Advanced preprocessing

- Motion artefact correction
- Physiological noise correction

Case Study: Motion Artefacts

Scenario:

Young/elderly/sick subjects that move a lot during an FMRI study

Problem:

Motion correction does not fully correct for excessive motion

Sudden motion creates massive distortion (>12 DOF)

Smaller, slower motion induces intensity changes due to physics effects (e.g. spin history) and interpolation

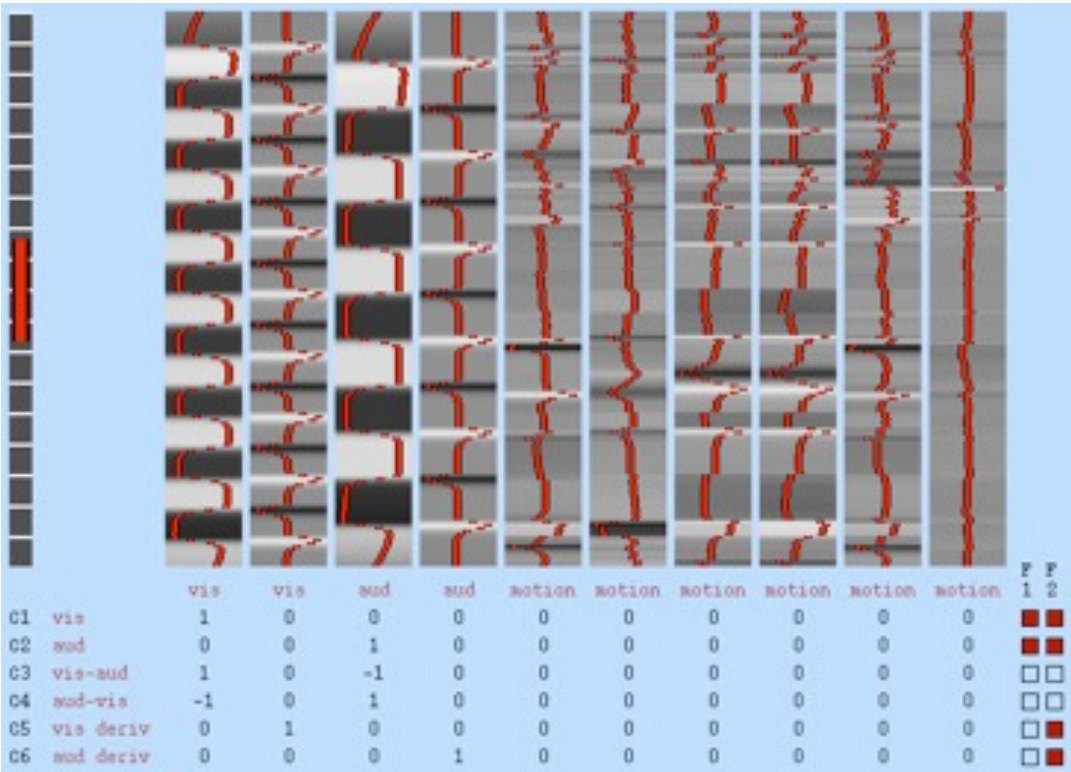
Solution:

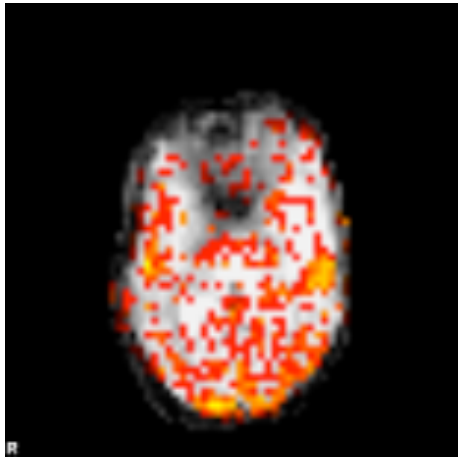
Remove or compensate for motion artefacts

Motion Artefact Correction

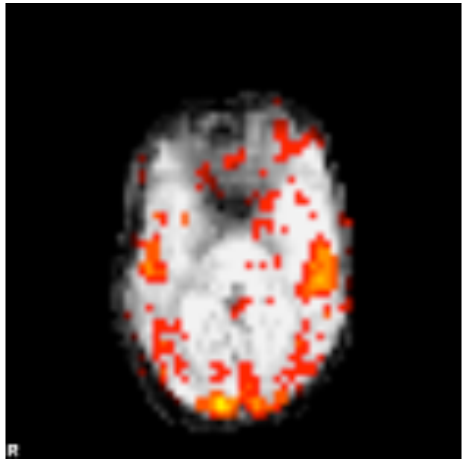
Options for motion artefact correction:

1. Add motion parameters as confound EVs
2. Detect "outlier" timepoints and remove them via confound EVs
3. Use ICA (MELODIC) denoising for cleanup





