SPM Introduction

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Slides adapted from T. Nichols

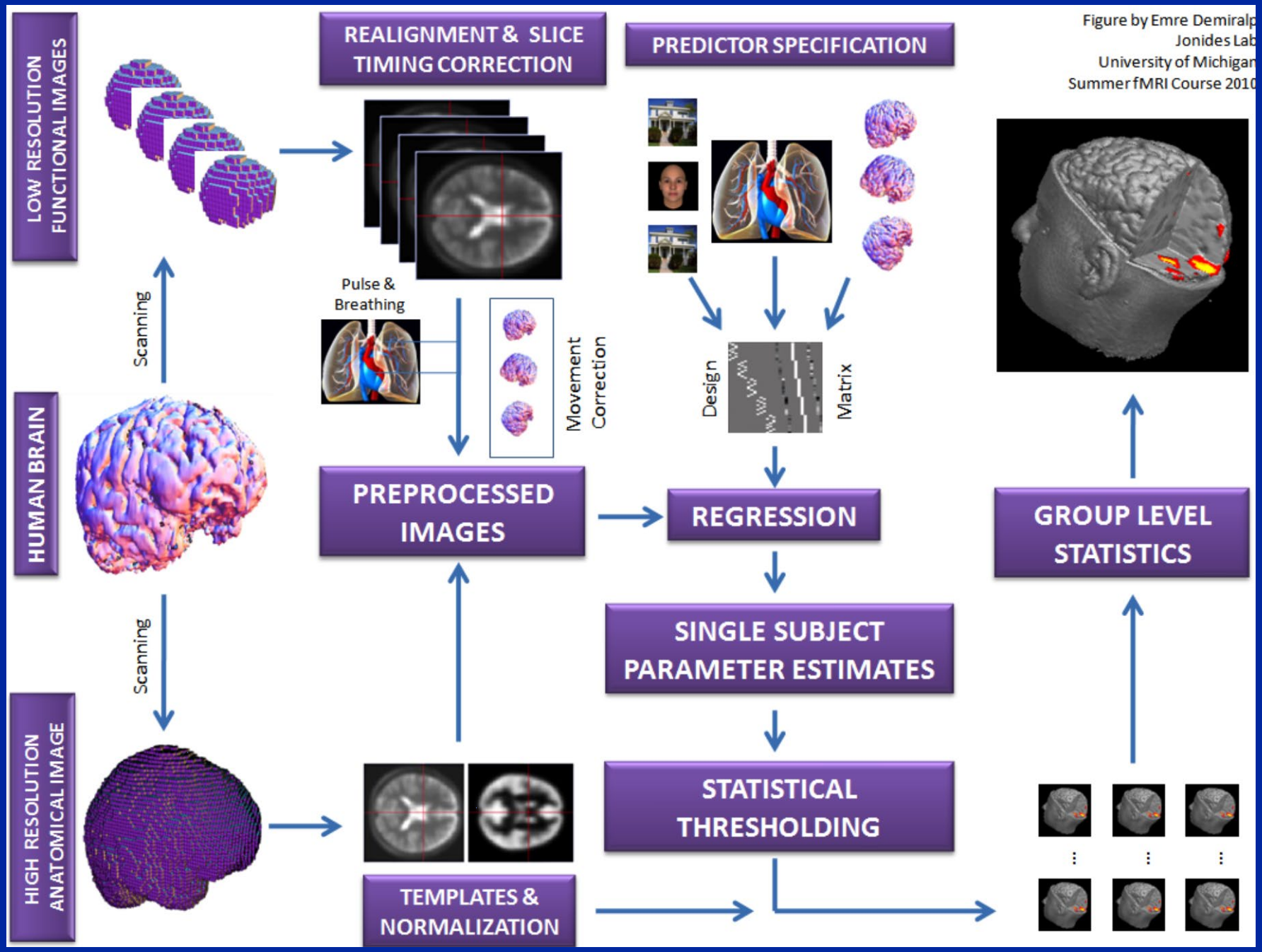
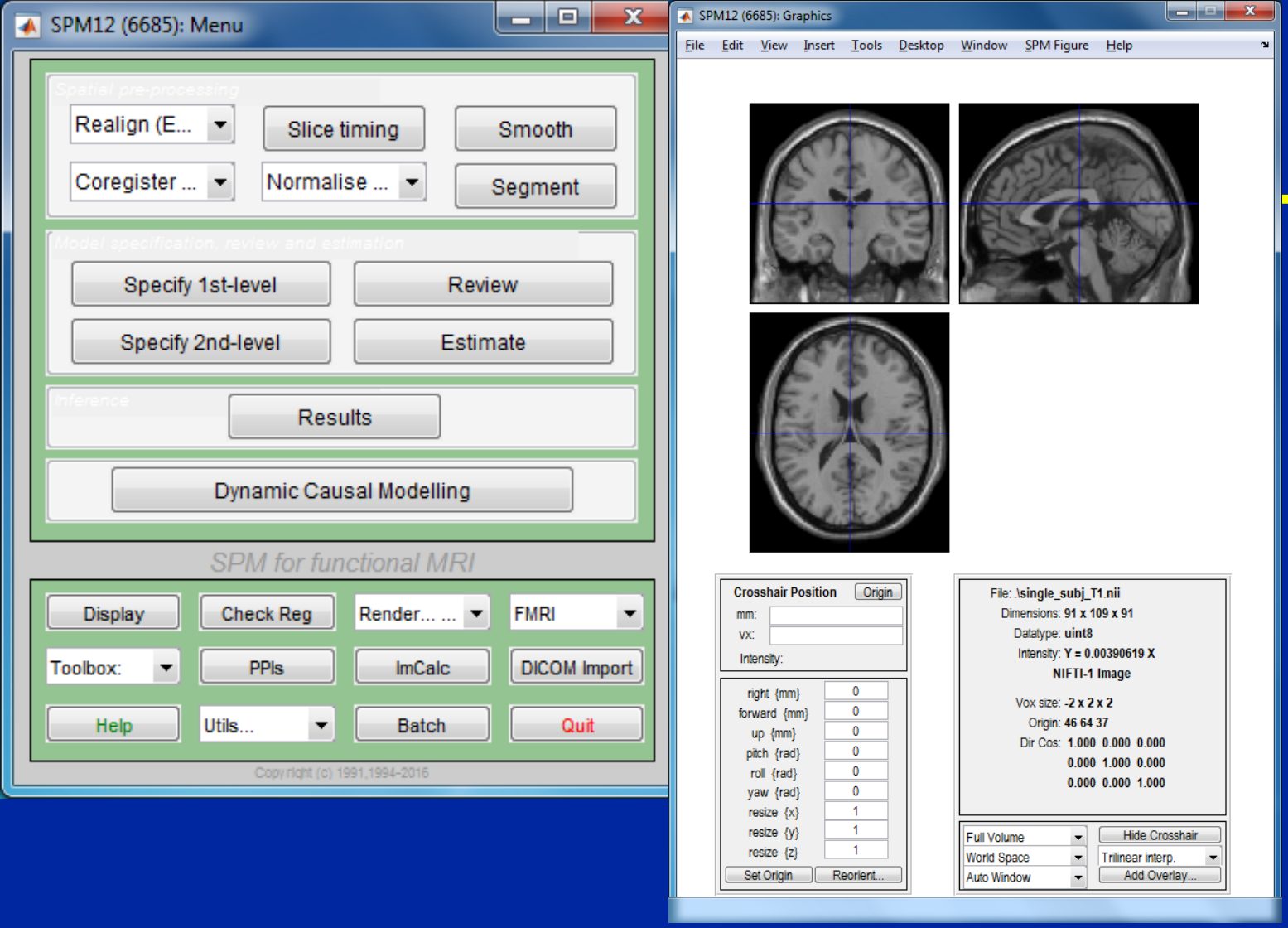
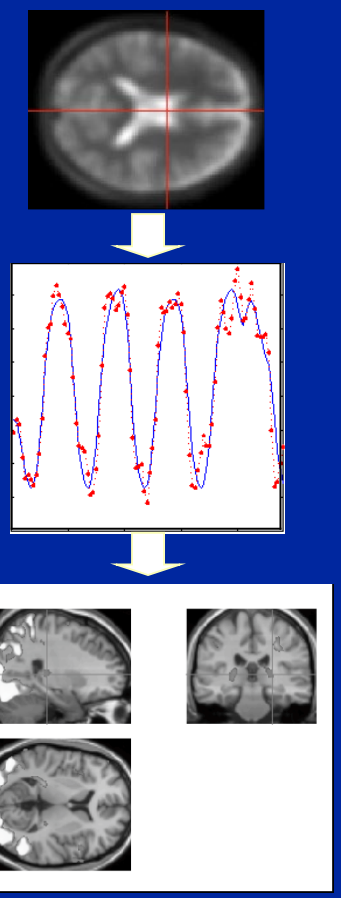


Figure by Emre Demiralp
Jonides Lab
University of Michigan
Summer fMRI Course 2010
LOW RESOLUTION FUNCTIONAL IMAGES
REALIGNMENT & SLICE TIMING CORRECTION
PREDICTOR SPECIFICATION
Scanning
Pulse & Breathing
Movement Correction
Design
Matrix
HUMAN BRAIN
PREPROCESSED IMAGES
REGRESSION
GROUP LEVEL STATISTICS
Scanning
SINGLE SUBJECT PARAMETER ESTIMATES
HIGH RESOLUTION ANATOMICAL IMAGE
STATISTICAL THRESHOLDING
TEMPLATES & NORMALIZATION

SPM!

