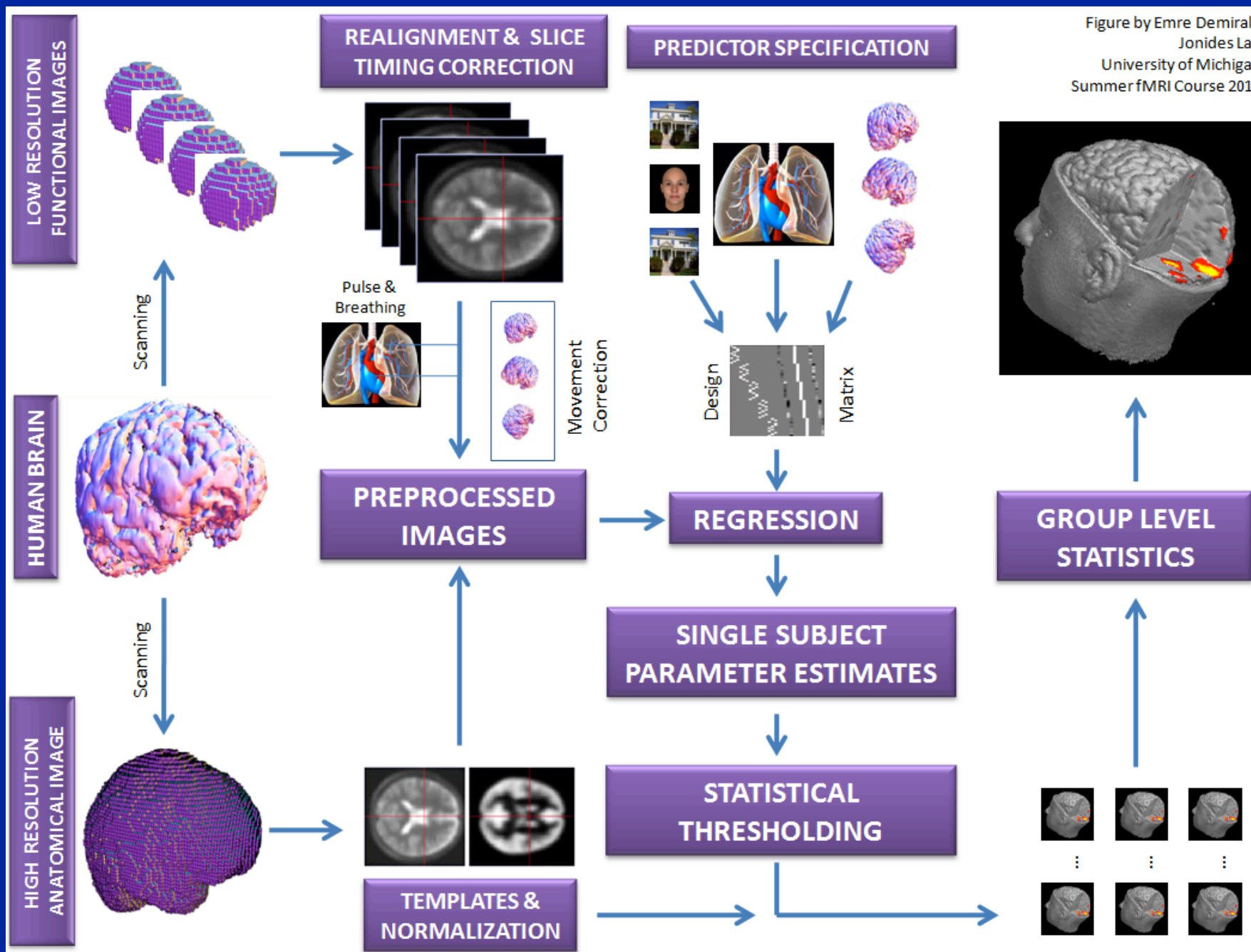

SPM

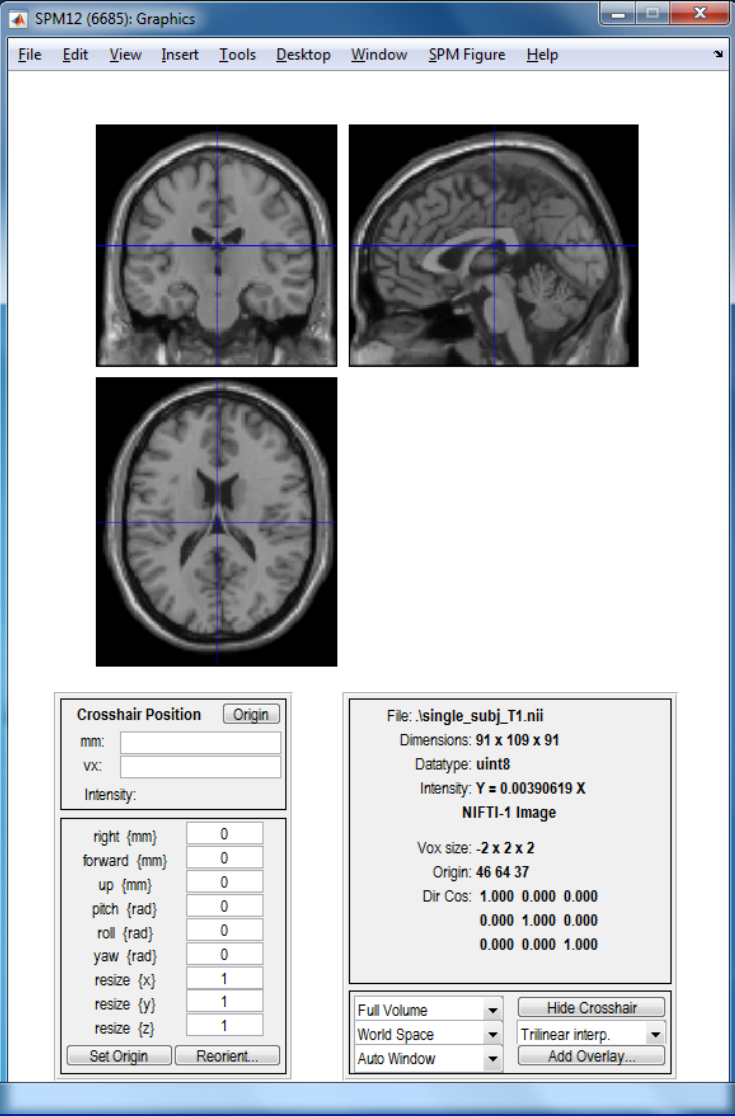
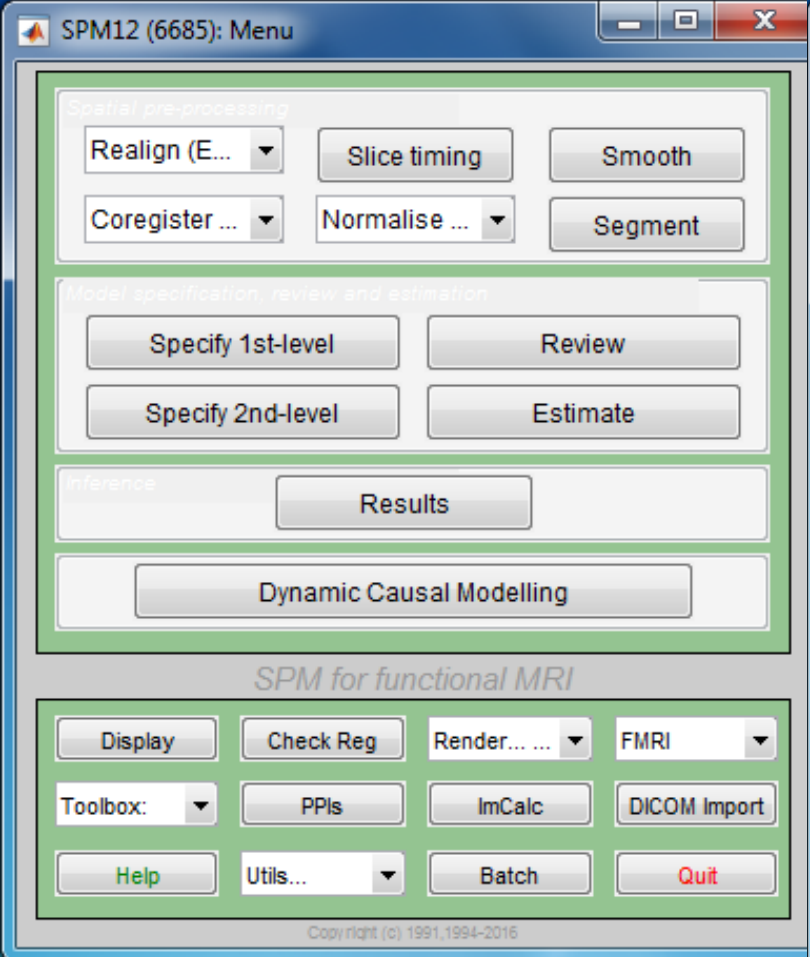
Introduction

