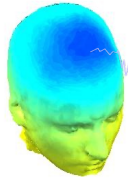


Cancel Values ACCEPT HELP OK

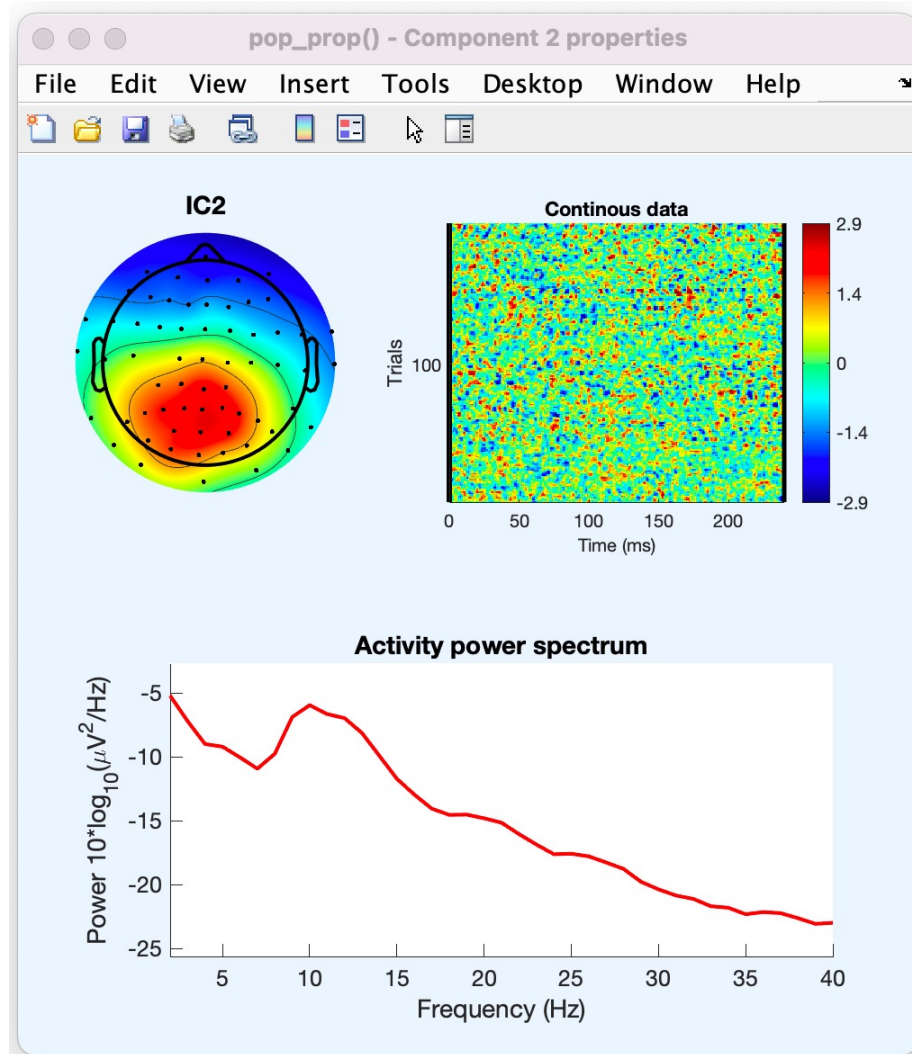
Plot IC Properties



IC Properties



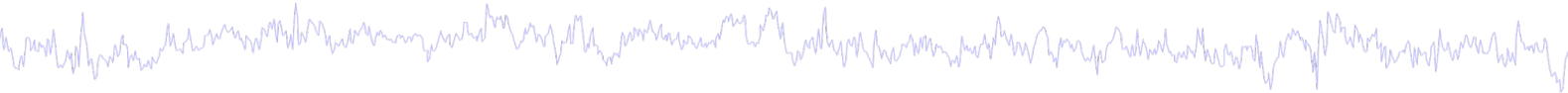
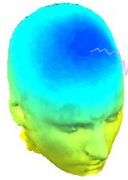
IC Topography
topoplot()



ERP Image
&
ERP
erpimage()

Power Spectrum
spectopo()





Part 1

Getting an overview of your ICs

Part 2

Classifying/Evaluating ICs

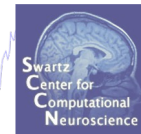
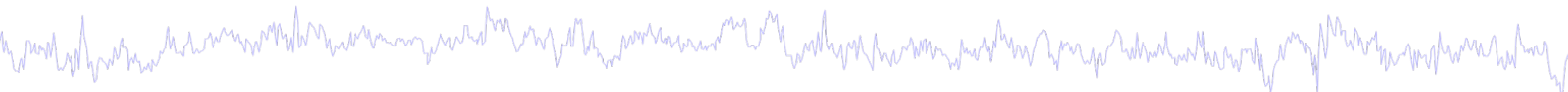
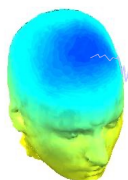
Eye Artifacts

Muscle Artifacts

Other Artifacts

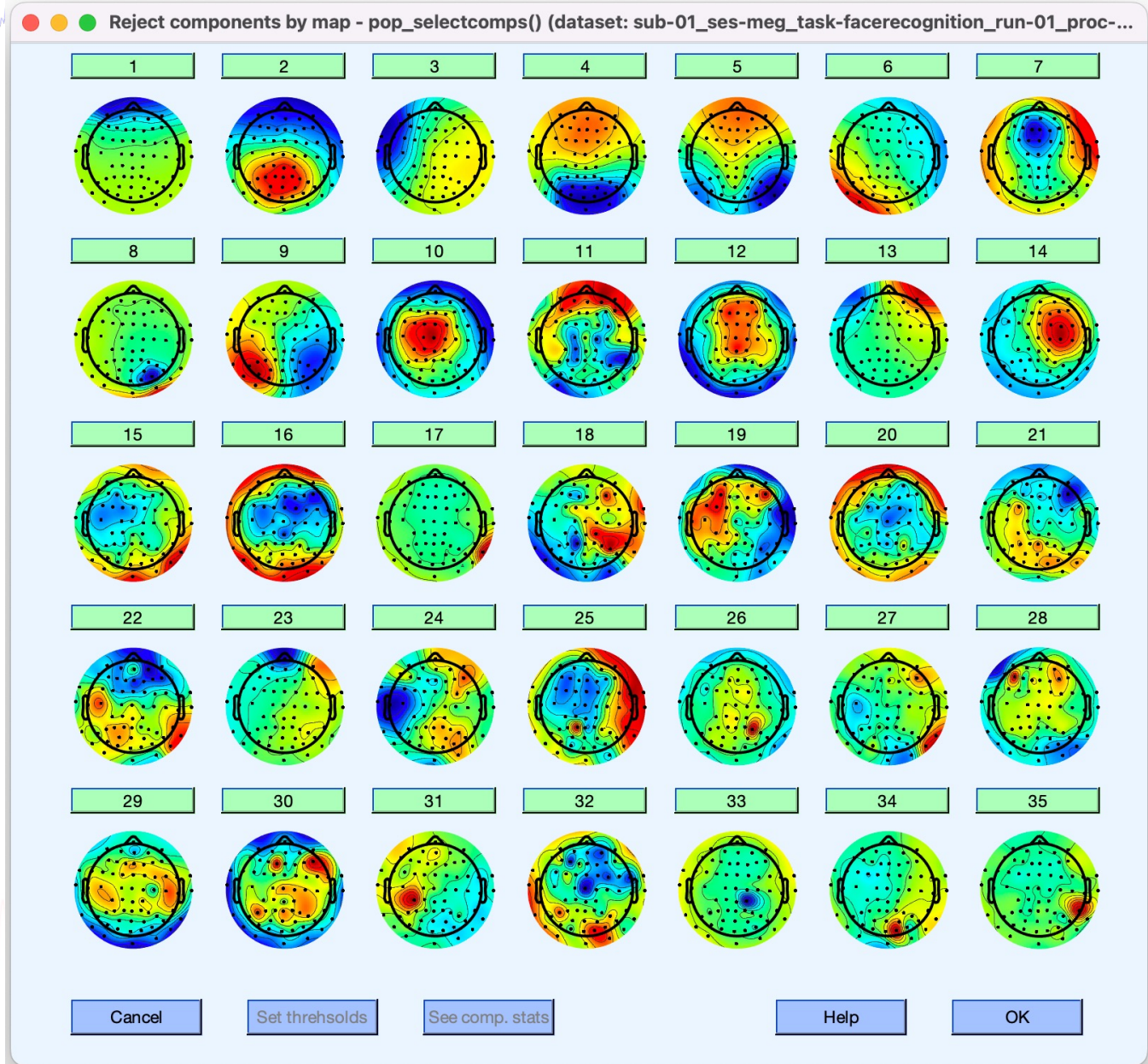
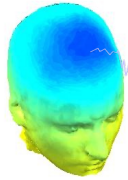


