EEG Data Eye-movement Artefact Rejection in SPM v1

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1 Introduction

This exercise teaches you the principles of removing eye-movement artefact from EEG data using Statistical Parametric Mapping (SPM). The exercise is based on Chapter 41.5 of the SPM12 manual, using a sample data set provided by Marta Garrido (MMN Dataset) from the SPM team of the Wellcome Trust Centre for Neuroimaging. The exercise duplicates most of the text from the chapter, but amendments have been made to suit the timeframe of this exercise.

The analysis of EEG/MEG data is not as standardised as the analysis of fMRI/PET data. There exist a number of software packages for EEG/MEG analyses. This exercise uses SPM, a newer way to approach EEG/MEG data. In contrast to commercial analysis packages (e.g., BrainVision Analyzer), SPM is freely available to the scientific community. The use of a readily available software and data set allows you to reproduce and extend your learning at home.

You will learn how you might analyse EEG data from a single subject in an auditory processing experiment. The experiment focuses on the mismatch negativity, an ERP component elicited by deviant stimuli. Work through the exercise, exploring as you go along. Reading Chapter 41.5 of the SPM12 manual provides additional help to understand the processing steps and you can get additional information via the `help` function in SPM. You can download SPM manual from this link.

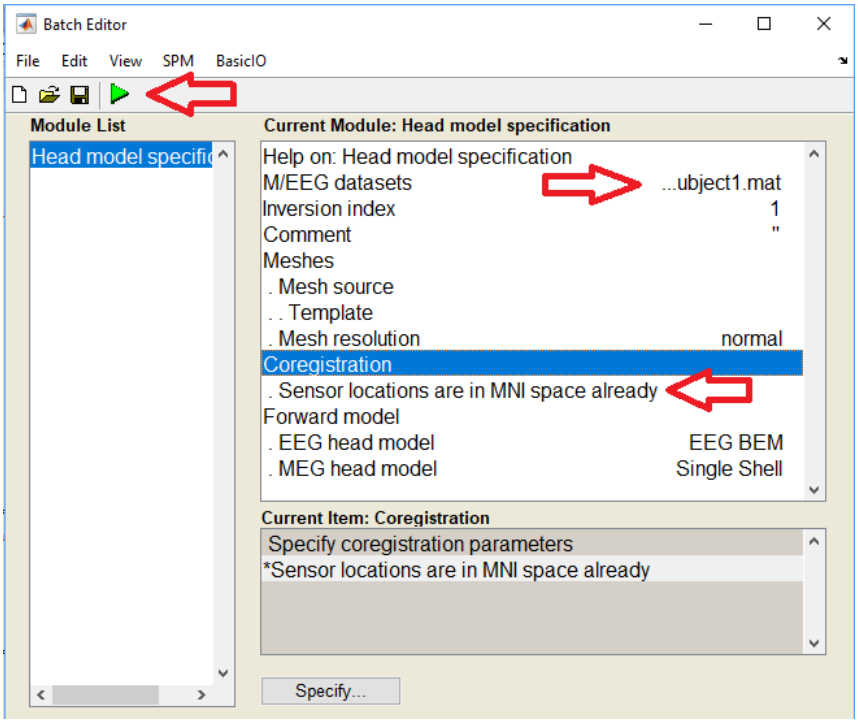
The following analysis is quite similar to Independent Component Analysis (ICA). However, unlike for ICA there is no need to in the time consuming procedure of estimating physiological and artefactual components based on data statistics. But rather these are provided to the algorithm explicitly by the user. This makes the method faster and easier to use. This method is called “Topography-based Artefact Correction”.

2 Practicalities

We will use the filtered and downsampled dataset from the other handout (SPM EEG Analysis). The EEG data have been copied onto the local hard disk of your computer to speed up the analyses and to allow sufficient disk space. The data are in the `Data` folder.