Scott Peltier

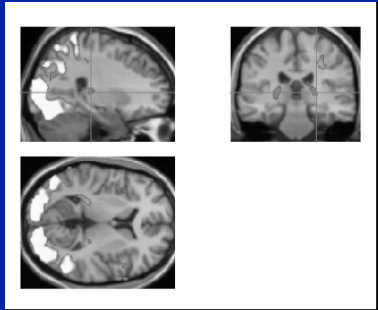
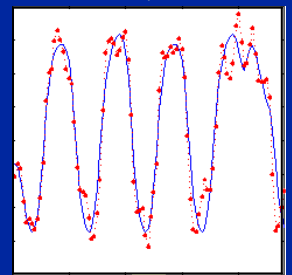
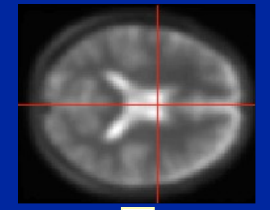
FMRI Laboratory
University of Michigan







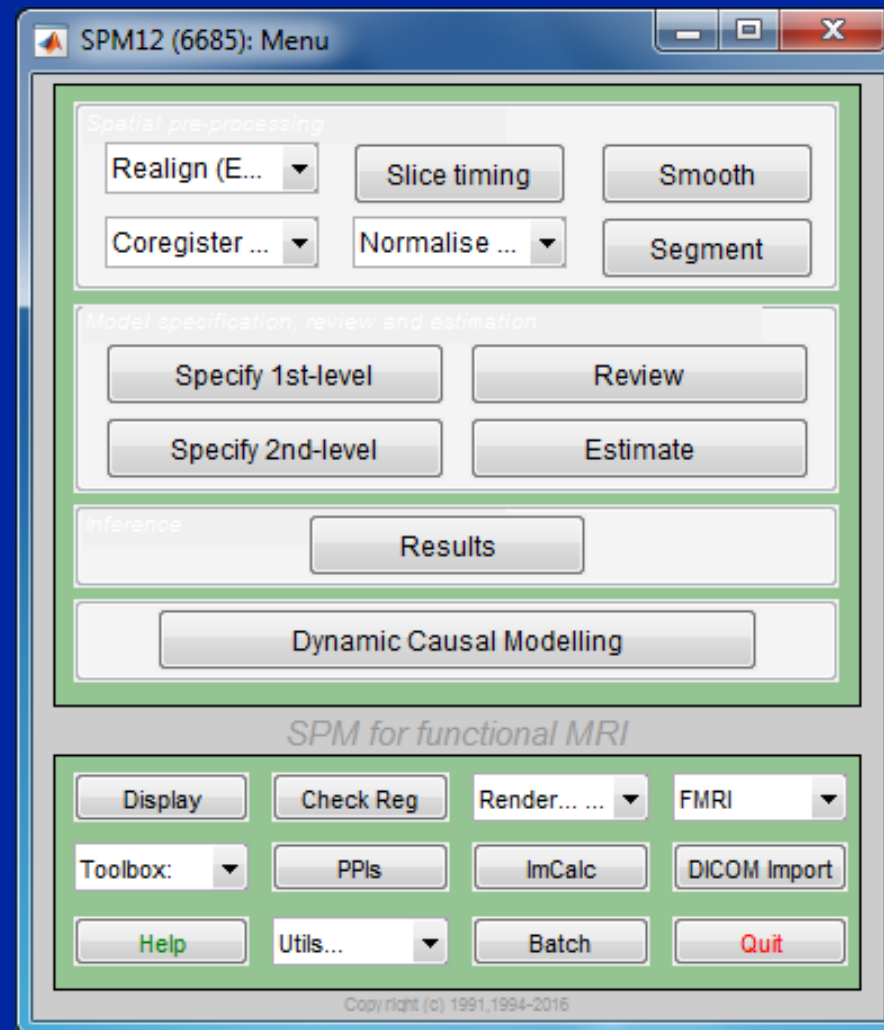
SPM!



Software to perform computation, manipulation and display of imaging data

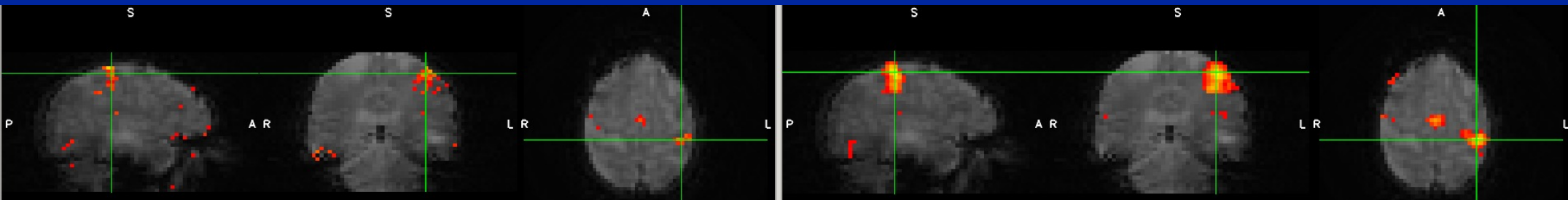
SPM : Overview

- Library of MATLAB and C functions
- Graphical user interface
- Four main components:
 - Preprocessing
 - Model Specification & Fitting
 - Inference & Results Interrogation
 - Supplemental Tools



Preprocessing

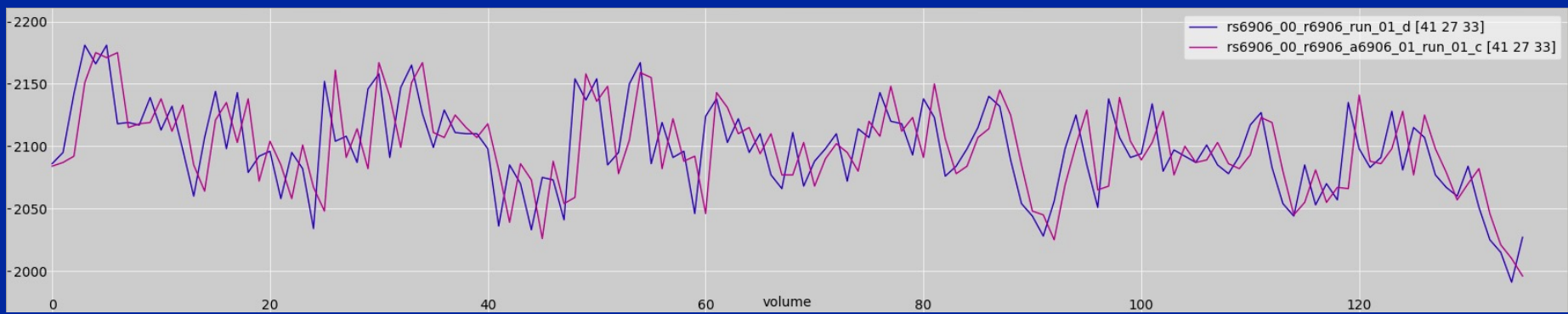
- Eliminate systematic variation before statistical modeling



