Preprocessing of volumometric brain imaging data

Jouni Tuisku

Post-doc reserarcher, Turku PET centre

jouni.tuisku@tyks.fi

Contents

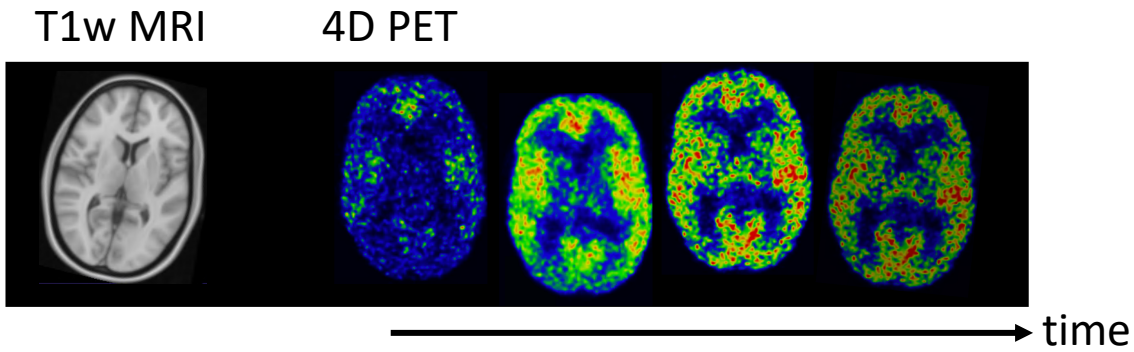
1. Introduction
2. Data formats & conversion
3. Motion correction for functional imaging data
4. Image registration
5. Spatial normalisation / MR-image segmentation
6. Smoothing

- Preprocessing is demonstrated in SPM with the course example data:
  - NRM2018 grand challenge data: https://openneuro.org/datasets/ds001705/versions/1.0.1

Why preprocessing?

Typical imaging study includes:

- Various images from different modalities with different data formats
  - Structural T1w MRIs (high anatomical detail)
  - Functional images (limited anatomical detail)



- Movement within image modalities
- Different orientations between images

Data formats & conversion

- After image reconstruction, the data is available in PACS storage
  - PACS = Picture Archiving and Communication Systems

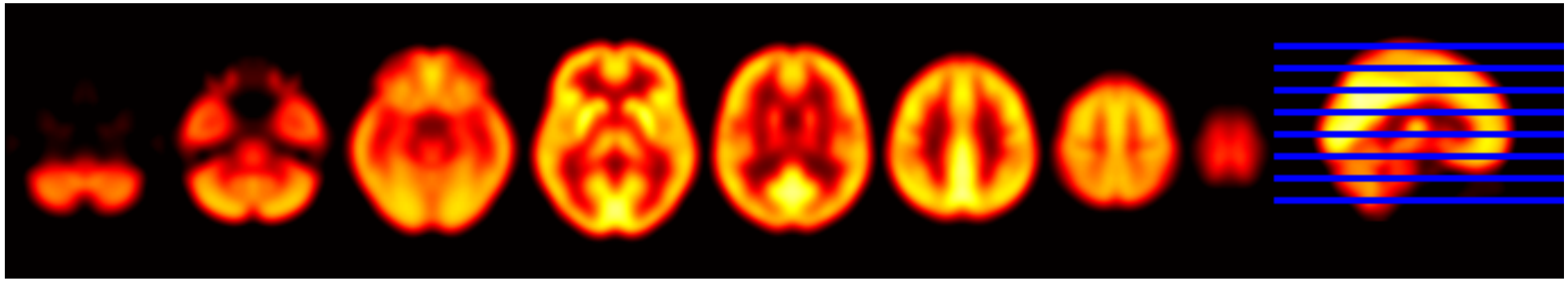
DICOM (.dcm)

- Extensive image format used in data archives
- 1 dicom file = 1 slice of brain, consists of e.g. 256 x 256 pixels

Data formats & conversion

NIfTI (.img + .hdr, or .nii)

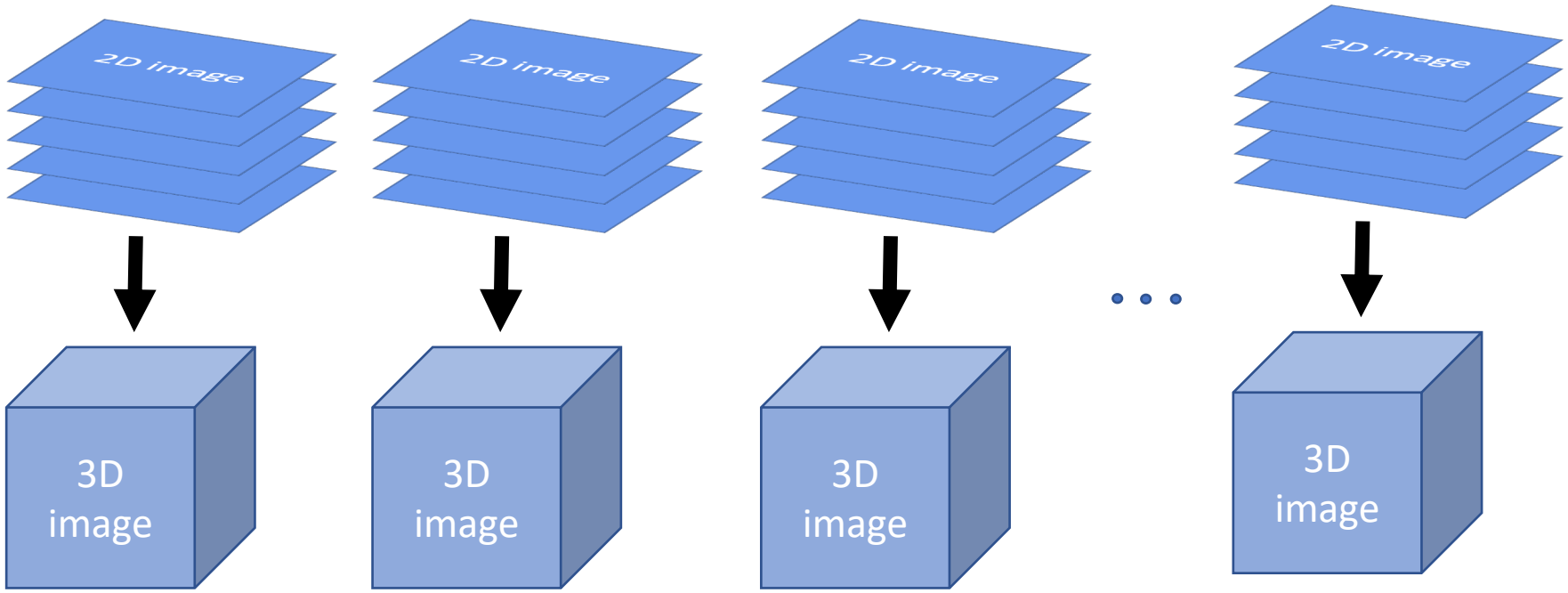
- 2D-slices are combined into 3D-images
- Standard neuroimaging file format
- Supported by several neuroimaging software: SPM, FSL, AFNI, FreeSurfer
- Anonymized format, header contains only image orientation information
- Conversion software: SPM, Mango, MRIcro, etc.



Functional 4D-imaging data

4D-images:

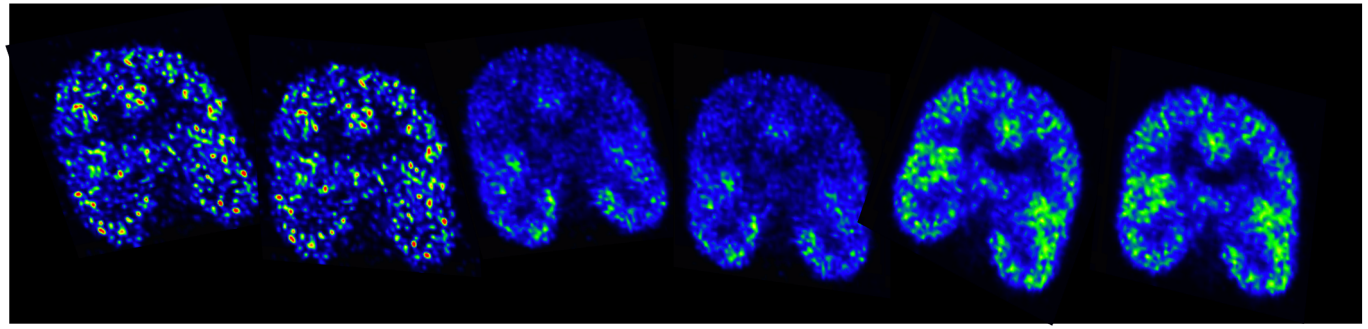
- time-series of 3D-images, all stored under the same file



Motion

- Increases variance and decreases sensitivity
- May create artificial effects, or e.g. correlate with the imaged task
- Possibly increases during long scans

