M/EEG pre-processing

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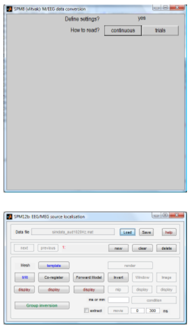
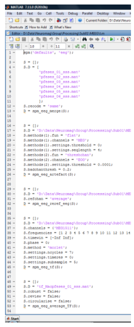
Clarification of terms – SPM speak

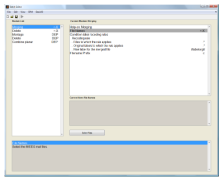
GUI



Script



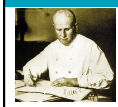
Batch



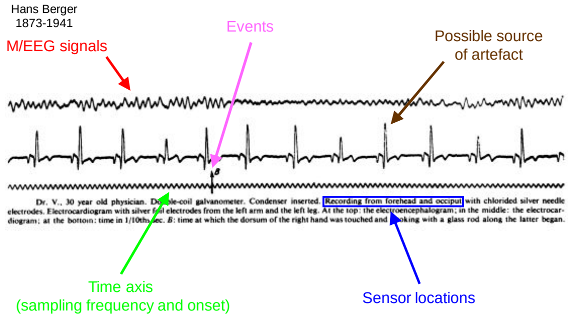
Why batch?

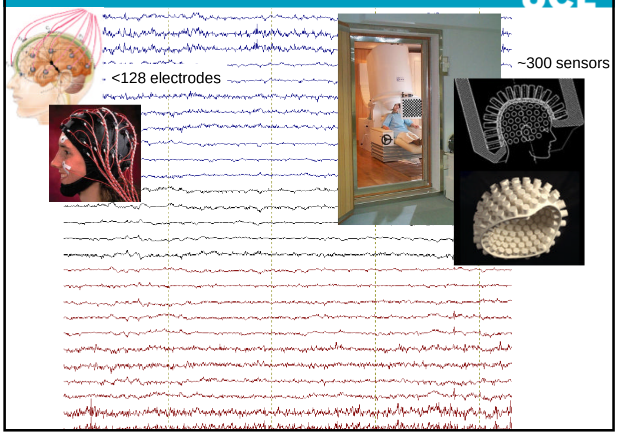
- As opposed to GUI
  - it is easy to reproduce analyses, apply them to different datasets and make modifications.
  - removing interactive GUI elements from the code makes it cleaner and easier to maintain.
- As opposed to script
  - complex pipelines can be built without programming expertise
  - saved pipelines can be examined without deciphering other people's code
  - batch provides uniform interface for scripting to different parts of SPM code.
- Disadvantages of batch
  - there is no step-by-step guiding of the user
  - the need to prepare all the inputs in advance makes some of the operations less intuitive and requires getting used to.

What do we need?