Before
t=5.89

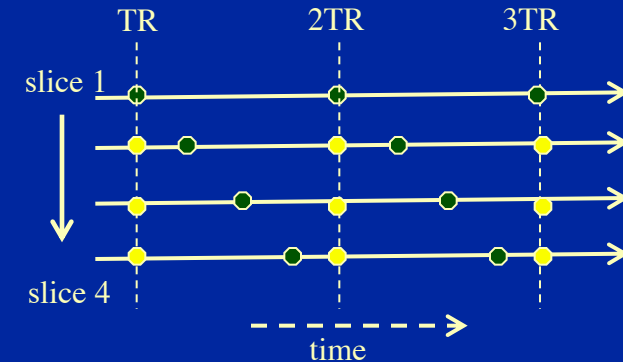
Processed with slice-timing correction, motion correction, and smoothed with 5mm isotropic kernel.

After
t=10.04

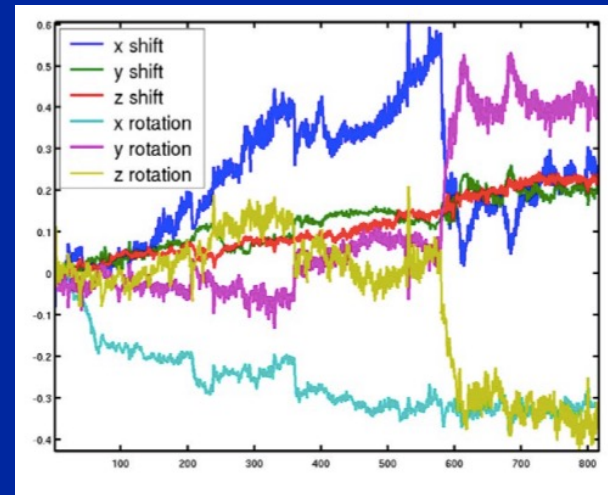


SPM: Preprocessing

- Slice timing
 - Adjust for variable acquisition time over slices
 - In UM processing stream, this is already done



- “Realign”ment
 - Intrasubject registration
 - Motion correction
 - Done in UM stream

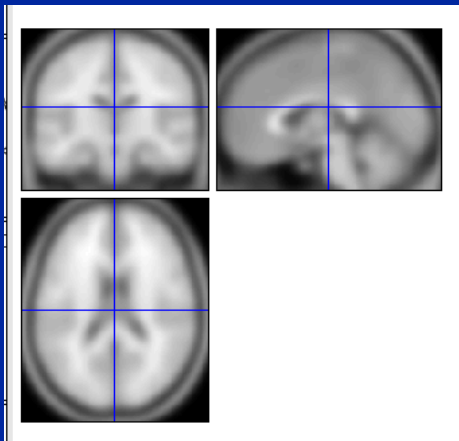


Spatial pre-processing

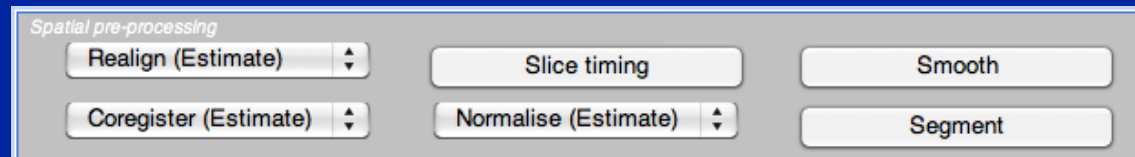
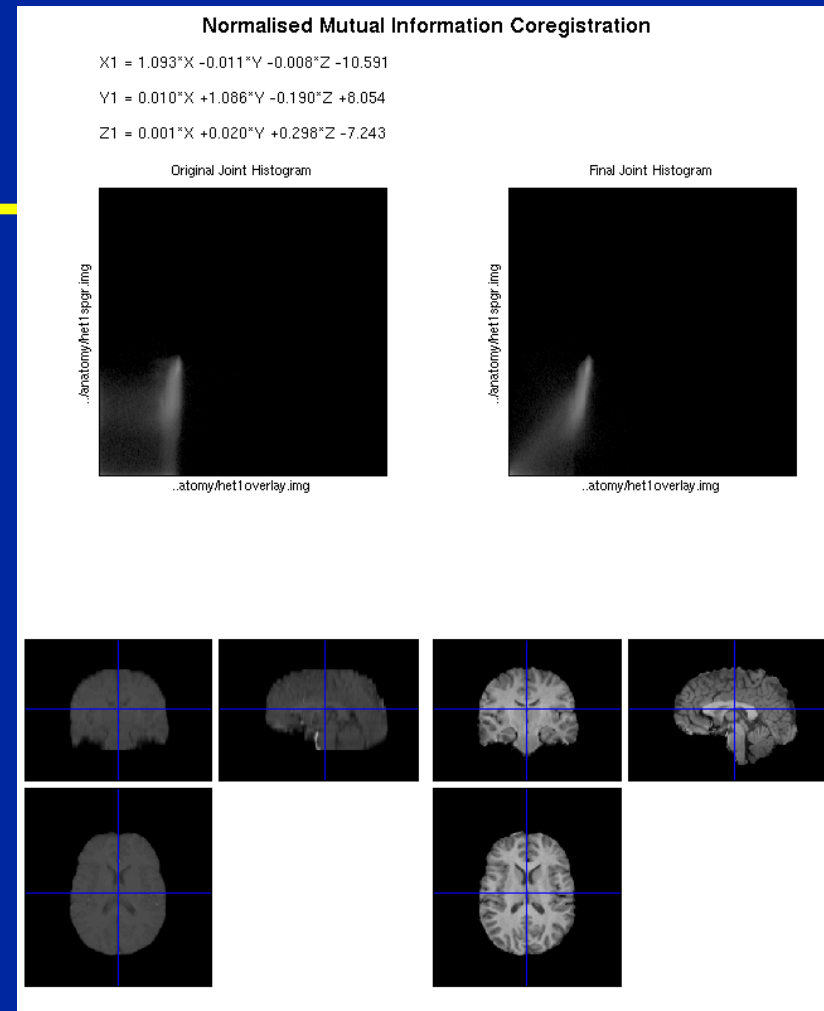
Realign (Estimate) ▾	Slice timing	Smooth
Coregister (Estimate) ▾	Normalise (Estimate) ▾	Segment

SPM: Preprocessing

- “Coregister”ation
 - Intrasubject, intermodality registration
 - Registration of MR images with different TR/TE
- Spatial “Normalize”ation
 - Intersubject registration
 - Register subject anatomy to atlas space