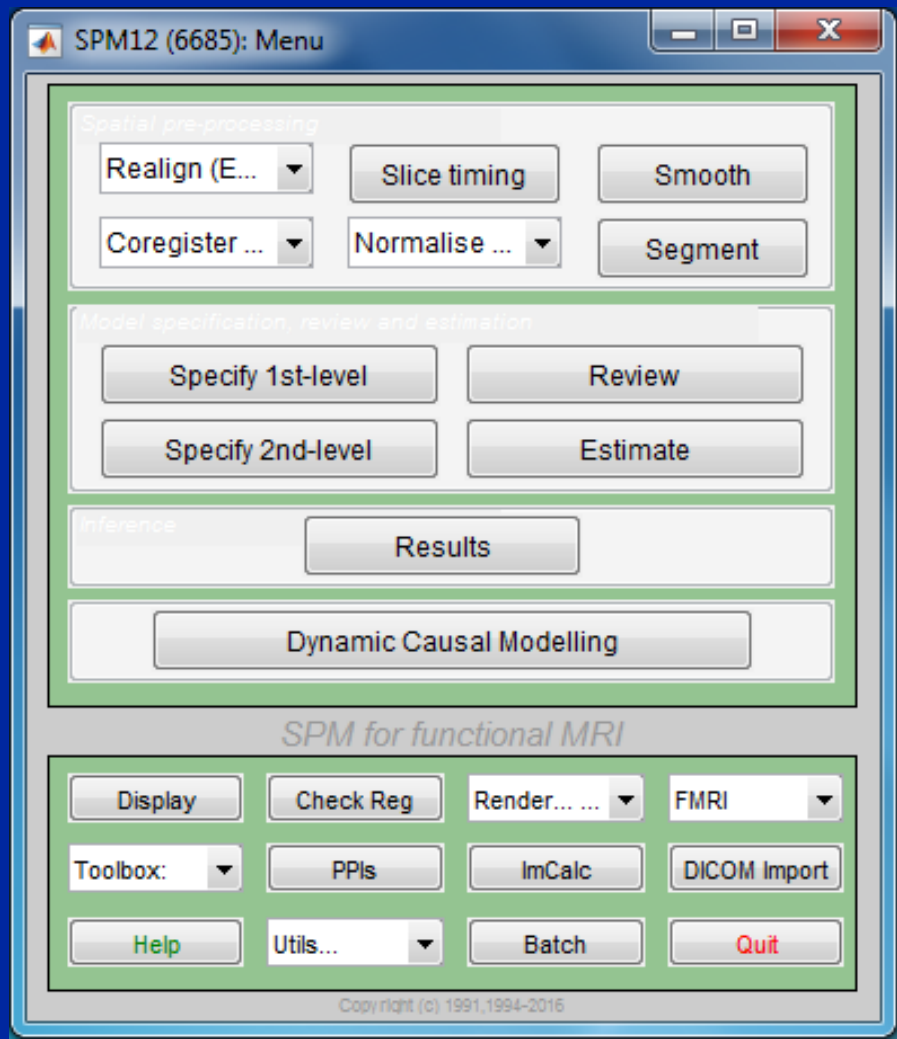




Software to perform computation, manipulation and display of imaging data

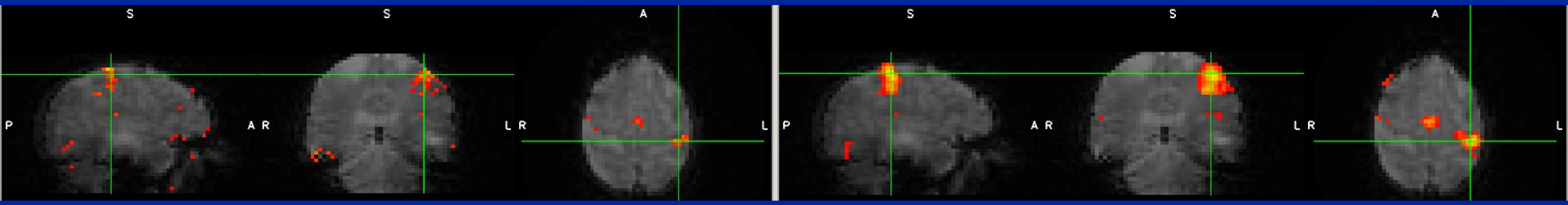
SPM : Overview

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



Preprocessing

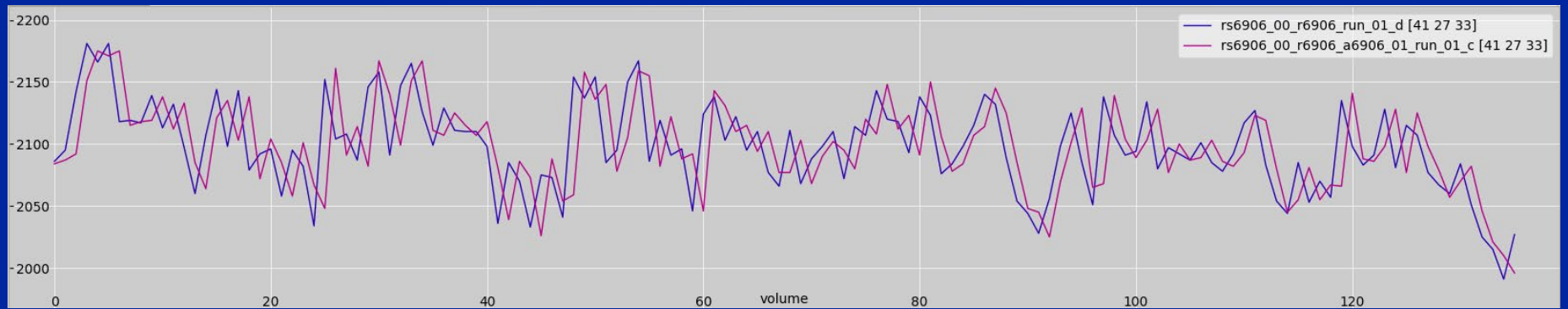
- Eliminate systematic variation before statistical modeling



