fMR Processing(1)

Ing. Jan Šanda

fMR processing (1. excercise)
Pipeline

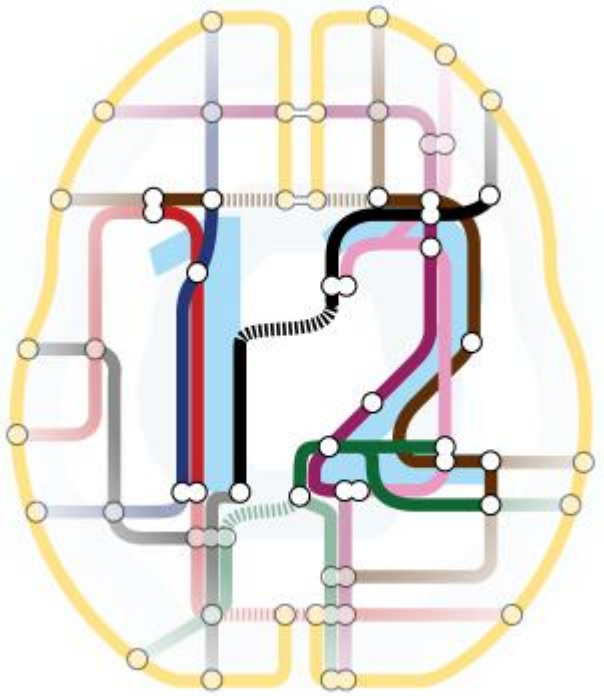
1. **Conversion** of data: DICOM -> NIFTI ✓ (done; *.nii suffix)
2. **Slice Timing:** temporal correction (TR vs. HRF) ✘ (skipping this step)
3. **Realignment** of functional data - spatial correction of data in time
4. **Smooth** Gaussovským filtrem
5. **Model specification** + **Review**
6. **Estimate Model**
7. **Results** + **Display**

Necessary SW:
Matlab + SPM12 toolbox (Win, MacOS)

Statistical **P**arametric **M**apping
SPM12 download:
https://www.fil.ion.ucl.ac.uk/spm/software/spm12/

SPM12 manual:
„../toolbox/spm12/man/manual.pdf“

4 basic SPM windows:- Menu
- Results
- Graphic
- Batch Editor



Recommended resources

SPM12

https://www.fil.ion.ucl.ac.uk/spm/doc/

GLM

https://www.fil.ion.ucl.ac.uk/mfd_archive/2011/page1/mfd2011_GLM.pdf

fMR processing
Data

Paradigm:

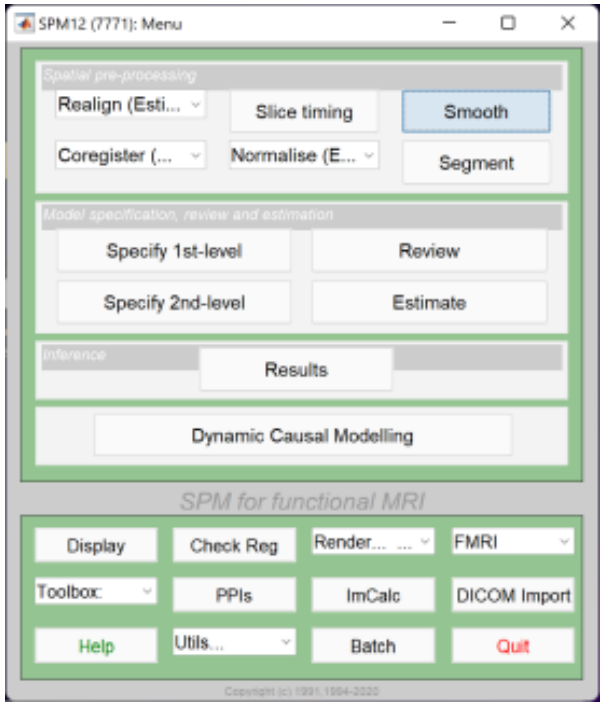
1. **Neurotracker** (moving objects - balls) 125vol, TR=2000ms, 60 slices
2. **2-back test** (same letter 2 back in row) 110vol, TR=2000ms, 60 slices
3. **Visual** test (chessboard) 135vol, TR=2000ms, 60 slices

Volunteer data: folders **zk84**, **zk 85**, **zk86**, **zk87**, **zk88**, **zk89**

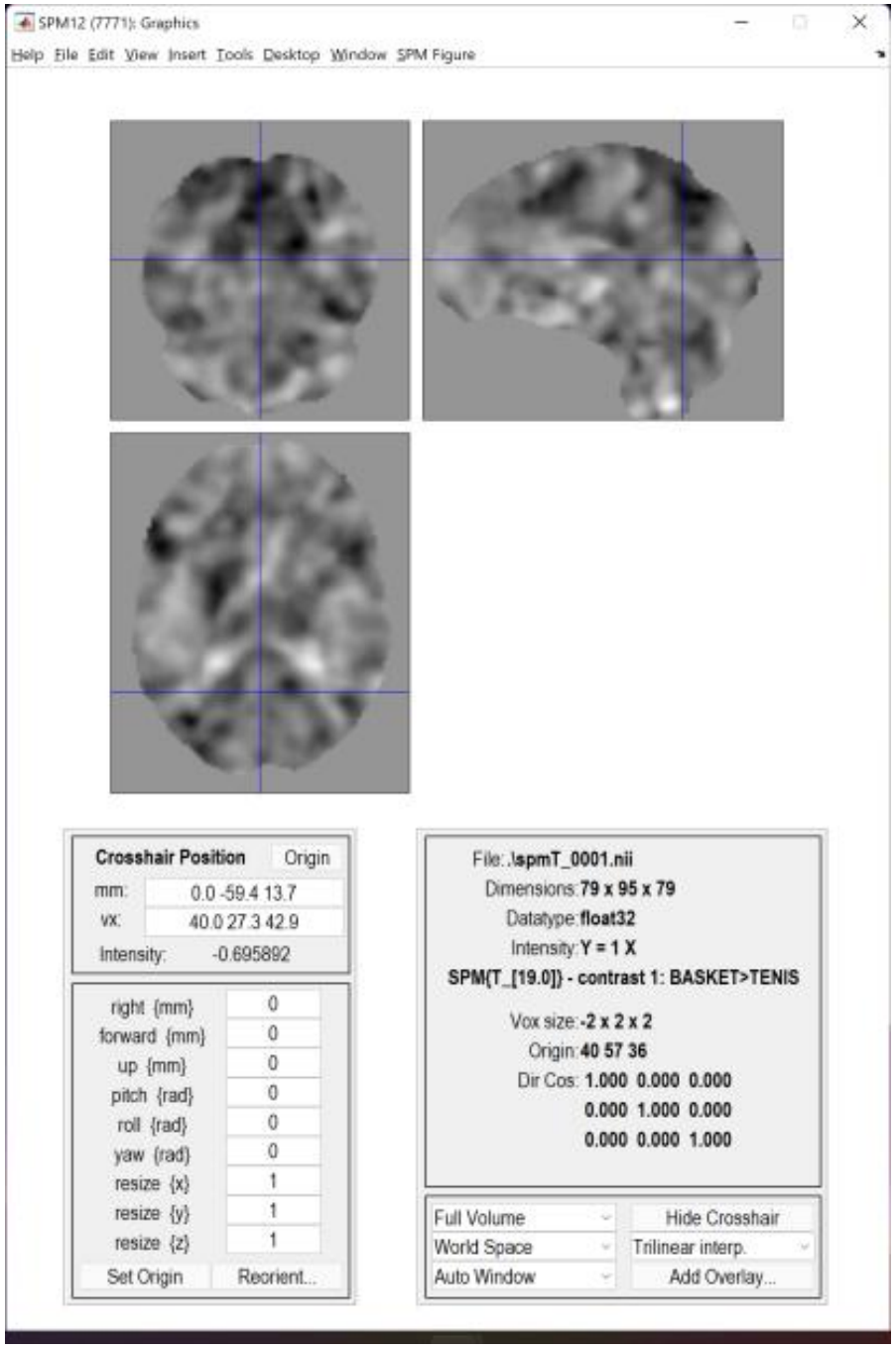
Folder structure:

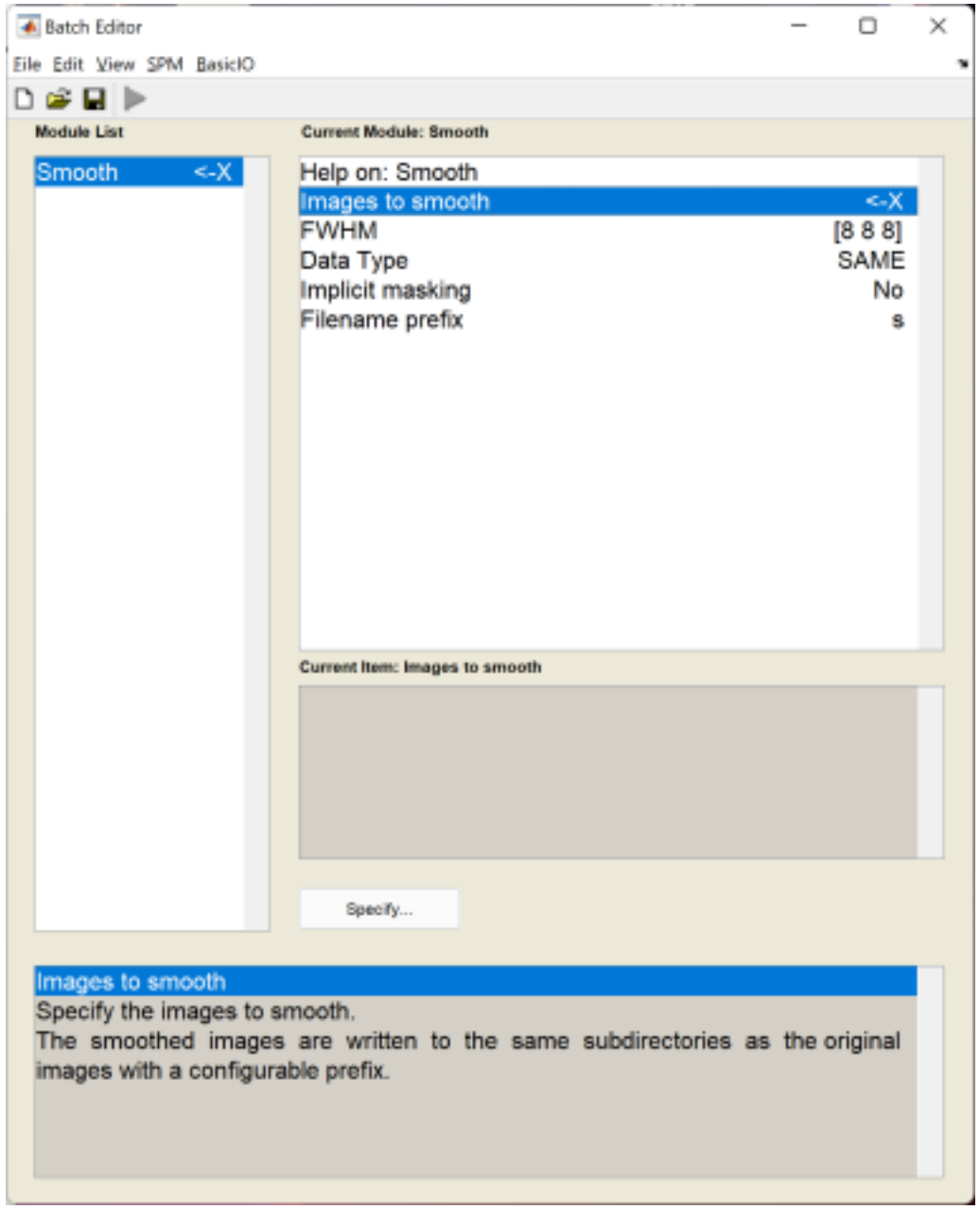
fMR_neurotracker (125 nii-files)
fMR_2back (110 nii-files)
fMR_visual (135 nii-files)
t1 (1 nii-file)

zk84	F-O	1997	16.02.2022
zk85	D-K	1996	16.02.2022
zk86	J-Š	1998	23.02.2022
zk87	J-S	1998	23.02.2022
zk88	B-R	1998	02.03.2022
zk89	Y-F	1997	02.03.2022