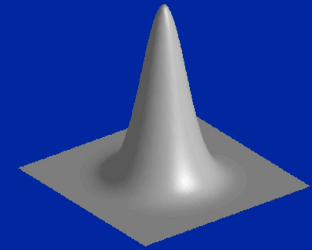


SPM
T1 template
MNI space

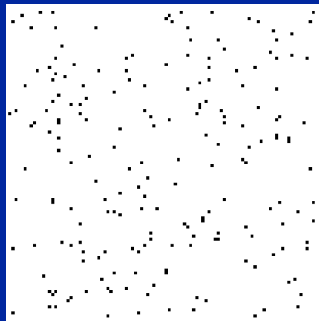


SPM: Preprocessing

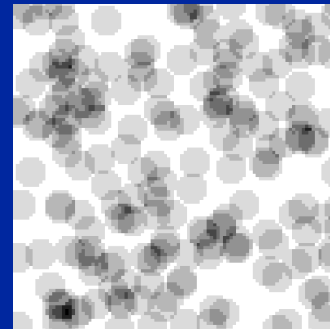
- Spatial “Smooth”ing
 - Blur data into submission...
 - To satisfy random field theory assumptions
 - For intersubject analyses



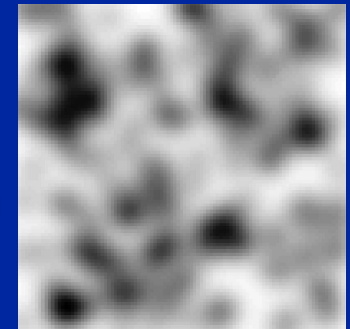
**Before
convolution**



**Convolved
w/ circle**

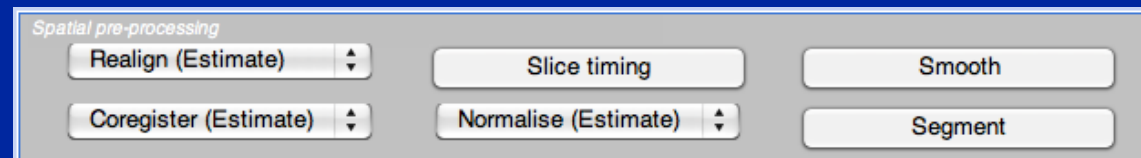


**Convolved
w/ Gaussian**



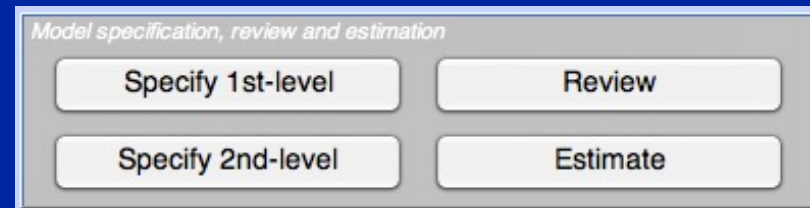
Adapted from SPM course slides

- “Segment”ation into GM/WM/CSF
 - Useful for structural studies



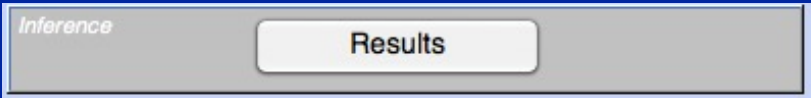
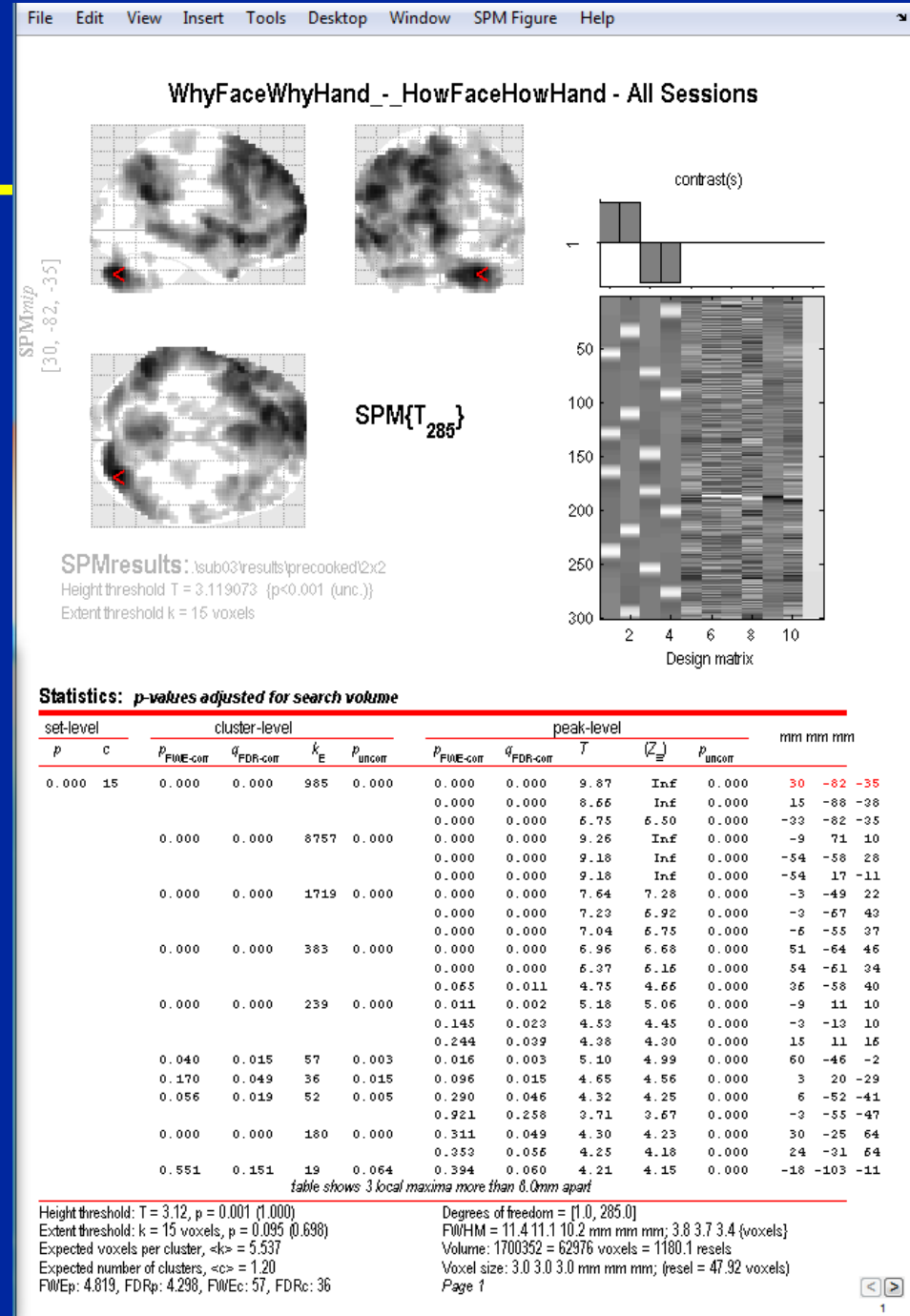
SPM: Model Specification

- “Specify 1st-level”
 - Specify the design, creating SPM.mat
- “Specify 2nd-level”
 - T-tests (One or two sample, paired)
 - Regression
- “Review”
 - Examine correlation of predictors
 - Power spectrum of experimental effects
- “Estimate”
 - Fit a specified model
based on a SPM.mat file