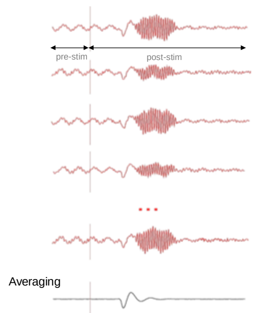


Hans Berger
1873-1941

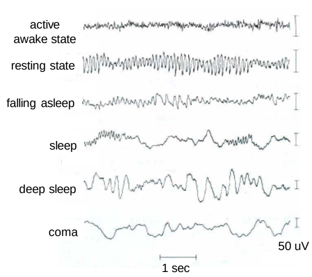




Evoked response vs. spontaneous activity

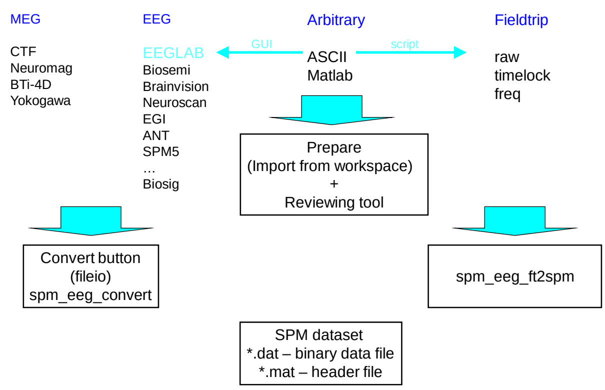


evoked response



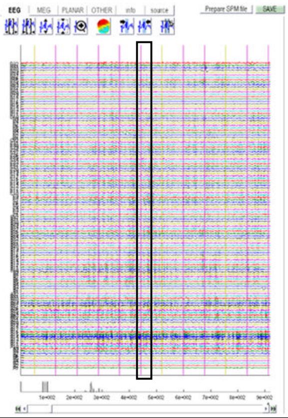
ongoing rhythms

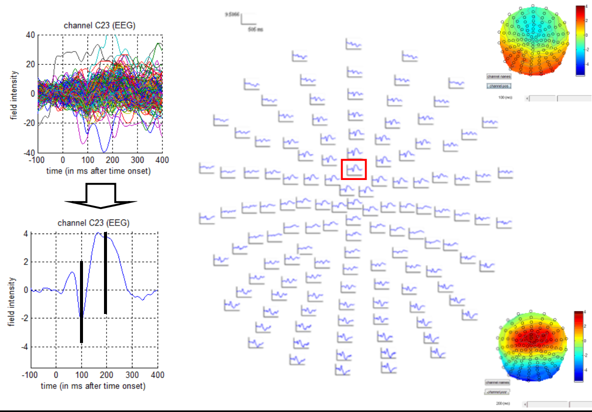
Conversion



Expert's corner

- The *.mat file contains a struct, named D, which is converted to an meeg object by spm_eeg_load.
- The *.dat file is memory-mapped and linked to the object.
- Special functions called 'methods' provide a simple interface for getting information from the object and updating it and ensure that the header data remain consistent.





Now lets take a step back

Sensor locations

MEG:

- Requires quite complex sensor representation including locations and orientations of the coils and the way MEG channels are derived from the sensors.
- Sensor representation is read automatically from the original dataset at conversion.

EEG:

- Requires electrode locations and a montage matrix (optional) to represent different referencing arrangements.
- Usually electrode locations do not come with the EEG data.
- SPM assigns default electrode locations for some common systems (extended 10-20, Biosemi, EGI – with user's input).
- Individually measured locations can be loaded; requires co-registration.
- The recording reference setup can be specified by the user. By default average reference is assumed.

Epoching

Definition: Cutting segments around events.

Need to know:
- What happens (event type, event value)
- When it happens (time of the events)

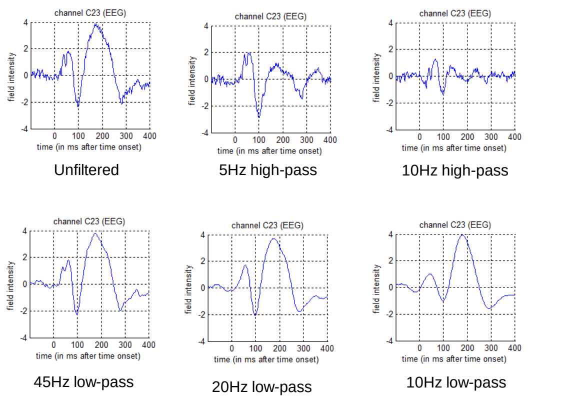
Need to define:
- Segment borders
- Trial type (can be different triggers => single trial type)
- Shift of time zero of the trial with respect to the trigger (no shift by default).

Note:
- SPM only supports fixed length trials (but there are ways to circumvent this).
- The epoching function also performs baseline correction (using negative times as the baseline).

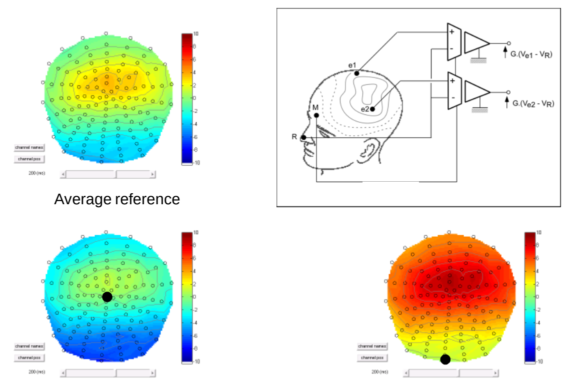
Filtering

- High-pass – remove the DC offset and slow trends in the data.
- Low-pass – remove high-frequency noise. Similar to smoothing.
- Notch (band-stop) – remove artefacts limited in frequency, most commonly line noise and its harmonics.
- Band-pass – focus on the frequency of interest and remove the rest. More suitable for relatively narrow frequency ranges.

Filtering - examples



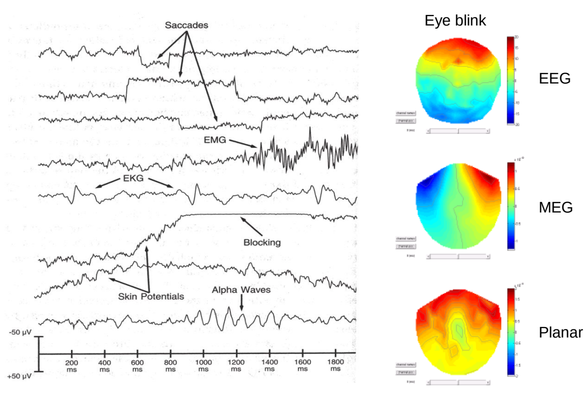
EEG – re-referencing



EEG – re-referencing

- Re-referencing can be used to sensitize sensor level analysis to particular sources (at the expense of other sources).
- For source reconstruction and DCM it is necessary to specify the referencing of the data. This can be done via the ‘Prepare’ tool.
- Re-referencing in SPM is done by the Montage function that can apply any linear weighting to the channels and has a wider range of applications.