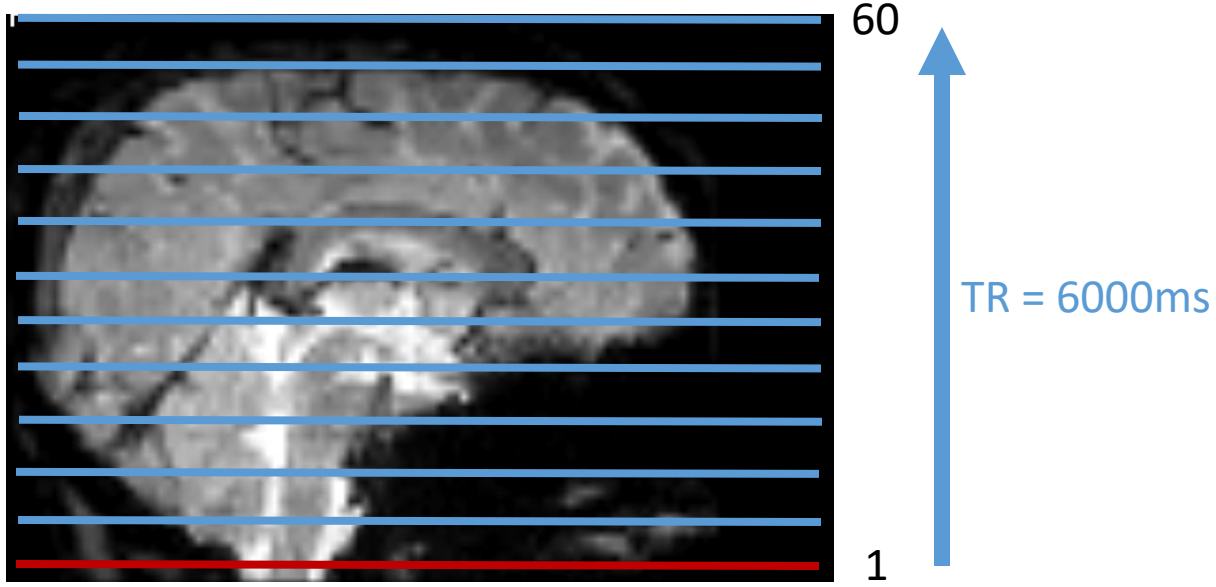

SPM12 (7771): Menu
Spatial pre-processing
Realign (Esti...
Slice timing
Smooth
Coregister (...
Normalise (E...
Segment
Model specification, review and estimation
Specify 1st-level
Review
Specify 2nd-level
Estimate
Inference
Results
Dynamic Causal Modelling
SPM for functional MRI
Display
Check Reg
Render...
FMRI
Toolbox:
PPIs
ImCalc
DICOM Import
Help
Utils...
Batch
Quit

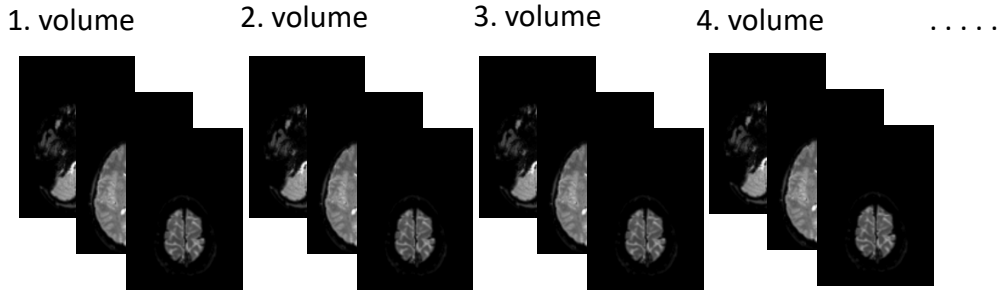
SPM12 (7771): SPM(T): Results
Design Contrasts Atlas
p-values
whole brain
current cluster
small volume
Multivariate
eigenvariate
CVA
multivariate Bayes
BMS
p-value
Display
plot
overlays...
save...
Hemodynamics
clear
exit
co-ordinates
x = 0.00 y = 0.00 z = 0.00
statistic

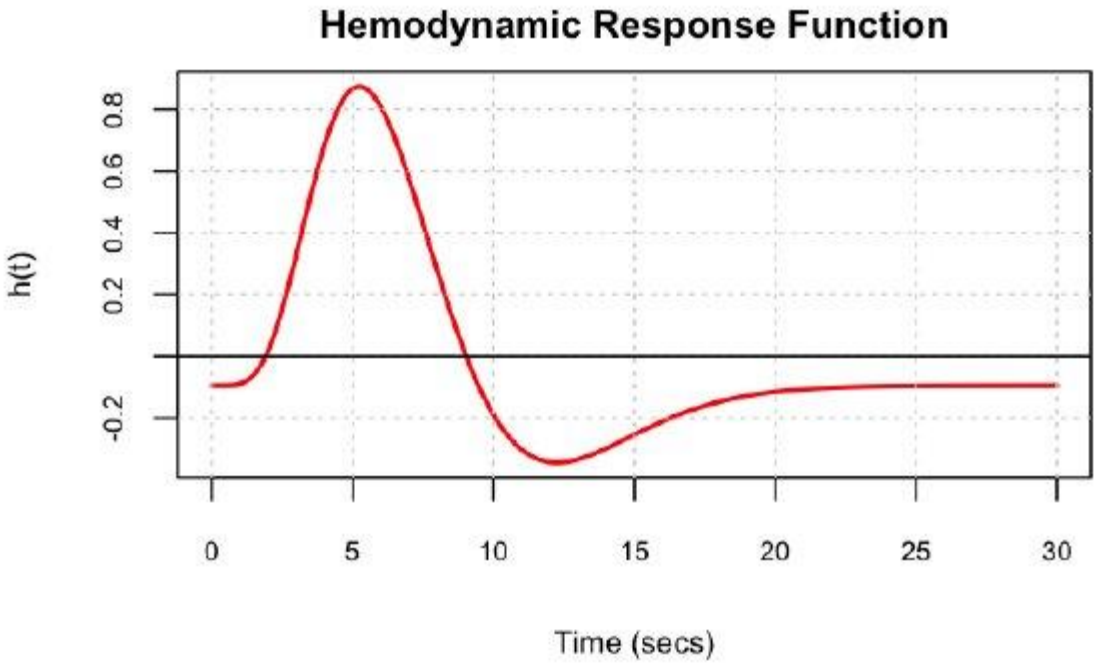

SPM12 (7771): Graphics
Help File Edit View Insert Tools Desktop Window SPM Figure
Crosshair Position
Origin
mm: 0.0 -59.4 13.7
vx: 40.0 27.3 42.9
Intensity: -0.695892
right {mm} 0
forward {mm} 0
up {mm} 0
pitch {rad} 0
roll {rad} 0
yaw {rad} 0
resize {x} 1
resize {y} 1
resize {z} 1
Set Origin
Reorient...
File: .\spmT_0001.nii
Dimensions: 79 x 95 x 79
Datatype: float32
Intensity: Y = 1 X
SPM{T_[19.0]} - contrast 1: BASKET>TENIS
Vox size: -2 x 2 x 2
Origin: 40 57 36
Dir Cos: 1.000 0.000 0.000
0.000 1.000 0.000
0.000 0.000 1.000
Full Volume
Hide Crosshair
World Space
Trilinear interp.
Auto Window
Add Overlay...


Batch Editor
File Edit View SPM BasicIO
Module List
Smooth <-X
Current Module: Smooth
Help on: Smooth
Images to smooth <-X
FWHM [8 8 8]
Data Type SAME
Implicit masking No
Filename prefix s
Current Item: Images to smooth
Specify...
Images to smooth
Specify the images to smooth.
The smoothed images are written to the same subdirectories as the original images with a configurable prefix.

Slice timing (skipping this step, **TR=2s**)



