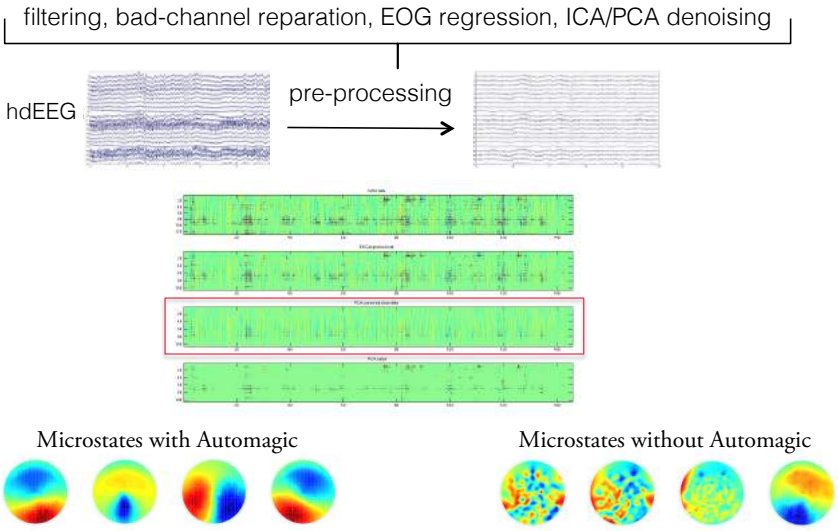
University of Zurich[UZH]

BRAIN HACK ZURICH 2017

Tutorial: Automagic EEG toolbox & Microstates toolbox

Nicolas Langer & Andreas Pedroni



Outline

- Importance of Clean Data
- Common Artifacts in EEG
- What is Automagic
- What does Automagic
- Step-by-step tutorial on example data
- Pre-processing steps:
  - Filtering
  - Bad Channel Detection and Interpolation
  - EOG Regression
  - ICA / PCA

Importance of Clean EEG Data

- Event-Related Potentials (ERPs) are tiny
  - Many experimental effects are less than a millionth of a volt
- ERPs are embedded in noise that is 20-100 μV
- Averaging is a key method to reduce noise
  - S/N ratio is a function of sqrt(# of trials)
  - Doubling # of trials increases S/N ratio by 41% [sqrt(2)=1.41]
  - Quadrupling # of trials doubles S/N ratio [sqrt(4)=2]

Importance of Clean EEG Data

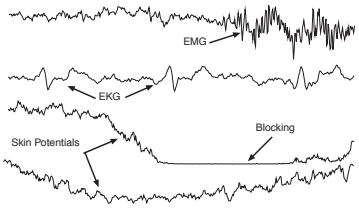
- Just having a lot of trials is often not enough to get clean data
- It pays to reduce sources of noise before the noise is recorded
- Hansen's Axiom: There is no substitute for clean data
- Cleaning up noise after recording has a cost
  - Averaging requires lots of trials (lots of time)
  - Filters can distort the time course of the ERPs
- "By reducing sources of noise before they are recorded, you could cut an hour off every recording session or cut the number of subjects in each experiment by 25% (or even more)" Steven Luck

Common Artifacts in EEG data

Common Artifacts in EEG:

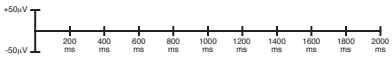
Subjects related Artifacts:

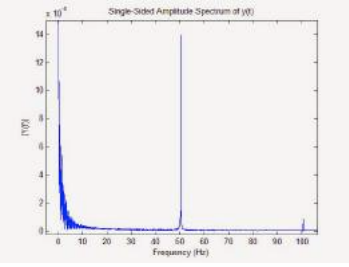
- Any minor body movement (EMG)
- Cardiac activity
- Blinks and eye-movement
- Sweating



Technical Artifacts:

- 50/60 Hz power line
- Impedance fluctuations
- Movement of cables
- Broken wire contacts
- Too much electrode gel/paste





What to do with Artifacts?

Artifact-rejection vs. Artifact-correction

- Throw out trials with problematic artifacts (e.g., rejection threshold >100 μ V); at the same time don‘t throw out „good“ trials
- Data gets lost!
- Use data reduction methods to eliminate artifacts (increase SNR)
- No data is lost!
- Automagic does Artifact-correction

What is Automagic

- Automagic is a MATLAB based toolbox for preprocessing of EEG-datasets.
- GUI vs. Open Source
- MATLAB (Octave) => Python version under construction
- Where to find it:
- https://github.com/amirrezaw/automagic

What does Automagic?

1. Automagic automatically removes artifacts (e.g. eye movements, noisy electrodes, etc.) from your raw EEG-data.
2. Automagic lets you check the entire dataset for remaining artifacts. You will be able to select and remove these manually in a very efficient way.
3. You can rate the quality of individual EEG-files.

Pre-processing with Automagic

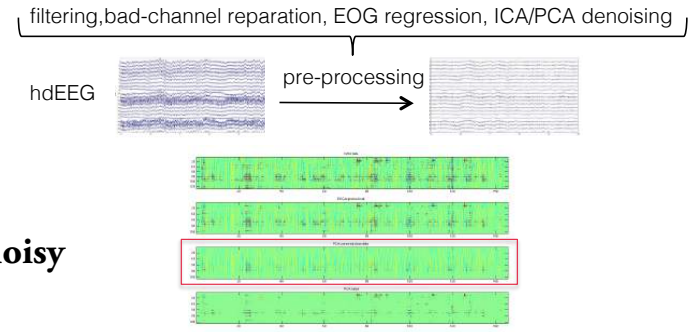
Filtering
- Highpass-filter (~1Hz)
- Optional lowpass-filter
- Notch-filter (50/60Hz)

Detect and interpolate noisy electrodes

Regress out eye-artifacts

ICA or PCA

Visual inspection and rating of data quality



STEP-BY-STEP TUTORIAL

Let‘s do some practical stuff

Step-by-step Tutorial

System Requirements

You need MATLAB installed and activated on your system to use *Automagic*. *Automagic* was developed and tested in MATLAB R2015b and newer releases.

Installation

Download the *Automagic EEG Toolbox* to a folder of your choice.

https://github.com/amirrezaw/automagic

Navigate to *gui/* folder

Double click the file named *Automagic* or *Automagic.mlappinstall*. Wait until MATLAB displays a dialogue box.

Please select Install. You will be notified as soon as the installation is complete.

How to Run Automagic

Start MATLAB.

Select the APPS tab.

Click on the Automagic icon. You might have to expand the APPS tab to see the *Automagic* icon by clicking the small triangle pointing down on the far right of the APPS tab.

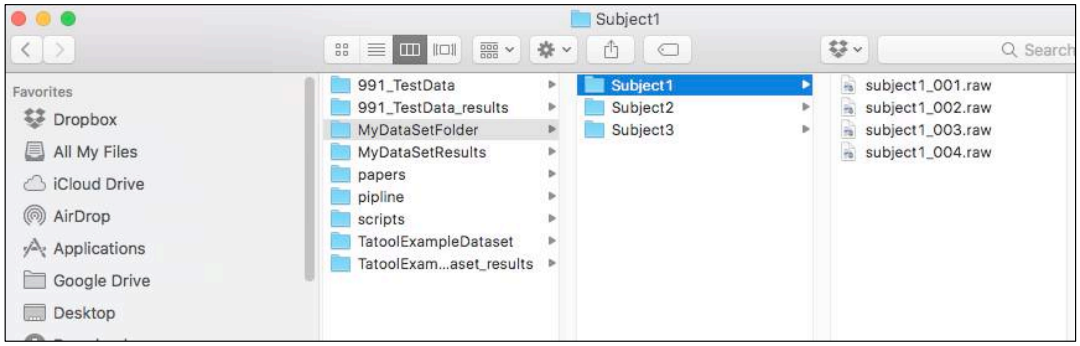
Smilla Pedroni (2016)

Step-by-step Tutorial

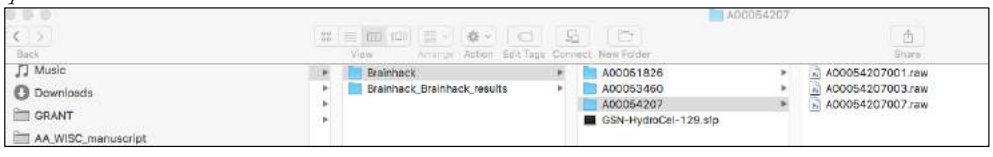
Before you start Automagic... prepare your data

Folder organization:

Each subject has a folder and the EEG files have the same names as the folder



Example Data Set:

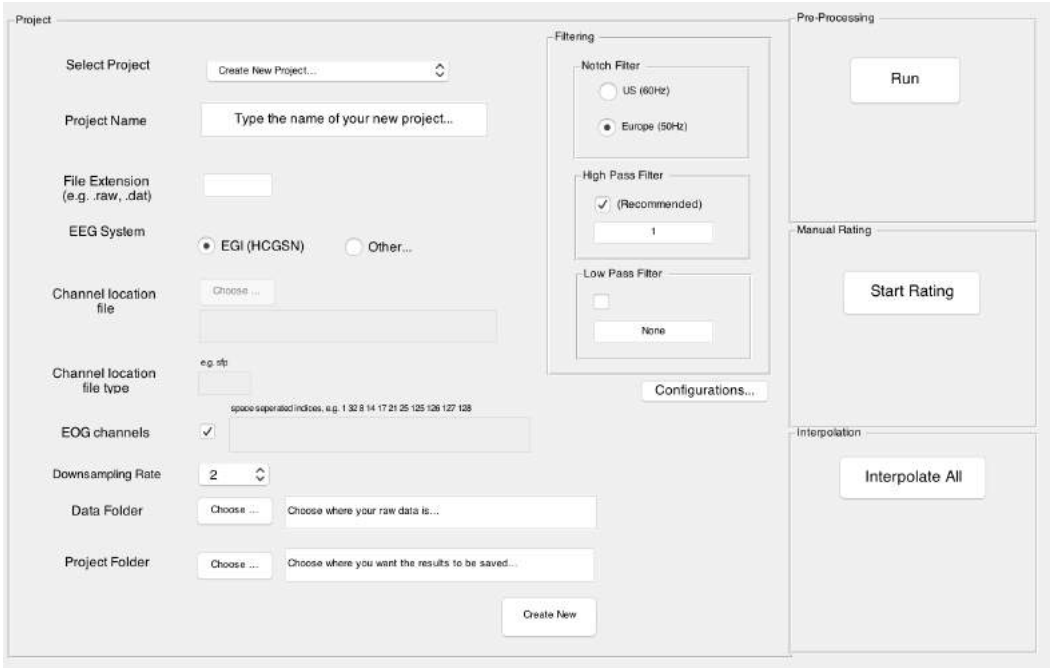


Step-by-step Tutorial

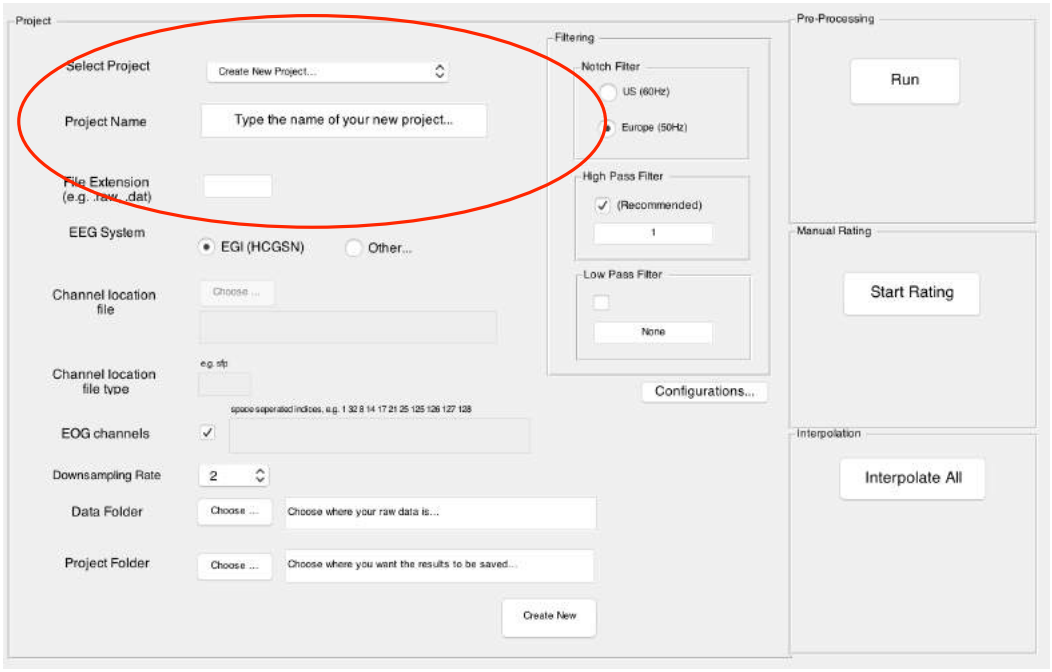
Work Flow in Automagic

1. Create a new project or load an existing project.
2. Preprocess the data.
3. Rate data and manually select bad channels if any.
4. Interpolate all bad channels.
5. Repeat steps 3 and 4 until all data is rated.