Artefacts

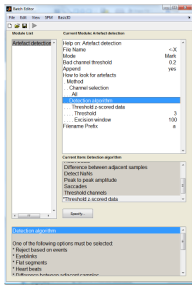


Artefacts

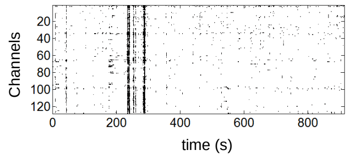
- SPM has an extendable artefact detection function where plug-ins implementing different detection methods ca be applied to subsets of channels.
- A variety of methods are implemented including, amplitude thresholding, jump detection, flat segment detection, ECG and eye blink detection.
- In addition, topography-based artefact correction method is available (in MEEGtools toolbox).

New in SPM12

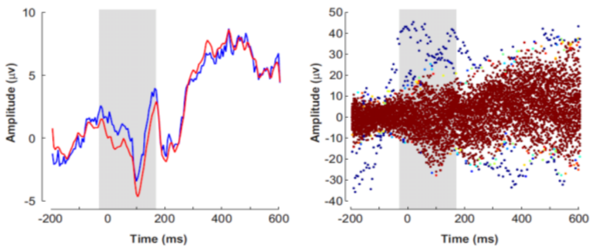
- It is now possible to mark artefacts in continuous data
- Marked artefacts are saved as events which are carried over with subsequent processing. So it is possible e.g. to mark artefacts before filtering and keep for later.
- Marked artefacts can either be used for trial rejection at a later stage ('Reject based on events') or used in a more sophisticated way with the new @meeg method 'badsamples'



>> imagesc(D.badsamples(D.indchantype('EEG'), ':', 1))



Robust averaging

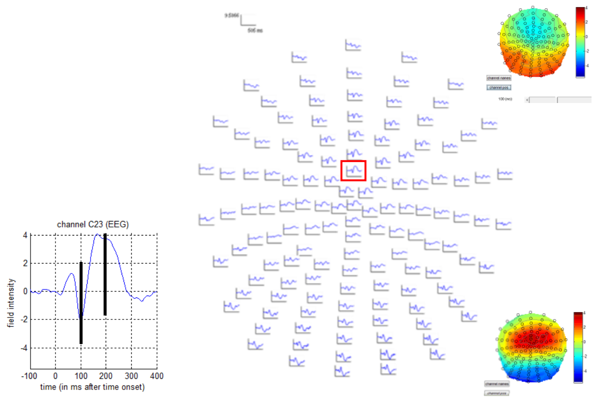


Kilner, unpublished
Wager et al. Neuroimage, 2005

Robust averaging

- Robust averaging is an iterative procedure that computes the mean, down-weights outliers, re-computes the mean etc. until convergence.
- It relies on the assumption that for any channel and time point most trials are clean.
- The number of trials should be sufficient to get a distribution (at least a few tens).
- Robust averaging can be used either in combination with or as an alternative to trial rejection.

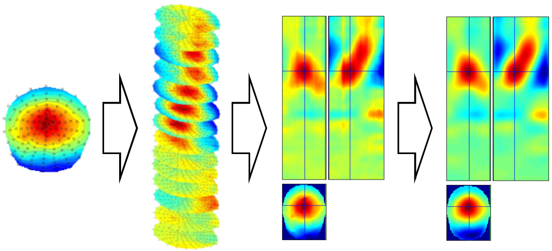
So that's how we got to this point



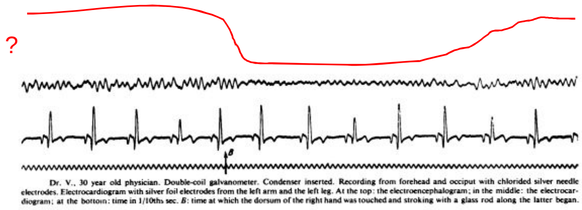
A note about order

- There is no single correct order of steps, but here are some considerations for order choices
  - It is better to filter continuous data prior to epoching to avoid filter ringing artefacts in every trial. Alternatively the epochs of interest can be padded with more data and then cropped after filtering.
  - It is better to do high-pass filtering or baseline correction before other filtering steps to reduce filter ringing.
  - It is convenient to put downsampling early in the pipeline to make the subsequent steps faster.
  - SPM only filters channels with physiological data. So the channel types should be set correctly before filtering.
  - Some artefacts (e.g. discontinuous jumps or saturations) are more difficult to detect after filtering.