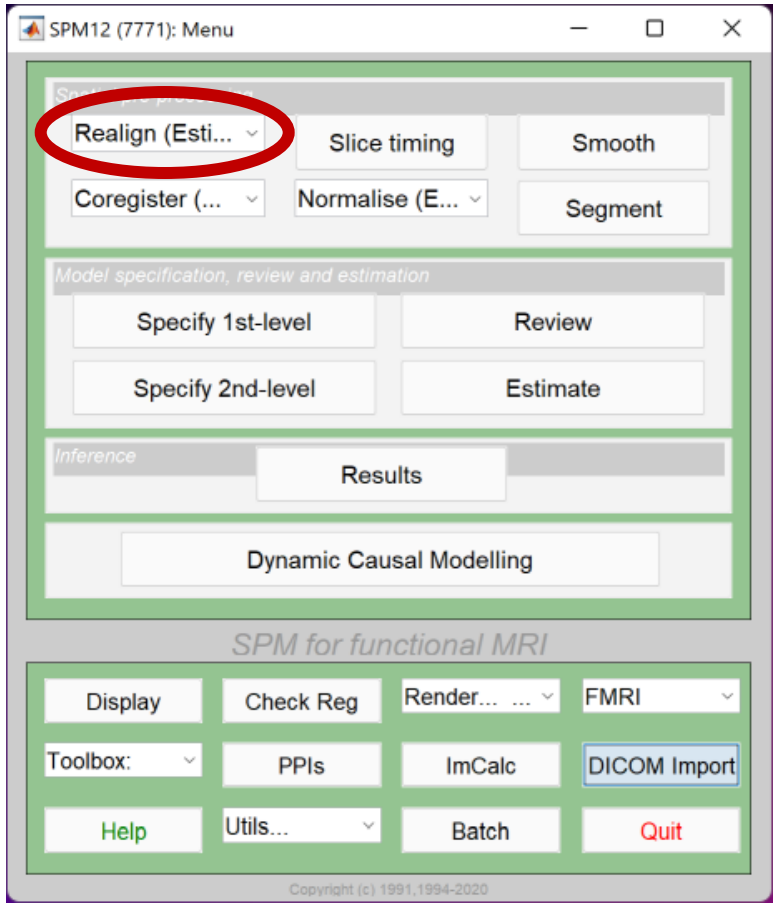


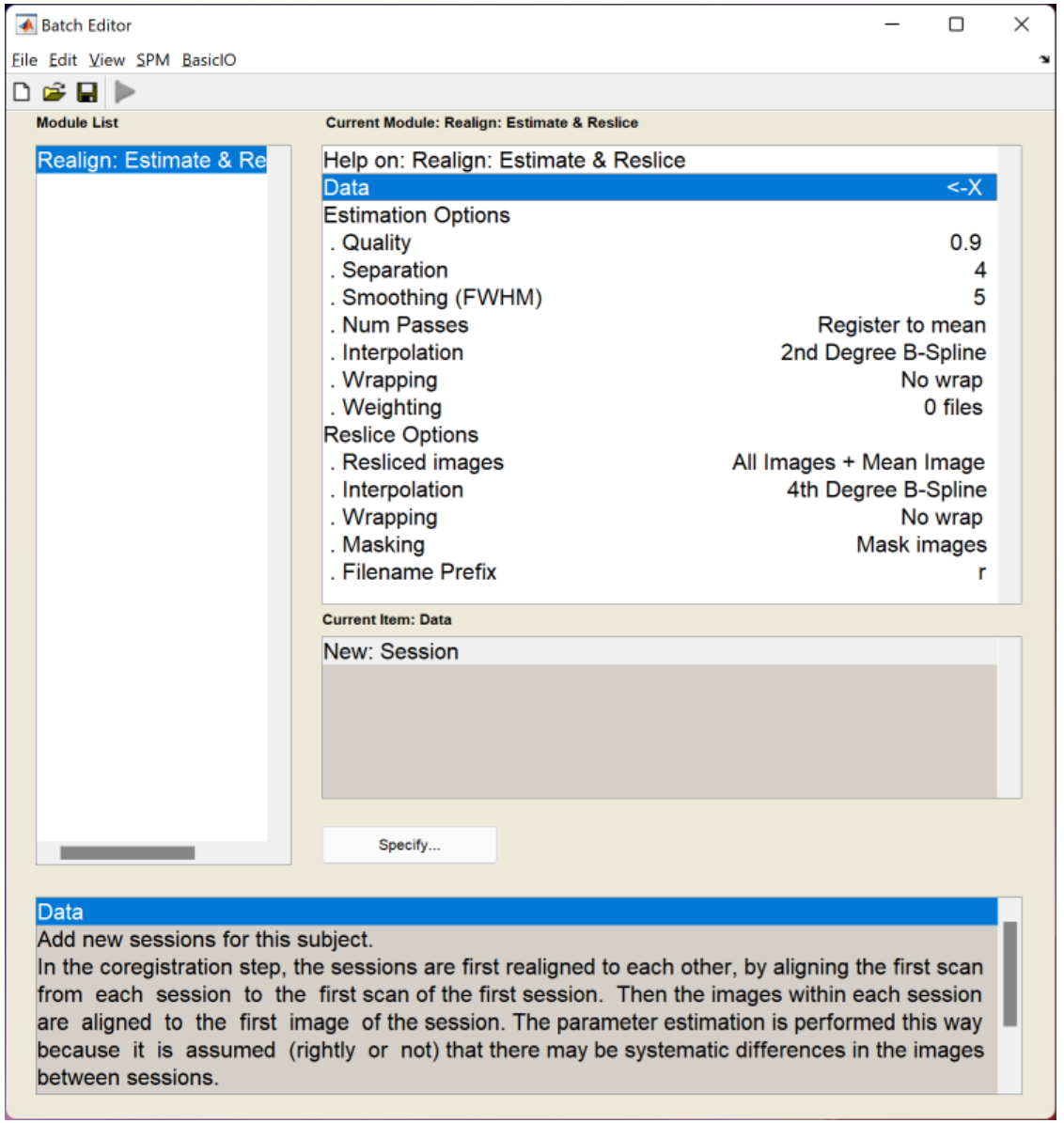


Realign data

- This routine realigns a time-series of images acquired from the same subject using a least squares approach and a 6 parameter (rigid body) spatial transformation. The first image in the list specified by the user is used as a reference to which all subsequent scans are realigned. The reference scan does not have to the the first chronologically and it may be wise to chose a "representative scan" in this role.
- The aim is primarily to remove movement artefact in fMRI and PET time-series (or more generally longitudinal studies). The headers are modified for each of the input images, such that. they reflect the relative orientations of the data. The details of the transformation are displayed in the results window as plots of translation and rotation. A set of realignment parameters are saved for each session, named rp_*.txt. These can be modelled as confounds within the general linear model

Realign data





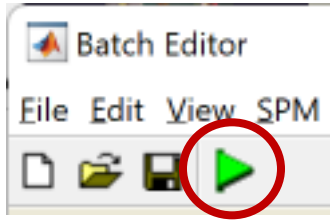
Realign data

MENU: Realign (Estimate & Reslice)

BATCH EDITOR:

a) Data – Session … all fMR files

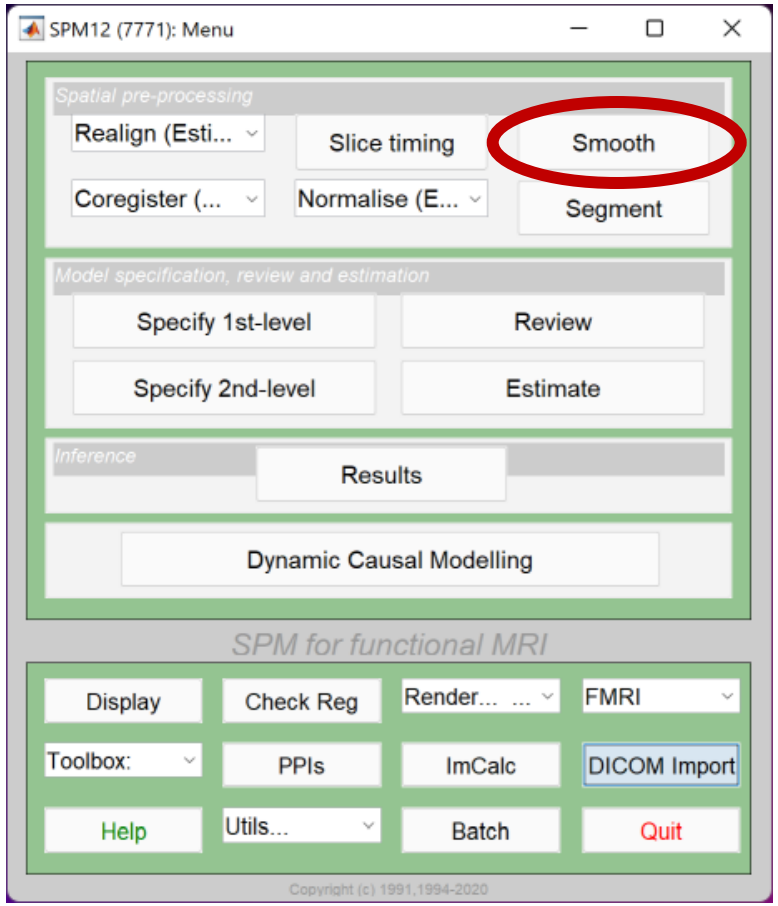
b) Run batch

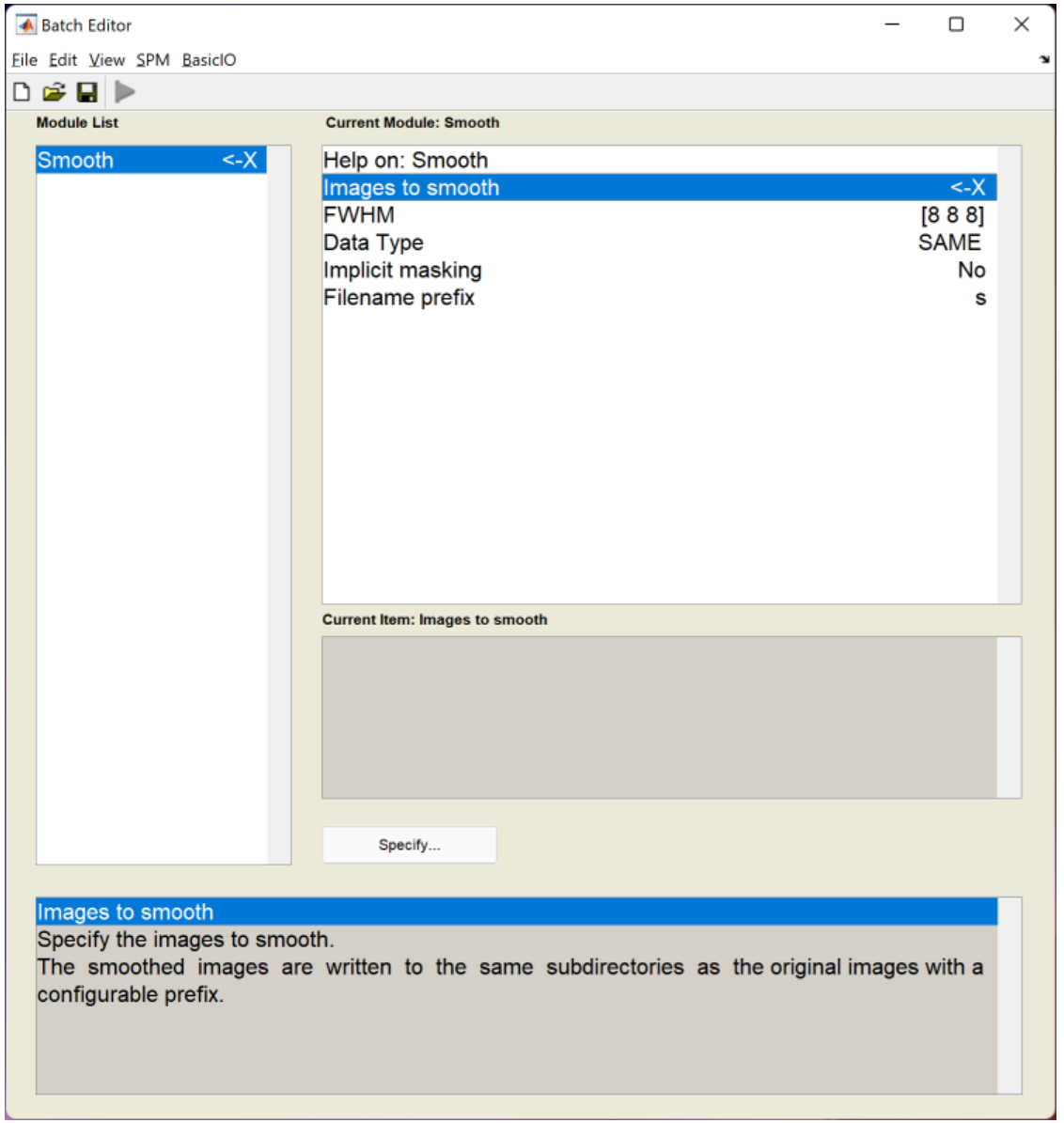


Output:

- Resliced files (prefix „**r*.nii**“)
- „**mean*.nii**“ file (mean of all fMR files)
- Realign parameters file „**rp_*.txt**“

Smooth


SPM12 (7771): Menu
Spatial pre-processing
Realign (Esti...
Slice timing
Smooth
Coregister (...
Normalise (E...
Segment
Model specification, review and estimation
Specify 1st-level
Review
Specify 2nd-level
Estimate
Inference
Results
Dynamic Causal Modelling
SPM for functional MRI
Display
Check Reg
Render... ...
FMRI
Toolbox:
PPIs
ImCalc
DICOM Import
Help
Utils...
Batch
Quit
Copyright (c) 1991,1994-2020


Batch Editor
File Edit View SPM BasicIO
Module List
Current Module: Smooth
Smooth <-X
Help on: Smooth
Images to smooth <-X
FWHM [8 8 8]
Data Type SAME
Implicit masking No
Filename prefix s
Current Item: Images to smooth
Specify...
Images to smooth
Specify the images to smooth.
The smoothed images are written to the same subdirectories as the original images with a configurable prefix.