Before
t=5.89

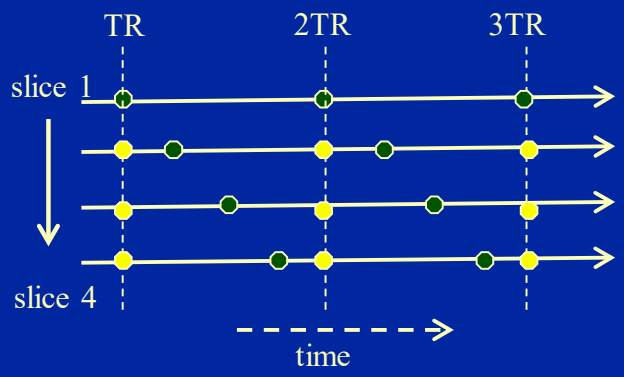
After
t=10.04

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

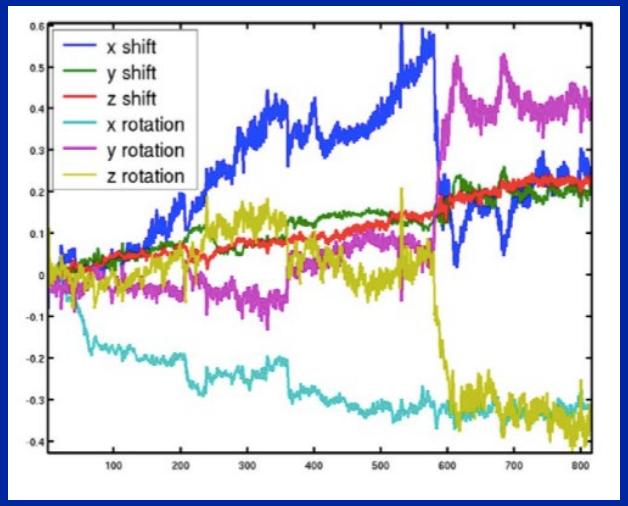


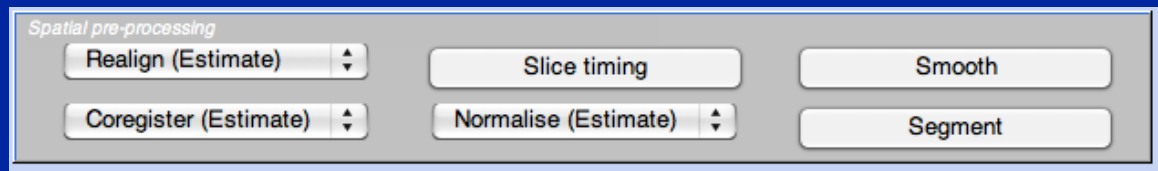
SPM: Preprocessing

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



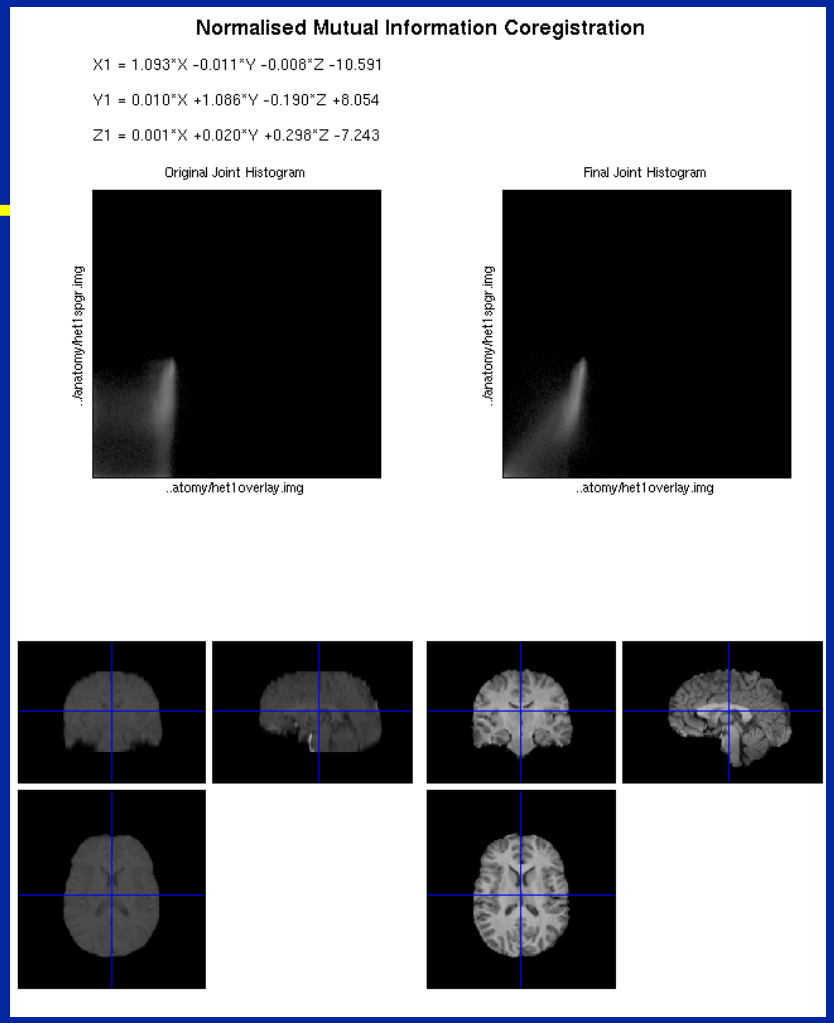
- "Realign"ment
  - Intrasubject registration
  - Motion correction
  - Done in UM stream



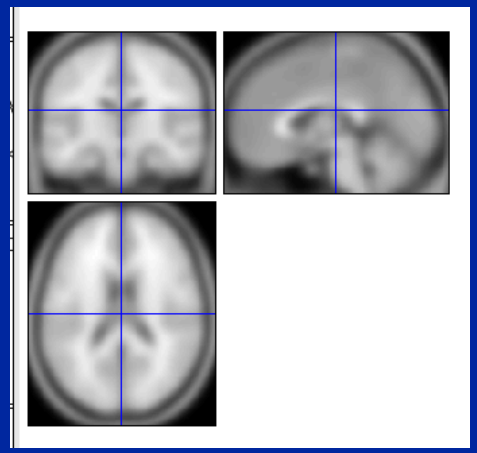


SPM: Preprocessing

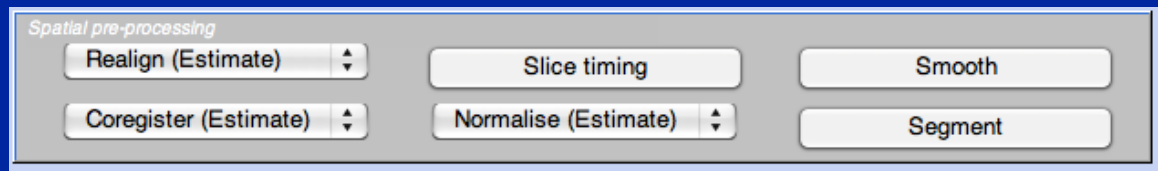
- "Coregister"ation
  - Intrasubject, intermodality registration
  - Registration of MR images with different TR/TE



- Spatial "Normalize"ation
  - Intersubject registration
  - Register subject anatomy to atlas space

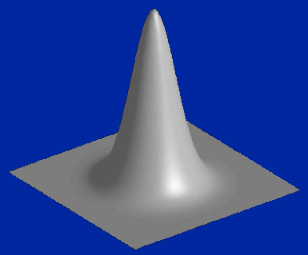


SPM
T1 template
MNI space

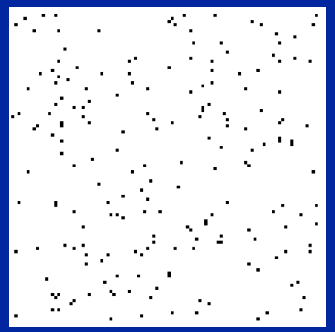


SPM: Preprocessing

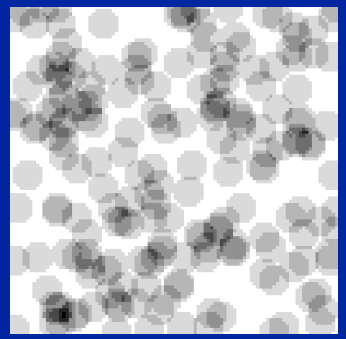
- Spatial "Smooth"ing
  - Blur data into submission…
    - To satisfy random field theory assumptions
    - For intersubject analyses