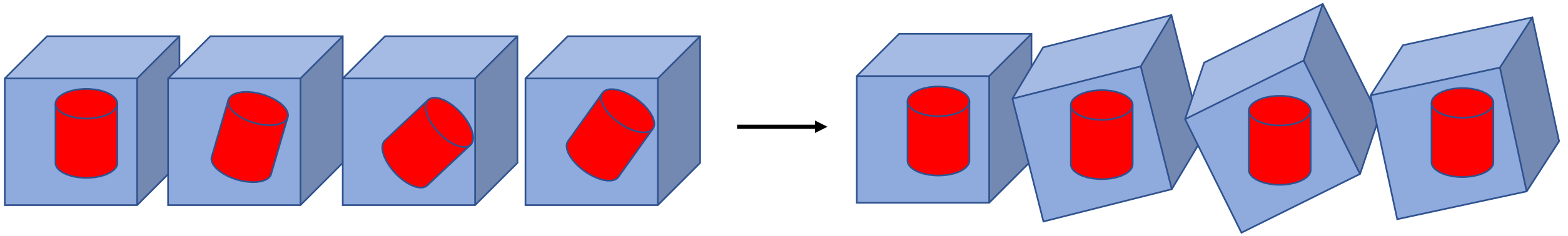
4D PET data



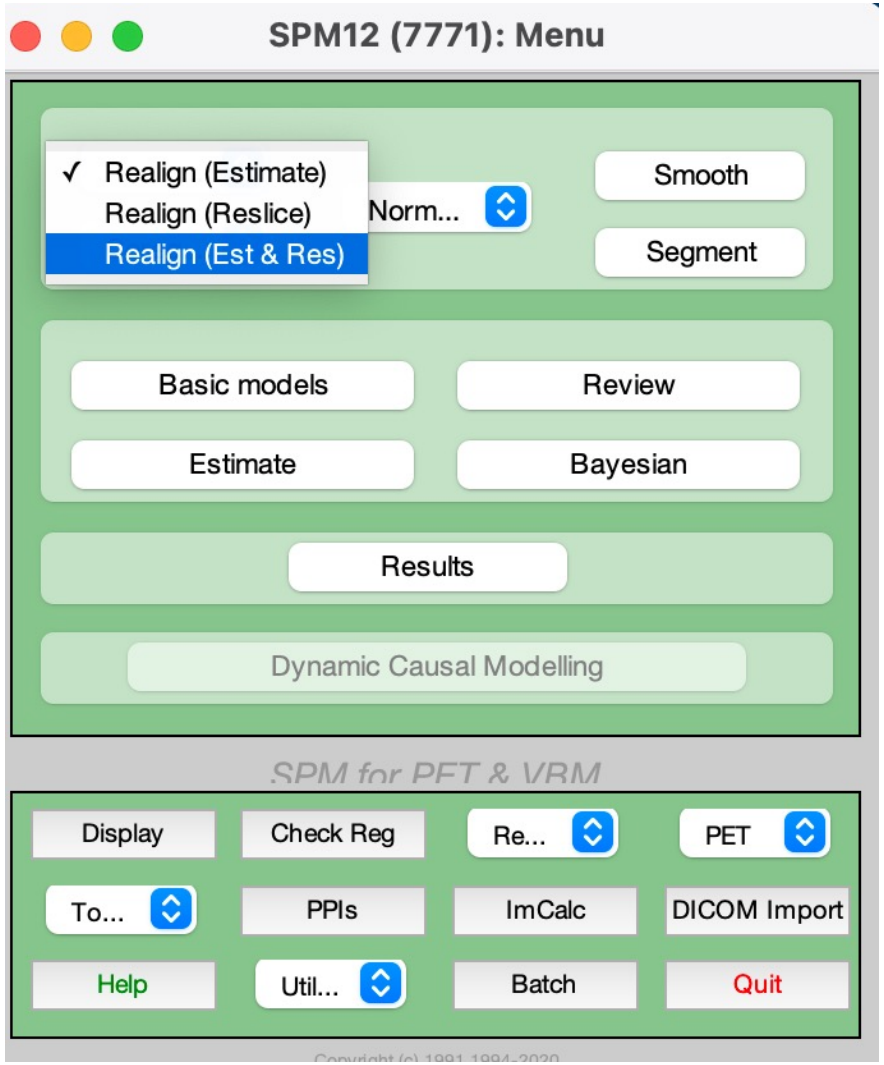
time

Motion correction

- Rigid-object transformation = rotation and translation
- Realigns the brains inside the 3D image volumes
- Realignment corrects only the motion between the sequential 3D images, not within the images