Smooth

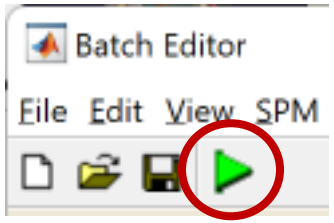
MENU: Smooth

BATCH EDITOR:

a) Images to smooth … select all *r*.nii* files

b) FWHM … [4 4 4] (Full width at half maximum of the Gaussian smoothing kernel in mm, doubled size of voxel recommended)

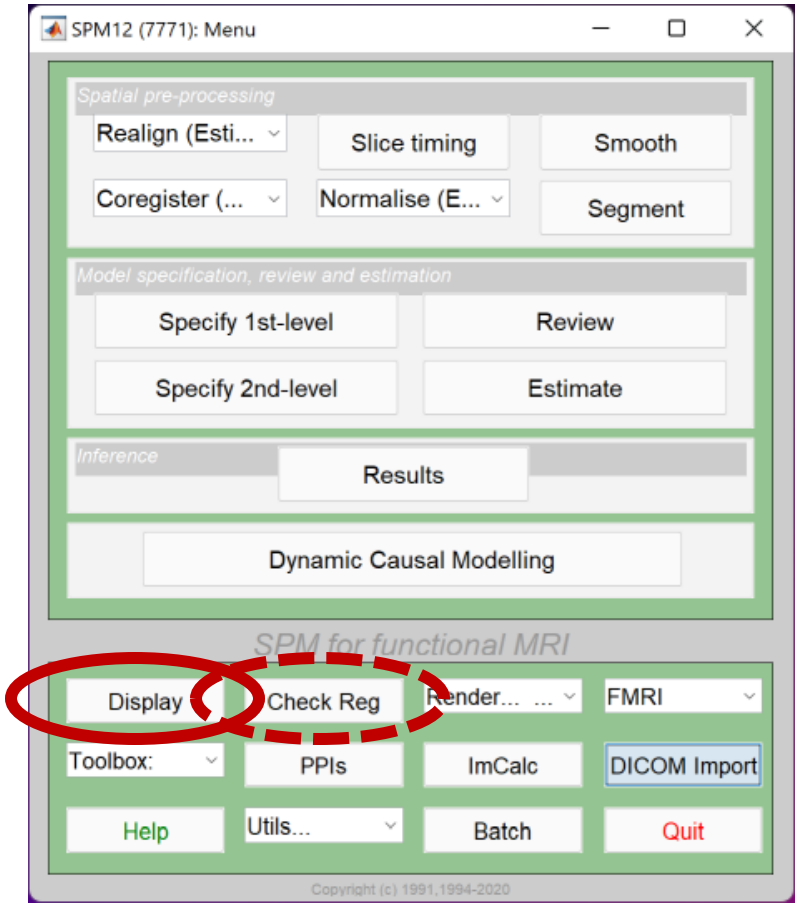
c) Run batch



Output:

- Smoothed files (all with prefix „**s*.nii**“)

Data check (!)


SPM12 (7771): Menu
Spatial pre-processing
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Slice timing
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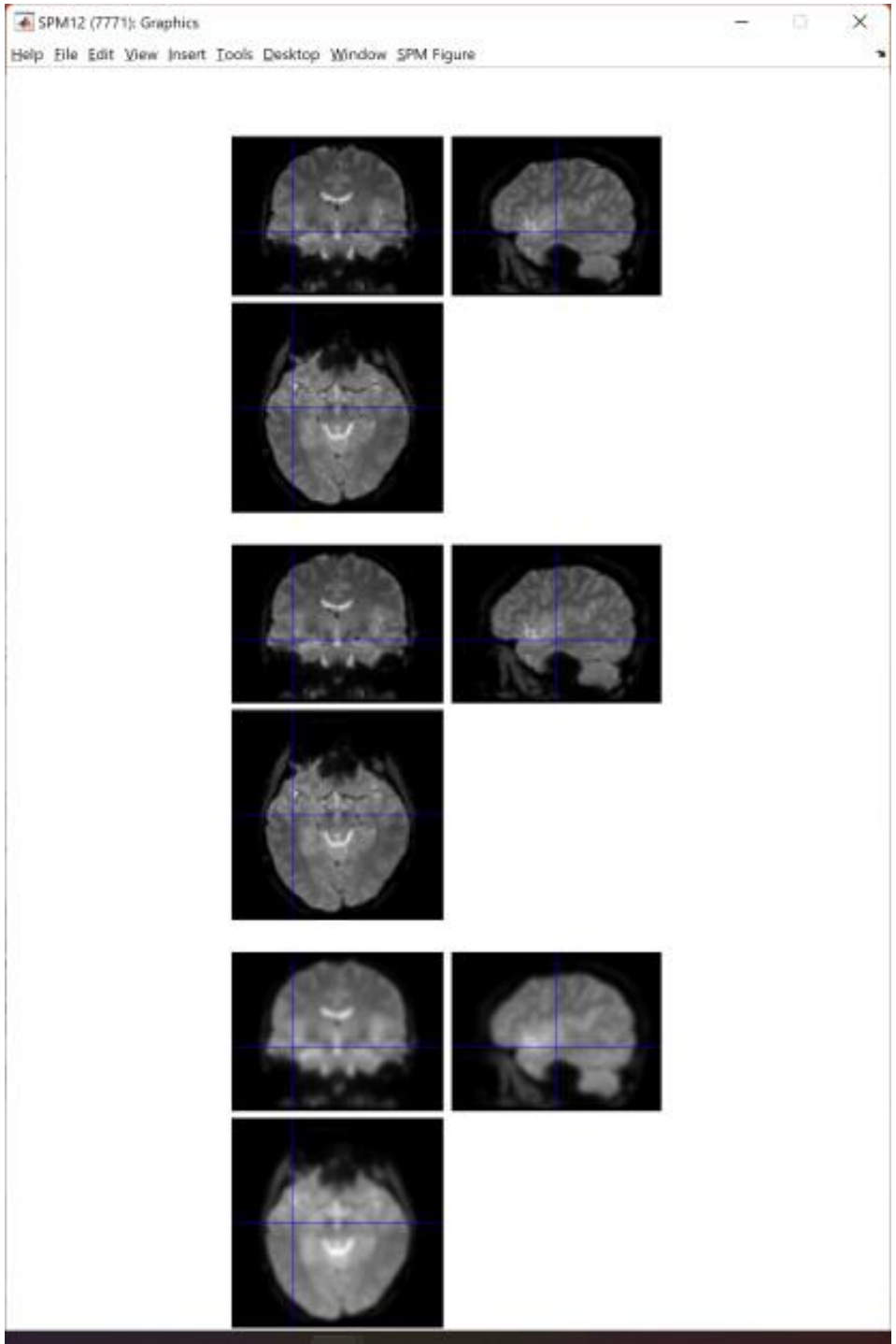
Copyright (c) 1991,1994-2020


SPM12 (7771): Graphics
Help File Edit View Insert Tools Desktop Window SPM Figure

GLM – General Linear Model

$$y = X\beta + e$$

Dependent variable
BOLD signal in particular voxels

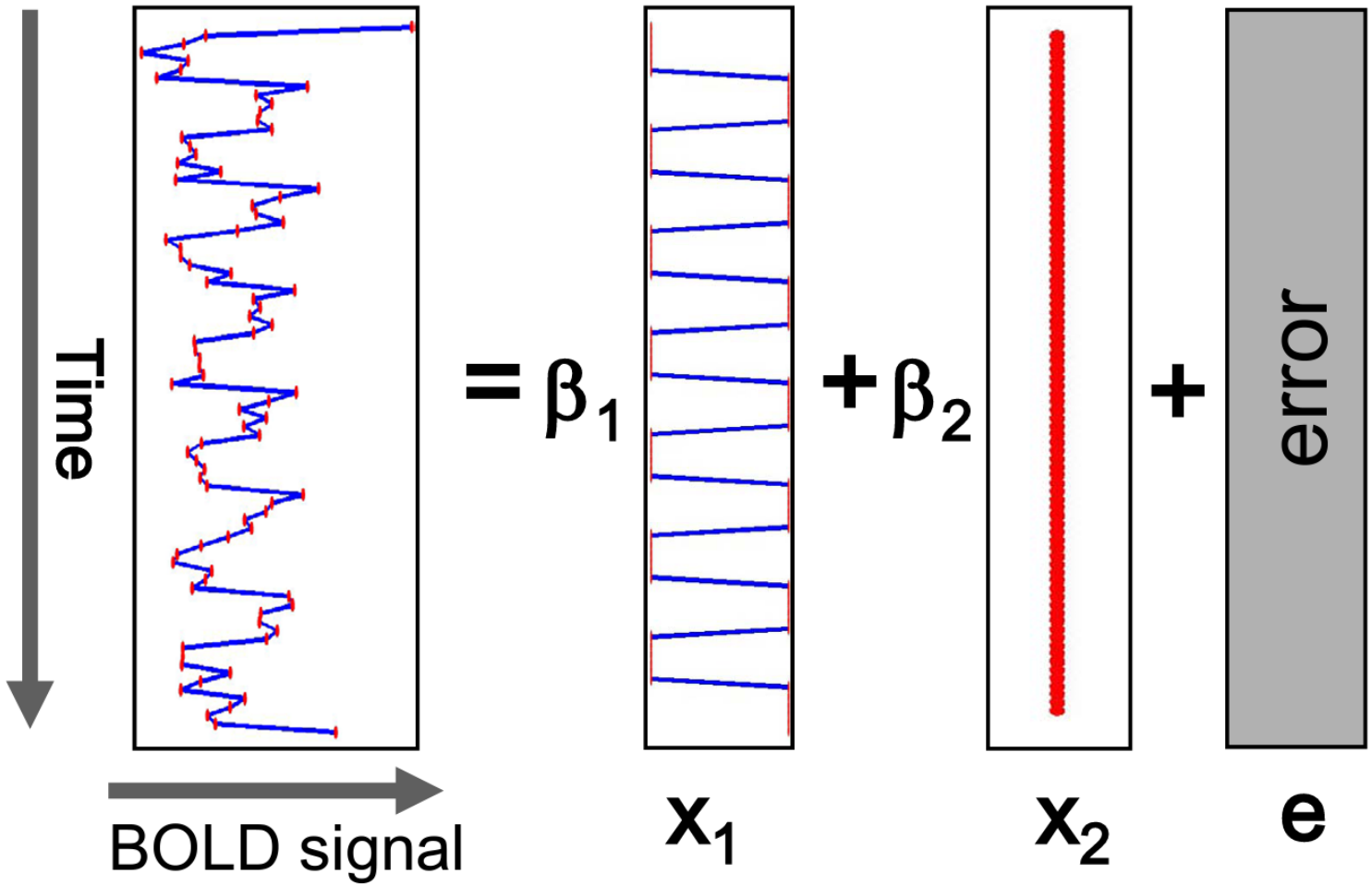
Independent variable (Predictor)
Experiment conditions