Without motion parameter EVs

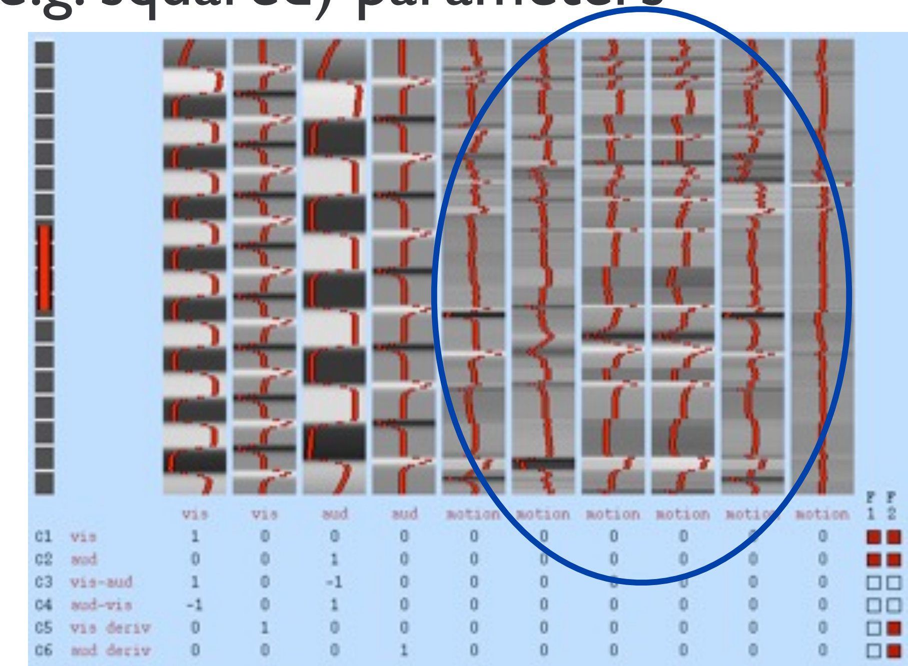


With motion parameter EVs

Motion Parameter Confounds

Add the 6 parameters (rotations and translations) as measured by MCFLIRT to the GLM as *confounds* - simple button in FEAT

- Removes any correlated signals (since they are confounds)
- Assumes a linear relationship between motion parameters and intensity of motion artefact
- Also possible to include non-linear (e.g. squared) parameters
- Assumes that MCFLIRT estimation is accurate
- Problematic if motion parameters and EVs of interest are highly correlated (stimulus-correlated motion)
  - can result in loss of activation
  - orthogonalising EVs does not change result

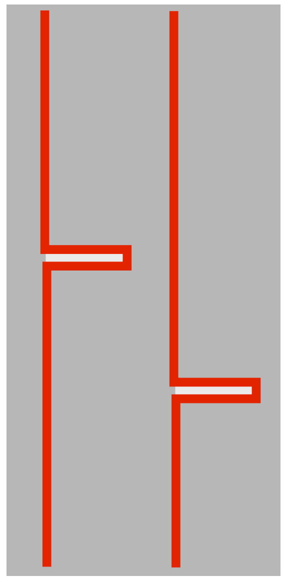


Outlier Timepoint Detection

Use *fsl_motion_outliers* to detect timepoints that display large intensity differences to the reference timepoint (after motion correction)

- Removes ***all*** influence of the timepoints declared as outliers but does not introduce any bias (unlike "deleting" timepoints from data)
- Uses one extra confound regressor per outlier timepoint
  - the regressor is zero at all timepoints except the outlier
- Implemented via confound matrix in the GLM
  - *Add additional confound EVs* button in FEAT
- Does not assume that MCFLIRT is accurate
  or that the effect is linear
- Can cope with very extreme motion effects
  but leaves other timepoints uncorrected
- Can be combined with other correction methods

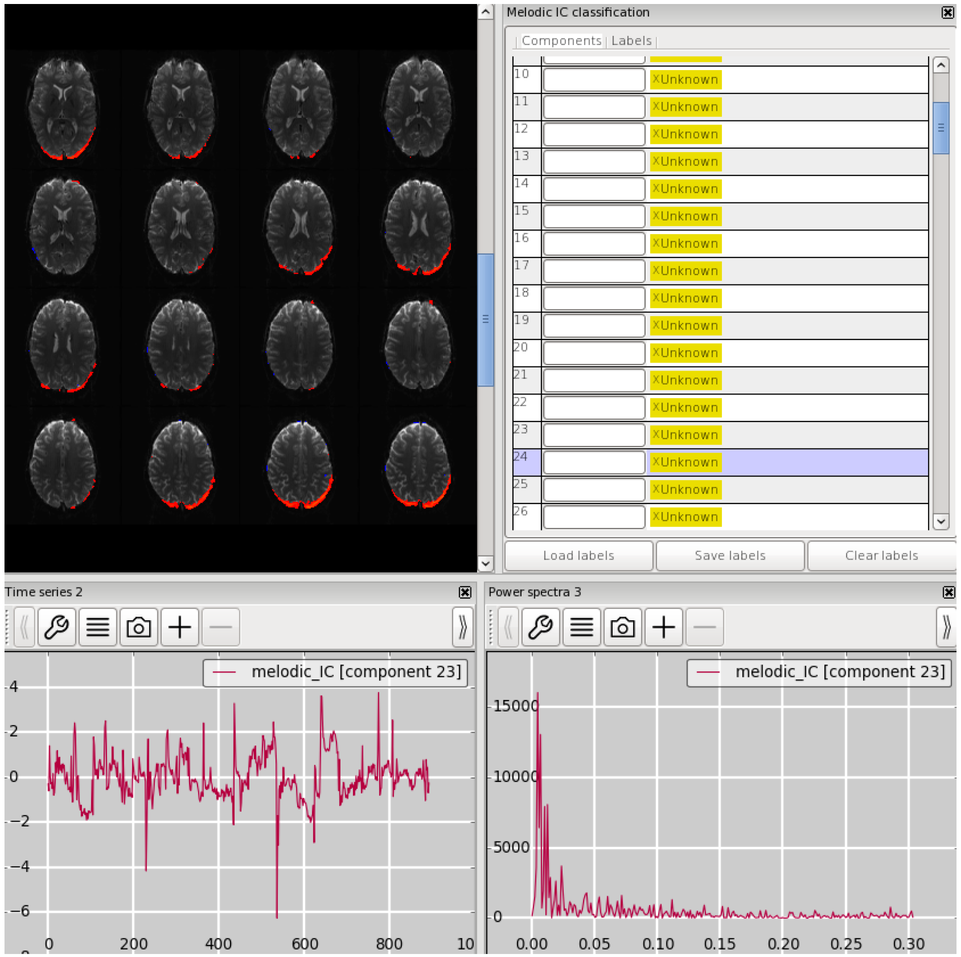
Confound matrix with 2 outlier timepoints