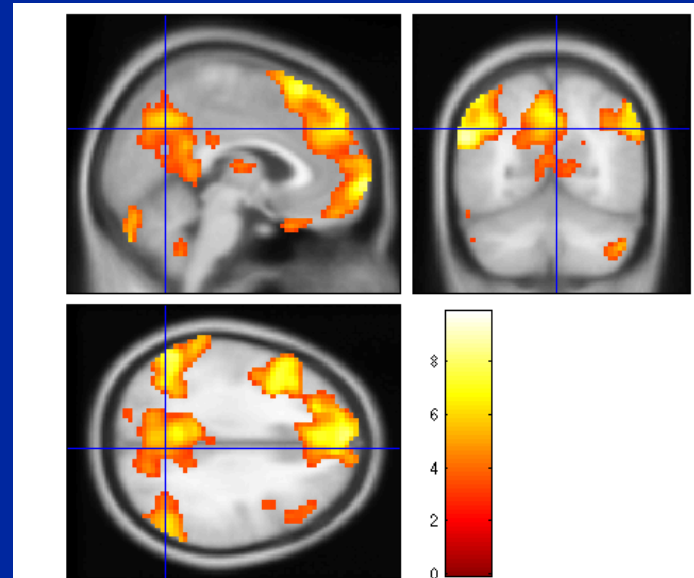
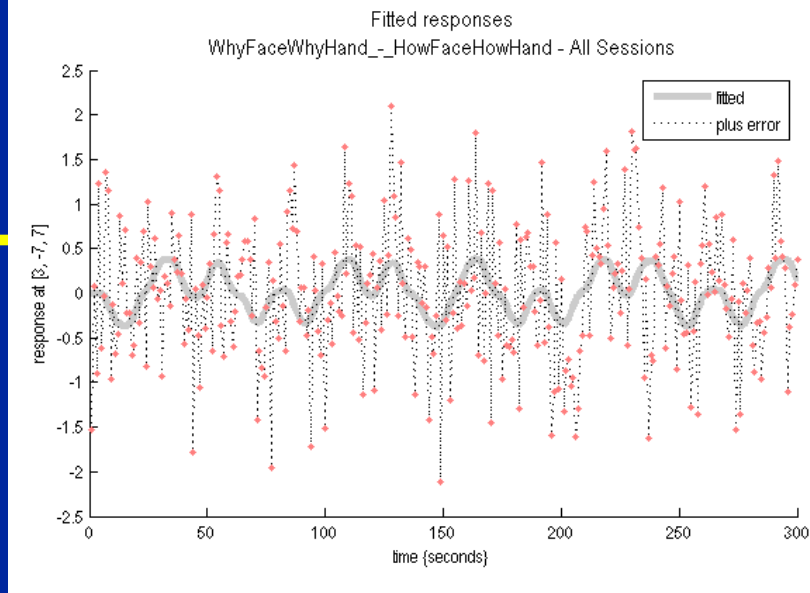
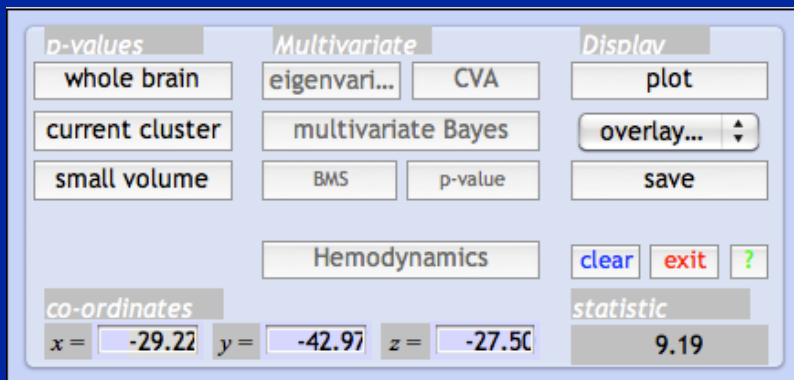
SPM: Inference

- “Results” button
- First brings up “Contrast Manager”
 - Can define single (t)
 - or sets (F) of contrasts
- Then displays MIP
 - MIP = Maximum Intensity Projection
 - Glass Brain
 - Can “surf” by dragging cursor



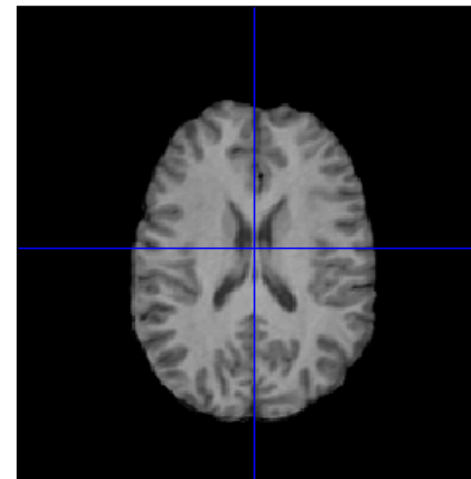
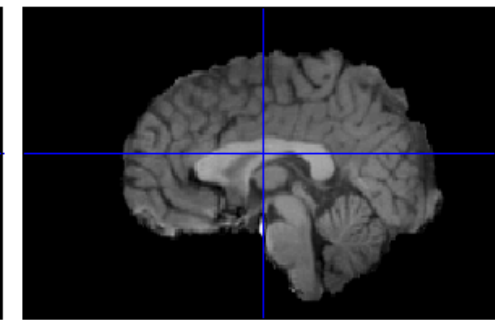
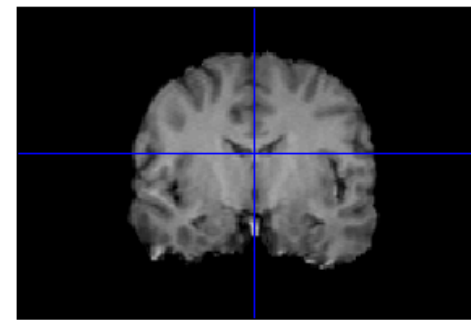
SPM: Inference

- Interactive window
 - p-values
 - Corrected for whole brain or subregion
 - Plotting of time courses
 - Superimpose results on other images
 - “Overlays”
 - Superimpose results on other images
 - Current location and value



SPM: Miscellaneous Tools

- “Display”
 - Displays image with orthogonal sections
 - Check intensity values
 - Change origin
 - Change world space
 - i.e. Apply rotations/translations



Crosshair Position

mm:	0.8 -2.5 4.5
vx:	129.4 125.9 56.5
Intensity:	534.268

right {mm}	0
foward {mm}	0
up {mm}	0
pitch {rad}	0
roll {rad}	0
yaw {rad}	0
resize {x}	1
resize {y}	1
resize {z}	1

Reorient images... Reset..

File: **..8ak/anatomy/het1spgr.img**

Dimensions: **256 x 256 x 106**

Datatype: **int16**

Intensity: **Y = 1 X**

FSL3.2beta

Vox size: **0.94 x 0.94 x 1.5**

Origin: **128 128 53.5**

Dir Cos: **1.000 0.000 0.000**
0.000 1.000 0.000
0.000 0.000 1.000

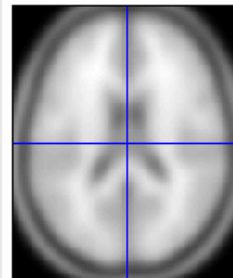
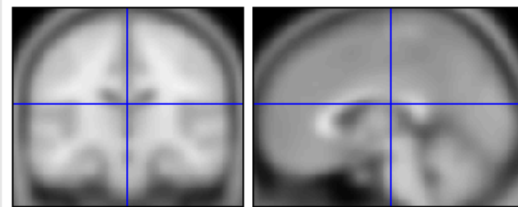
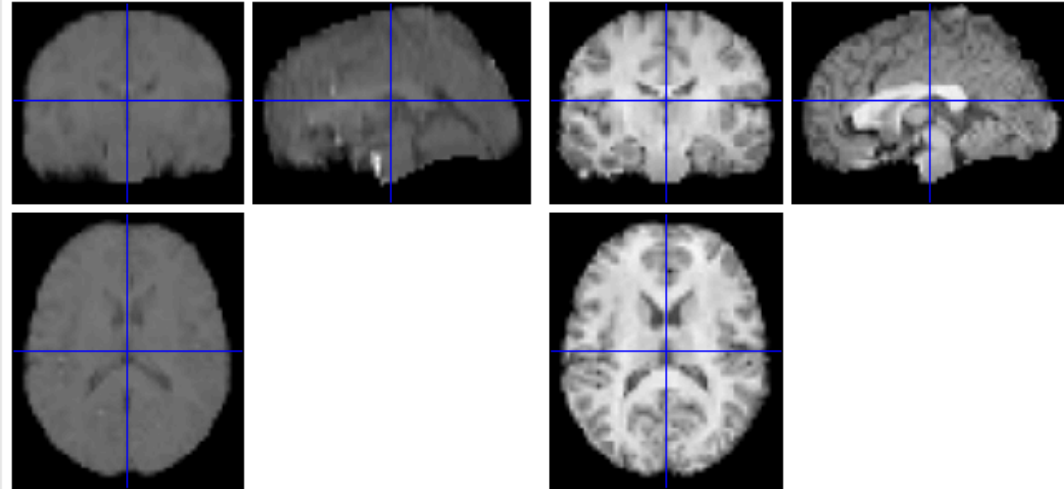
Full Volume	Hide Crosshairs
World Space	NN interp
Auto Window	Add Blobs