Evaluating ICs

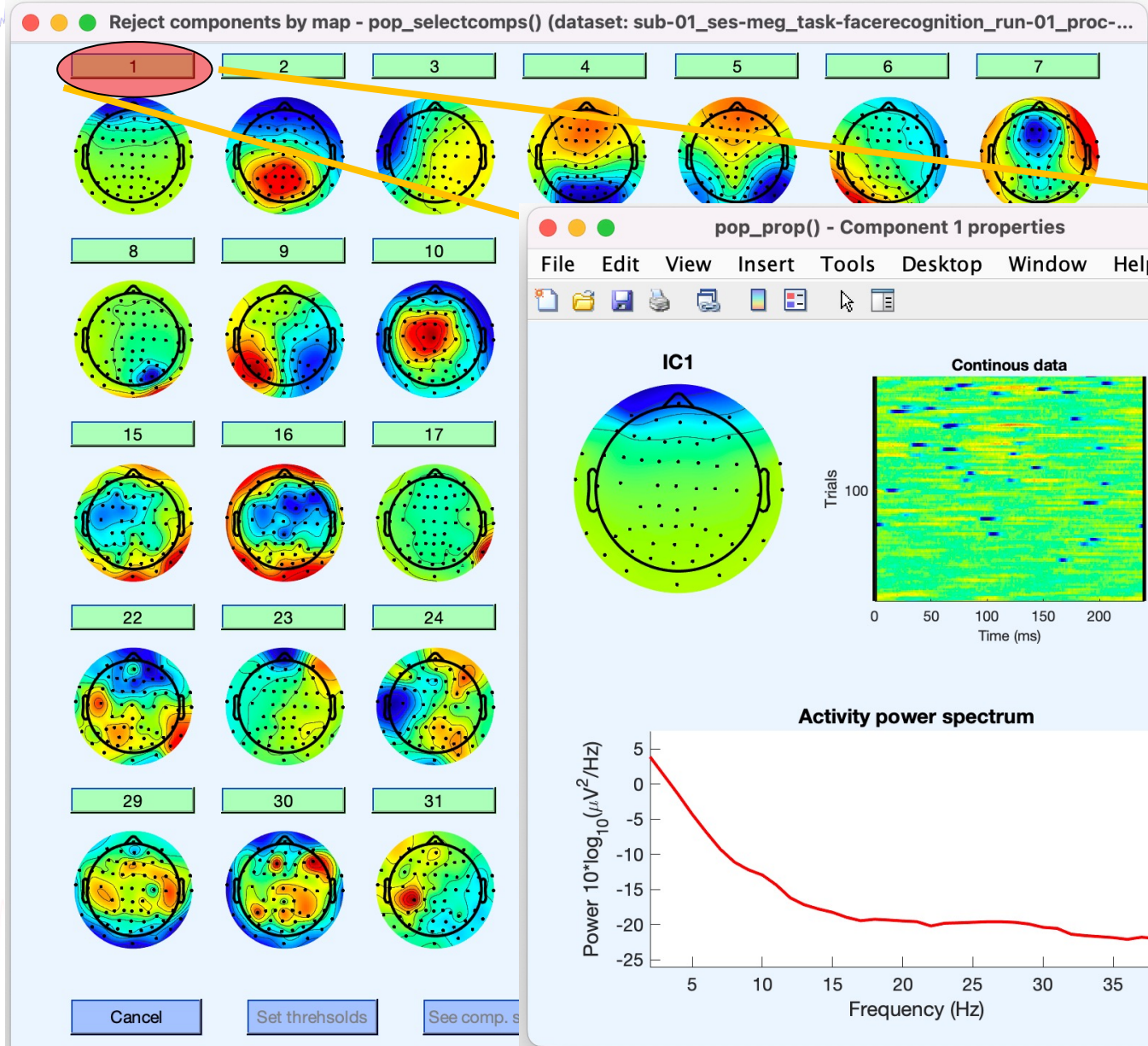
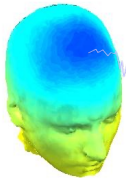


- Over time, most EEGLAB users develop a *heuristic* sense of which ICs might be brain vs. artifact.
- Heuristics are generally based on:
 - Topography
 - Component Activities (scroll)
 - ERP
 - Power Spectrum
- IC Classification can be used to ‘clean’ data—study likely brain activity without artifacts
- *There are new efforts to automate this process, but doing it by hand is a good place to start to build intuition – **IC Label plugin***

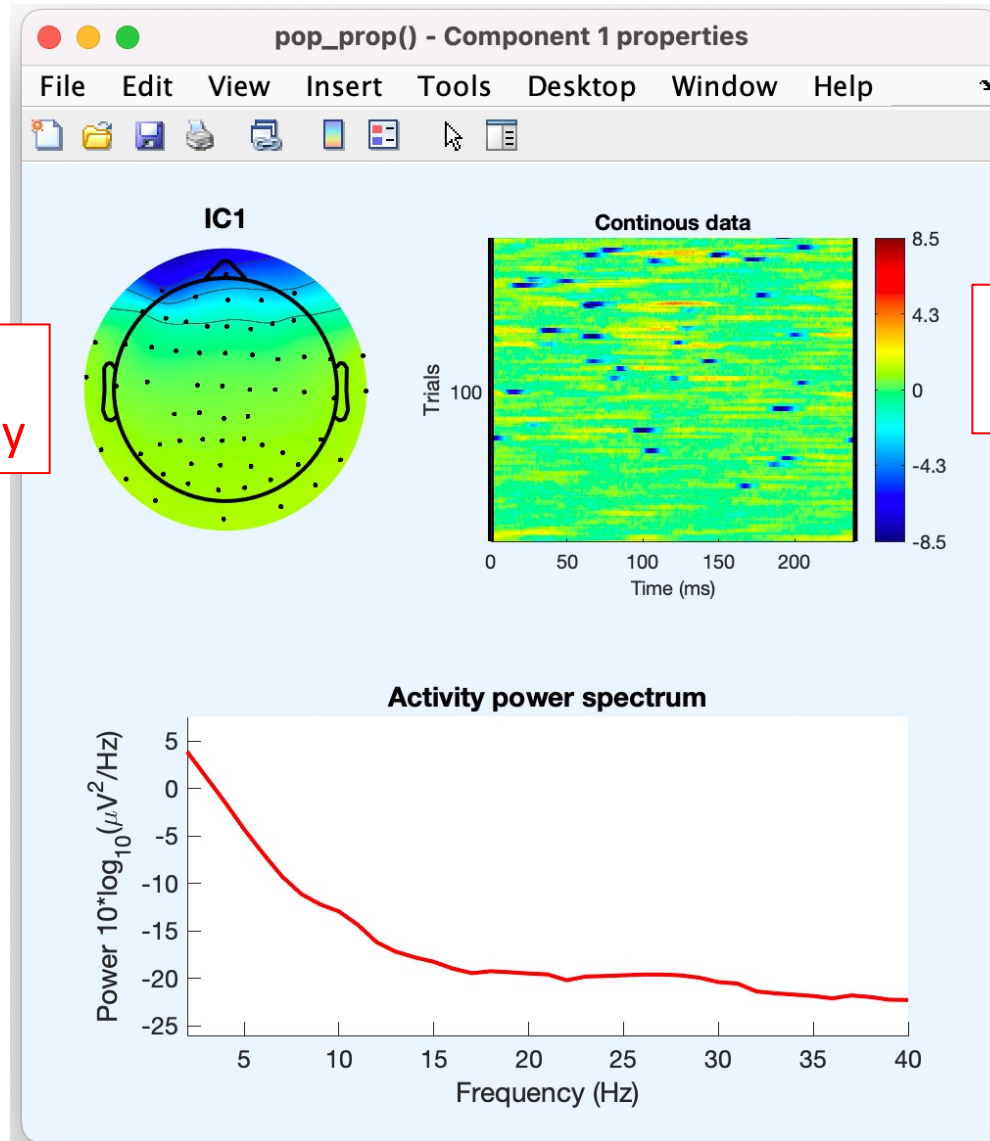
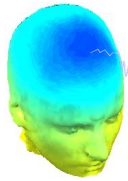
Topography



