# fMR Processing(1)

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27.3.2024

# 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** with Gauss filter kernel
5. **Model specification** + **Review**
6. **Estimate Model**
7. **Results** + **Display**

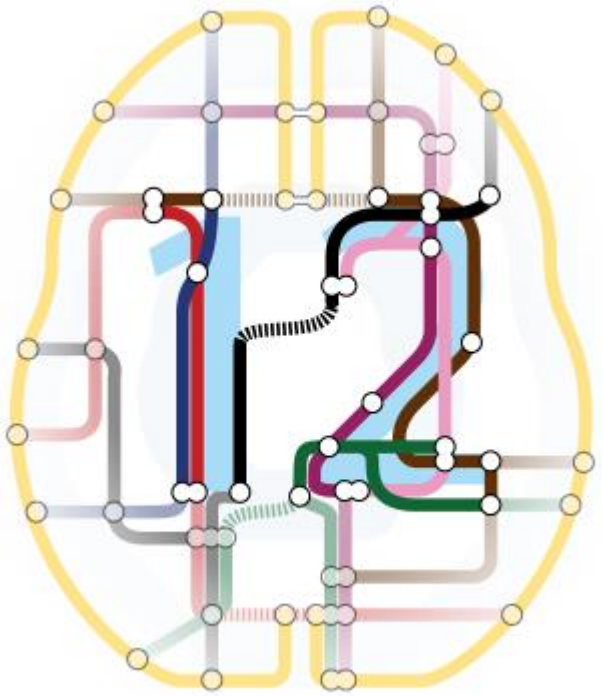
***DICOM*** *= **D**igital **I**maging and **Co**mminications in **M**edicine*
***NIFTI*** *= **N**euroimaging **I**n**f**ormatics **T**echnology **I**nitiative

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

**S**tatistical **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/

**MRIcroGL**

https://www.nitrc.org/projects/mricrogl

**GLM**

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

# fMR processing
# Data

**Paradigm:**

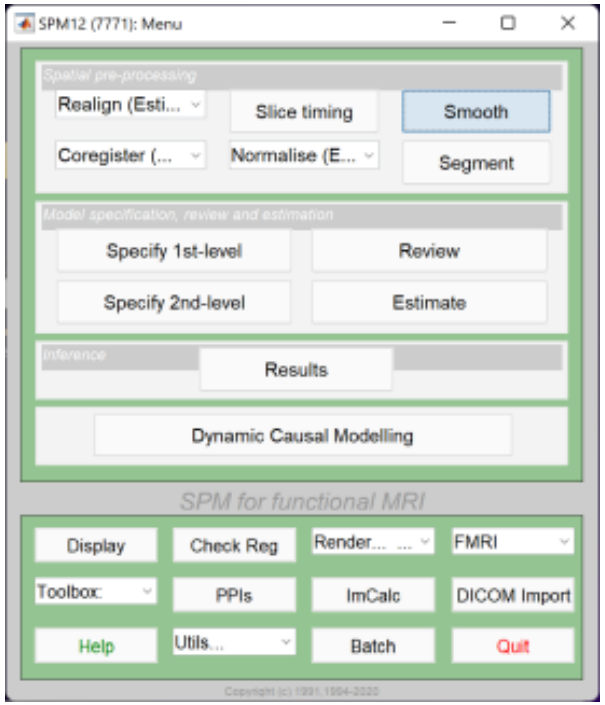
**FingerTapping** (upper extremities fingers) 150vol, TR=2000ms, 60 slices

Volunteer data: folders **Subj01, Subj02, … Subj13**

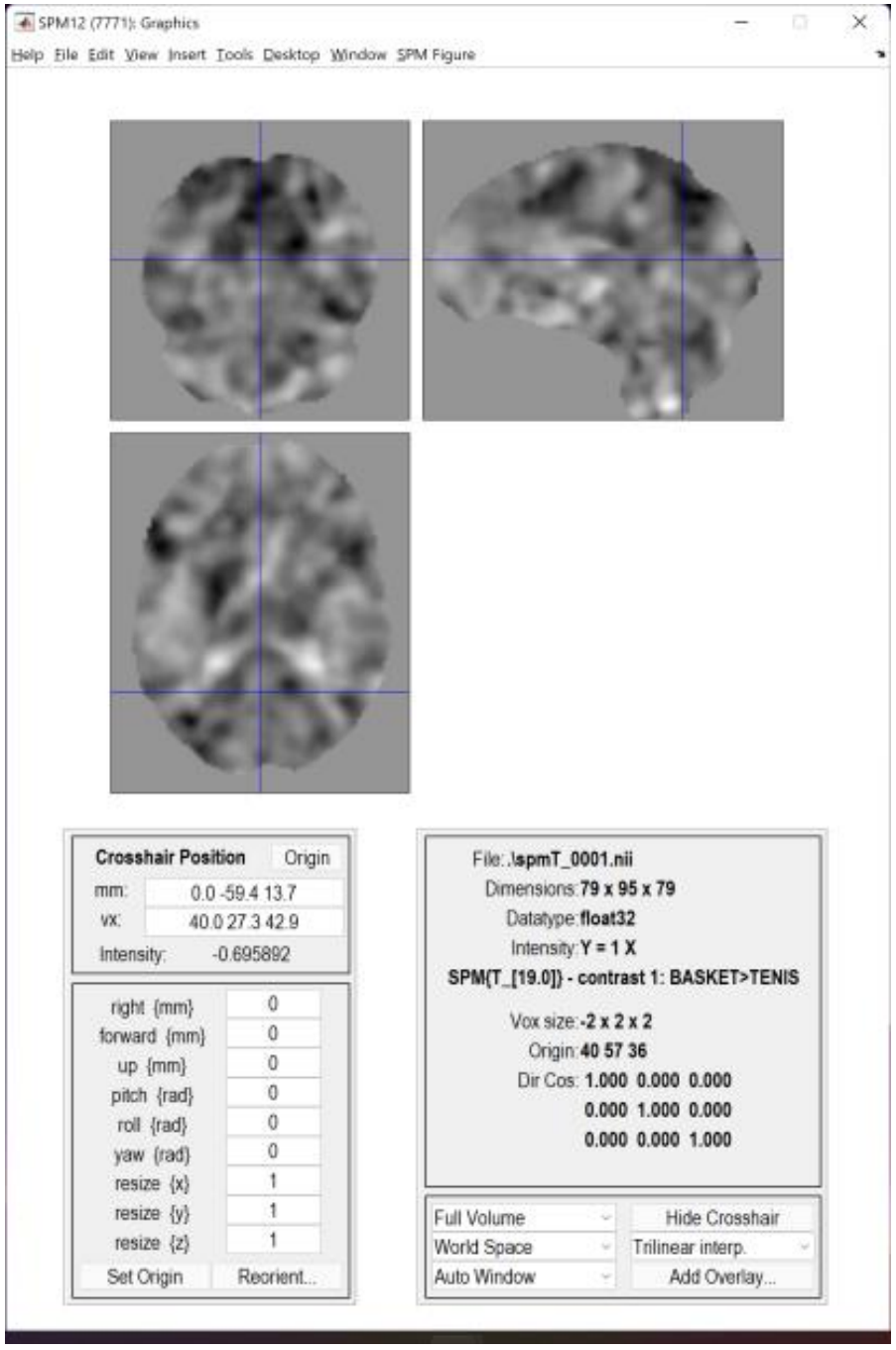
| | | |
|---|---|---|
| Subj09 | D-S | 6.3.2024 |
| Subj10 | P-B | 6.3.2024 |
| Subj11 | T-T | 13.3.2024 |
| Subj12 | M-L | 20.3.2024 |
| Subj13 | M-H | 20.3.2024 |

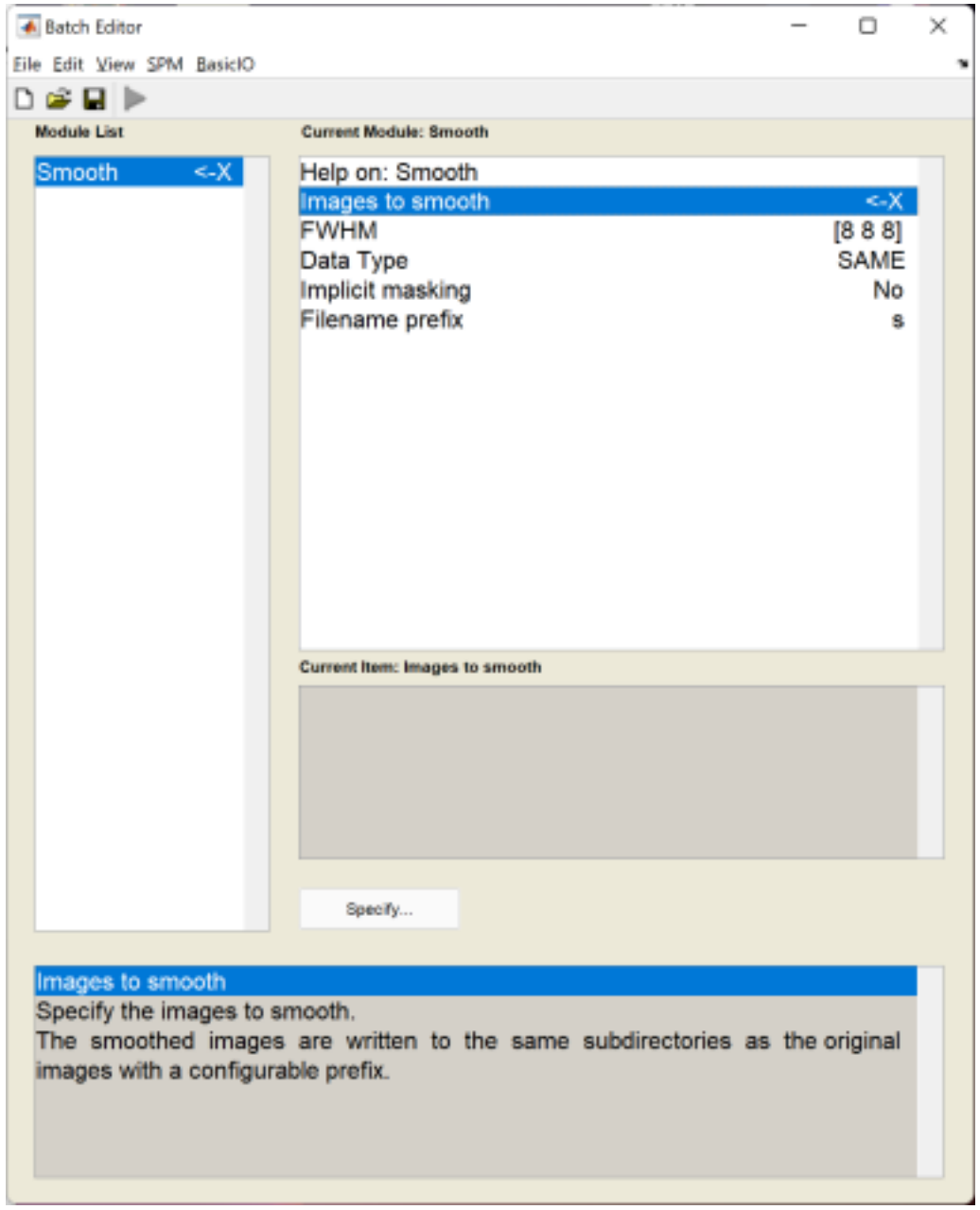
Folder structure: **fmr** (150 nii-files: “fmr_*[XXX]*.nii”)