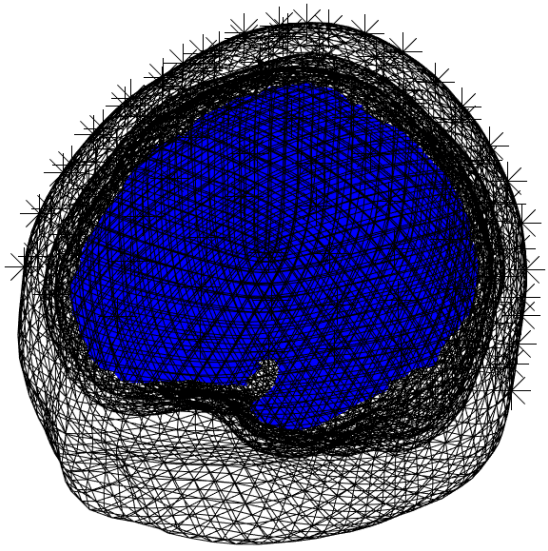
The following files are provided: `dfMspmeeg_subject1.dat` and `dfMspmeeg_subject1.mat`

After this exercise, you should be able to automatically remove eye-blinks and eye-movement artefacts from EEG data.



3 Forward Model

Let us start with defining a forward model. To do so you need to open Batch Editor window (by clicking on Batch in SPM12 Menu window). Then from menus select SPM → M/EEG → Source Reconstruction → Head model specification. Select dfMspmeeg_subject1.mat file as input, under Coregistration switch to Sensor locations are already in MNI space and run the tool. You should see a head model after run. This head model is now added to dfMspmeeg_subject1.mat file (no extra files are created at this stage). You can save your batch and clear the batch for the next step (the save and new options in the File menu). Now we are ready to proceed.



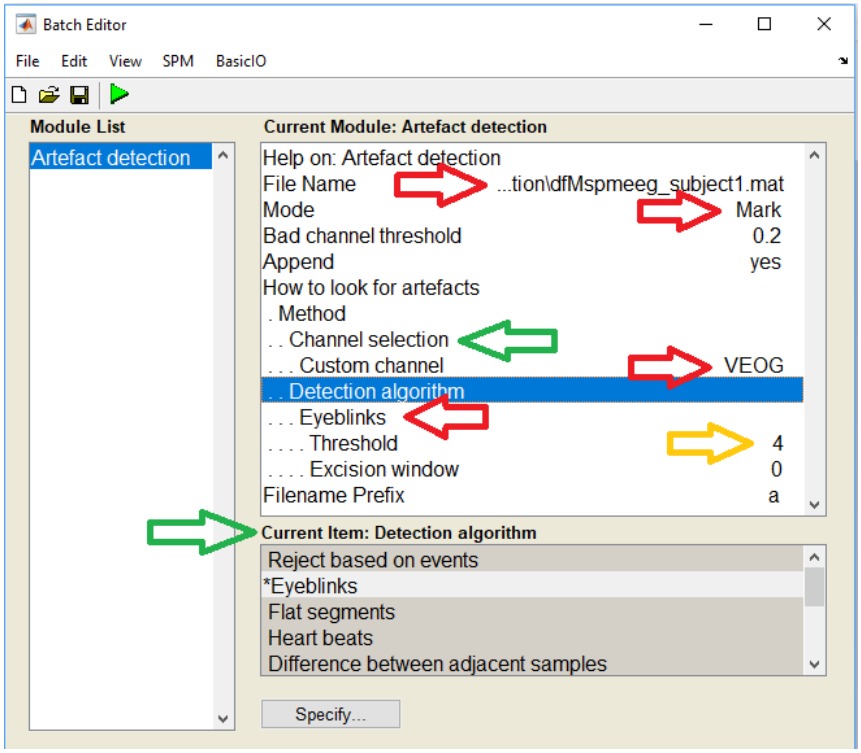
→ For reasons that will become clear below we might need a forward model for some of the steps we will demonstrate. In principle, however, depending on the settings topography-based artefact correction is also possible without a forward model.

