Pre-analysis of concurrent
EEG and eyetracker data

Table of content

1. Introduction

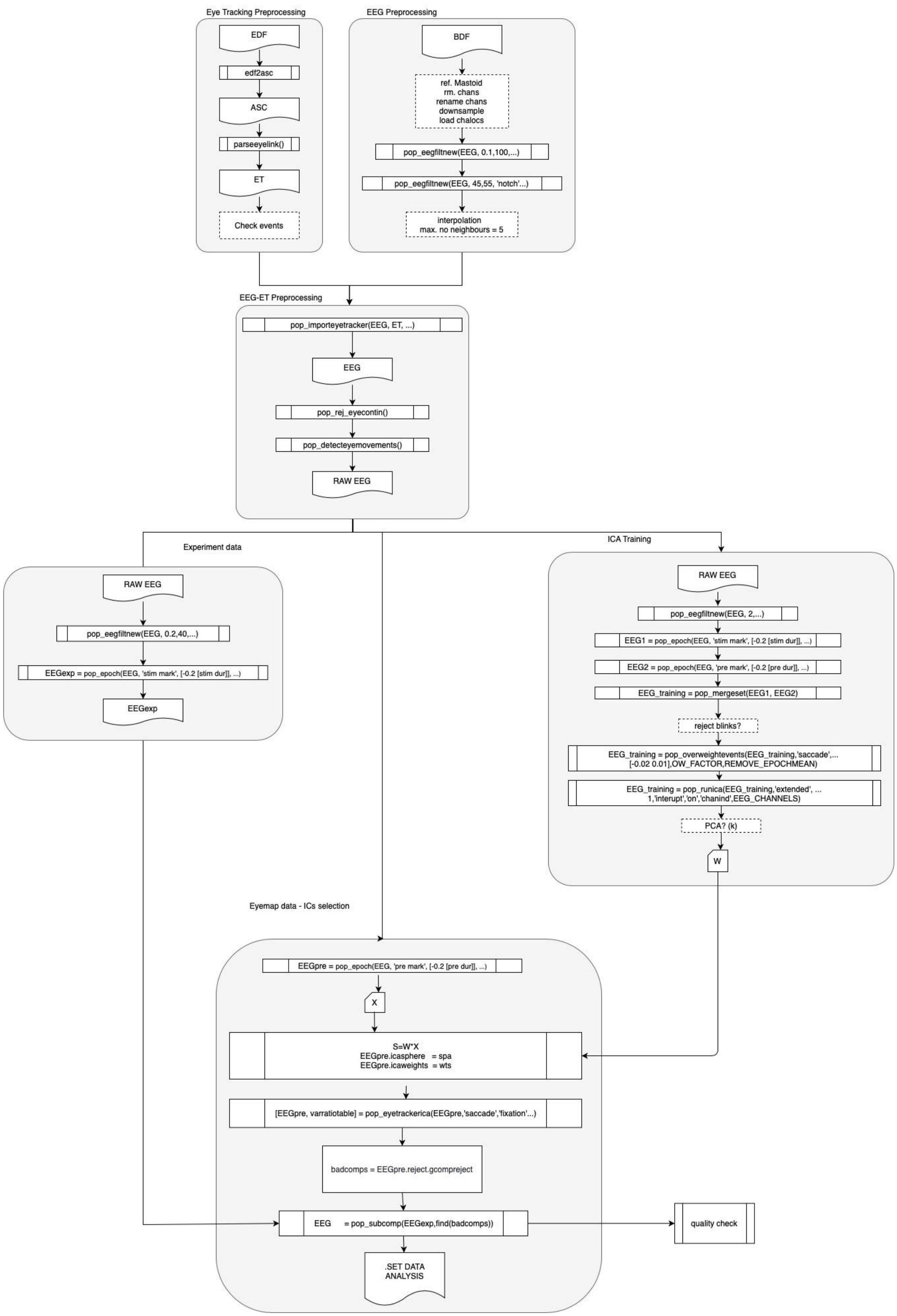
Recording concurrent EEG and eyetracker data provides a rich framework to study natural vision and visualsearch. However, EEG data from these experiments is known to be highly polluted by different potentials related to eye movements which produce spurious effects on data. One well known technique used to improve the signals is ICA that enables us to find a linear transformation of data into a space where artifacts may be found in a few components and then removed before coming back to original space.

