Neural Networks to Consumer Networks: EEG in Research and Marketing

Introduction to ERP Analysis using EEGLAB

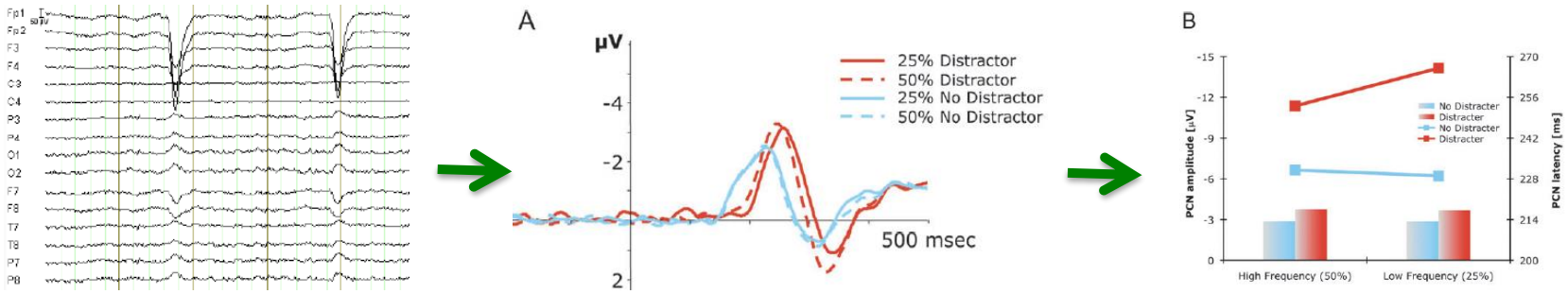
Dr. Artyom Zinchenko

PART II

MUNICH-ÇANAKKALE 2026

15.04.2026

Main aims of the next 2 sessions …



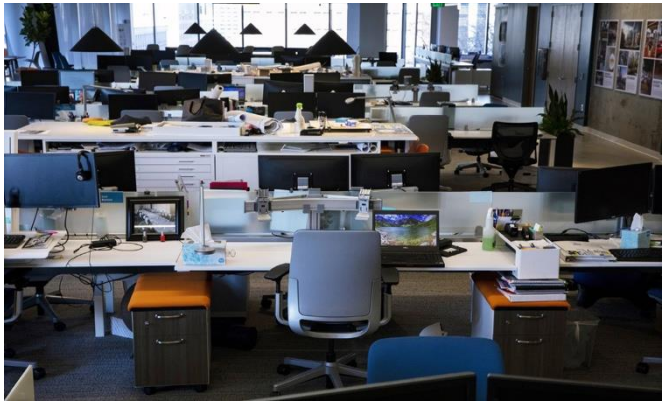
1a: How to extract ERPs from ongoing EEG?

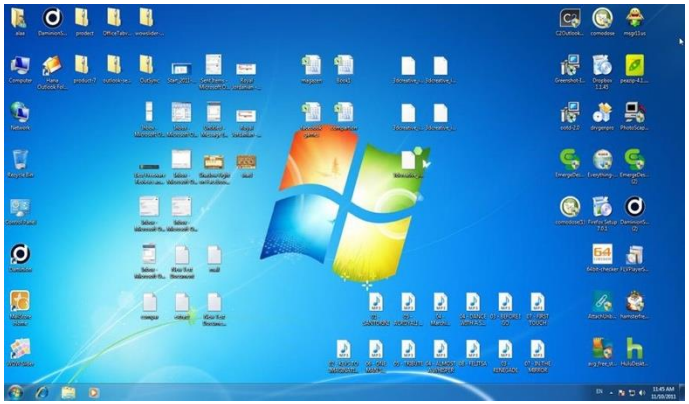
1b: How to visualize ERPs?

2a: How to compute ERP amplitudes & latencies?

2b: How to analyze ERP data statistically?

Paradigm: Contextual Cueing

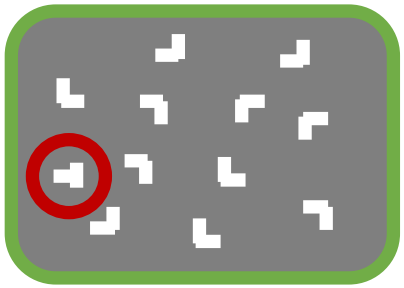


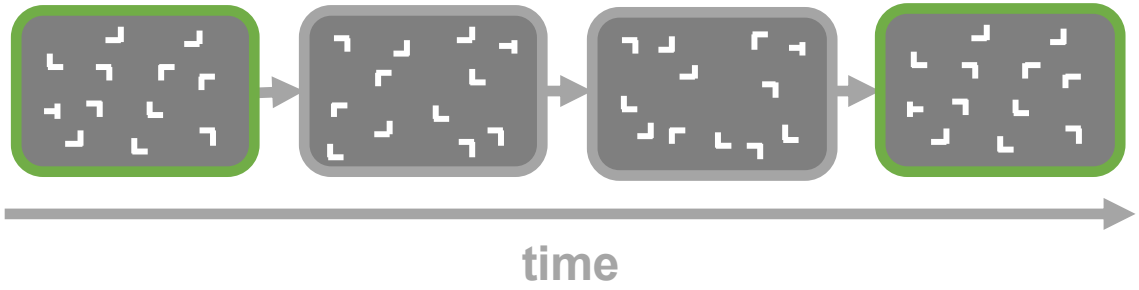


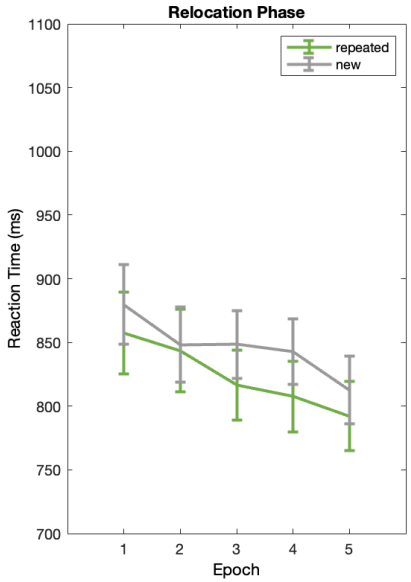
Paradigm: Contextual Cueing

Repeated display: same array, same target location

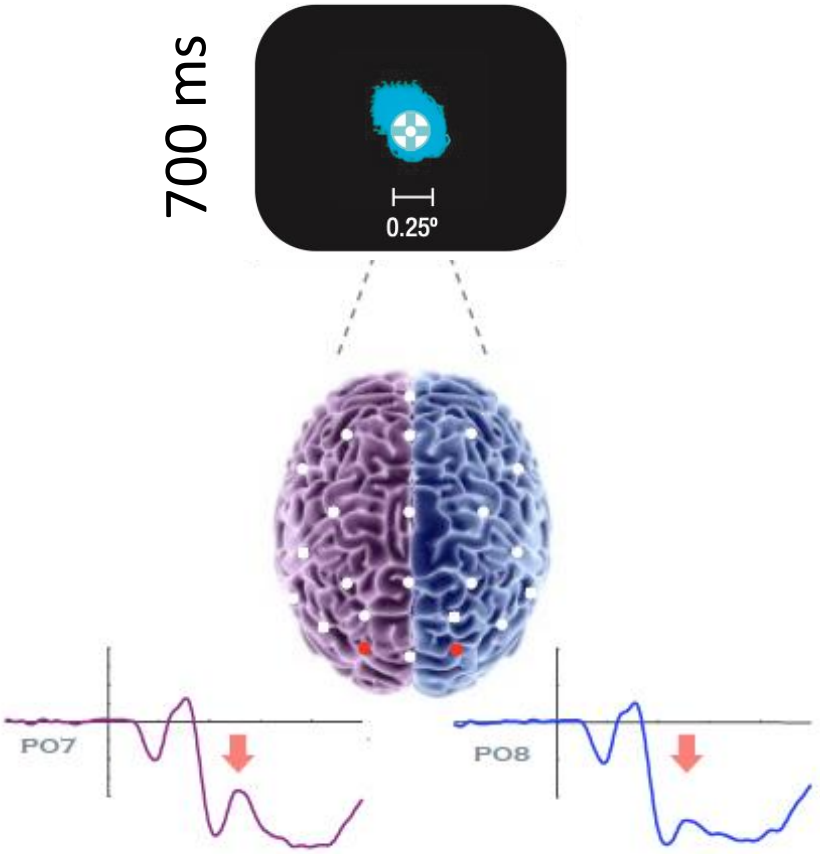
Non-repeated display: different array, same target location

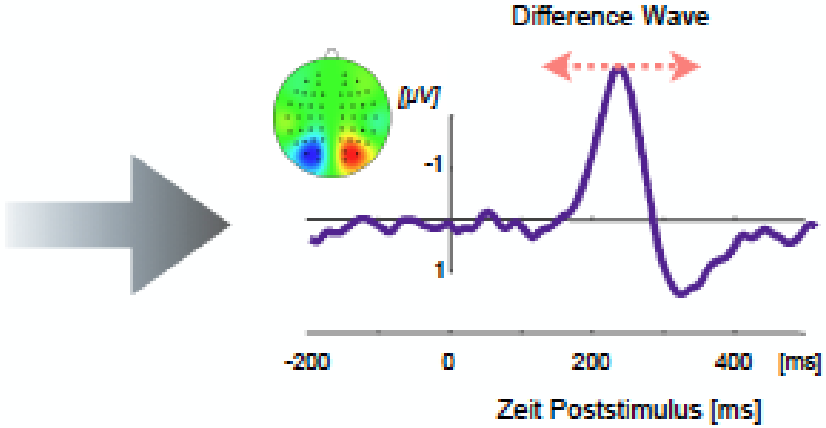






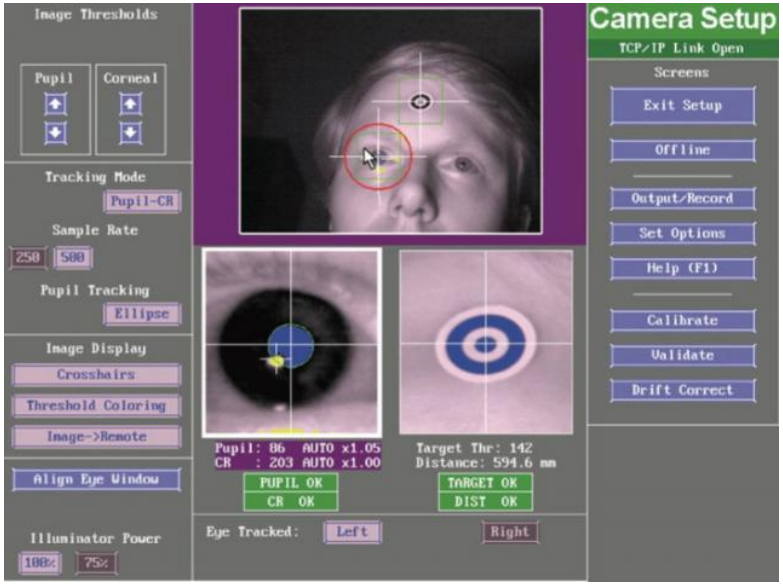
Neural correlates of contextual modulation of attention



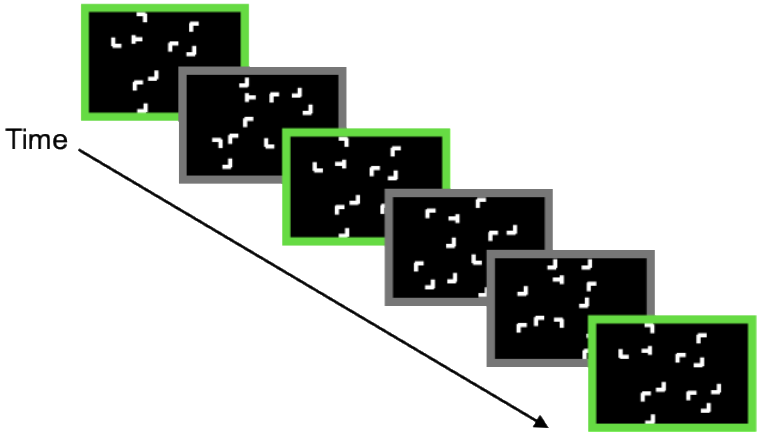


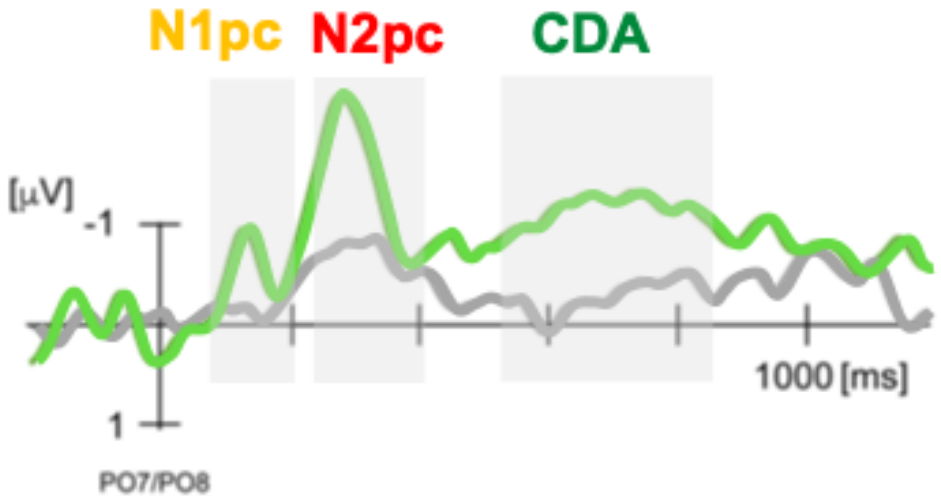
Zinchenko, Conci, Töllner, Müller, & Geyer (2020)

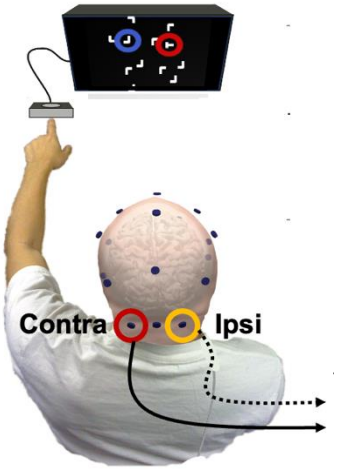
Neural correlates of contextual modulation of attention



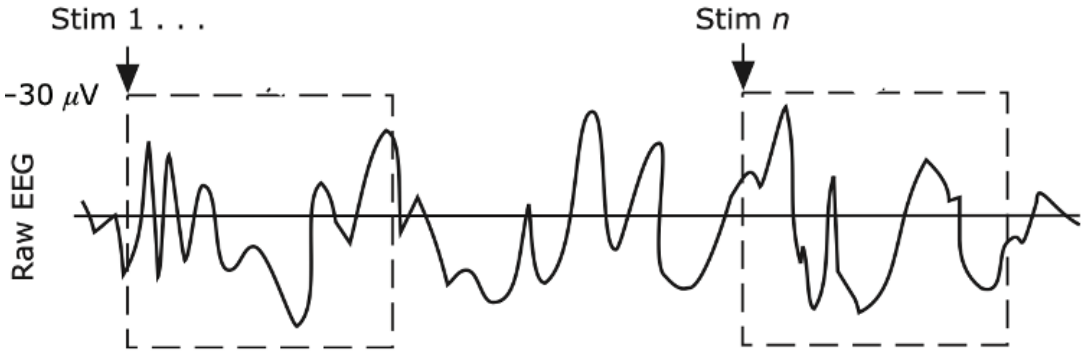
Neural correlates of contextual modulation of attention



