SPM Introduction

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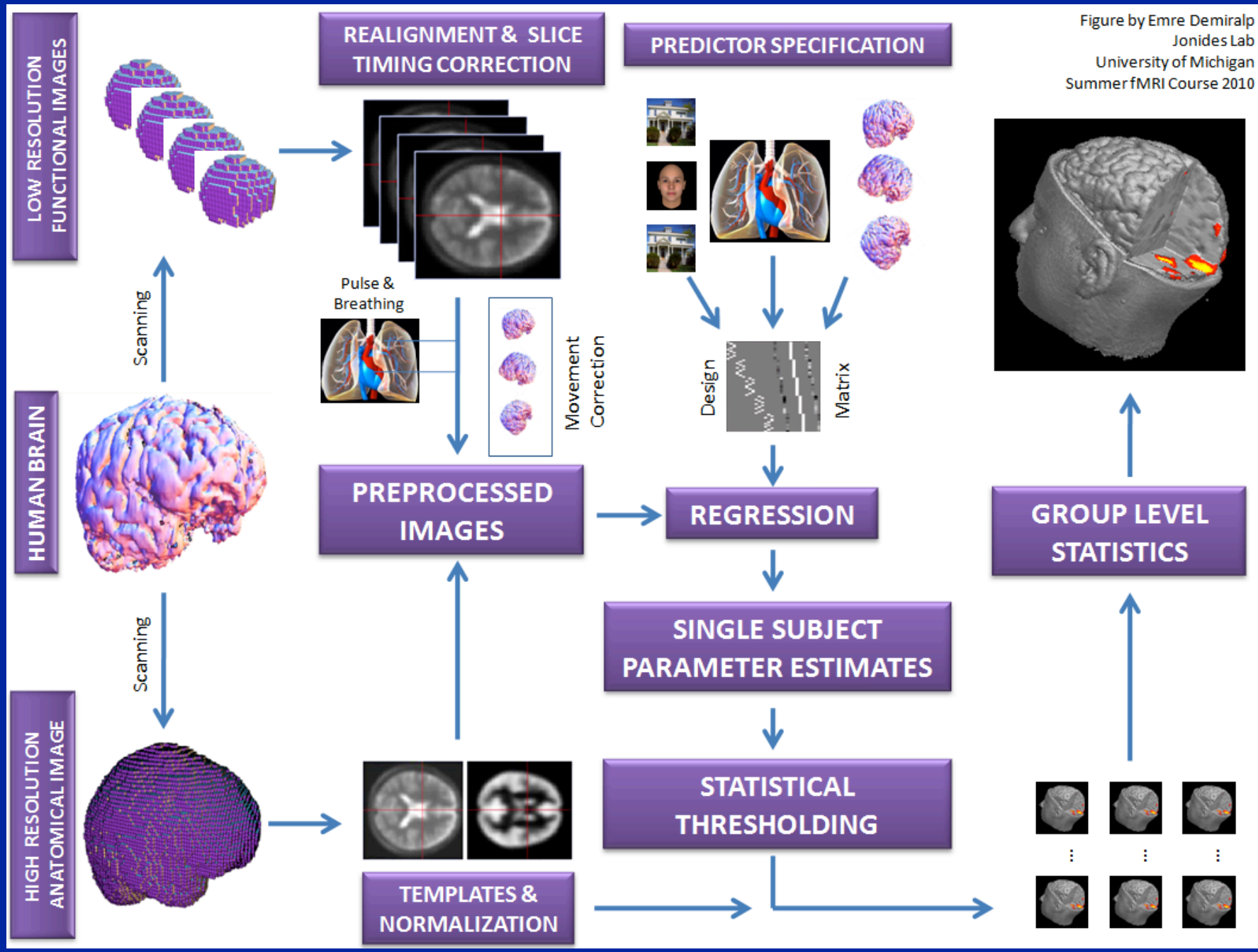
Slides adapted from T. Nichols


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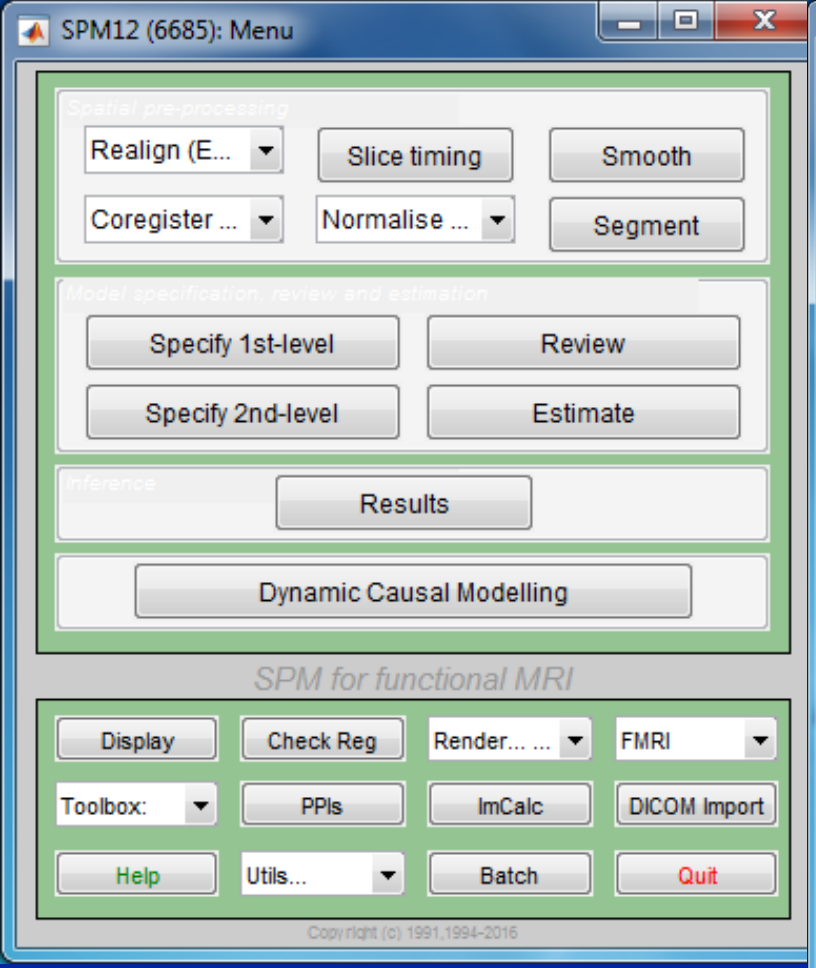
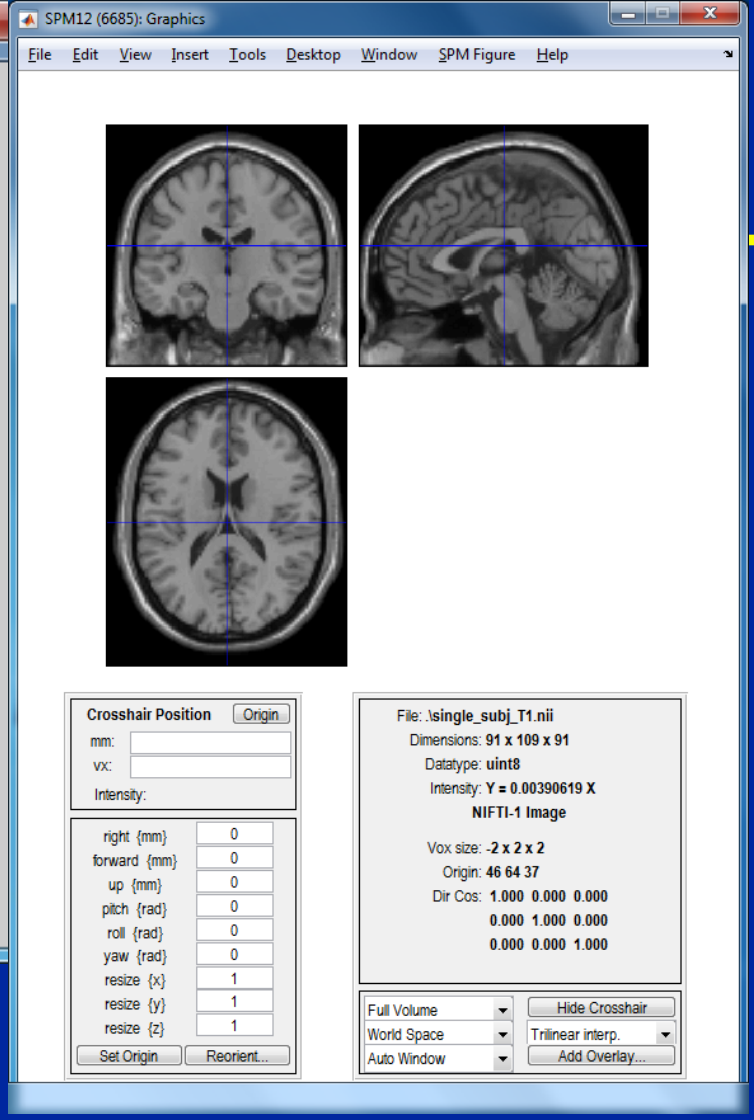
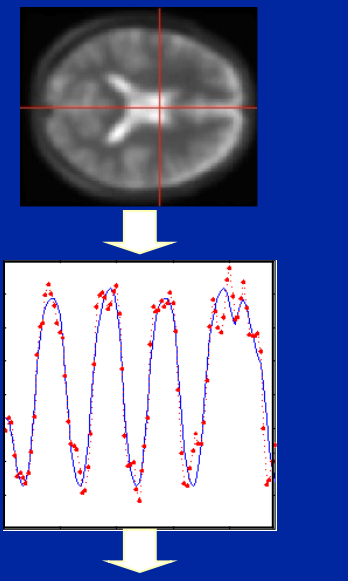
REALIGNMENT & SLICE TIMING CORRECTION
Pulse & Breathing
Movement Correction
PREPROCESSED IMAGES
TEMPLATES & NORMALIZATION
PREDICTOR SPECIFICATION
Design
Matrix
REGRESSION
SINGLE SUBJECT PARAMETER ESTIMATES
STATISTICAL THRESHOLDING
GROUP LEVEL STATISTICS
Figure by Emre Demiralp
Jonides Lab
University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