Generating time x scalp images

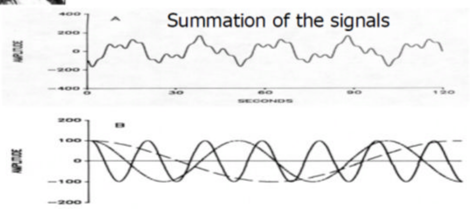


How can we characterize this?

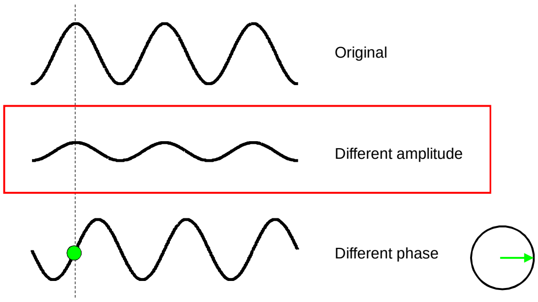


Fourier analysis

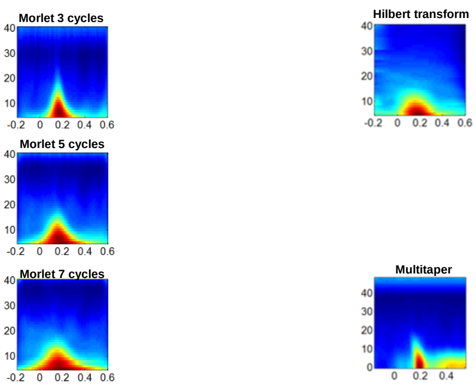
- Joseph Fourier (1768-1830)
- Any complex time series can be broken down into a series of superimposed sinusoids with different frequencies



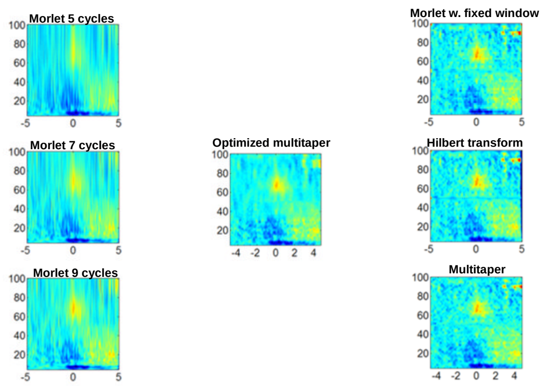
Fourier analysis



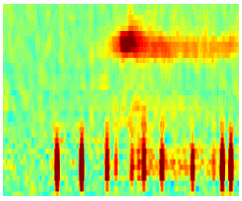
Methods of spectral estimation – example 1



Methods of spectral estimation – example 2

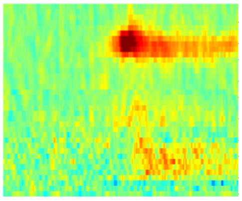


Robust averaging for TF

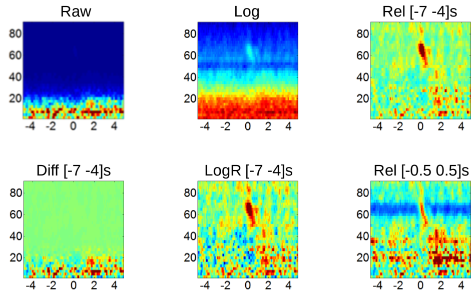


Unweighted averaging

Robust averaging

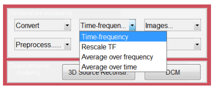


TF rescaling

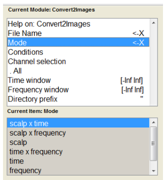


Changes to TF data handling in SPM12

- TF analysis can be done on continuous data.
- Continuous TF data can be filtered, epoched and used as input to convolution modelling (see below).
- TF datasets can be montaged (e.g. to create channel ROIs), averaged over frequency (to create datasets in the time domain) and averaged over time (to create spectra).



- When converting to images the data can be averaged over any possible combination of dimensions to produce images of 1-3D. For instance, when selecting 'EEG' for channels and 'time' for mode in TF case the data will be averaged over channels and frequencies to give 1D waveforms.



- New Neuromag-specific option 'Combine planar' was added (as in Fieldtrip). Works for both time and TF data.
    - Allows additional processing after combining planar channels (e.g. baseline correction) which was not possible in SPM8.
    - New channel type MEGCOMB is generated

Thanks to:

The people who contributed material to this presentation (knowingly or not):

- Stefan Kiebel
- Jean Daunizeau
- Gareth Barnes
- James Kilner
- Robert Oostenveld
- Arnaud Delorme
- Laurence Hunt

and all the members of the methods group past and present