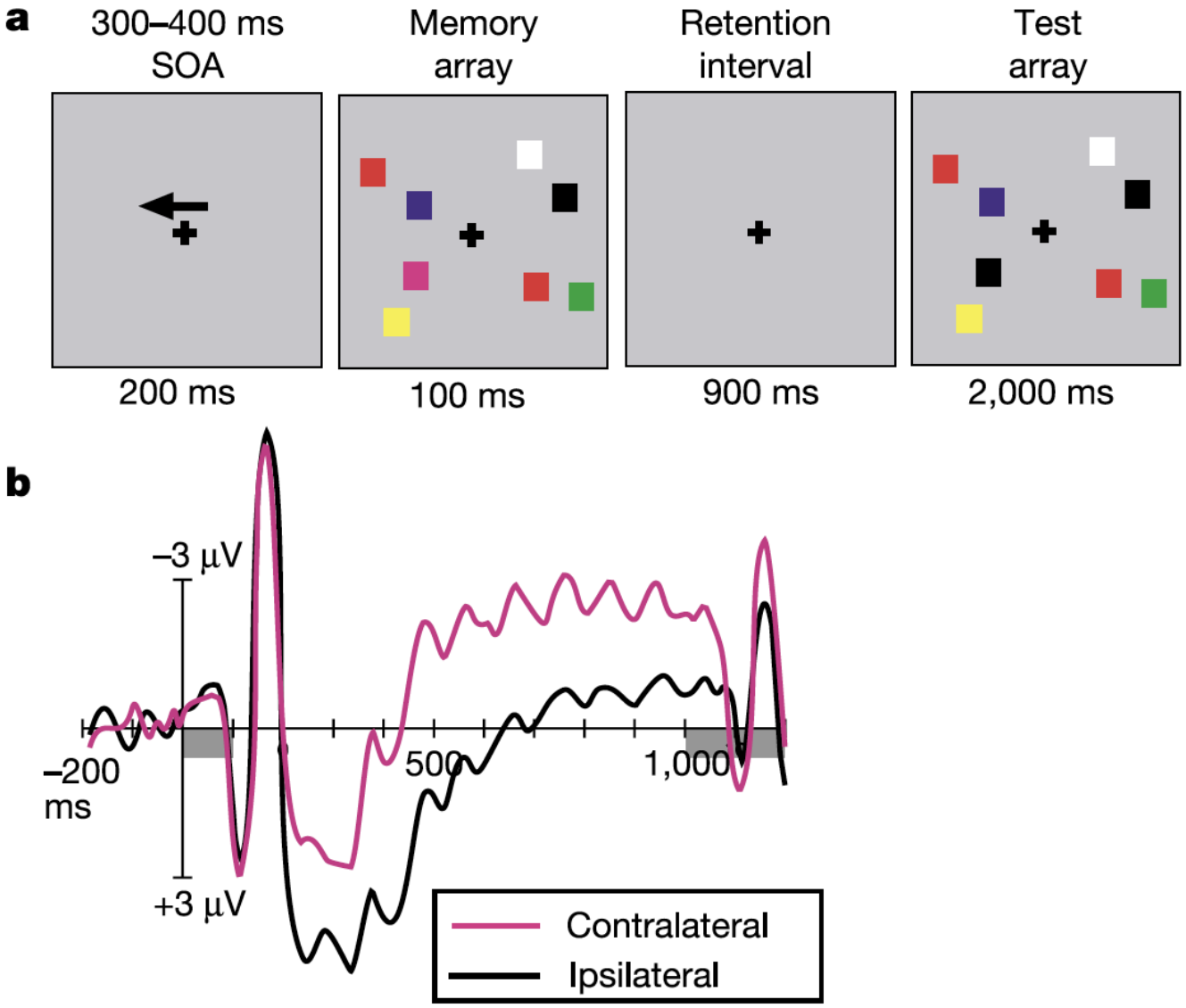




Adaptiert von: Woodman (2010); APP

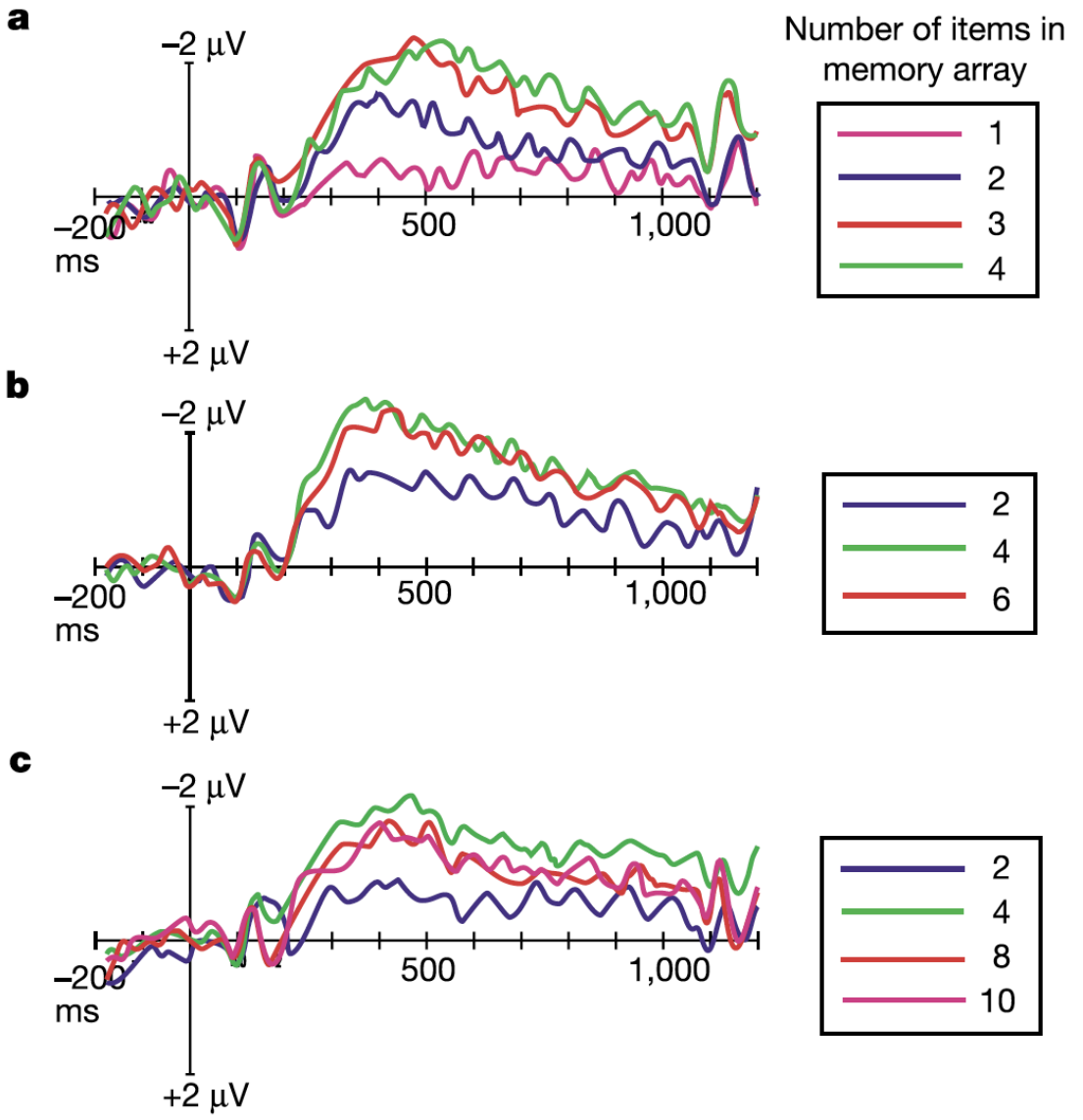


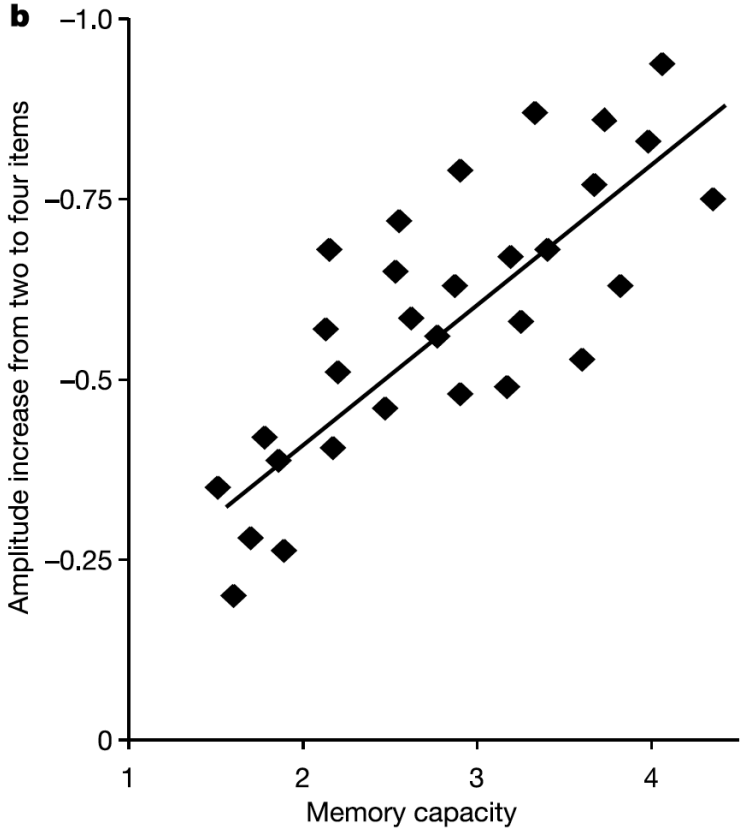
CDA and working memory



Vogel and Machizava, 2004

CDA and working memory





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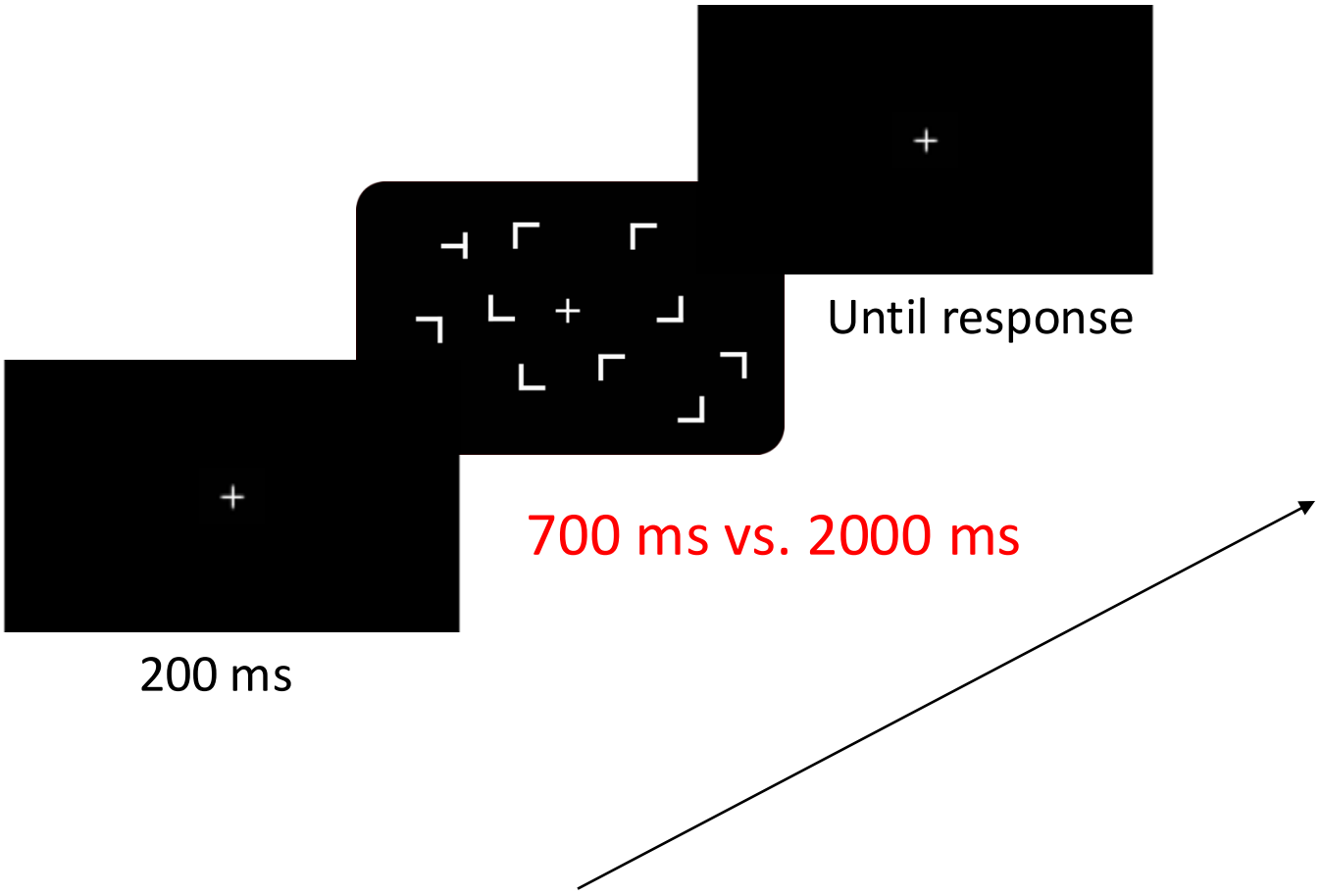


- EEG data need pre-processing before we can report them through graphs and run statistics on them.

EEG pre-processing software

Commercial

Brain Vision Analyzer

BRAIN PRODUCTS
Solutions for neurophysiological research

Neuroscan

COMPUMEDICS Neuroscan

MNE
MEG + EEG ANALYSIS & VISUALIZATION

https://mne.tools/stable/_images/mne_logo.svg

Open source

EEGLAB
http://sccn.ucsd.edu/eeglab

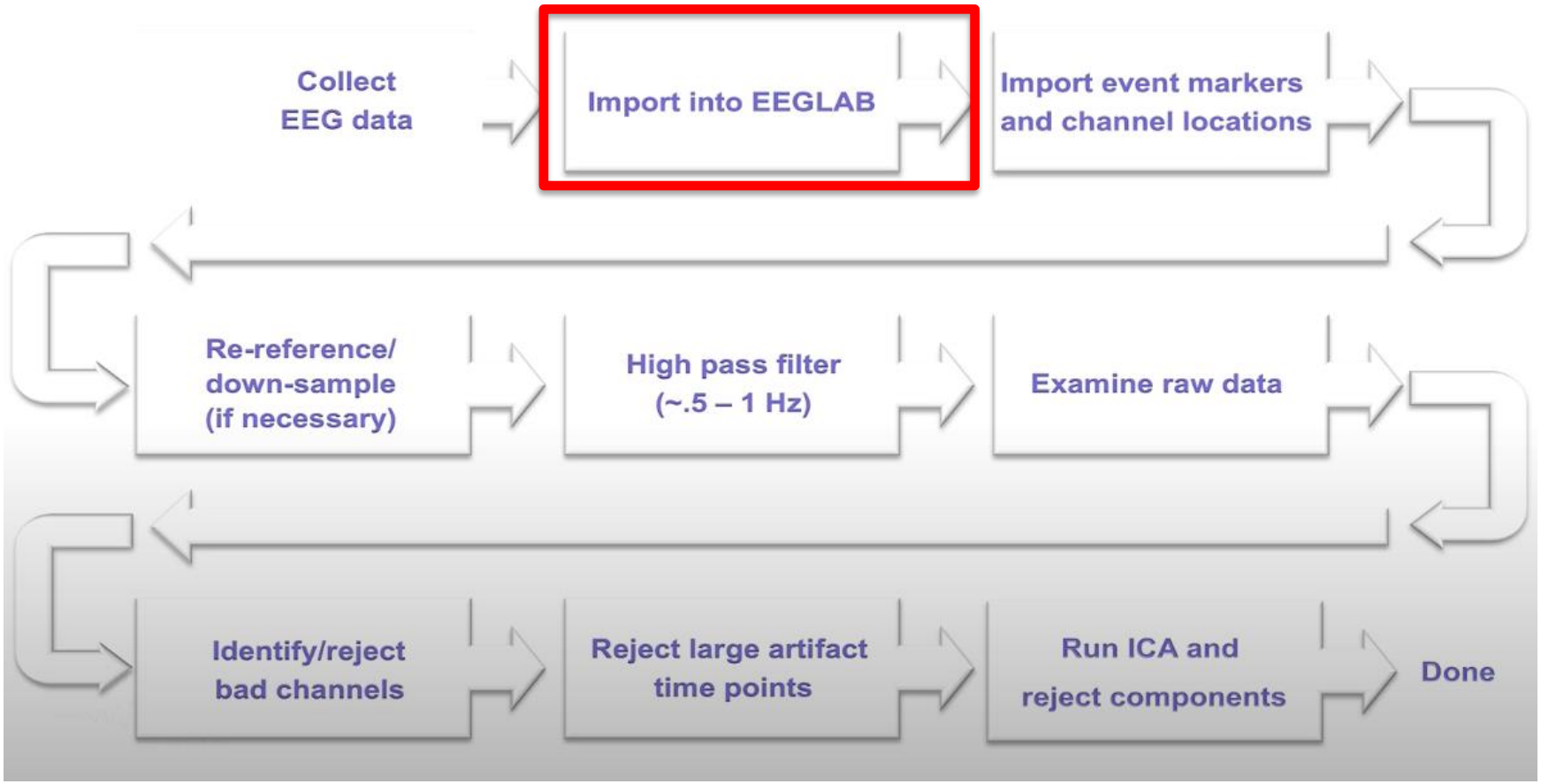
ERPLAB

http://erpinfo.org/erplab

Overview

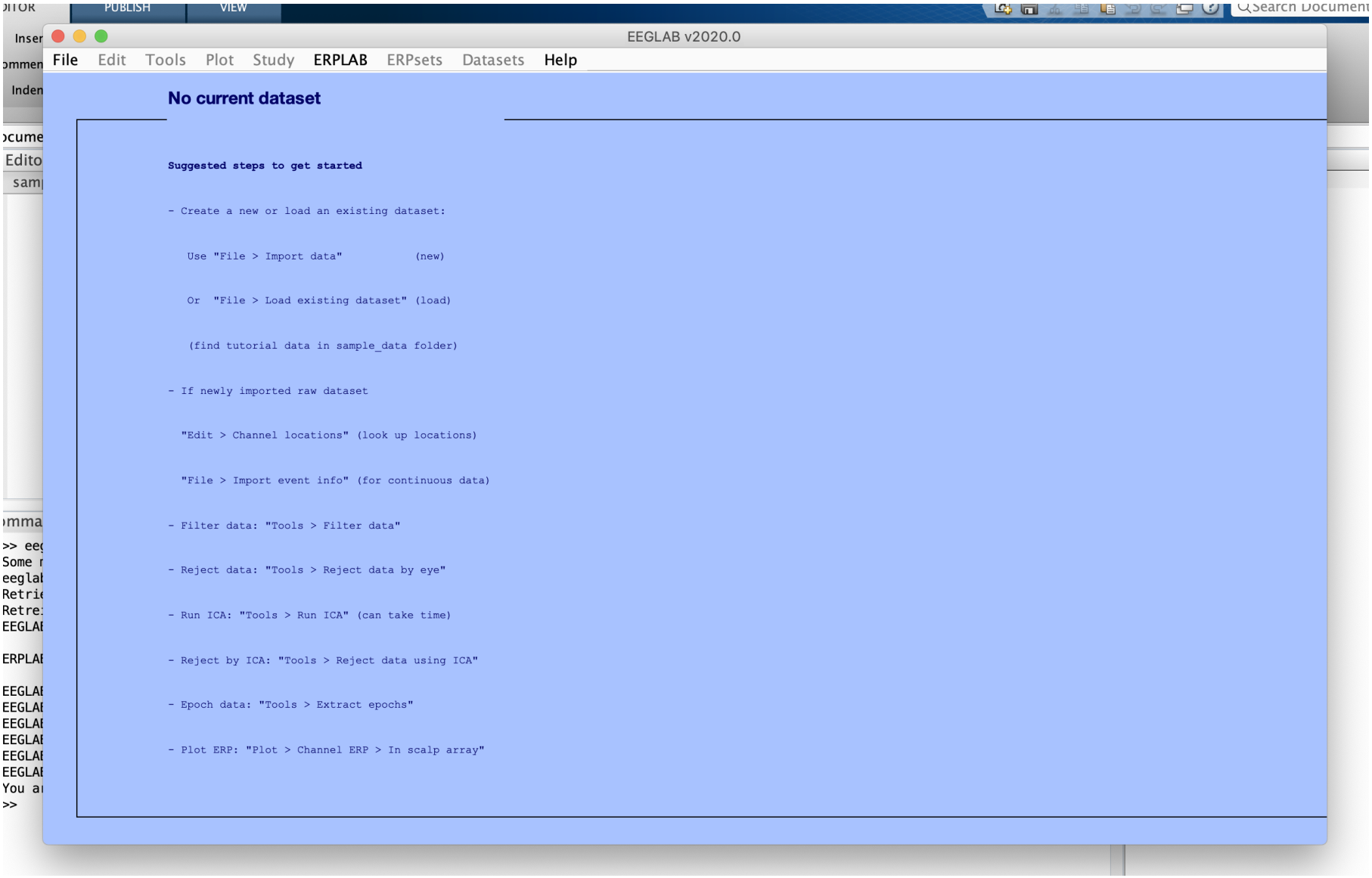
- 1. Basic preprocessing with EEGLAB
  - Read-in raw EEG file
  - Import event marker and channel locations
  - Re-reference
  - Filter
  - Reject artifact and bad channels
  - ICA
- 2. Advanced options with ERPLAB

EEG pre-processing steps

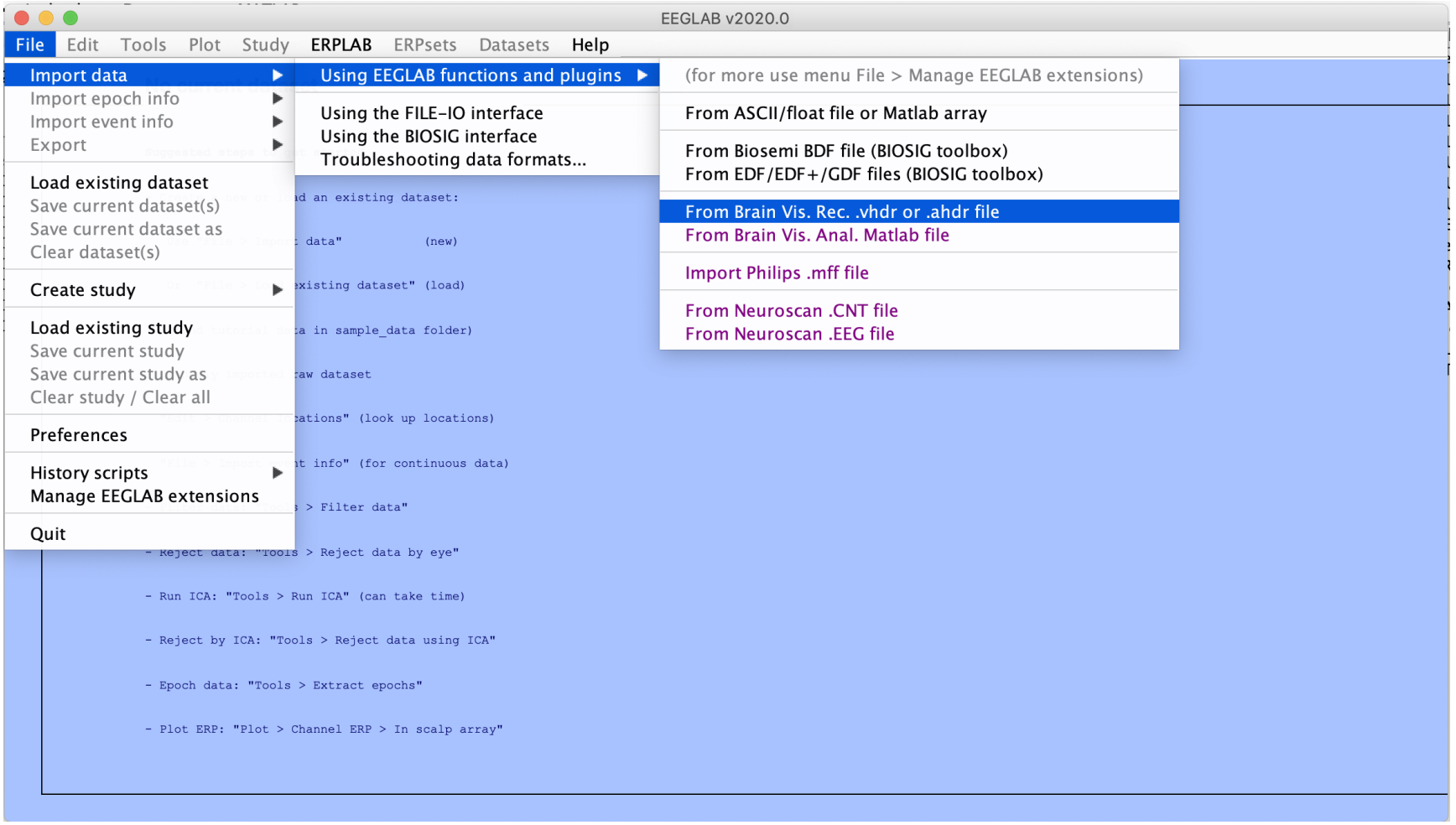


https://www.youtube.com/watch?v=gEk33jWB0MY&list=PLXc9qfVbMMN1ZS3sU2xT2hhfB5PAmuNae