SPM!



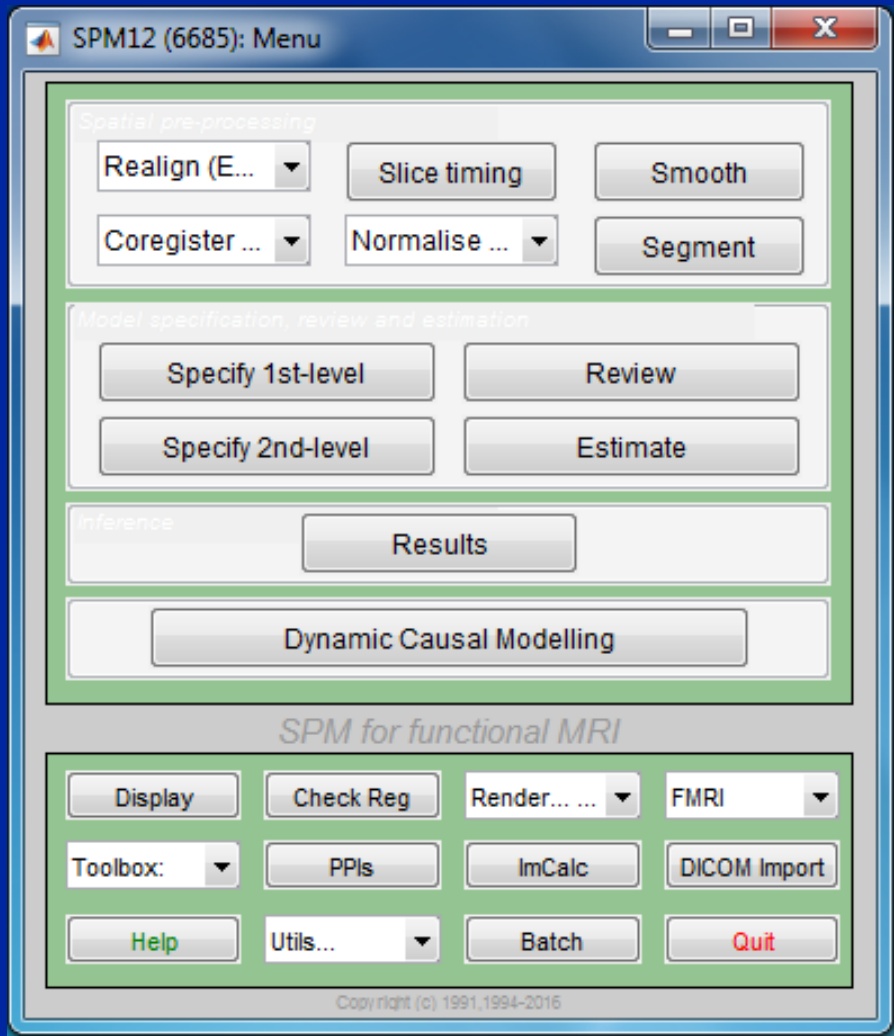




Software to perform computation, manipulation and display of imaging data

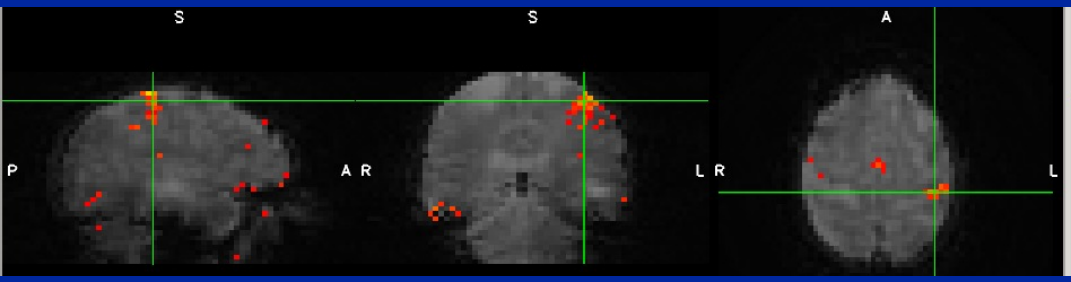
SPM : Overview

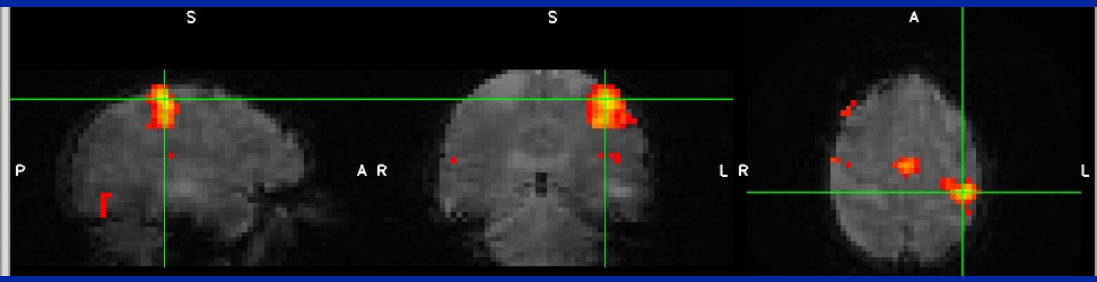
- Library of MATLAB and C functions
- Graphical user interface
- Four main components:
  - Preprocessing
  - Model Specification & Fitting
  - Inference & Results Interrogation
  - Supplemental Tools