4 Artefact Detection

From the menu, select SPM → M/EEG → Preprocessing → Artefact Detection.

1. Select the dfMspmeeg_subject1.mat file as input.
2. Change Mode from Reject to Mark.
3. In How to look for artefacts make a new method (by selecting New: Method).
4. In Channel selection delete All (by selecting Delete: All(1) in the Current Item window), add Custom channel and enter VEOG (capital letters) for the channel name. If in your own data you do not have an EOG channel any scalp EEG channel or MEG channel with clear eyeblinks can be used for the same purpose.
5. Under Detection algorithm choose Eyeblinks.

Keep the default settings and run the tool. In SPM12 Graphics window two plots will appear and adfMspmeeg_subject1 files will be created. The top and bottom plots show the points where blinks were detected and aligned blink time courses, respectively. For topography-based correction it is not critical to detect all the blinks, just a representative sample will suffice. If you think too many non-eye-blinks or too few eyeblinks were detected, you can adjust the Threshold parameter.



5 Epoching Data Around Eyeblinks

At the next step we will epoch the data around detected eyeblinks. From the menu, select SPM → M/EEG → Preprocessing → Epoching.

1. Choose the adfMspmeeg_subject1.mat produced by the previous step as input.
2. In How to define trials choose Define trial.
3. Set Time window to [-500 500].
4. Under Trial definitions create a new trial with label Eyeblink, event type artefact_eyeblink (exact spelling) and event value 'VEOG' (capital letters and with single quotes).
5. Set Baseline correction to no.
6. It would also be a good idea to change the default out prefix e to eyeblink because we might epoch the same file later around stimuli and we would like to avoid a name clash.

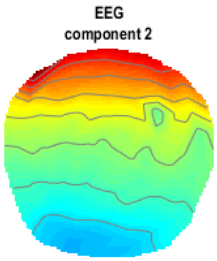
Now you can run the batch. The output dataset eyeblinkadfMspmeeg_subject1 will contain epochs with eyeblinks. You can review it in the reviewing tool (from the SPM12 Menu window, Display → M/EEG) and also average to get an average eye blink (from SPM12 Menu window, Average). Either epoched or averaged eyeblink file can be used to define eye blink topography. We will use the epoched file as this might enable to also better capture the variability between eyeblinks.

6 Define Spatial Confounds

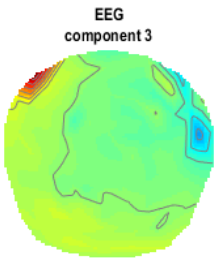
From the menu, select SPM → M/EEG → Preprocessing → Define Spatial Confounds. Use the eyeblinkadfMspmeeg_subject1 as input. From Current Item section, New: SVD under Mode. The tool performs singular value decomposition of the trial data to find the spatial patterns that explain most of

the variance in the data. What we would like to do now is to keep for artefact template the minimal number of components that are clearly eye-blink related. Since we do not know what that number is we could start with a large number such as 4 (set in Number of components) and run the tool.

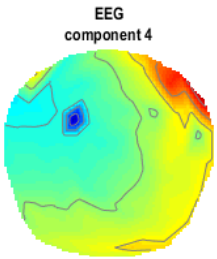
A plot will appear with four subplots in it. For averaged referenced EEG eyeblink related activity appears at the frontal sensors. Thus only the 2nd of the four components is clearly eye-blink related. We could, therefore, only keep that first two for our correction.



The tool does not produce a separate output file and appends the confound topographies to the same file. So, if you run the same batch again, you will see eight components. So, to keep only the first two components, we need to first clear the current components. We will first Delete: SVD (1) and then click on New: Clear under Mode. Run the tool again and then return Mode to SVD (remember to Delete: Clear as well), set Number of components to 2 and run once again. For your own analysis you might want to explore the typical numbers of eye-blink components for different subjects and runs and decide whether it is safe to always use the same number of check for each file separately.