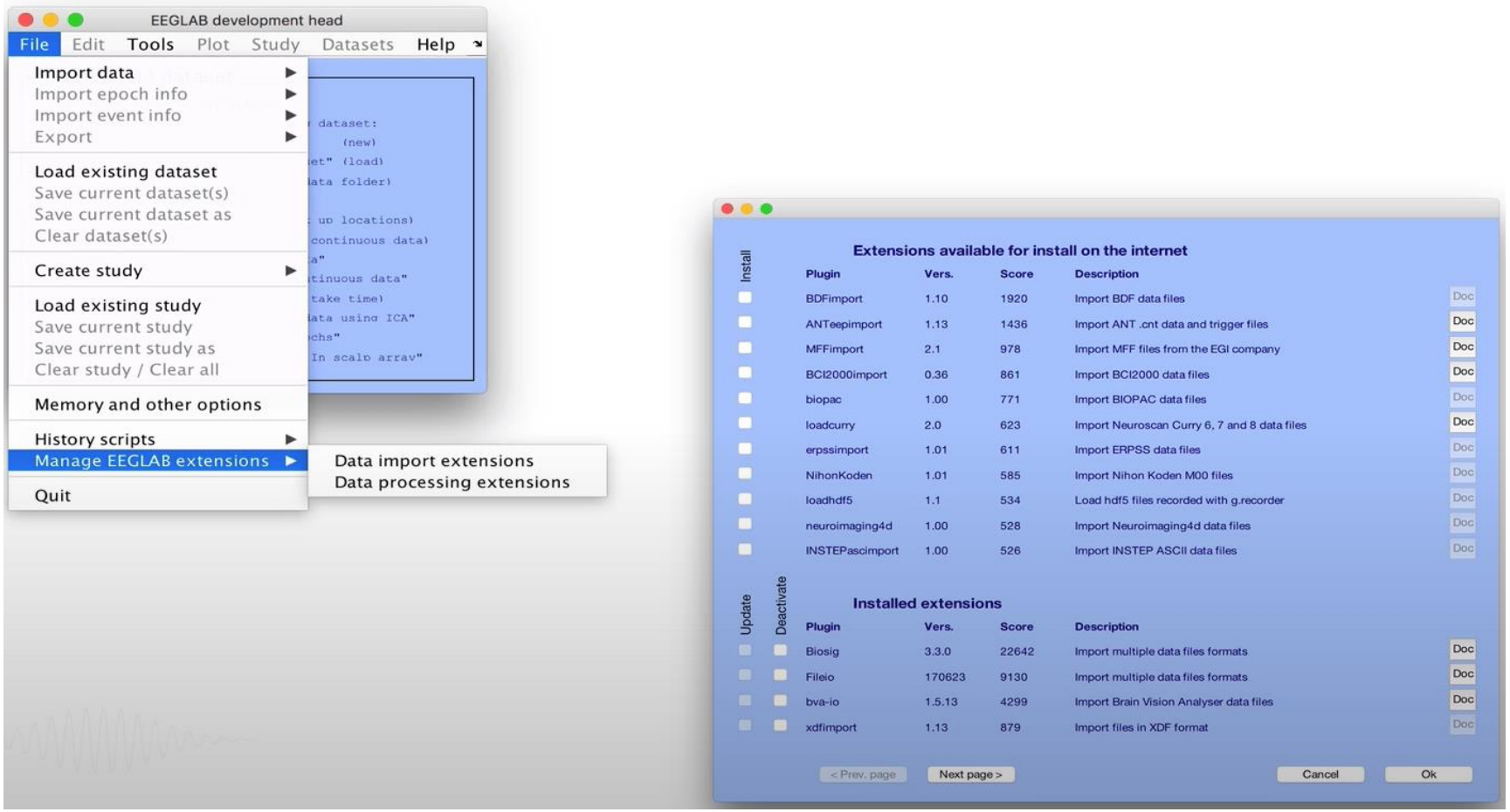
Starting EEGLAB



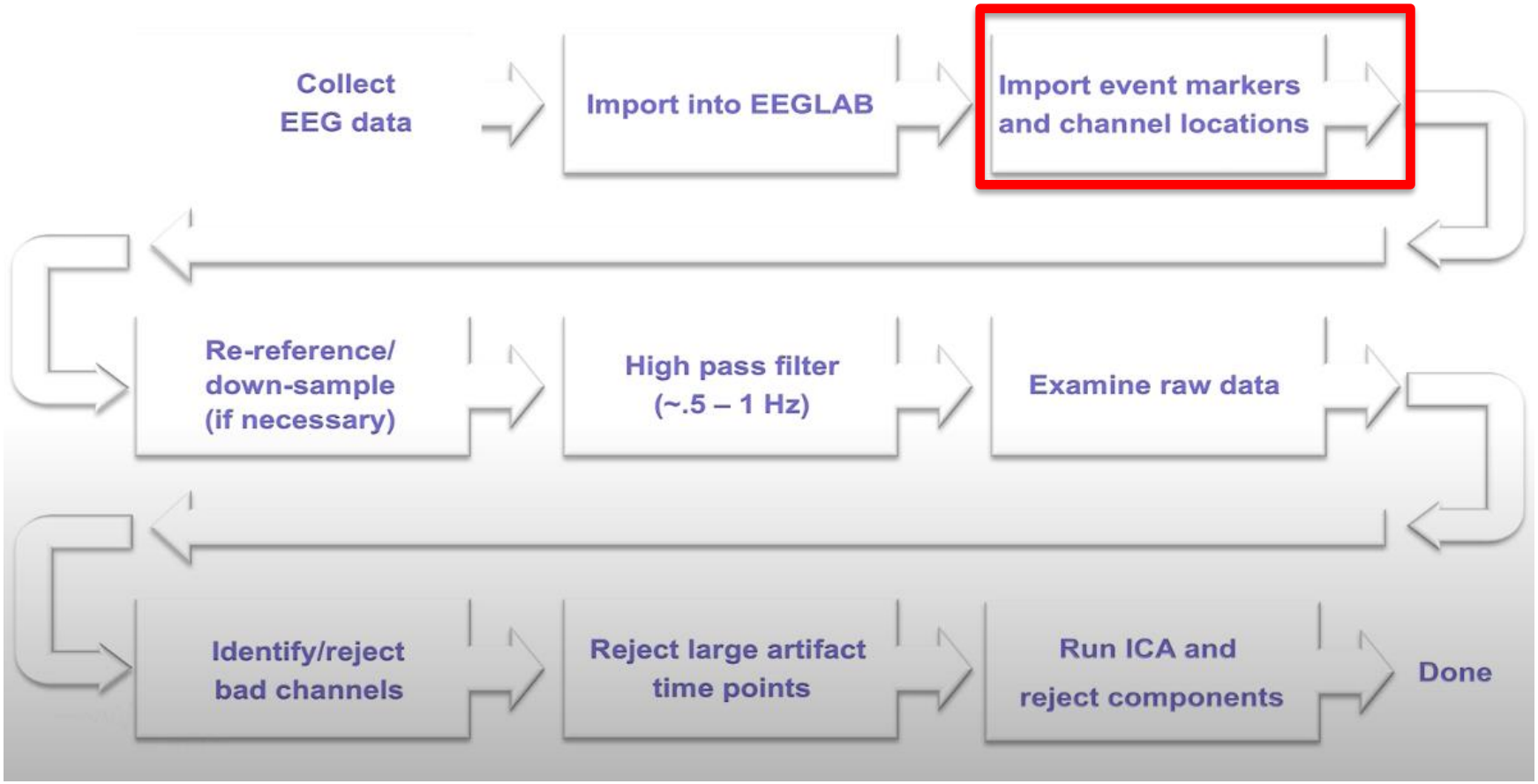
Loading-in raw EEG data



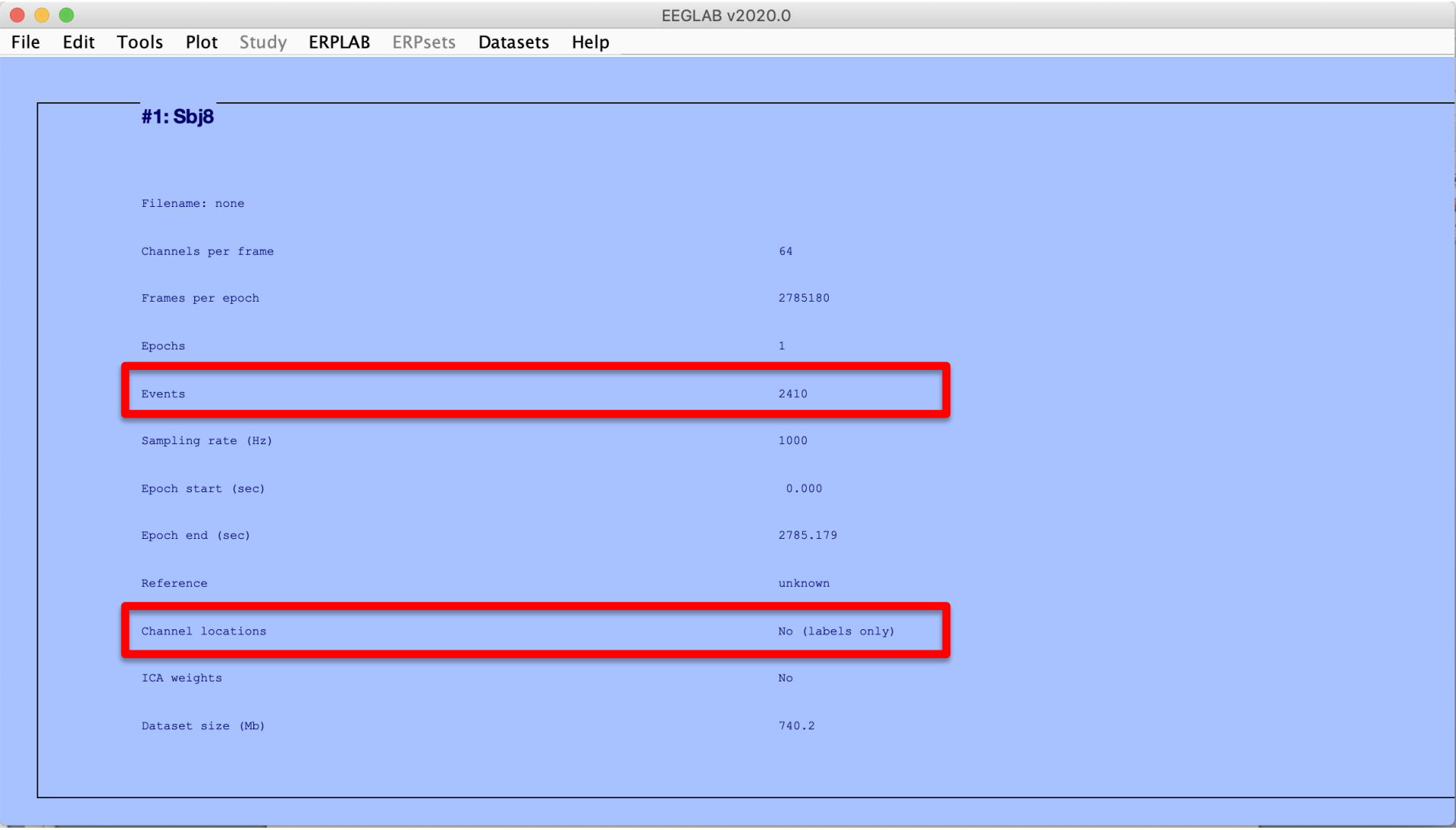
Loading-in raw EEG data



Loading-in raw EEG data



Import events and channel locations



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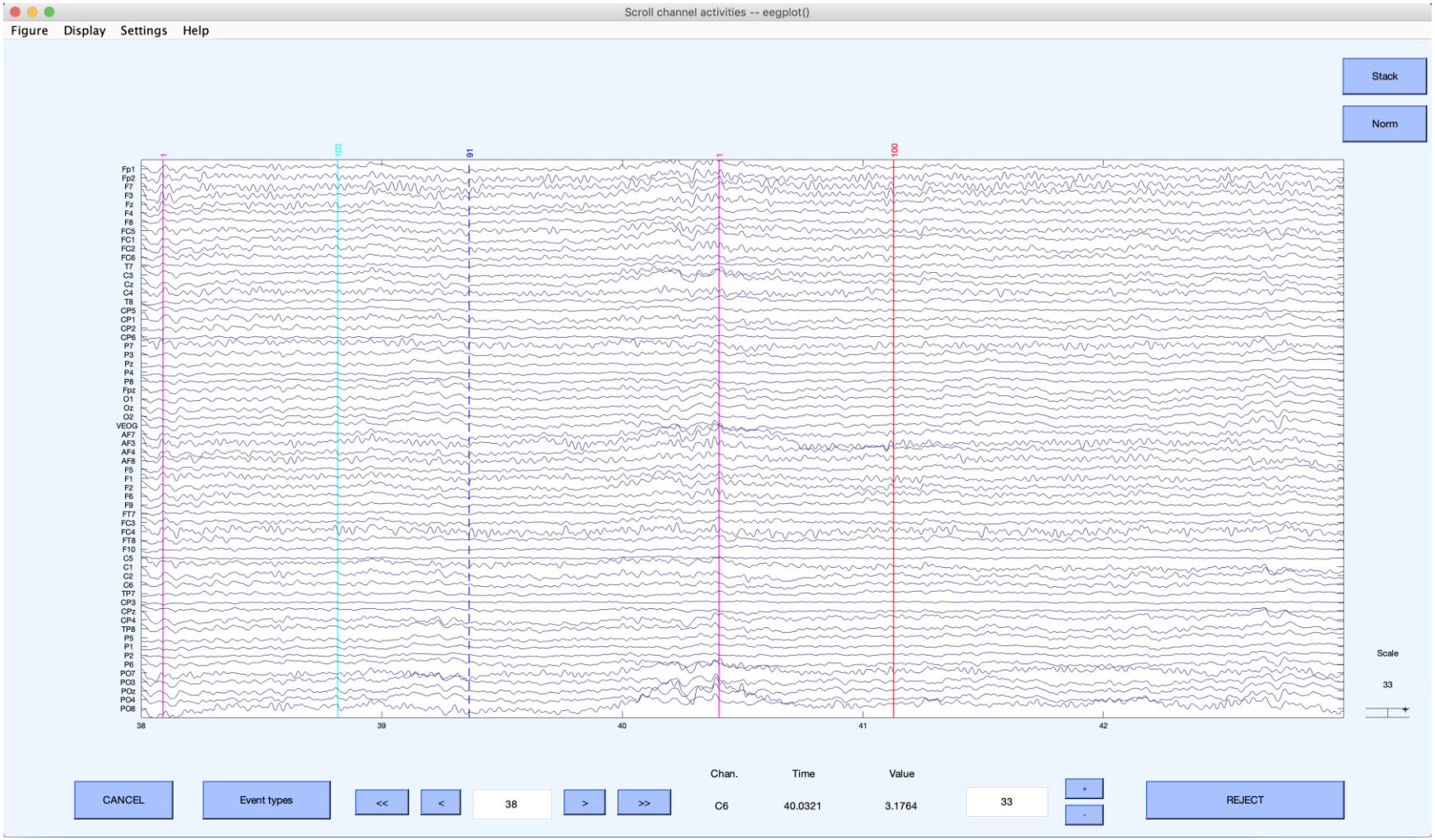

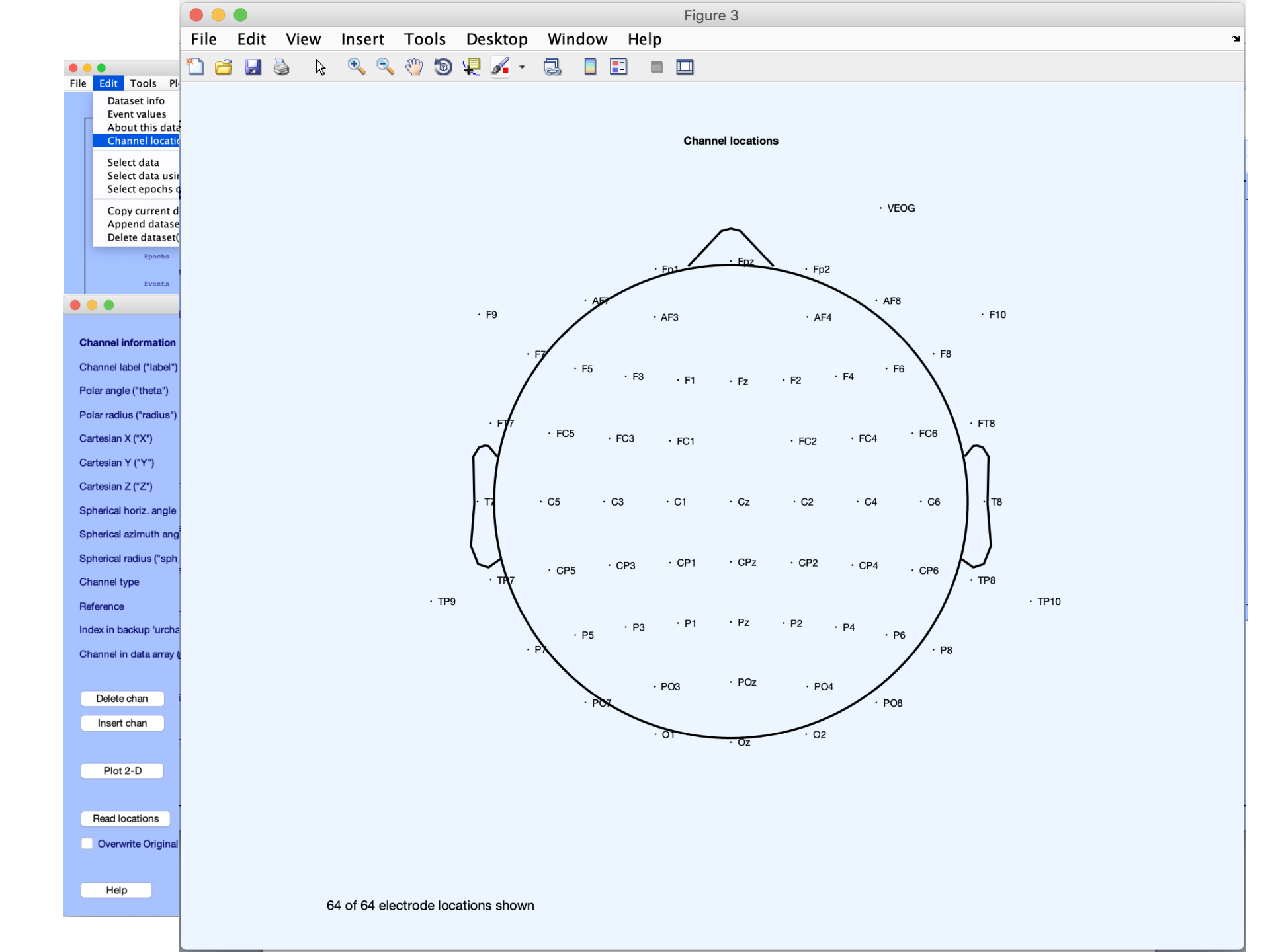
Figure 3
File Edit View Insert Tools Desktop Window Help
Channel locations
VEOG
Fp1
Fpz
Fp2
AF7
AF8
F9
AF3
AF4
F10
F7
F5
F3
F1
Fz
F2
F4
F6
F8
FT7
FC5
FC3
FC1
FC2
FC4
FC6
FT8
T7
C5
C3
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Pz
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P7
P8
PO3
POz
PO4
PO7
PO8
O1
Oz
O2
64 of 64 electrode locations shown
File Edit Tools
Dataset info
Event values
About this data
Channel locati
Select data
Select data usi
Select epochs
Copy current d
Append datase
Delete dataset(
Epochs
Events
Channel information
Channel label ("label")
Polar angle ("theta")
Polar radius ("radius")
Cartesian X ("X")
Cartesian Y ("Y")
Cartesian Z ("Z")
Spherical horiz. angle
Spherical azimuth ang
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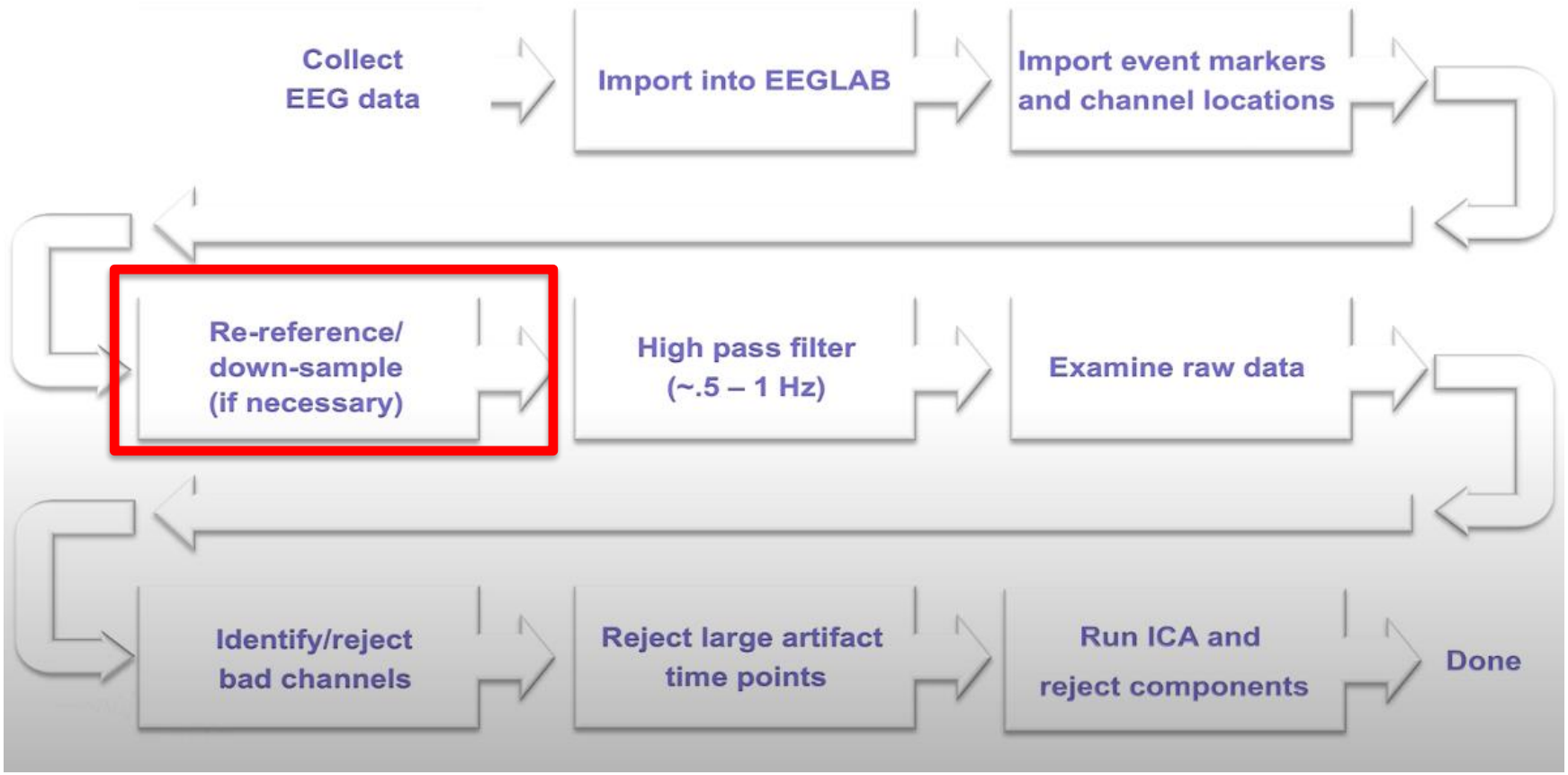
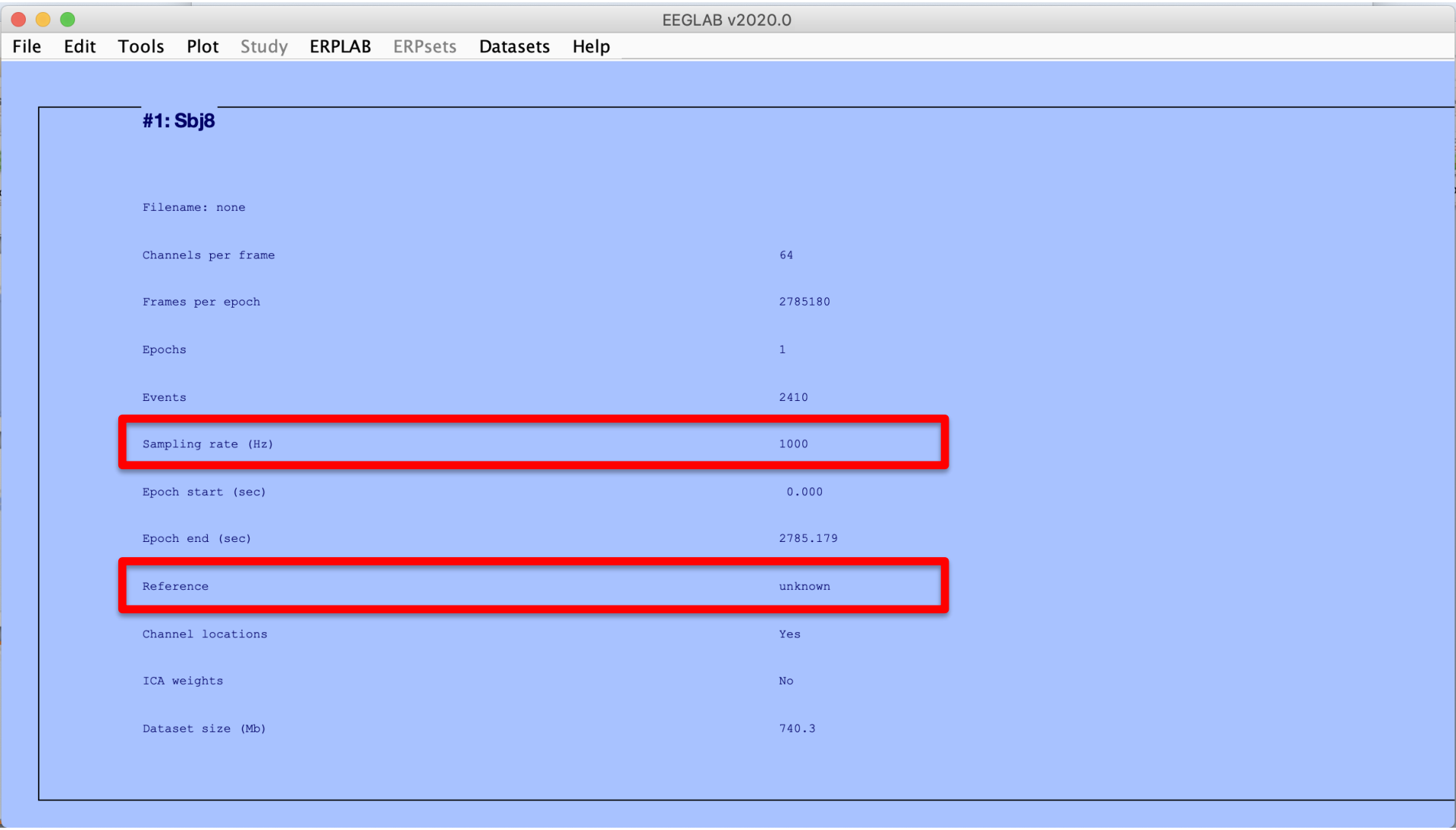
Channel type
Reference
Index in backup 'urcha
Channel in data array
Delete chan
Insert chan
Plot 2-D
Read locations
Overwrite Original
Help