Beta parameters (regression coeff.)
Quantifies how much each predictor (X) independently influences the dependent variable (Y)

Error (Residuals)
Variancein the data (y), which is not explained By the linear combination of predictors (x)

https://www.fil.ion.ucl.ac.uk/mfd_archive/2011/page1/mfd2011_GLM.pdf

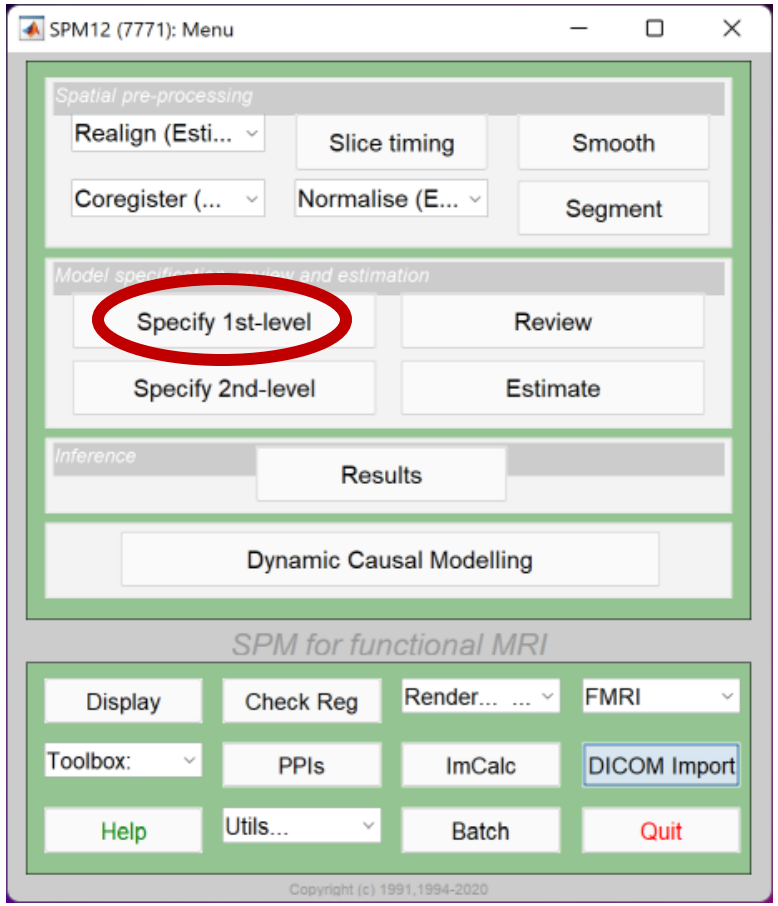
Single voxel regression model

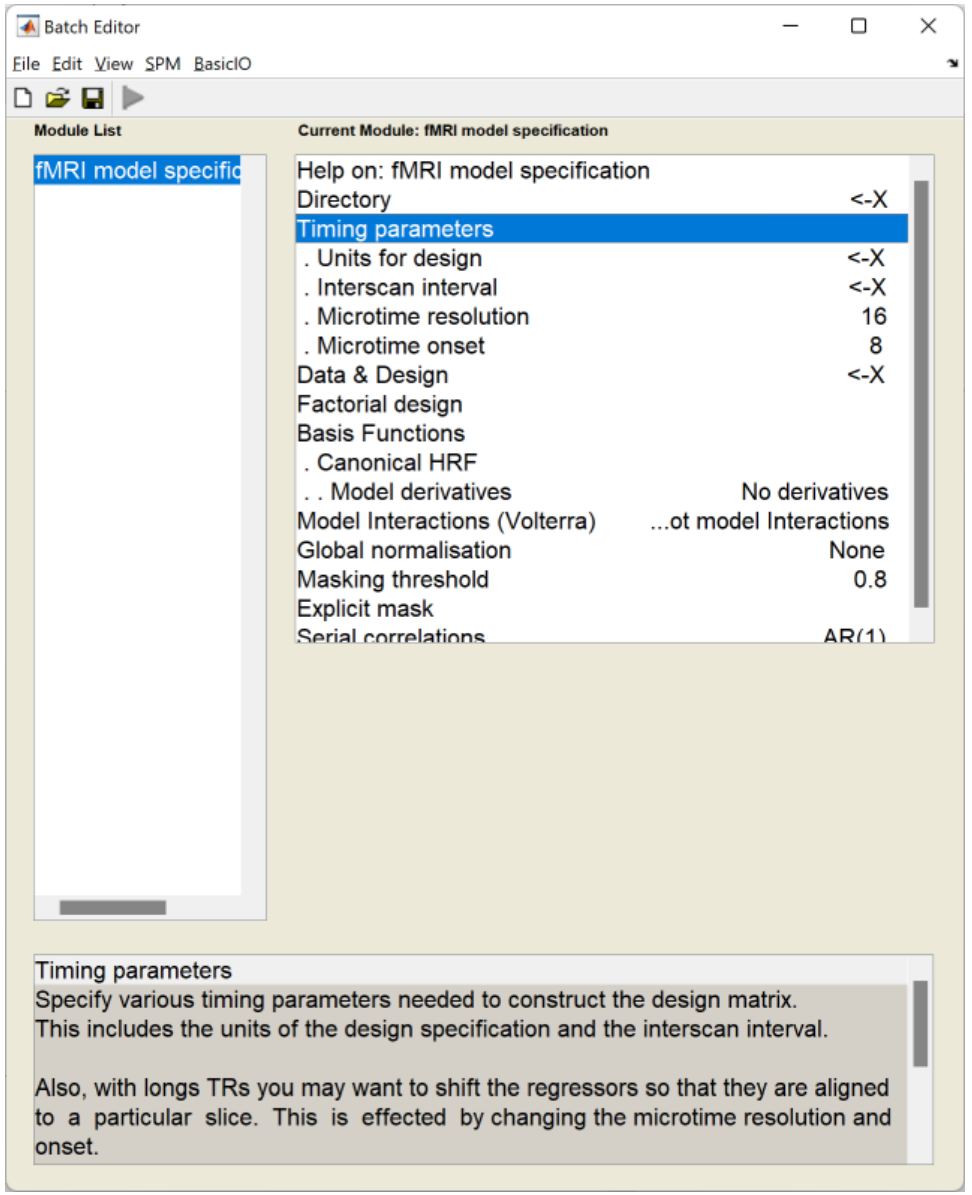


$$y = x_1\beta_1 + x_2\beta_2 + e$$

fMR Statistics

Model specification





fMR Statistics
Model specification

MENU: Specify 1st-level

BATCH EDITOR:

a) Directory … select (pre-created) folder to store model and statistics results
b) Units for design … Scans
c) Interscan interval … 2 (equals to TR)
d) Data & Design
    a) Scans … select sr*.nii data
    b) Conditions
        a) Condition
            a) Name … name of processed paradigm, for example VISUAL
            b) Onset … vector of scans where the activations begins
            c) Durations … duration of activation (in scans)
e) Run batch

Output:
- **SPM.mat** file (GLM model)