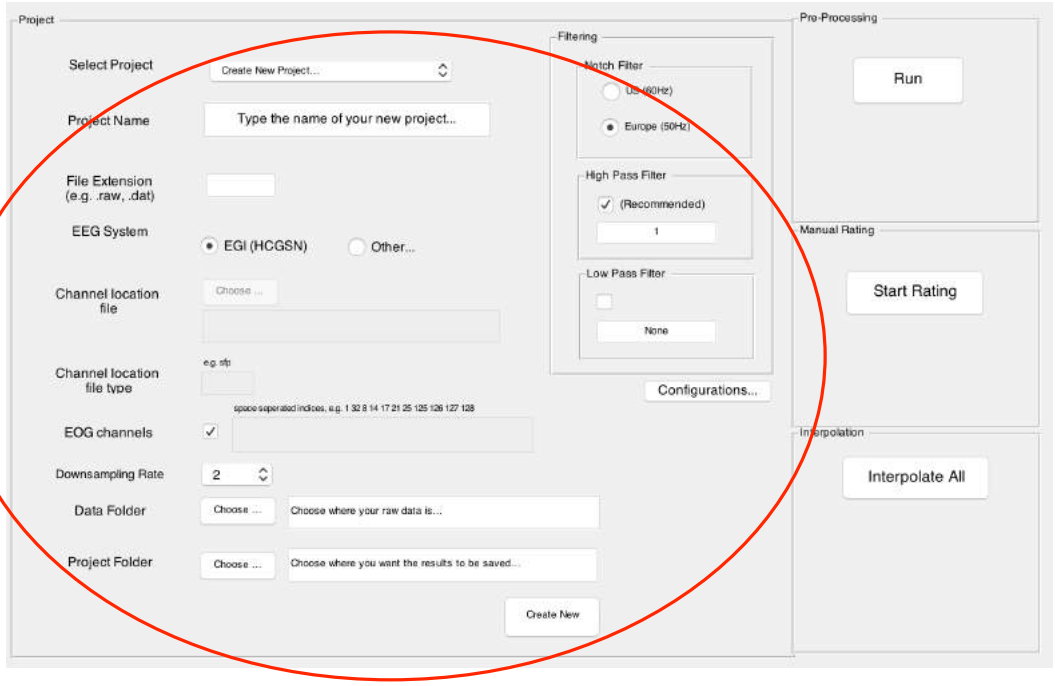
The Automagic GUI



1. Create a new project or load an existing project



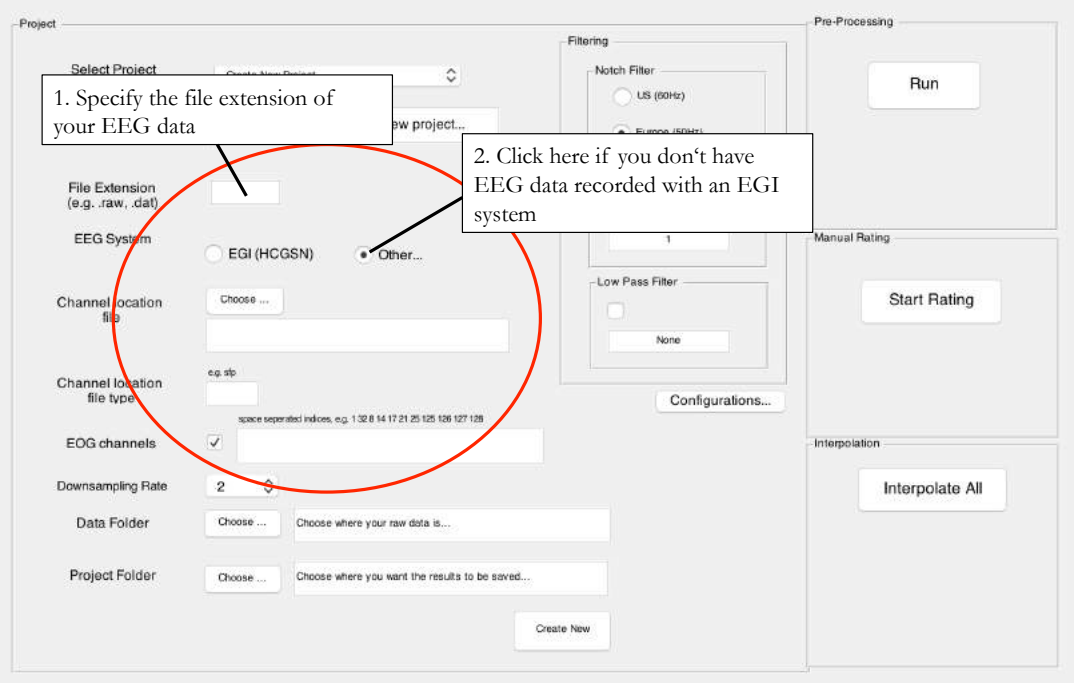
1b. Specify your data (super easy with EGI data)



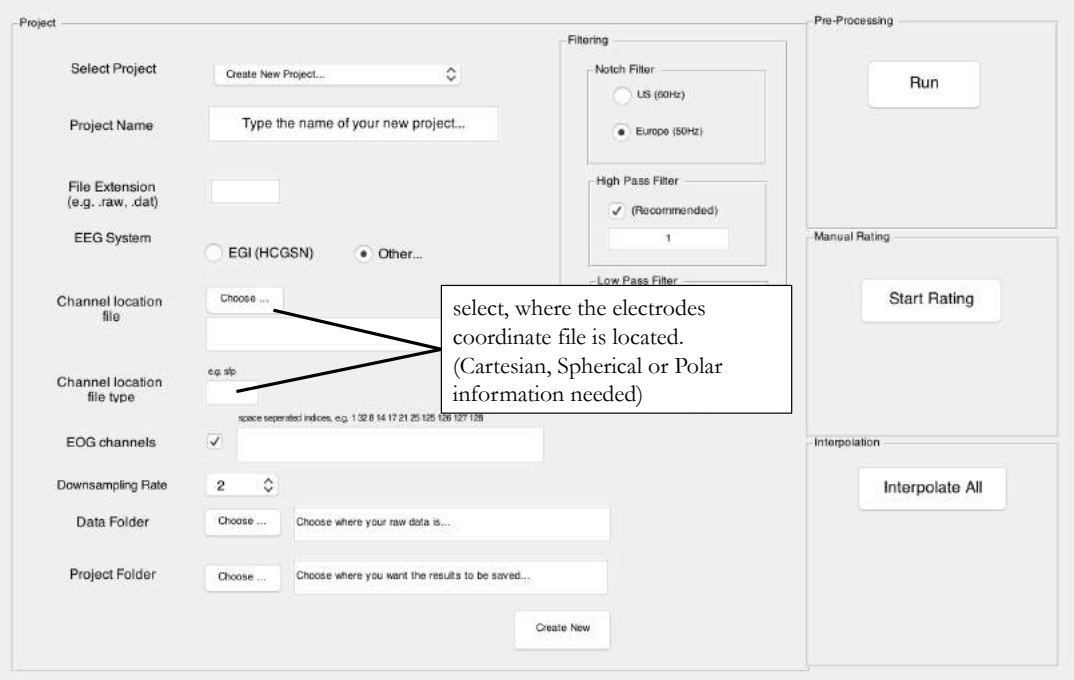
Let‘s quickly look at the configurations if you don‘t have EEG data recorded with an EGI system

... other data formats need a bit more work

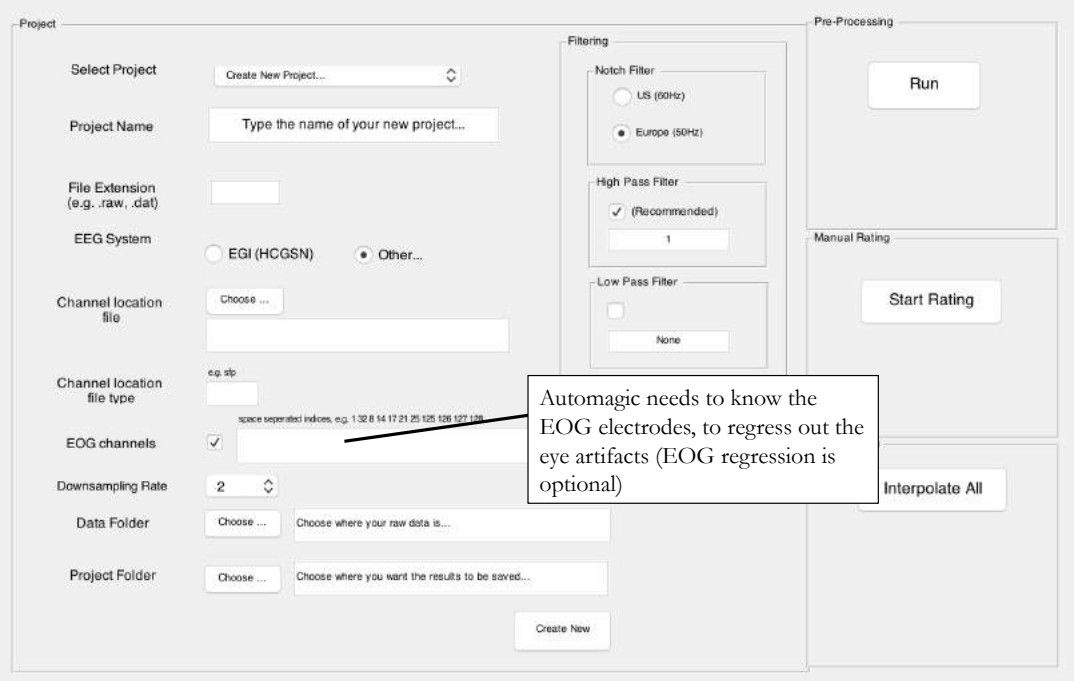
(yes, the EEG worlds needs a similar approach as BIDS (Gorgolewski), maybe the ESS-format)



... Specifying the electrodes location file
(only if you don‘t have EGI data)