ICA denoising

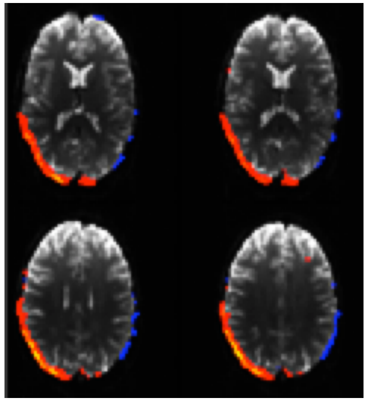
Use ICA (MELODIC) on individual runs to identify components related to motion artefacts and remove these from the 4D data

- Requires identification of components
    - manual classification
    - (semi-) automated classification (FIX/ AROMA)
- Can also be combined with other cleanup techniques
    - ICA denoising should be done first
- Can also be used to identify and remove structured noise that is not related to motion

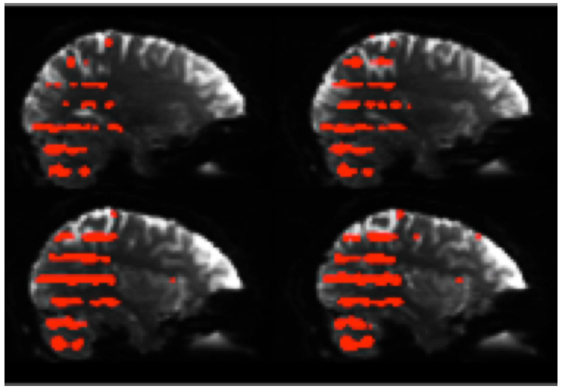


ICA denoising

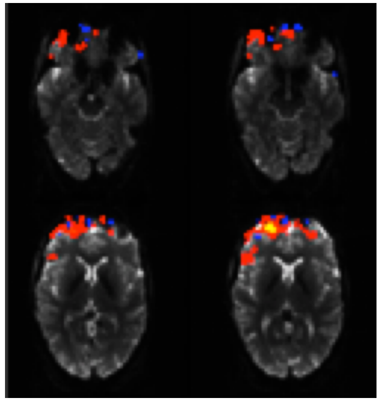
- Typical motion components display ringing around brain edge
- Can also note sharp effects in timecourses
- There are typically a large number of noise components (70-90%)



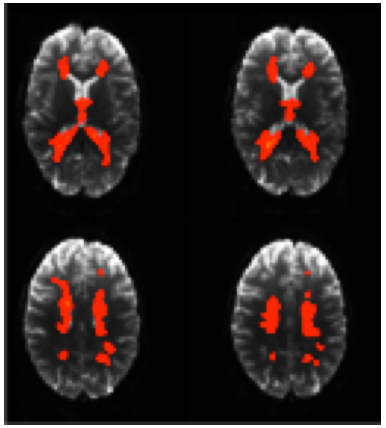
Classic motion



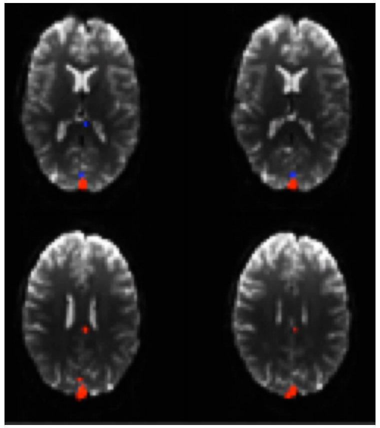
Multiband motion



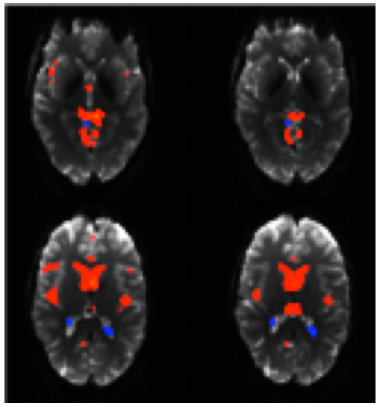
Susceptibility motion



White matter

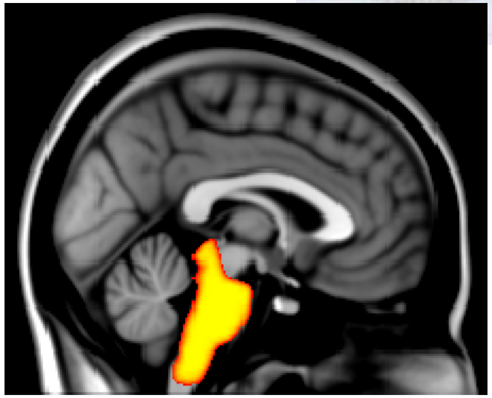


Sagittal sinus



Cardiac/CSF

Case Study: Physiological Noise Correction



Scenario:

FMRI study of the brainstem

Problem:

High levels of pulsatility and respiratory effects in the brainstem and in other inferior areas

Solution:

Use Physiological Noise Model (PNM) to correct for physiological noise

Requires independent physiological measurements

Physiological Measurements

Need to measure cardiac and respiratory cycles.

Several options available - the easiest are:

Respiratory Bellows

Pulse Oximeter

Also ***record scanner triggers*** from the scanner console

Triggers are essential for accurate timing over the course of the experiment. Beware of standard scanner recordings and timing drift or rescalings.

Location of Effects

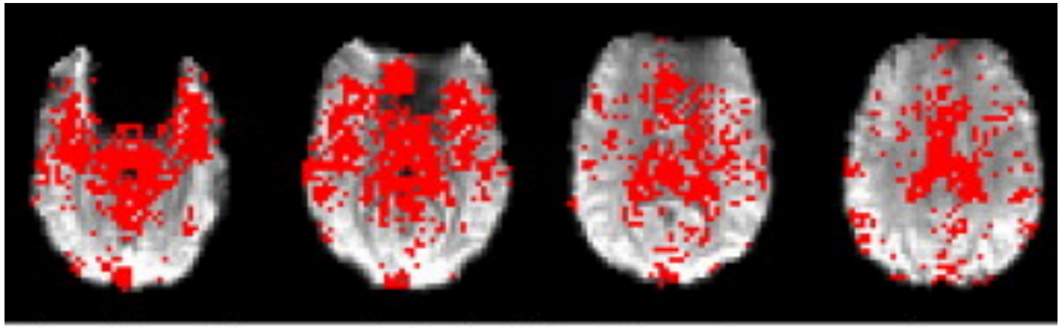
Cardiac effects typically occur:

- near vessels and areas of CSF pulsatility (e.g. brainstem, ventricles)

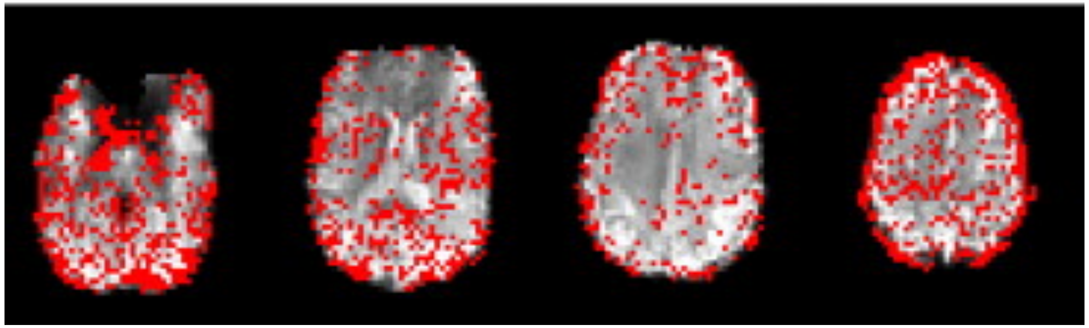
Respiratory effects typically occur:

- in inferior areas (where the induced B0 field changes due to lung volume changes are highest)
- near image edges (due to geometric shifts/distortion by B0 causing large intensity changes)
- throughout the grey matter (due to oxygenation changes)