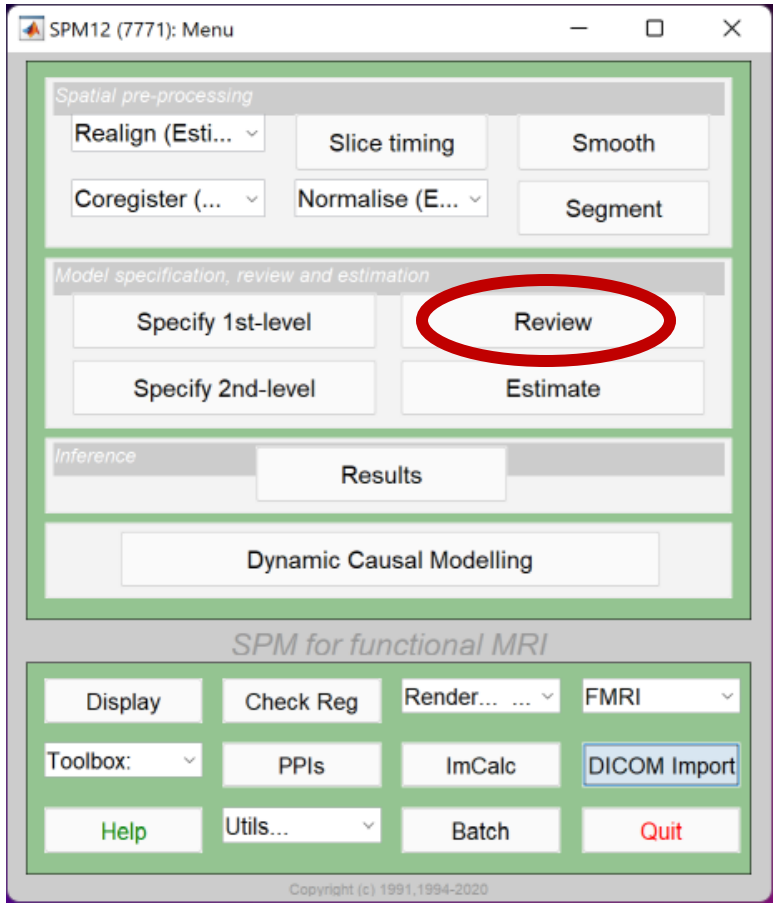
fMR Statistics
Model specification

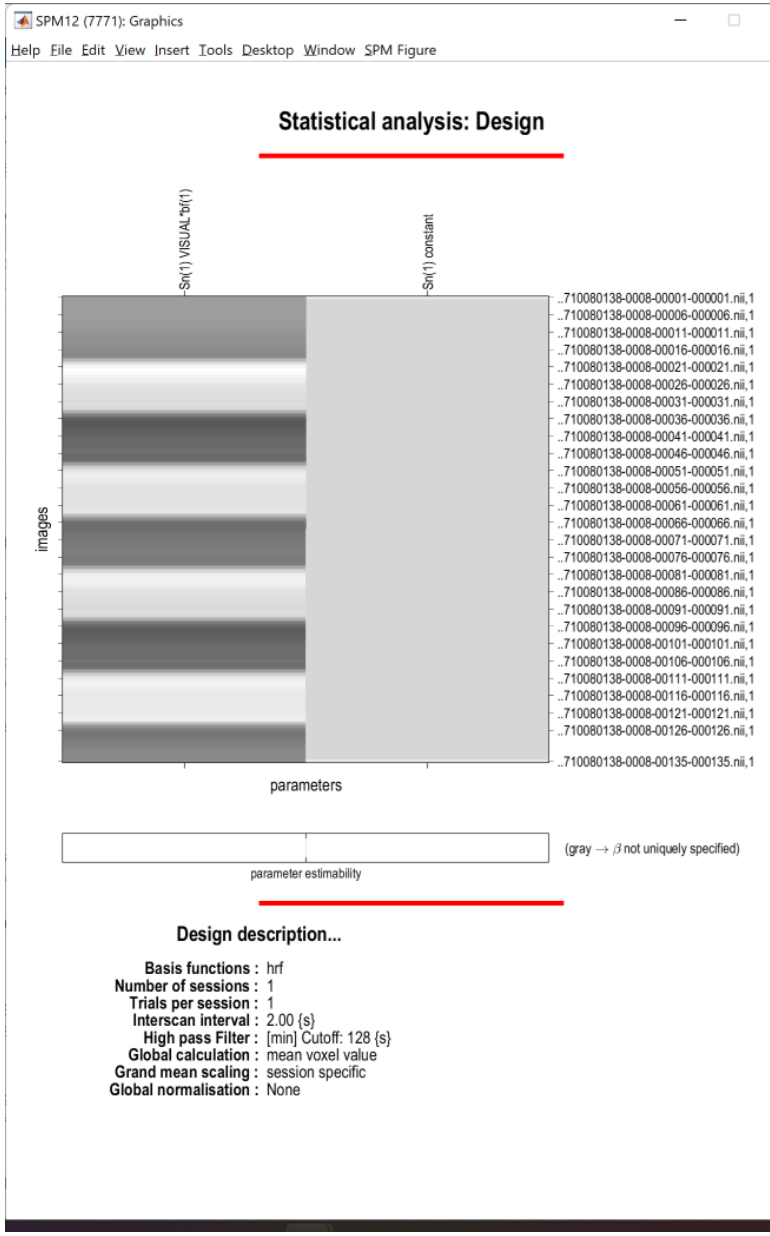
1. Condition NEUROTRACKER
   - Name … NEUROTRACKER
   - Onset … [11 36 61 86 111]
   - Durations … 10

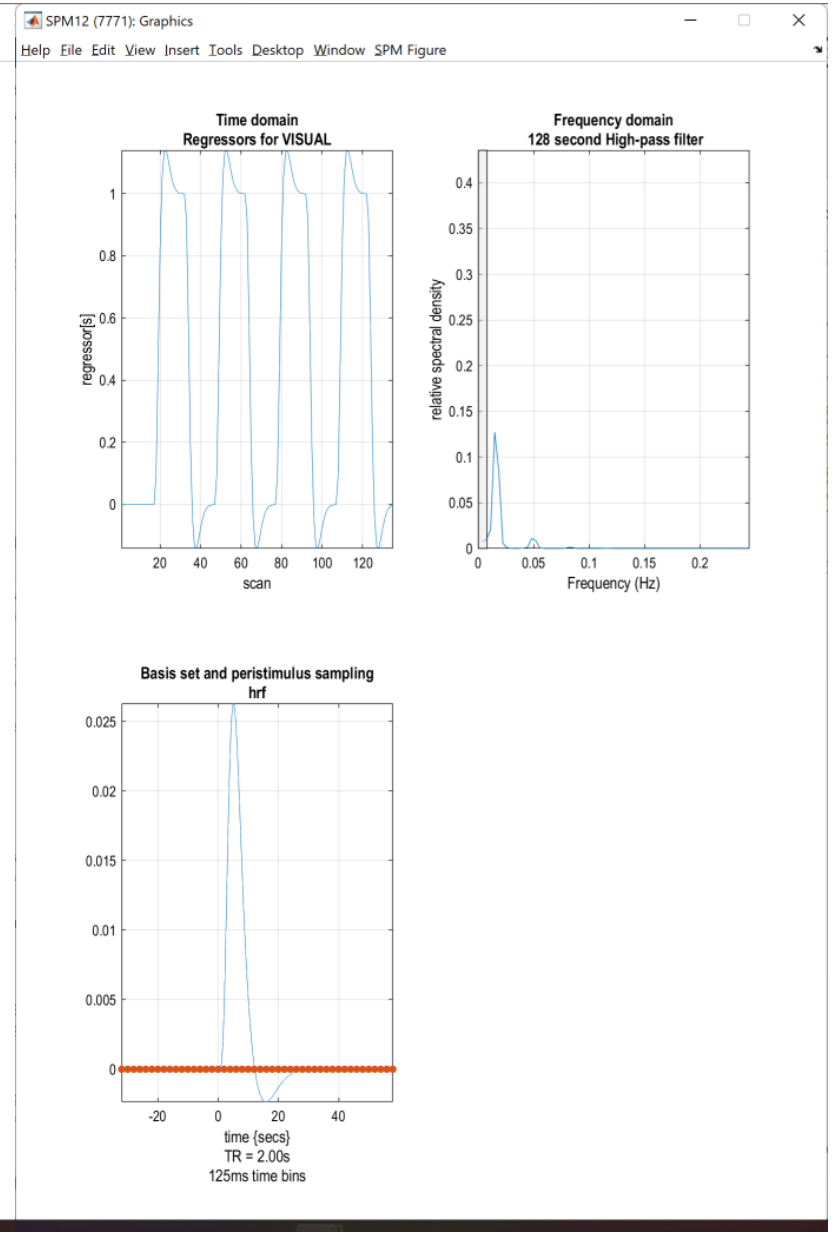
2. Condition 2-BACK
   - Name … 2BACK
   - Onset … [11 36 61 86]
   - Durations … 15

3. Condition VISUAL
   - Name … VISUAL
   - Onset … [16 46 76 106]
   - Durations … 15

fMR Statistics
Model review







fMR Statistics

Model review

MENU: Review

BATCH EDITOR:

a) Select SPM.mat … select *SPM.mat*

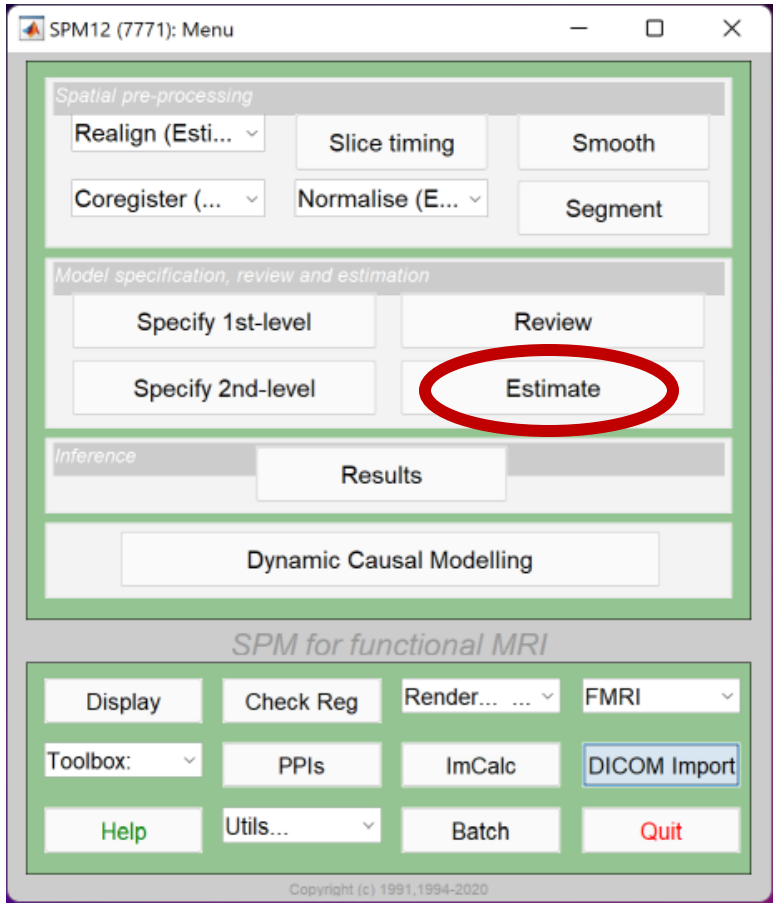
b) Run batch

RESULTS:

- Design – Design Matrix (model design for selected parameters)
- Design – Explore – Session 1 – VISUAL (time and frequency domain of the model)

fMR Statistics

Model estimation



fMR Statistics

Model estimation

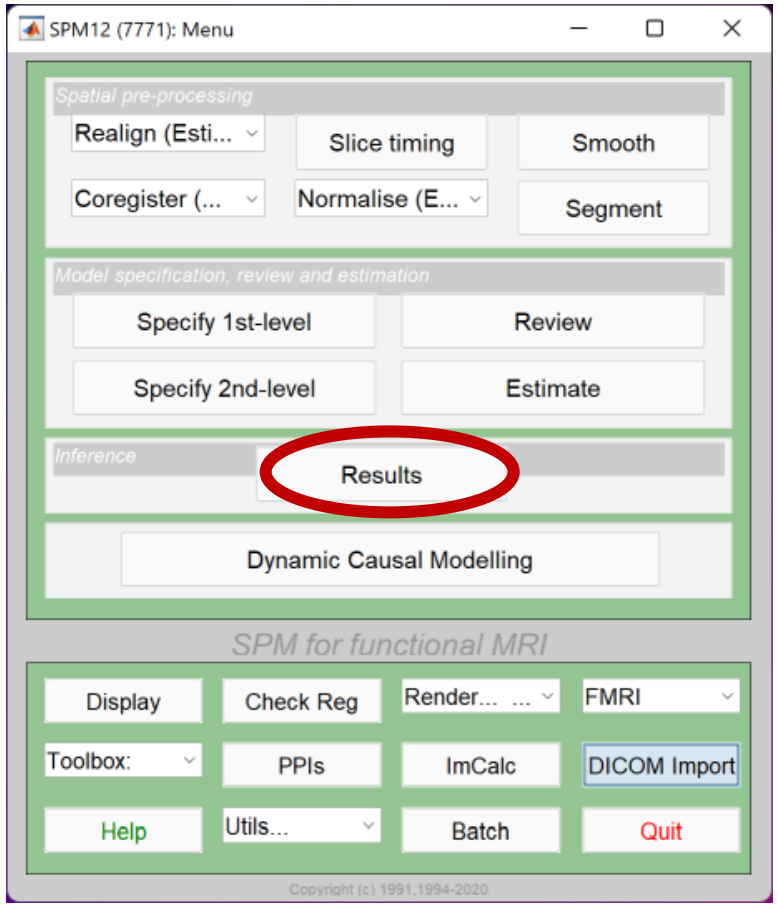
MENU: Estimate

BATCH EDITOR:

a) Select SPM.mat … select *SPM.mat*

b) Run batch

fMR Statistics
Results



fMR Statistics

Model estimation

MENU: Results

Select SPM.mat

SPM contrast manager:

a) Define new contrast

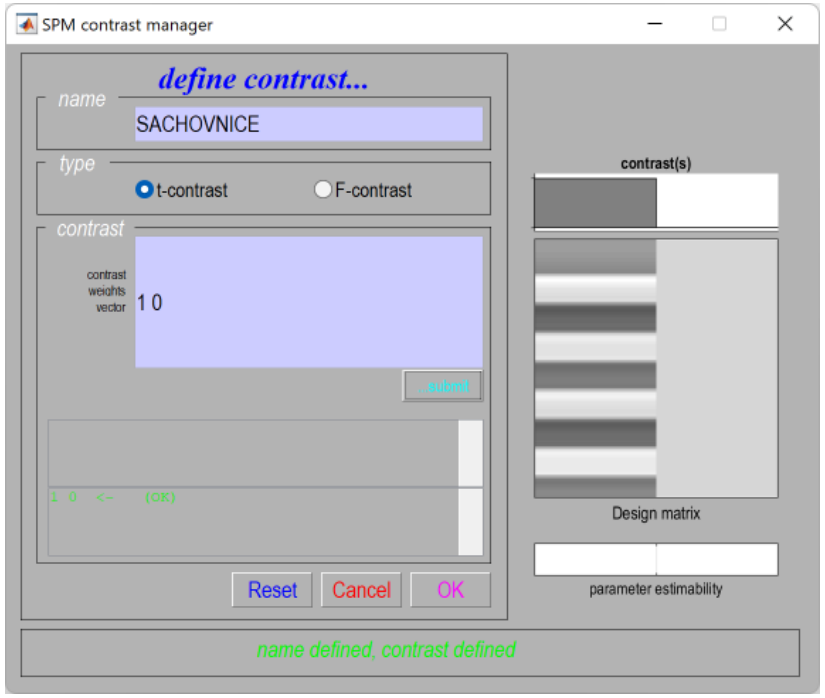
Name: SACHOVNICE (NEUROTRACKER / 2BACK)