IC1 - eyeblink



IC1 - eyeblink



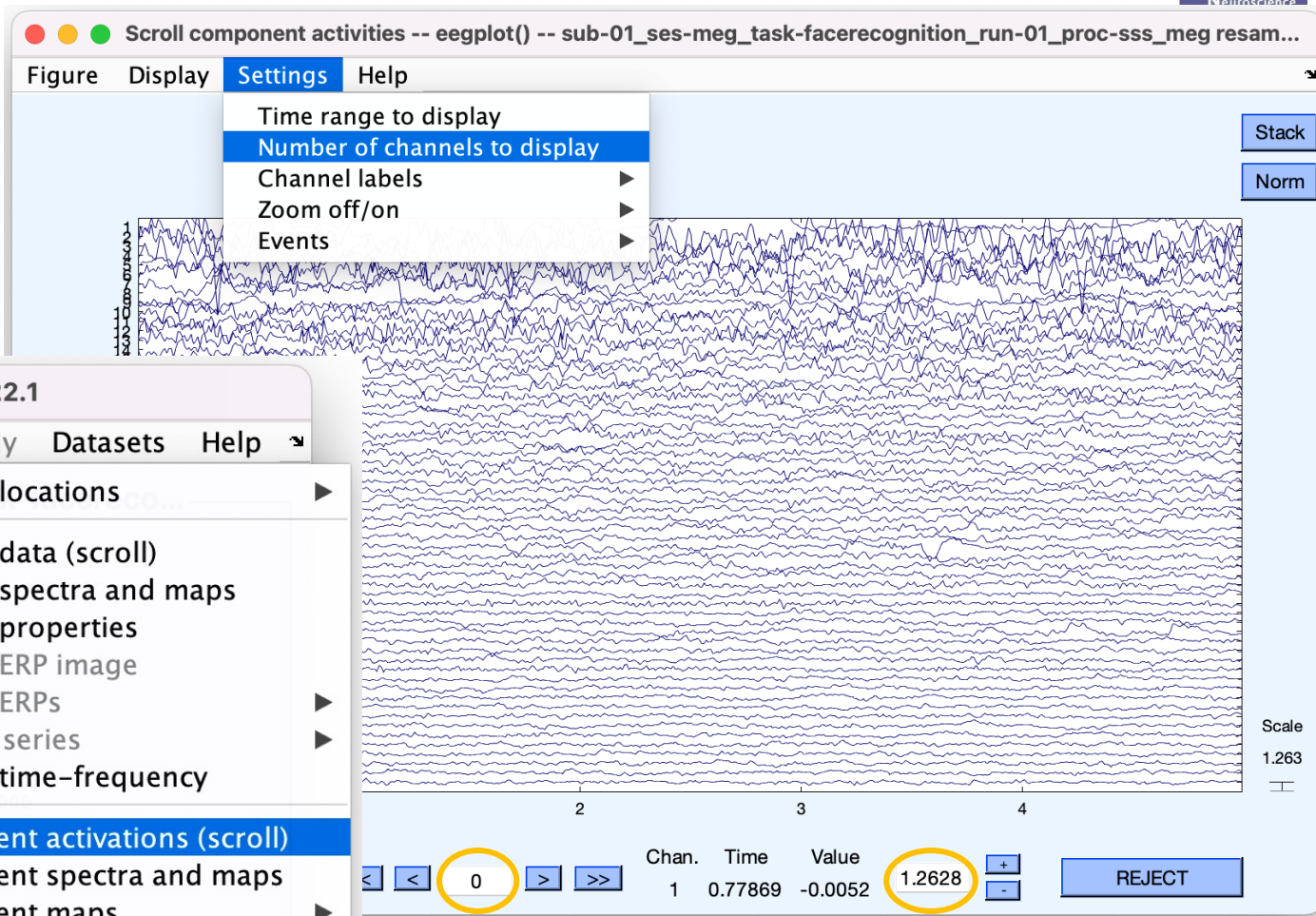
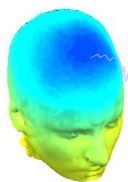
Classic frontal
eye-blink topography

Sporadic large
biphasic pulses

Low frequency
activity



Plot → Component Activations (scroll)



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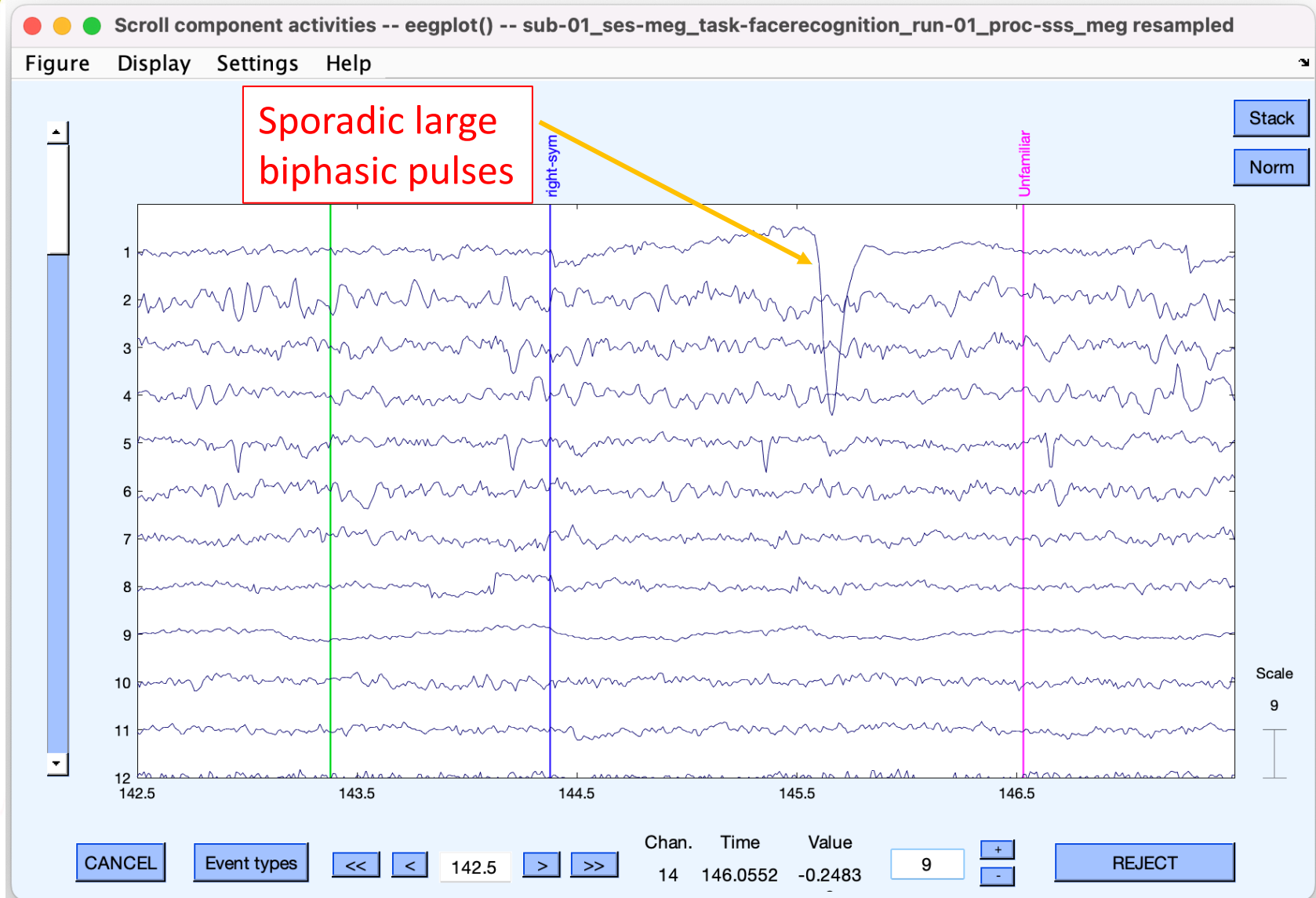
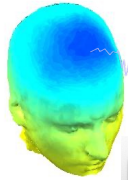
File Edit Tools Plot Study Datasets Help