**t1** (1 nii-file: “t1.nii”)

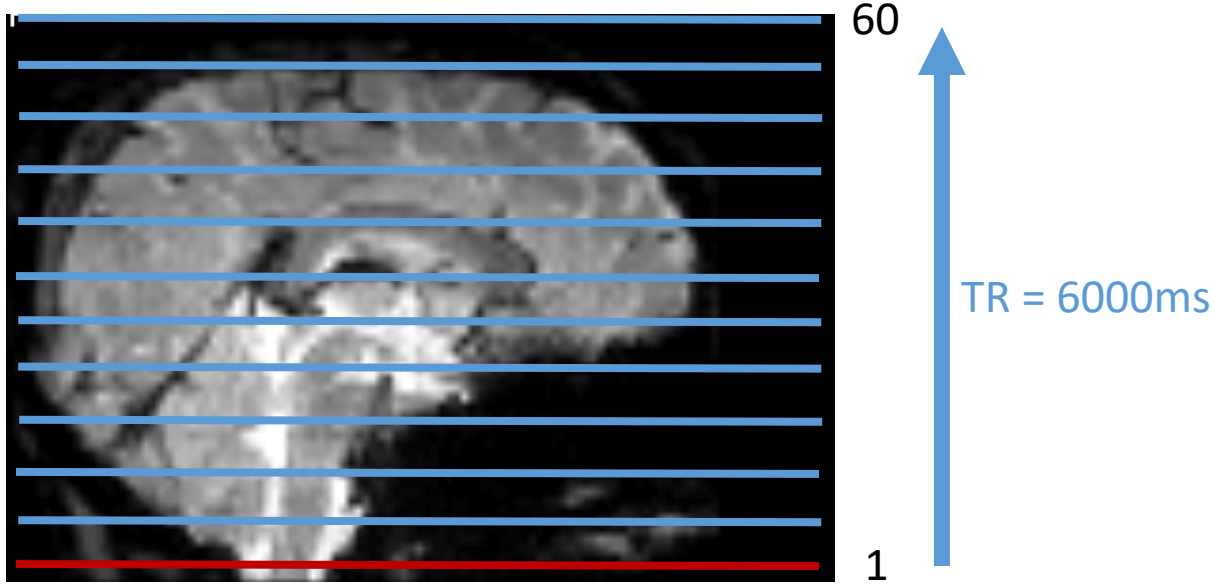

SPM12 (7771): Menu
Spatial pre-processing
Realign (Esti...
Slice timing
Smooth
Coregister (...
Normalise (E...
Segment
Model specification, review and estimation
Specify 1st-level
Review
Specify 2nd-level
Estimate
Inference
Results
Dynamic Causal Modelling
SPM for functional MRI
Display
Check Reg
Render...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

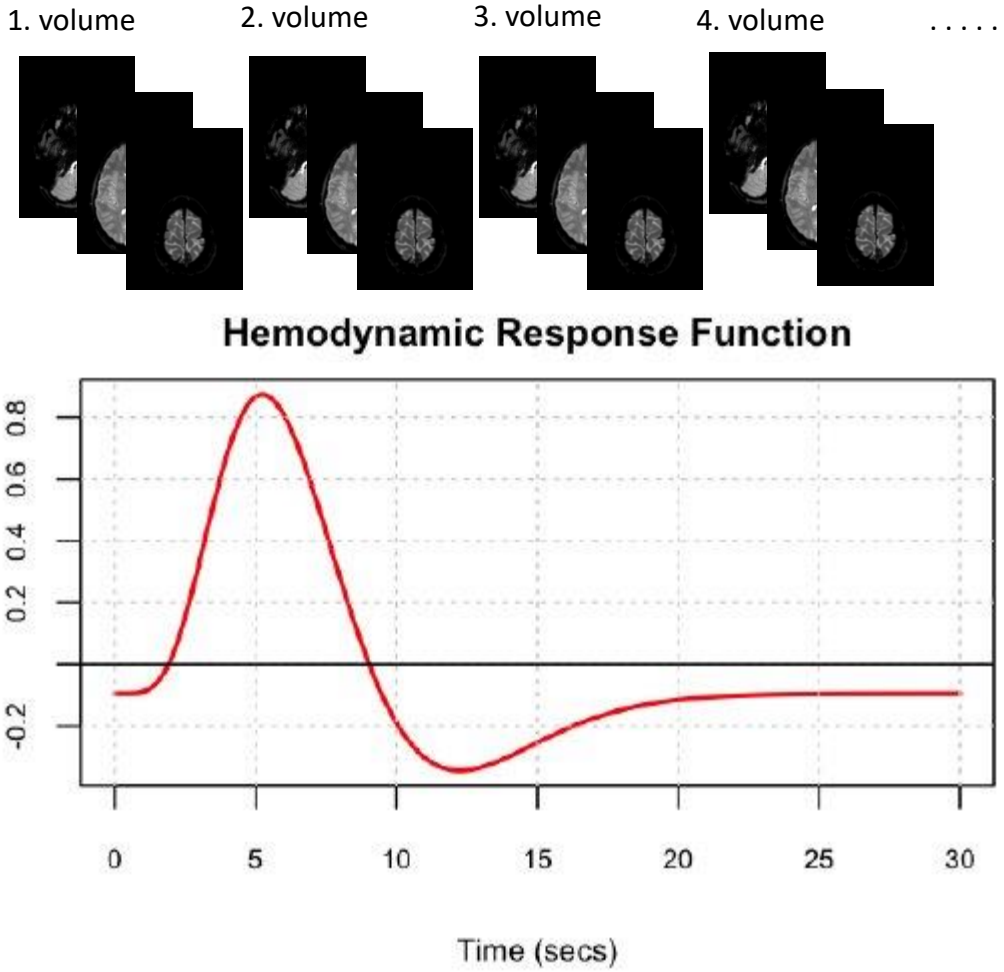
SPM12 (7771): SPM{T}: Results
Design Contrasts Atlas
p-values
whole brain
current cluster
small volume
Multivariate
eigenvariate
CVA
multivariate Bayes
BMS
p-value
Display
plot
overlays...
save...
Hemodynamics
clear
exit
co-ordinates
x = 0.00 y = 0.00 z = 0.00
statistic


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**)