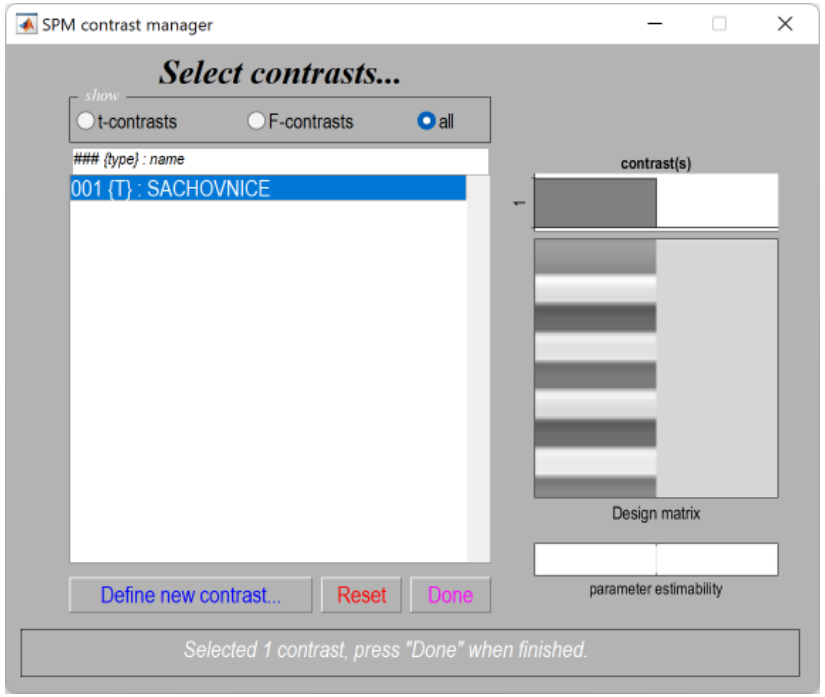
type: t-contrast

contrast: 1 0 …submit

b) OK

c) Done





fMR Statistics

Model estimation

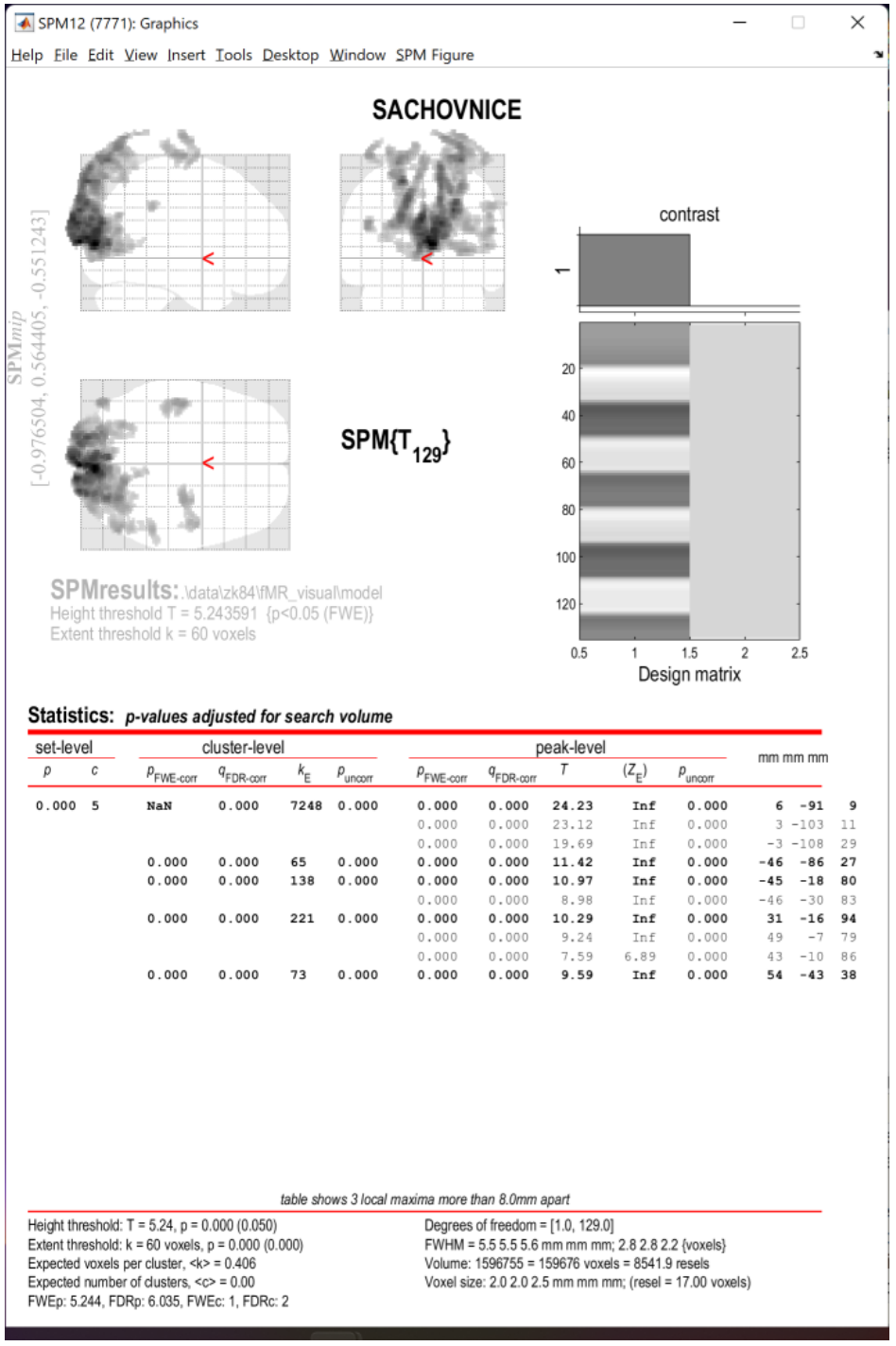
RESULTS:

apply masking … none

P value adjustment to control … FWE

P value (FWE) … 0.05

& extent threshold {voxels} … 60



Statistics: *p-values adjusted for search volume*

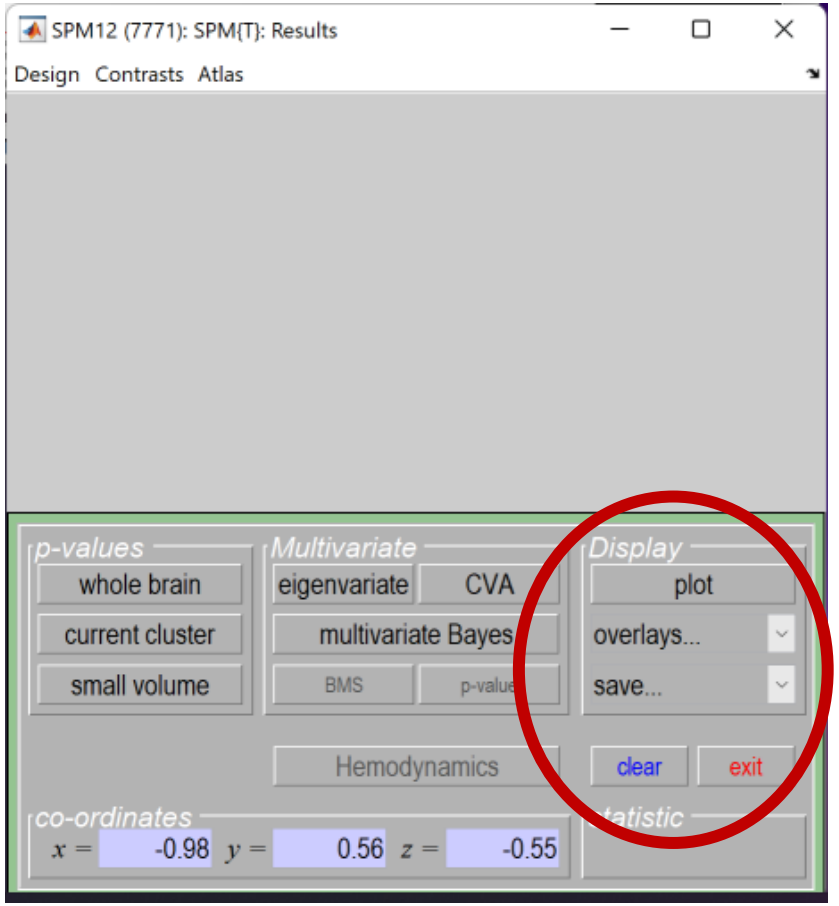
set-level		cluster-level				peak-level					mm mm mm		
p	c	$p_{FWE\text{-}corr}$	$q_{FDR\text{-}corr}$	k_E	p_{uncorr}	$p_{FWE\text{-}corr}$	$q_{FDR\text{-}corr}$	T	(Z_E)	p_{uncorr}			
0.000	5	NaN	0.000	7248	0.000	0.000	0.000	24.23	Inf	0.000	6	-91	9
						0.000	0.000	23.12	Inf	0.000	3	-103	11
						0.000	0.000	19.69	Inf	0.000	-3	-108	29
		0.000	0.000	65	0.000	0.000	0.000	11.42	Inf	0.000	-46	-86	27
		0.000	0.000	138	0.000	0.000	0.000	10.97	Inf	0.000	-45	-18	80
						0.000	0.000	8.98	Inf	0.000	-46	-30	83
		0.000	0.000	221	0.000	0.000	0.000	10.29	Inf	0.000	31	-16	94
						0.000	0.000	9.24	Inf	0.000	49	-7	79
						0.000	0.000	7.59	6.89	0.000	43	-10	86
		0.000	0.000	73	0.000	0.000	0.000	9.59	Inf	0.000	54	-43	38

table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 5.24, p = 0.000 (0.050)
Extent threshold: k = 60 voxels, p = 0.000 (0.000)
Expected voxels per cluster, <k> = 0.406
Expected number of clusters, <c> = 0.00
FWEp: 5.244, FDRp: 6.035, FWEc: 1, FDRc: 2