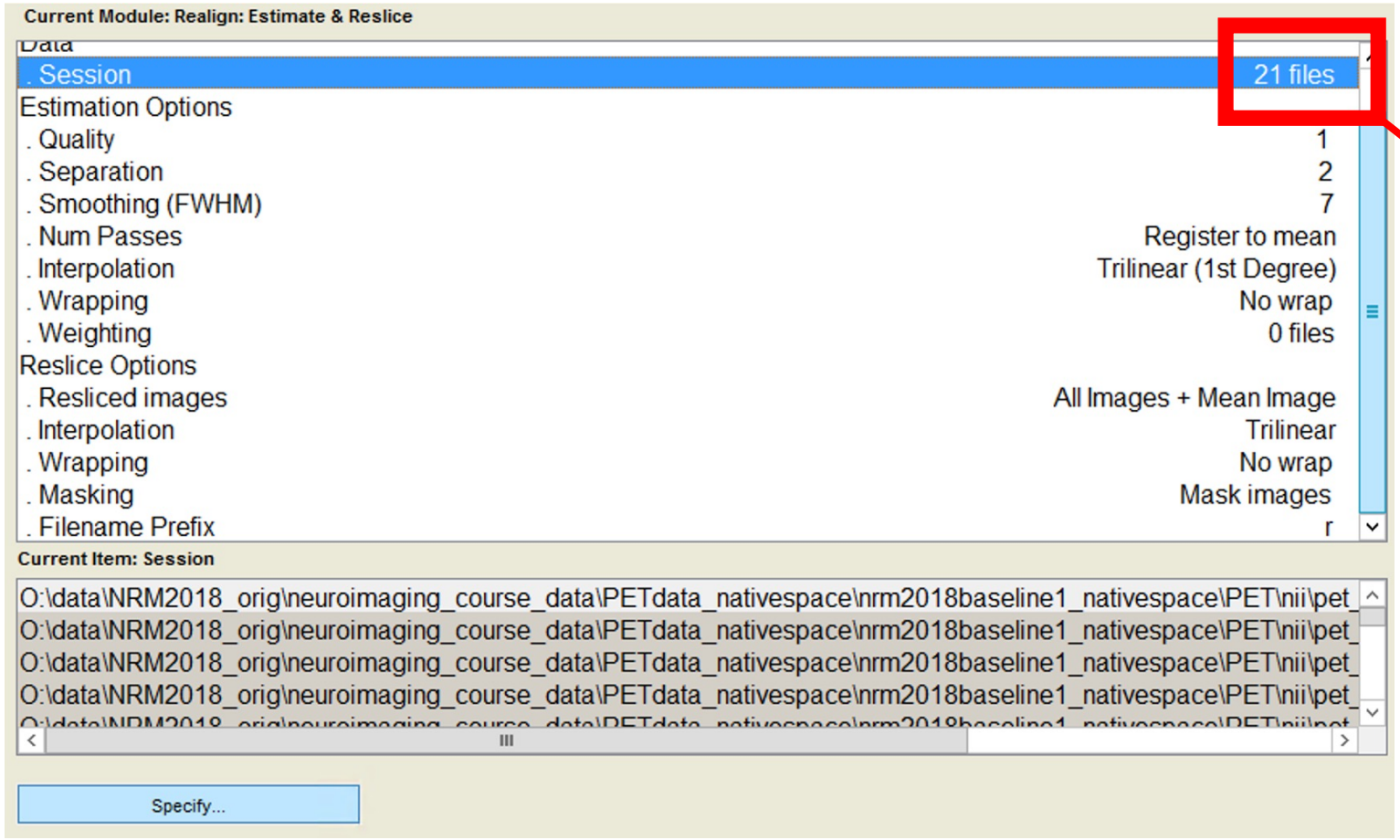


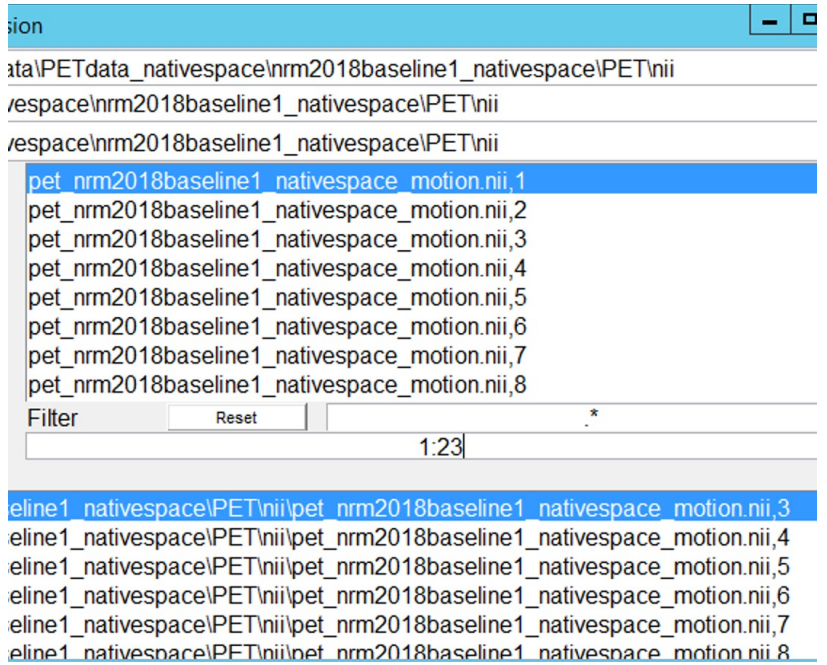
Motion correction in SPM



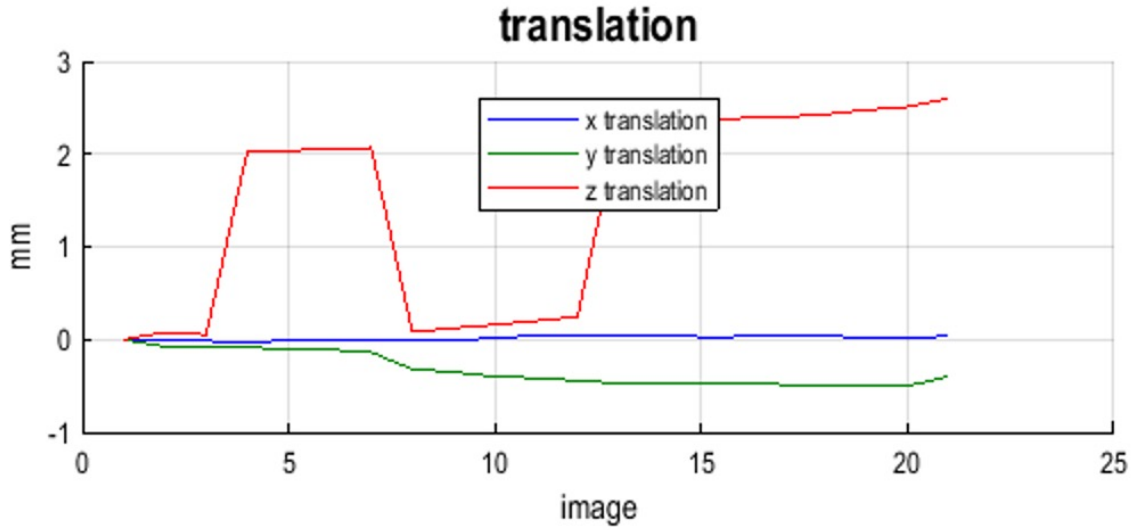
Motion correction in SPM

PETdata_nativespace/../../pet_nrm2018baseline1_nativespace_motion.nii





SPM motion correction results



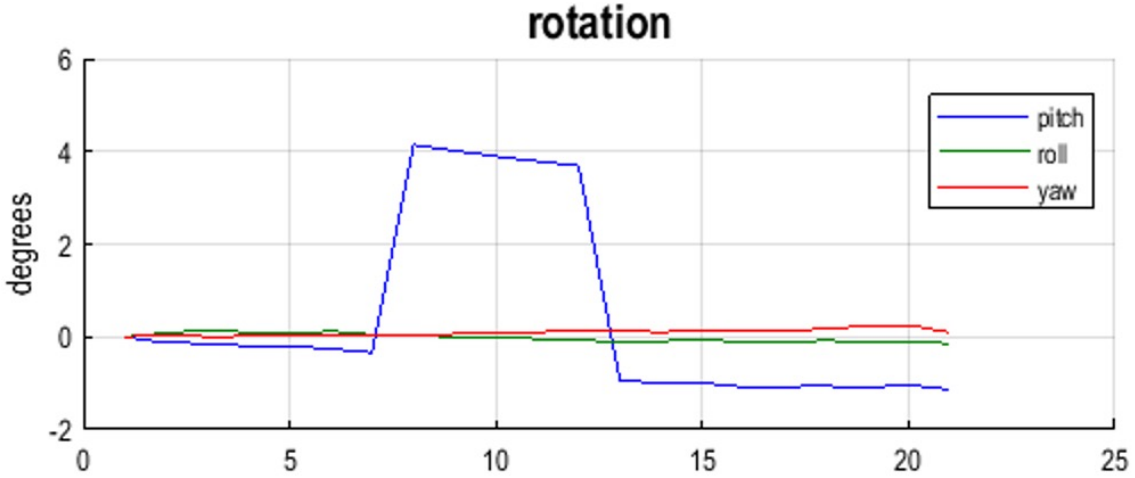
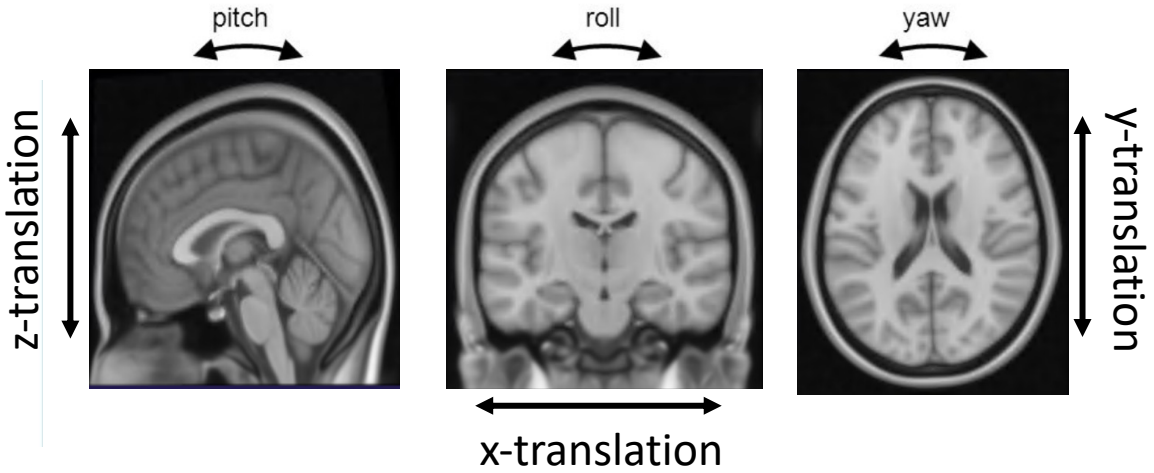
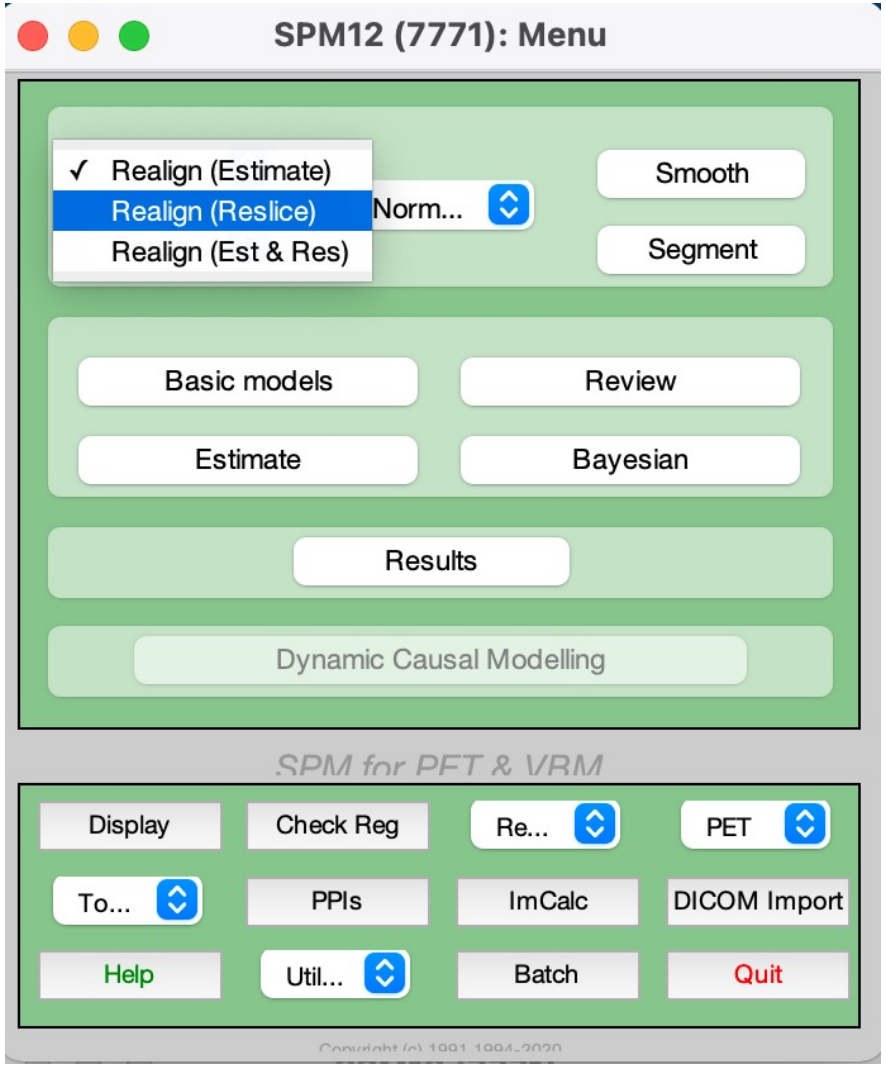


Image realignment

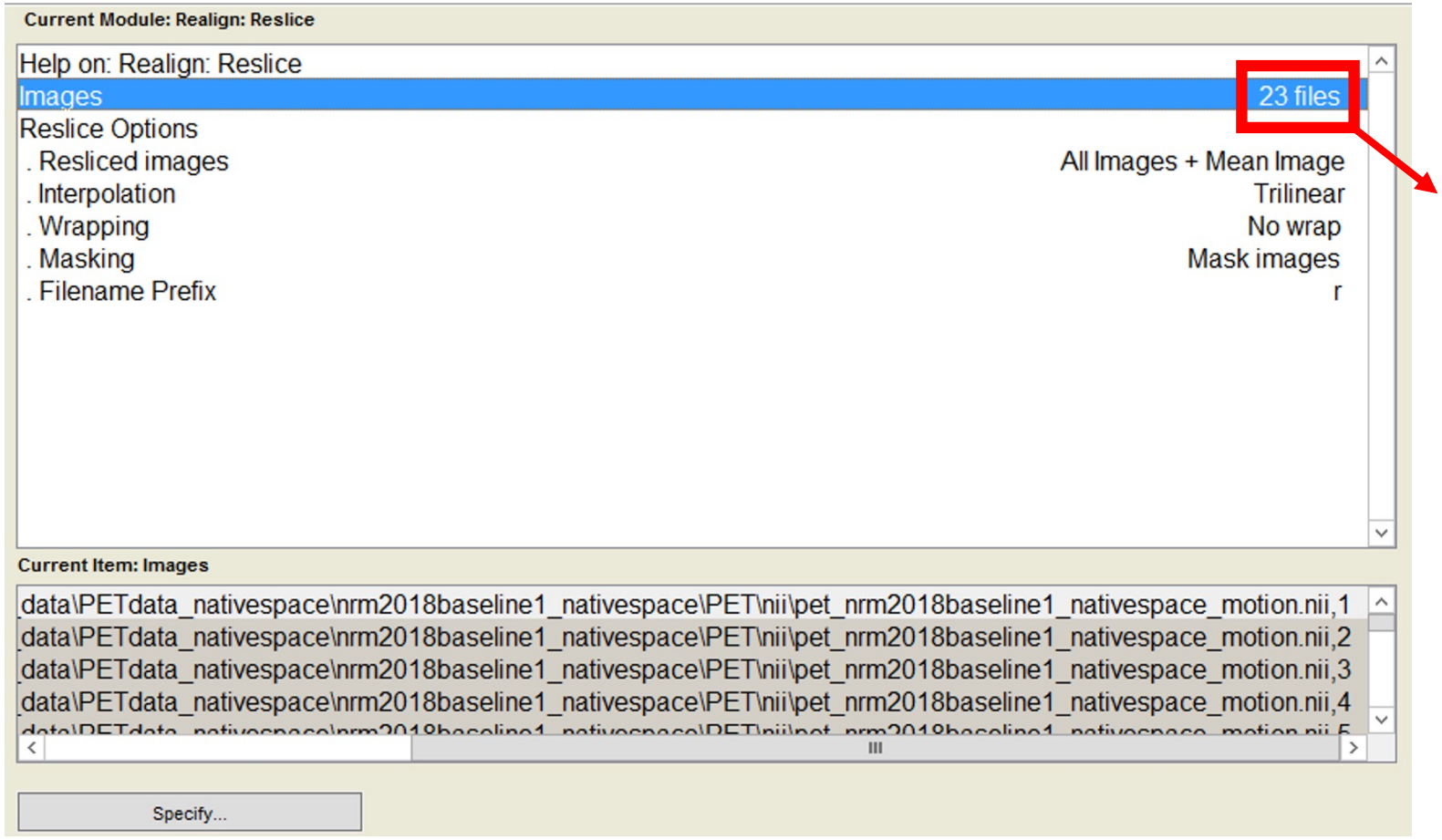
1 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
2 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
3 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
4 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
5 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
6 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
7 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
8 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
9 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_n
10 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_
11 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_
12 O:\data\NRM2018_orig\neuroimaging_course_data\PETdata_nativespace\nrm2018baseline1_
..... etc