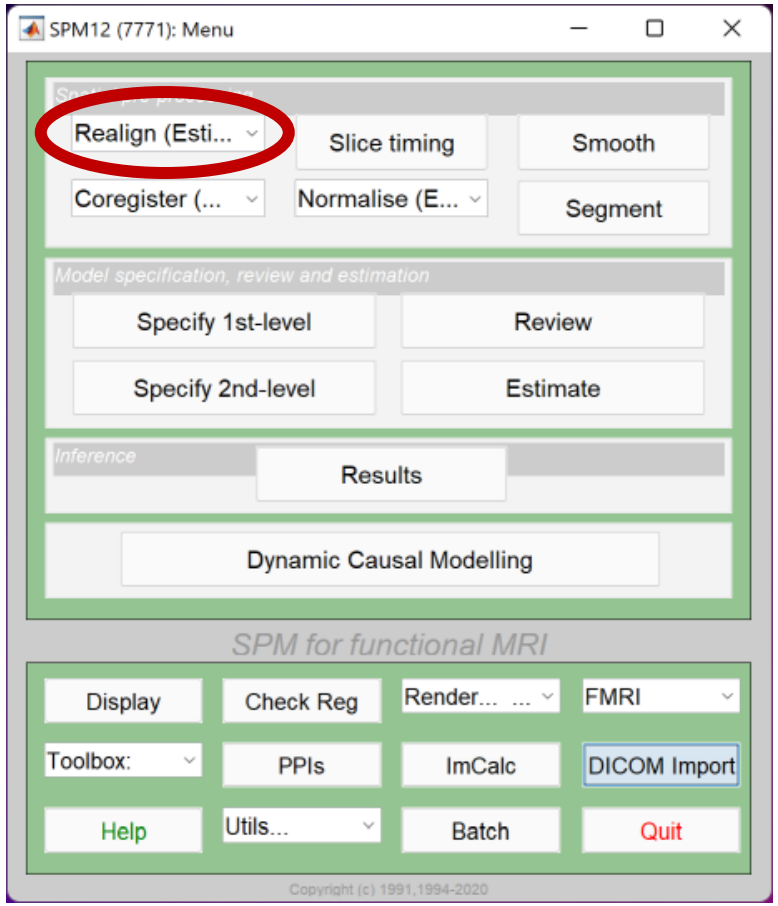


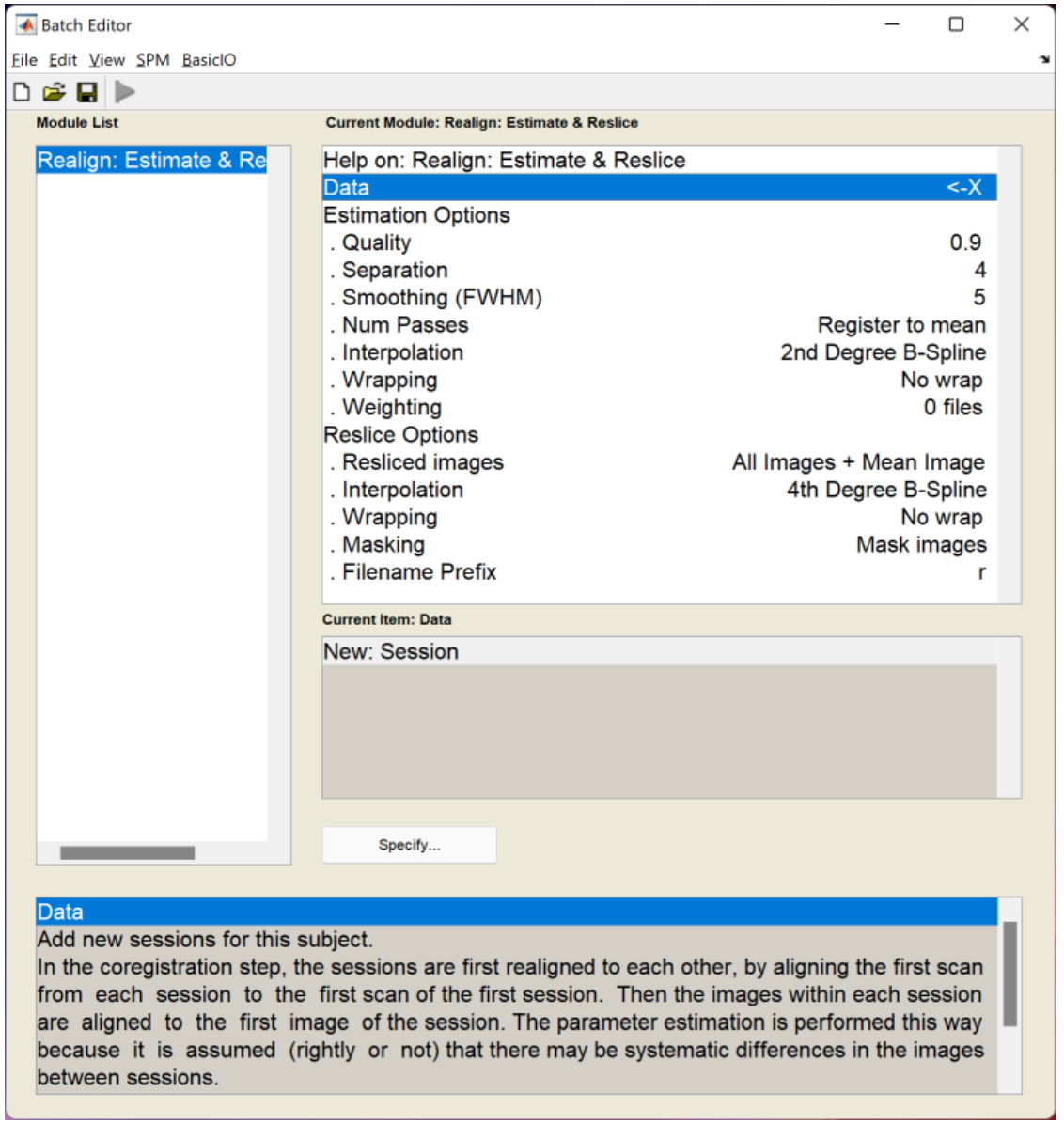



# Realign data

- 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



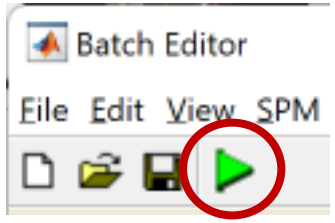
# Realign data

**MENU:** Realign (Estimate & Reslice)

**BATCH EDITOR:**

a) Data – Session … all fMR files

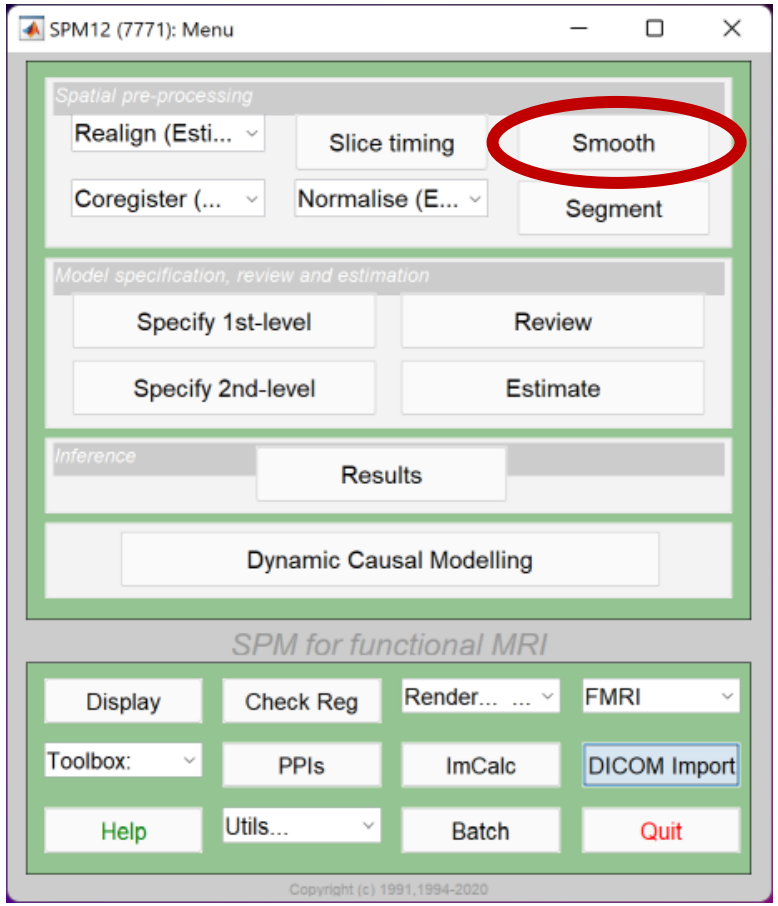
b) Run batch




**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
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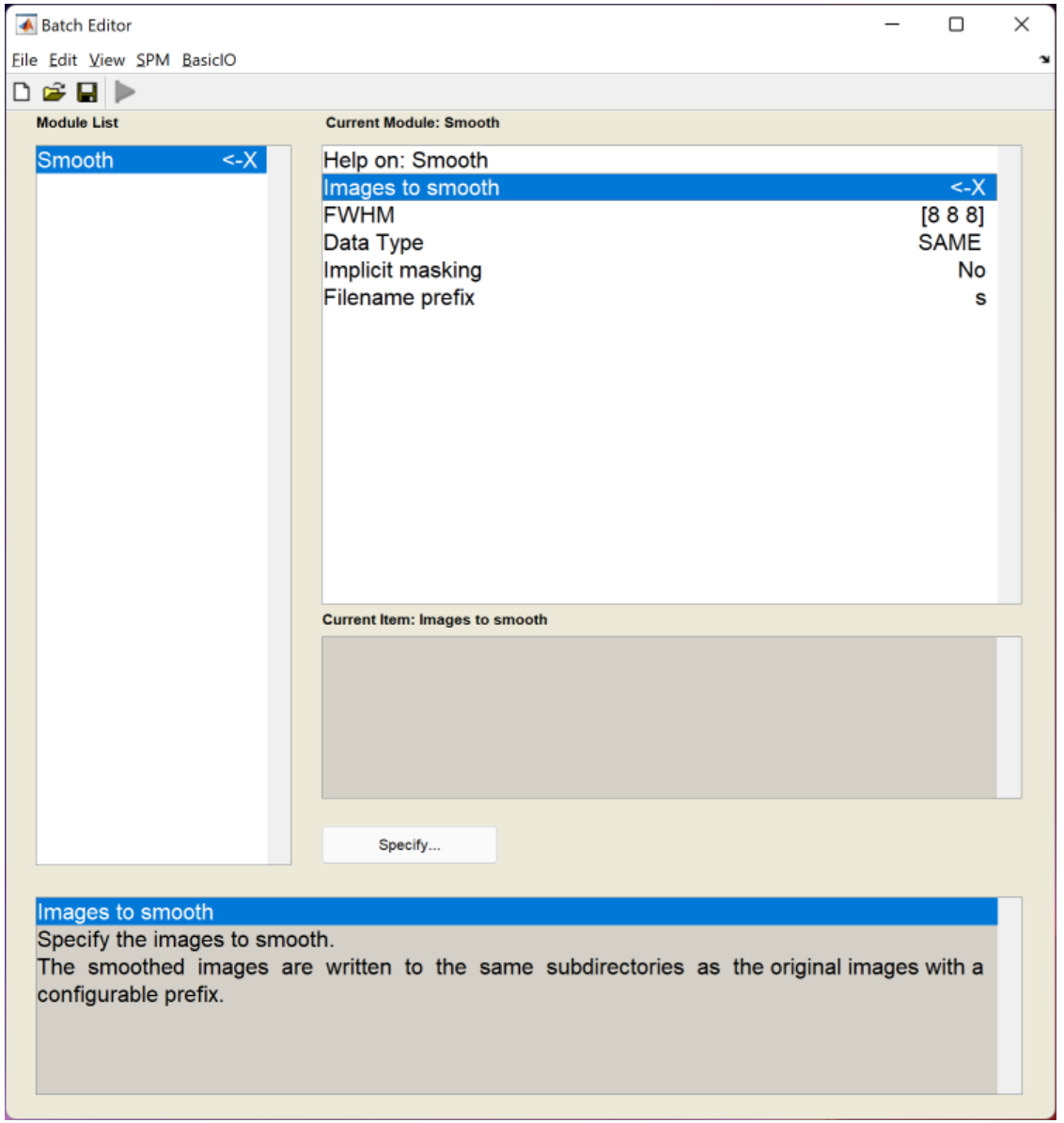
Inference
Results
Dynamic Causal Modelling
SPM for functional MRI
Display
Check Reg
Render...
FMRI
Toolbox:
PPIs
ImCalc
DICOM Import
Help
Utils...
Batch
Quit
Copyright (c) 1991,1994-2020


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

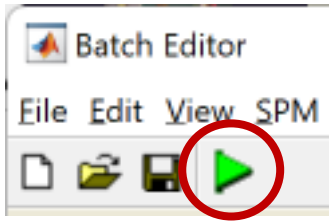
**MENU:** Smooth

**BATCH EDITOR:**

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

b) FWHM … **[6 6 6]** (Full width at half maximum of the Gaussian smoothing kernel in mm, doubled size of voxel recommended)