#1: sub-01_ses

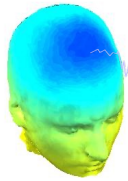
- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties
- Channel ERP image
- Channel ERPs
- ERP map series
- Channel time-frequency
- Component activations (scroll)**
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component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

Filename: ...sing...
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)

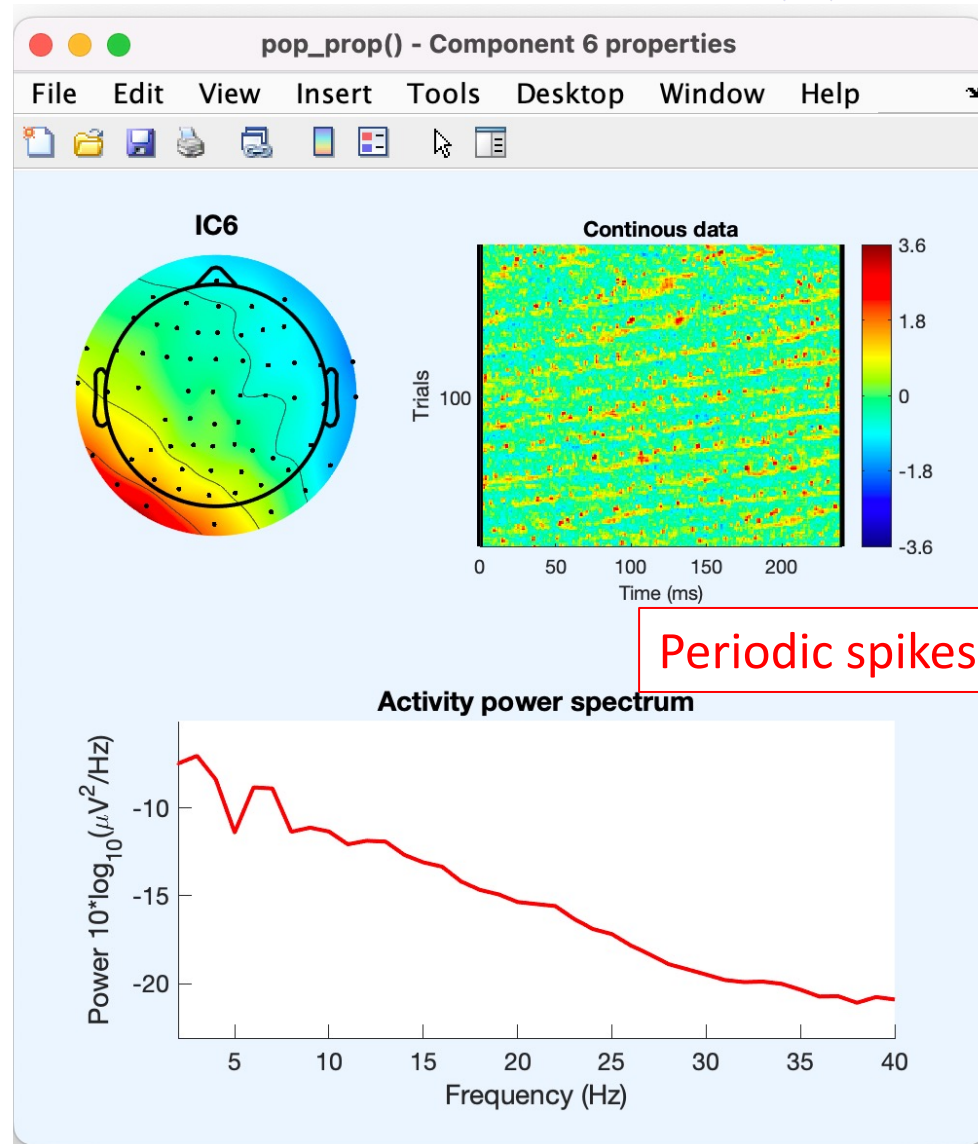
IC 1 Activation – eyeblink



IC 6 - cardiac



Cardiac-like topographies:
Shallow gradient =
extremely distant source

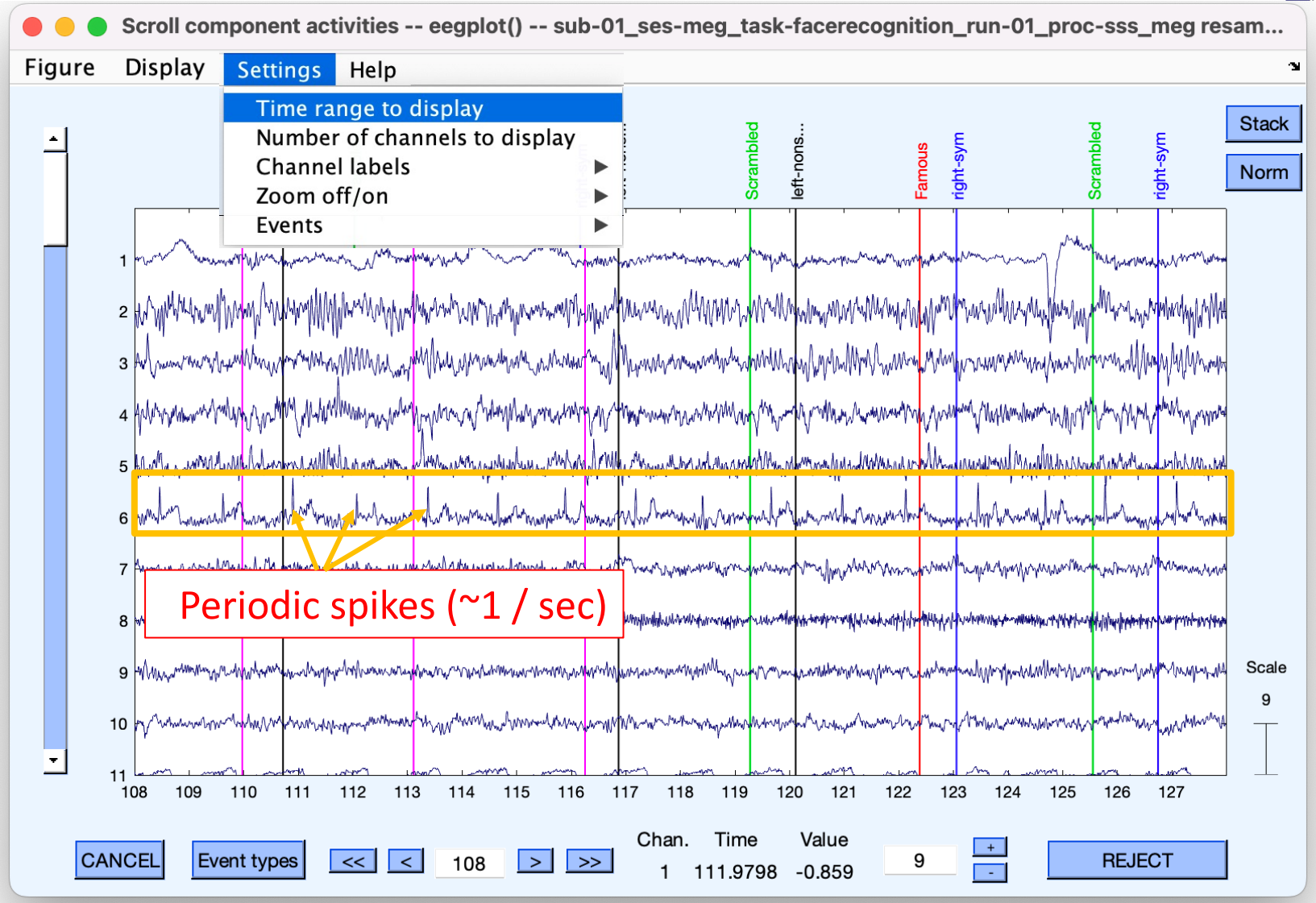
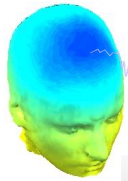