Interpolation of motion corrected data



Interpolation of motion corrected data



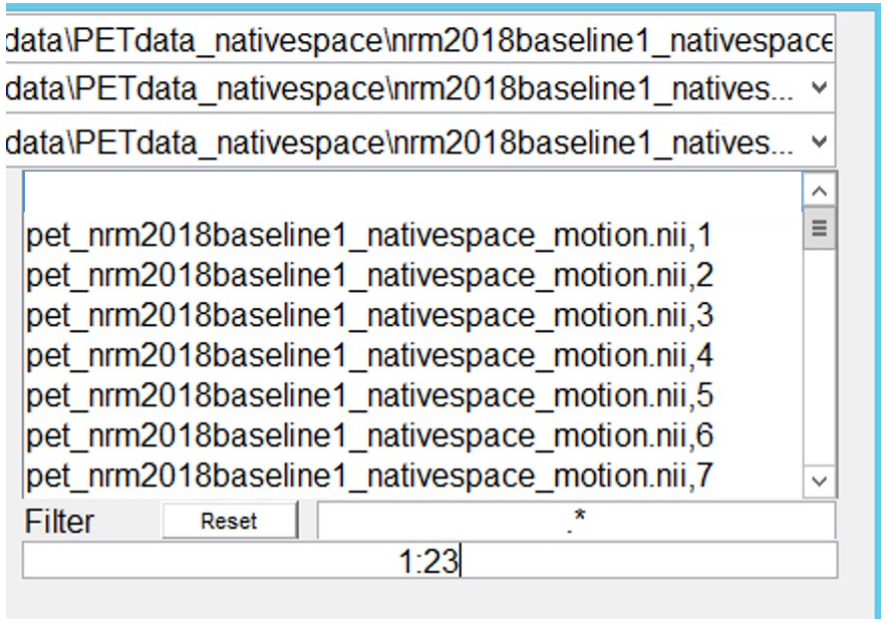
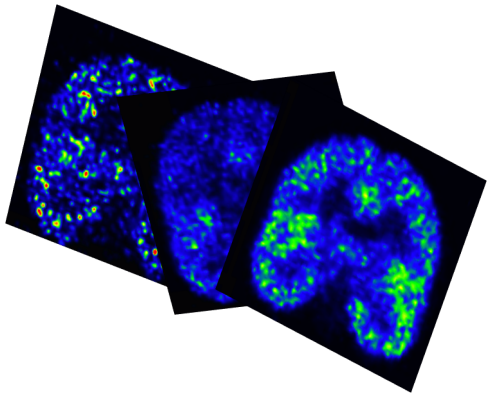
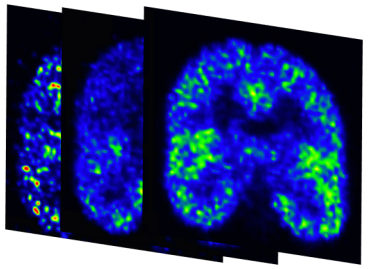


Image registration



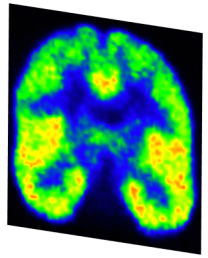
4D Functional imaging data

Motion correction



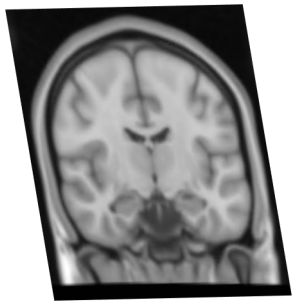
Motion corrected data

+



Mean functional image

Registration + interpolation



T1w MRI

Image registration

- Process of estimating the optimal transformation between images
- Within modality registration (find affine translation + rotation)
- Between modality registration (maximize image similarity)
  - PET mean image contains more details compared to single frame
- Interpolation (reslice) to match the image dimensions & voxel sizes

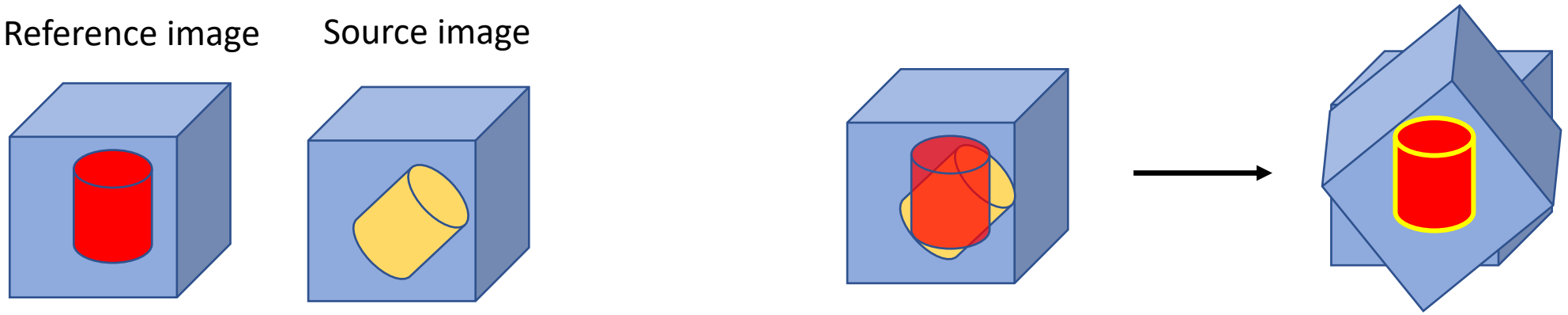


Image registration in SPM

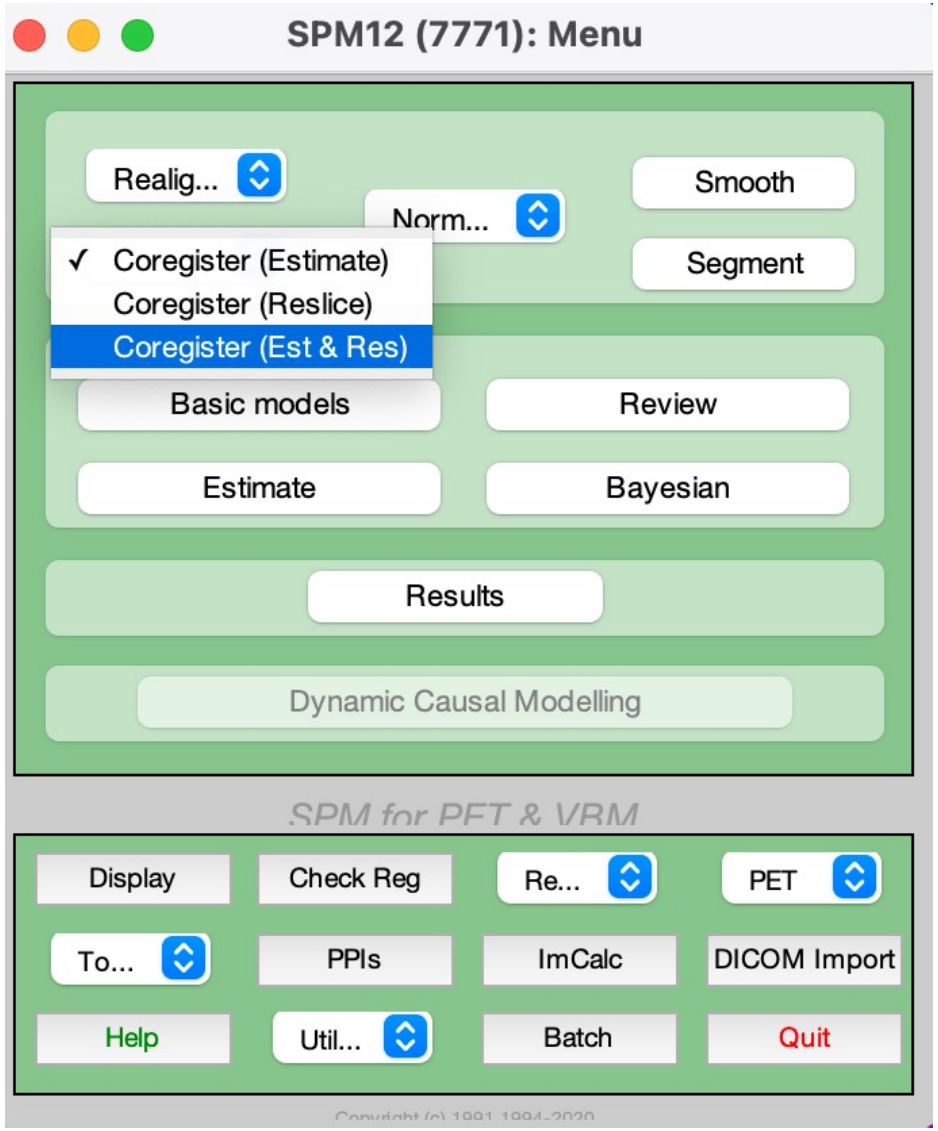
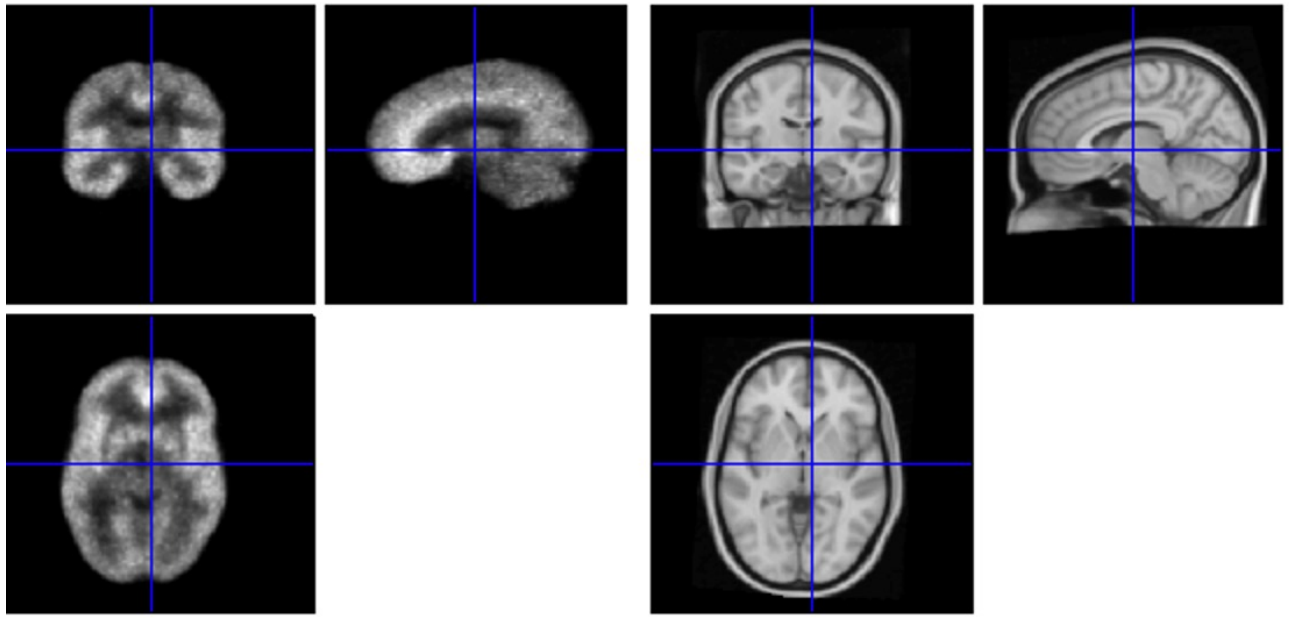