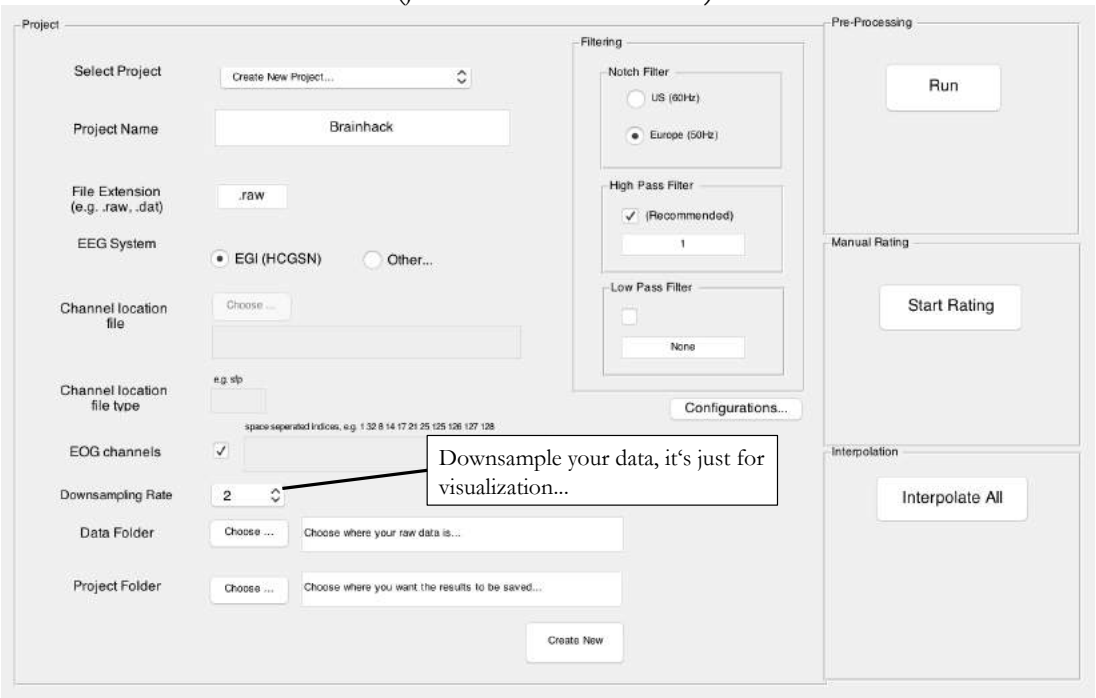
... Specifying the EOG channels
(only if you don‘t have EGI data)



Let‘s assume we have EEG data recorded with an EGI system (see example data)

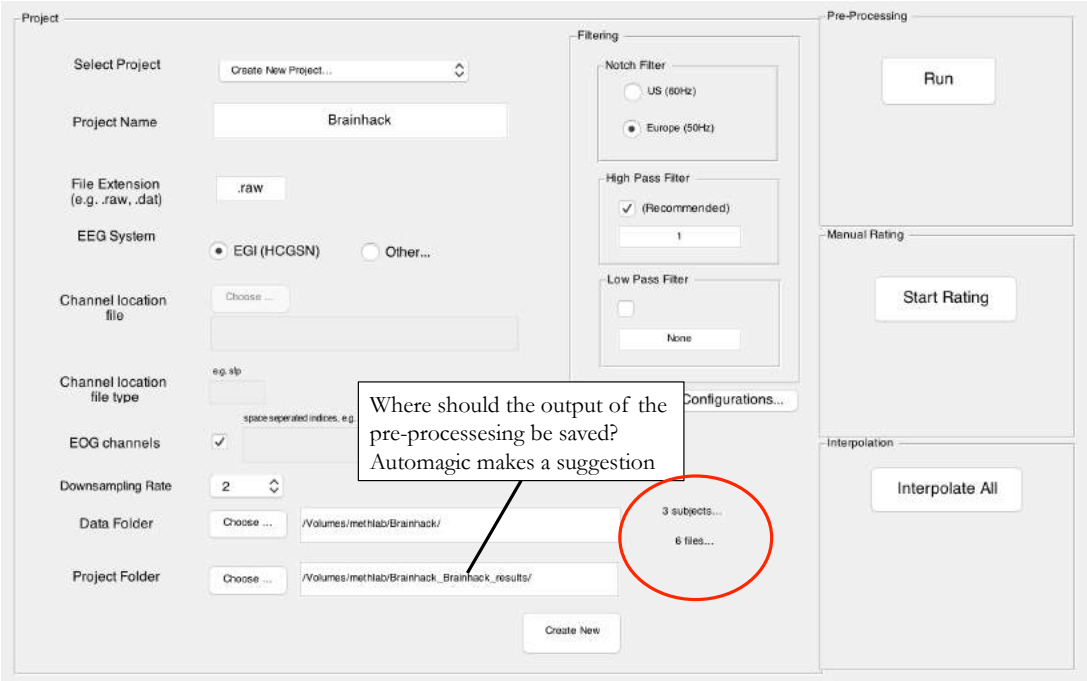
We‘re using the example data on github...

... Specifying downsampling rate
(just for visualization)