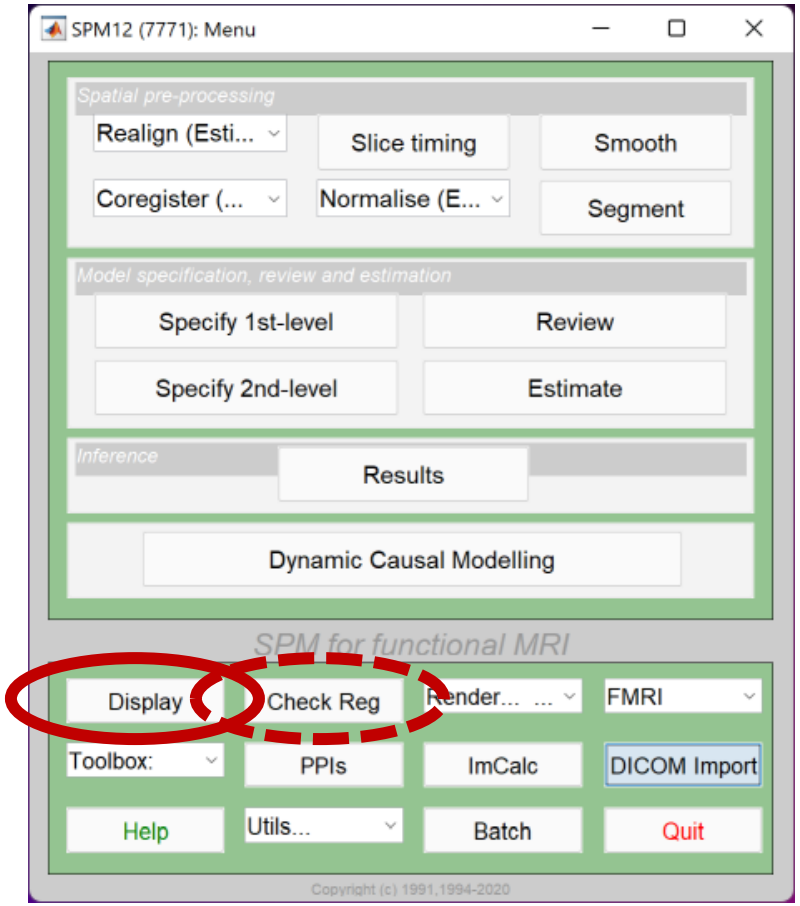
c) Run batch




**Output:**

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

# Data check (!)


SPM12 (7771): Menu
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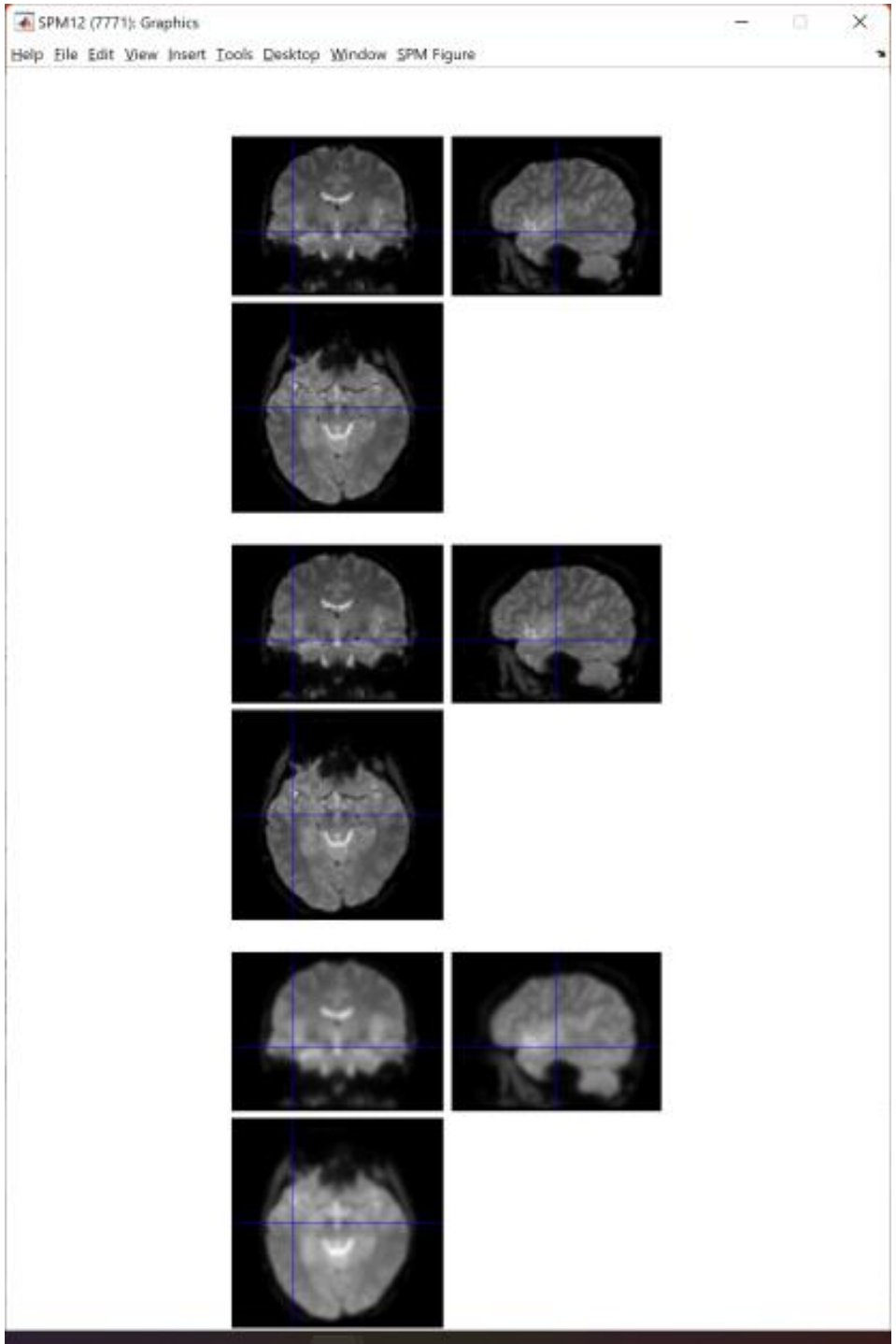
ImCalc
DICOM Import
Help
Utils...
Batch
Quit
Copyright (c) 1991,1994-2020


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

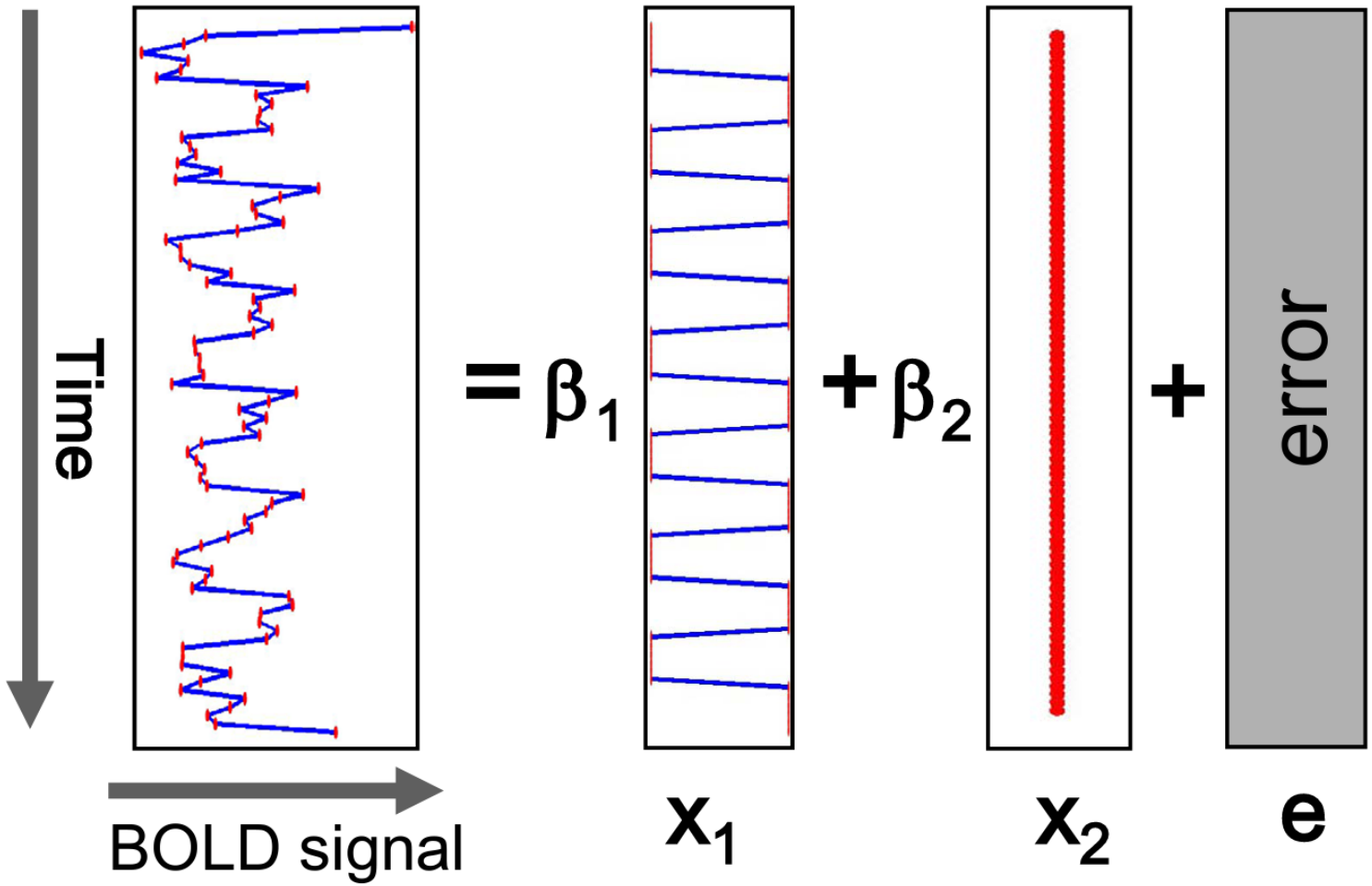
**Independent variable (Predictor)**
Experiment conditions