Degrees of freedom = [1.0, 129.0]
FWHM = 5.5 5.5 5.6 mm mm mm; 2.8 2.8 2.2 {voxels}
Volume: 1596755 = 159676 voxels = 8541.9 resels
Voxel size: 2.0 2.0 2.5 mm mm mm; (resel = 17.00 voxels)

fMR Statistics
Display



overlays…:

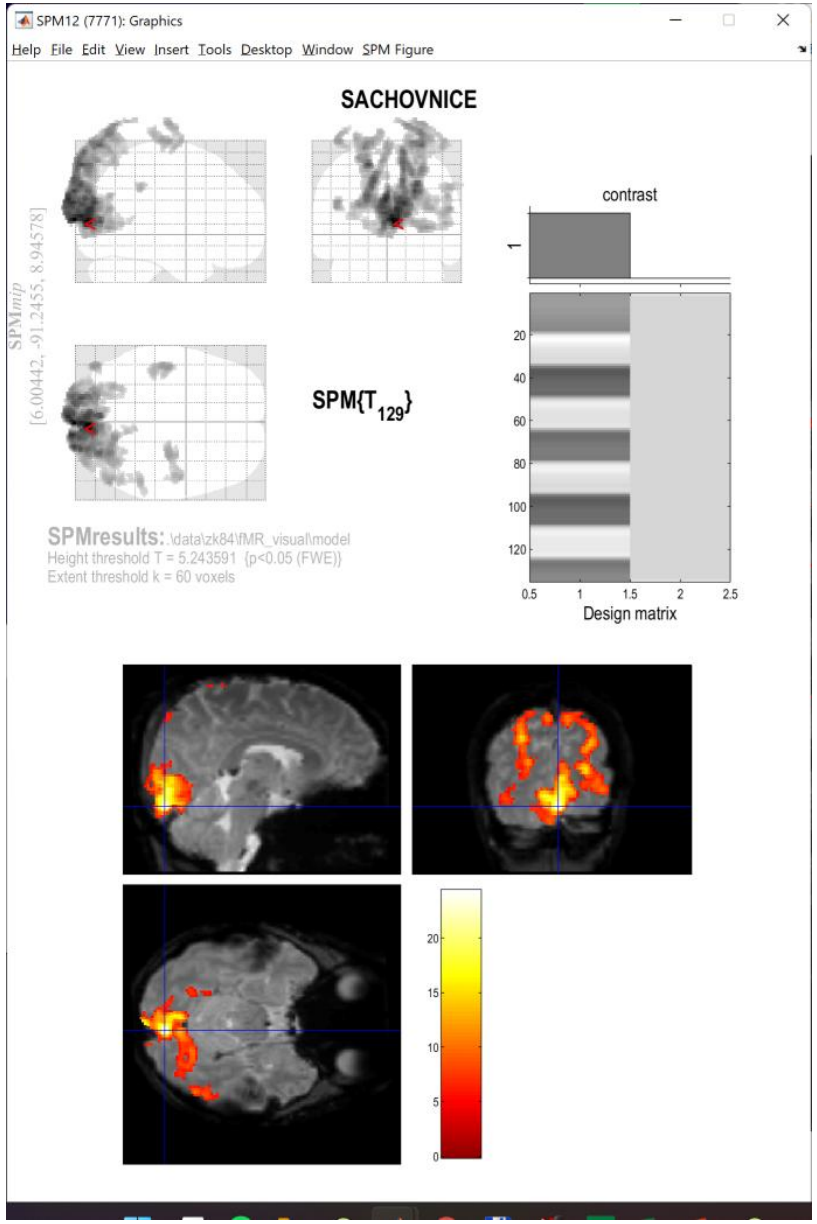
- Slices
- Sections (multiplanar)
- Montage (Axial / Coronal / Sagittal)

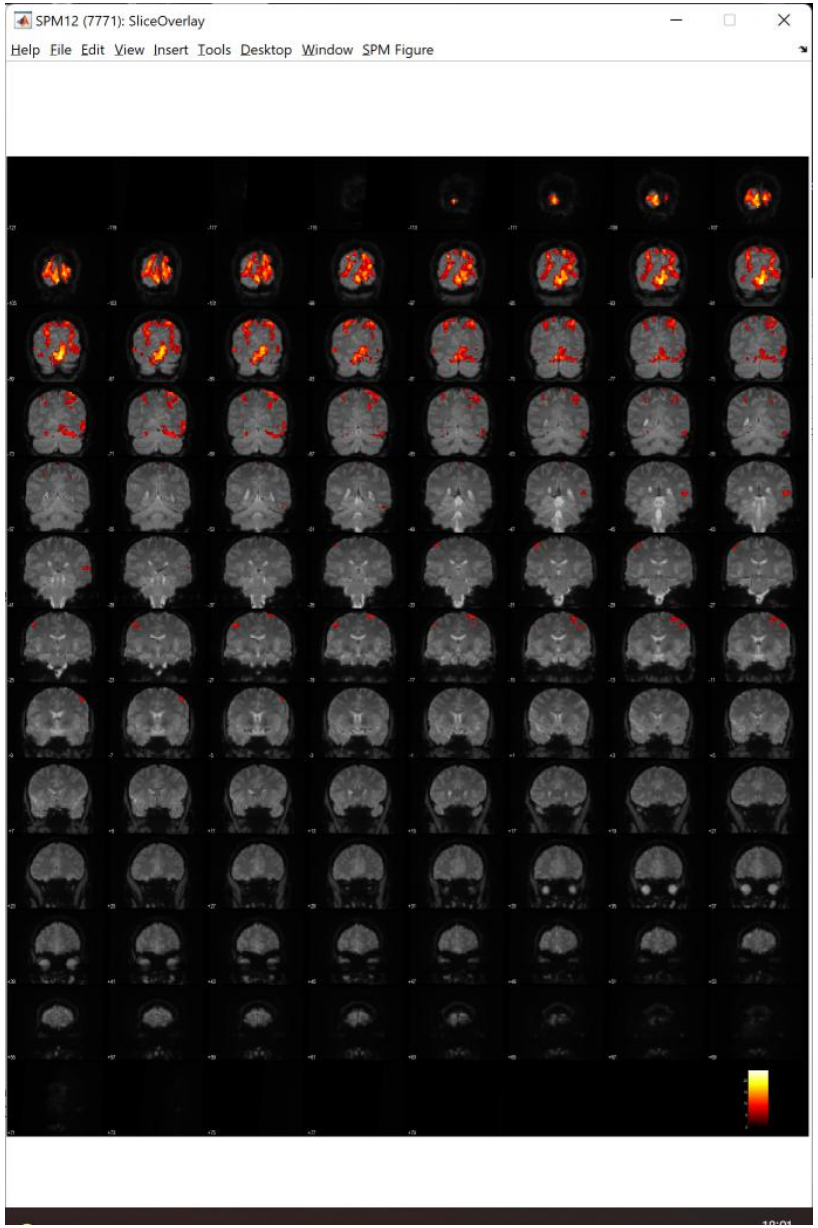
mean*.nii

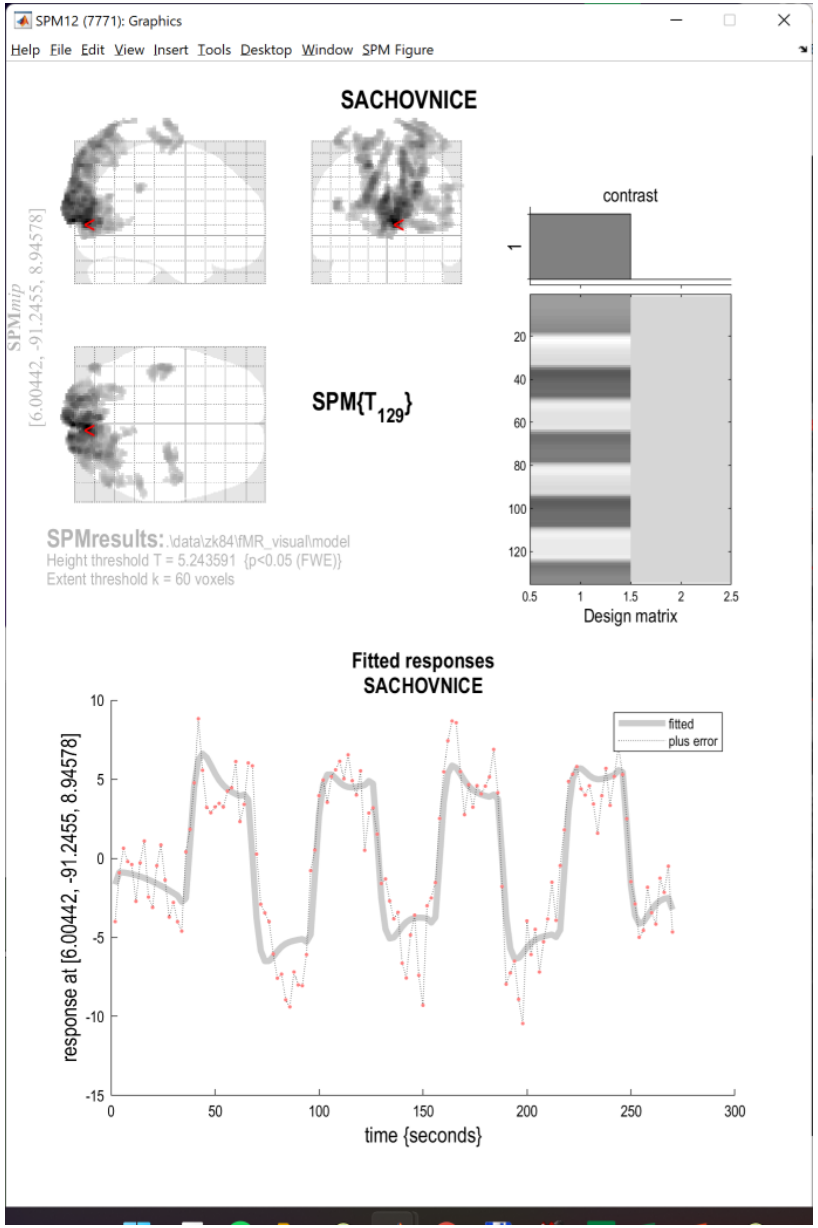
plot:

Plot … Fitted responses – adjusted

Plot against … scan or time


SPM12 (7771): Graphics
Help File Edit View Insert Tools Desktop Window SPM Figure
SACHOVNICE
SPM{T129}
contrast
Design matrix
SPMresults: \data\zk84\fMR_visual\model
Height threshold T = 5.243591 {p<0.05 (FWE)}
Extent threshold k = 60 voxels


SPM12 (7771): SliceOverlay
Help File Edit View Insert Tools Desktop Window SPM Figure


SPM12 (7771): Graphics
Help File Edit View Insert Tools Desktop Window SPM Figure
SACHOVNICE
SPM{T129}
contrast
Design matrix
SPMresults: \data\zk84\fMR_visual\model
Height threshold T = 5.243591 {p<0.05 (FWE)}
Extent threshold k = 60 voxels
Fitted responses
SACHOVNICE
fitted
plus error
response at [6.00442, -91.2455, 8.94578]
time {seconds}