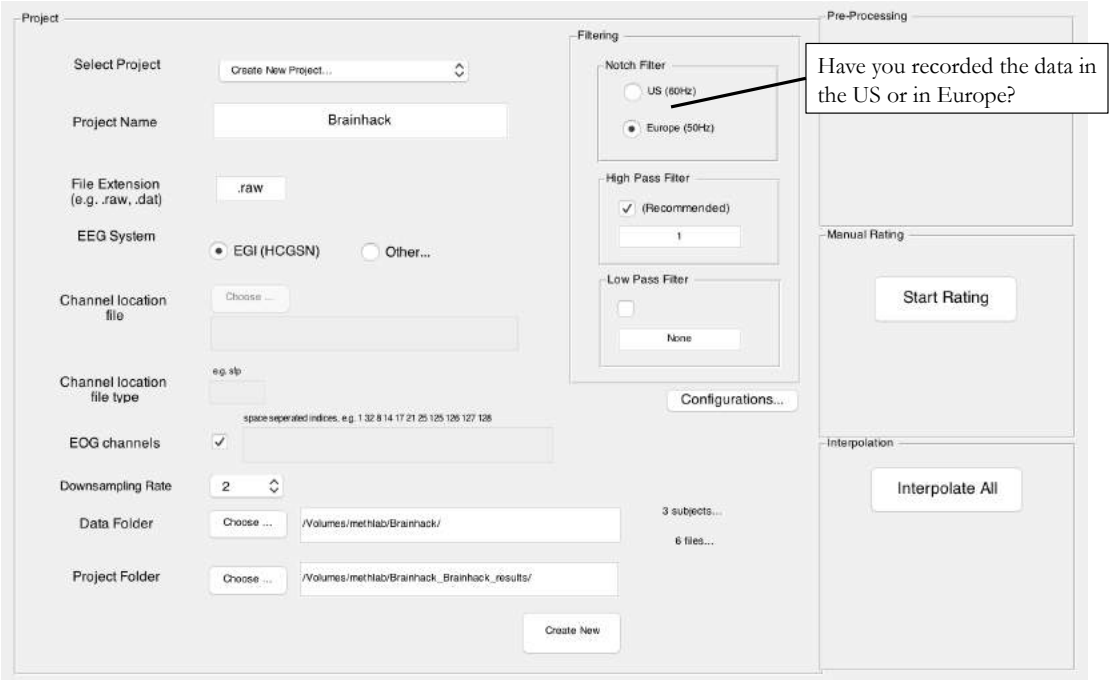


... Specifying the path to the data

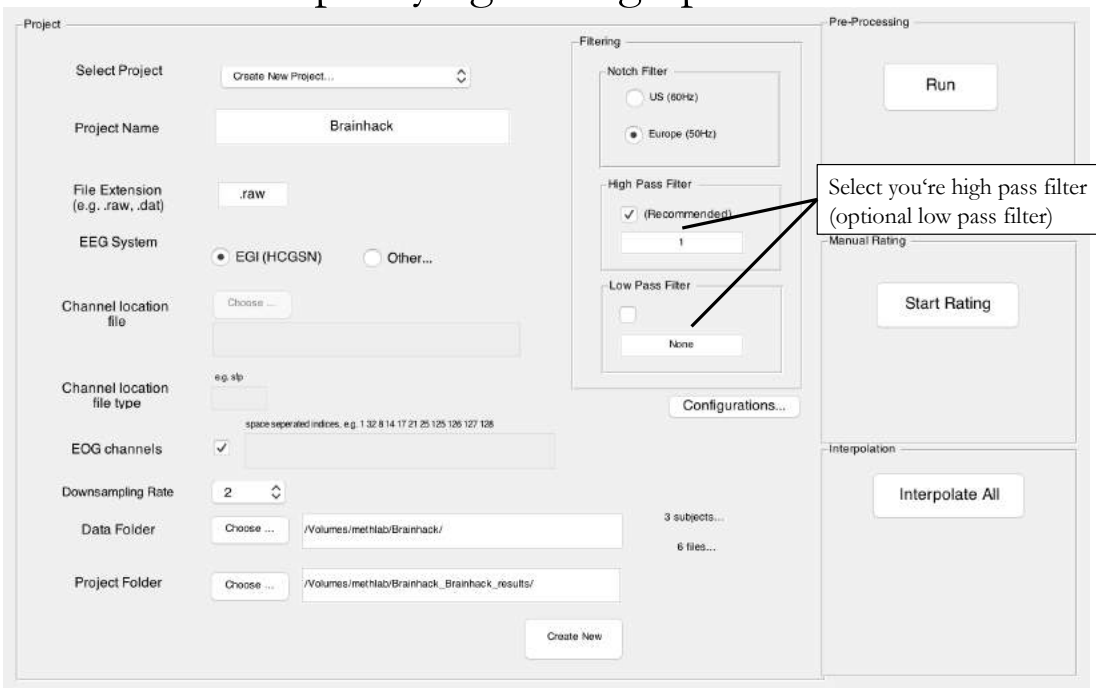
... Specifying the path of the output



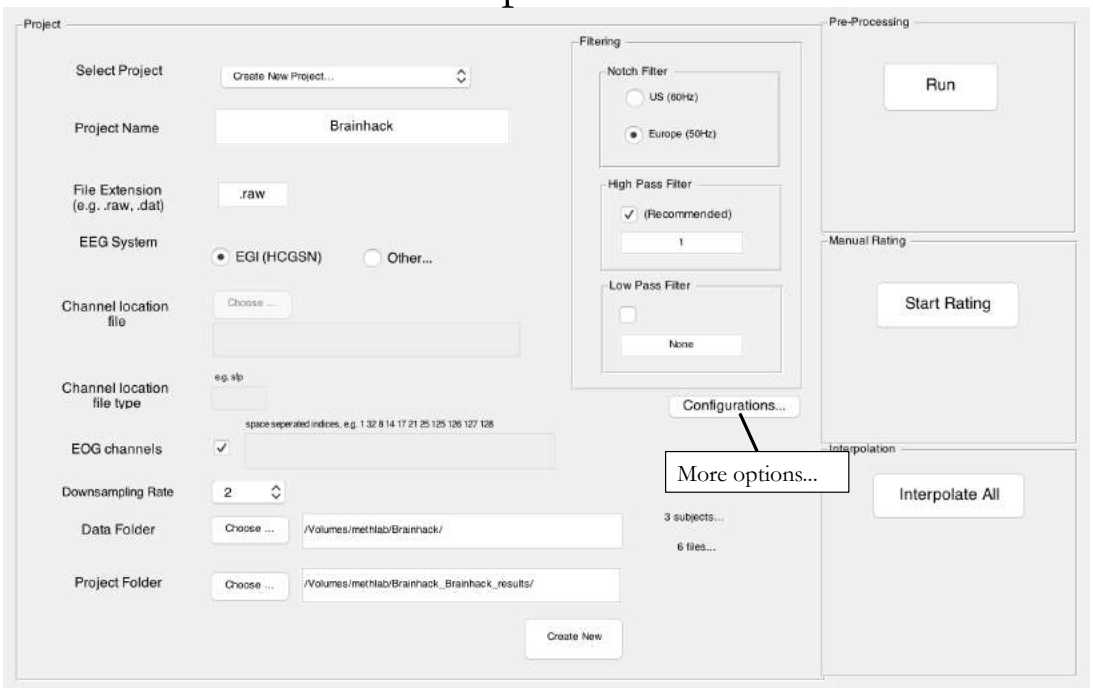
... Specifying the notch filter

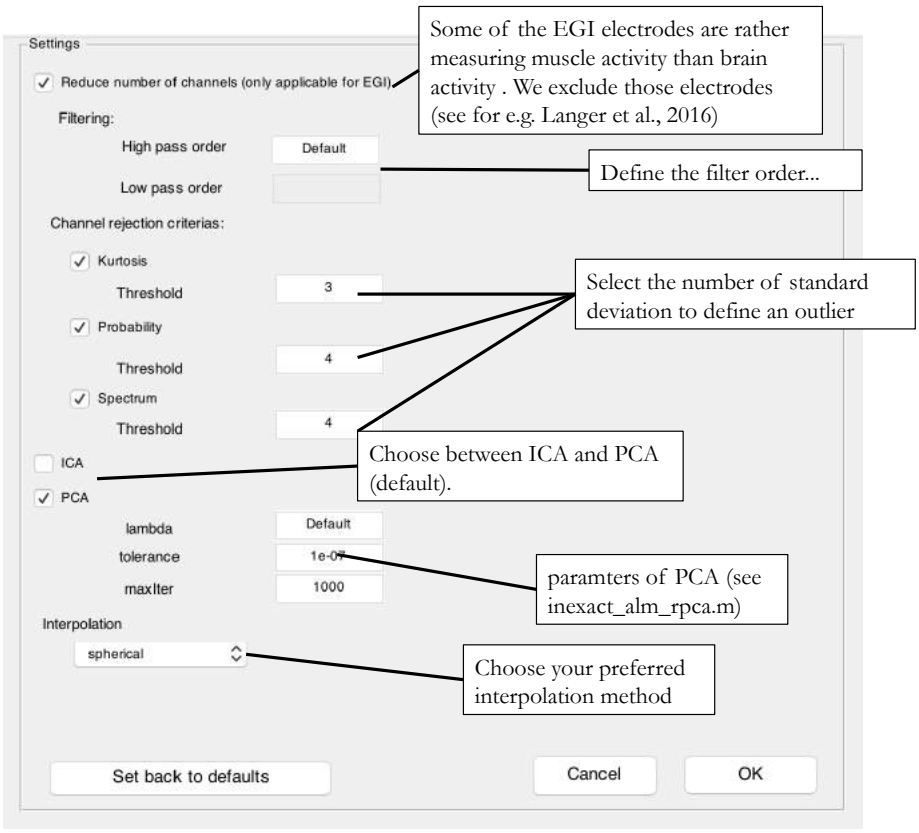


... Specifying the high pass filter



... More options available

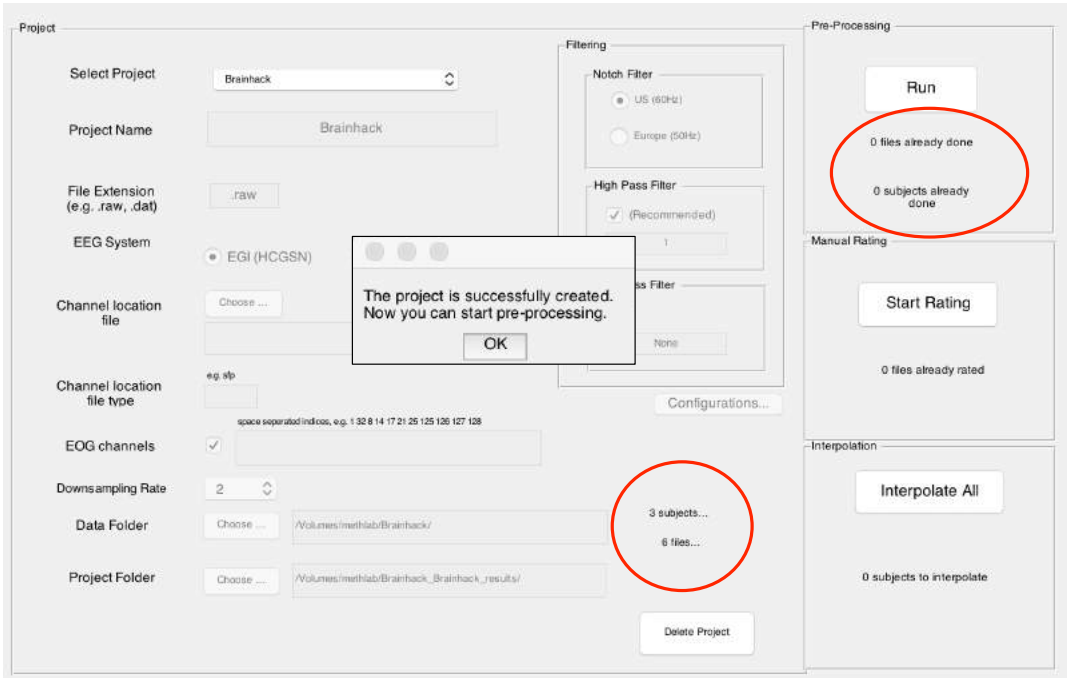




... Press the „Create New“ button

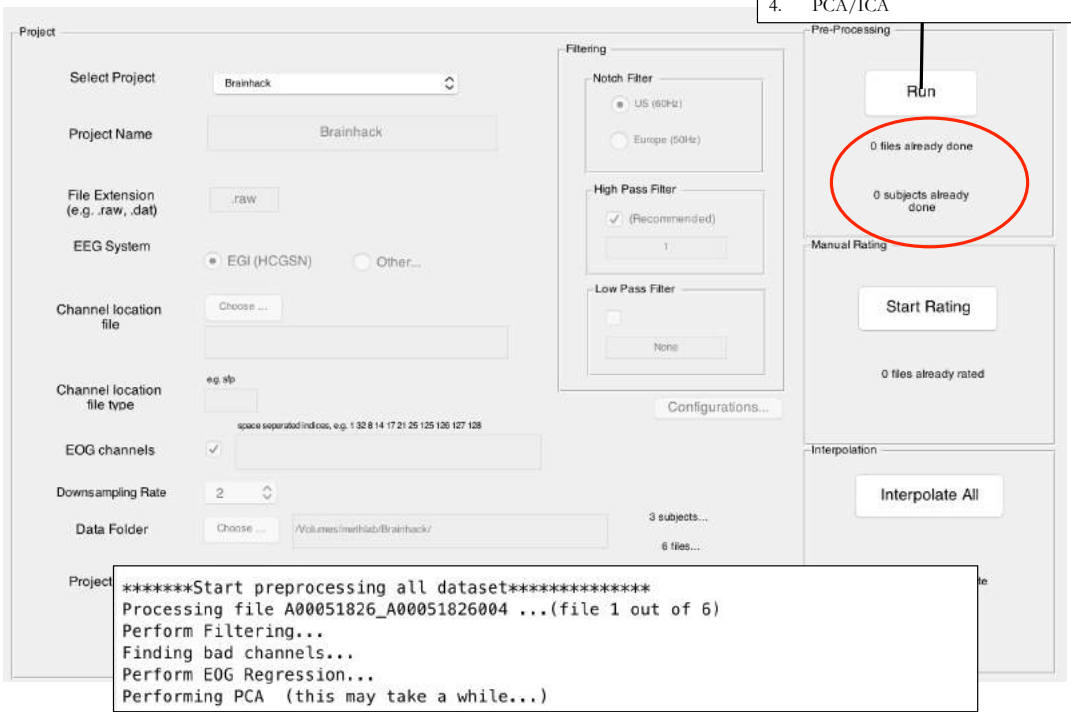
(Automagic will tell you, if you have specified everything correctly)

... Automagic will show you, how many subjects and files were found



2. Let‘s start the pre-processing

Run pre-processing
1. Filter
2. Automated bad channel detection
3. EOG regression
4. PCA/ICA



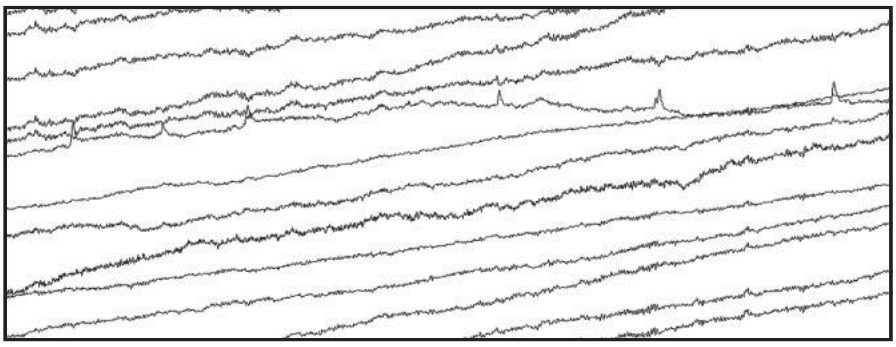
FILTERING

pop_eegfiltnew.m (EEGLAB)

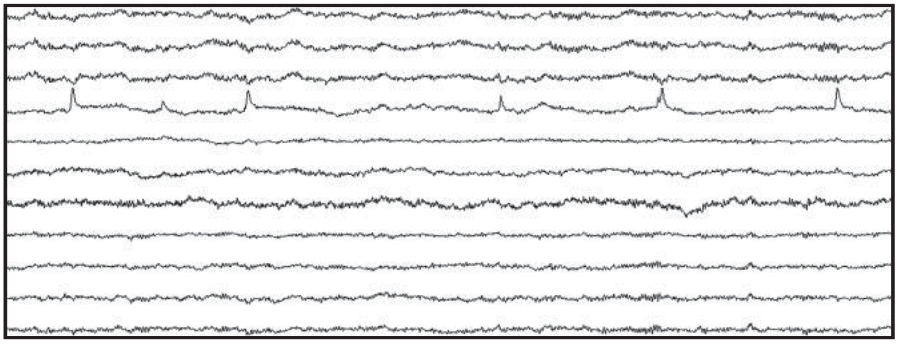
Filtering

High-pass filter: Remove low frequencies

EEG,
Unfiltered

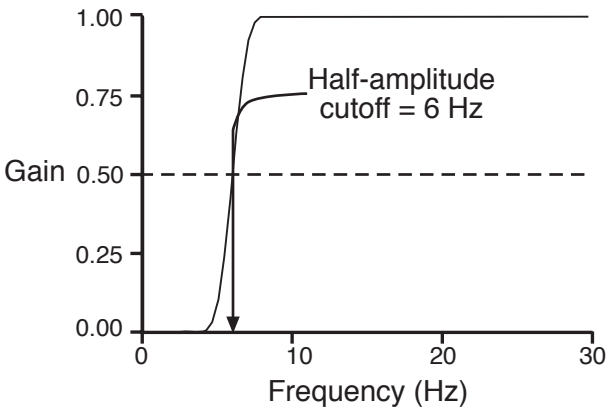


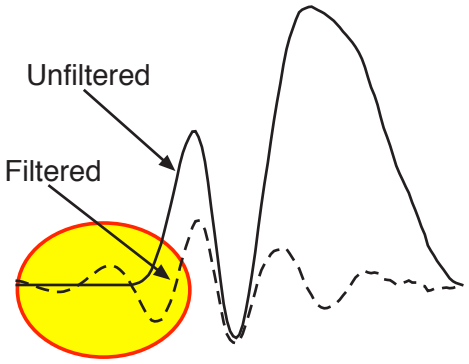
EEG,
Filtered @ 0.1
Hz



Filtering

High-pass filter: Remove low frequencies

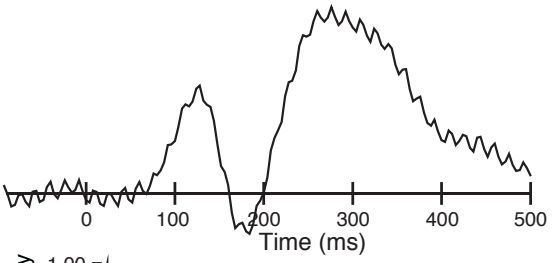


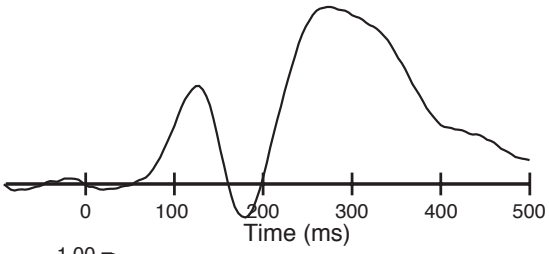


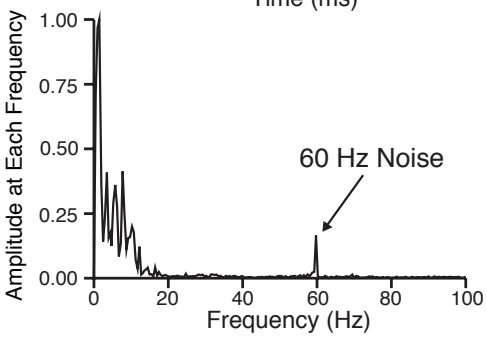
Extreme filters can significantly distort an ERP waveform