**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

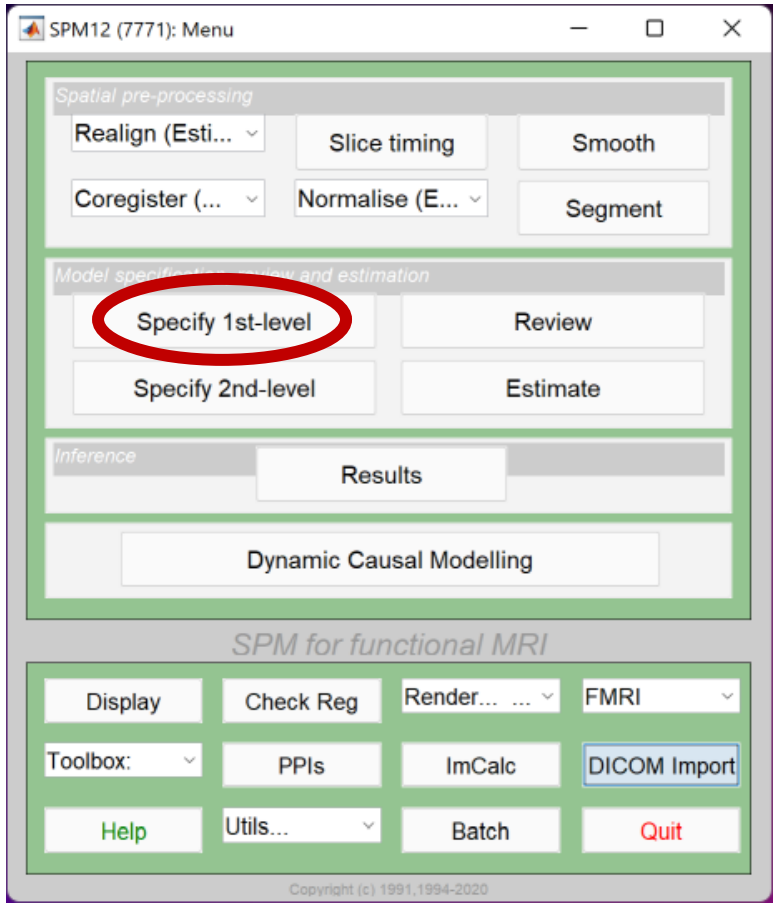
# Single voxel regression model

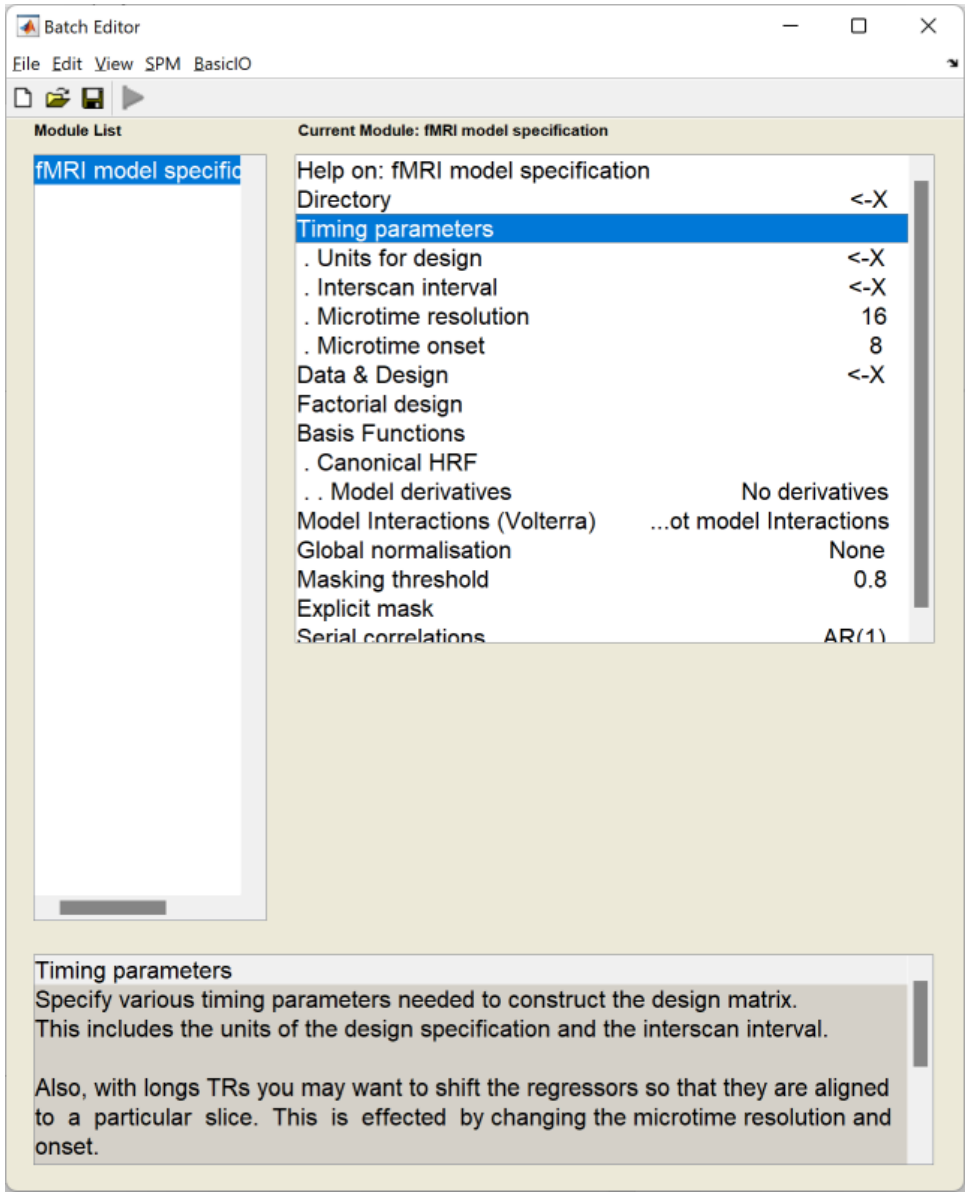



$$y = x_1\beta_1 + x_2\beta_2 + e$$

# fMR Statistics

## Model specification



# fMR Statistics
## Model specification

**MENU:** Specify 1st-level

**BATCH EDITOR:**

a) Directory … select (pre-created) folder "**model**" 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 "RightHand", "LeftHand"
            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)

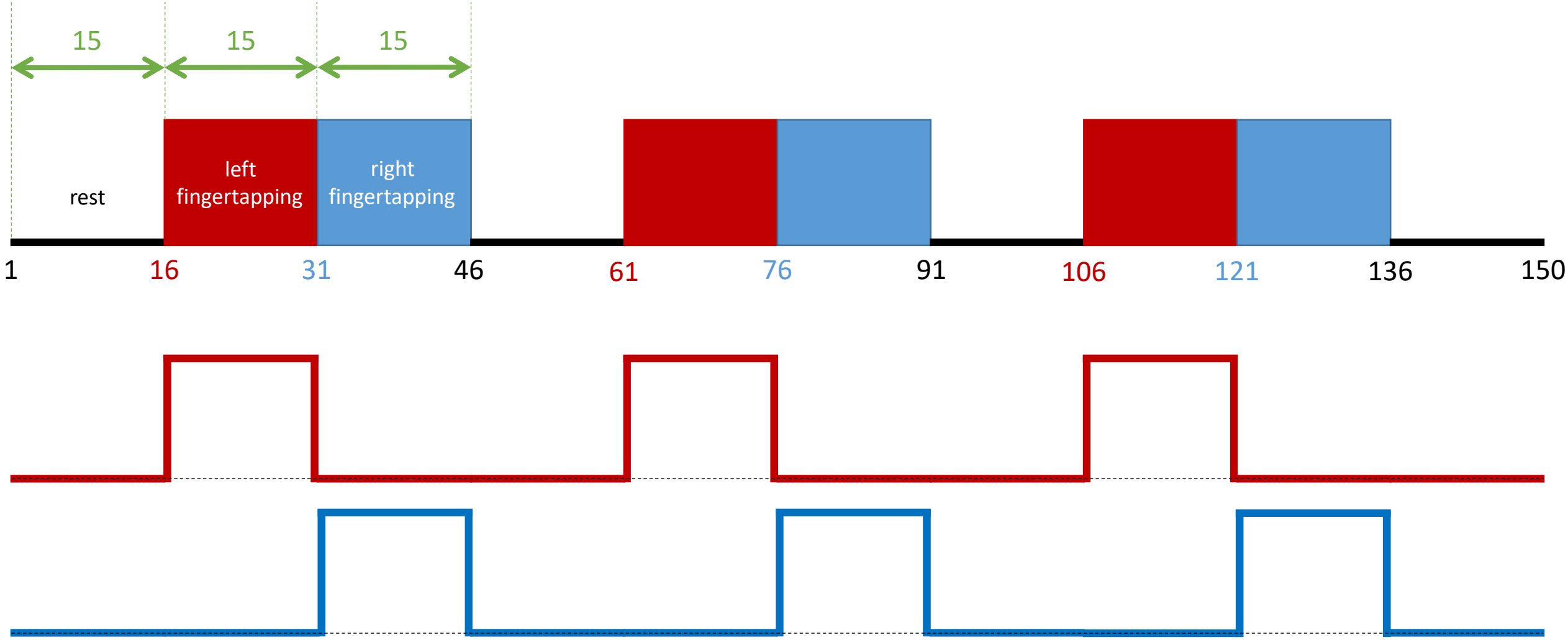
# fMR Statistics

## Model specification

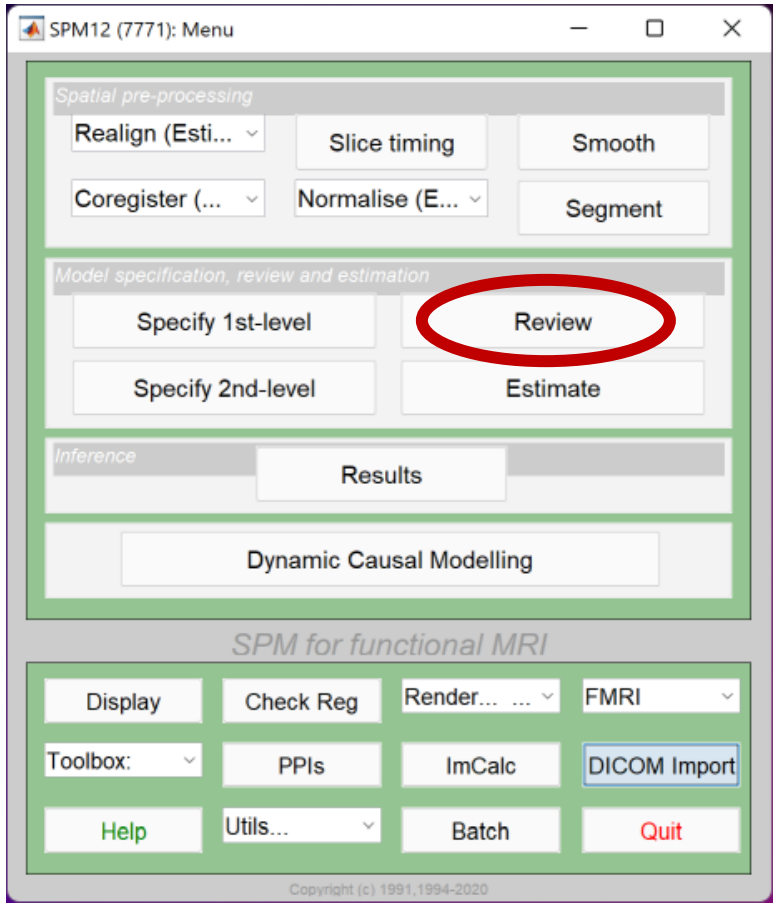
1. Condition **LeftHand**
   - Name … **LeftHandFingerTapping**
   - Onset … **[16 61 106]**
   - Durations … **15**