Import events and channel locations

EEG pre-processing steps



Re-reference and down-sample



(Re-)Referencing

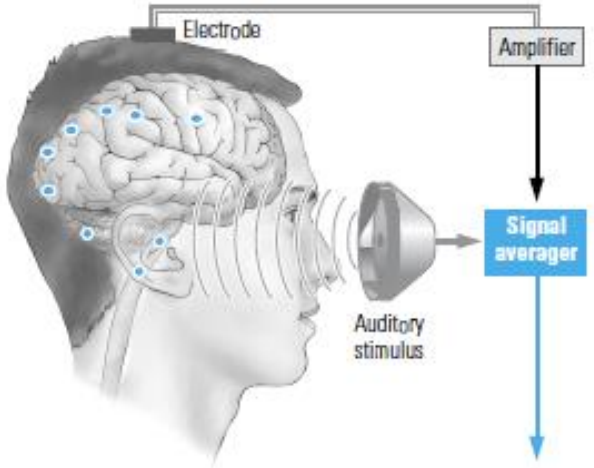
differential amplifier ...

- uses 3 electrodes: active (A), reference (R), ground (G)

- and amplifies then the difference between active and reference site (AG minus RG)

- ambient electrical activity will be the same for AG and RG and will therefore be eliminated by the subtraction

- there is no „voltage“ at a single electrode site

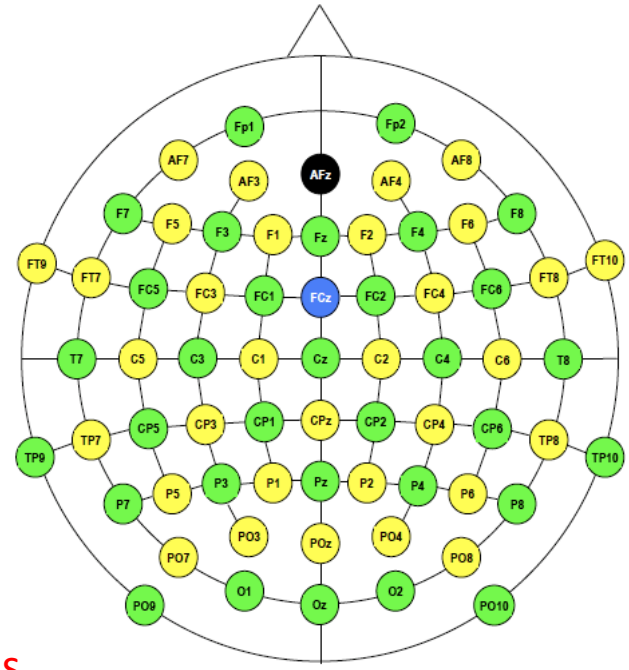


„One of the most important principles is that an ERP waveform reflects the difference in activity between two sites, not the activity at a single site!“

Choosing a Reference Site

online reference should be ...

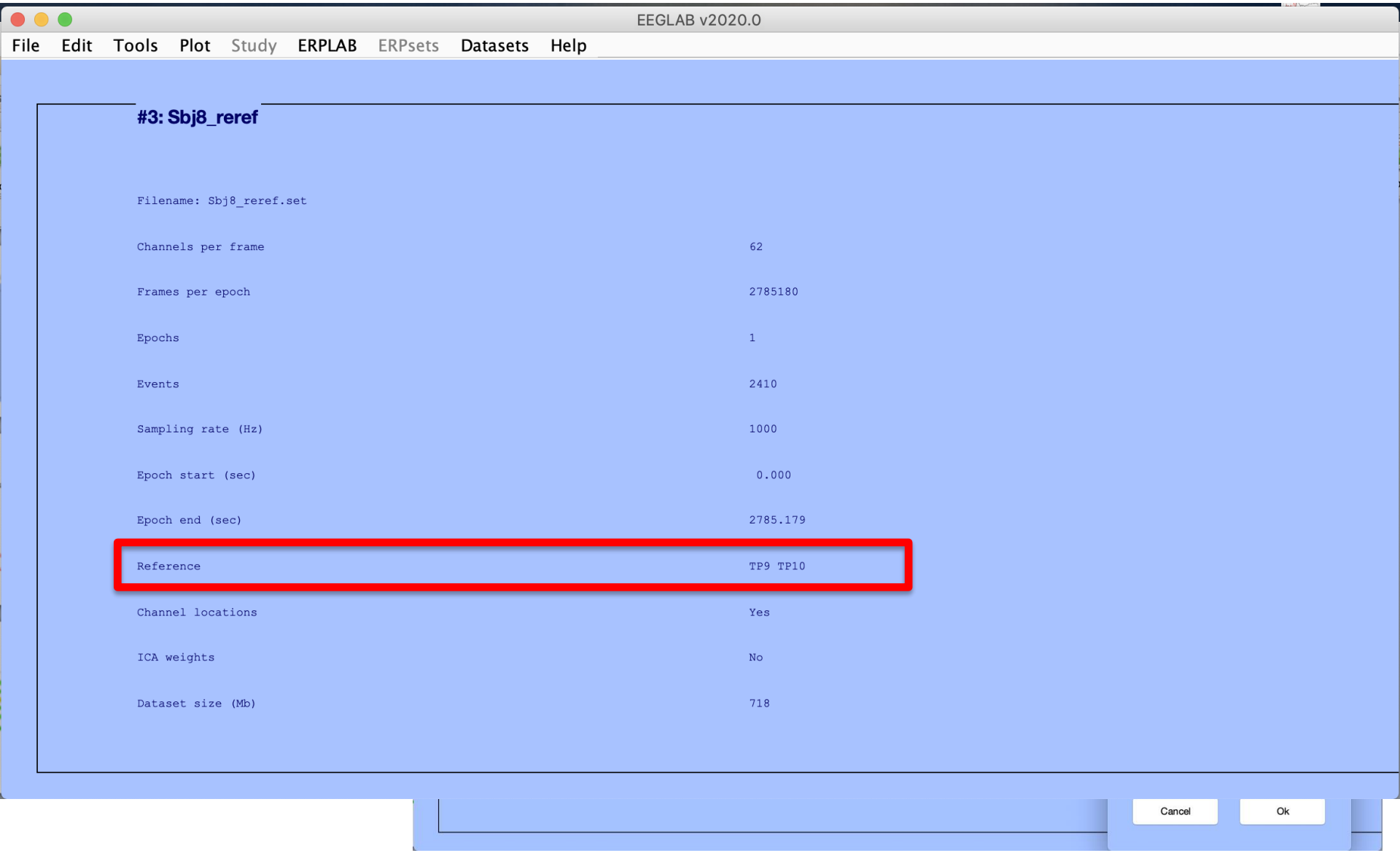
- as neutral as possible
- convenient and comfortable
- not be biased to one hemisphere



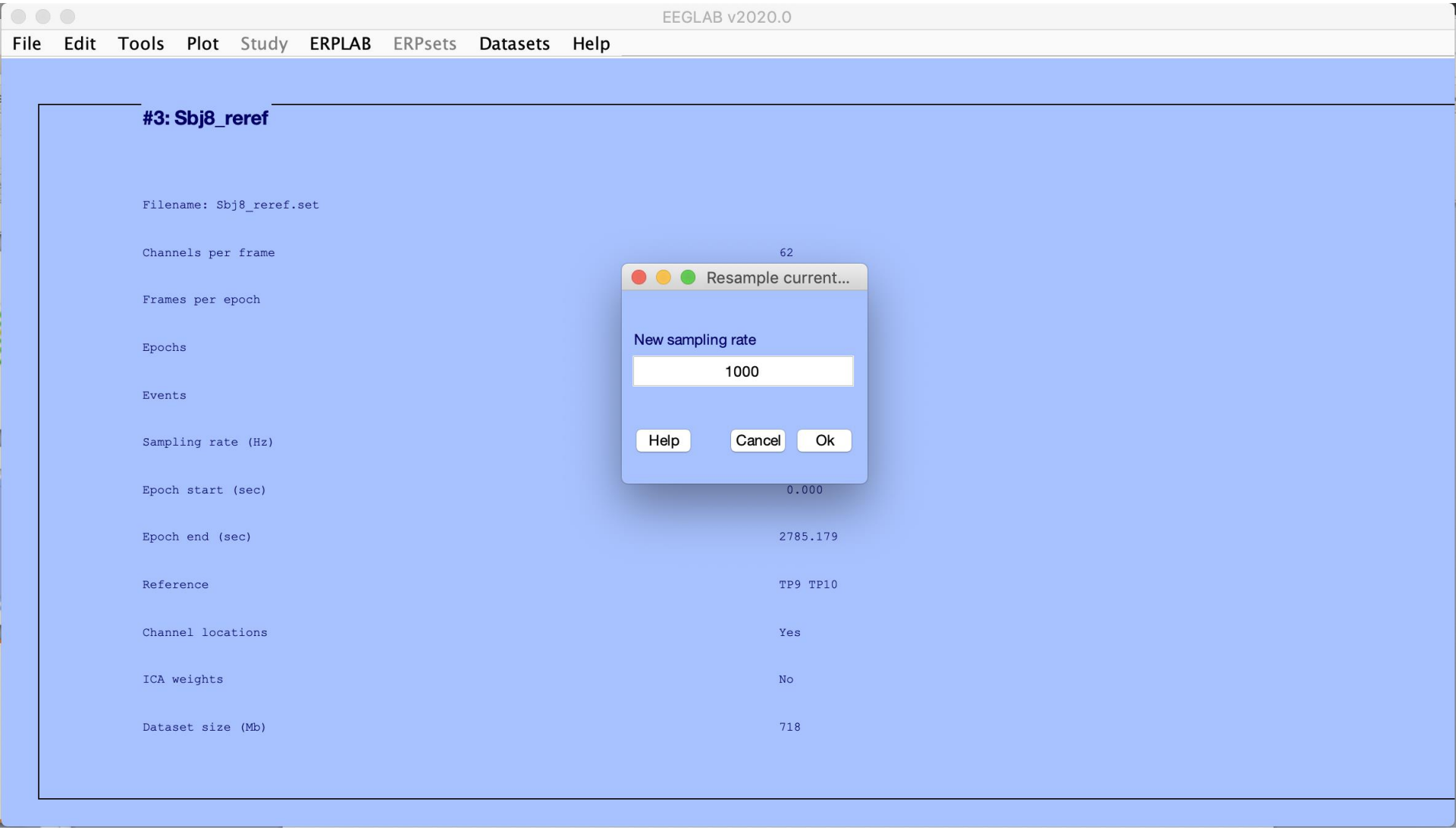
Most common reference: earlobes & averaged mastoids

Be careful with common average reference! Might reverse polarity!