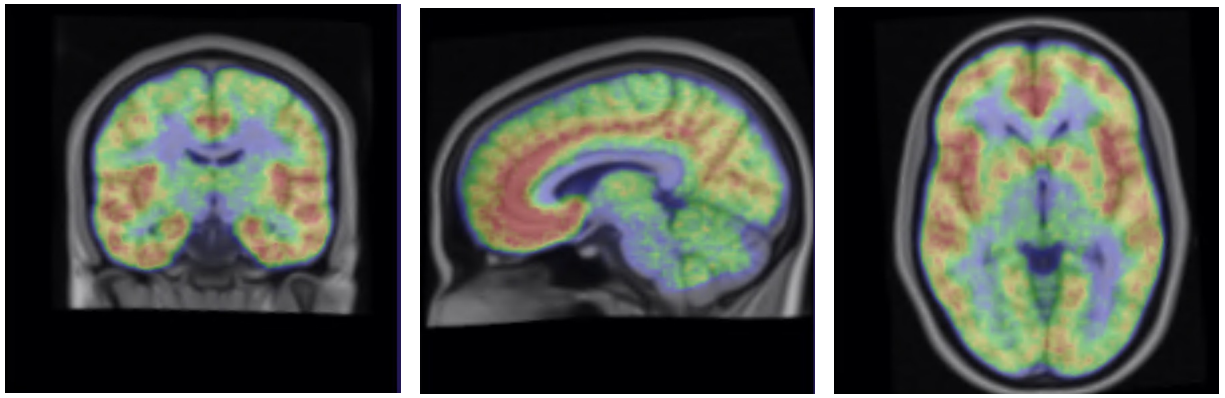
Image registration in SPM

Current Module: Coregister: Estimate & Reslice

Help on: Coregister: Estimate & Reslice	
Reference Image	..._nativespace\PET\nii\meanpet_nrm2018baseline1_nativespace_motion.nii,1
Source Image	...ata_nativespace\nrm2018mri_nativespace\T1\nrm2018mri_nativespace.nii,1
Other Images	
Estimation Options	
. Objective Function	Normalised Mutual Information
. Separation	[4 2]
. Tolerances	1x12 double
. Histogram Smoothing	[7 7]
Reslice Options	
. Interpolation	Trilinear
. Wrapping	No wrap
. Masking	Dont mask images
. Filename Prefix	r

Image registration in SPM



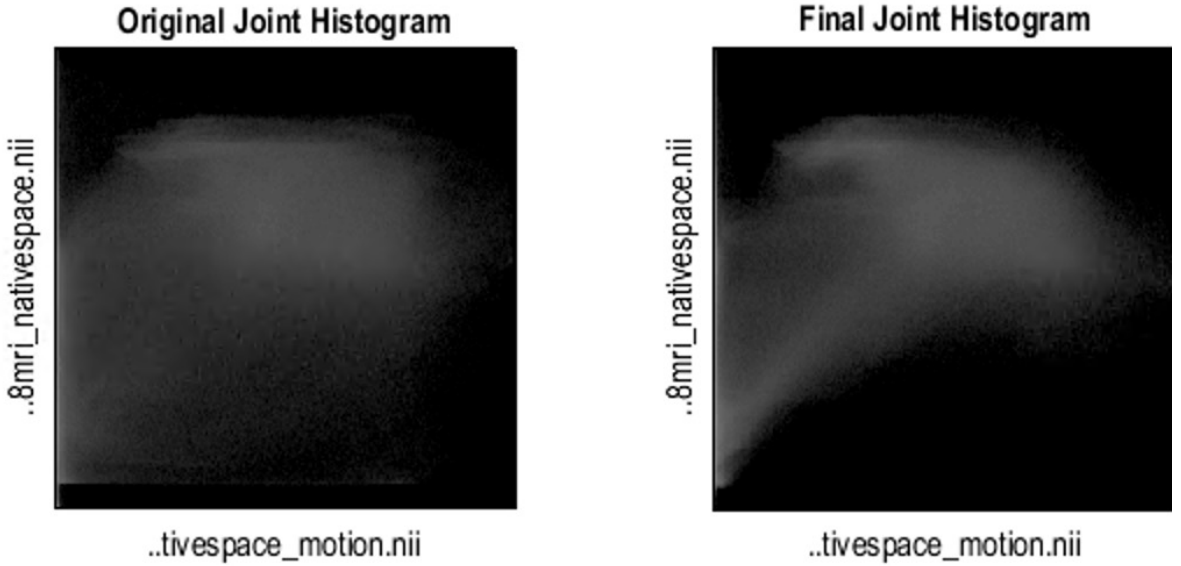


Normalised Mutual Information Coregistration

X1 = 0.989*X -0.108*Y +0.104*Z +0.904

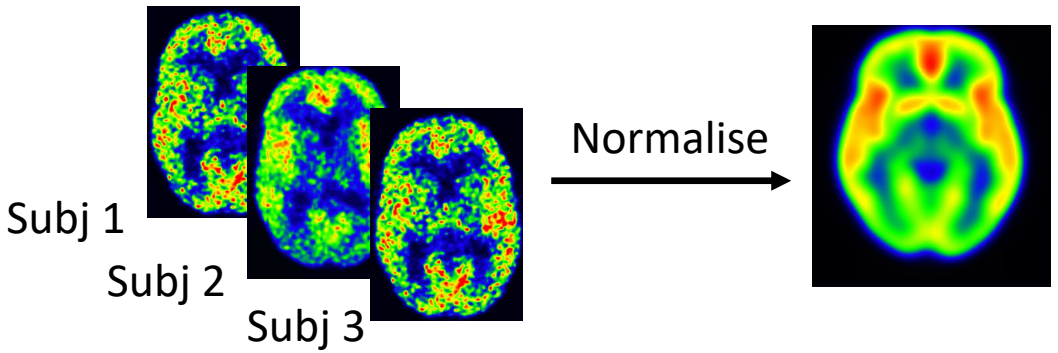
Y1 = 0.110*X +0.994*Y -0.011*Z -9.382

Z1 = -0.103*X +0.022*Y +0.994*Z +4.679



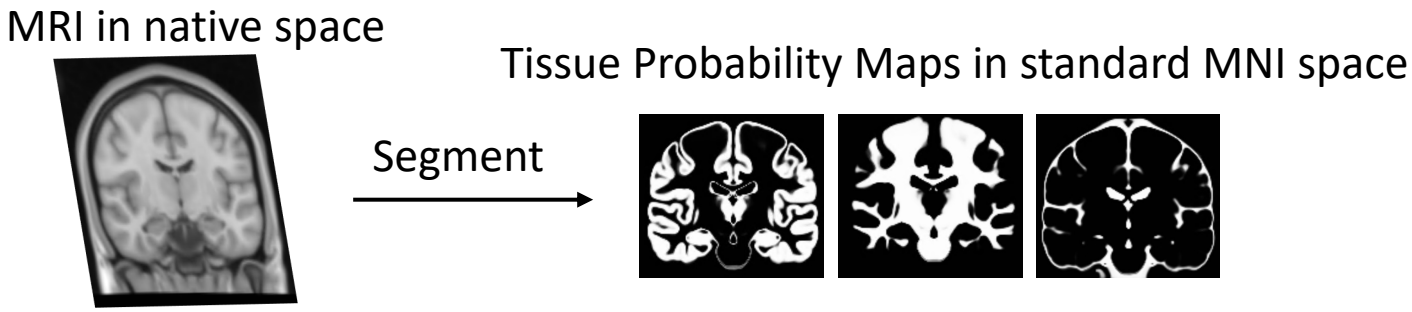
Registration to standard space image

- Brains differ in size and shape
  - Individual native space images are not suitable for the voxel-level statistical analysis
- Native-space images are matched approximately with a template image in a standard space:
  - Affine transformations (translations, rotations, scaling/zoom, shearing/skewing)
  - Nonlinear warps

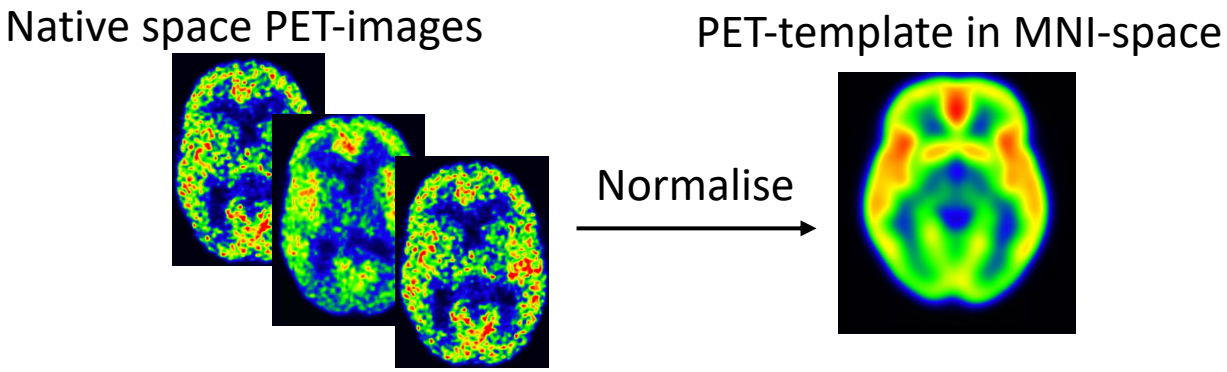


Spatial normalisation (MRI & PET-templates)