Preprocessing

- Eliminate systematic variation before statistical modeling

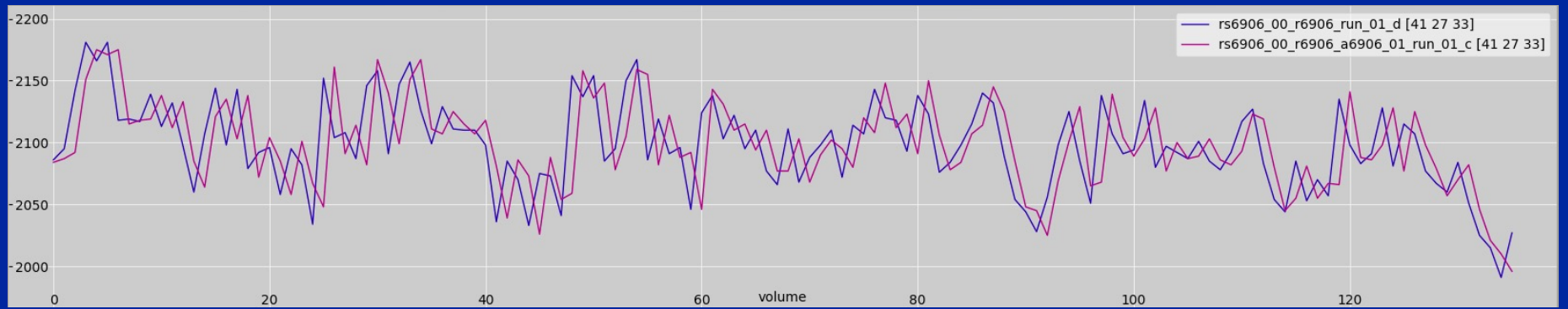




Before
t=5.89

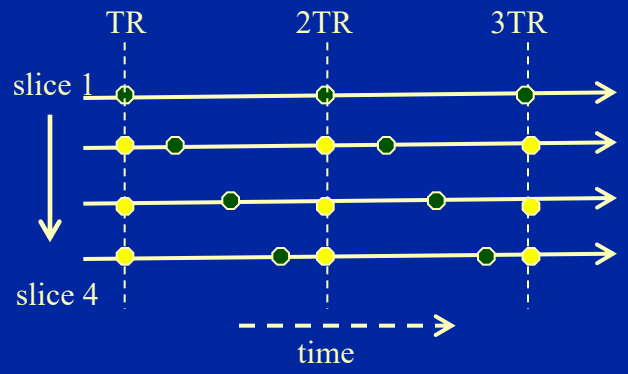
After
t=10.04

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

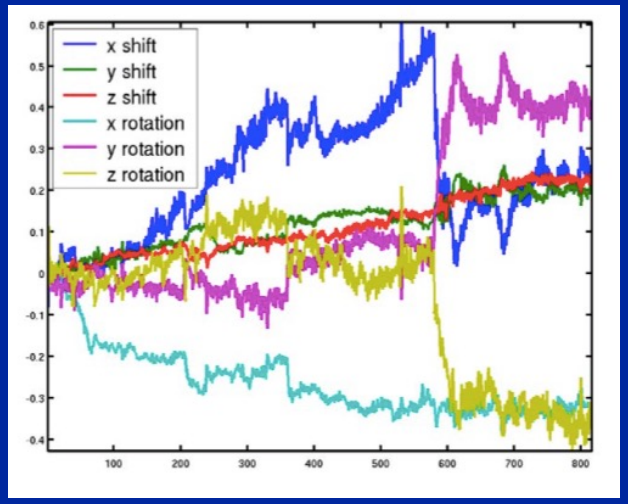


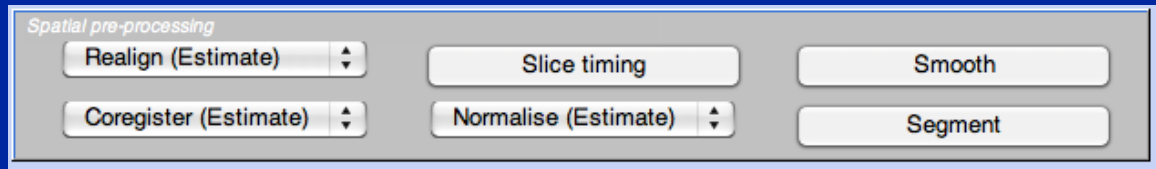
SPM: Preprocessing

- 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

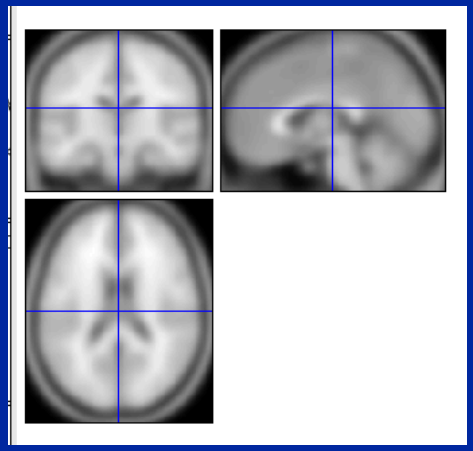




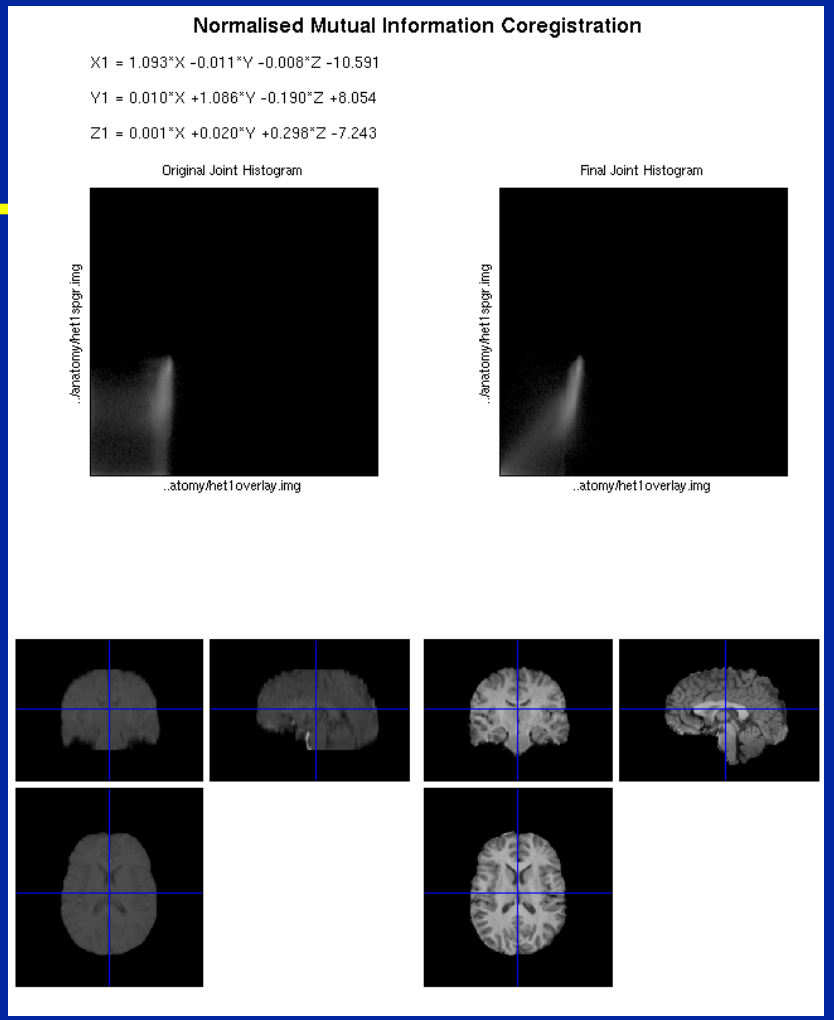
SPM: Preprocessing

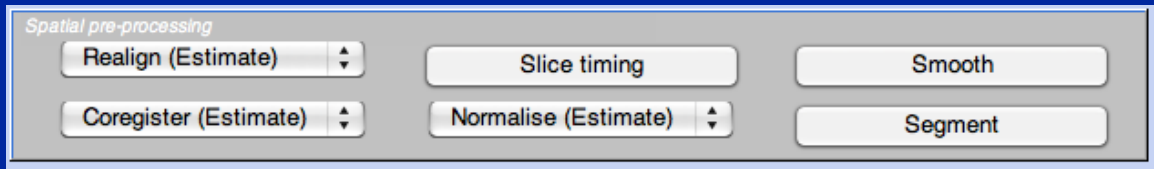
- "Coregister"ation
  - Intrasubject, intermodality registration
  - Registration of MR images with different TR/TE