Cardiac



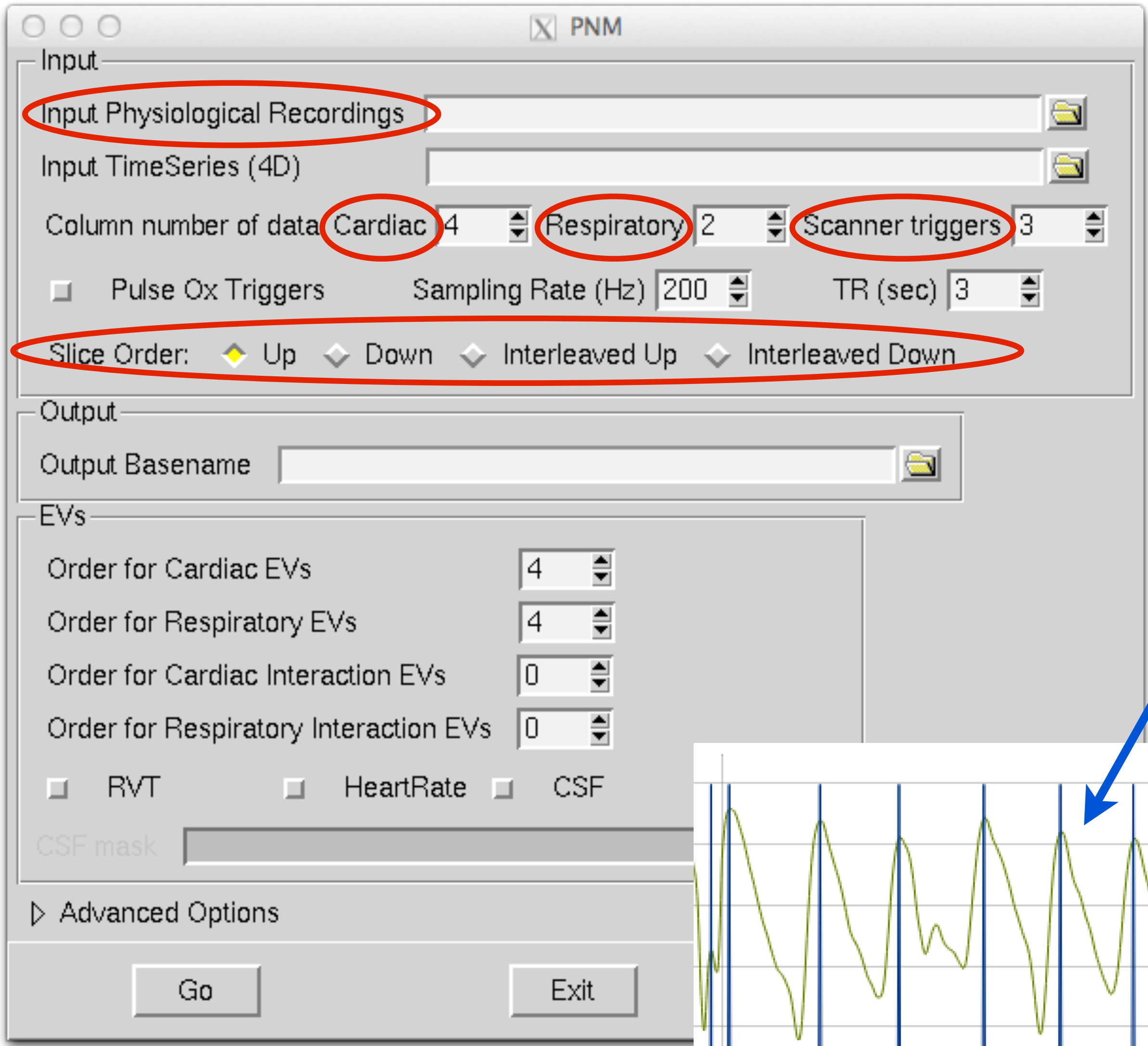
Respiratory



Bright & Murphy, NeuroImage, 2013

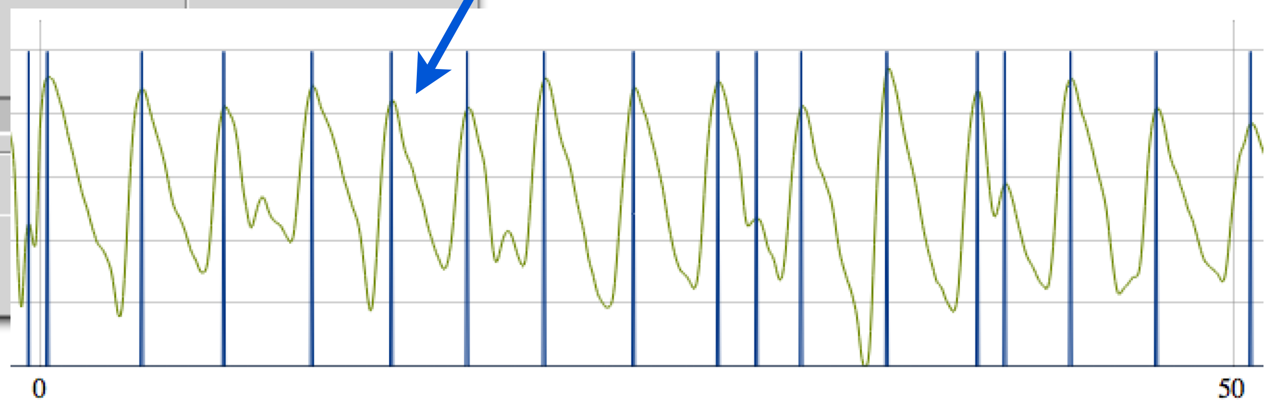
PNM

Physiological Noise Model (GUI)