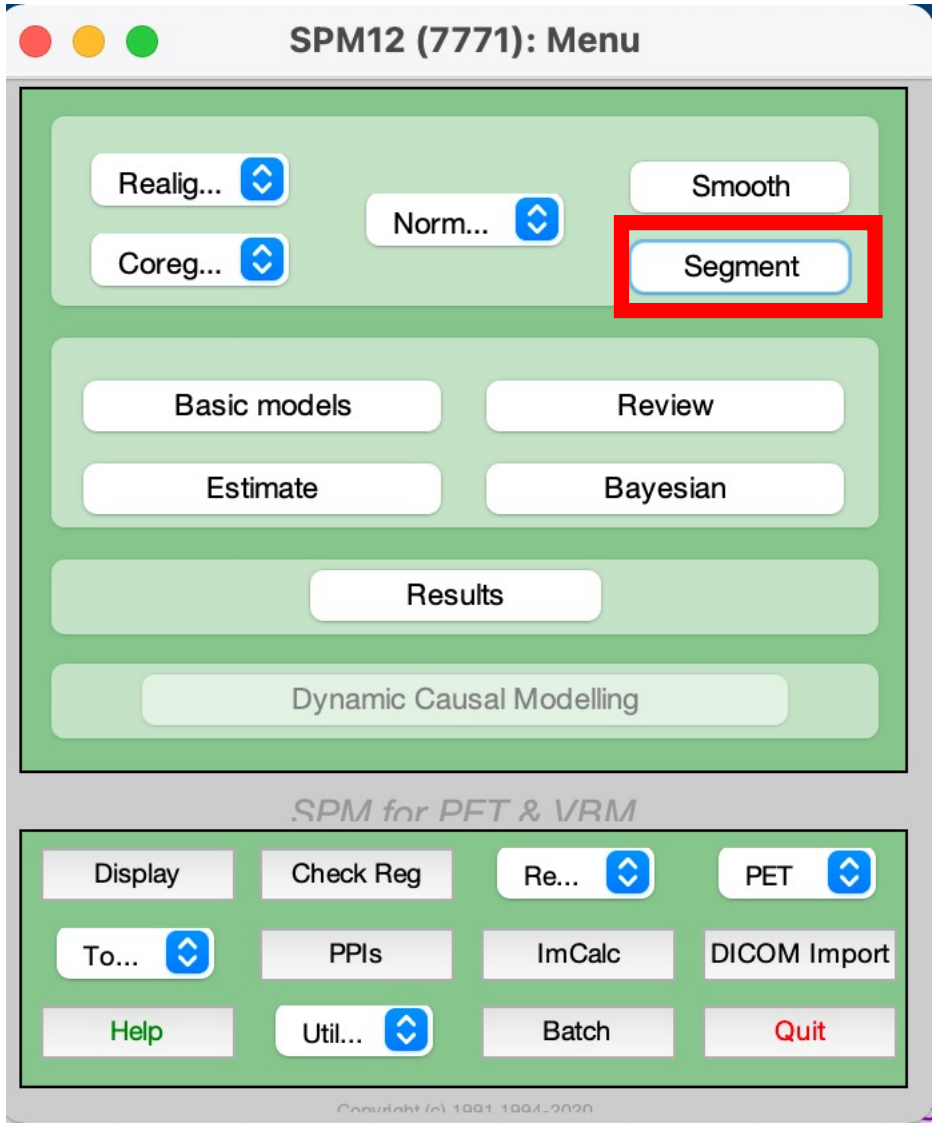
- MRI-based normalisation via MRI-segmentation
  - Tissue class segments (GM, WM, CSF) are matched with template TPMs



- PET-template-based normalisation



Spatial normalisation in SPM (MRI-based)



Spatial normalisation in SPM (MRI-based)

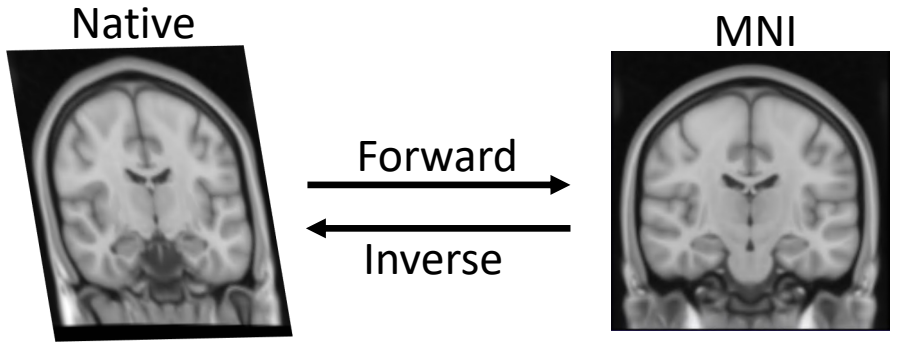
Current Module: Segment

Help on: Segment
Data
. Channel
. . Volumes ..._data\MRIdata_nativespace\nrm2018mri_nativespace\T1\rnrm2018mri_nativespace.nii,1
. . Bias regularisation light regularisation (0.001)
. . Bias FWHM 60mm cutoff
. . Save Bias Corrected Save Nothing
Tissues
. Tissue
. . Tissue probability map o:\spm12\tpm\TPM.nii,1

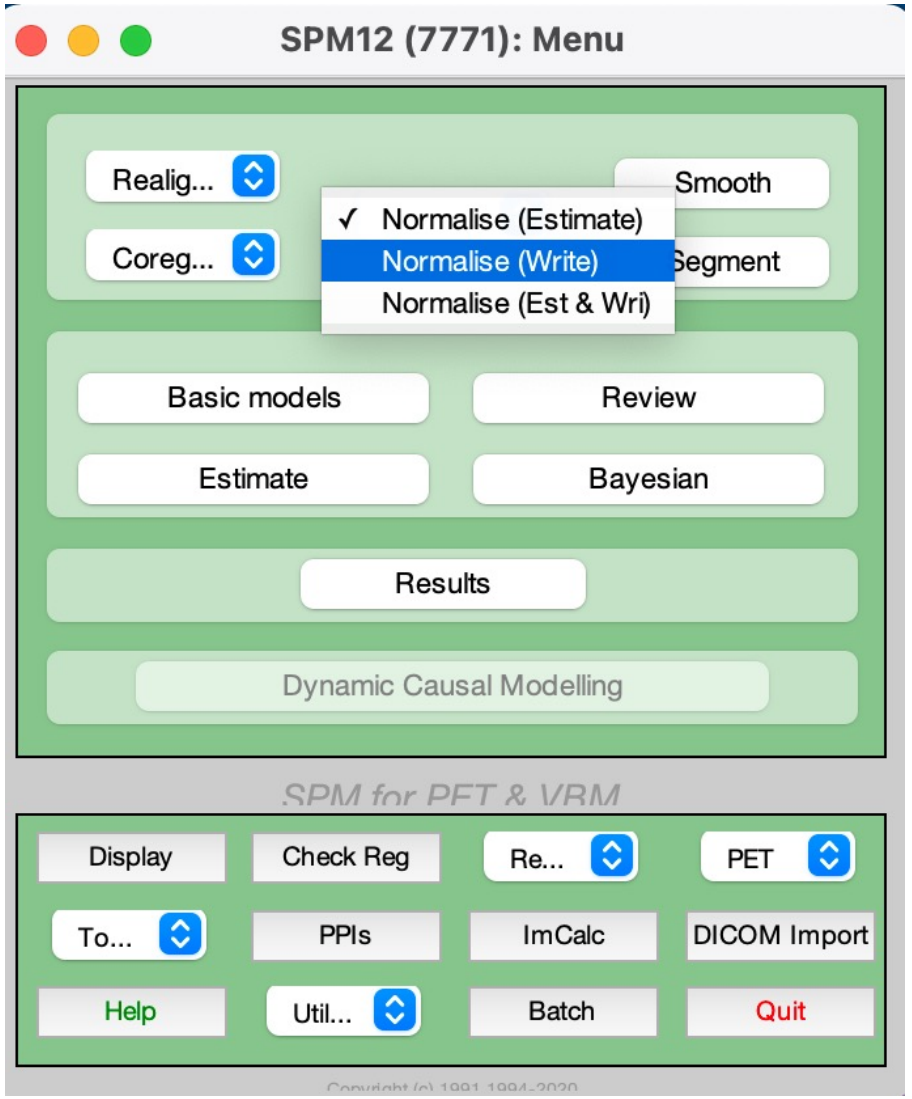
. Smoothness 0
. Sampling distance 3
. Deformation Fields Inverse + Forward