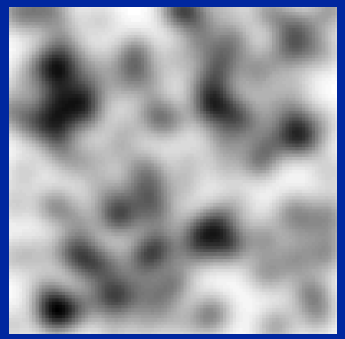
Before convolution



Convolved w/ circle

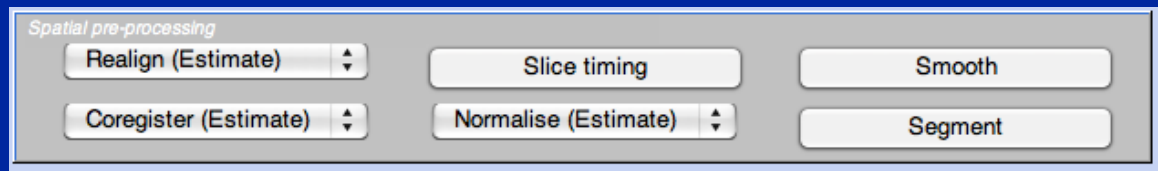


Convolved w/ Gaussian



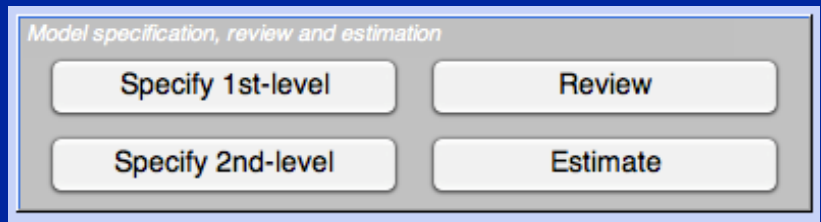
Adapted from SPM course slides

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



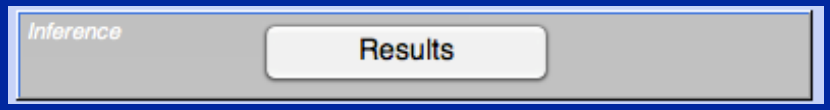
SPM: Model Specification

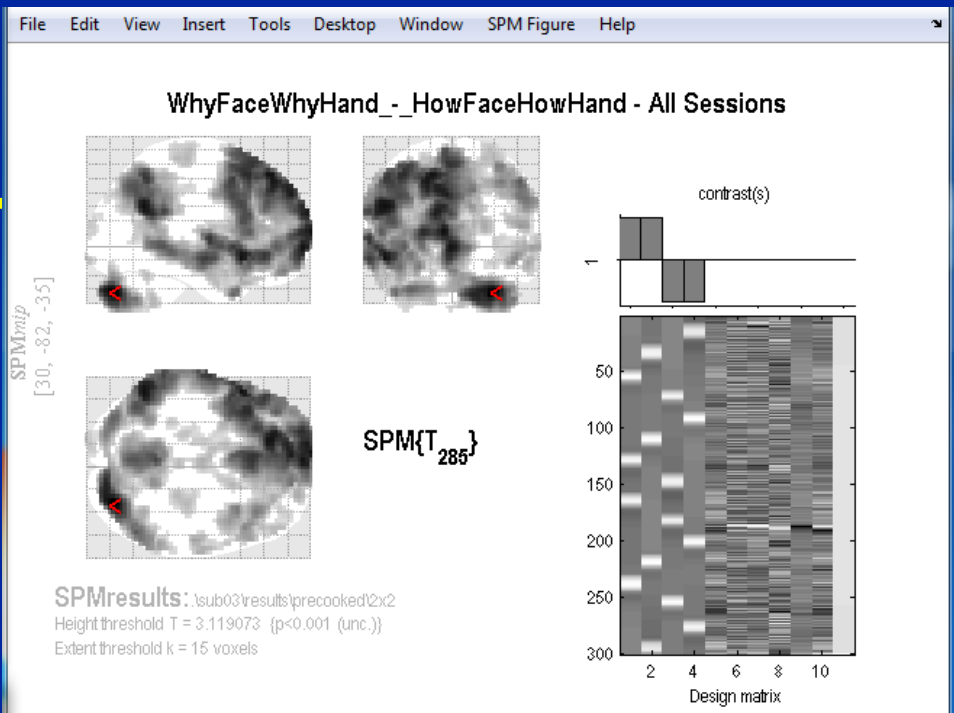
- "Specify 1st-level"
  - Specify the design, creating SPM.mat
- "Specify 2nd-level"
  - T-tests (One or two sample, paired)
  - Regression
- "Review"
  - Examine correlation of predictors
  - Power spectrum of experimental effects
- "Estimate"
  - Fit a specified model based on a SPM.mat file



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





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	$(Z_=)$	p_{uncorr}			
0.000	15	0.000	0.000	985	0.000	0.000	0.000	9.87	Inf	0.000	30	-82	-35
						0.000	0.000	8.66	Inf	0.000	15	-88	-38
						0.000	0.000	6.75	6.50	0.000	-33	-82	-35
		0.000	0.000	8757	0.000	0.000	0.000	9.26	Inf	0.000	-9	71	10
						0.000	0.000	9.18	Inf	0.000	-54	-58	28
						0.000	0.000	9.18	Inf	0.000	-54	17	-11
		0.000	0.000	1719	0.000	0.000	0.000	7.64	7.28	0.000	-3	-49	22
						0.000	0.000	7.23	6.92	0.000	-3	-67	43
						0.000	0.000	7.04	6.75	0.000	-6	-55	37
		0.000	0.000	383	0.000	0.000	0.000	6.96	6.68	0.000	51	-64	46
						0.000	0.000	6.37	6.16	0.000	54	-61	34
						0.065	0.011	4.75	4.66	0.000	36	-58	40
		0.000	0.000	239	0.000	0.011	0.002	5.18	5.06	0.000	-9	11	10
						0.145	0.023	4.53	4.45	0.000	-3	-13	10
						0.244	0.039	4.38	4.30	0.000	15	11	16
		0.040	0.015	57	0.003	0.016	0.003	5.10	4.99	0.000	60	-46	-2
		0.170	0.049	36	0.015	0.096	0.015	4.65	4.56	0.000	3	20	-29
		0.056	0.019	52	0.005	0.290	0.046	4.32	4.25	0.000	6	-52	-41
						0.921	0.258	3.71	3.67	0.000	-3	-55	-47
		0.000	0.000	180	0.000	0.311	0.049	4.30	4.23	0.000	30	-25	64
						0.353	0.056	4.25	4.18	0.000	24	-31	64
		0.551	0.151	19	0.064	0.394	0.060	4.21	4.15	0.000	-18	-103	-11

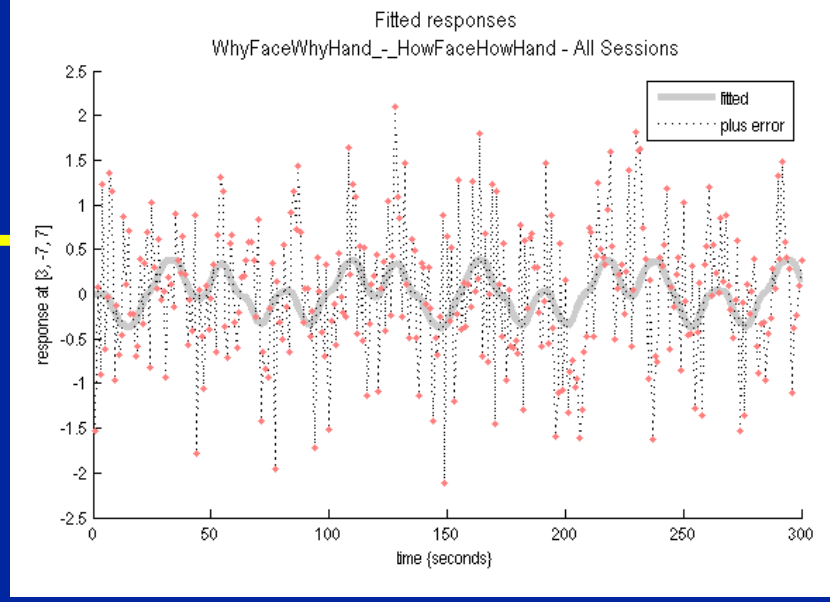
table shows 3 local maxima more than 8.0mm apart

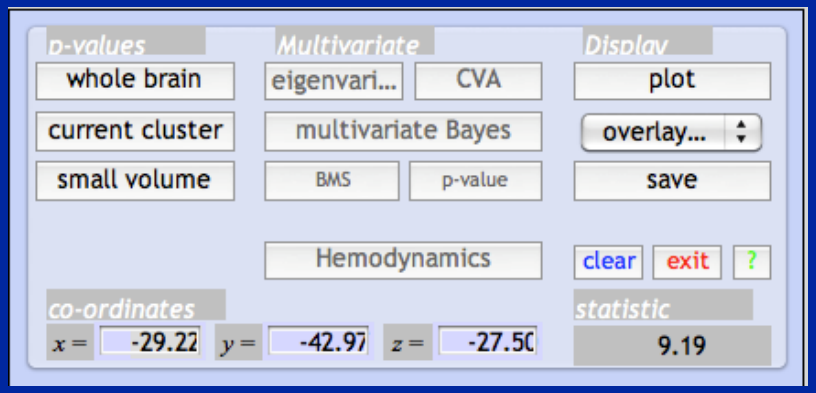
Height threshold: T = 3.12, p = 0.001 (1.000)
Extent threshold: k = 15 voxels, p = 0.095 (0.698)
Expected voxels per cluster, <k> = 5.537
Expected number of clusters, <c> = 1.20
FWEp: 4.819, FDRp: 4.298, FWEc: 57, FDRc: 36

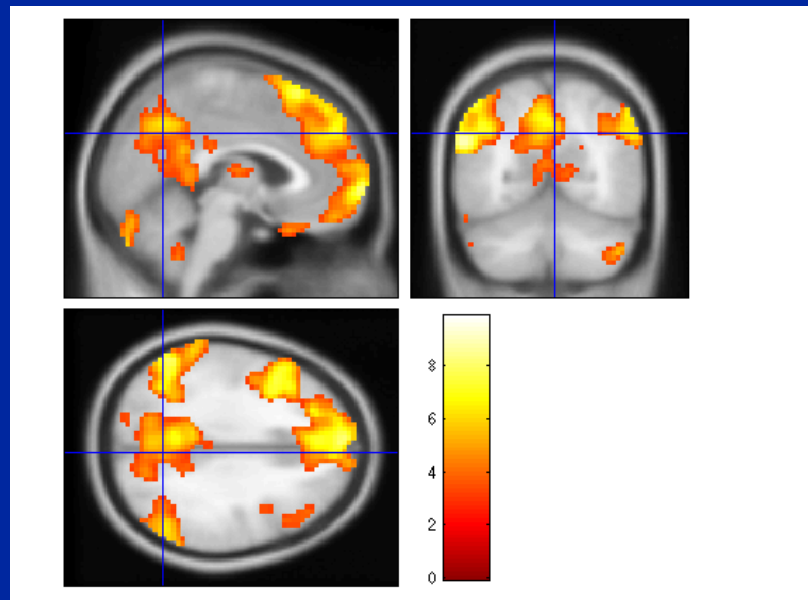
Degrees of freedom = [1.0, 285.0]
FWHM = 11.4 11.1 10.2 mm mm mm; 3.8 3.7 3.4 (voxels)
Volume: 1700352 = 62976 voxels = 1180.1 resels
Voxel size: 3.0 3.0 3.0 mm mm mm; (resel = 47.92 voxels)
Page 1