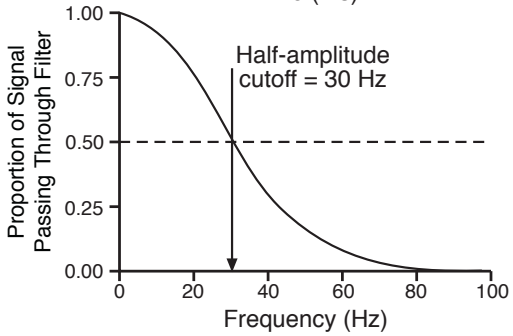
Filtering

Low-pass filter: Remove high frequencies



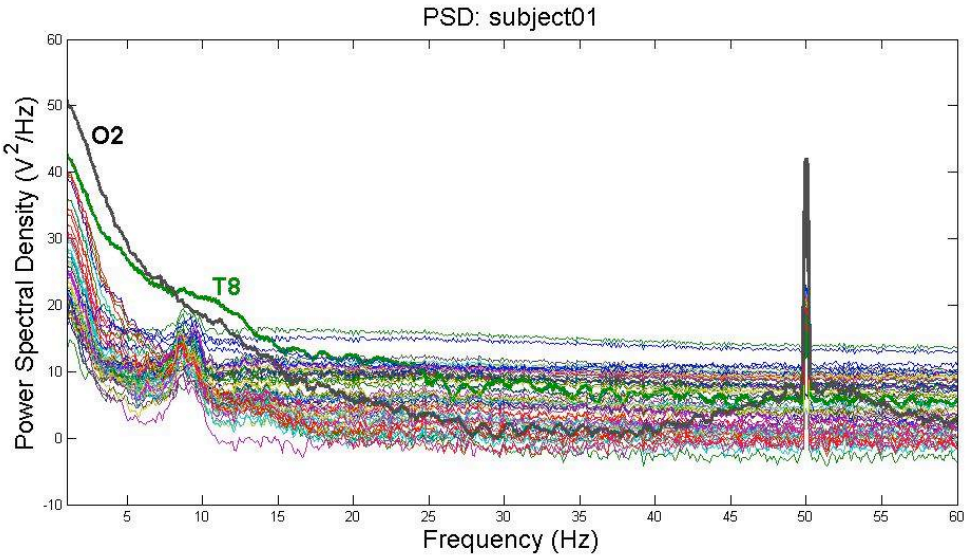






Filtering

Notch filter: removes power line artifacts (50/60 Hz)



BAD CHANNEL DETECTION

pop_rejchan.m (EEGLAB)

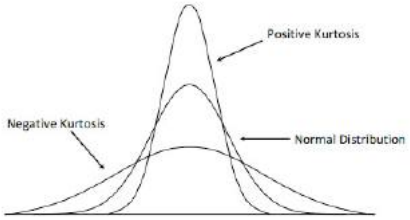
Noisy Electrodes

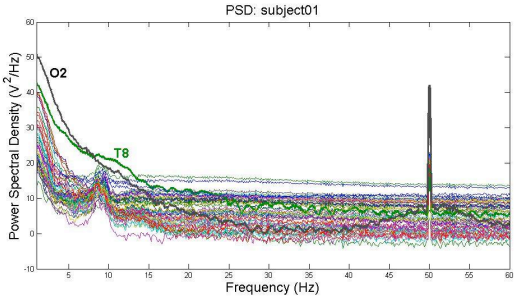
Noisy electrodes are defined as statistical outliers (e.g. > 3 STD) based on:

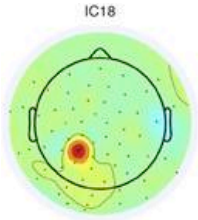
Probability

Kurtosis (Verteilung der Daten)

(Frequency) Spectrum







EOG Regression

Parra, L.C., Spence, C.D:, Gerson, A.D., Sajda, P. (2005). Recipes for the linear analysis of EEG. *Neuroimage,* (28): 326-341.

EOG Regression

Electrooculography (EOG)

- Goal: Estimate contribution of EOG artifact at each EEG channel and subtract it
- Problem: Signal at EOG electrodes contains non-artifact activity as well as artifact activity
  - The first technique (Gratton et al., 1983) "overcorrects" and distorts the scalp distribution of the ERP components
- The best approaches use more sophisticated ways of estimating the actual ocular activity
  - EOG Regression (Parra et al., 2005)

EOG regression

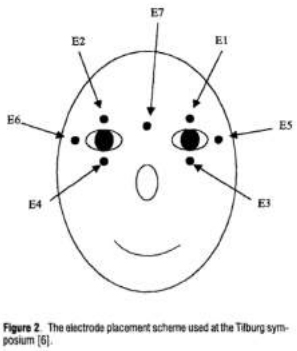


Figure 2. The electrode placement scheme used at the Tilburg symposium [6].

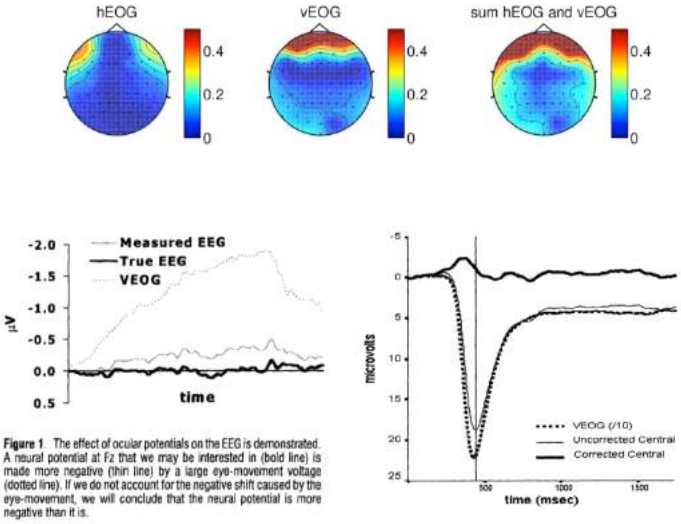


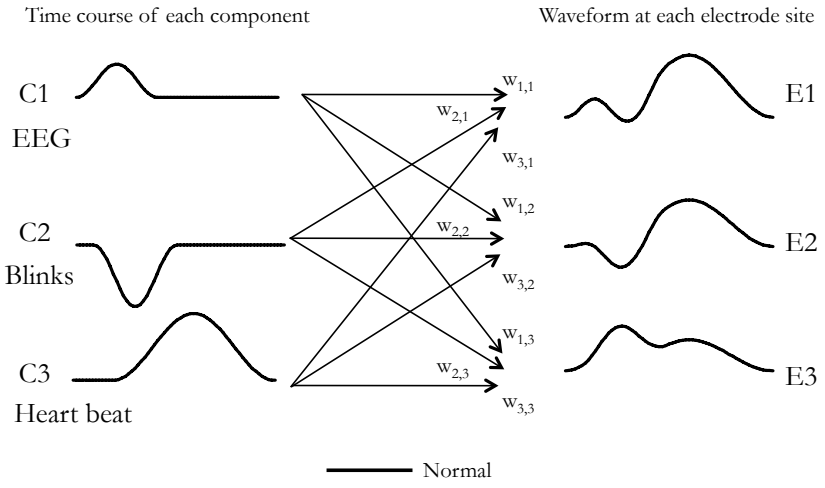
Figure 1. The effect of ocular potentials on the EEG is demonstrated. A neural potential at Fz that we may be interested in (bold line) is made more negative (thin line) by a large eye-movement voltage (dotted line). If we do not account for the negative shift caused by the eye-movement, we will conclude that the neural potential is more negative than it is.

Croft and Barry, 2000; Parra et al., 2005

Independent Component Analysis (ICA)

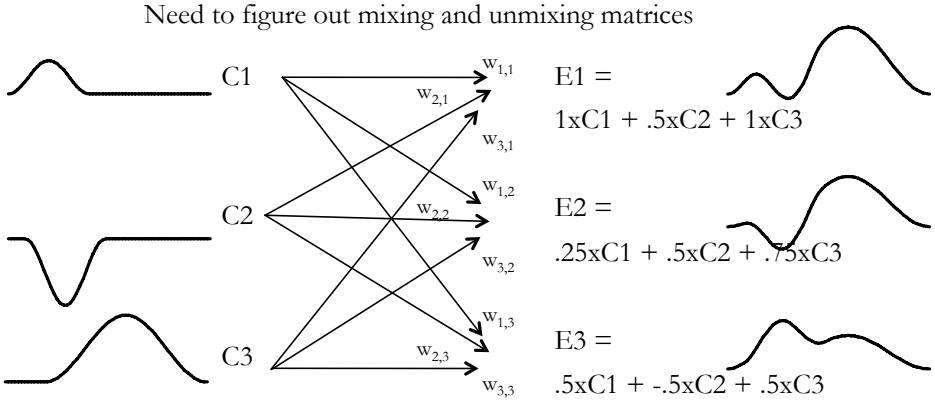
Winkler I., Haufe S., Tangermann, M. (2011). Automatic Classification of Artifactual ICA-Components for Artifact Removal in EEG Signals. *Behavioral and Brain Functions*, 7:30.

General Logic



Mixing and Unmixing

Need to figure out mixing and unmixing matrices

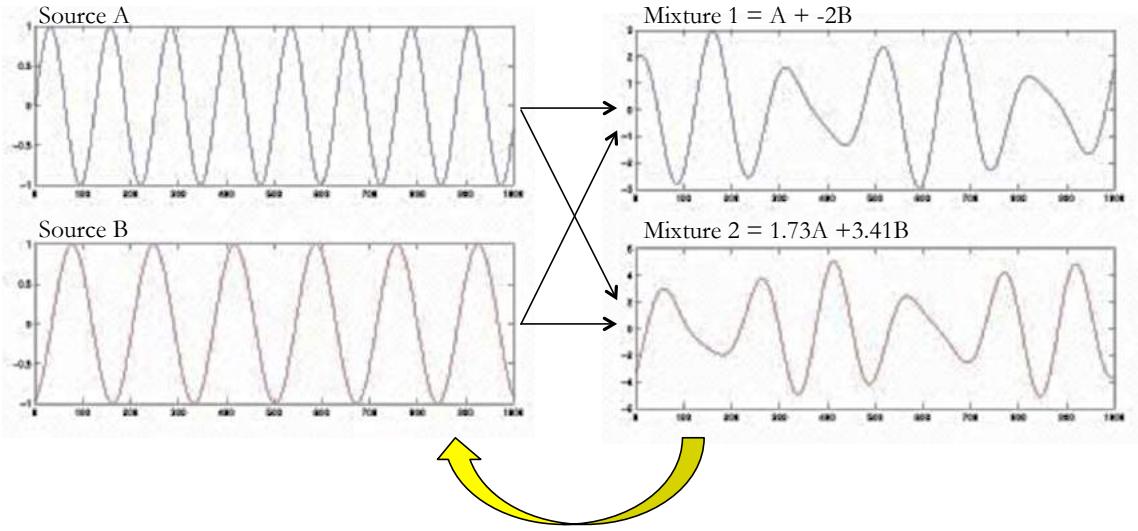


$w_{i,j}$ = weight from component i to Electrode j
w_i = scalp distribution of component i