7 Data Correction



To finally correct the data, we need to first copy the components that we calculated in the previous step to the actual data and then correct the EEG signals based on those. For the first step we will need to use Define Spatial Confounds tool once again, but this time our data of interest will be the input, in this case the continuous data file adfMspmeeg_subject1.mat. Under Mode switch to SPM M/EEG Dataset and choose the eyeblinkadfMspmeeg_subject1.mat for which we defined confounds above. Run the tool and the confound definition will be copied from eyeblinkadfMspmeeg_subject1.mat to adfMspmeeg_subject1.mat.

→ Another way to define spatial confounds is to use the Eyes options under Mode. The idea there is that three orthogonal dipoles are placed at each eye and their lead-fields are computed using the forward model (that's one place where you would need one) and used as artefact topographies. If you want to try this option do not forget to clear the previously defined components first. You can see here that all the six components are expressed at the frontal sensors. This method can also work for removing eye-blinks. Its advantage is that also other activities coming from the eyes can possibly be captured (such as eye movements). However, you will have to sacrifice six dimensions of your data which is effectively like removing six channels. If you do not have many channels to begin with this can distort your sensor waveforms quite substantially (which might or might not matter depending on the aim of your analysis). Also if the forward model is imprecise it can also happen that some eye-blink related activity will not be removed. Thus where possible the data-driven (SVD) approach is advised.

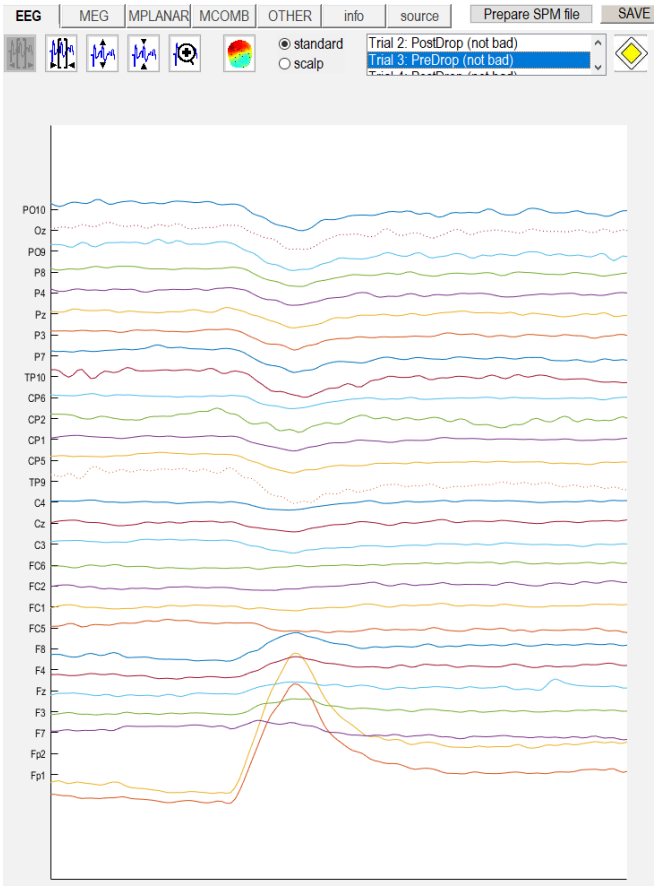
We are now ready to correct our data. Choose SPM → M/EEG → Preprocessing → Correct Sensor Data. Choose adfMspmeeg_subject1.mat as input. There are two options for correction mode. SSP (default) removes everything that can be linearly matched by the artefact topographies from the data. This method does not require a forward model so if you use SVD in combination with SSP setting you do not

have to define a forward model for your data. Berg method uses the forward model to define 'representative' cortical topographies and keeps the part of the variance that is shared between cortical and artefact topographies, thereby only removing the part that is unlikely to come from the cortex.