SPM: Inference

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

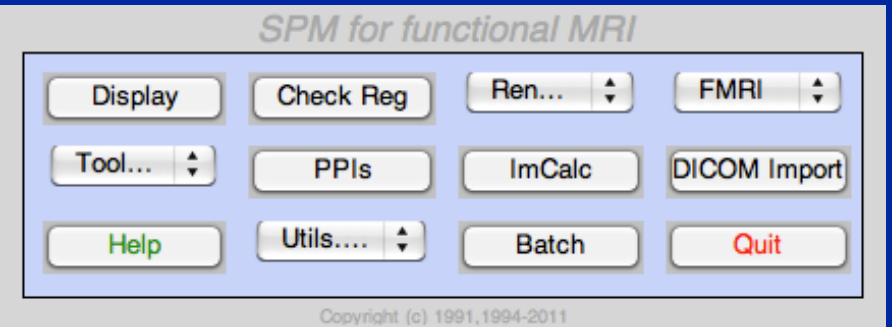


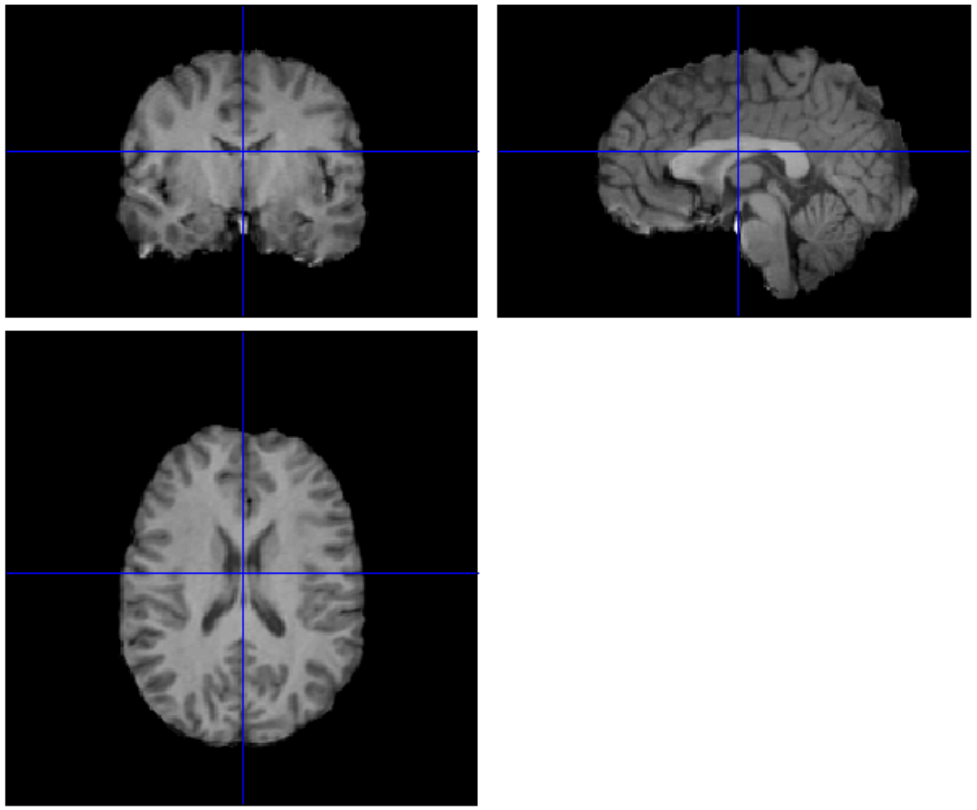


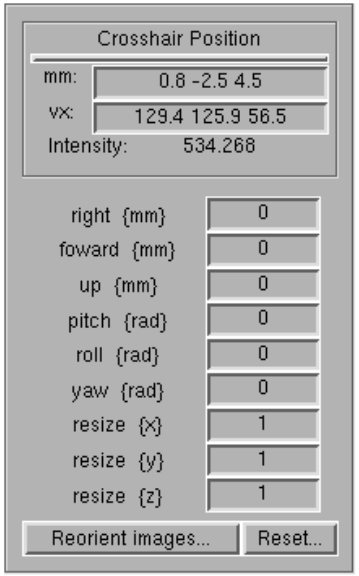


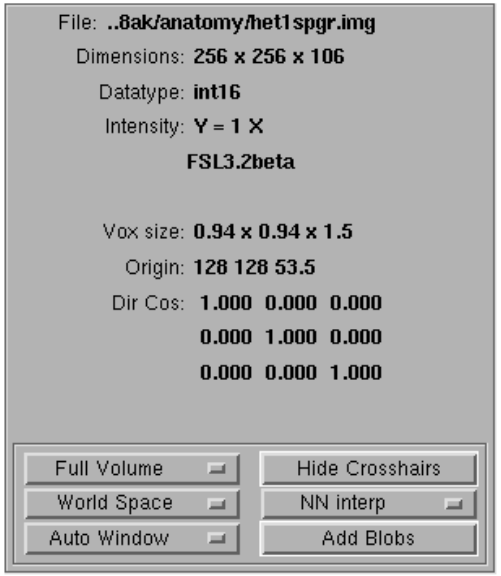
SPM: Miscellaneous Tools

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



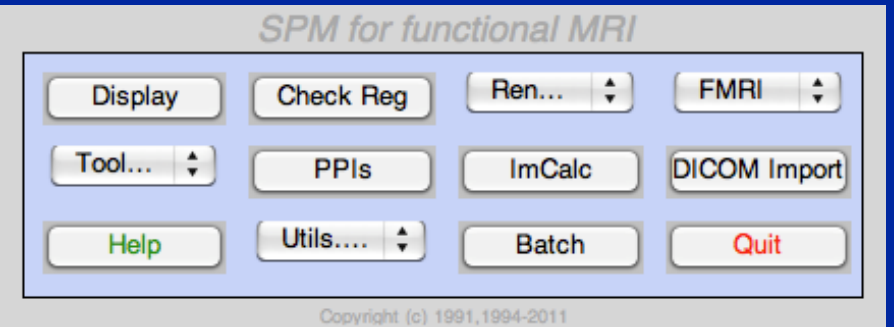


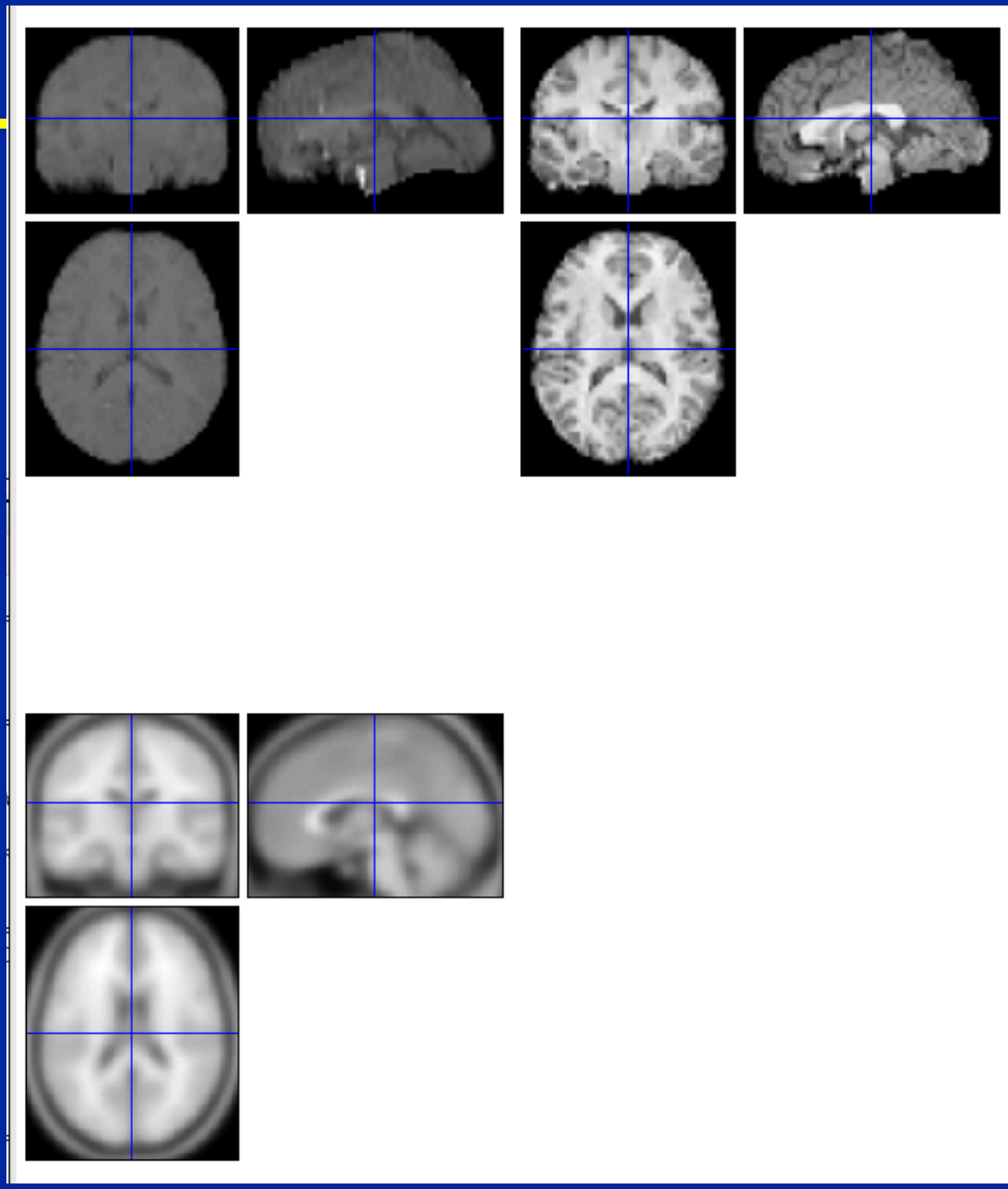




SPM: Miscellaneous Tools

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

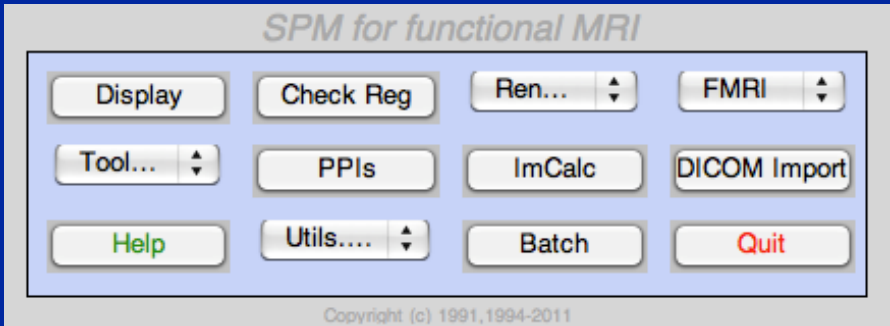




SPM: Miscellaneous Tools

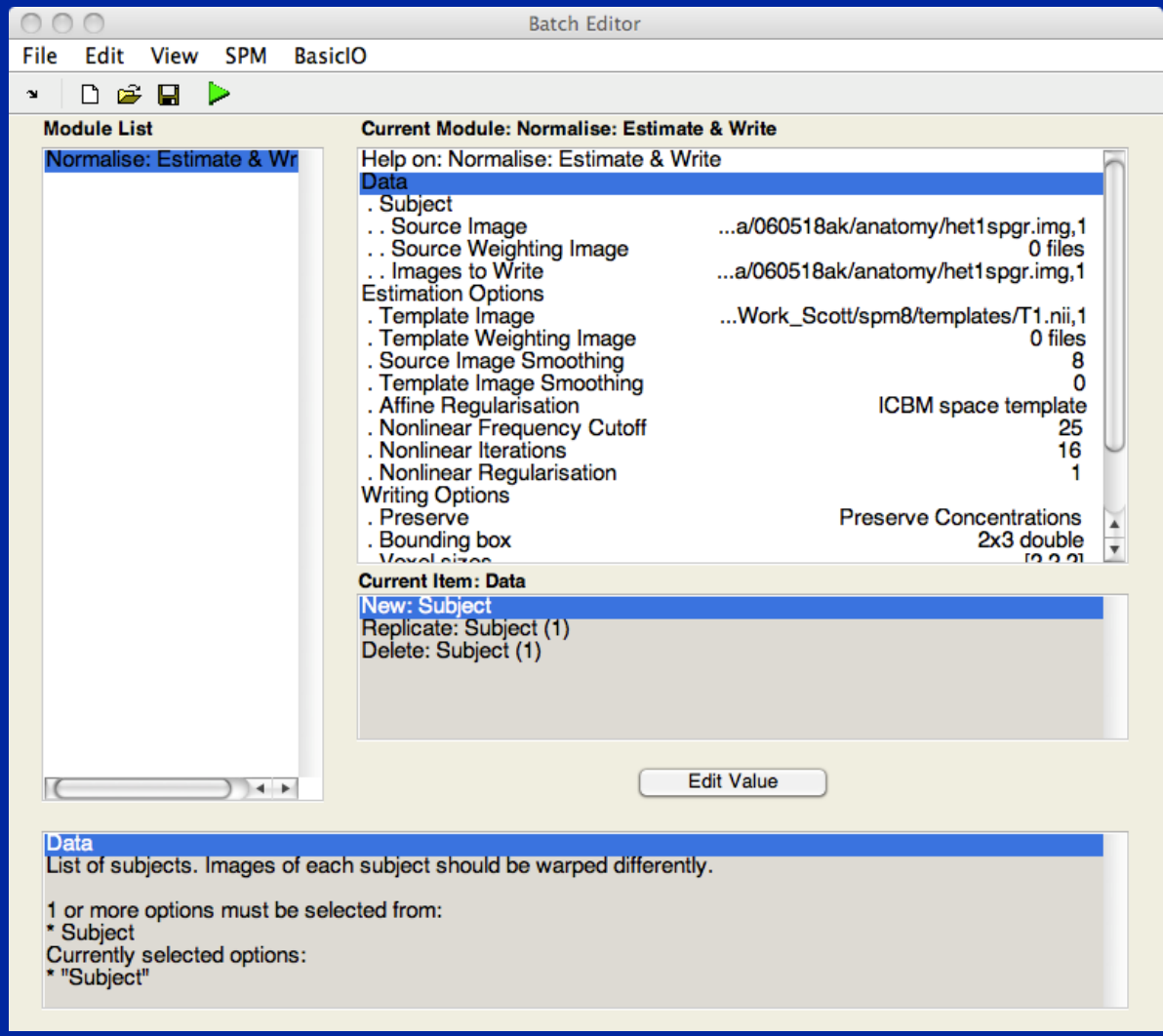
- "ImCalc"
  - Image calculator
  - Give one or more images, perform MATLAB arithmetic and write out result

- "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