Mixing Matrix

	Component 1	Component 2	Component 3
Electrode 1	1	0.5	1
Electrode 2	0.25	0.5	0.75
Electrode 3	0.5	-0.5	0.5

Mixing and Unmixing

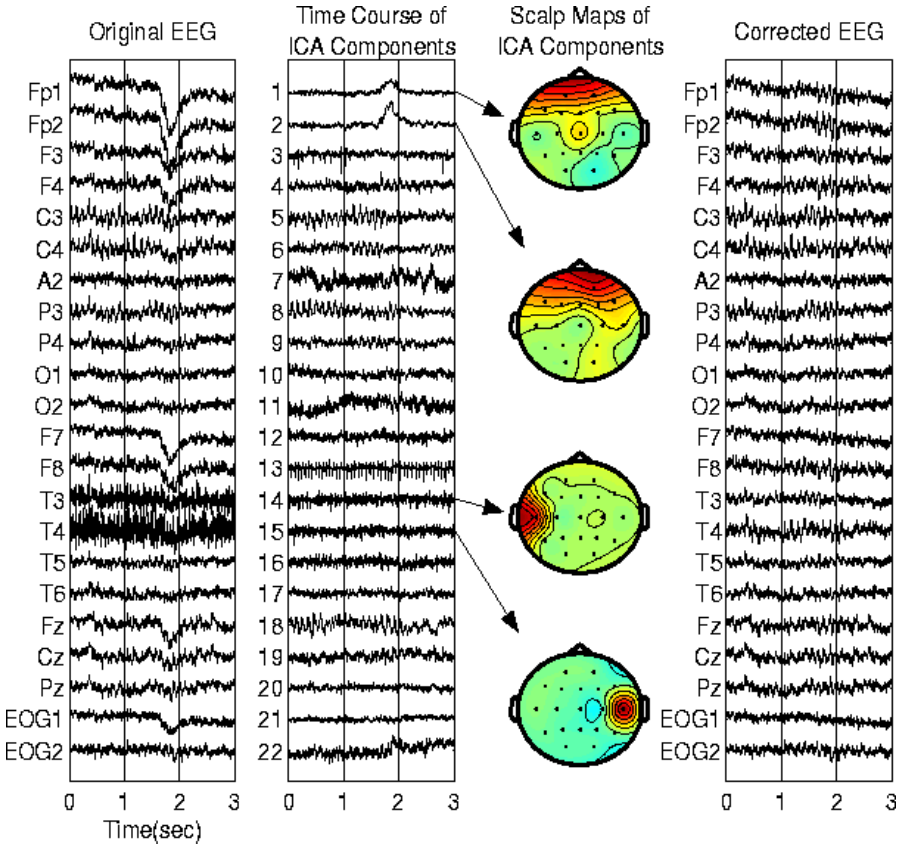


Goal of ICA- Figure out an "unmixing" matrix that will allow us to recover the time courses of the sources from the observed mixtures

Blind Source Separation- No assumptions about the sources except that (a) they are independent, and (b) # of sources = # of mixtures

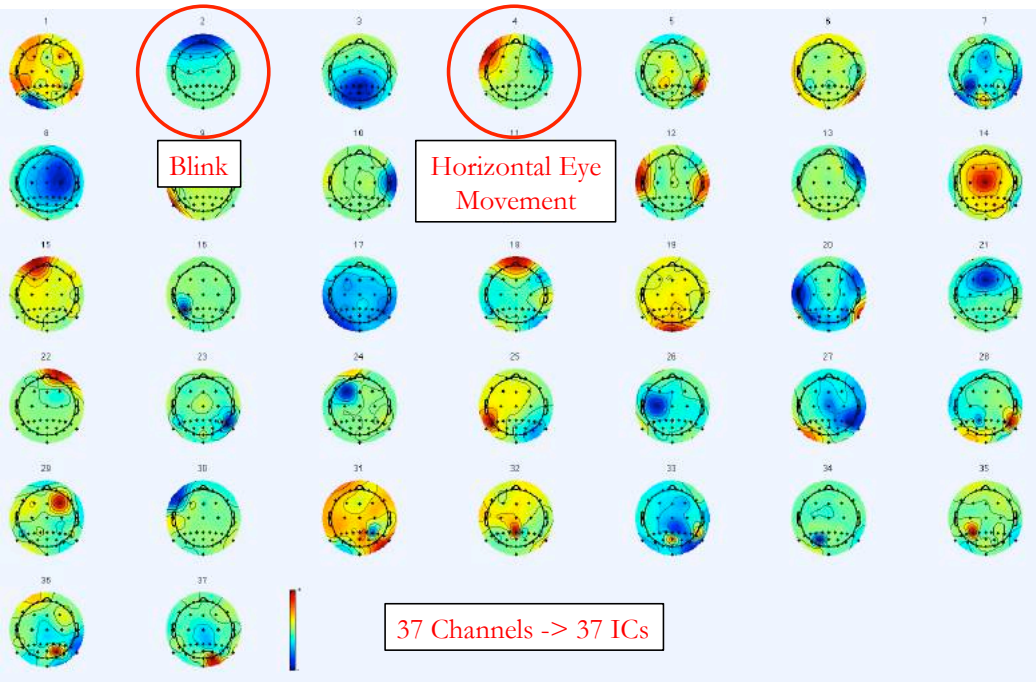
Artifact Correction with ICA

- In most (but not all) cases, artifacts will have a fixed scalp distribution and will be statistically independent of brain acitivity of interest.
  - Examples: Blinks, line noise
- To remove artifact, data are reconstructed by simply adding together the non-artifact components