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



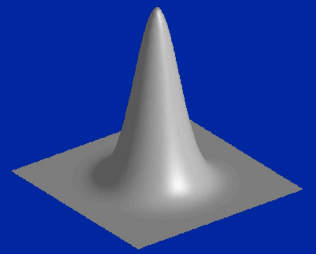
SPM
T1 template
MNI space



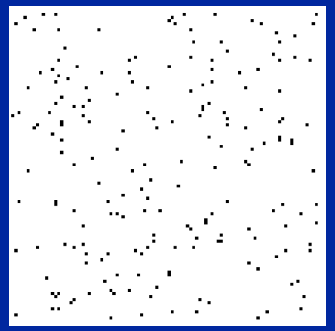


SPM: Preprocessing

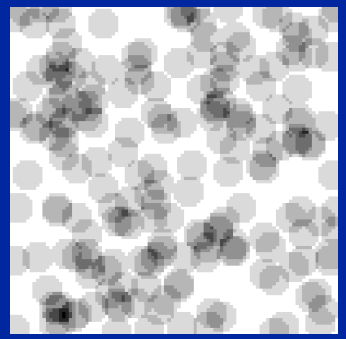
- Spatial “Smooth”ing
  - Blur data into submission…
    - To satisfy random field theory assumptions
    - For intersubject analyses



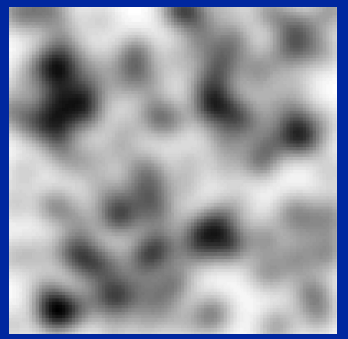
Before convolution



Convolved w/ circle

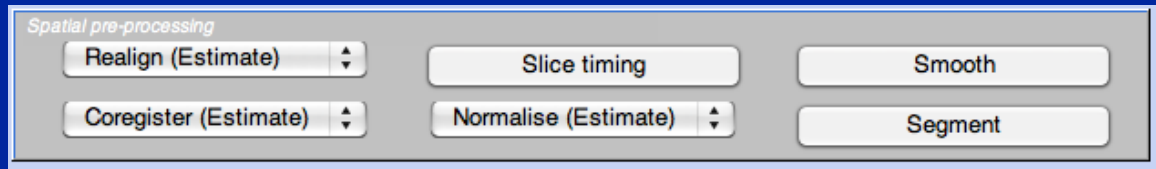


Convolved w/ Gaussian



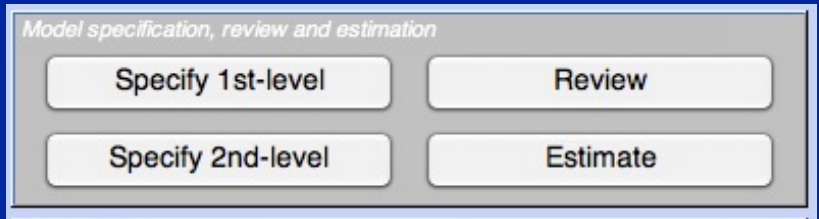
Adapted from SPM course slides

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



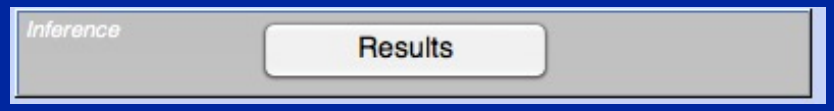
SPM: Model Specification

- "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



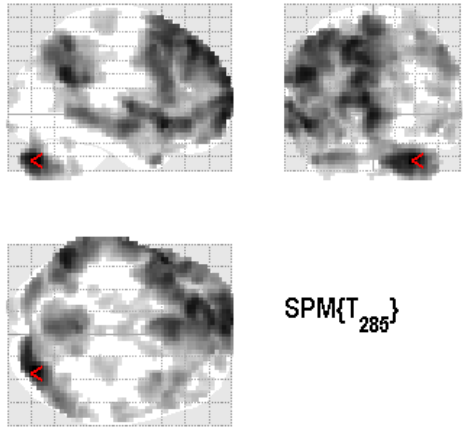
SPM: Inference

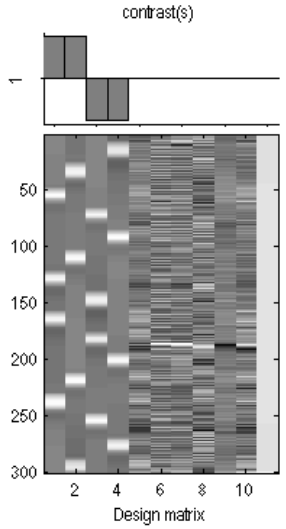
- " Results" button
- First brings up "Contrast Manager"
  - Can define single (t)
    - or sets (F) of contrasts
- Then displays MIP
  - MIP = Maximum Intensity Projection
  - Glass Brain
  - Can "surf" by dragging cursor



File Edit View Insert Tools Desktop Window SPM Figure Help

WhyFaceWhyHand_-_HowFaceHowHand - All Sessions





SPMresults: \sub03\results\precooked\2x2
Height threshold T = 3.119073 {p<0.001 (unc.)}
Extent threshold k = 15 voxels

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	$(Z_{\equiv})$	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	15
		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

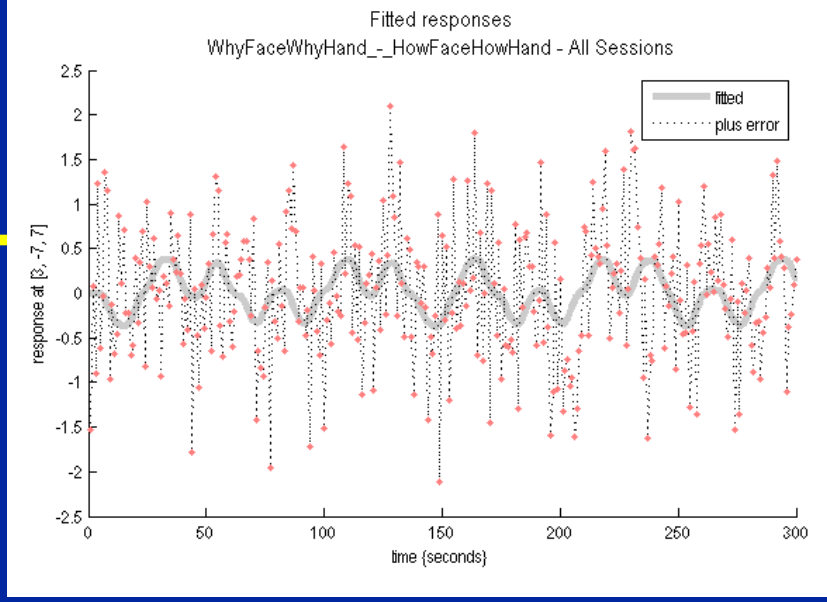
Height threshold: T = 3.12, p = 0.001 (1.000)
Extent threshold: k = 15 voxels, p = 0.095 (0.698)
Expected voxels per cluster, <k> = 5.537
Expected number of clusters, <c> = 1.20
FWEp: 4.819, FDRp: 4.298, FWEc: 57, FDRc: 36