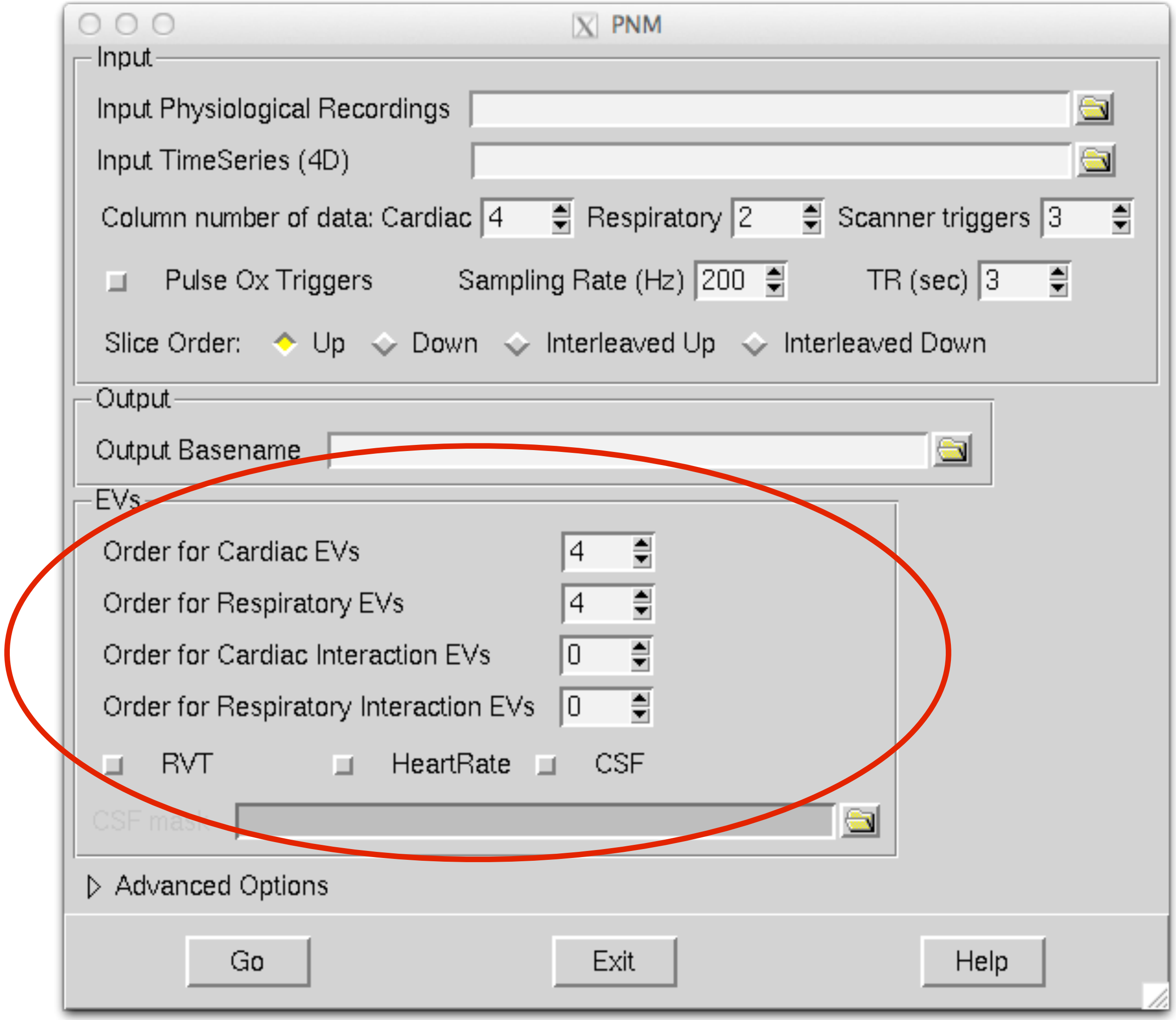
Requires text file with physiological recordings (cardiac, respiratory, triggers)

Peak detection in physiological trace needs manual checking via webpage



PNM

Physiological Noise Model (GUI)



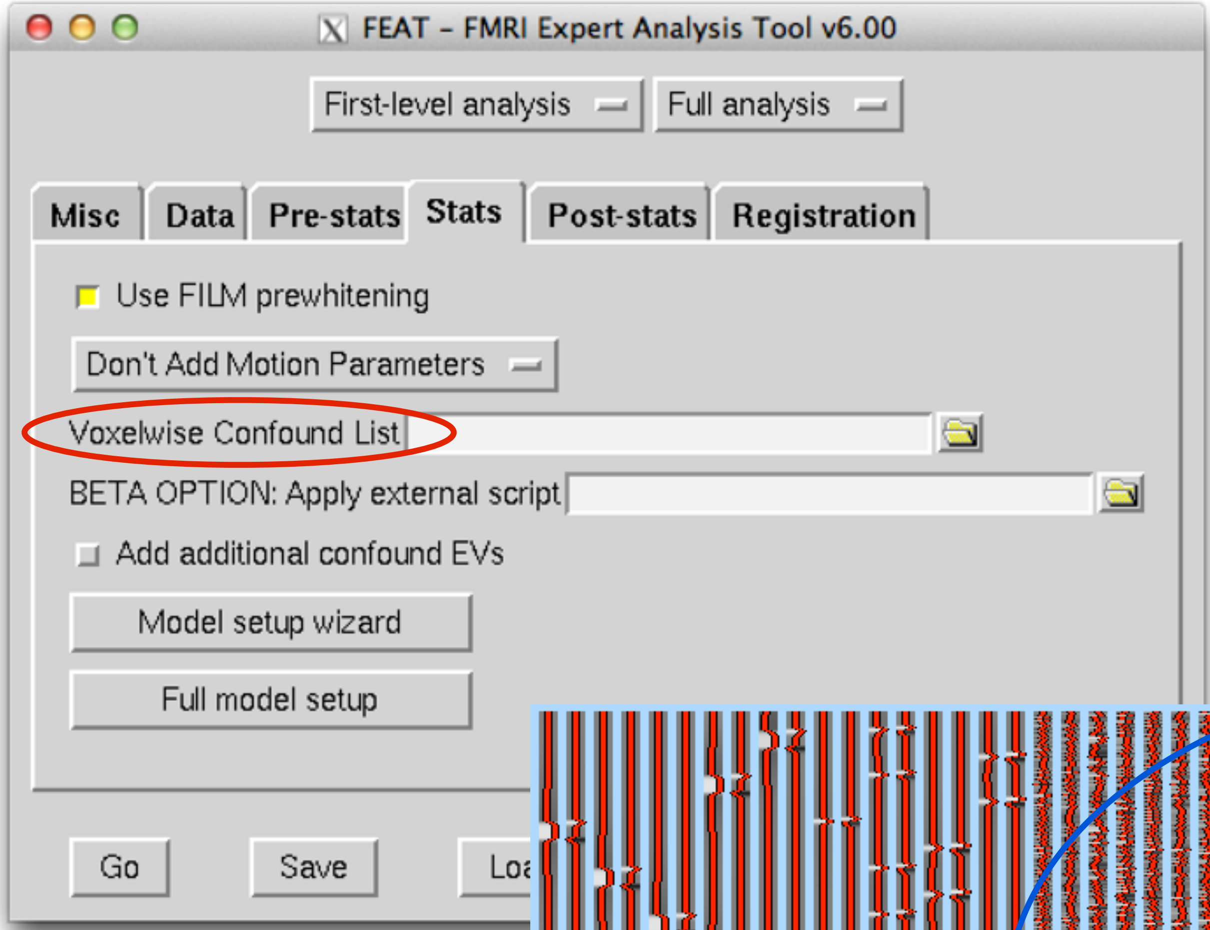
Need to specify what type of corrections:

- Fourier series
  (harmonics / shape)
- Interactions
  (resp x cardiac)

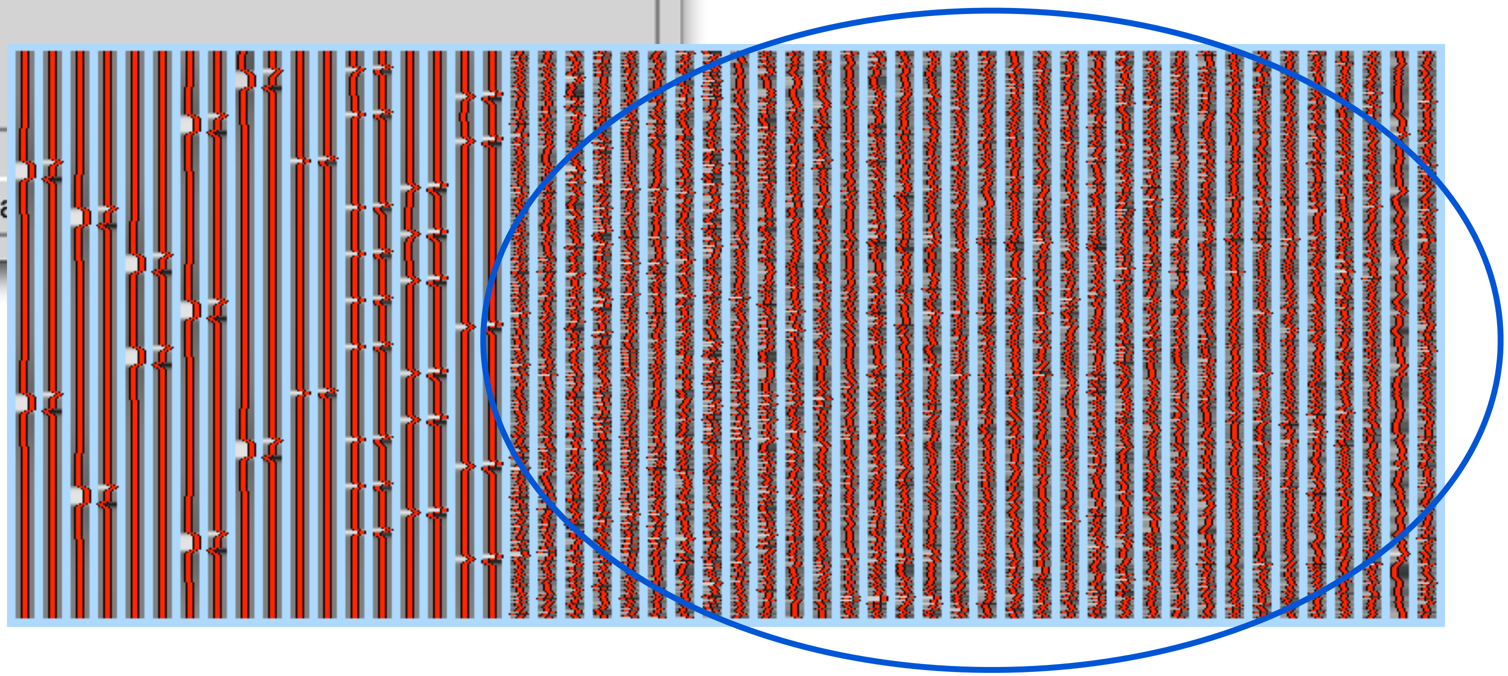
NB: higher orders = better fit to shape, but many more EVs and so less DOF