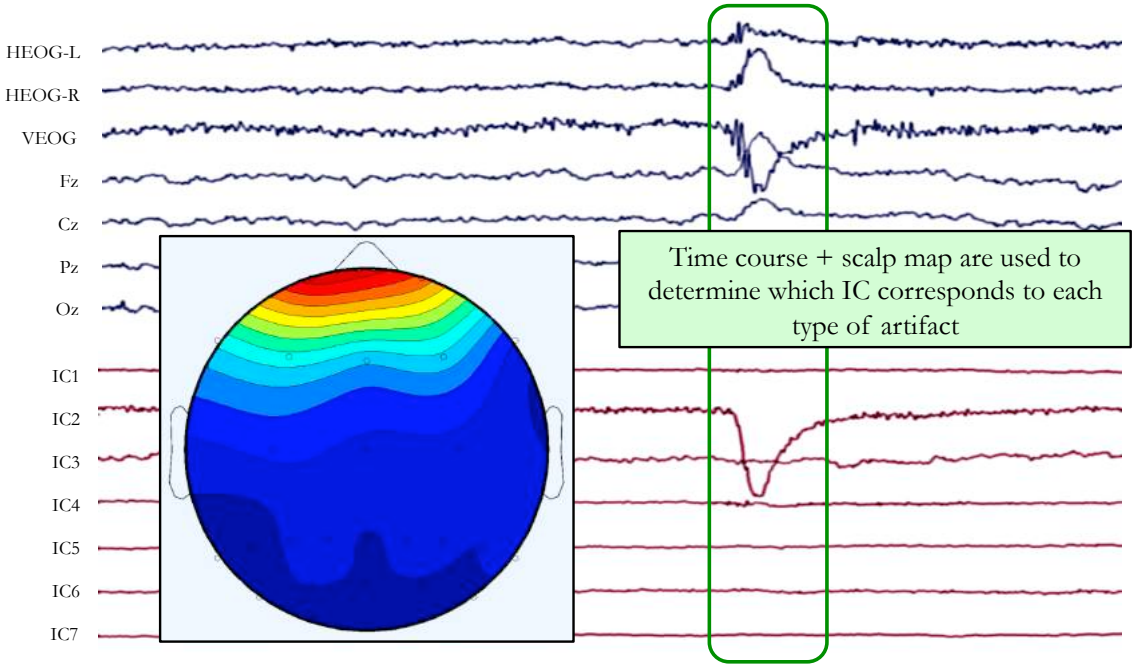


http://www.sccn.ucsd.edu/~scott/tutorial/icatutorial8.html

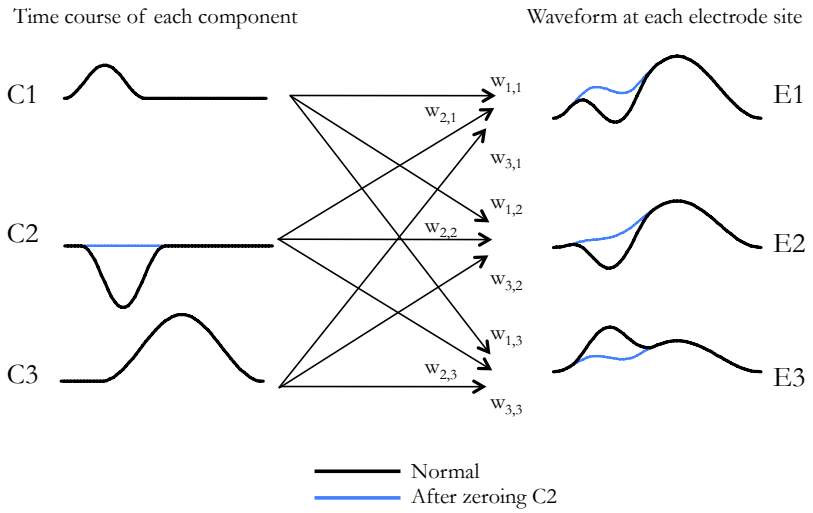
ICA Component Maps



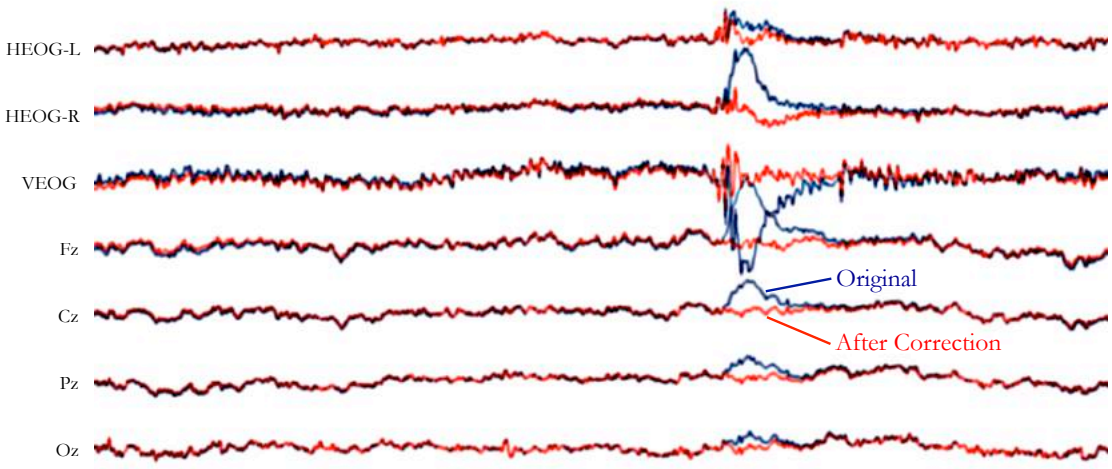
Single-Trial Time Course



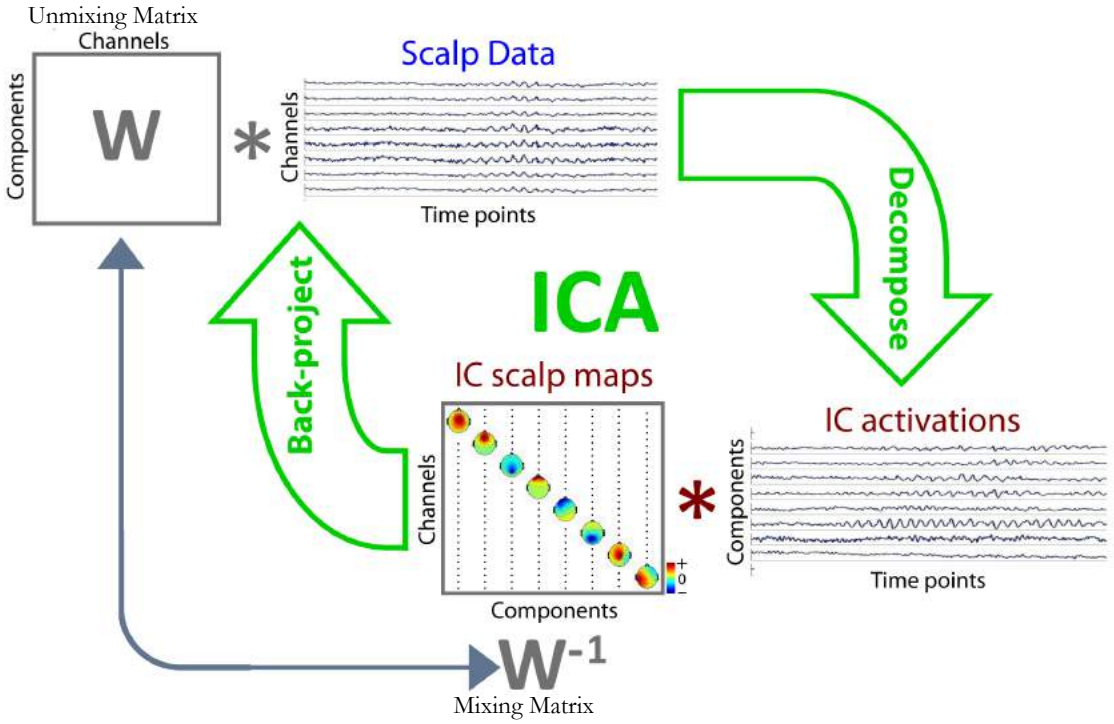
General Logic



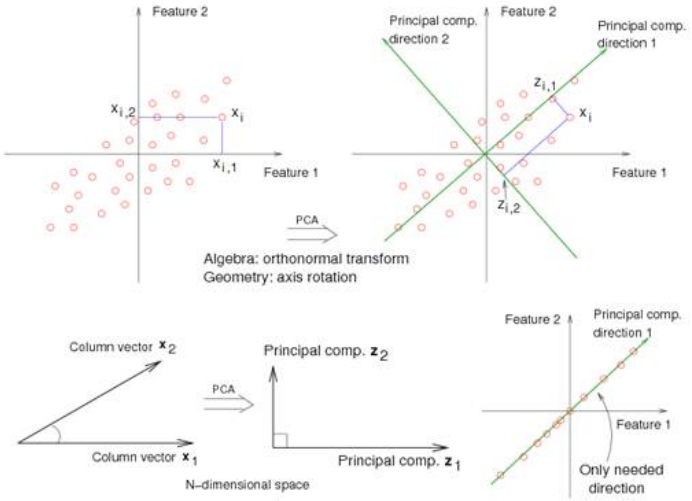
Single Trial After Correction



ICA Flow



Modified PCA



Lin Z., Chen M., Ma Y. (2010). The Augmented Lagrange Multiplier Method for Exact Recovery of Corrupted Low-Rank Matrices. arXiv:10095055.

BACK TO AUTOMAGIC...

Pre-processing with Automagic

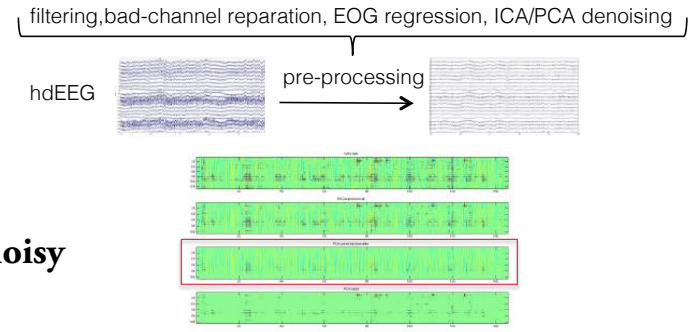
Filtering
- Highpass-filter (~1Hz)
- Optional lowpass-filter
- Notch-filter (50/60Hz)

Detect and interpolate noisy electrodes

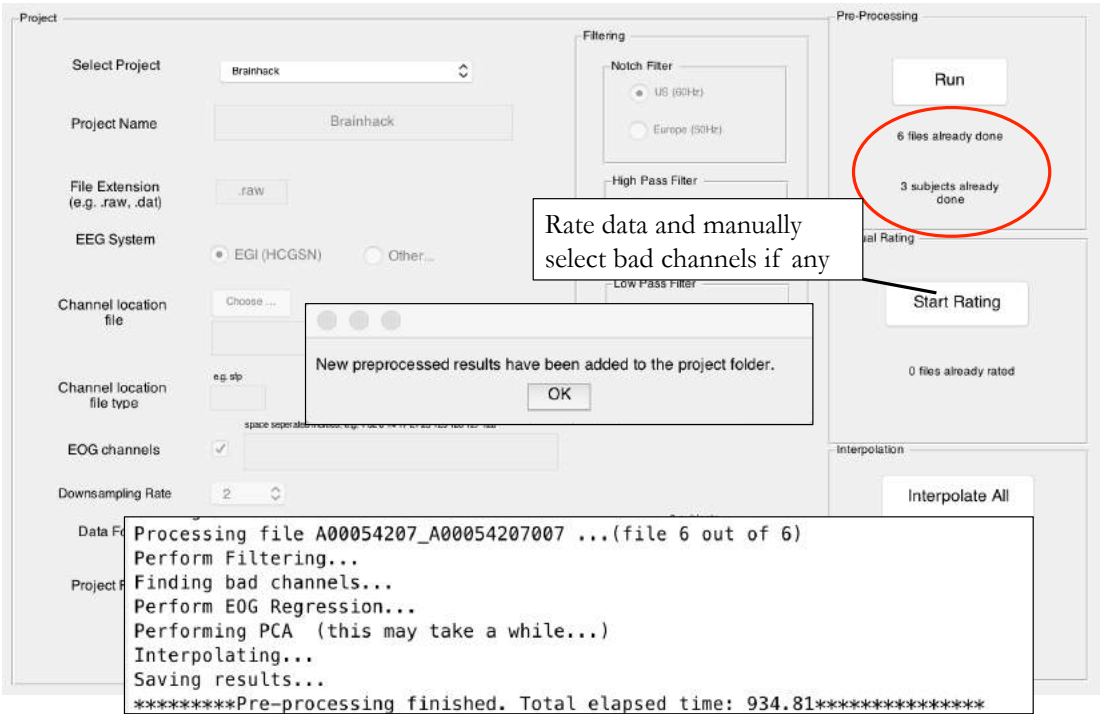
Regress out eye-artifacts

ICA or PCA

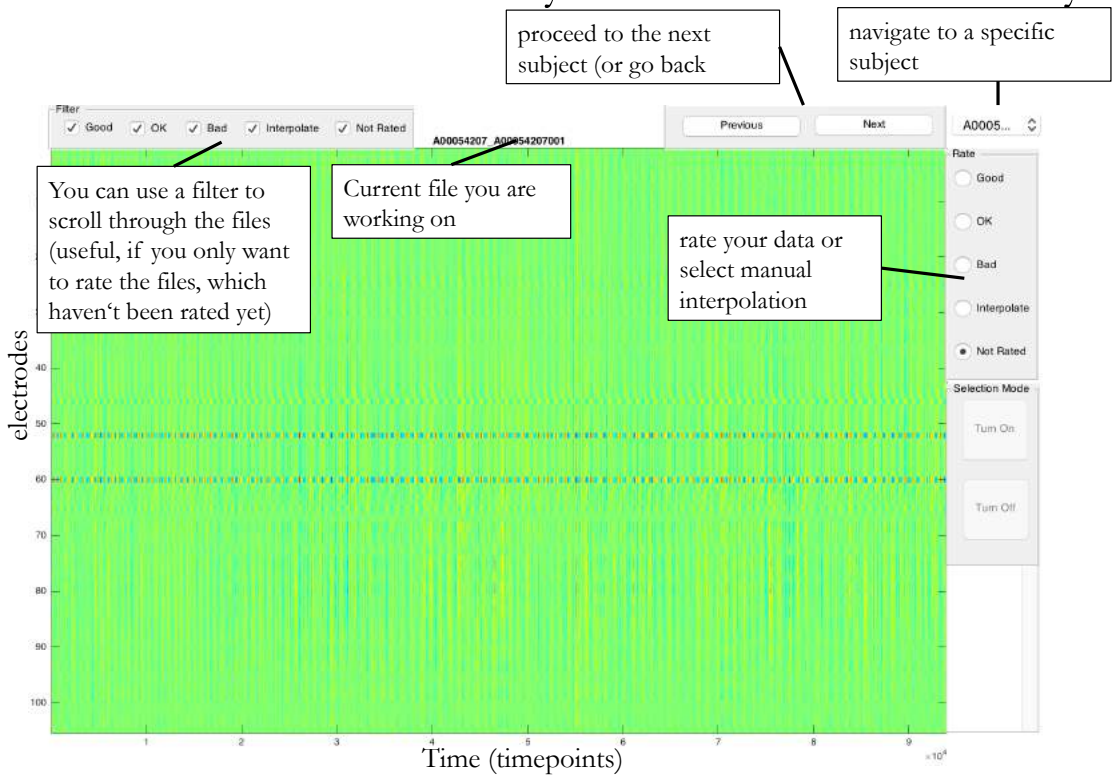
Visual inspection and rating of data quality



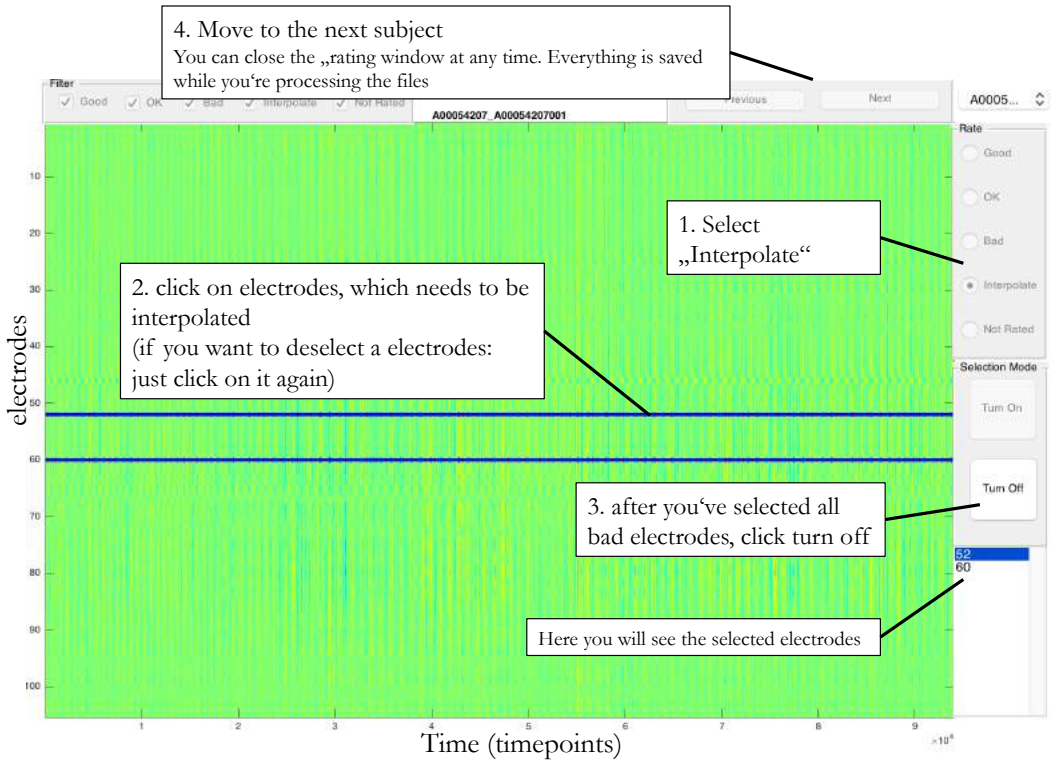
3. Rate data and manually select bad channels if any