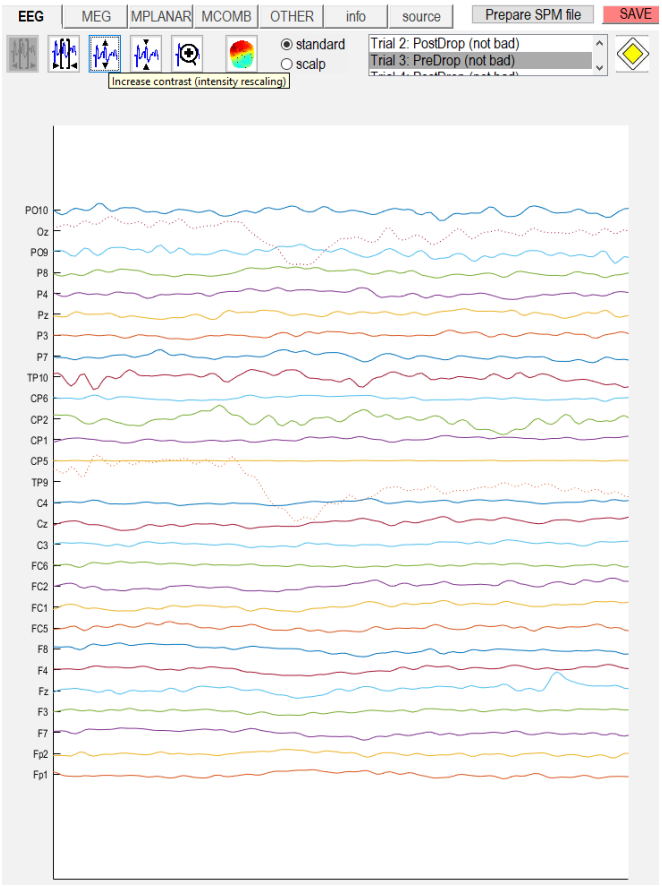
Artefact correction will produce a new dataset with the prefix defined: `TadfMspmeeg_subject1.mat`. You might want to run both SSP and Berg correction changing the default prefix to generate two separate files and compare them later. Review the continuous datasets in the reviewing tool and compare with the uncorrected file to make sure the eyeblinks are indeed gone. You can also epoch and average the corrected files around the eyeblink events and compare the average of the eyeblink dataset we created before (use 'Merge' tool to combined different eyeblinks in the same dataset and plot them together).

Below you can see a comparison between with and without eyeblink on a single trial. This is an epoch of a different dataset with 32 channels only, shown for demonstration purposes. As you can see, the eyeblink visible on Fp2 and Fp1 and also the shift of activity on other electrodes are removed in the without eyeblink condition.