Periodic spikes (~ 1 / sec)

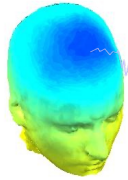
Unusual, peaky spectrum
(often peaks $\sim 5, 10$ Hz)



IC 6 - cardiac

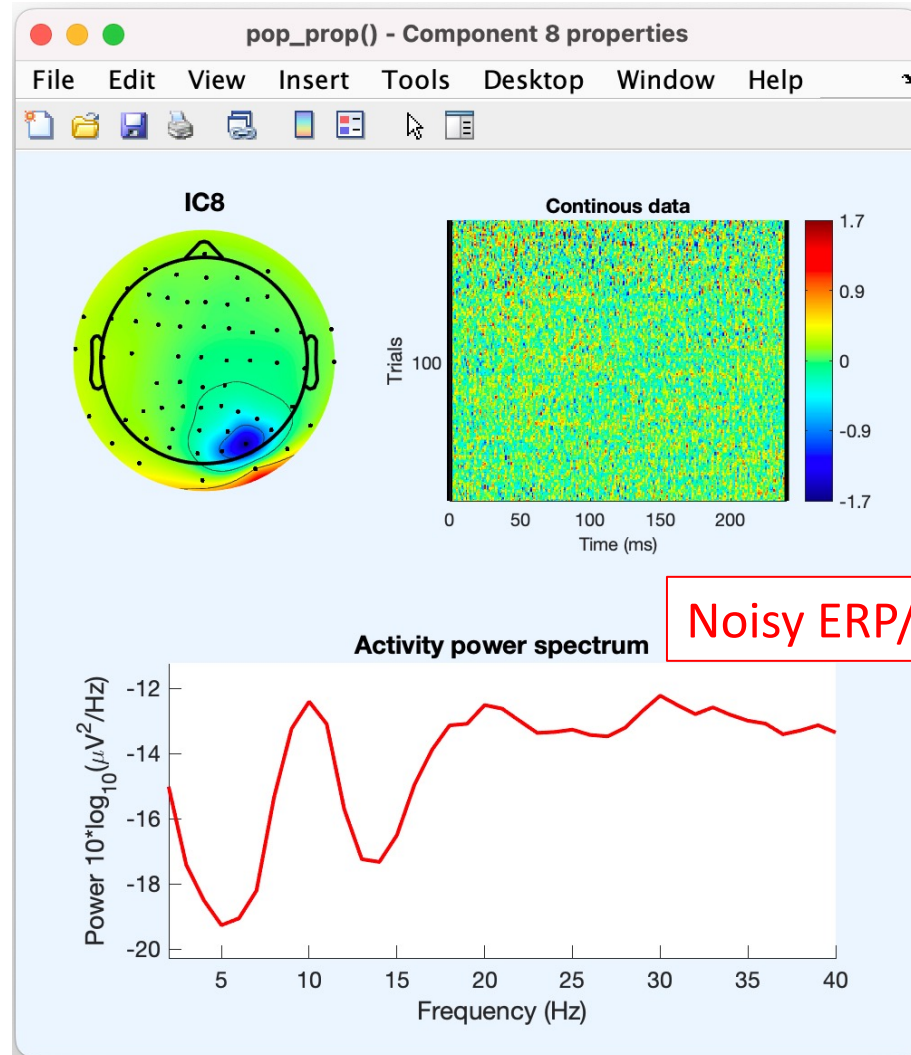


IC 8 – Muscle



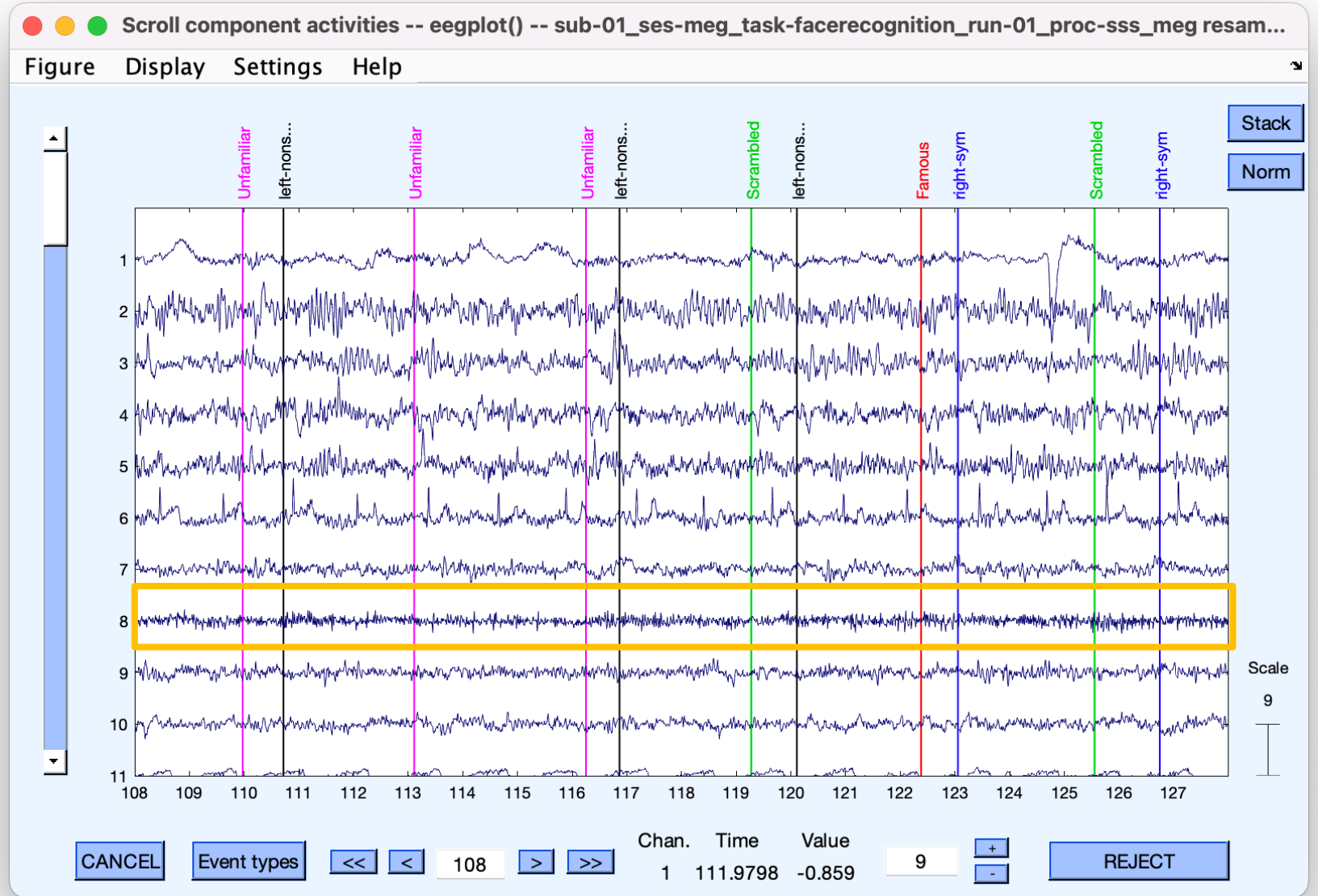
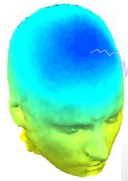
Narrowly spaced dipolar topography (consistent with superficial source)