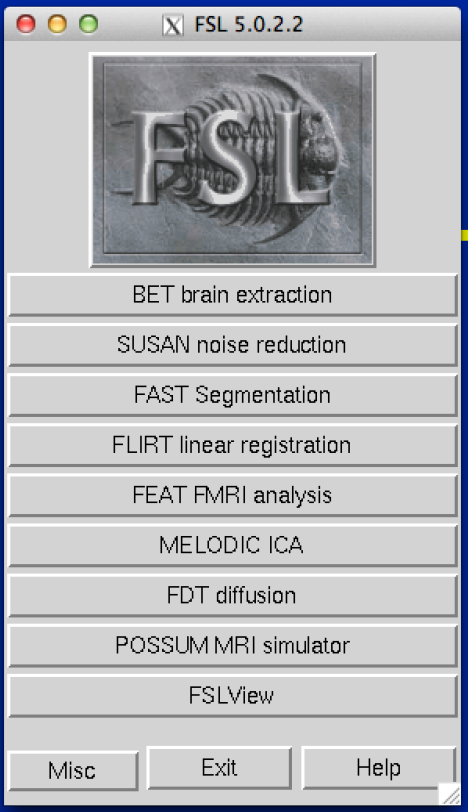
- SPM tries to be a single solution for all fMRI processing and analysis, but there can be no such thing!
  - FMRI is a rapidly evolving field where each dataset has huge number of observations!
- Don't let SPM be a black box!
- Understand what each component does
- Understand how to get at the data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

Resources

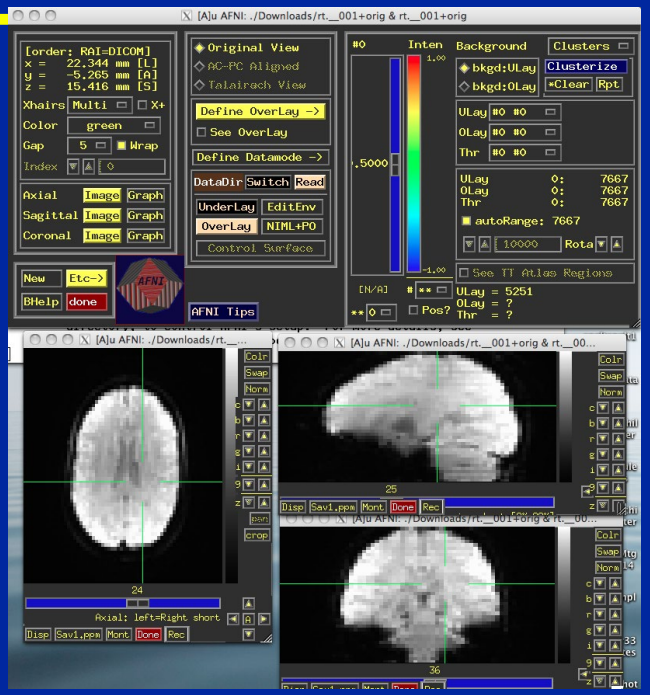
- **SPM*web* site: http://www.fil.ion.ucl.ac.uk/spm/**
  - **Introduction to SPM**
  - **SPM code download: SPM12 (also older versions)**
  - **Documentation & Bibliography**
  - **SPM course videos**
  - **Example data sets**
  - **SPM extensions**
  - **SPM email discussion list**