Current Item: Deformation Fields

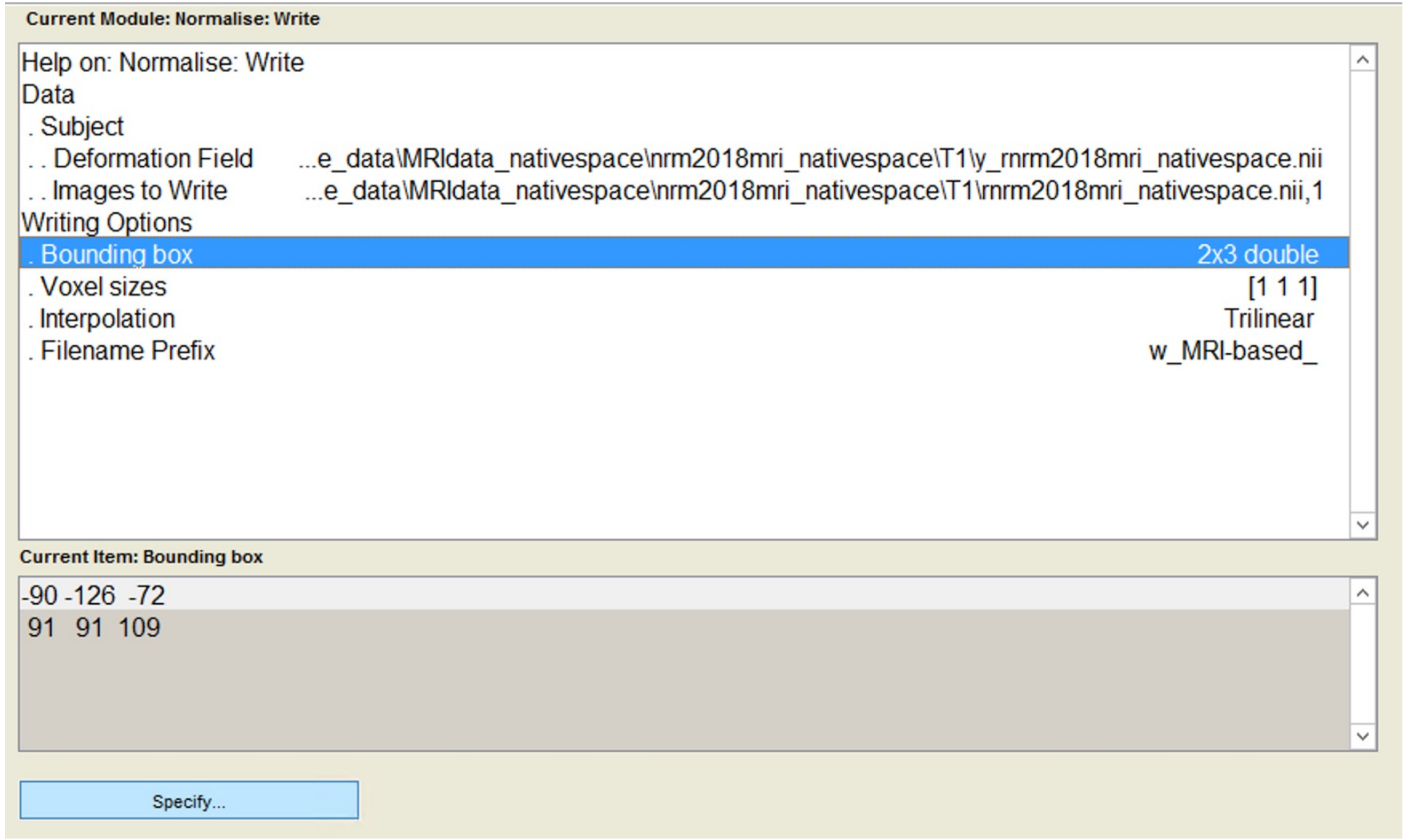
None
Inverse
Forward
*Inverse + Forward



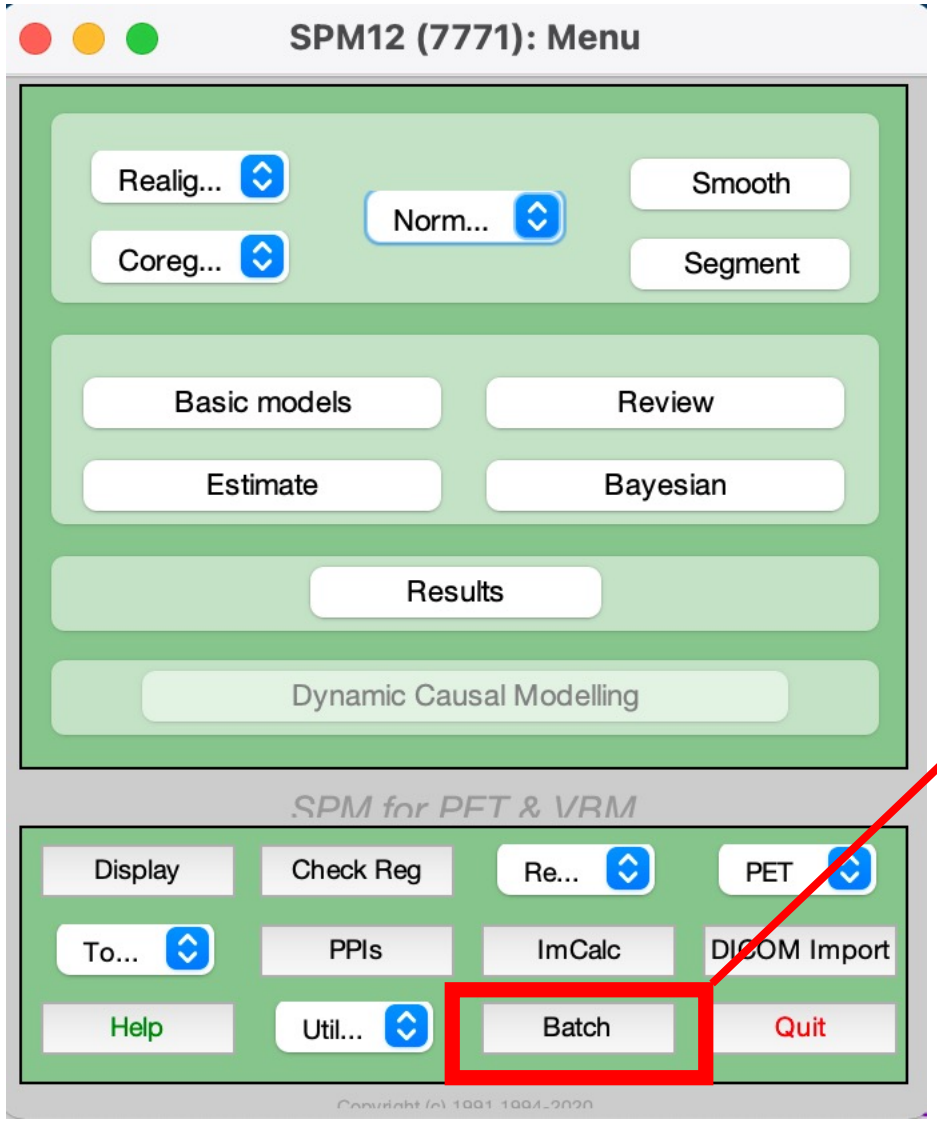
Spatial normalisation in SPM (MRI-based)

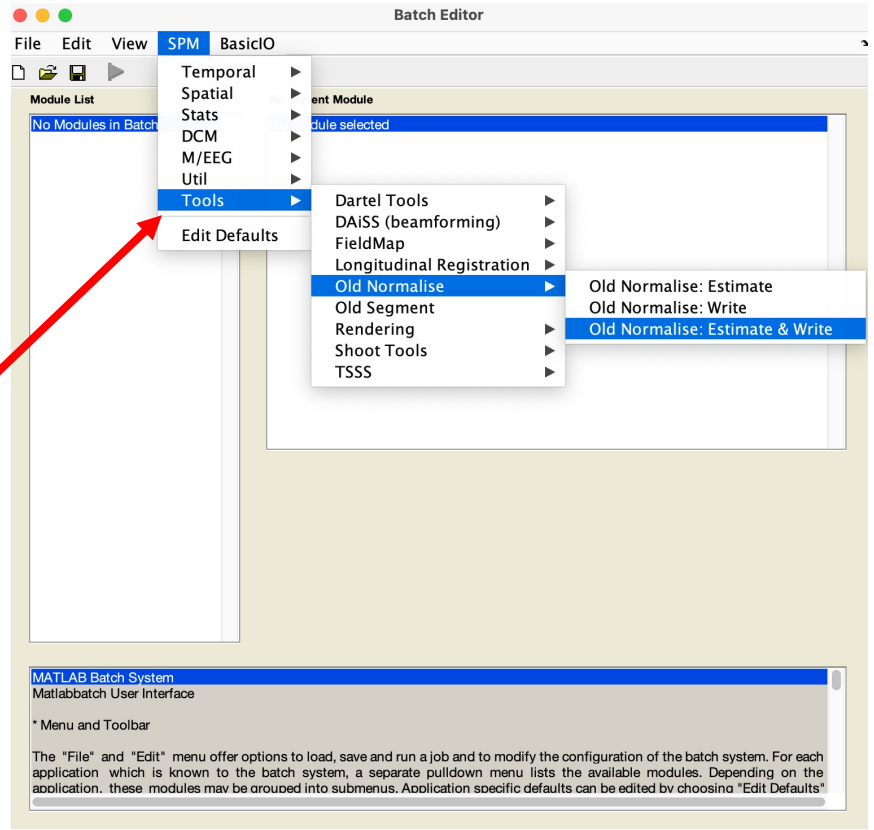


Spatial normalisation in SPM (MRI-based)



Spatial normalisation in SPM (PET-template)





Spatial normalisation in SPM (PET-template)

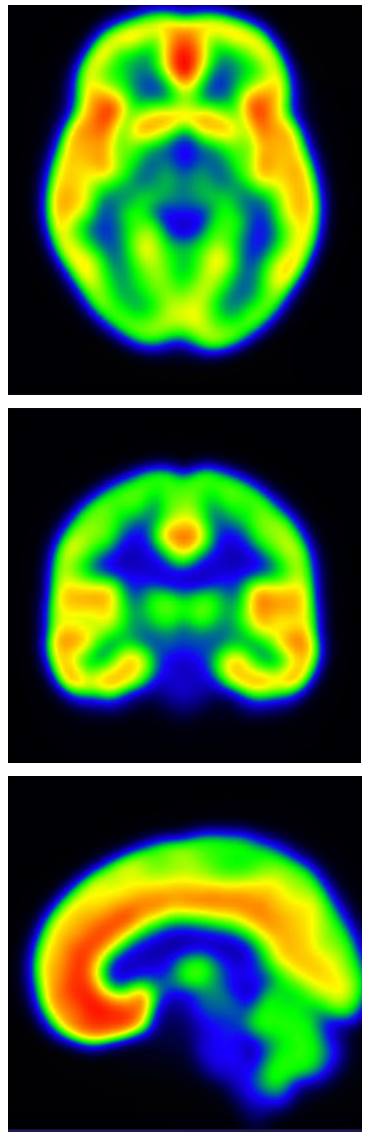
Current Module: Old Normalise: Estimate & Write

Help on: Old Normalise: Estimate & Write	
Data	
. Subject	
. . Source Image	...\nii\meanpet_nrm2018baseline1_nativespace_motion.nii,1
. . Source Weighting Image	0 files
. . Images to Write	24 files
Estimation Options	
. Template Image	...ging_course_data\rs8mm_RO15_PET_template_MNI.nii,1
. Template Weighting Image	0 files
. Source Image Smoothing	8
. Template Image Smoothing	0
. Affine Regularisation	ICBM space template
. Nonlinear Frequency Cutoff	25

Current Item: Images to Write

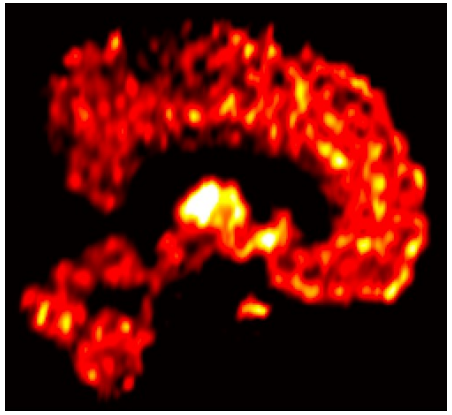
ativespace\nrm2018baseline1_nativespace\PET\nii\rpet_nrm2018baseline1_nativespace_motion.nii,21
ativespace\nrm2018baseline1_nativespace\PET\nii\rpet_nrm2018baseline1_nativespace_motion.nii,22
ativespace\nrm2018baseline1_nativespace\PET\nii\rpet_nrm2018baseline1_nativespace_motion.nii,23
tivespace\nrm2018mri_nativespace\T1\nrm2018mri_nativespace.nii,1

Specify...

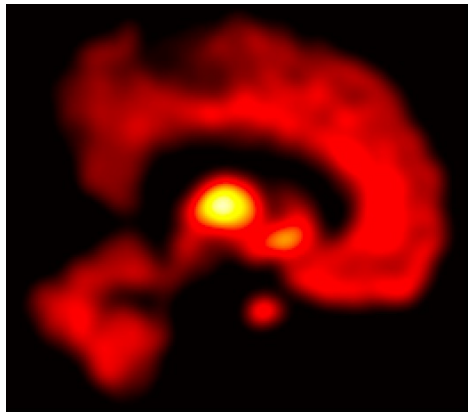


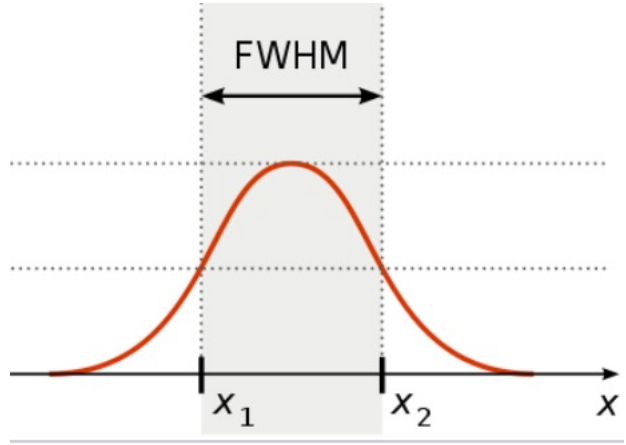
Smoothing

- The resulting normalised images are noisy
  - Violates the normality assumption in the voxel-level statistical analysis
- Smoothing increases signal-to-noise ratio and compensates the normalisation errors
- Cost: reduced spatial resolution