In order to capture as much as possible from the non desired patterns one option is to carry out a pre-experiment or eyemap to overweight these effects on training and also to have determined windows to later recognize the ICA components more susceptible to these known exaggerated eye movements (Plöchl).

Here we mainly use for filtering and training the parameter suggested by Dimingen in OPTICAT where he presented an improved version of the classic ICA use for cleaning the signal from eye artifacs. The method includes an overweighting step, before ICA training, for spike artifacs we also used here. Although the way we chose to use the ICA trained data was to apply Plöch variance criteria only on eyemap/pre-experiment data to detect ocular artifact related components. Afterwards these selected ICA components were removed from the analysis dataset.

2. Chart for the pre-analysis pipeline

Text



3. Block description

General description

The pipeline is made of six blocks, each of which contains different functions. In an attempt to keep the code compact as well as having acces to any function independently we wraped these functions in a class called *FP_basePreAnalysis.* The functions which should be used ubiquously through the pipeline, general functions of accesory use, were set as static methods while the important ones which need arguments that generally doesnt change along the whole pipeline, save for the *inFile outFile* variables, were fed using a property *cfg,* a struct containing the pertinent information. On top of that there are some functions deffined by the user that are passed to the main class when this is instantiated regarding the value of the property *Mode:* e.g. 'bb', 'dac'

fp = FP_basePreAnalysis('bb') ,

From now on the functions called as *fp.fn.xx* would be the ones deffined by the user 'bb' as static methods of the custom class FP_bb() this way the user can tune every step of the pipeline according to the characteristics of their experimental data. All functions involving EEG data manipulation were ended with a line *´eeg_checkset(EEG)´.*

We implemented each block in separate sections of the main preanalysis script where the pertient information was passed through the *cfg* property struct.

E.g.:

```
fp.cfg.inFile        = [ folderIn   suj ];
fp.cfg.outFile       = [ folderOut  suj '.set'];
fp.cfg.ref           = [69 70];              % vector of references for mastoids
fp.cfg.nChansKeep = 64;                      % number of channels with data
```

Eyetracking preprocessing block

The *EDF* files are transduced into *ASC* files and then parsed using *parseeyelink.m* funtion from eye-eeg toolbox of MATLAB. Here we checked marks that would be used later to sychronize (e.g.: eyemap , preexperiment). Parsed data is store in *ET* structure.

In Nottingham data marks where not correctly parsed so I had to look for relevant events (eyemap) and reasing values to them a user defined function were apply automatically after *parseeyelink.m* for this purpose when in mode ='dac' the function *ET_preprocessing* were run.

EEG preprocessing block

First a custom deffined function *EEG_preprocessing()* is to cheked if the number and name of channels is correct based on *Mode* property value. Then the *EEG_prefiltering()* is called which implements the notch filter to eliminate power-line noise and a bandpass filter.

fp. cfg.lineFreq = 50; %the notch filter would use [47.5, 52.5]
fp.cfg.preFilterEdges = [0.1 100];

The filter edges were chosen following recomendations of the OPICAT analysis in NeuroImage 207 (2020) 116117. The idea is to preserve ocular artifact ralated information to be captured later by ICA. Interpolations were carried out according to the array *badchanlist.*

E.g.:

```
badchanslist = {'EEGEYEE01', [52];
                'EEGEYEE02', [28 2];
                'EEGEYEE03', [34 52 54];
                ……}
```