- RVT
  (resp volume per time)
- HeartRate
- CSF

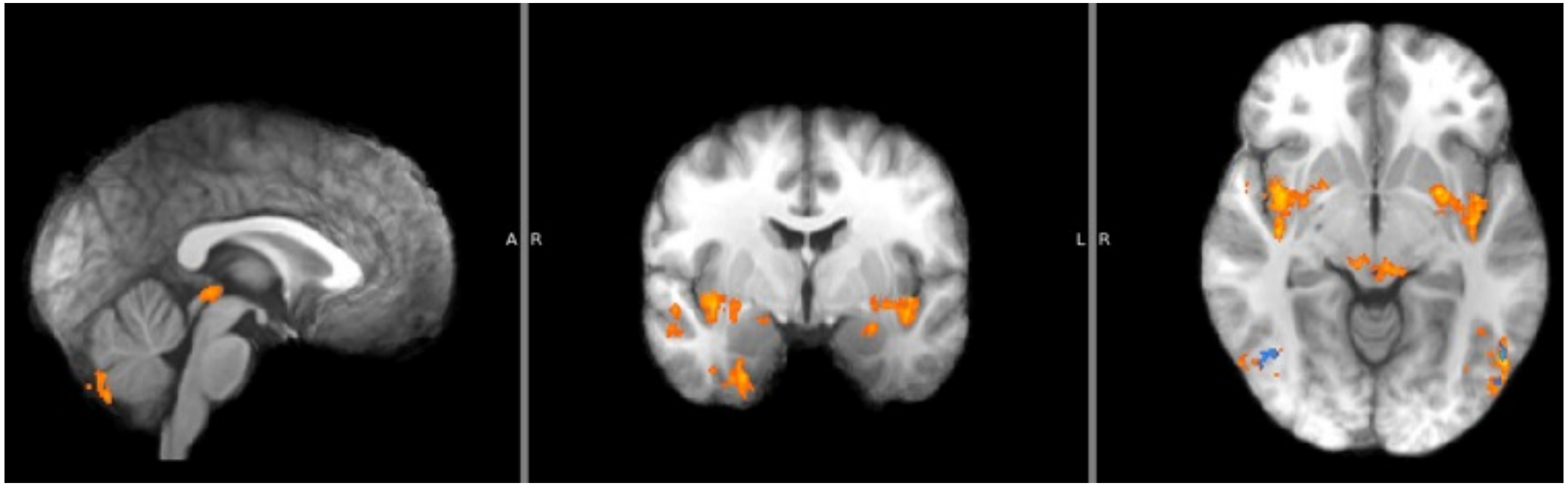
Use in FEAT



PNM GUI creates a set of files suitable for use as ***Voxelwise Confounds*** in FEAT

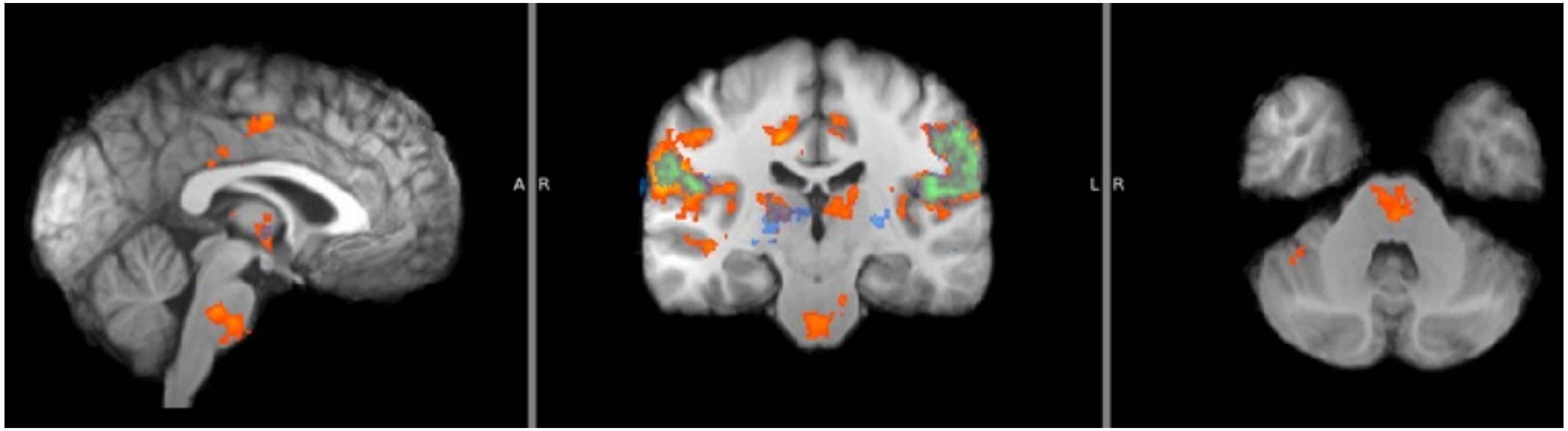


Results: Pain-punctate arm



AXIAL

N=6, Group mean (Fixed effects), Z=1.8 $p<0.05$



CORONAL

With PNM ■ Without PNM ■ Both ■

Courtesy of Jon Brooks - University of Bristol

Advanced preprocessing summary

Options for **motion artefact correction**:

1. Add motion parameters as confound EVs
2. Detect outliers (fsl_motion outliers) and remove them via confound EVs
3. ICA-based cleanup

Options for **physiological noise correction**:

1. ICA-based cleanup
2. Physiological recordings + PNM + voxelwise confound EVs