High frequencies dominate power spectrum

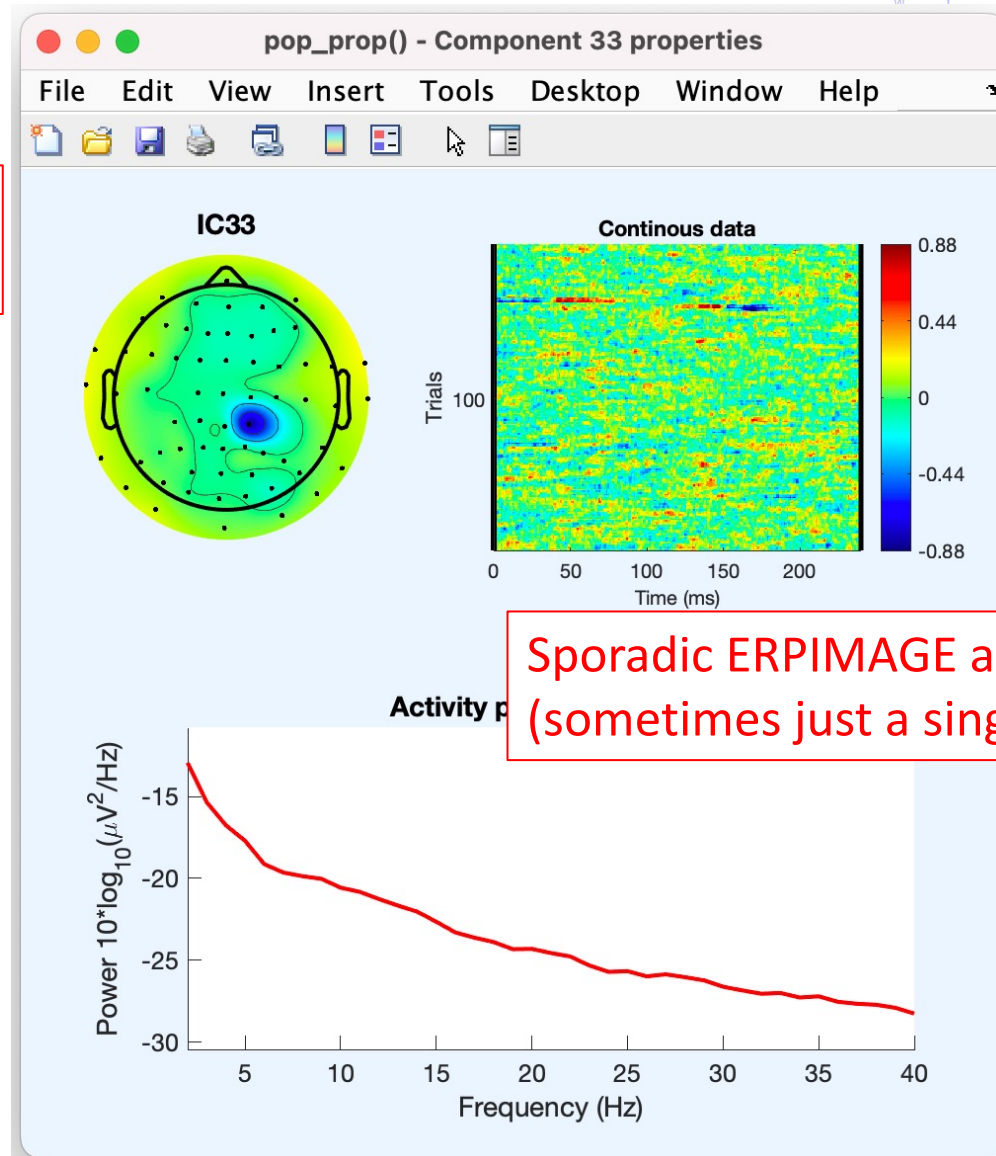
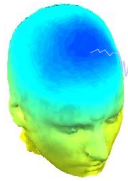


Noisy ERP/ERP Image

IC 8 Activation – Muscle



IC 33 – Bad channel

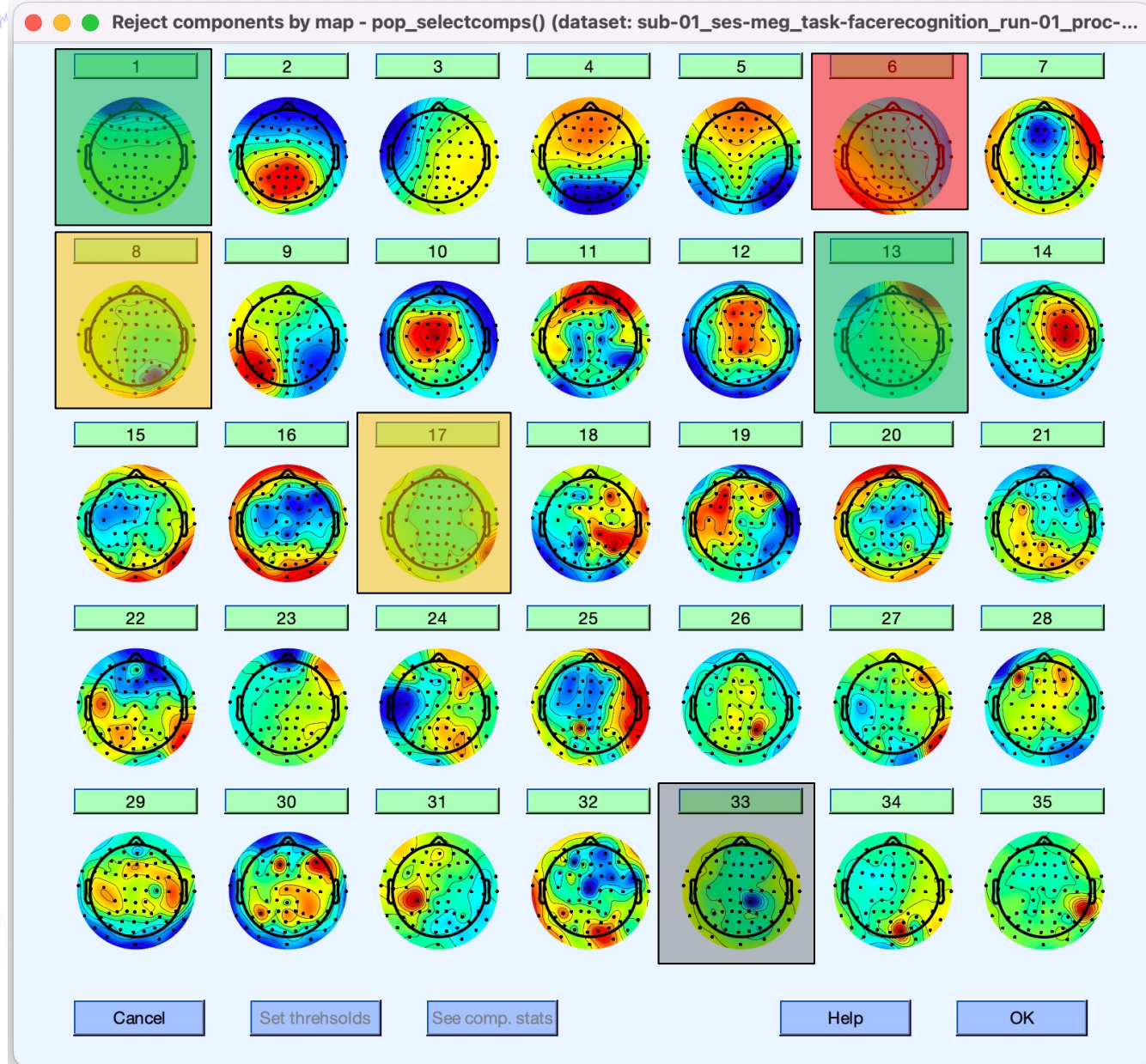
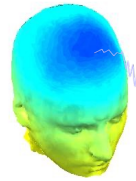


Punctate topography
(single channel)

Sporadic ERPIMAGE activity
(sometimes just a single large spike)

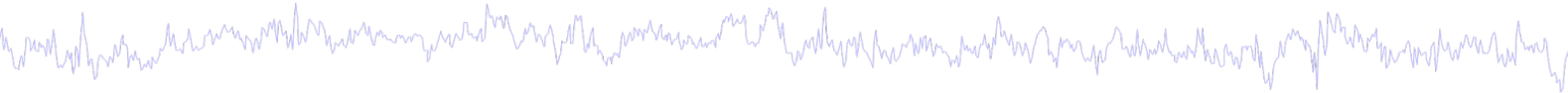
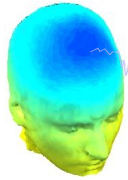


IC classification so far...