- **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

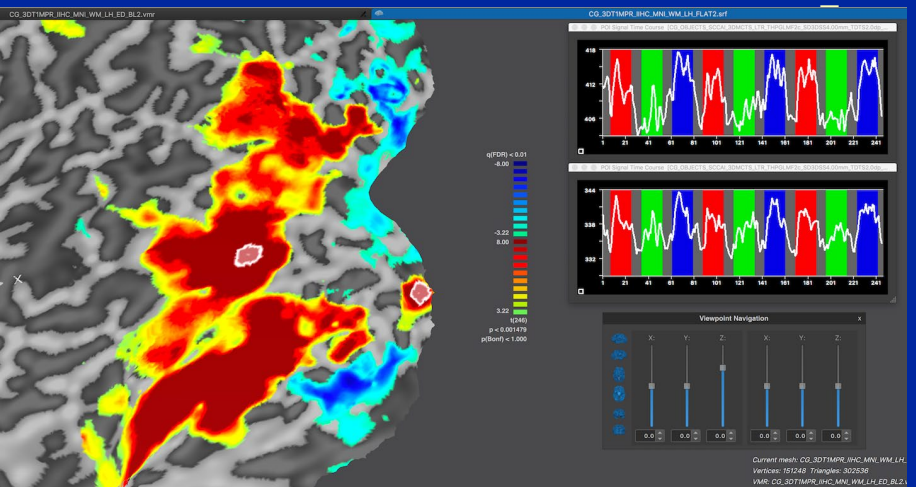
Alternatives



- **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

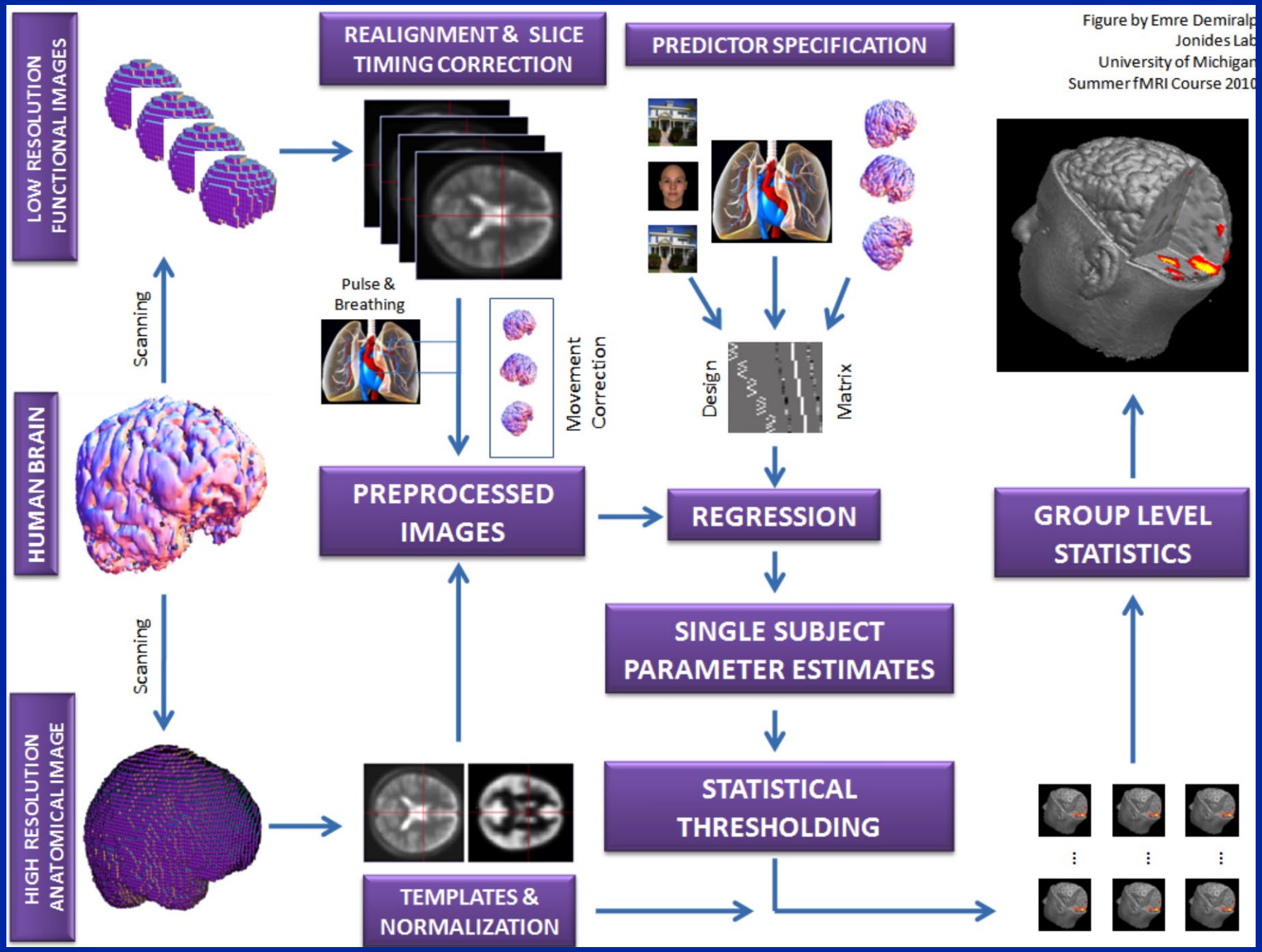


Figure by Emre Demiralp
Jonides Lab
University of Michigan
Summer fMRI Course 2010
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SPM
Spatial Transformations