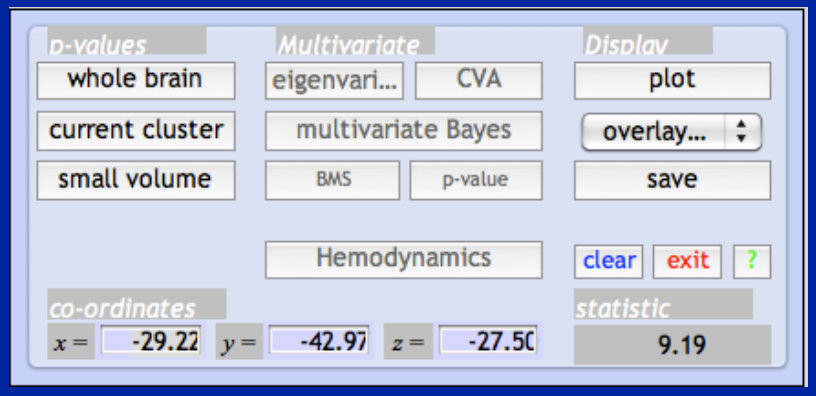
Degrees of freedom = [1.0, 285.0]
FWHM = 11.4 11.1 10.2 mm mm mm; 3.8 3.7 3.4 {voxels}
Volume: 1700352 = 62976 voxels = 1180.1 resels
Voxel size: 3.0 3.0 3.0 mm mm mm; (resel = 47.92 voxels)

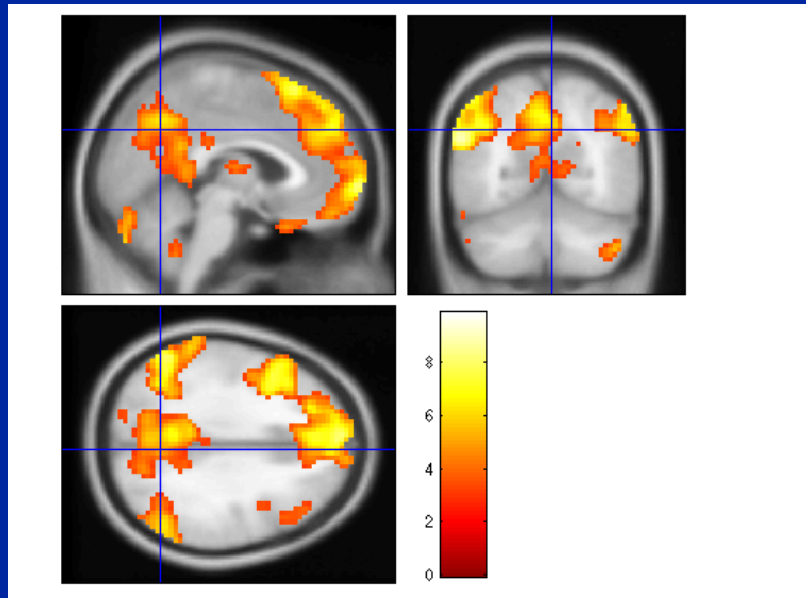
Page 1

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

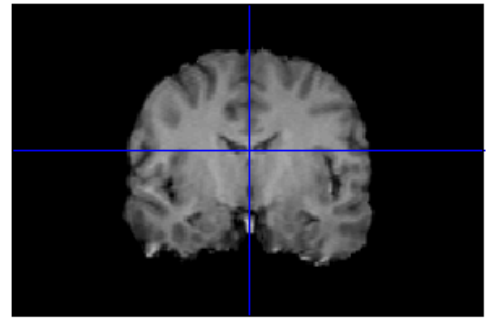


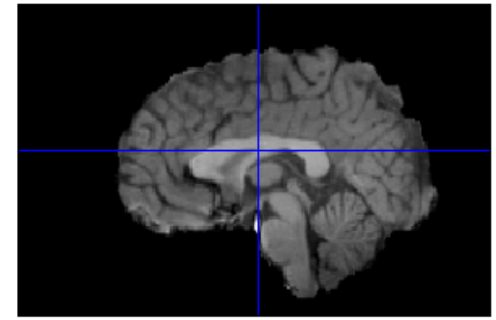


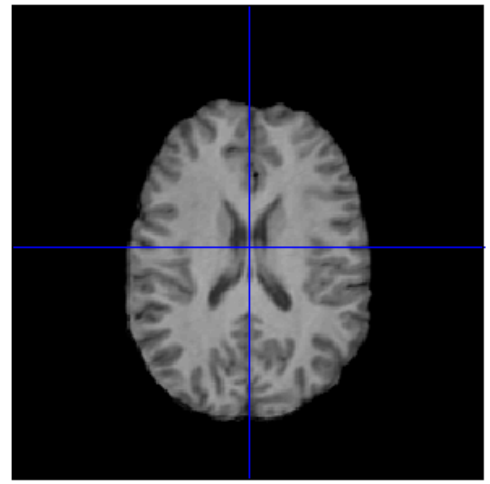


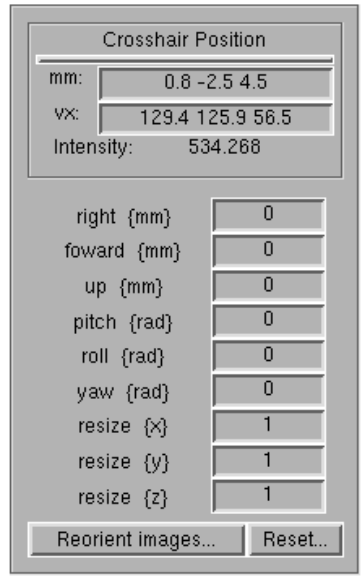
SPM: Miscellaneous Tools

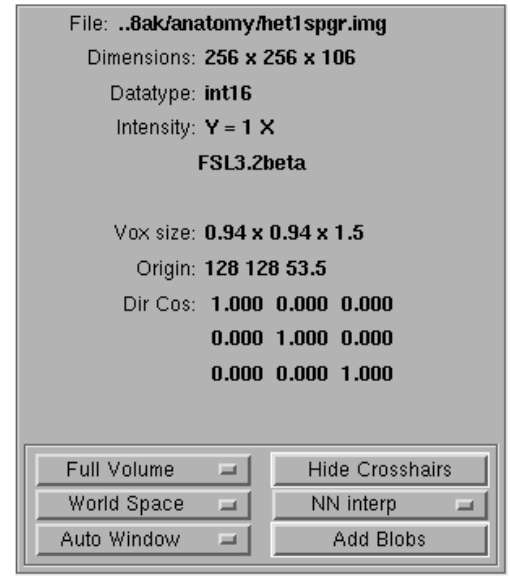
- "Display"
  - Displays image
    with orthogonal sections
  - Check intensity values
  - Change origin
  - Change world space
    - i.e. Apply rotations/translations