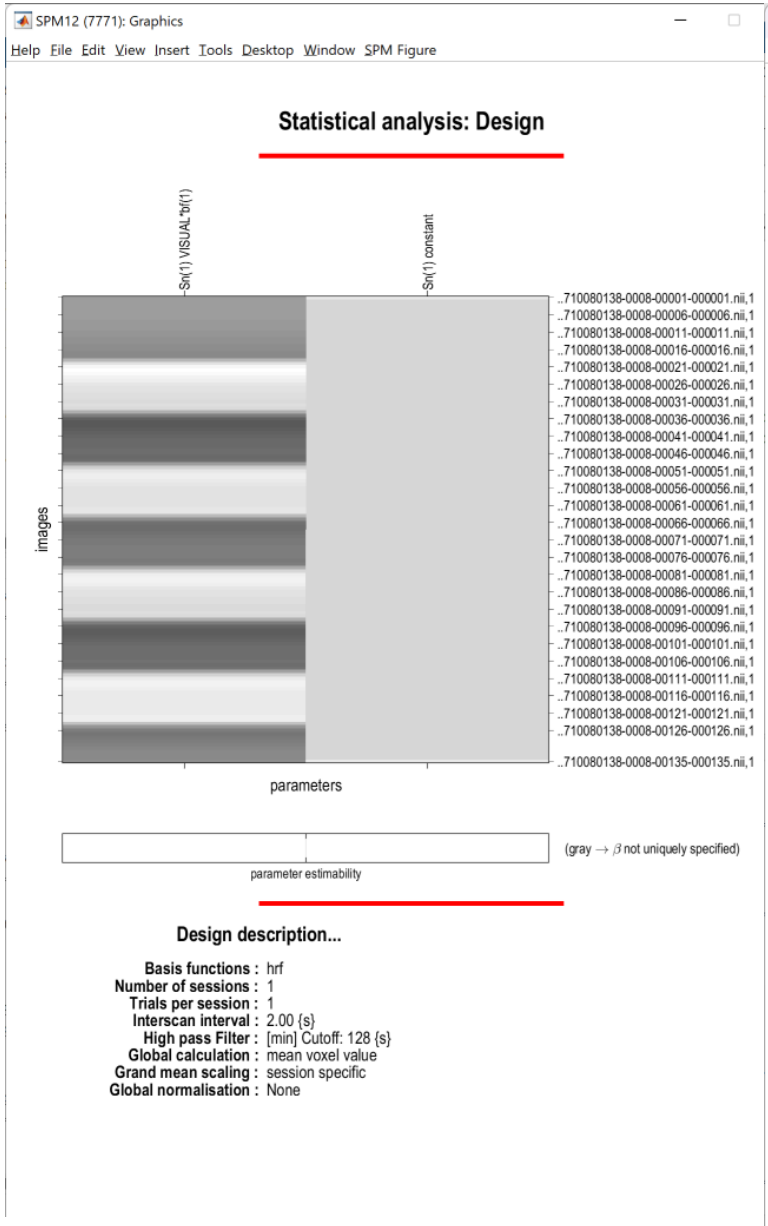
2. Condition **RightHand**
   - Name … **RightHandFingerTapping**
   - Onset … **[31 76 121]**
   - Durations … **15**

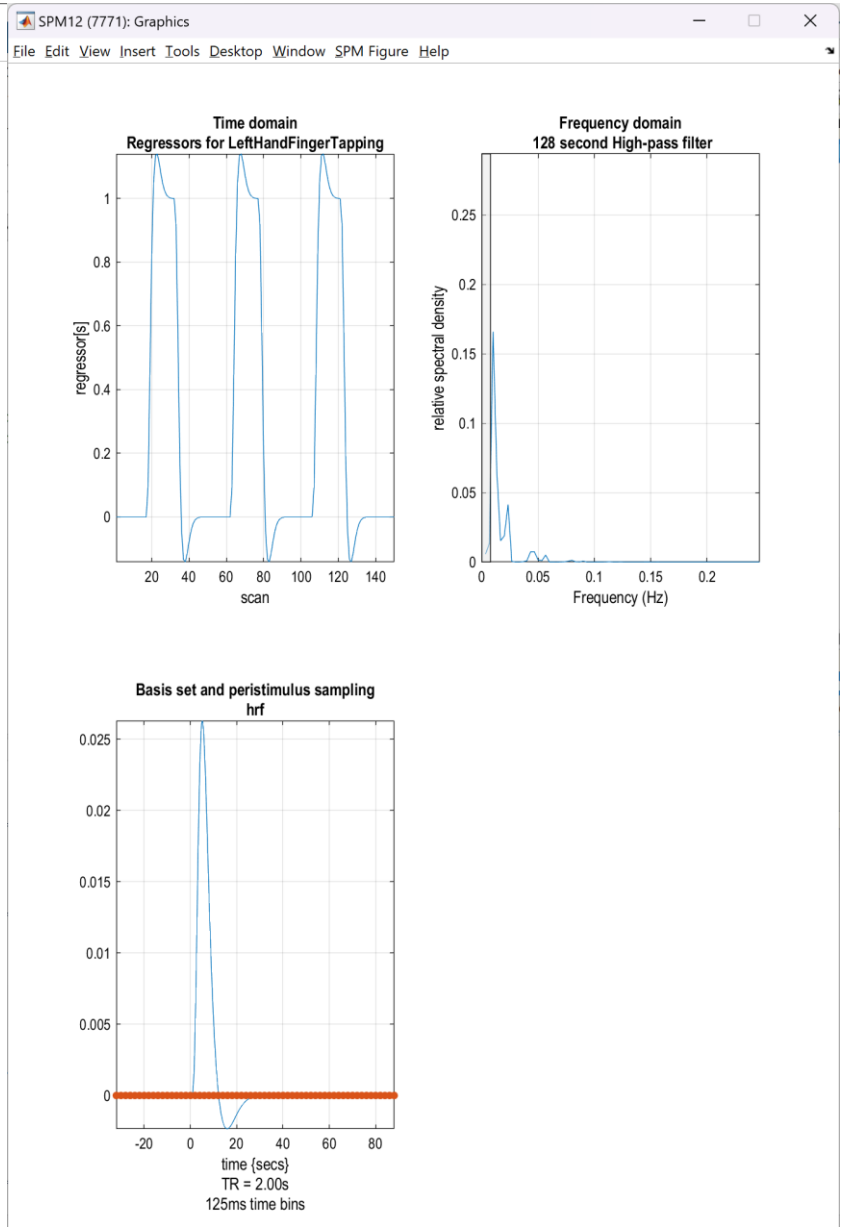
# fMR Motor paradigm (in scans; scan = 2s)



# fMR Statistics
## Model review



# fMR Statistics

## Model review

**MENU:** Review

**BATCH EDITOR:**

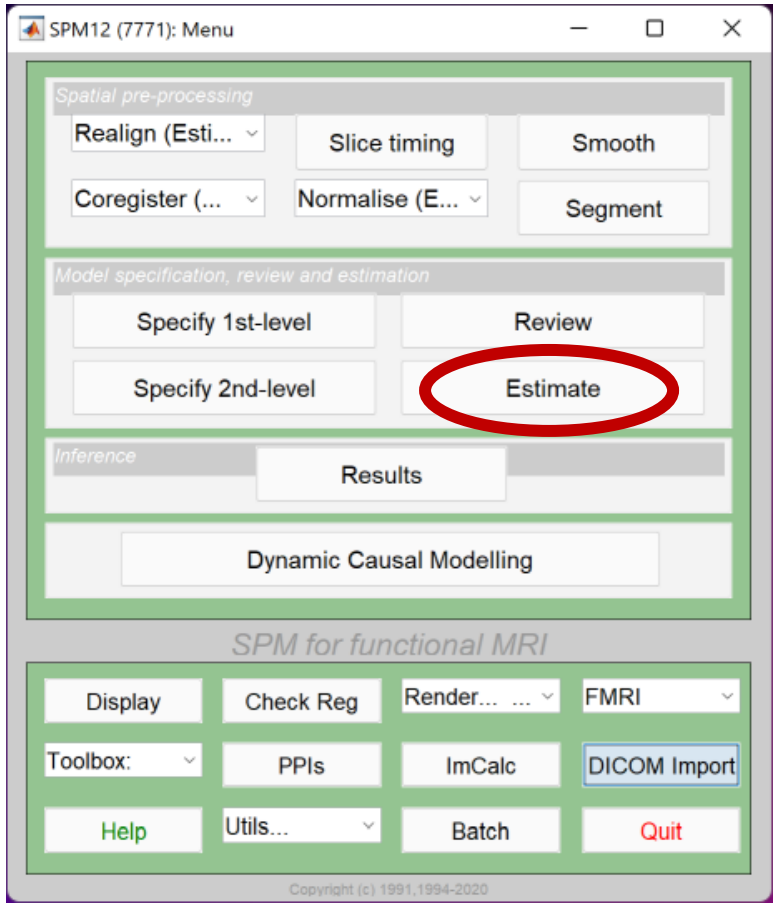
a) Select SPM.mat … select *SPM.mat*
b) Run batch