SPM for functional MRI

Display	Check Reg	Ren...	FMRI
Tool...	PPIs	ImCalc	DICOM Import
Help	Utils....	Batch	Quit

SPM: Miscellaneous Tools

- “Check Reg”
 - Display multiple images
 - Essential tool for assessing alignment of images
 - All images are displayed in the space of the first image



SPM for functional MRI

Display

Check Reg

Ren... ▾

FMRI ▾

Tool... ▾

PPIs

ImCalc

DICOM Import

Help

Utils... ▾

Batch

Quit

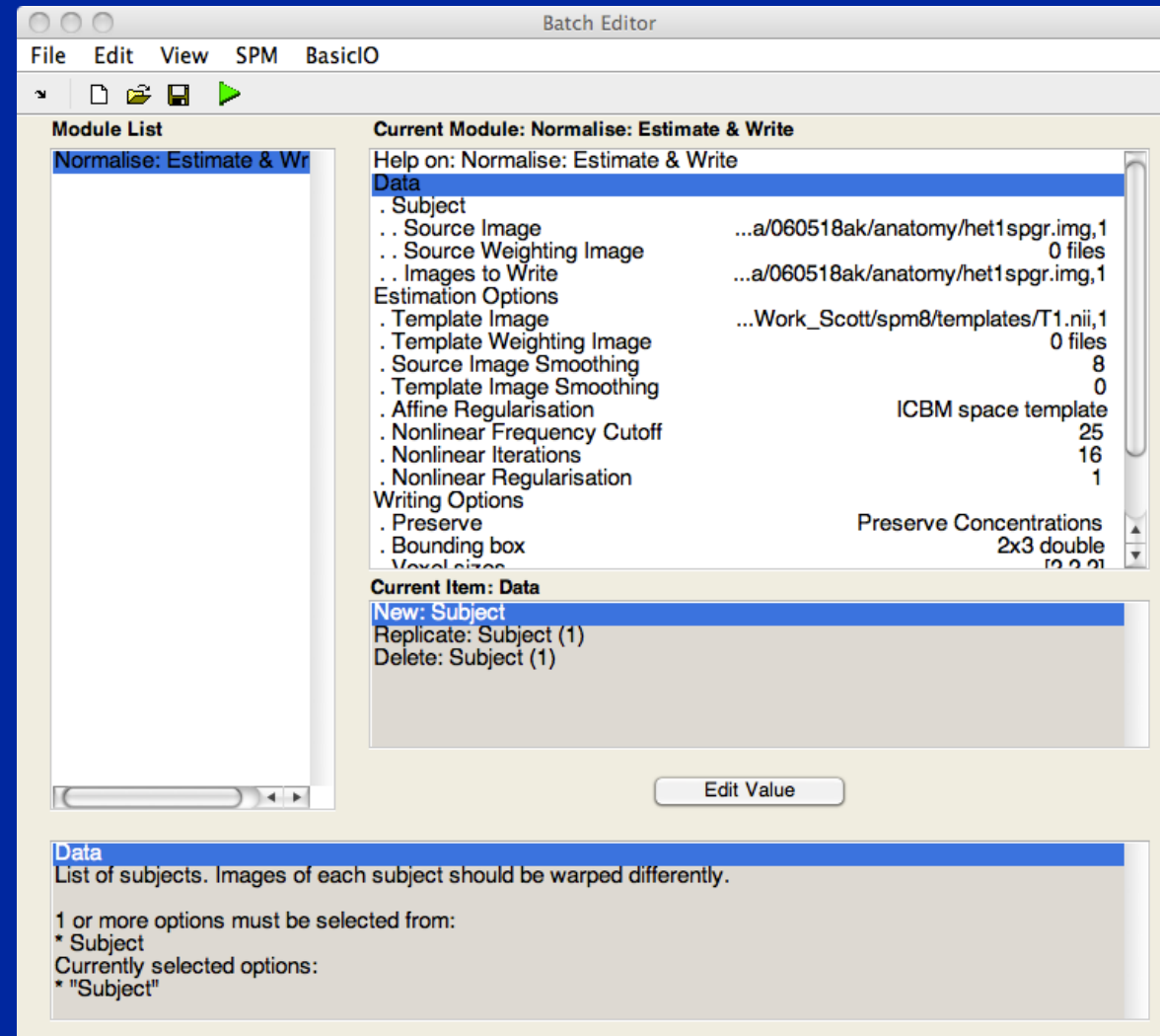
SPM: Miscellaneous Tools

- “ImCalc”
 - Image calculator
 - Give one or more images, perform MATLAB arithmetic and write out result
- “Utils”
 - Change directory
 - Results are written to current directory!
 - Delete files, etc.



SPM12 Batch Editor

- Allows jobs to be saved, re-loaded, changed
- Helps remove “Oops!” factor
- Multiple steps can be loaded, run at once

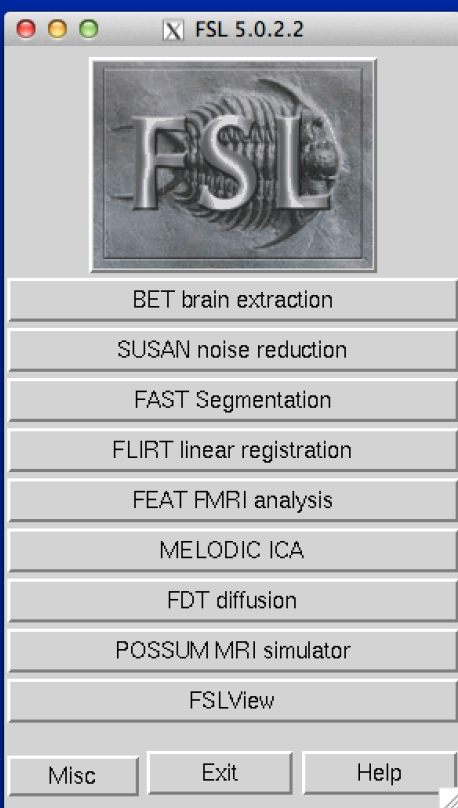


SPM: Perspective

- SPM tries to be a single solution for all fMRI processing and analysis, but there can be no such thing!
 - fMRI is a rapidly evolving field where each dataset has huge number of observations!
- Don't let SPM be a black box!
- Understand what each component does
- Understand how to get at the data
 - e.g. using 'Display', 'Check Reg'