Imaging data formats

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

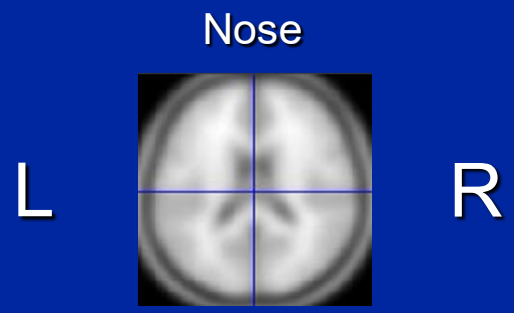
Historical

- 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

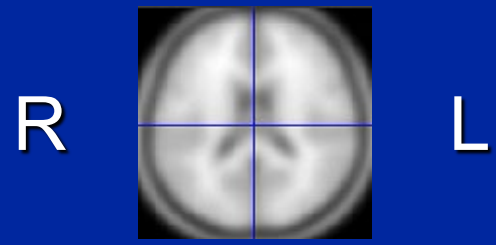
Current

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



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



- 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

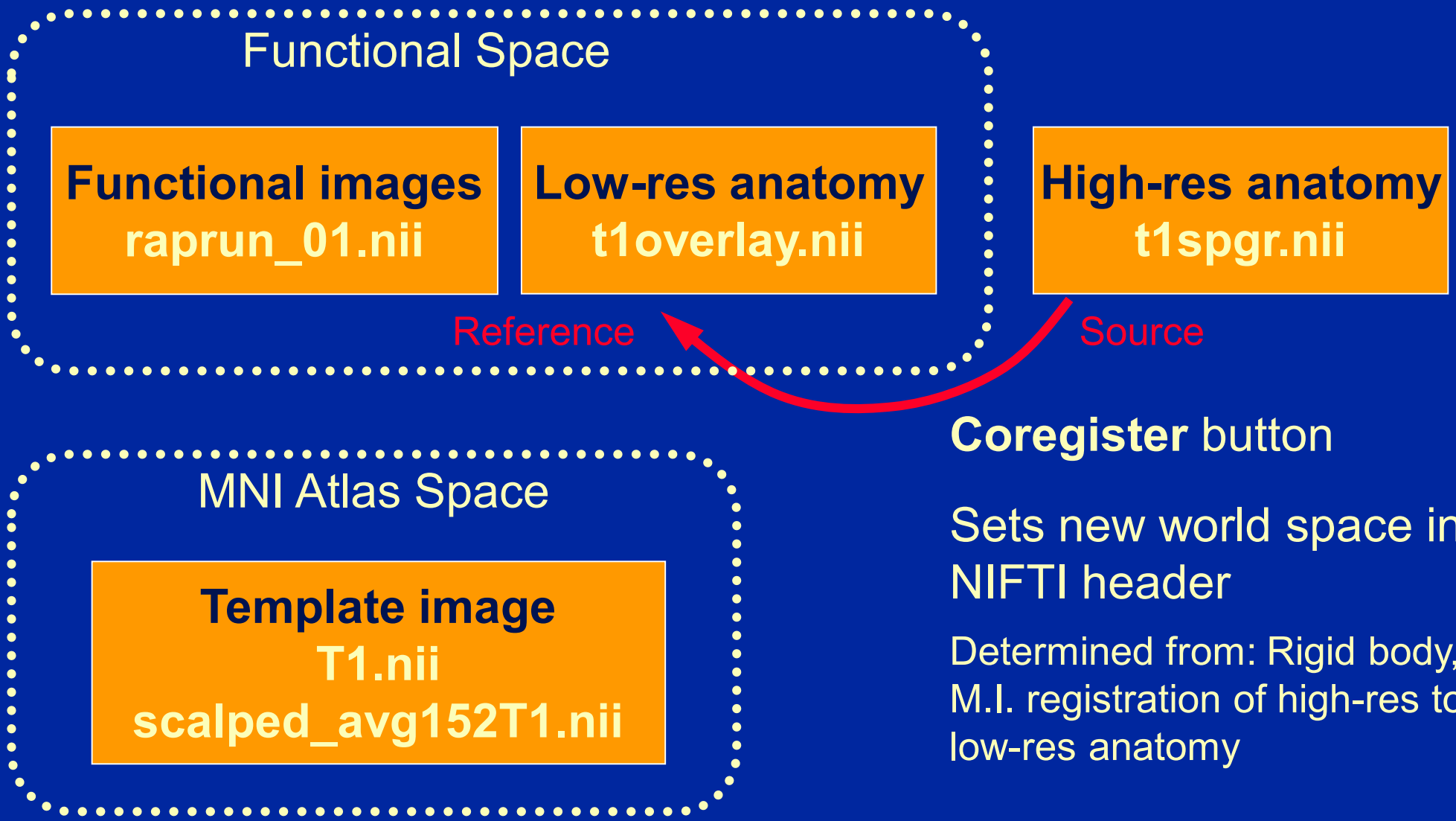
Low-res anatomy
t1overlay.nii

High-res anatomy
t1spgr.nii

MNI Atlas Space

Template image
T1.nii
scalped_avg152T1.nii

Coregistration



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

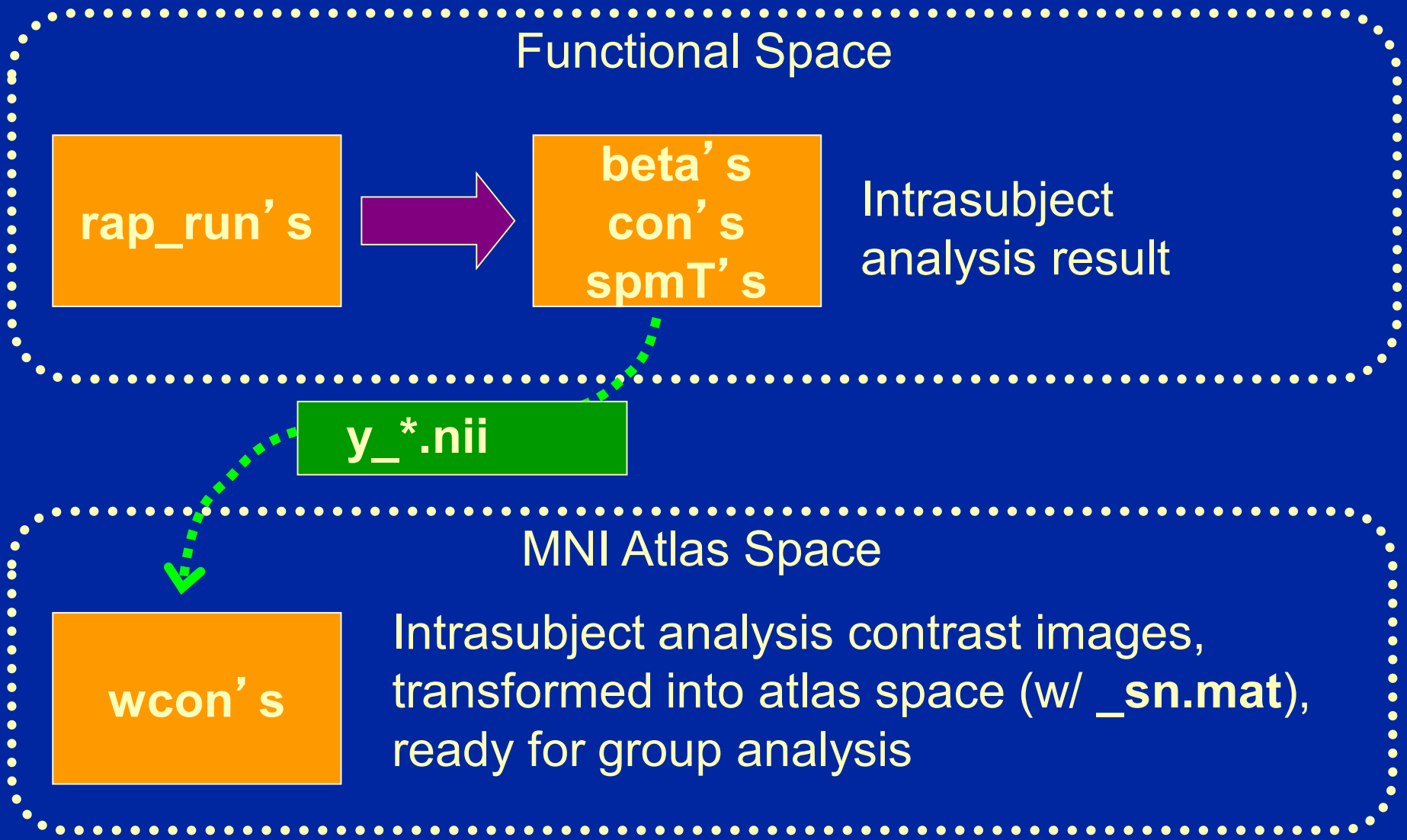
High-res anatomy
t1spgr.nii
(NIFTI header)

MNI Atlas Space

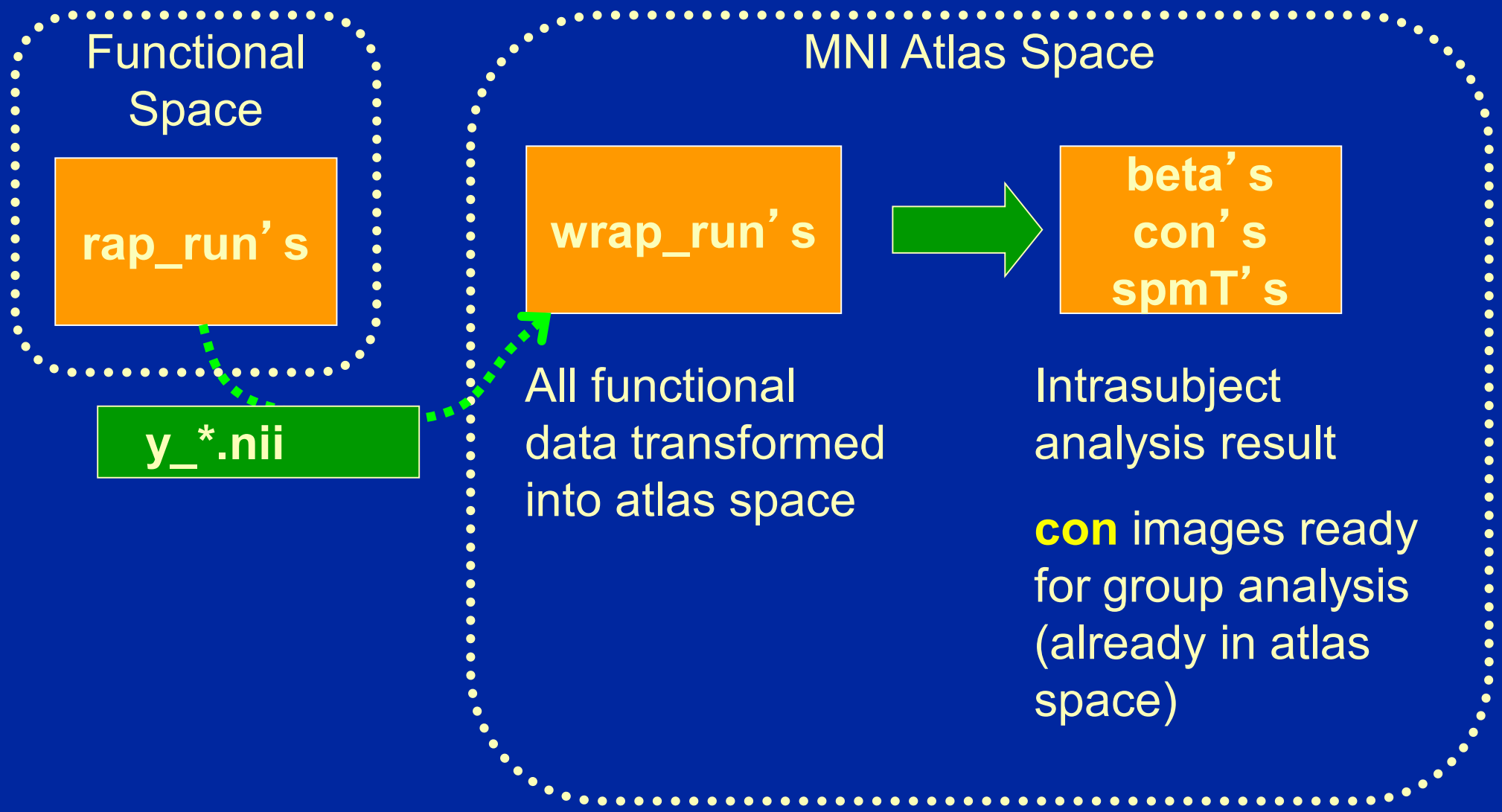
Template image
T1.nii
scalped_avg152T1.nii

Normalized images
wt1spgr.nii
wraprun_01.nii

Group Analysis: Strategy 1
Only transform contrast img's



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**