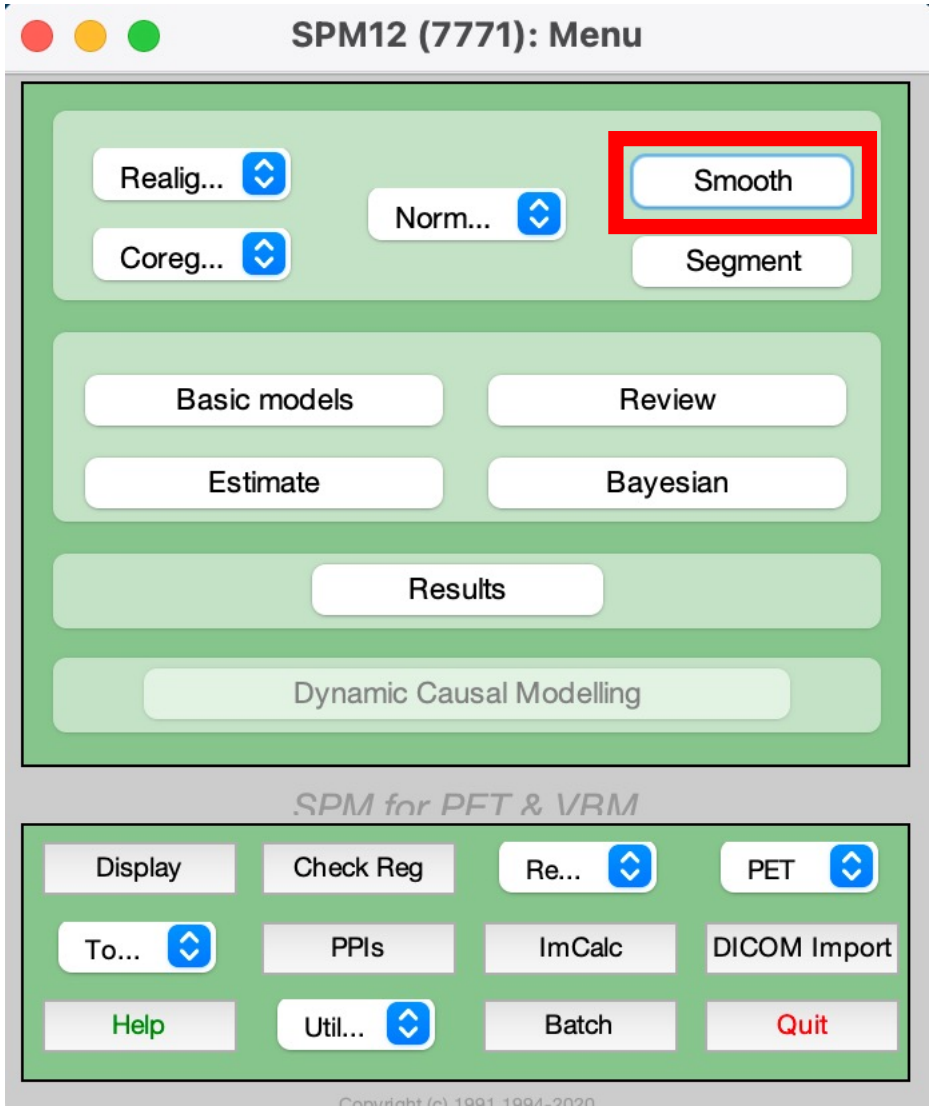


Gaussian 8mm
FWHM smooth

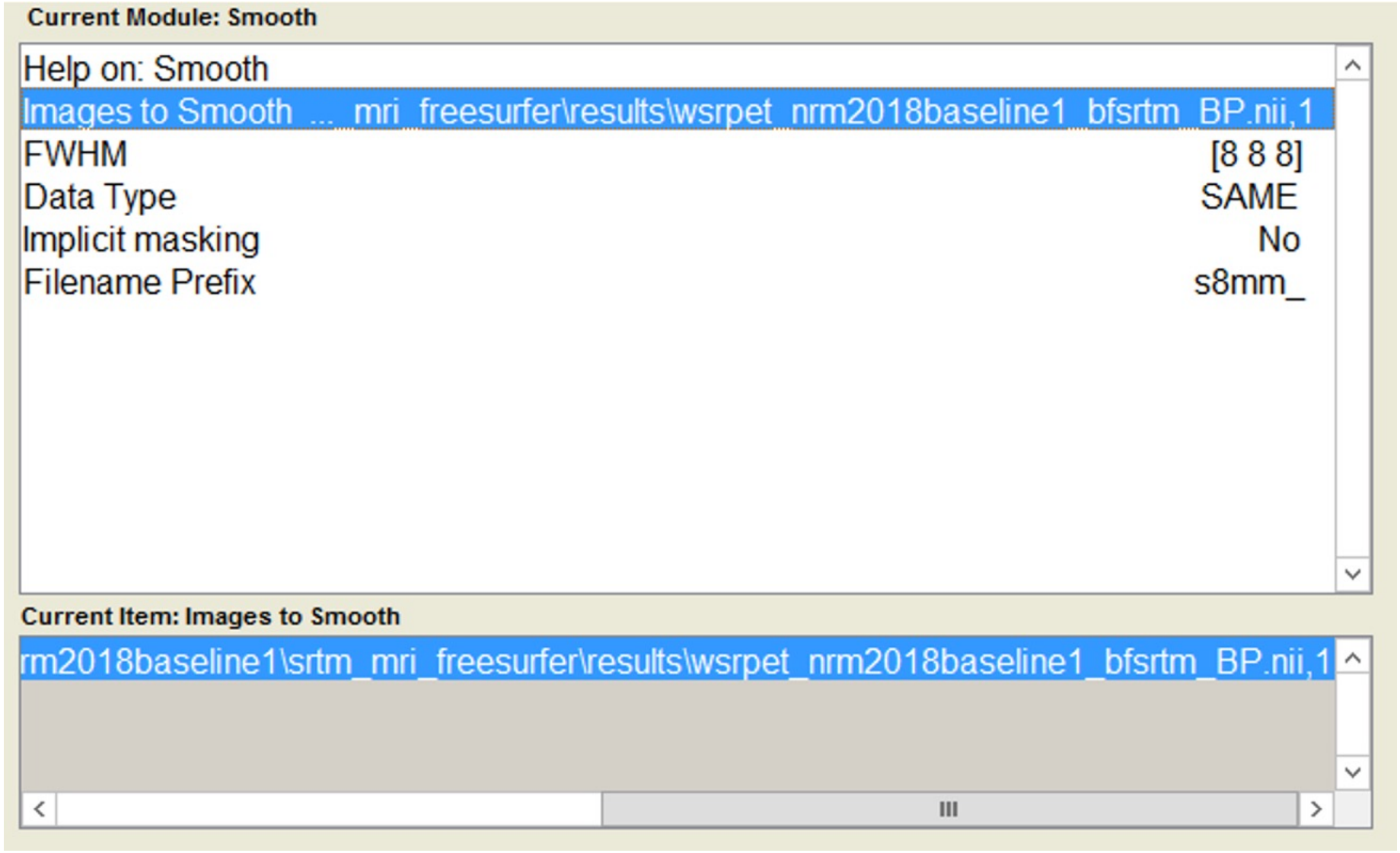




Smoothing in SPM

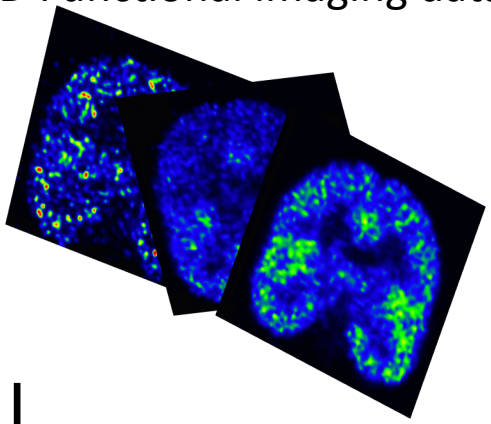


Smoothing in SPM

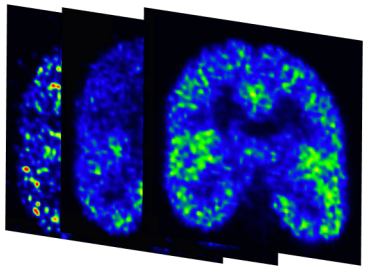


Preprocessing overview

4D Functional imaging data

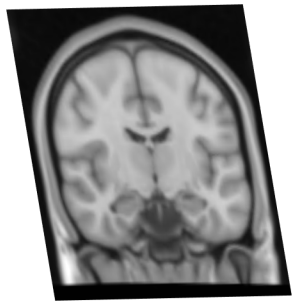


Motion correction



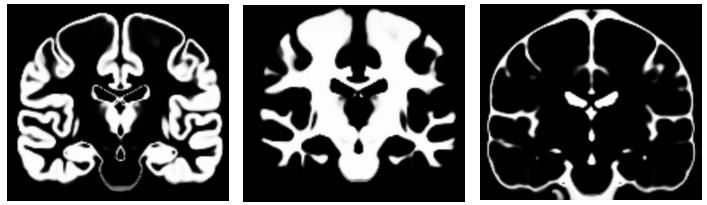
Motion corrected data

Anatomical MRI

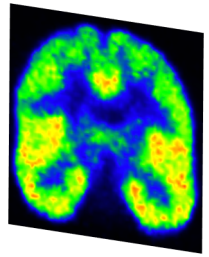


Segment

Tissue Probability Maps (TPM)

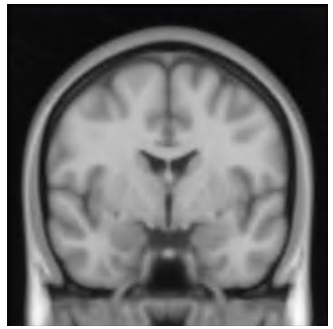


Registration + interpolation



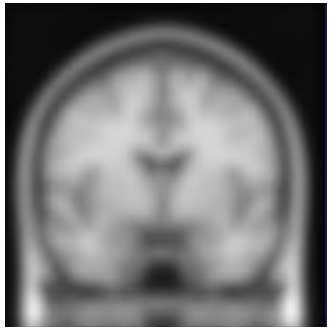
Mean functional image

Normalisation



Normalised image in MNI space

Smooth



Analysis

Further details

- R. Frackowiak, K. Friston et al., Human brain function, 2003
  - online book: https://www.fil.ion.ucl.ac.uk/spm/doc/books/hbf2/
- SPM spatial preprocessing tutorial / preprocessing demo (Ged Rigdway / John Ashburner):
  - https://www.fil.ion.ucl.ac.uk/spm/course/video/
- Nifti format
  - https://brainder.org/2012/09/23/the-nifti-file-format/