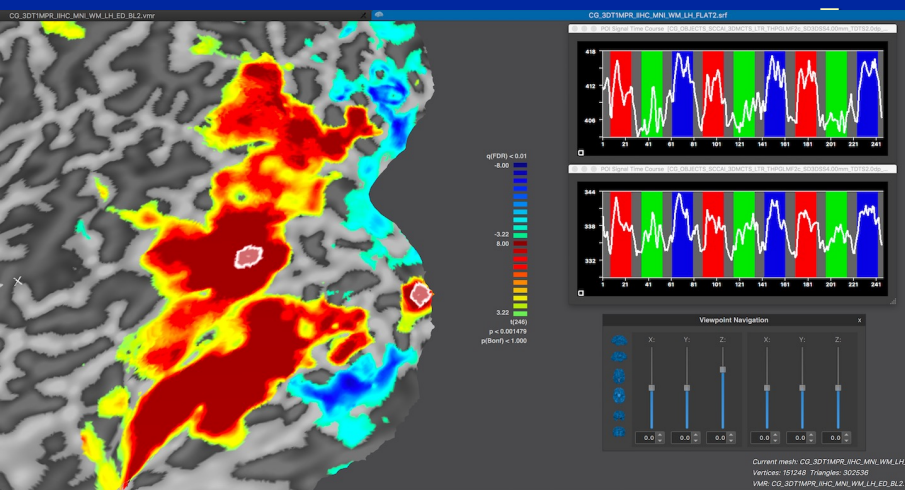
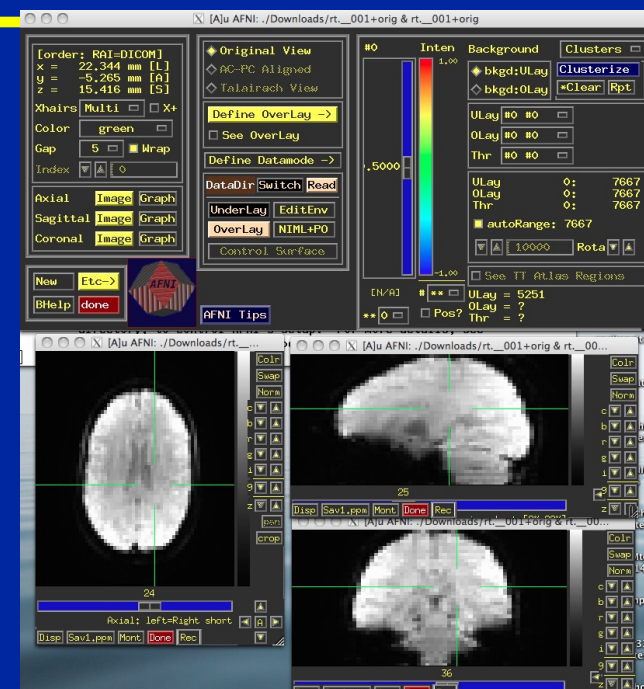
Resources

- **SPMweb site:** <http://www.fil.ion.ucl.ac.uk/spm/>
 - Introduction to SPM
 - SPM code download: SPM12 (also older versions)
 - Documentation & Bibliography
 - SPM course videos
 - Example data sets
 - SPM extensions
 - SPM email discussion list
- **Other software packages can complement SPM**
 - MRICron: <https://people.cas.sc.edu/rorden/mricron/index.html>
 - Quick and easy to read, display, and convert image data

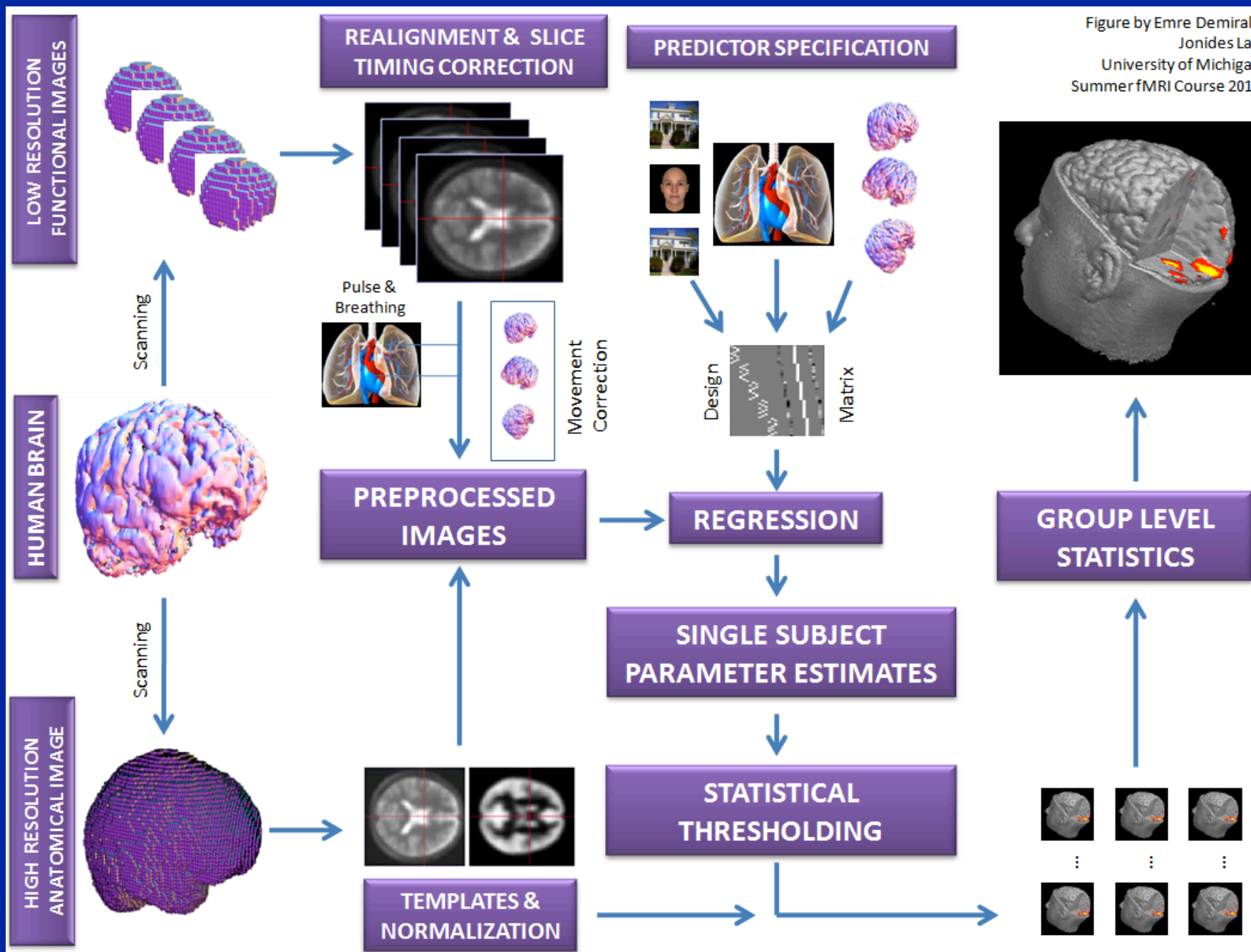


Alternatives

- **FSL:** <http://www.fmrib.ox.ac.uk/fsl>
 - Open source
 - Comprehensive tools for FMRI and DTI, has nice ICA analysis tool (MELODIC)
 - Free
- **AFNI:** <http://afni.nimh.nih.gov>
 - Open source
 - Active community, multiple plugins



- **BrainVoyager:** <http://www.brainvoyager.com>
 - Excellent visualization
 - Closed source, ~\$7k



SPM

Spatial Transformations

Imaging data formats

- Analyze format

- .img Raw, binary data; 3D or 4D
- .hdr Small binary header
 - Image dimension
 - Voxel size

Historical

- NIFTI format

- .img + .hdr
- Like Analyze, but different .hdr definition
- .nii *Single file!* Header and Image file concatenated
- World space transformation coded in NIFTI header

Current

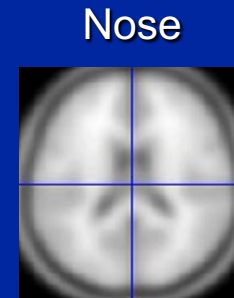
Is Left Right?