EEG-ET preprocessing block

This block is basically a pipeline of three functions from eye-egg toolbox which implement sequentially the synchronization of EEG and ET data , rejection of bad data (actually it was rather marked for future rejection as 'Bad_data') and the algorithm of eye movement detection proposed in Engbert & Mergenthaler, 2006. This was carried out by *fp.EEG_ET_sync()* and *fp.engbertDetection()* functions, the relevant configuration values in this step are.

```
fp.cfg.inFileEEG = [folderIn suj '.set'];
fp.cfg.inFileET  = [ etMATfolder suj 'ET.mat'];
fp.cfg.eye       = 'L';%eye to be used 'L'
```

Each user can here define a way to rename events relevant to synchronization *fn.renameEEGevents(EEG).*

The functions for rejection and recognition have several parameters that were chosen following recomendations from the toolbox documentation. When the function *pop_importeyetracker()* is run a figure pops showing the amount of marks that were matched and a histogram of errors to measure the quality of synchronization.

At the end of this block we have our RAW EEG already synchronyze.

ICA training block

The goal here is to prepare data to let ICA “learn” as much as possible about artifacs, keeping high frequencies that would seem uninteresting regarding ERPs and overweighting some specific events is a way of enhancing this learning.
First a high-pass band filter is applied to the data to avoid adverse known results on ICA training explored in OPTICAT paper. The *fp.trainICA()* function implements the filter and then creates a continuous data out of stimuli epochs and eyemap (preexperiment) epochs. This function also implemets bad data rejection, previously marked as so, and the overweighting of spikes provided by *eye-eeg* toolbox function *pop_overweightevents().* Finally it runs *binica()* with PCA depending on the initial and final amount of channels and the amount of interpolated channels so that no singular matrix is obtained on ICA iterations. The output of the block is:

weights.sph = sph;
weights.wts = wts;

Experiment data block

This branch is devoted to data that is going to reach the end of the pipeline transformed into the data analysis set. The function *fp.epochData()* implements a band-pass filter (we used [0.2 40] as frequency edges) and the *pop_epoch()* function contruct epochs with stimuli parts of the data so that we passed the relevant marks and trail information.

```
postFilterEdges    = obj.cfg.postFilterEdges;
chanlocsFilePath  = obj.cfg.chanlocsFilePath;
noFiltAnalog        = obj.cfg.noFiltAnalog;
stimMark              = obj.cfg.stimMark;
preMark               = obj.cfg.preMark;
trialDur               = obj.cfg.trialDur;
```

ICs selection block

This block combines the three outputs from previous blocks and rejects ICA components from the data analysis set in order to filter out ocular artifacts. First, the function *fp.selectIcPlochl()* takes the raw data coming from EEG-ET preprocessing block and extracts eyemap/pre-experiment epoched data to apply the Plöchl criteria. Before doing that old ICA data is deleted from de EEG estruct and learnt weights and sphere data are added, then *pop_eyetrackerica()* from *eye-eeg* is run. Parameters needed here are the location of raw synchronized data and:

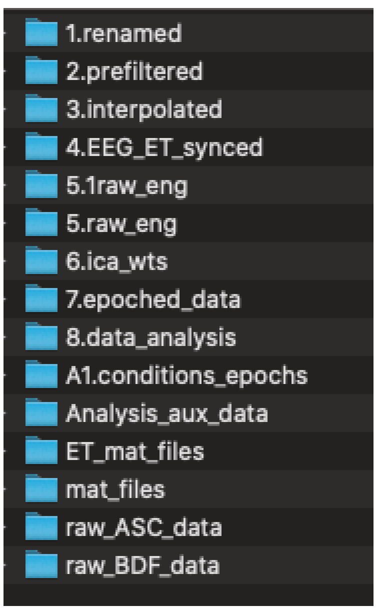
fp.cfg.weights

Lastly, the function *fp.removeComp()* takes the selected componets and the output from experiment data block as arguments:

fp.cfg.badcomp = EEG.reject.gcompreject

4. Data storage structure used

I used numerated folders for each step of the main script the list is as follows:

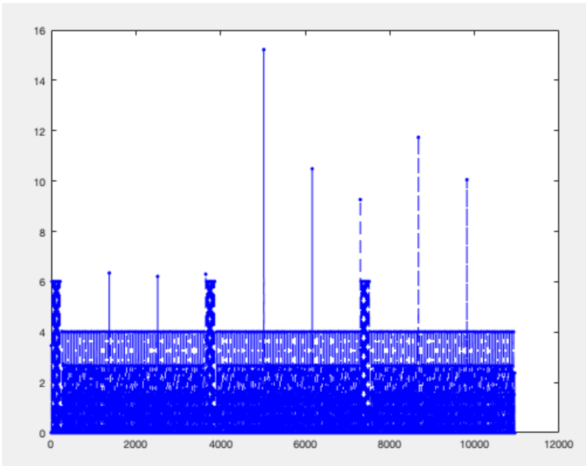


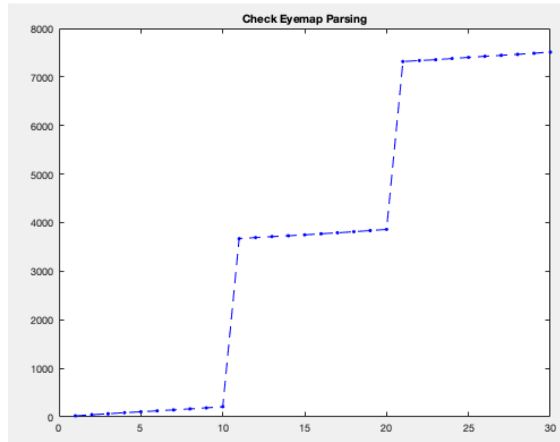
5. Pre-analysis script

Some blocks were implemented in several sections mainly because of the need of visual inspection between steps to control for quality and validate the actions.

<u>ET events recognition and renaming check:</u>

To find marks corresponding to eyemap events I took all the 'BUTTON's events parsed from ASC file and looked for the ones whose differences were according to the known eyedata duration and renamed this events as '290' then I found the corresponding mark related to the end ok the last trial and named it '300'.
To check the consistency of this proceeding a plot of marks vs time were shown when custom function *fp.fn.renameEtEvents()* was called by *fp.ET_preprocessing().*

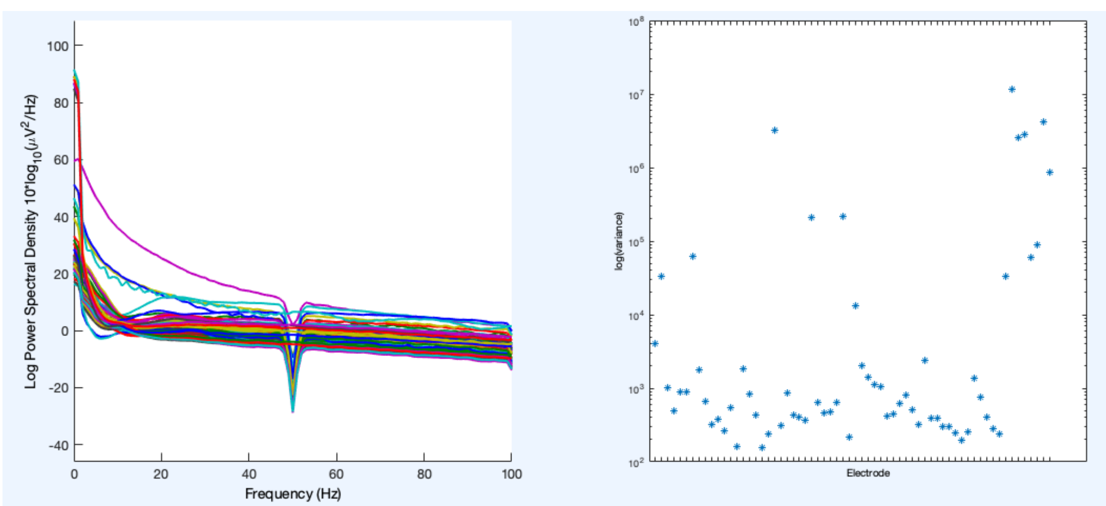




EEG channels and reference quality:

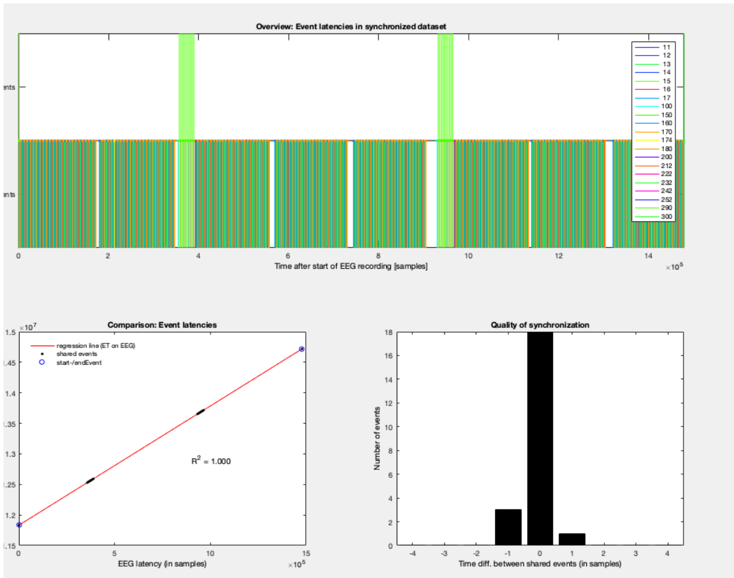
Here the function fp.EEG_selectChanInterpolate() was used to evaluate power frequency distribution for each channel and variance, looking for abnormal noises or loss of signal. Visual inspection of these plots were needed to construct the *badchanlist* array.

E.g.:



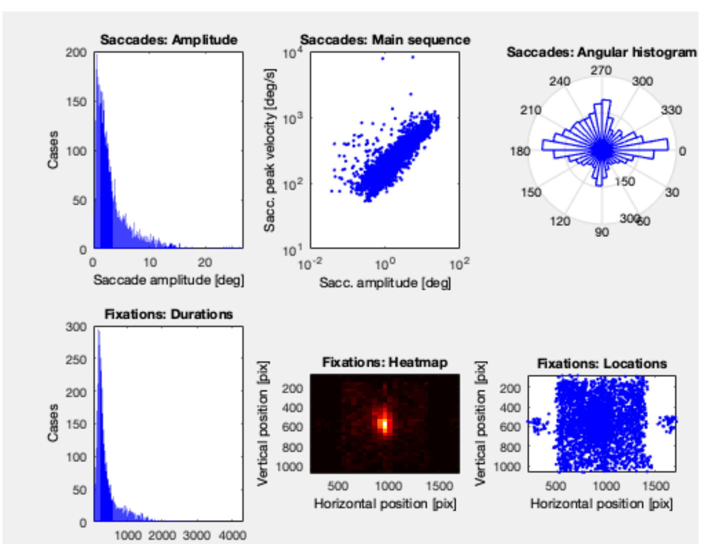
EEG-ET synchronization quality:

The *pop_importeyetracer()* funcion shows a figure with matching marks in both files and how well they were synchronized. The criteria was that no more than 3 marks could dephase more than one sample.



Engbert algorithm check:

The eey-eeg function shows recognized eye movement properties: histograms of recognizaed fixations ,sacades and angular histograms ; analysis of saccade velocity vs saccade ampllitud; fixation location and heatmap. All these properties were checked for each dataset controlling they were typical.



ICs selection check:

Although the Plöchl criteria along with filtering parameters and training suggestions from OPTICAT succeeded in automatically detect artifactual components manual selection were also carried out to include those components with obvious ocular movement sources looking at ICA components projections on the scalp. Whenever a componet had a frontal or too localized and periferical projection its spetral were inspected so that to find …….