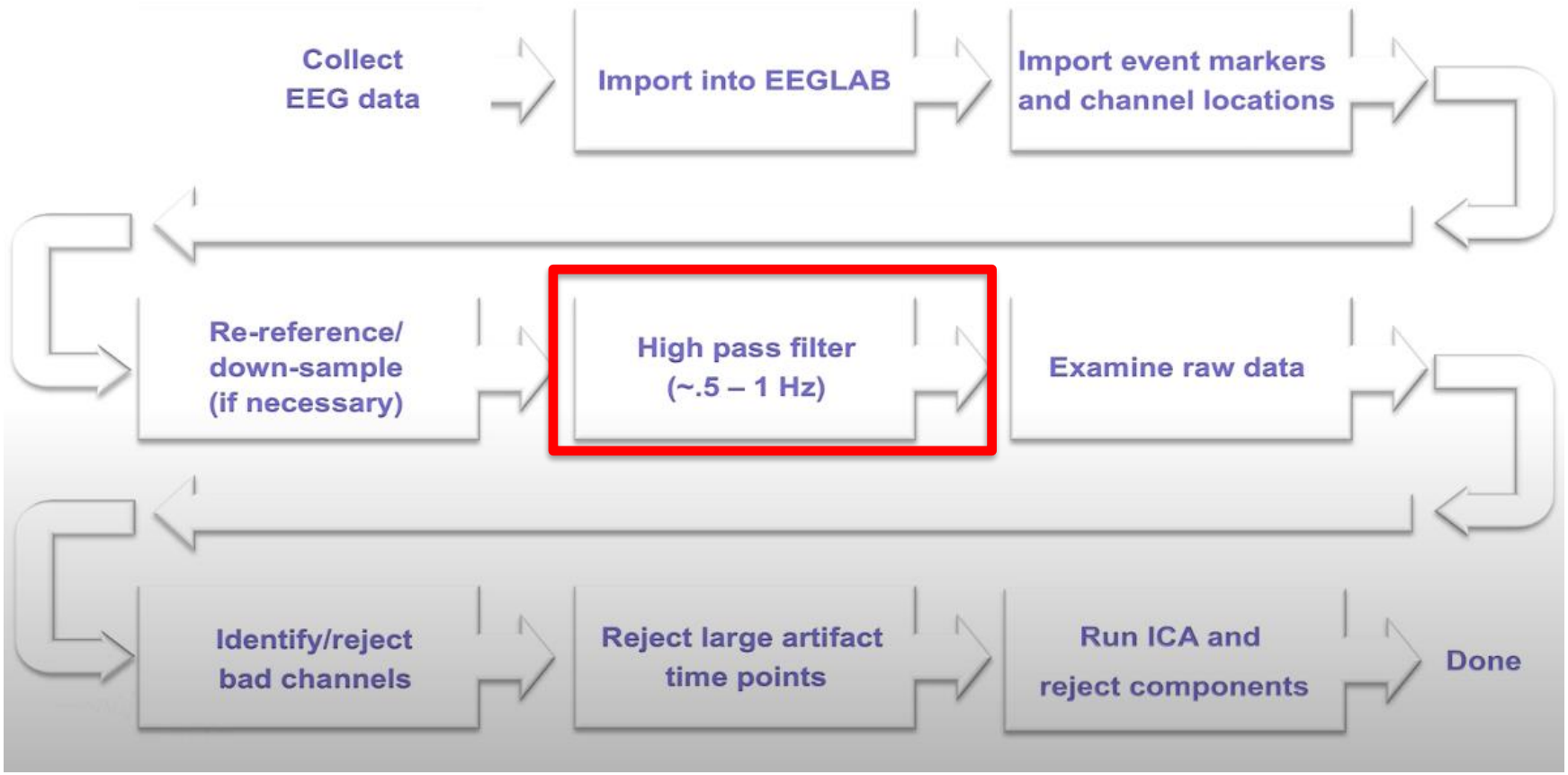
(Re-)Referencing



Change sampling rates



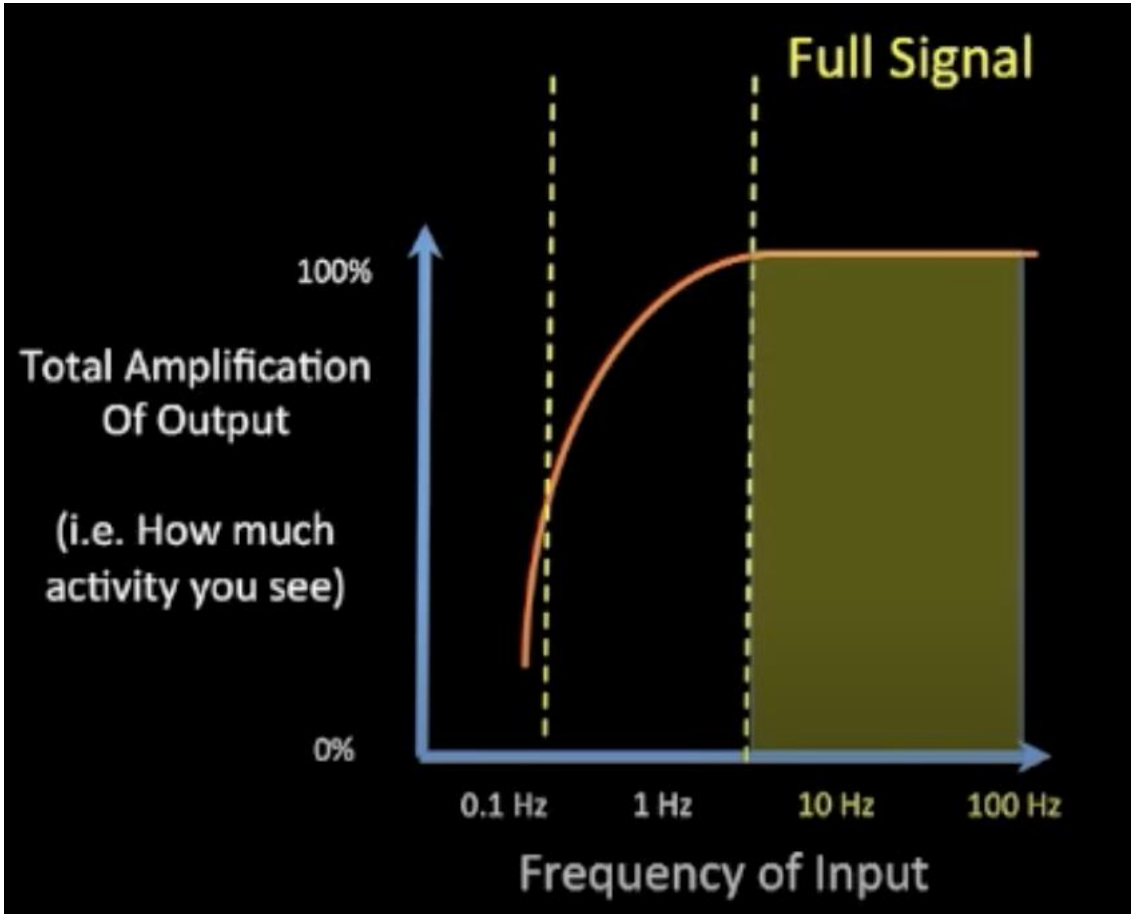
EEG pre-processing steps



- **4 Most Common Types of Filters:**

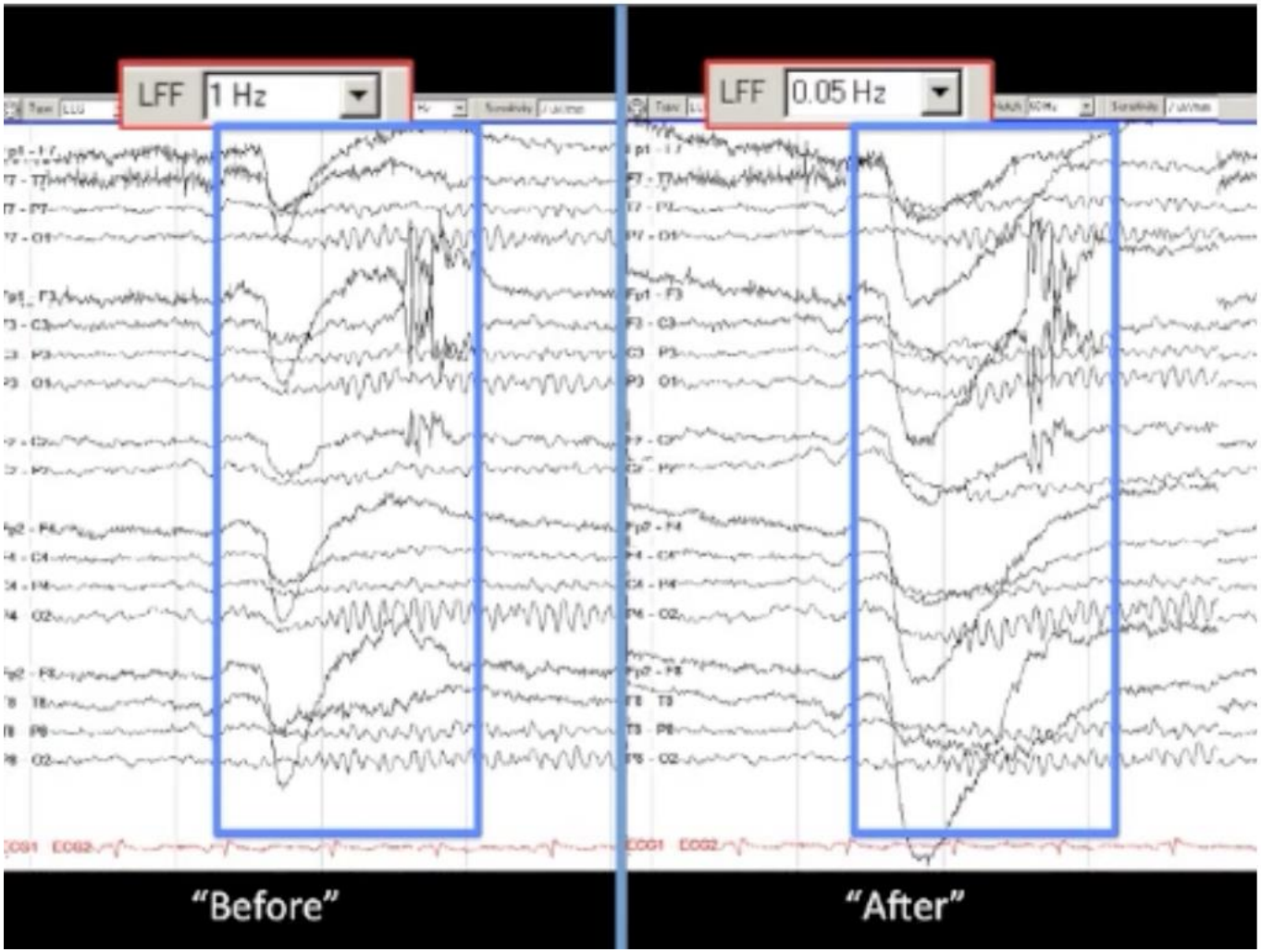
- *High-pass filter (or low-cutoff)*
- ‣ higher frequencies can pass; Filter determines lower cutoff frequency

High-pass filter (or low-cutoff)



Jeremy Moeller; https://www.youtube.com/watch?v=KrJaJDMBo54

High-pass filter (or low-cutoff)



Jeremy Moeller; https://www.youtube.com/watch?v=KrJaJDMBo54

- **4 Most Common Types of Filters:**

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- *Low-pass filter (or high-cutoff)*
- ‣ lower frequencies can pass; Filter determines upper cutoff frequency

- *Bandpass filter*
- ‣ combination of both high- and low-pass filters

Low-pass filter (or high-cutoff)

Jeremy Moeller; https://www.youtube.com/watch?v=KrJaJDMBo54

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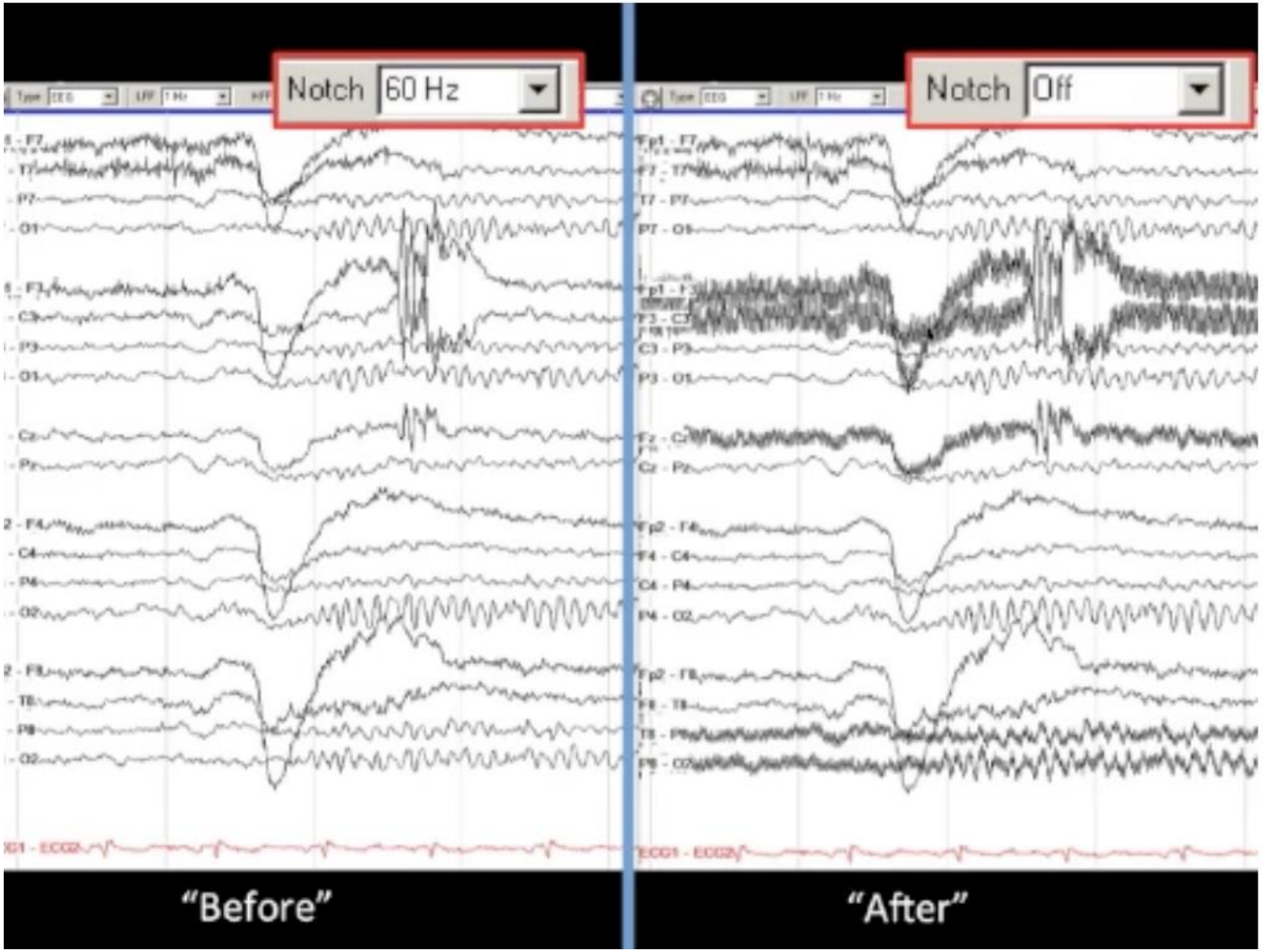
- *Bandpass filter*
- ‣ combination of both high- and low-pass filters

- *Notch filter*
- ‣ attenuates a narrow frequency-band while letting everything else pass

Notch filter

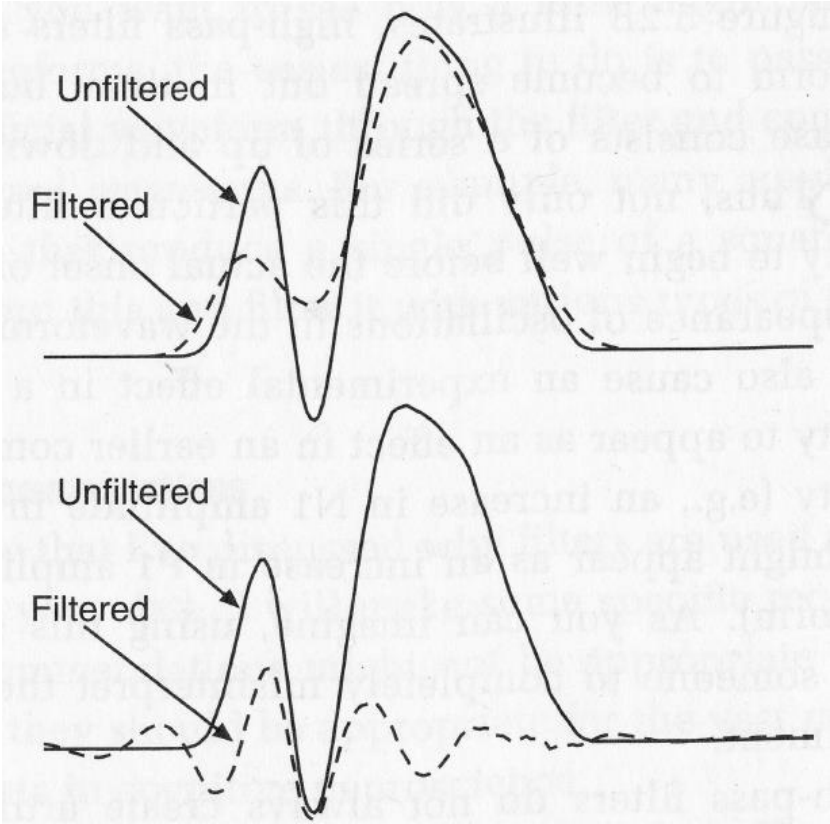


Jeremy Moeller; https://www.youtube.com/watch?v=KrJaJDMBo54

Keep in mind:

Filtering can severely distort ERPs!!!

- may change the onset and duration of an ERP component
- may make monophasic waveforms appear multiphasic
- may induce artificial oscillations



Why/When are filters necessary?

1 - if sampling rate is too low (Nyquest Theorem)

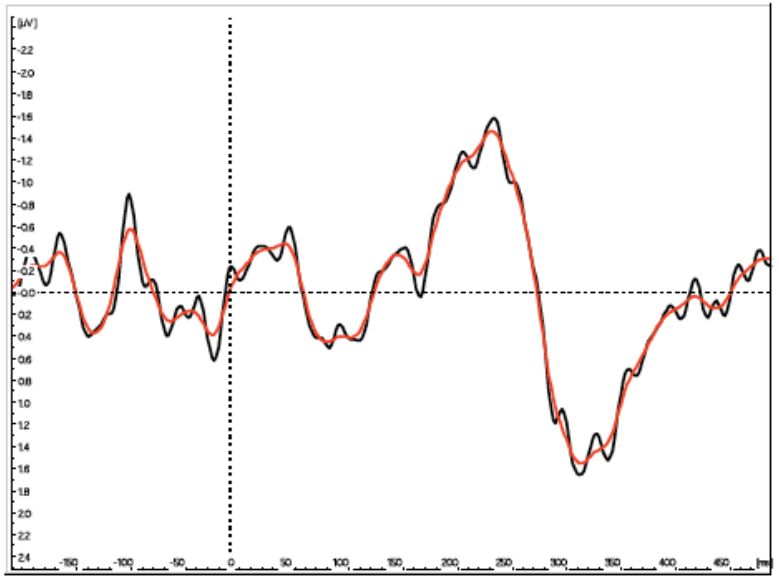
- aliasing, if original signal contains frequencies that are more than twice as high as the digitization rate

2 - to reduce noise

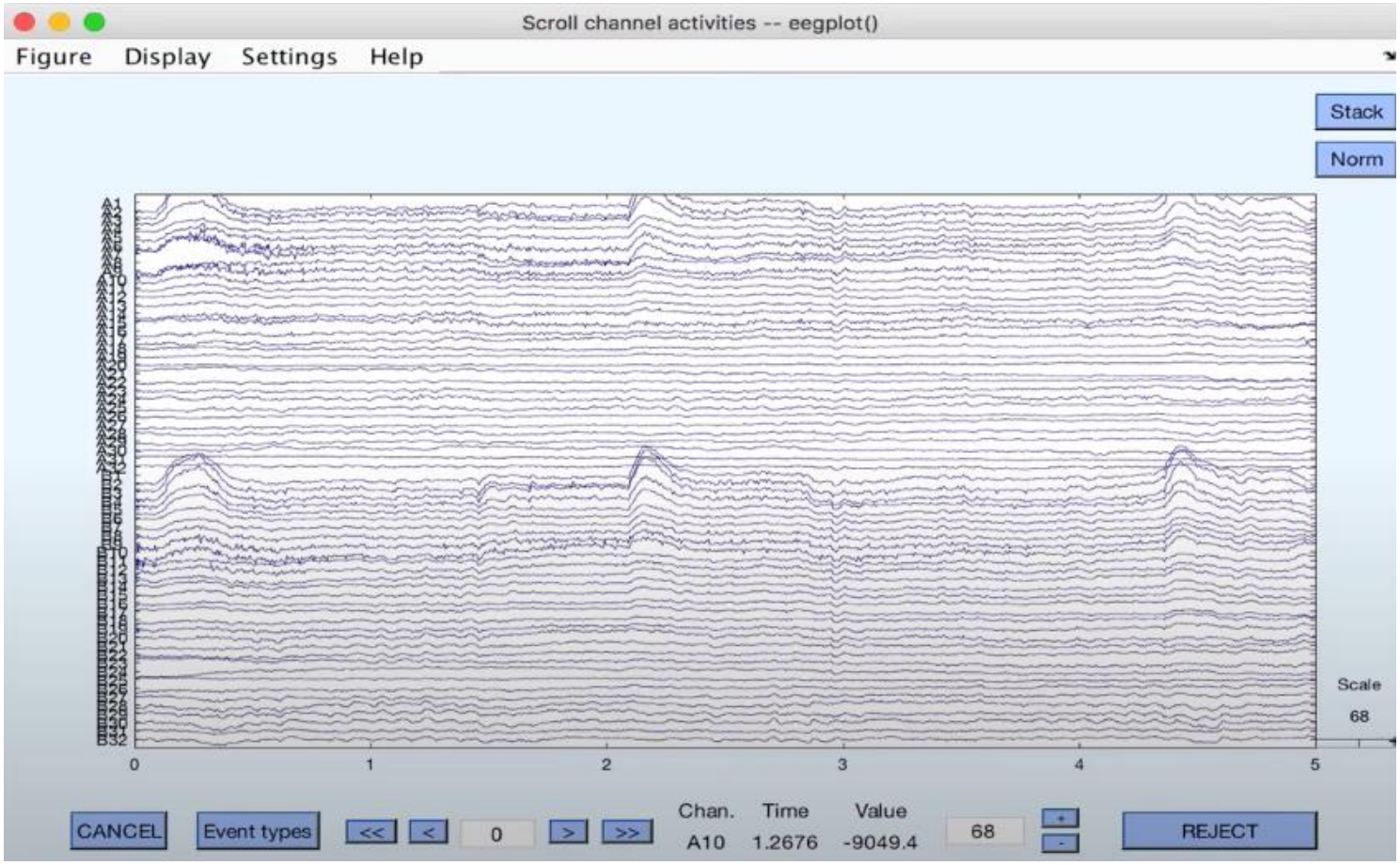
- muscle noise (EMG) >> 100 Hz low pass filter
- slow voltage drifts (sweating) >> 0.1 Hz high pass filter
- (line noise >> 50 Hz notch filter)