Eye
Muscle
Cardiac
Badchan

IC Label plugin



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File Edit **Tools** Plot Study Datasets Help

#1: 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

Label components
Flag components as artifacts
View extended component properties

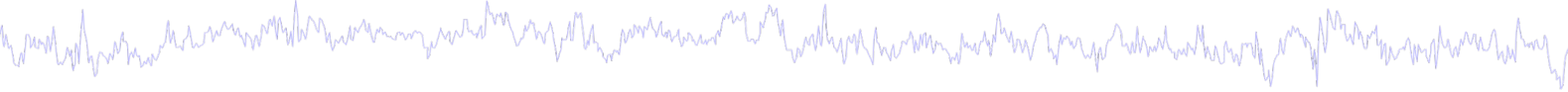
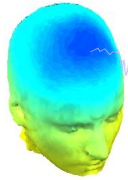
ICLabel

Select which version of ICLabel to use:

Default (recommended)

Cancel Ok

IC Label plugin



```
>> EEG.etc.ic_classification.ICLabel
```

```
ans =
```

```
struct with fields:
```

```
    classes: {'Brain' 'Muscle' 'Eye' 'Heart' 'Line Noise' 'Channel Noise' 'Other'}  
classifications: [63x7 single]  
    version: 'default'
```

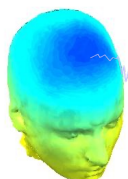
```
>> EEG.etc.ic_classification.ICLabel.classifications
```

```
ans =
```

```
63x7 single matrix
```

```
0.0003    0.0009    0.9871    0.0006    0.0000    0.0011    0.0100  
0.9992    0.0001    0.0000    0.0001    0.0002    0.0000    0.0004  
0.9989    0.0000    0.0001    0.0001    0.0001    0.0000    0.0008  
0.9998    0.0000    0.0000    0.0000    0.0000    0.0000    0.0001  
0.9963    0.0001    0.0000    0.0001    0.0009    0.0000    0.0026  
0.2034    0.0008    0.0004    0.7153    0.0024    0.0013    0.0763  
0.8176    0.0021    0.0002    0.0098    0.0213    0.0003    0.1487  
0.3447    0.5817    0.0021    0.0046    0.0003    0.0174    0.0492  
0.9953    0.0002    0.0000    0.0004    0.0019    0.0001    0.0022
```

View extended component properties



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File Edit **Tools** Plot Study Datasets Help

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

- Change sampling rate
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- 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

- Label components
- Flag components as artifacts
- View extended component properties**

View many chan or comp. properties -- pop_vie...

Component indices to plot: 1:60

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

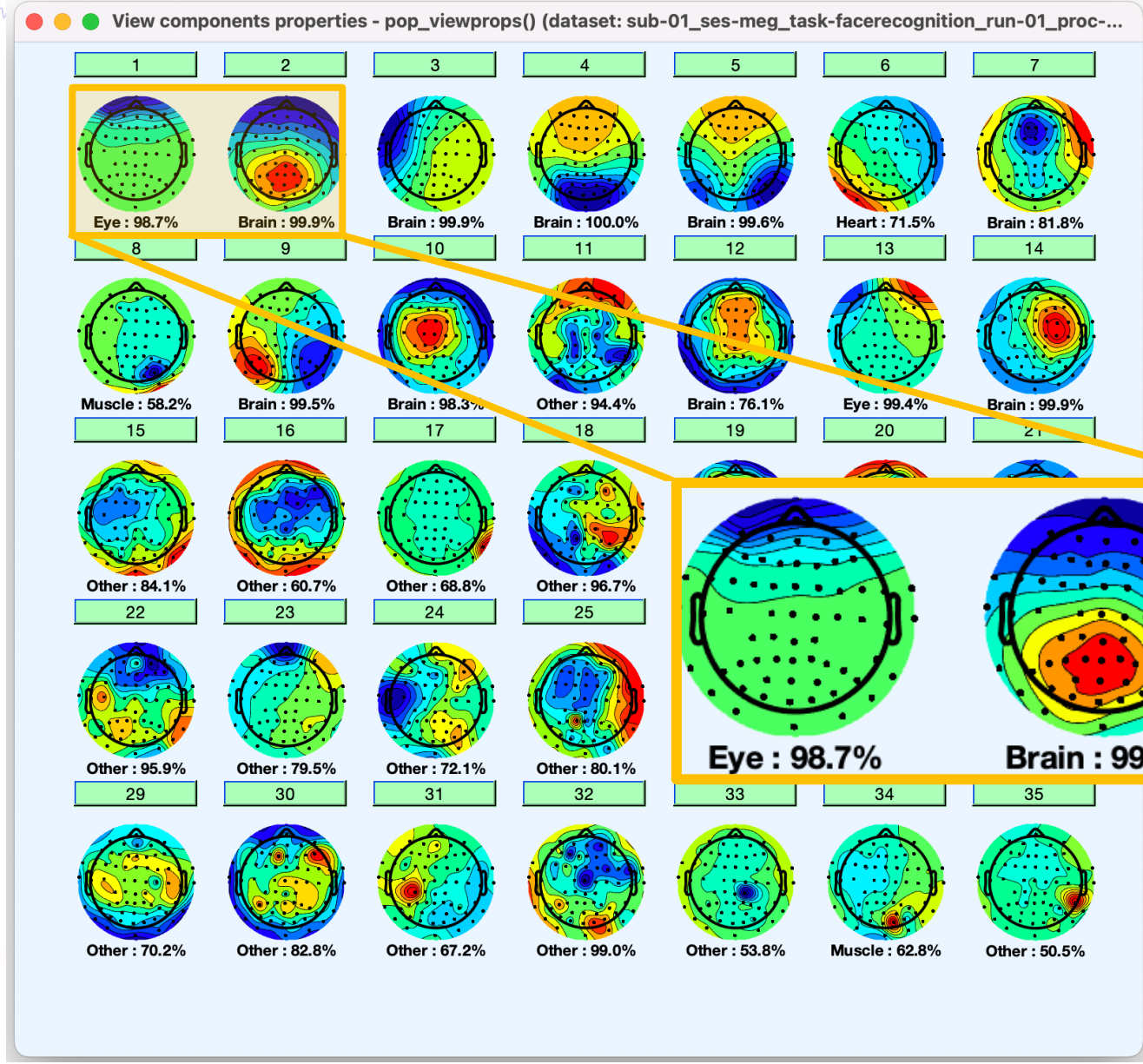
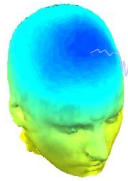
Erpimage options (see erpimage() help): |