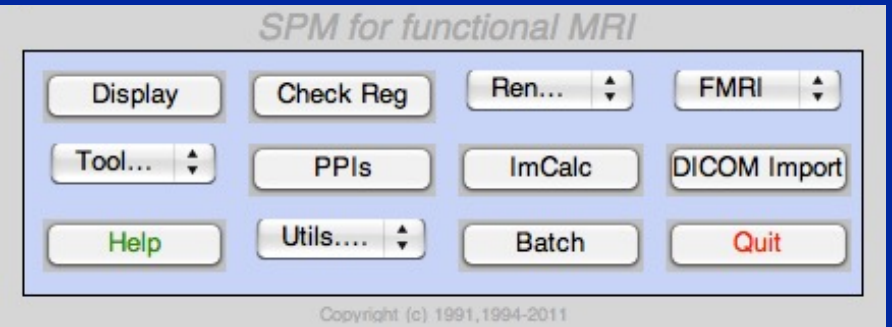


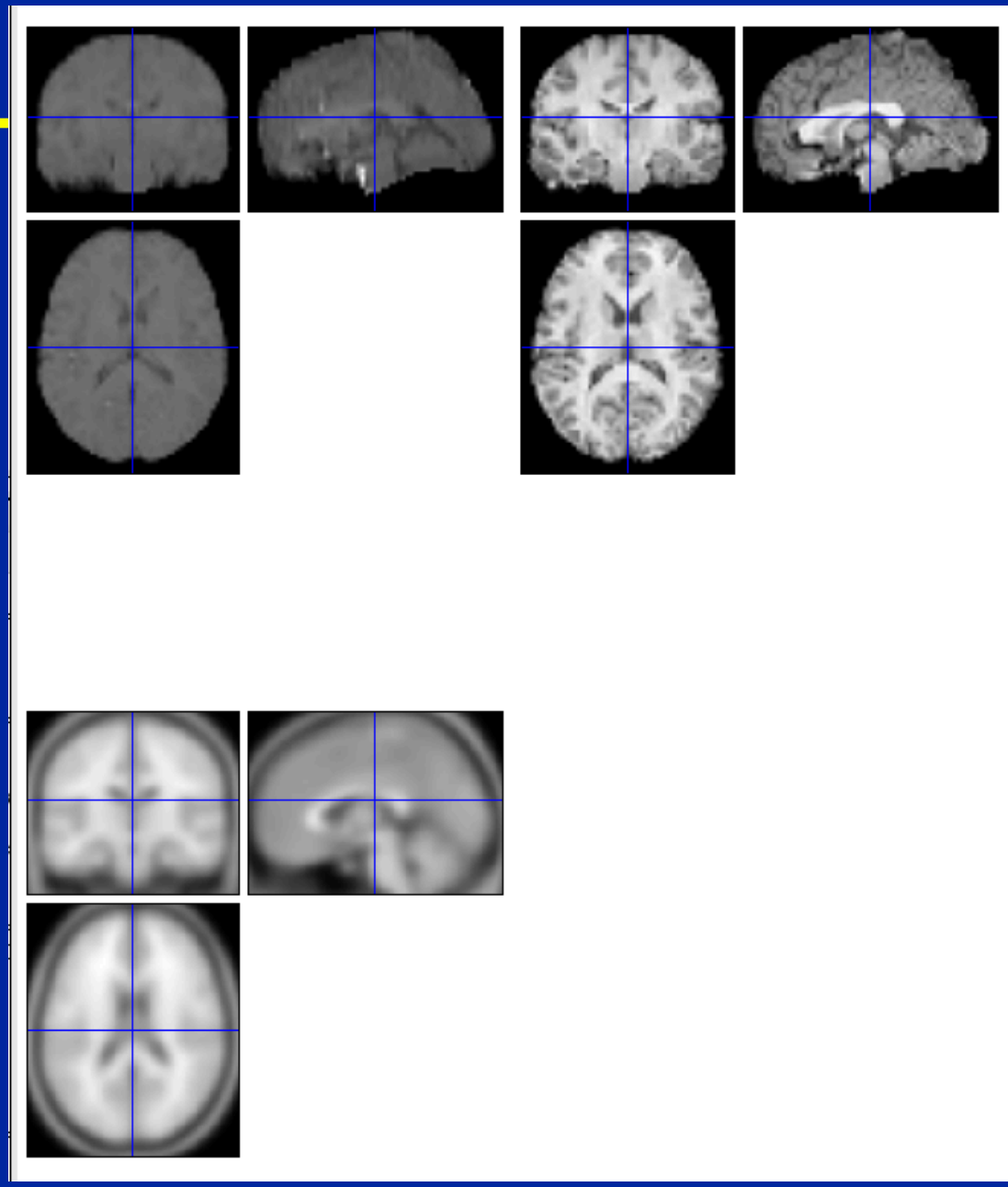




SPM: Miscellaneous Tools

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





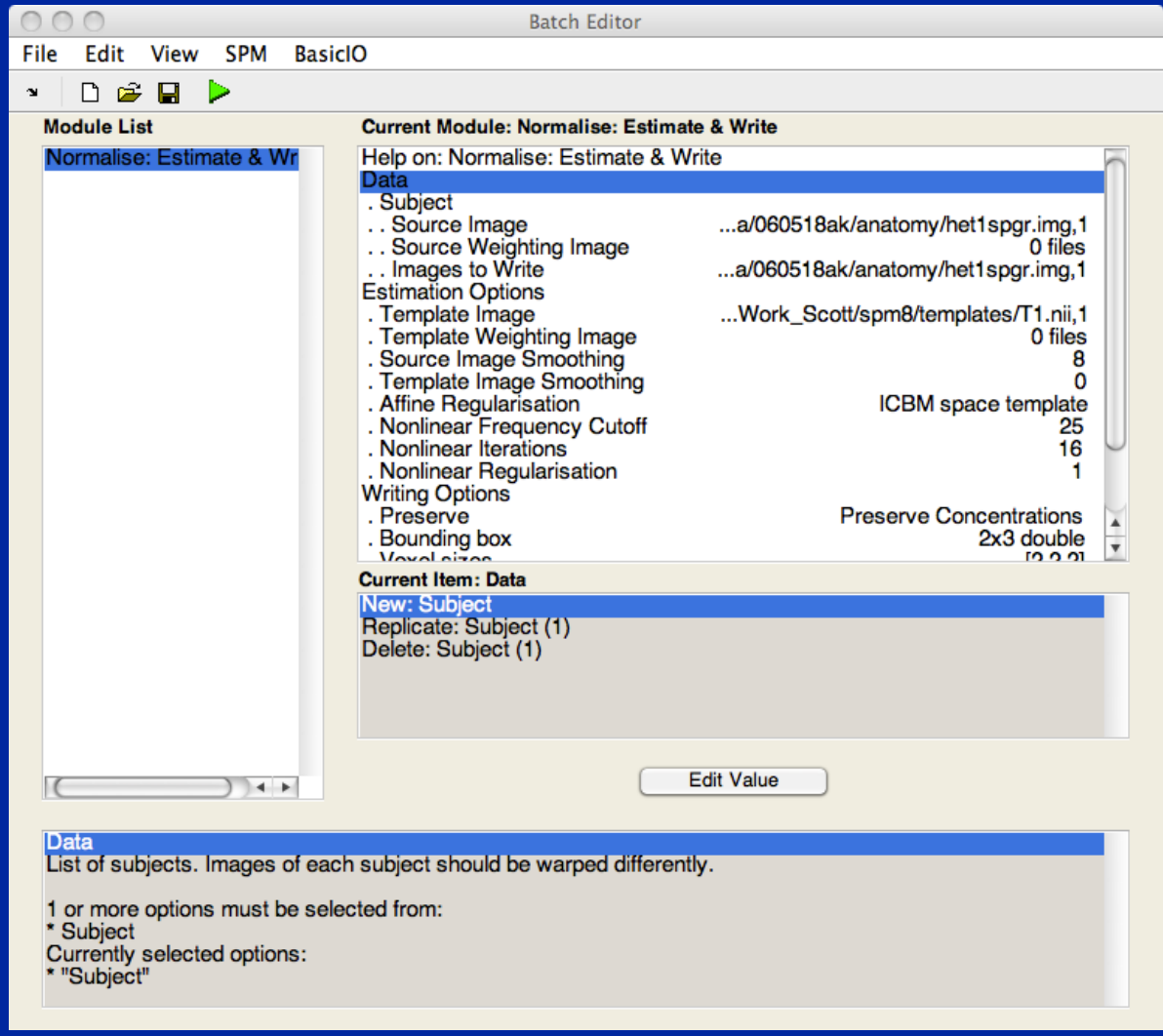
SPM: Miscellaneous Tools

- "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

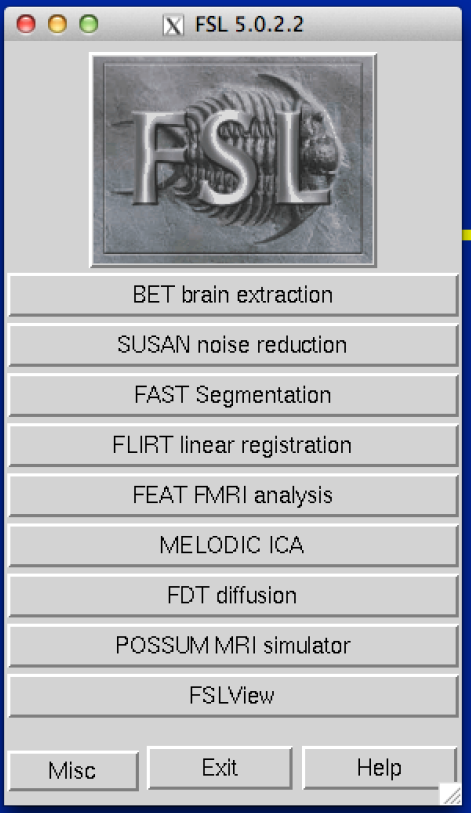
- SPM tries to be a single solution for all fMRI processing and analysis, but there can be no such thing!
  - FMRI is a rapidly evolving field where each dataset has huge number of observations!
- Don't let SPM be a black box!
- Understand what each component does
- Understand how to get at the data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