3 - to „smooth“ data for visualization

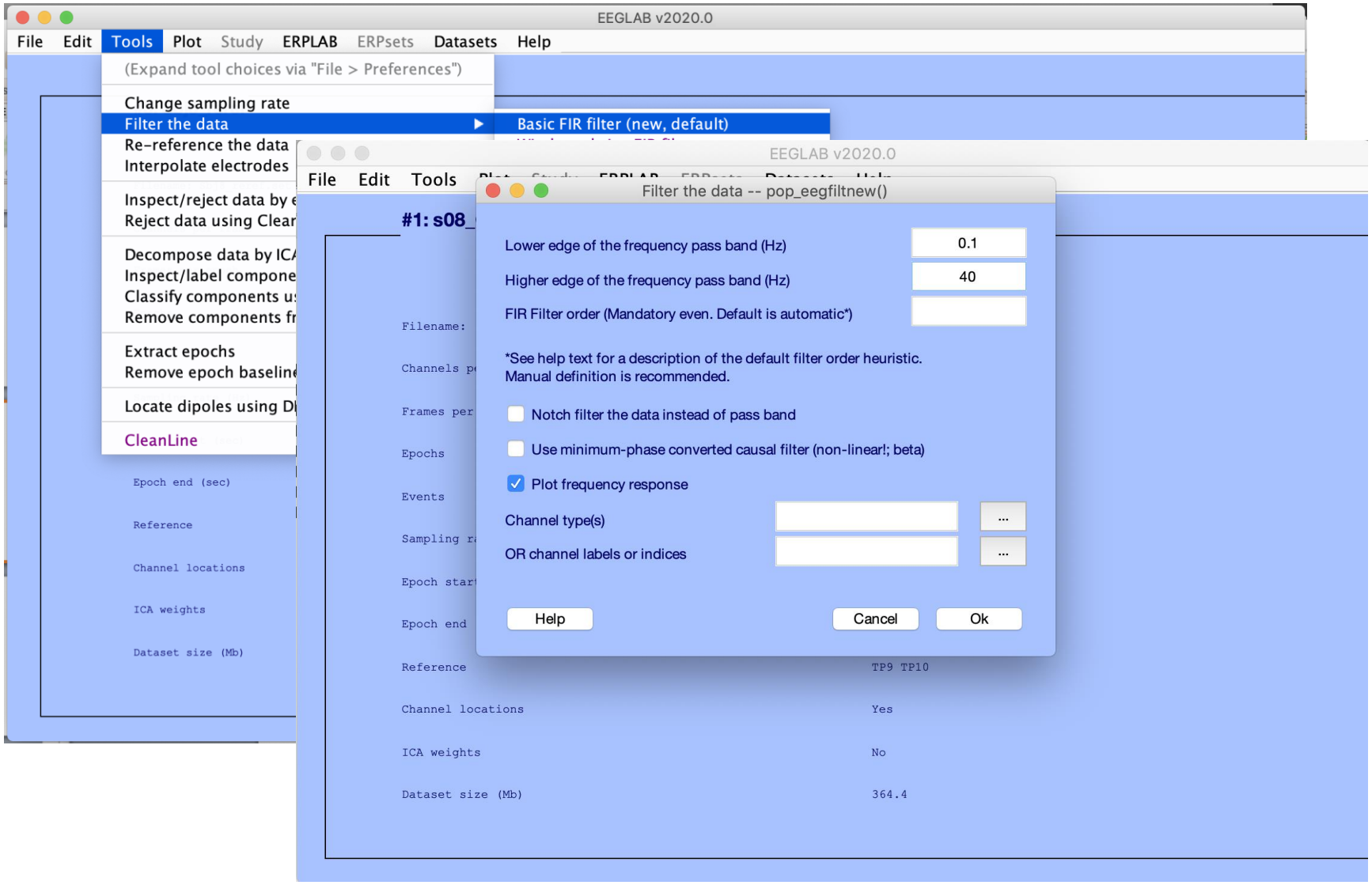
- ERP figures >> 20 Hz low pass filter



Filtering: remove DC offset

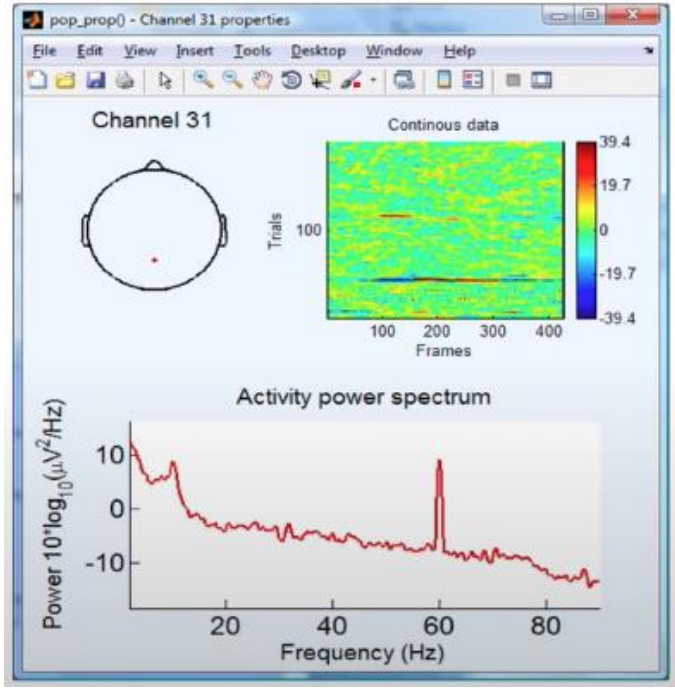


Filtering: remove slow, possibly large amplitude, drift

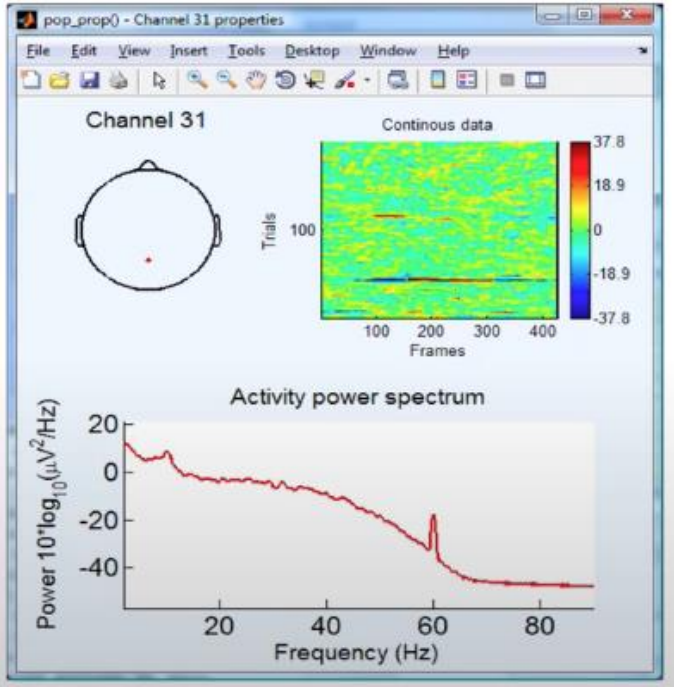


Filtering: remove slow, possibly large amplitude, drift

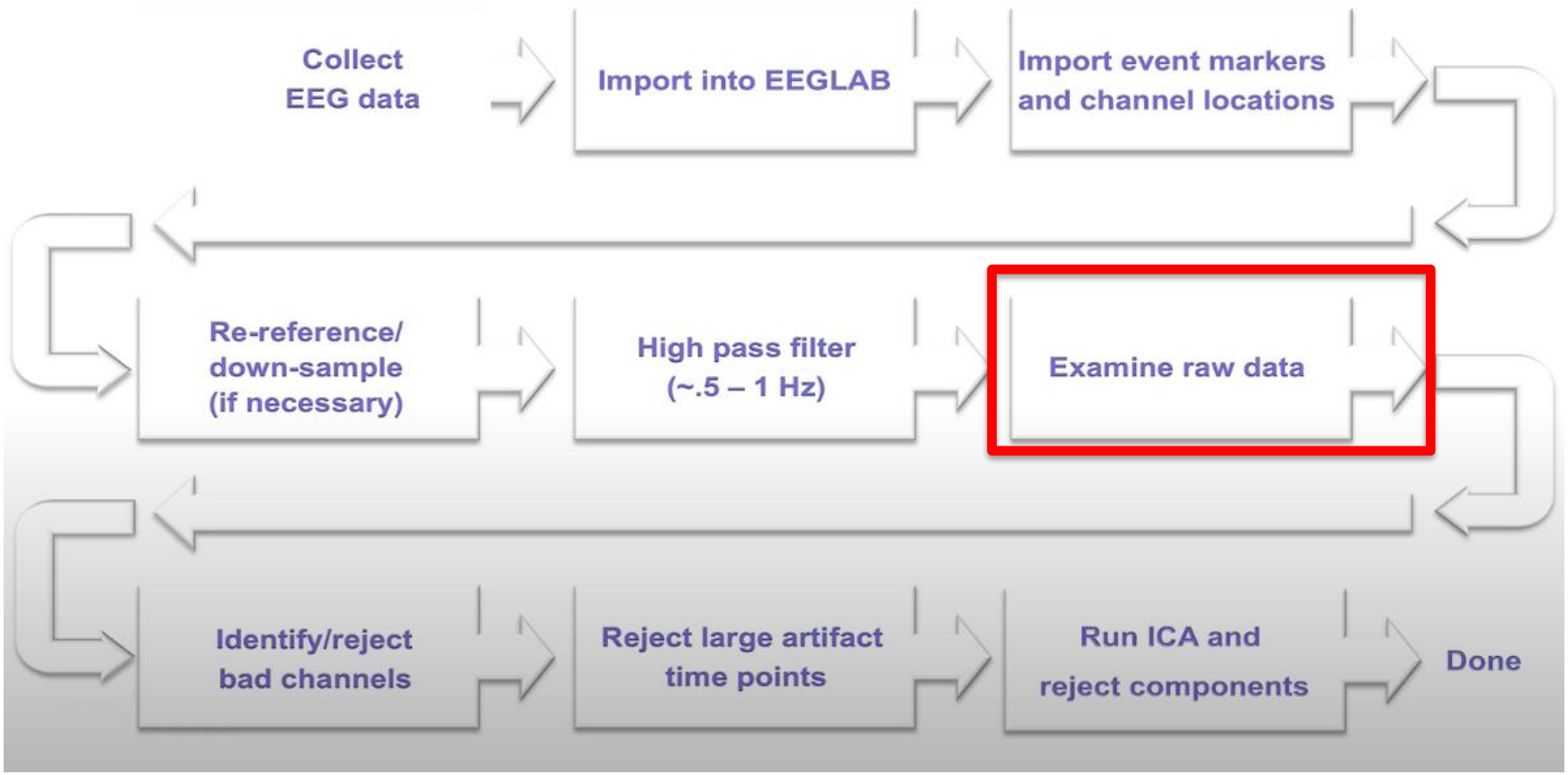
0.5 Hz high-pass filter



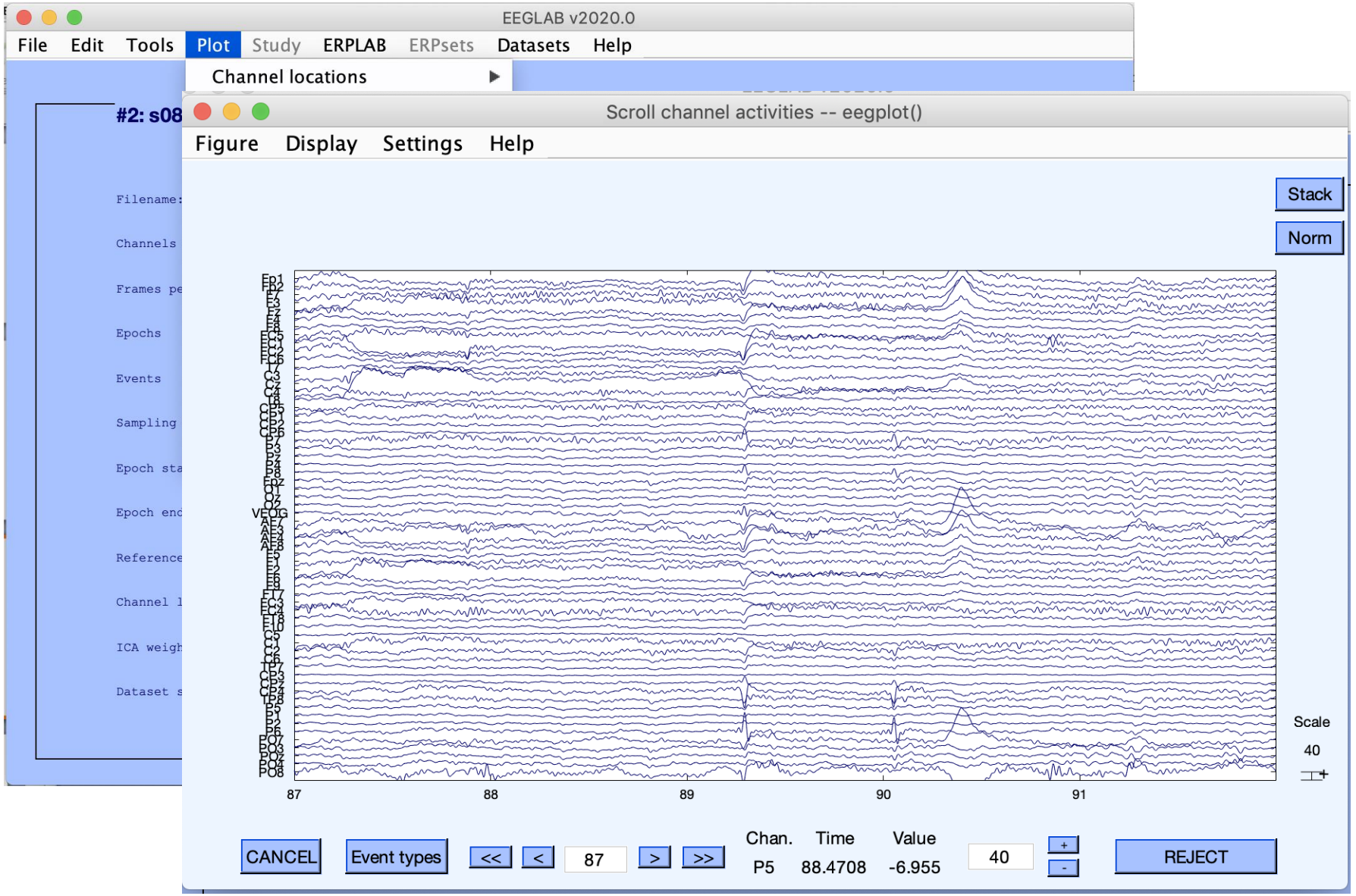
0.5 Hz high-pass filter
50 Hz low-pass filter



EEG pre-processing steps



Examine raw data



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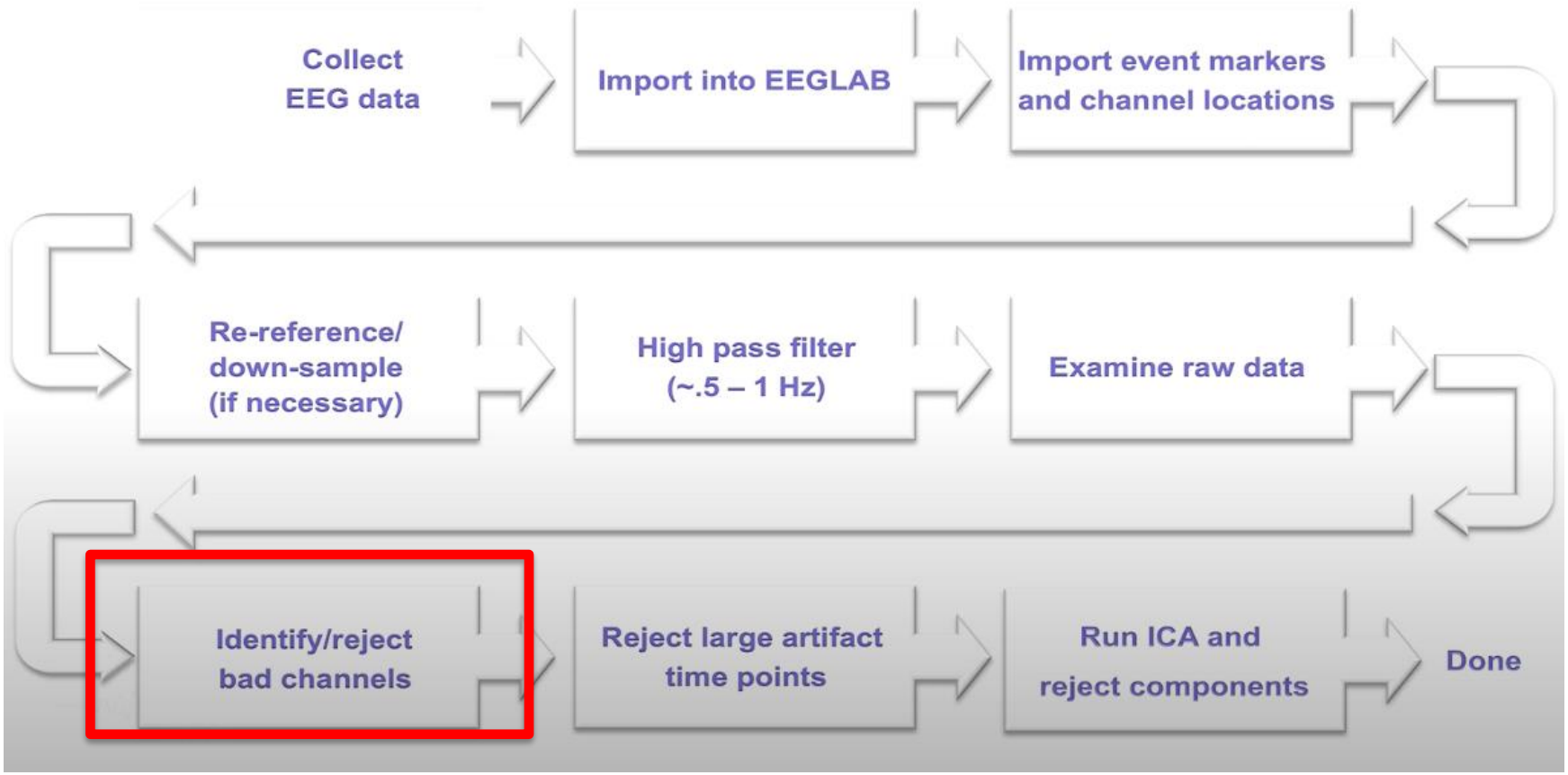
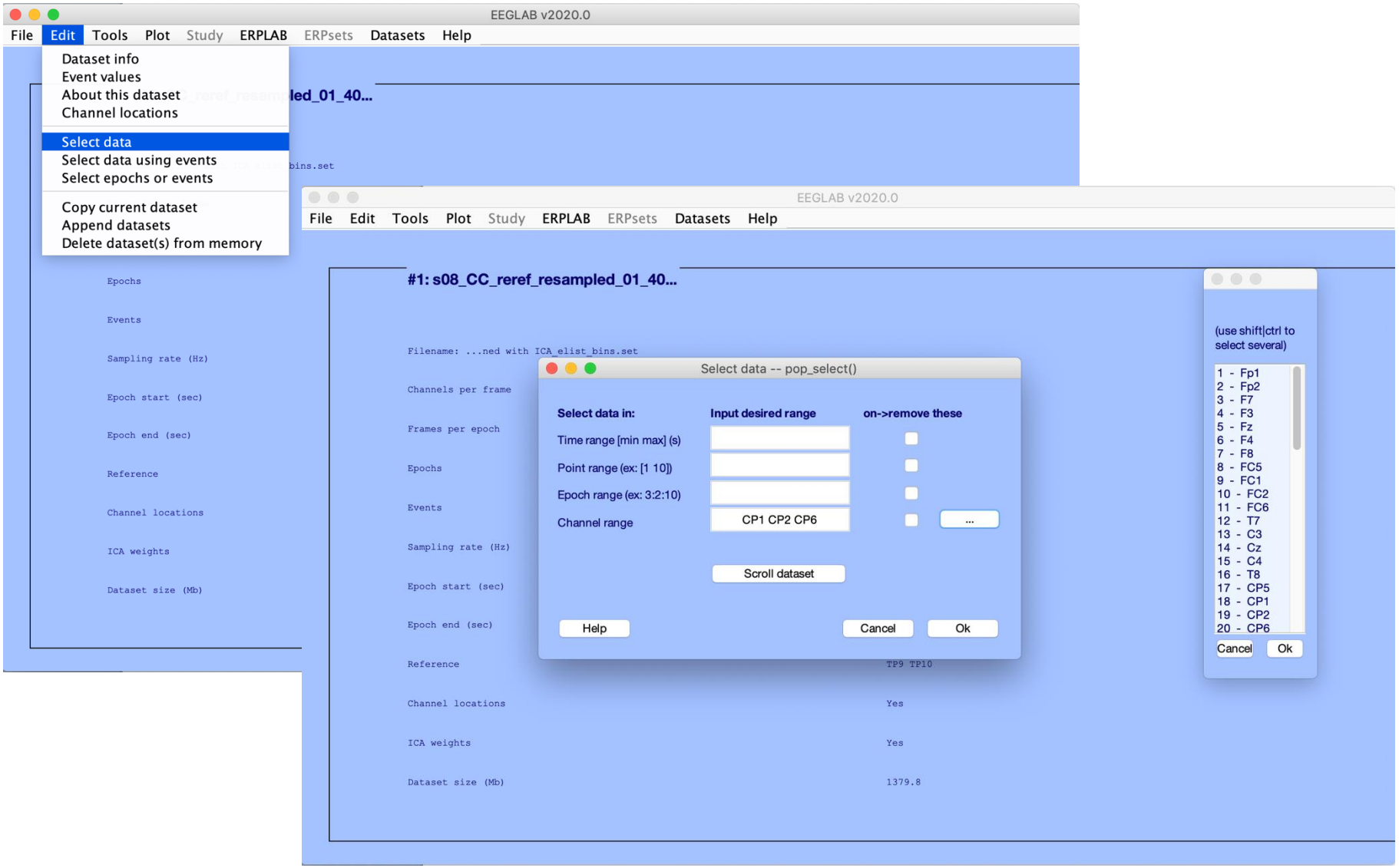


Identify/ reject bad channels



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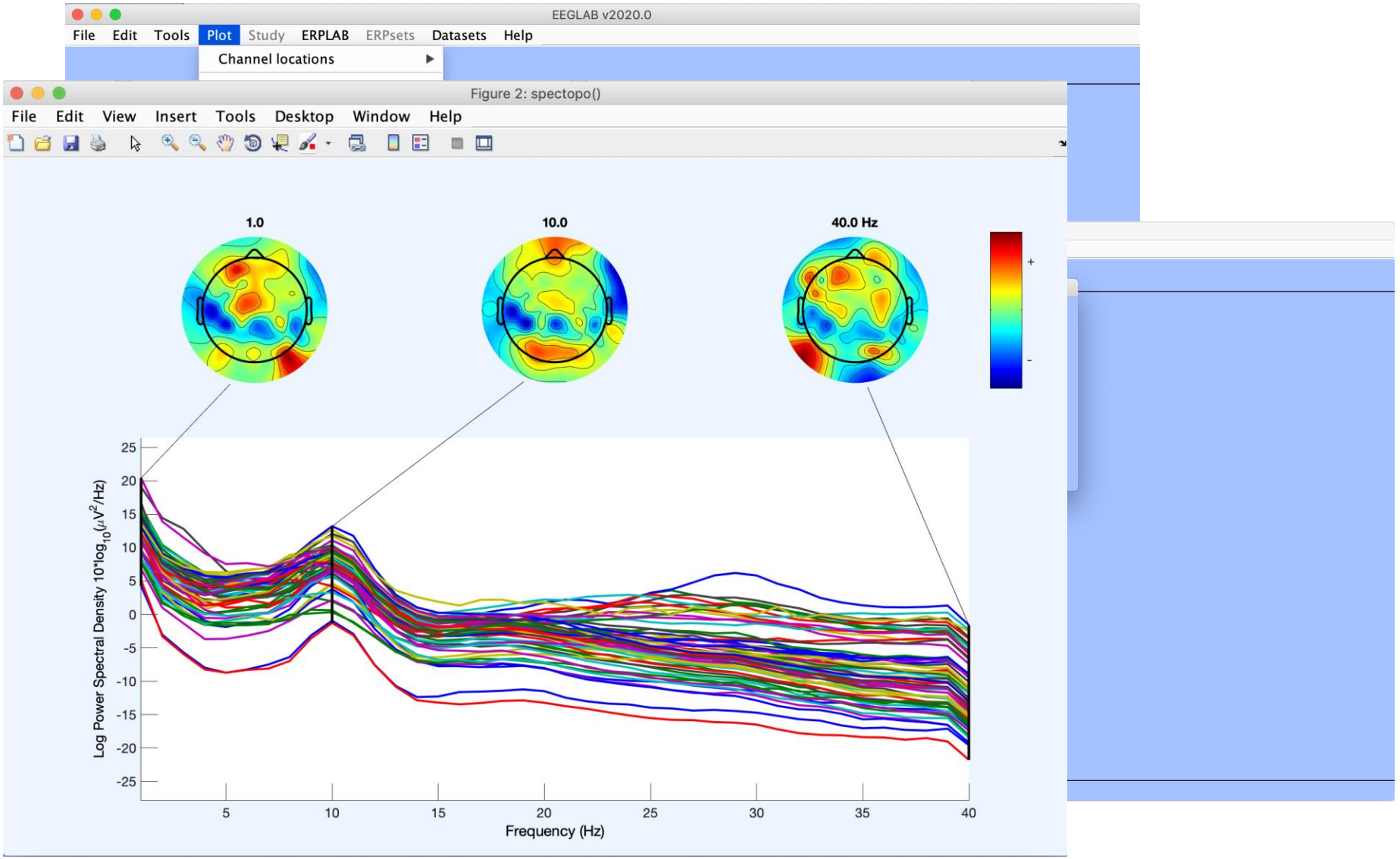