with eyeblink

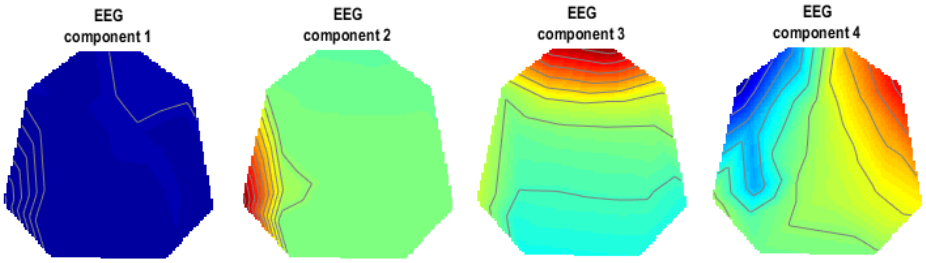


without eyeblink



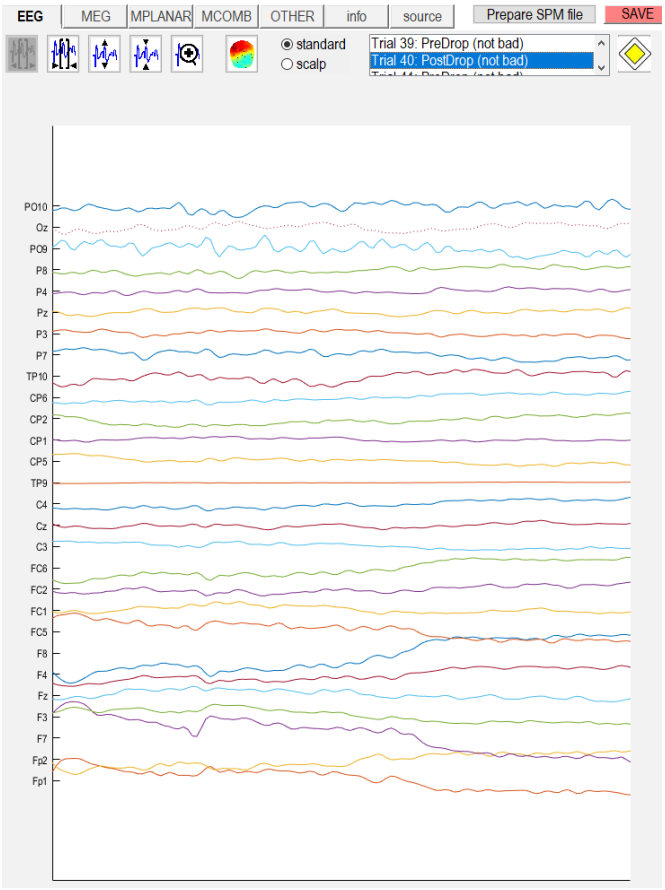
Below you see the comparison between removing three or four compounds of the following four compounds. As you can see the fourth compound represents horizontal eye movement, while the third compound represents eyeblinks.

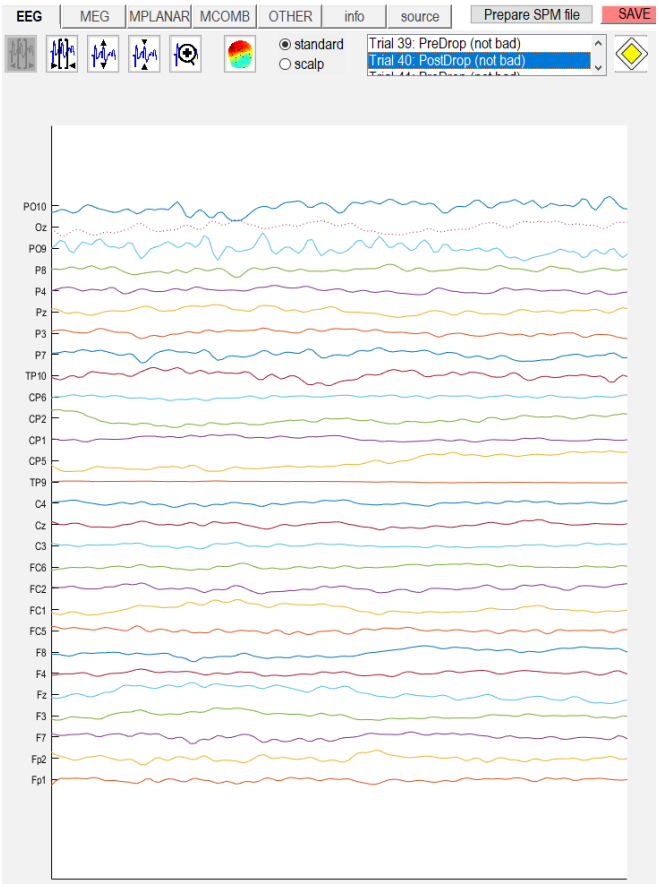
→ Pay attention that including more compounds is not necessarily better, as you might actually remove some of the actual brain activity. Therefore, you need to be very careful in selecting the compounds.



three compounds

four compounds





As a final exercise, you can test the effect of increasing the number of SVD components and compare with the 'Eyes' method.