Resources

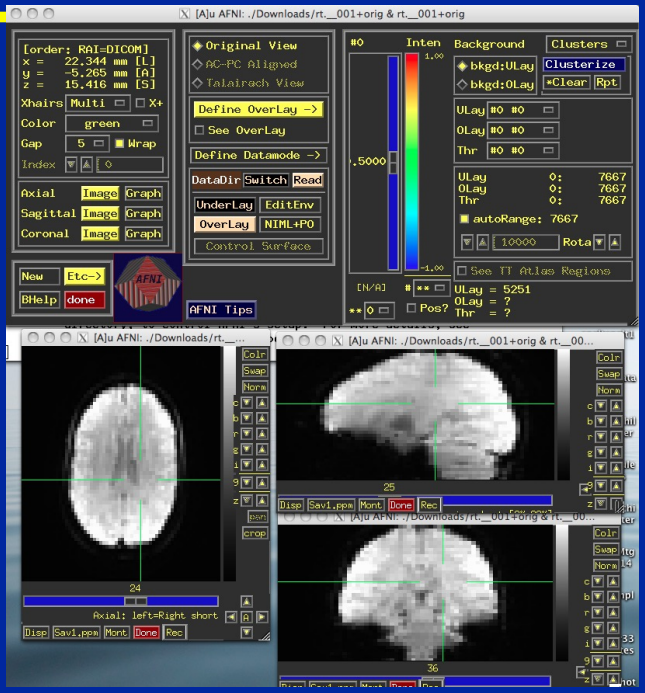
- **SPM*web* site: http://www.fil.ion.ucl.ac.uk/spm/**
  - **Introduction to SPM**
  - **SPM code download: SPM12 (also older versions)**
  - **Documentation & Bibliography**
  - **SPM course videos**
  - **Example data sets**
  - **SPM extensions**
  - **SPM email discussion list**

- **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

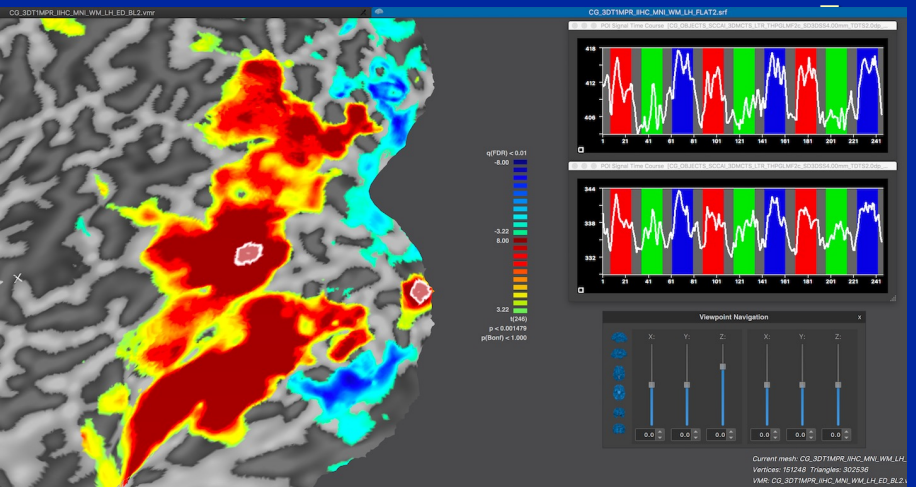
Alternatives



- **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.gov**
  - Open source
  - Active community, multiple plugins



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

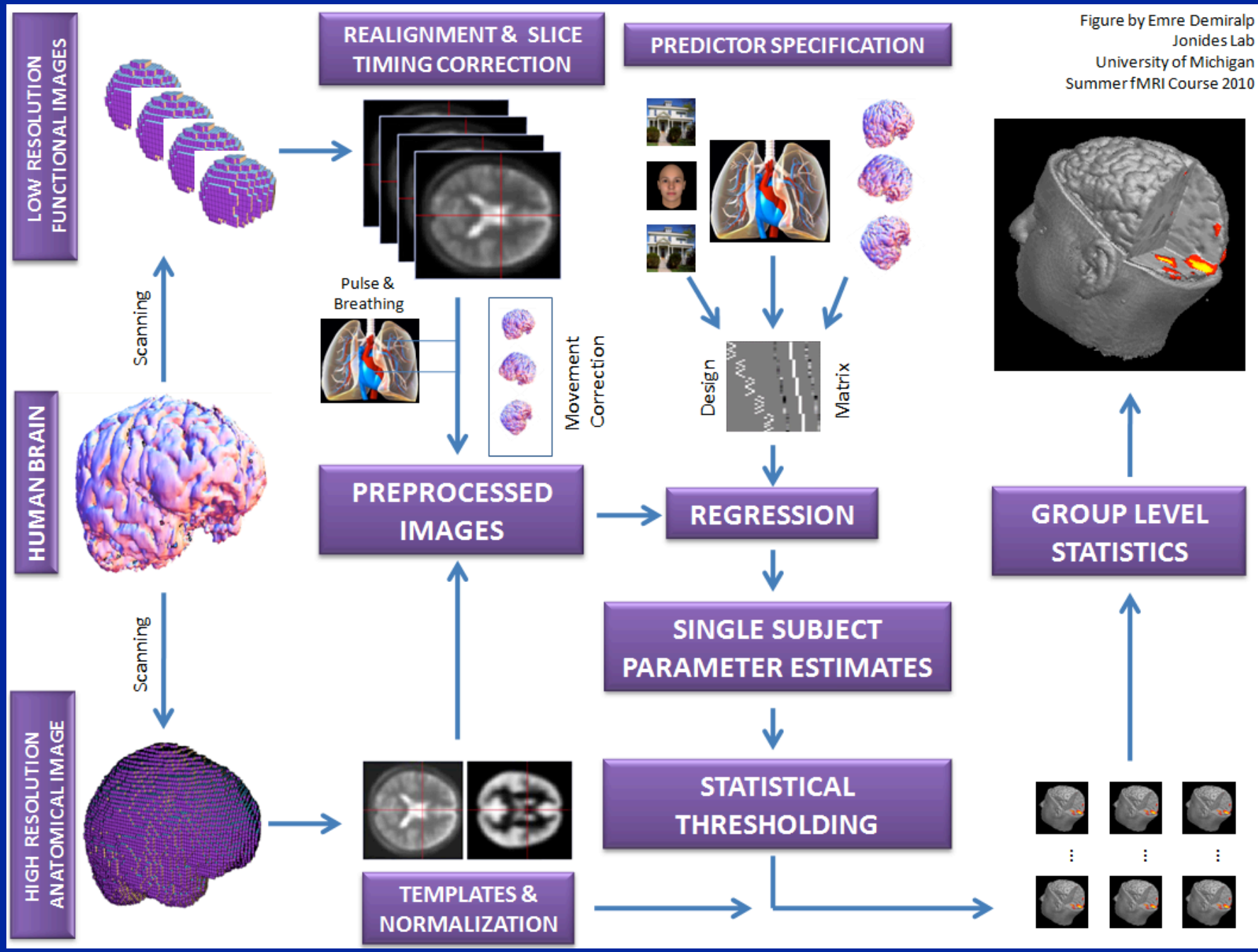

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Figure by Emre Demiralp
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SPM
Spatial Transformations