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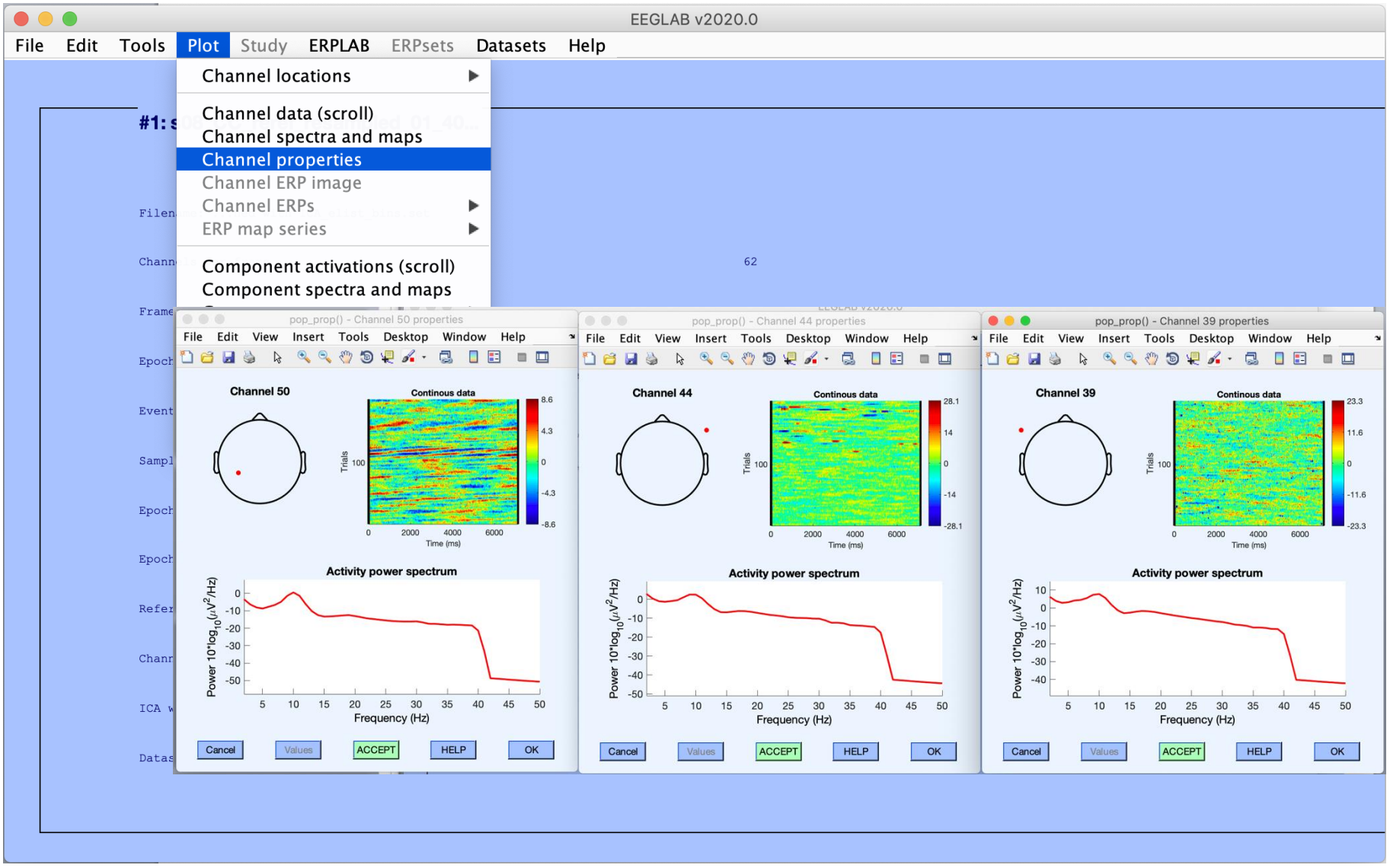

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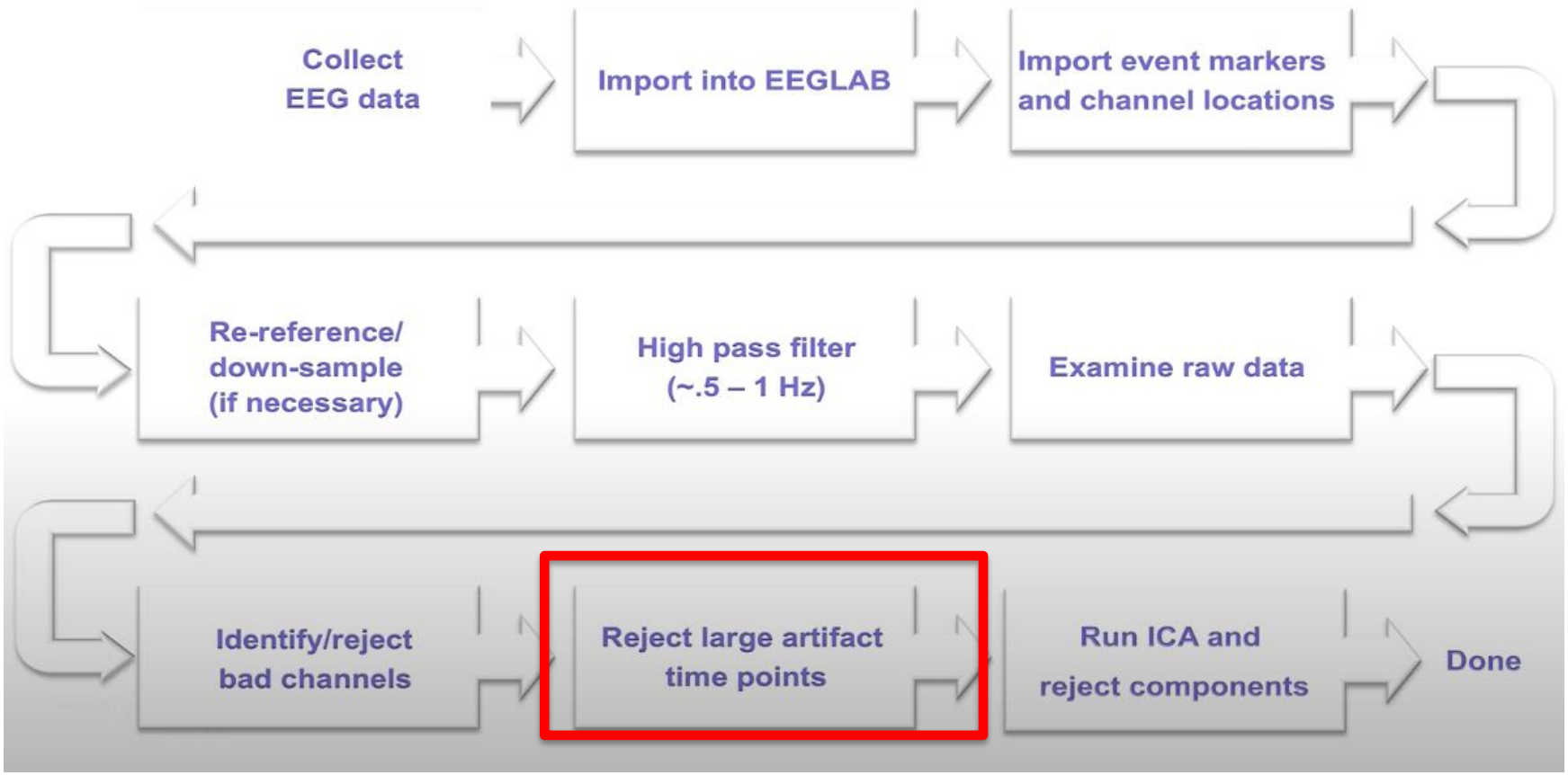
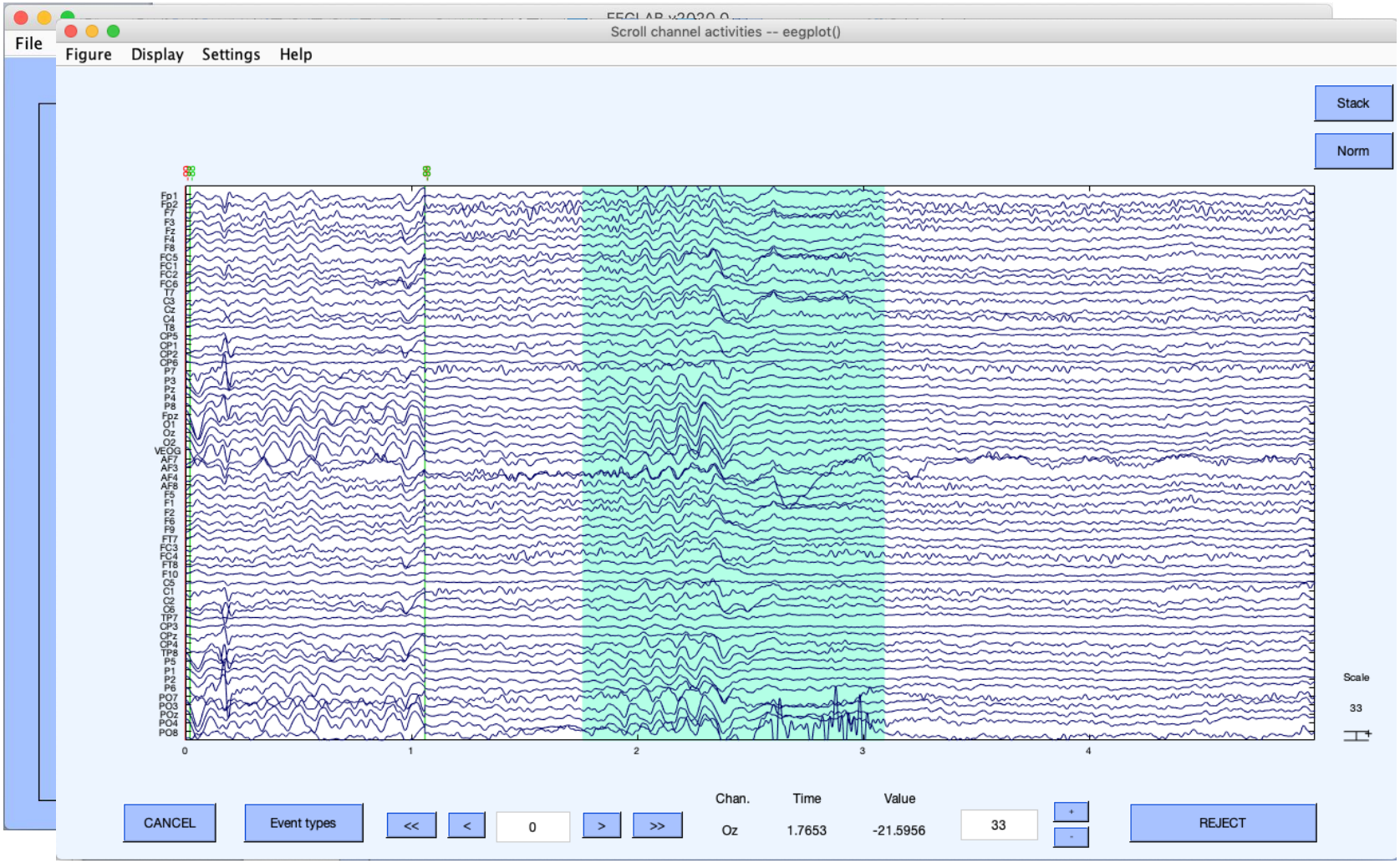
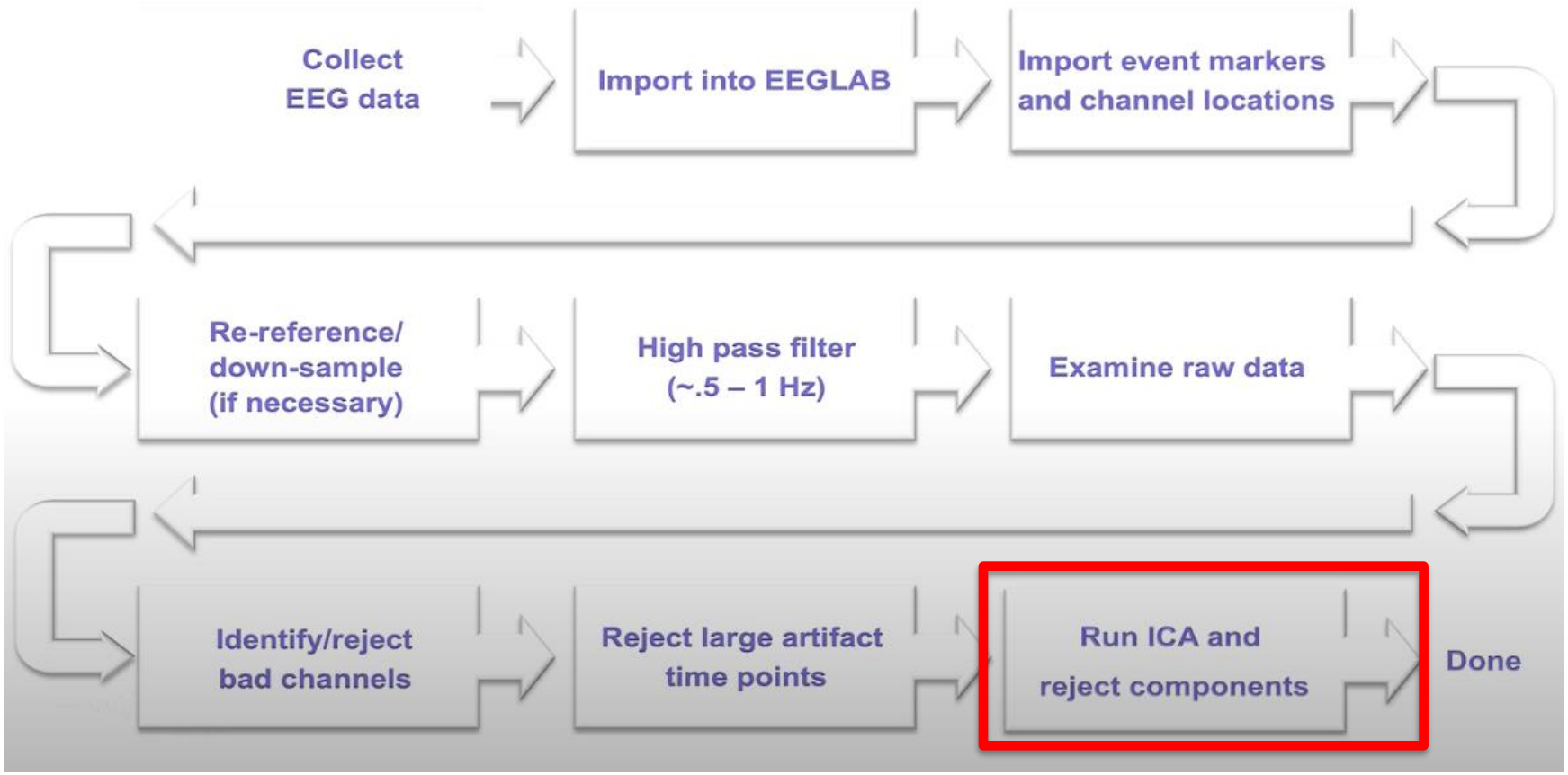


Removing bad data segments



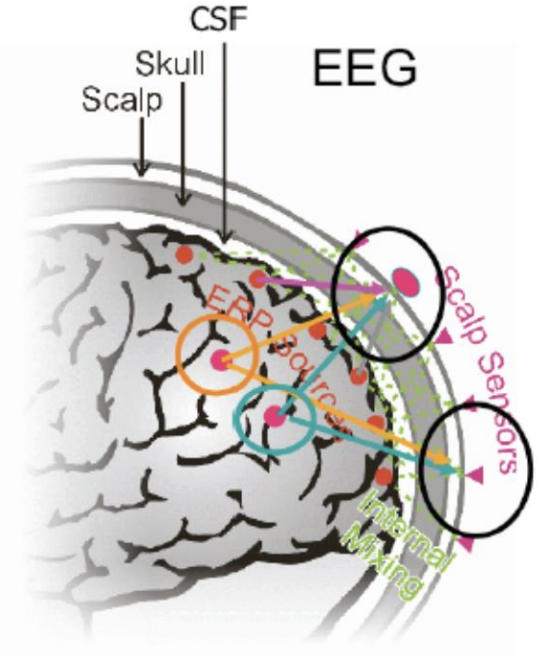
EEG pre-processing steps

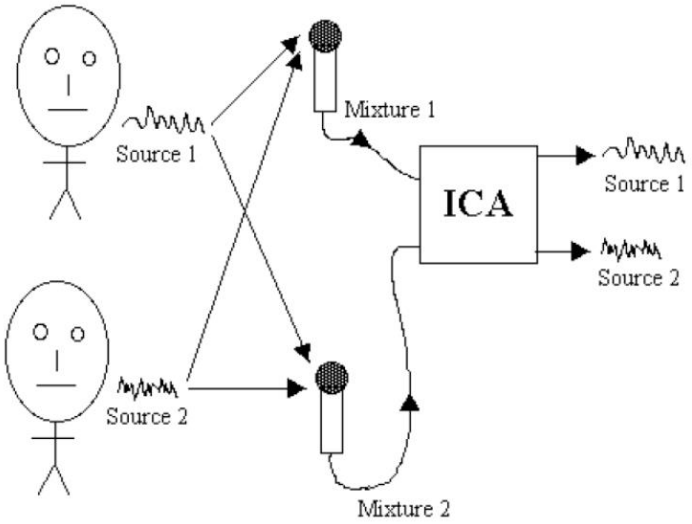


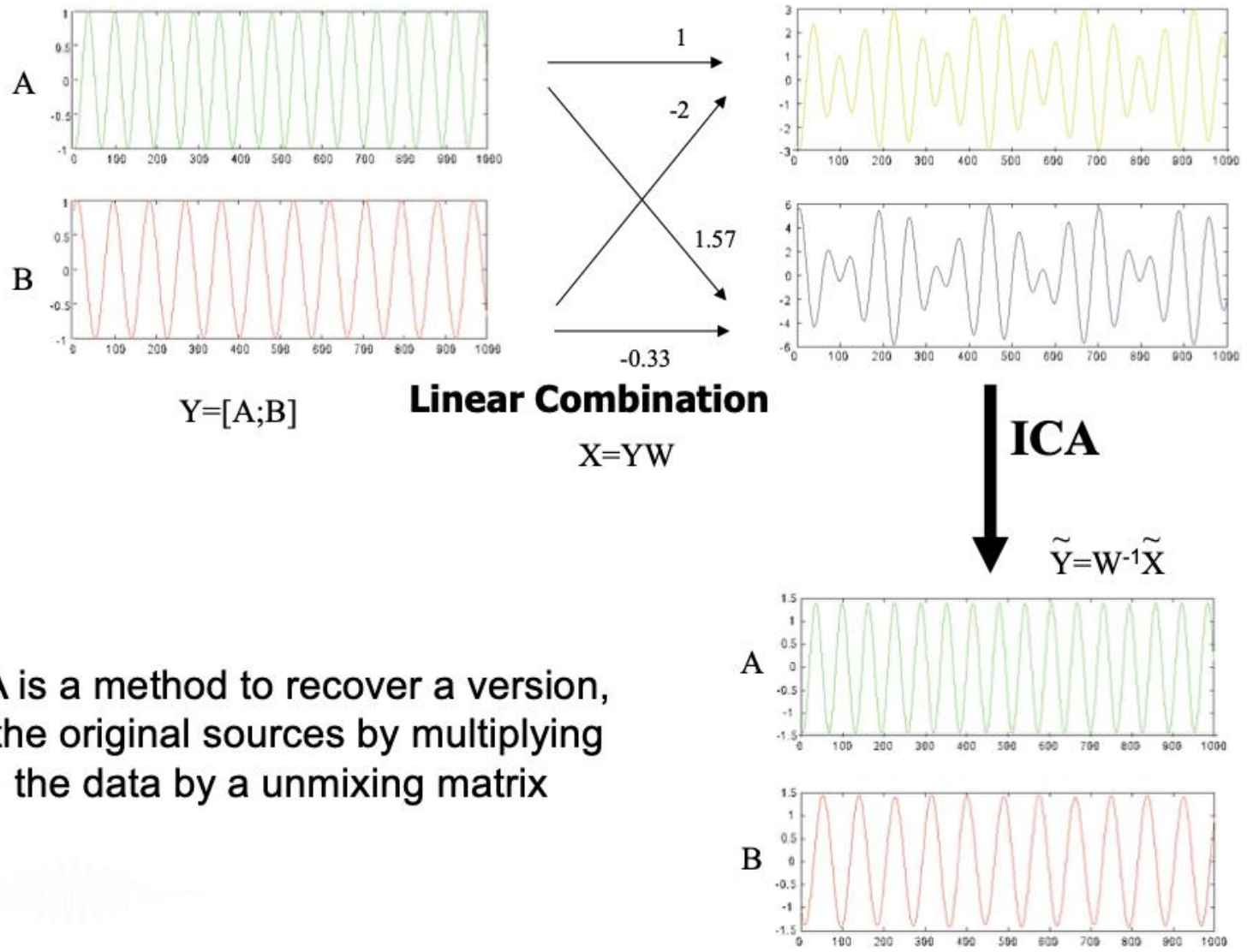
Independent Component Analysis (ICA)

- „blind source separation“
- tries to decompose EEG signals into maximally independent components
- purely statistical method!
- results strongly depend on data quality