**RESULTS:**

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

# fMR Statistics

## Model estimation



# fMR Statistics

## Model estimation

**MENU:** Estimate

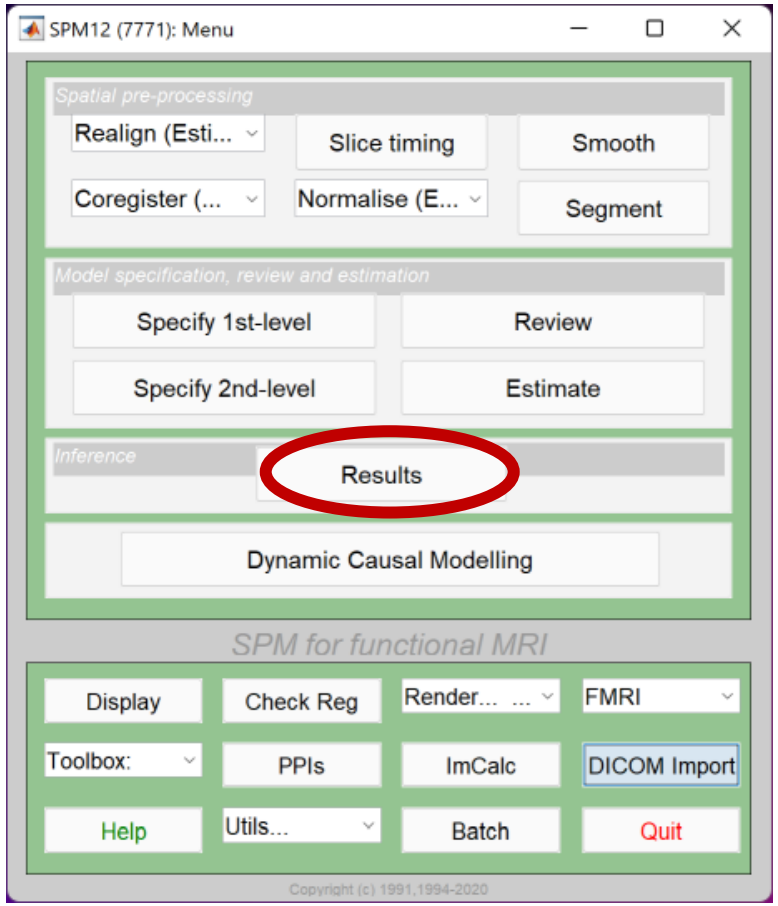
**BATCH EDITOR:**

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

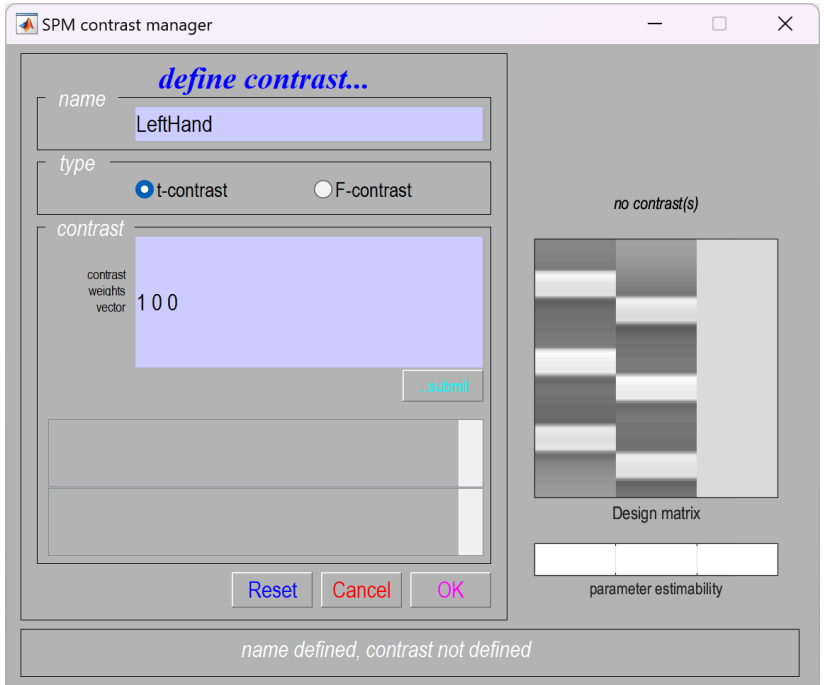
Name: **LeftHand** / **RightHand**

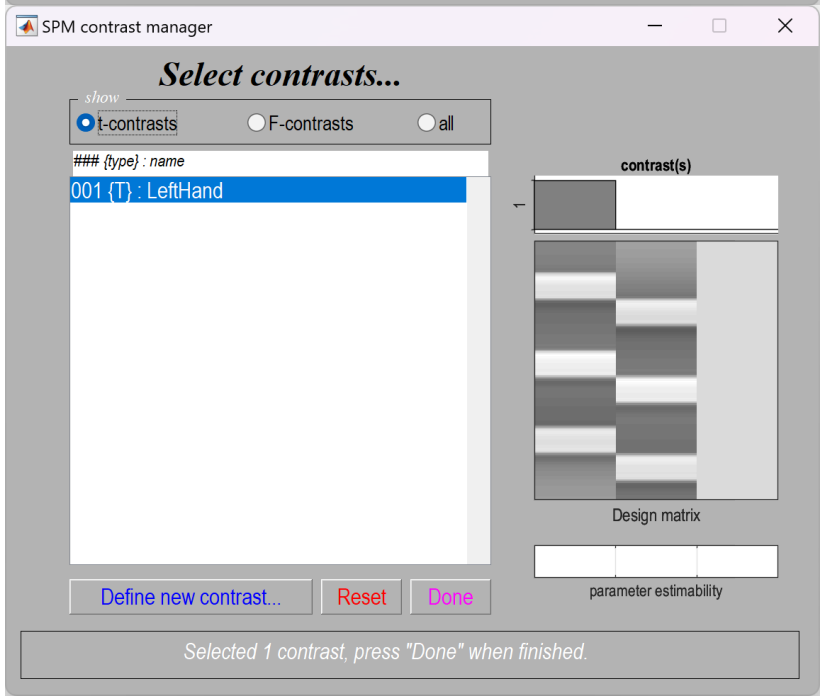
type: **t-contrast**

contrast: **1 0 0** / **0 1 0** …submit

b) OK

c) Done



# fMR Statistics

## Model estimation

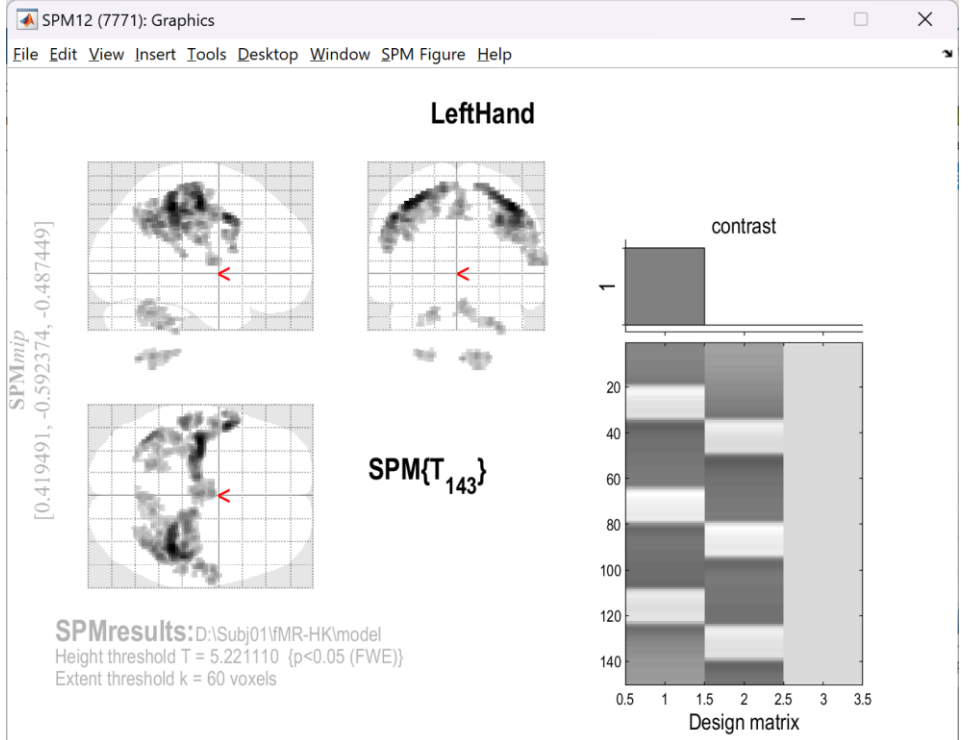
**RESULTS:**

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $p$ | $c$ | $p_{FWE-corr}$ | $q_{FDR-corr}$ | $k_E$ | $p_{uncorr}$ | $p_{FWE-corr}$ | $q_{FDR-corr}$ | $T$ | $(Z_E)$ | $p_{uncorr}$ | |
| 0.000 | 12 | 0.000 | 0.000 | 1305 | 0.000 | **0.000** | **0.000** | **18.14** | **Inf** | **0.000** | **41 -37 46** |
| | | | | | | 0.000 | 0.000 | 15.58 | Inf | 0.000 | 47 -29 44 |
| | | | | | | 0.000 | 0.000 | 15.37 | Inf | 0.000 | 31 -39 54 |
| | | 0.000 | 0.000 | 751 | 0.000 | **0.000** | **0.000** | **17.69** | **Inf** | **0.000** | **-39 -17 50** |
| | | | | | | 0.000 | 0.000 | 16.51 | Inf | 0.000 | -50 4 39 |
| | | | | | | 0.000 | 0.000 | 14.41 | Inf | 0.000 | -26 -22 57 |
| | | 0.000 | 0.000 | 307 | 0.000 | **0.000** | **0.000** | **12.72** | **Inf** | **0.000** | **-40 -56 37** |
| | | | | | | 0.000 | 0.000 | 10.14 | Inf | 0.000 | -42 -46 43 |
| | | | | | | 0.000 | 0.000 | 10.09 | Inf | 0.000 | -40 -33 26 |
| | | 0.000 | 0.000 | 113 | 0.000 | **0.000** | **0.000** | **12.31** | **Inf** | **0.000** | **-51 -29 32** |
| | | | | | | 0.000 | 0.000 | 10.56 | Inf | 0.000 | -55 -17 23 |
| | | 0.000 | 0.000 | 97 | 0.000 | **0.000** | **0.000** | **10.78** | **Inf** | **0.000** | **53 -16 35** |
| | | | | | | 0.000 | 0.000 | 8.77 | 7.82 | 0.000 | 57 -12 25 |
| | | | | | | 0.000 | 0.004 | 6.56 | 6.12 | 0.000 | 59 -20 27 |