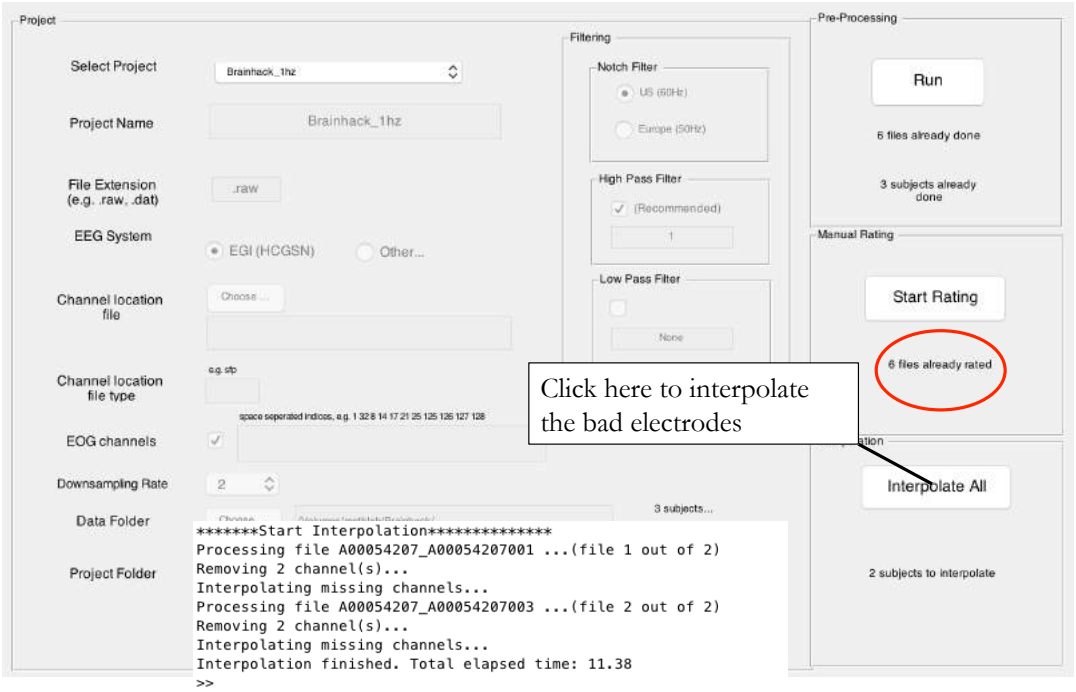
3. Rate data and manually select bad channels if any



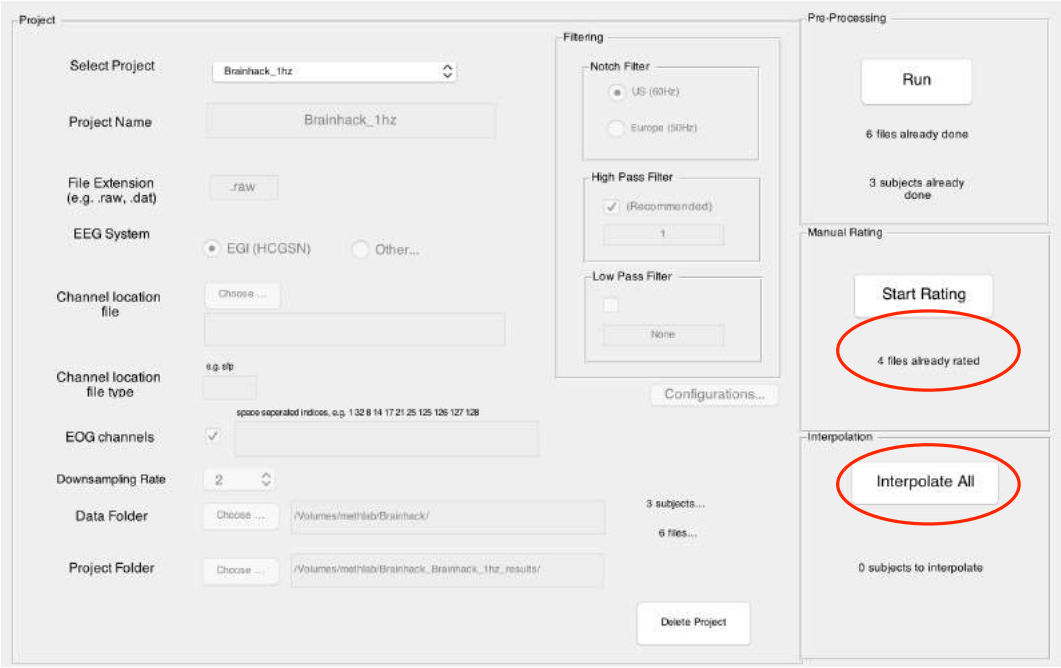
3. Manually select bad electrodes



4. Interpolate all bad channels



5. Repeat steps 3 and 4 until all data is rated



Pre-processing with Automagic

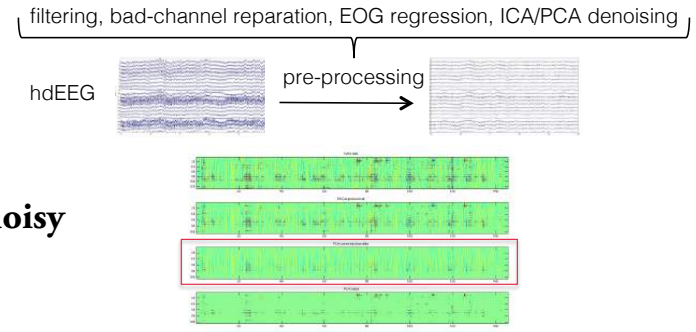
Filtering
- Highpass-filter (~1Hz)
- Notch-filter (50Hz)

Detect and interpolate noisy electrodes

Regress out eye-artifacts

ICA or PCA

Visual inspection and rating of data quality

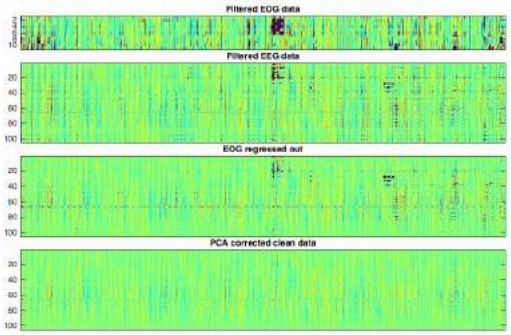


OUTPUT of Automagic

- What‘s in the „Results“ folder:

Automagic creates for each EEG file 3 output files:

- Data quality image (.jpg)
- **The final (clean) pre-processed file (.mat)**
- The downsampled raw file (reduced2_xxx.mat)



There‘s also a „*project_state.mat*“ file in the results folder. You can ignore that, but don‘t delete it.

OUTPUT of Automagic

The final (clean) pre-processed file: **nomenclature**

gip_subject1_file1.mat

First letter indicates quality of the data:
g = good
o = okay
b = bad
n = not rated (yet)

gi**p**_subject1_file1.mat

An „i“ indicates that some electrodes were interpolated.

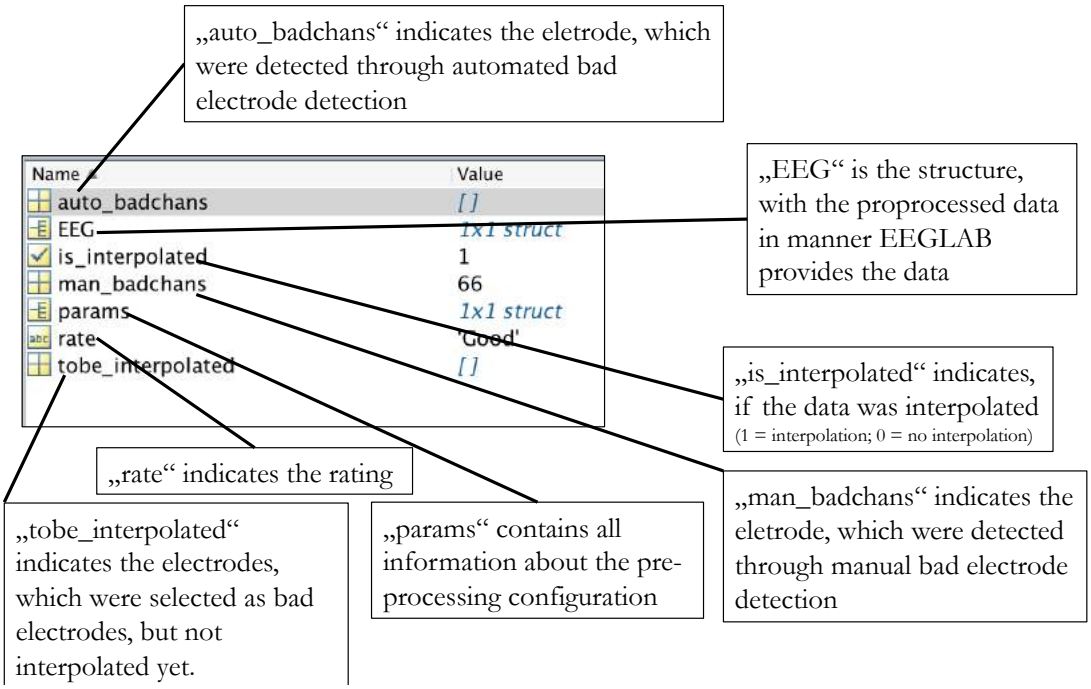
An „p“ indicates that data was pre-processed

Other possible file names:
gp_subject1_file1.mat
gp_subject1_file1.mat
oip_subject1_file1.mat
op_subject1_file1.mat
bip_subject1_file1.mat
bp_subject1_file1.mat
np_subject1_file1.mat

OUTPUT of Automagic

The final (clean) pre-processed file contains 7 variables in MATLAB

(try to load it in MATLAB)

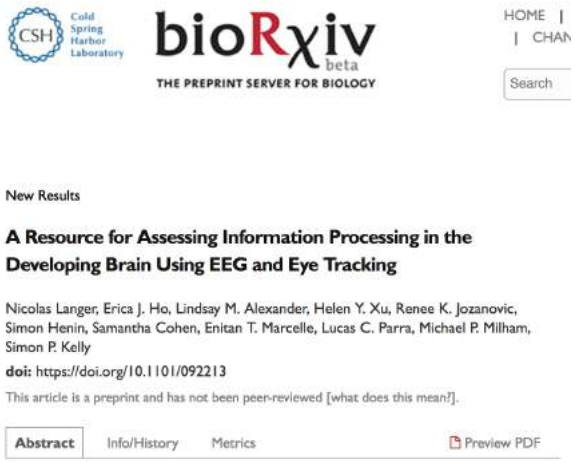


Do I really need to use the GUI?

- NO! You can use the individual pre-processing files independent from the gui. (see Automagic manual)
- All m-files are in the „preprocessing“ folder

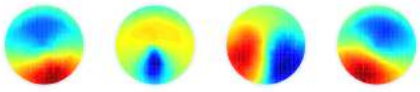
You need data? Here you go:

FREE EEG AND EYE-TRACKING DATA SET

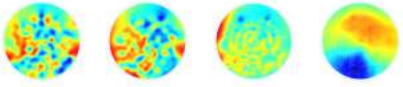


Validation

Microstates with Automagic



Microstates without Automagic



Credentials

„No one can do EEG pre-processing better than I do, except maybe Automagic. It‘s magic.“ Donald Trump, 2017, Journal of Alternative Facts