EEG decomposition using ICA







ICA is a method to recover a version, of the original sources by multiplying the data by a unmixing matrix

https://sccn.ucsd.edu/githubwiki/files/EEGLAB2021_JW_ICA_Practicum.pdf

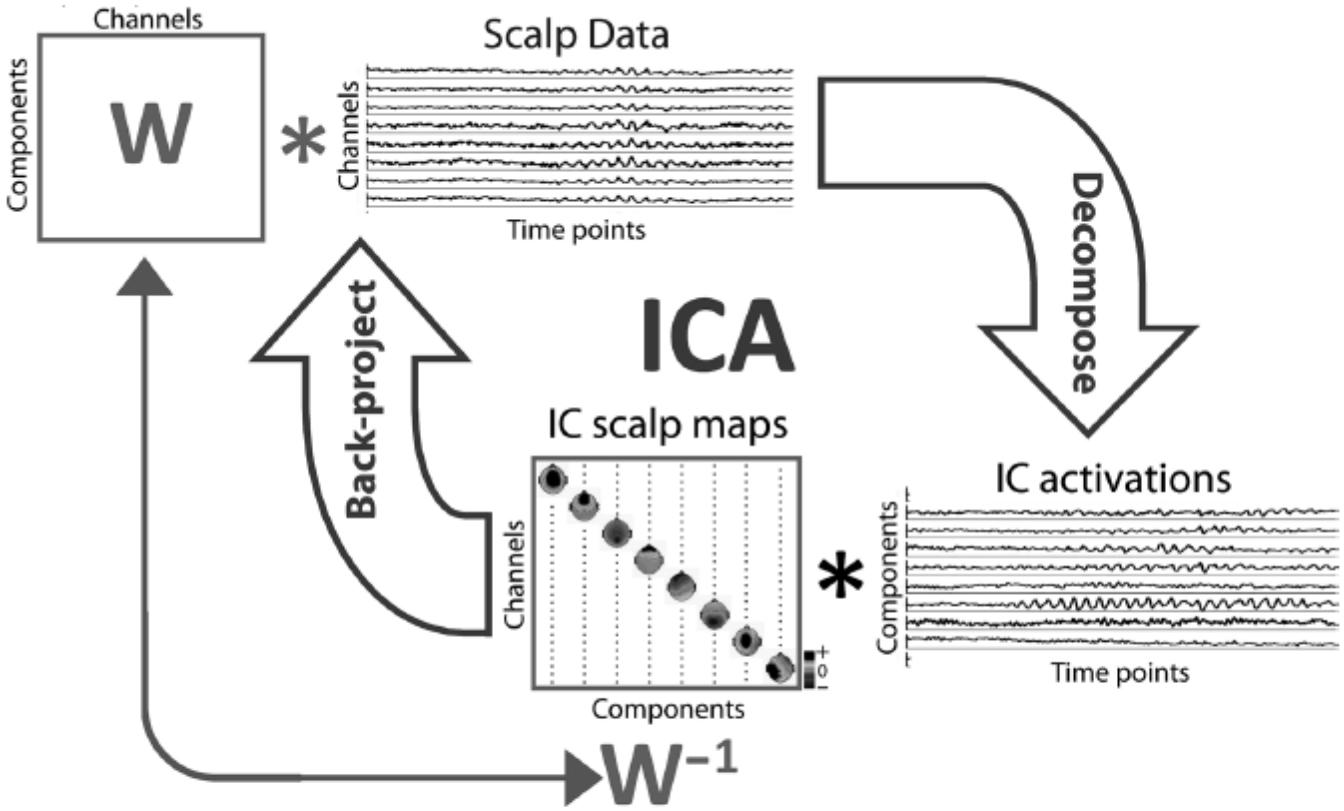
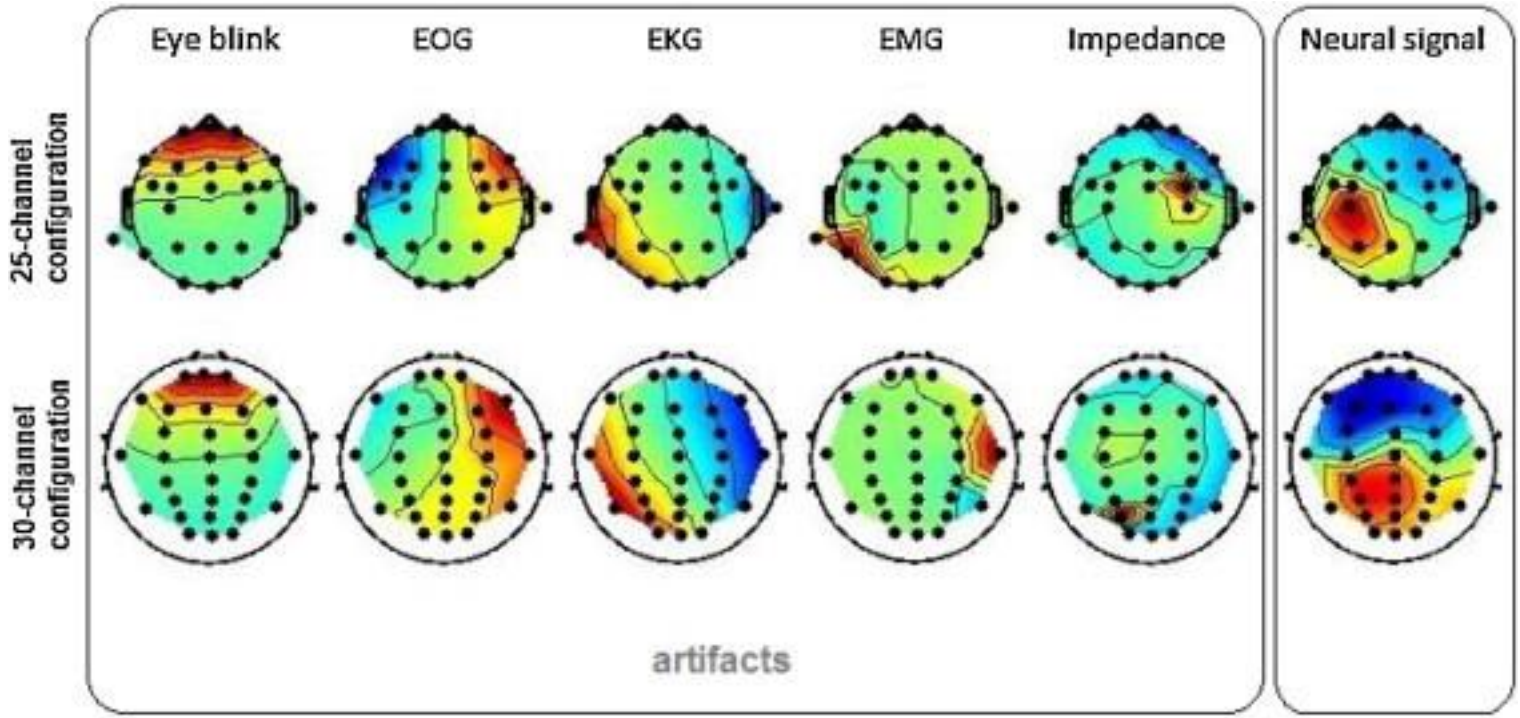


Figure S6.2
Flow diagram of ICA. The scalp EEG/EOG data are passed through a neural network to obtain the unmixing matrix, W. If the unmixing matrix is multiplied by the EEG/EOG data at each time point (the scalp data), this yields the activation of each of the independent components (ICs) at each time point (the IC activations). The mixing matrix, W^{-1}, is the inverse of the unmixing matrix, and it represents the scalp distribution of each IC. If we multiply the IC activations by the mixing matrix, we recover the original scalp data. Reprinted with permission from Makeig and Onton (2012). Copyright 2012 Oxford University Press.

EEG decomposition using ICA



https://arnauddelorme.com/ica_for_dummies/

https://www.sciencedirect.com/science/article/pii/S0165027015000370

EEG decomposition using ICA

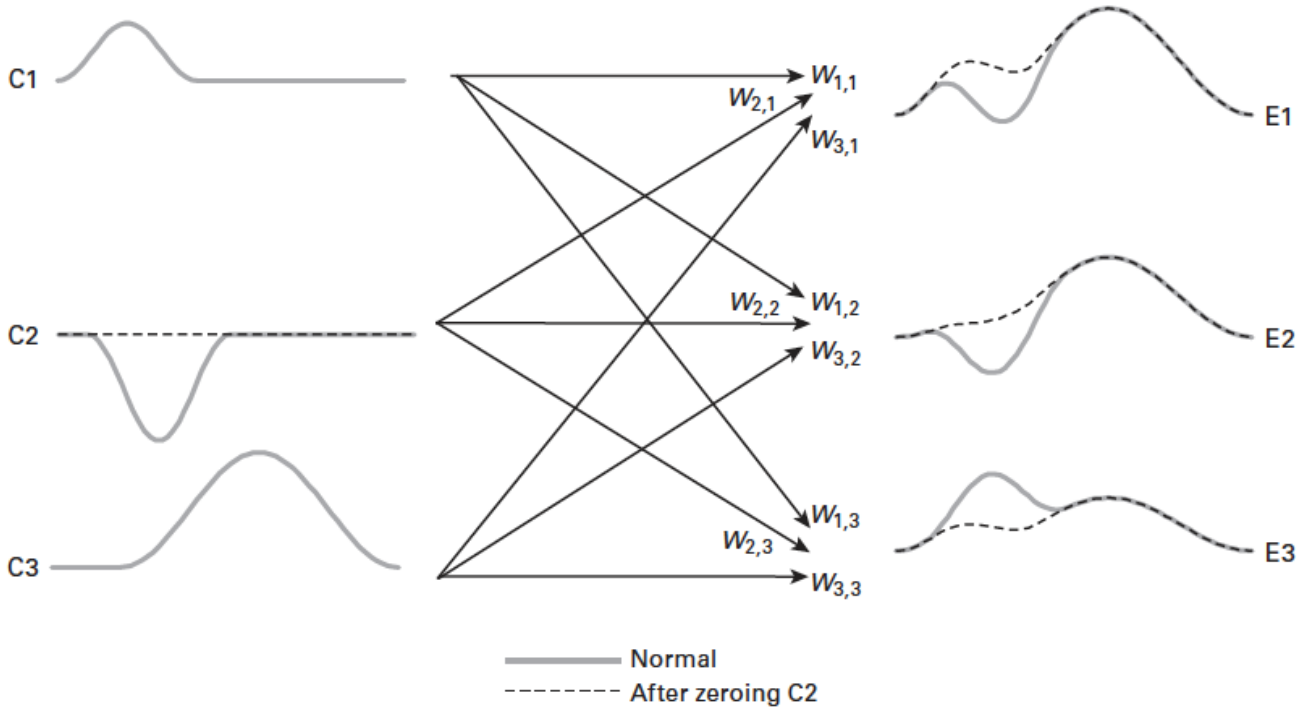
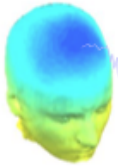


Figure S6.1
Reminder of how intracranial ERP sources propagate to the scalp electrodes. The voltage at each electrode is simply the weighted sum of each internal source. If one source is an artifact, we could eliminate the contribution of this source by setting it to zero and then recomputing the voltage at each electrode site. This is illustrated here by showing what happens when we set the activity of component C2 to zero and recompute the waveforms at each electrode site (blue line).

“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

Main types of artifacts

I. Environmental electrical activity

- Line frequency noise from video monitors, and other electrical devices

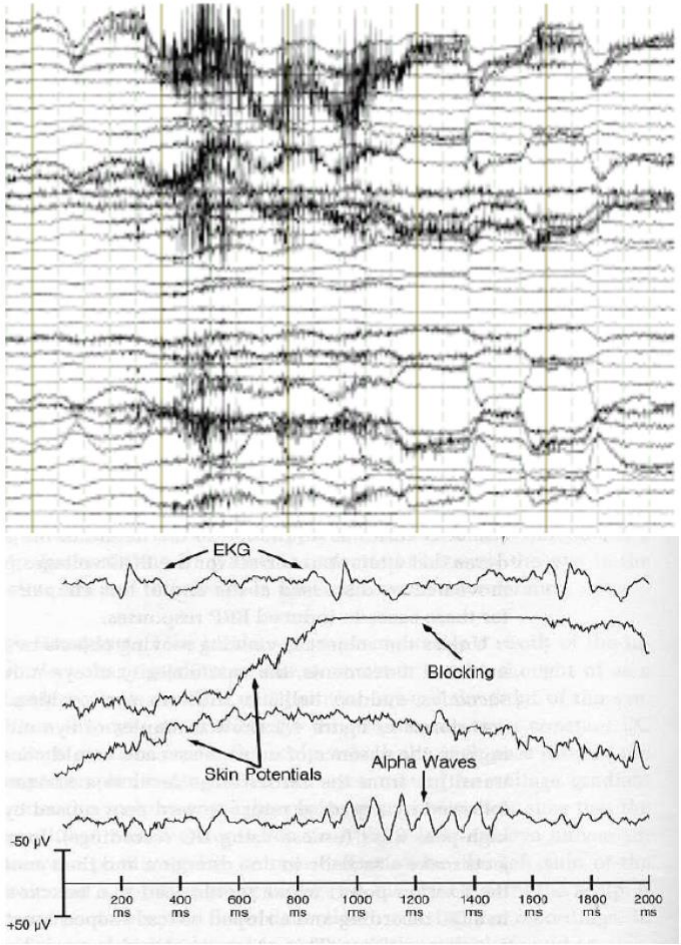
II. Artifactual bioelectric activity

- Blinks & eye movements
- Muscle (EMG) & heart activity (EKG)
- Skin potentials (=slow voltage shifts)

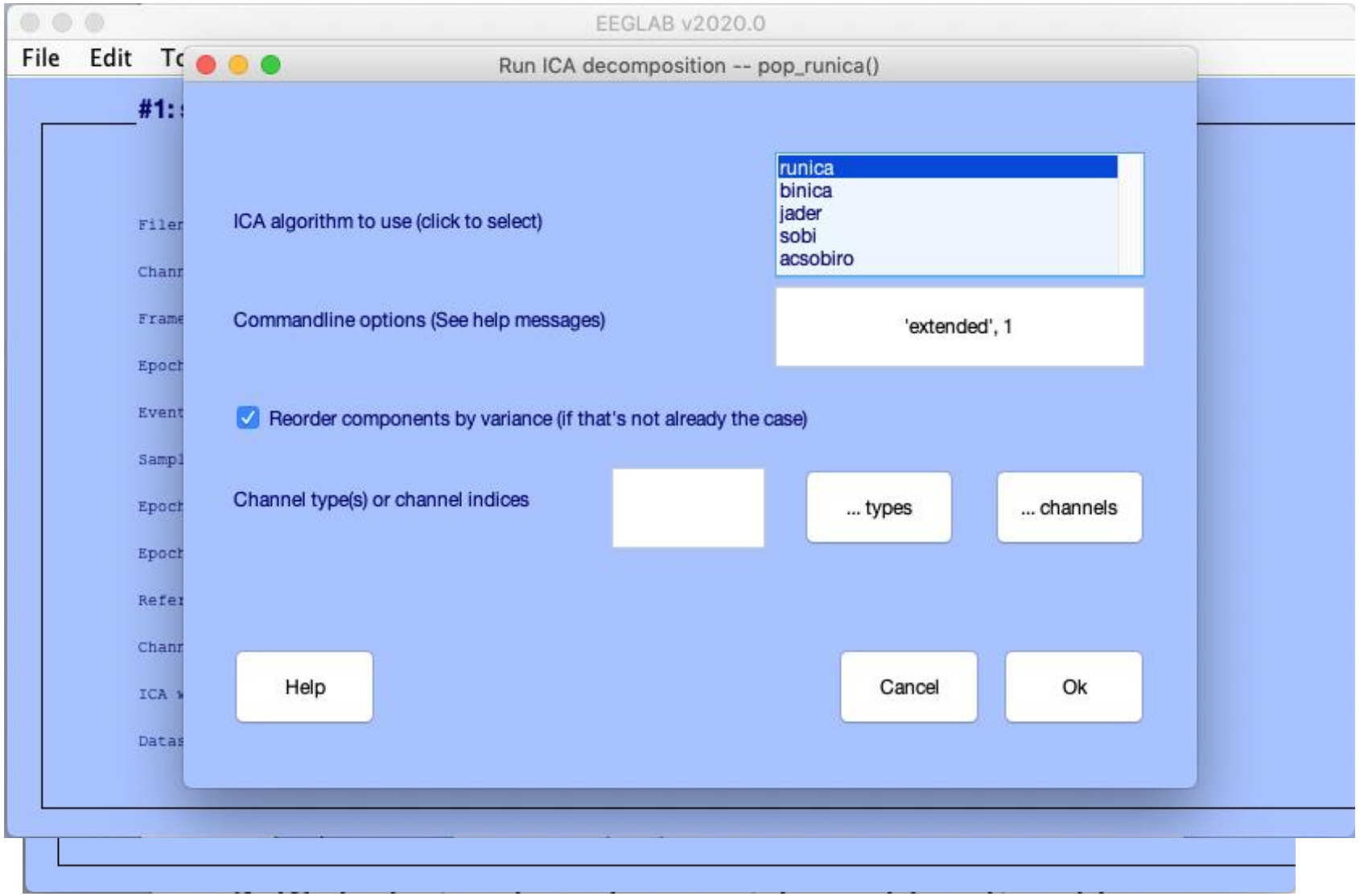
III. EEG activity not elicited by the stimuli

- Alpha waves

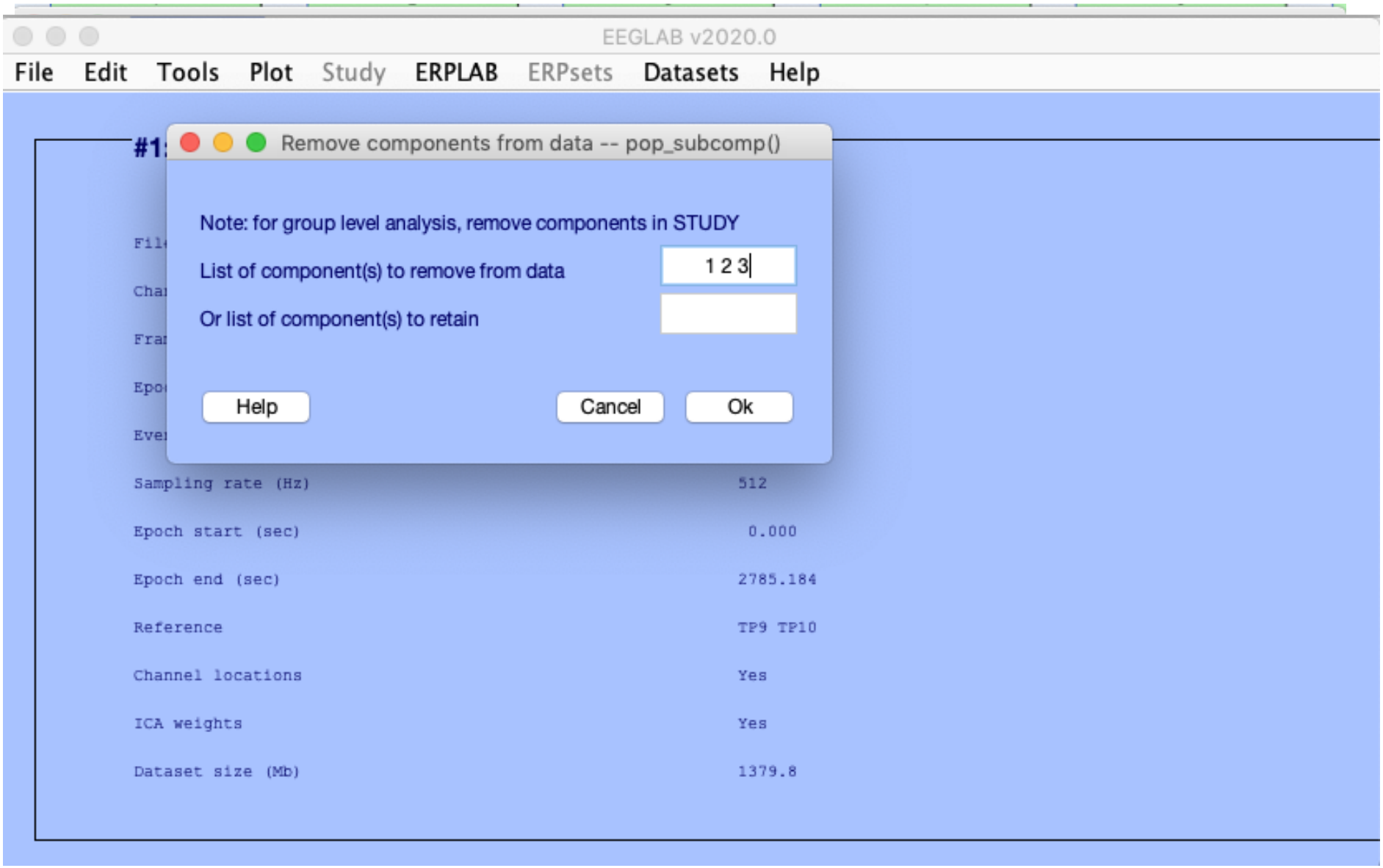
IV. EEG trial-to-trial variability due to variations in neural/cognitive activity



EEG decomposition using ICA



EEG decomposition using ICA



And finally averaging.

Underlying logic ... is that ERPs are embedded in larger EEG waves.

Thus, activity that is unrelated to specific sensory, cognitive, or motor events will be cancelled out ...