- Two conventions for viewing images

- Neurological

- On the screen, Left is Left side of subject
- As if standing behind the head of the patient

L

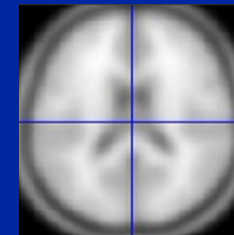


R

- Radiological

- On the screen, Left is Right side of subject
- As if standing at the foot of the patient

R



L

- Standard in clinical radiology is, um, radiological
- SPM always uses Neurological convention
 - Default for Analyze set by defaults.analyze.flip in spm defaults.m
 - flip = 0 ,Neuro., flip = 1 ,Rad.
 - NIFTI images *allegedly* have no ambiguity about left & right

Coregister & realignment

- Coregistration & Realignment are rigid body transformations
 - Subject's head doesn't change size or warp between scans
 - Well, actually...
- Each requires a “Reference” and a “Source”
 - Reference: Fixed image
 - Source: Image that is transformed
- SPM modifies the header of the *object* image
 - Unless you explicitly ask it to, it doesn't write out a new image
 - Saves lots of disk space!

Voxel space vs. world space

- Voxel Space
 - Just the original image
 - No reorientations or flips
- World Space
 - Space defined by transformation from voxel to mm matrix M
 - Let v be a voxel location indexed from $(1,1,1)$
 - Then $w=M*[v;1]$ is that location in world space, in mm
 - Can represent rotations, translations and flips

Data Fresh from fMRI Lab

Functional Space

Functional images
raprun_01.nii

Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

Coregistration

Functional Space

Functional images
raprun_01.nii

Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii

Reference

Source

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

Coregister button

Sets new world space in NIFTI header

Determined from: Rigid body, M.I. registration of high-res to low-res anatomy

After Coregistration

Functional Space

Functional images
raprun_01.nii

Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii
(NIFTI header)

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

Spatial Normalization

Functional Space

Functional images
raprun_01.nii

Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii
(NIFTI header)

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

Normalize button

Creates **y_*.nii** file

Determined from:

Deformation fields calculated
using segmented images

Spatial Normalisation

Functional Space

Functional images
raprun_01.nii

Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii
(NIFTI header)

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

y_*.nii

file maps *any*

Functional Space image to MNI space!

After “Writing Normalized”

Functional Space

Functional images
raprun_01.nii

Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii
(NIFTI header)

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

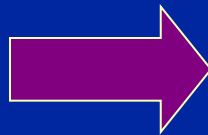
Normalized images
wt1spgr.nii
wraprun_01.nii

Group Analysis: Strategy 1

Only transform contrast img's

Functional Space

rap_run's



beta's
con's
spmT's

Intrasubject
analysis result

y_*.nii

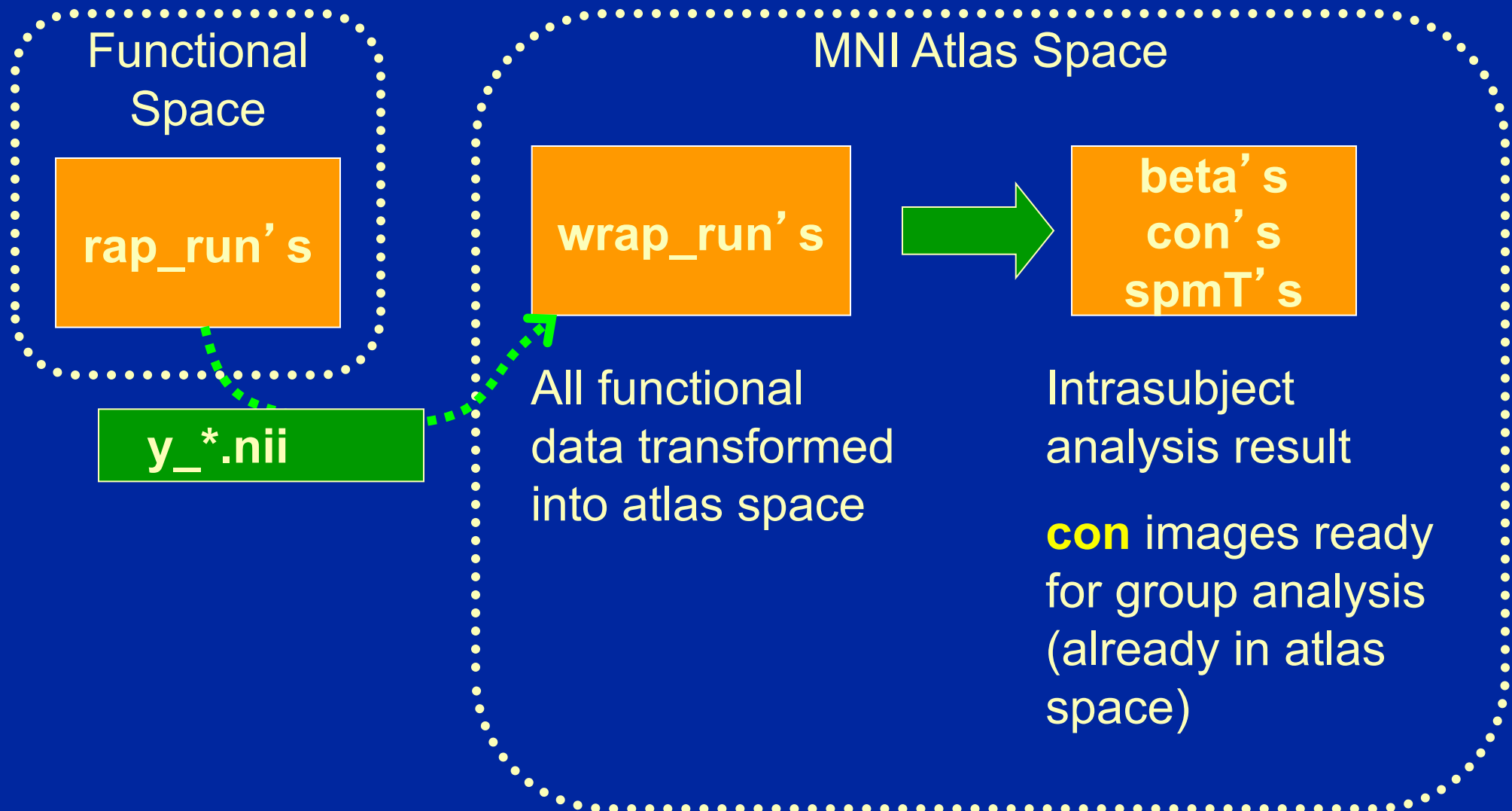
MNI Atlas Space

wcon's

Intrasubject analysis contrast images,
transformed into atlas space (w/ `_sn.mat`),
ready for group analysis

Group Analysis: Strategy 2

Transform all functionals



Normalization recommendations

- If not doing segmented normalization, with ‘scalped’ brains use ‘scalped’ template
 - Scalped template **scalped_avg152T1.nii**
 - *Should* give best results
 - We don’ t care about scalp alignment!
- Make sure WM equal in brightness
 - T1’ s can have inhomogeneity artifact, where center of volume is brighter
 - Should apply homogeneity correction (bias correction)
 - UM: make sure to use **(e)ht1spgr**, **(e)ht1overlay**