Draw events over scrolling component activity

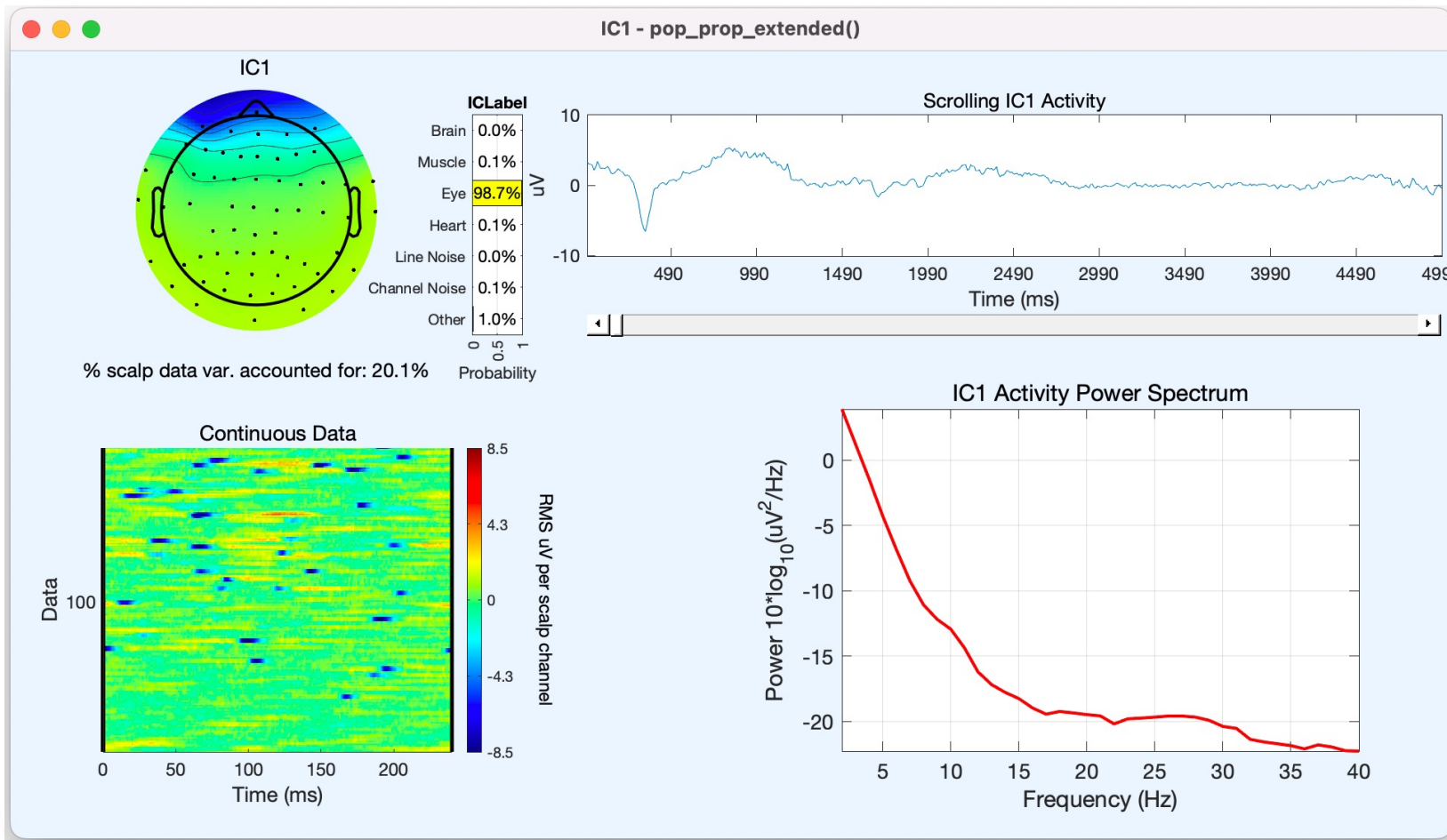
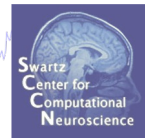
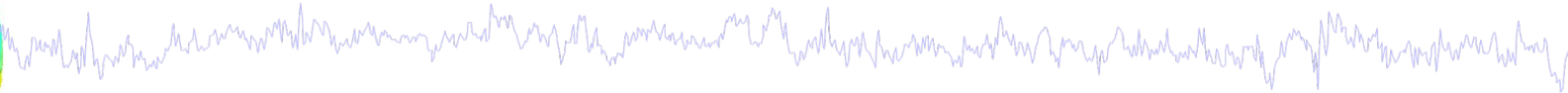
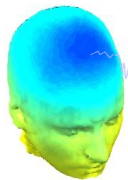
ICLabel

Cancel Ok

View extended component properties



IC Label plugin

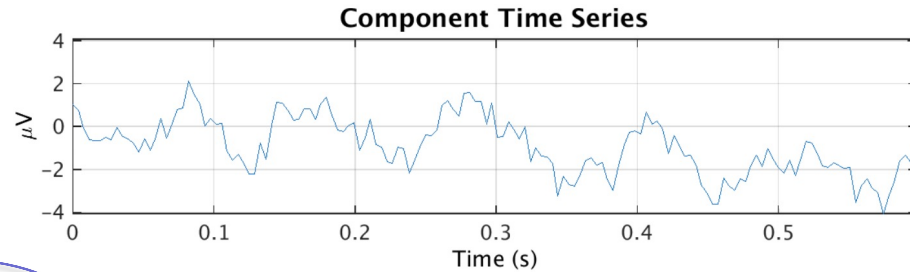
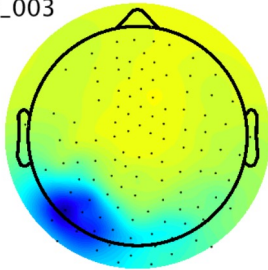


Practice Labeling...

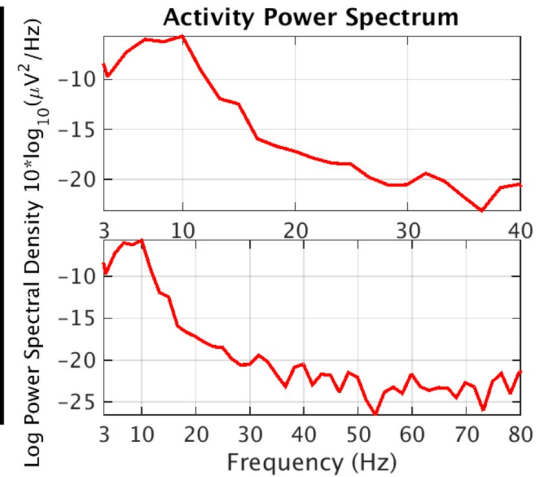
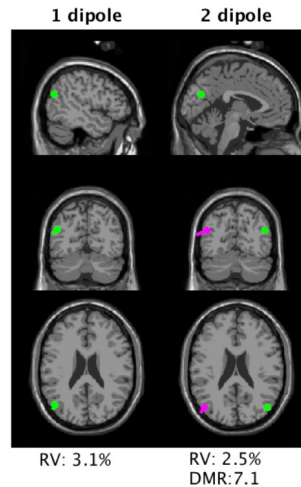
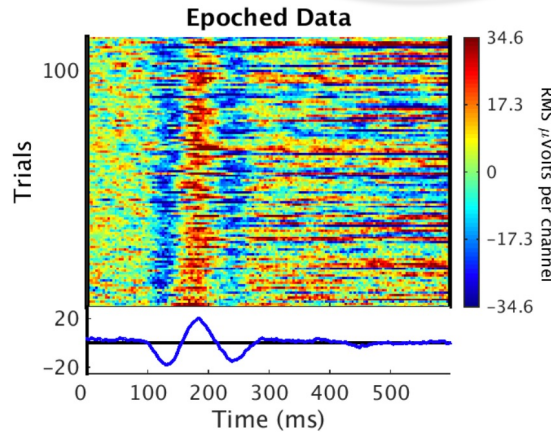
<https://labeling.ucsd.edu/tutorial>



072949_003

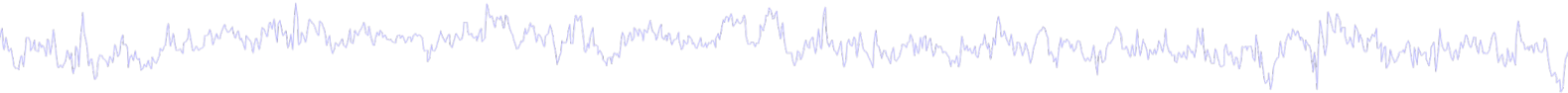
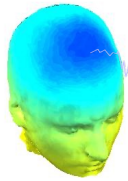


IC 3 of 112
Data Var. Accounted For:
3.63%



- Brain
- Muscle
- Eye
- Heart
- Submit
- Line Noise
- Chan Noise
- Other
- ?

Save dataset



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File Edit Tools Plot Study Datasets Help

- Import data
- Import epoch info
- Import event info
- Export
- BIDS tools
- 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

Save dataset with .set extension -- pop_saveset()

Save As: wh_S01_run_01_preprocessing_dat

Tags:

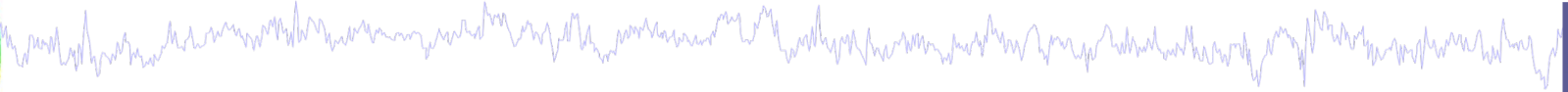
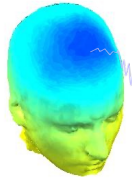
sub-01

Previous 30 Days

	Date M
wh_S01_run_01_ERP_Analysis_Session_2_famous_out.set	Decem
wh_S01_run_01_preprocessing_data_session_1_out.set	Decem
wh_S01_run_01_ERP_Analysis_Session_2_unfamiliar_out.set	Decem
wh_S01_run_01_ERP_Analysis_Session_2_scrambled_out.set	Decem

Format: (*.set)

New Folder Cancel Save



Thank You!