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

Nose

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

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

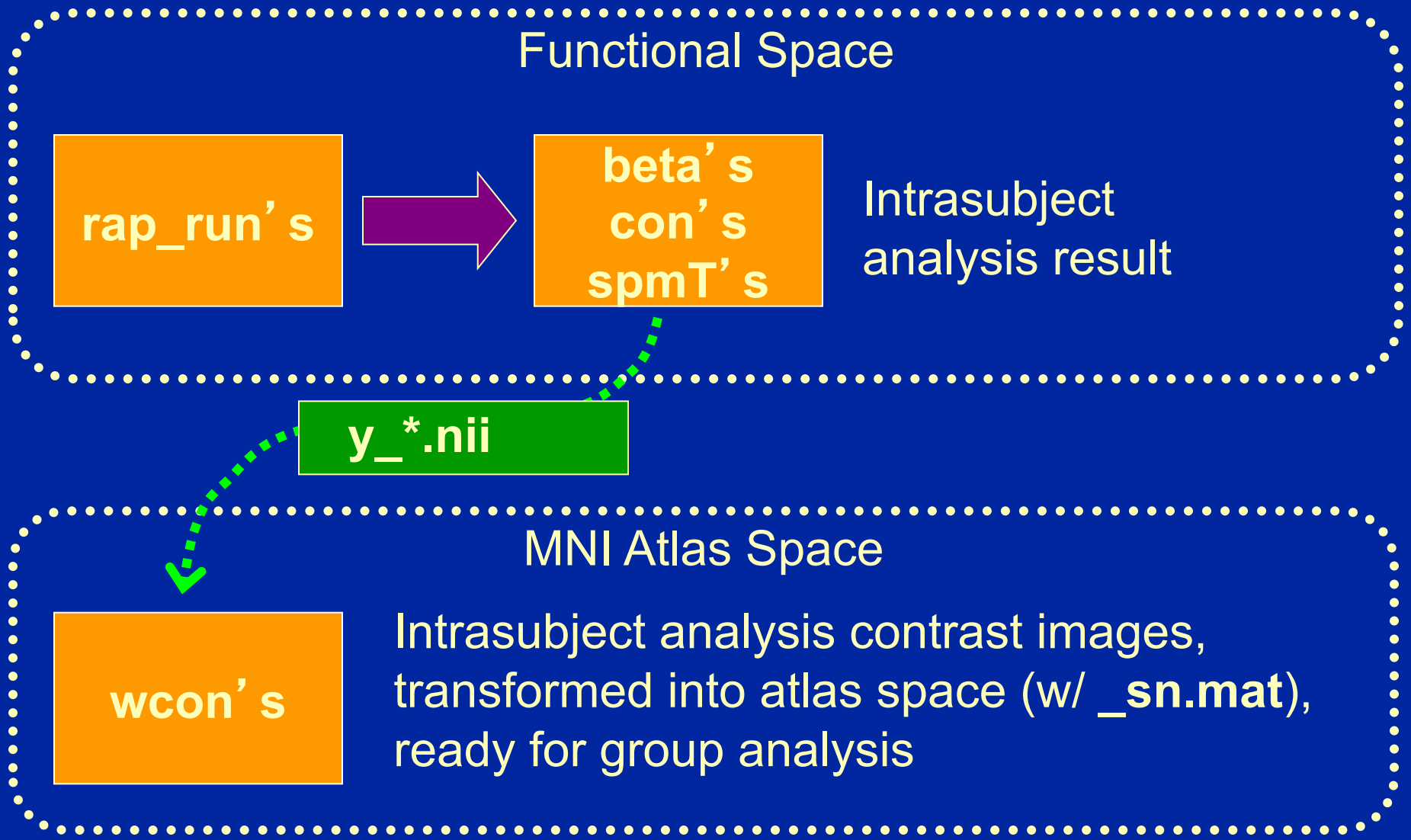
High-res anatomy
t1spgr.nii
(NIFTI header)

MNI Atlas Space

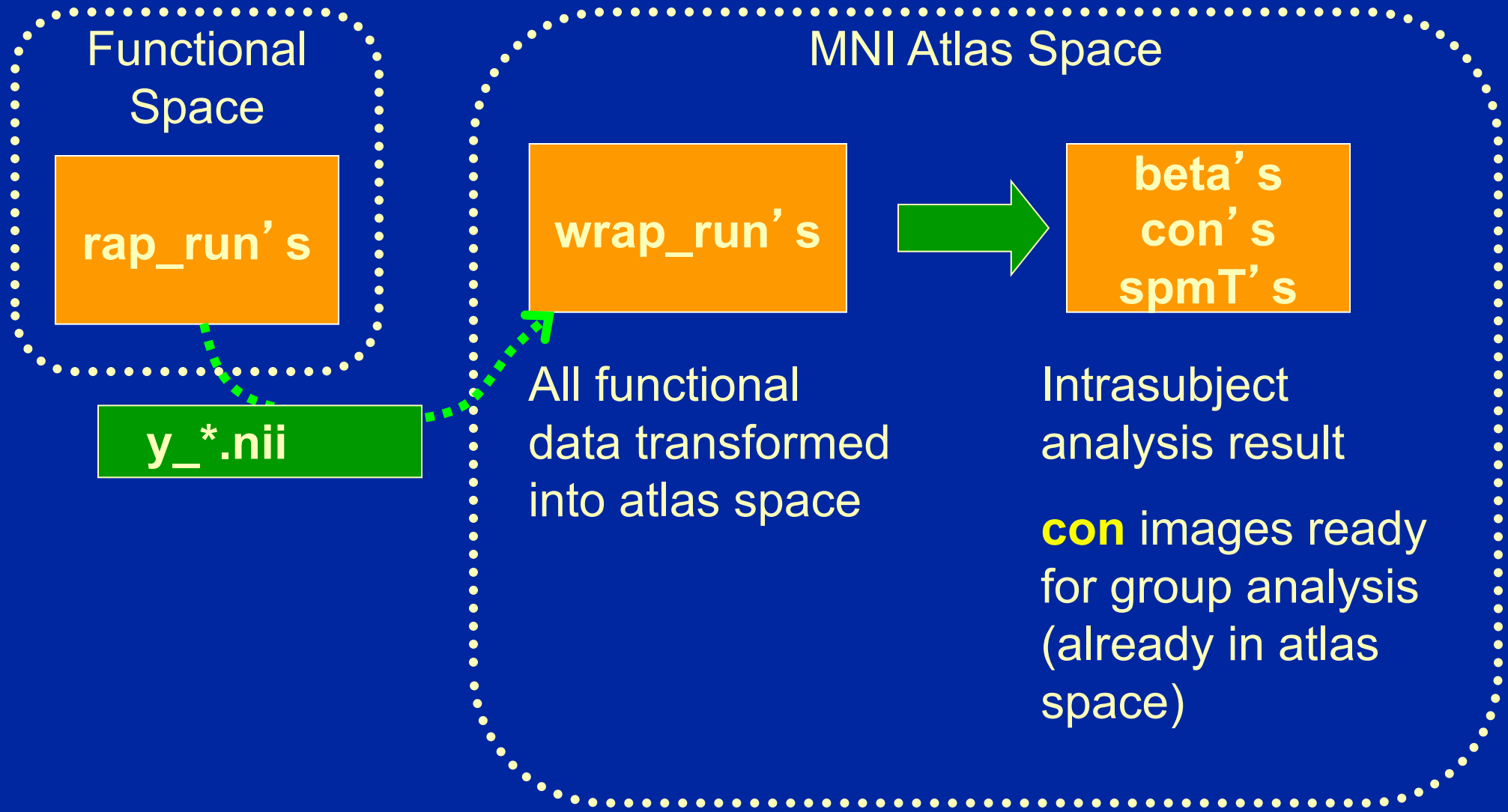
Template image
T1.nii
scalped_avg152T1.nii

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**