| | | 0.000 | 0.000 | 177 | 0.000 | **0.000** | **0.000** | **10.70** | **Inf** | **0.000** | **1 -18 48** |
| | | | | | | 0.000 | 0.000 | 9.71 | Inf | 0.000 | 1 -7 42 |
| | | | | | | 0.000 | 0.000 | 8.13 | 7.36 | 0.000 | 2 -10 56 |
| | | 0.000 | 0.000 | 63 | 0.000 | **0.000** | **0.000** | **9.64** | **Inf** | **0.000** | **57 -7 8** |
| | | | | | | 0.000 | 0.000 | 9.10 | Inf | 0.000 | 64 -7 5 |
| | | 0.000 | 0.000 | 115 | 0.000 | **0.000** | **0.000** | **9.31** | **Inf** | **0.000** | **30 -47 -42** |
| | | | | | | 0.000 | 0.000 | 8.81 | Inf | 0.000 | 24 -41 -39 |

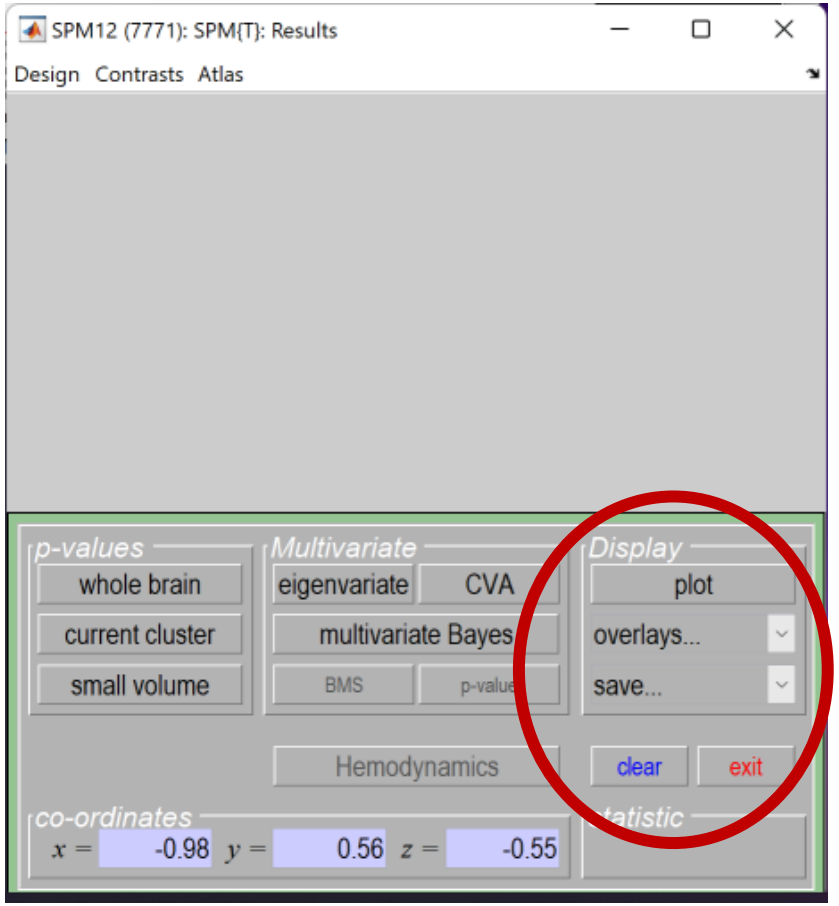
*table shows 3 local maxima more than 8.0mm apart*

Height threshold: T = 5.22, p = 0.000 (0.050)
Extent threshold: k = 60 voxels, p = 0.000 (0.000)
Expected voxels per cluster, <k> = 0.388
Expected number of clusters, <c> = 0.00
FWEp: 5.221, FDRp: 6.004, FWEc: 1, FDRc: 2

Degrees of freedom = [1.0, 143.0]
FWHM = 5.4 5.3 5.6 mm mm mm; 2.7 2.7 2.2 {voxels}
Volume: 1626420 = 162640 voxels = 9240.1 resels
Voxel size: 2.0 2.0 2.5 mm mm mm; (resel = 16.04 voxels)

*Page 1*

# 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

File Edit View Insert Tools Desktop Window SPM Figure Help

## LeftHand

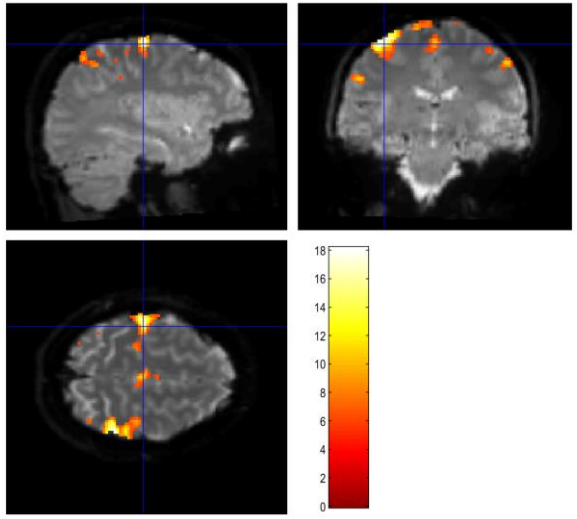
SPMmip [-36.0935, -16.179, 47.9068]

SPM{$T_{143}$}

contrast

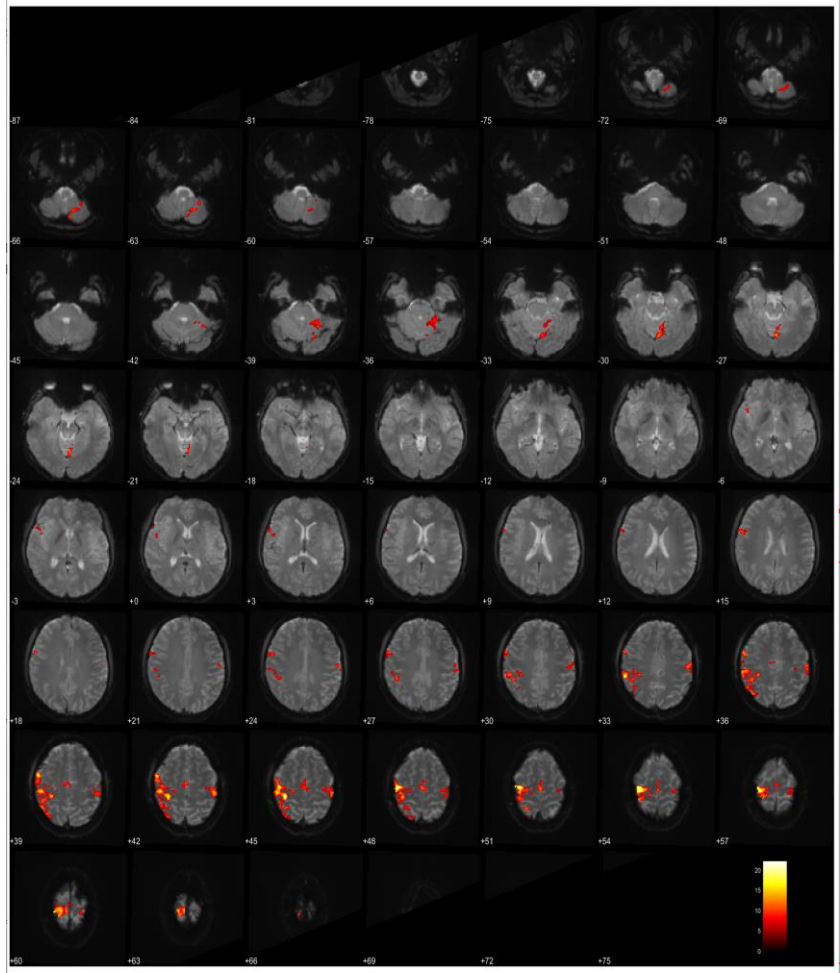
Design matrix

**SPMresults:** D:\Subj01\fMR-HK\model
Height threshold T = 5.569077 {p<0.01 (FWE)}
Extent threshold k = 60 voxels



SPM12 (7771): SliceOverlay

File Edit View Insert Tools Desktop Window SPM Figure Help



SPM12 (7771): Graphics

File Edit View Insert Tools Desktop Window SPM Figure Help

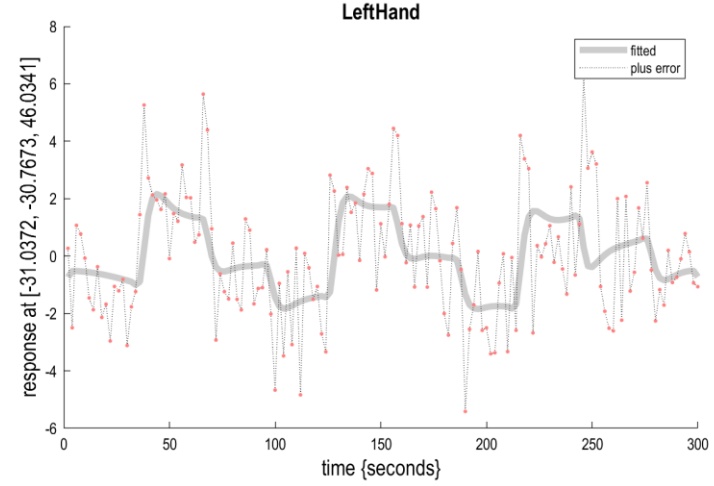
## LeftHand

SPMmip [-31.0372, -30.7673, 46.0341]

SPM{$T_{143}$}

contrast

Design matrix

**SPMresults:** D:\Subj01\fMR-HK\model
Height threshold T = 5.569077 {p<0.01 (FWE)}
Extent threshold k = 60 voxels

### Fitted responses
### LeftHand