

# Introduction to SPM Outline

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- SPM Components
- Spatial Transformations
- Comments

# SPM: Overview

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- Library of Matlab and C functions
- “Point-&-click” graphical user interface
- Consists of 4 general components
  - Preprocessing
  - Model Specification & Fitting
  - Inference & Results Interrogation
  - Supplemental Tools

# SPM: Preprocessing

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- Elimination of systematic variation before statistical modeling
- “Realign”ment
  - Intrasubject registration
  - Motion correction
  - “Realign & Unwarp”
    - Correct EPI effects of movement-dependent changes in susceptibility
- “Coregister”ation
  - Intrasubject, *intermodality* registration
  - Registration of MR images with different TR/TE
  - PET-MR registration

# SPM: Preprocessing

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- Slice timing
  - Adjust for variable acquisition time over slices
  - SPM's slice timing can induce artifacts; use UM's
- Spatial “Normalize”ation
  - *Intersubject* registration
  - Register subject anatomy to atlas space
- Spatial “Smooth”ing
  - Blur data into submission...
    - To satisfy random field theory assumptions
    - For intersubject analyses
- “Segment”ation into GM/WM/CSF
  - Usually not directly used
  - Useful for structural studies

# SPM: Model Specification & Fitting

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

# SPM: Inference & Results Interrogation

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

# SPM: Job Manager *New in SPM5*

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- Allows jobs to be saved
  - .mat - 'job' variable, manipulate in Matlab
  - .m - Text version of all variables, in Matlab-ese
  - .xml - Text version of all variables, in XML
- Jobs can be re-loaded, changed
  - No more “Doh! Last question was wrong!”
- Multiple jobs can be loaded, run at once

# SPM: Inference & Results Interrogation

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

# SPM: Miscellaneous Tools

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- “Display”
  - Display an image with orthogonal sections.
  - Check intensity values
  - Change origin
  - Change world space
    - I.e. apply rotations/translations to mat file
- “Check Reg”
  - Display multiple images
  - *Essential* tool for assesing estimated or assumed alignment of images.
  - All images are displyed in the space of the first image.

# SPM: Miscellaneous Tools

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- “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.

# SPM: Miscellaneous Tools

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- “Rendering”
  - Sexy brains
- “Defaults”
  - Change defaults for one session.
  - To make permanent changes, edit `spm_defaults.m`
- “Help”
  - Some help
  - Also not “Tool tip” help balloons

# SPM: Pipeline

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# Spatial Transformations: Image File

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- Analyze format
- `.img` Raw, binary data; 3D or 4D
- `.hdr` Small binary header
  - Image dimension
  - Voxel size
  - Origin, in voxels
    - First element 1, not 0
- `.mat` Optional, SPM2 extension (depricated in SPM5!)
  - Defines transformation from voxel to world space
  - If exists, `.hdr` voxel size & origin are ignored
  - Origin can be represented as mm location
    - e.g. between voxels

# Spatial Transformations: Image File

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- NIFTI format
- .img + .hdr
  - Like Analyze, but different .hdr definition different
- .nii *Single file!*
  - Header and Image file concatenated
  - SPM can read .nii files, but doesn't write them
- World space transformation coded in NIFTI header
  - No more (image) .mat files!

# Spatial Transformations: Voxel vs. World Space

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- Voxel Space
  - Just the original image
  - No reorientations or flips
- World Space
  - Space defined by transformation from voxel to mm matrix  $M$ 
    - $4 \times 4$  homogeneous transformation
    - Let  $v$  be a voxel location indexed from  $(1,1,1)$
    - Then  $w = M * [v; 1]$  is that location in world space
  - Has units of *mm*
  - Can represent rotations, translations and flips
  - Was in SPM2 .mat files; represented with quaternions in

# Spatial Transformations: Coregistration & Realignment

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- Coregistration & Realignment are rigid body transformations
  - Subject's doesn't change size or warp between scans
    - Well, actually...
- Each requires a “Reference” and an “Source”
  - Reference — Fixed image
  - Source — Image that is transformed
- SPM modifies the .hdr file of the *object* image
  - Unless you explicitly ask it to, it doesn't write out an image

# Spatial Transformations: Coregistration & Realignment

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- This is very cool!
  - You have 1000 images
  - You realign 2nd through the 1000th to the 1st
    - Reference=1st, Object=2nd-1000th
  - Instead of doubling the disk space required by writing out 1000 images, you only need to modify the `.mat`'s!

# Spatial Transformations: Coregistration

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- `.mat`'s handy for coregistration
- e.g. Coregister
  - Reference: Functional space, 7 slices
    - e.g. 7 slice, low resolution anatomical in space of func's, "t1overlay"
  - Object: Structural space
    - e.g. high resolution anatomical, 120 slices difference space, "t1spgr"
- Reslicing an image, creating "rt1spgr"
  - You get a 7 slice, low resolution SPGR

# Spatial Transformations: Coregistration

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- But don't have to reslice
  - `t1spgr`'s world space now corresponds to `t1overlay`
  - The `.mat` file has captured the transformation *without* throwing away any information

# Spatial Transformations: Easy to forget about transformation

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- Easy to forget about the transformation stored in headers
  - If you want to start over and re-do registration
    - Must use Reset button in Display!*
    - (In SPM2, you would delete the .mat files)

# Spatial Transformations: Left is Right is Left is Right is ...

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- Two conventions for viewing images
- Neurological
  - On the screen, Left is Left side of subject
  - As if standing behind 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
  - (FSL always uses Radiological convention)

# Spatial Transformations: Rad. vs. Neuro., SPM2 vs. SPM99

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- SPM99
  - Analyze images read and written in *Neurological* format  
nb: Official Analyze standard specifies Radiological format
  - **Exception:** Spatial Normalization reads in Radiological (by default; switchable to Neurological)
  - Default set by `spt1_Ornt` in `spm_defaults.m`
- SPM2
  - Analyze images *consistently*, always assumed to have the same format
  - Default set by `defaults.analyze.flip` in `spm_defaults.m`
    - `flip = 0`  $\Leftrightarrow$  Neuro.
    - `flip = 1`  $\Leftrightarrow$  Rad. (SPM2 default; *diff. from SPM99!*)

# Spatial Transformations: Rad. vs. Neuro., SPM5

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- SPM5
  - Like SPM2, Analyze images treated consistently, as set by `defaults.analyze.flip`
  - SPM5 *always* writes NIFTI
    - NIFTI images *allegedly* have no ambiguity about left & right

# Spatial Transformations: Left is Right is Left is Right is ...

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- Best to make a lab convention
  - fMRI Lab produces everything in neurological!!!
  - SPM99
    - Set `spt1_Ornt` to Neurological option
  - SPM2 & SPM5
    - Set `defaults.analyze.flip` to 0, Neurological
- If paranoid
  - Tape a vitaman E capsule to head and call me in the morning  
(Note location of capsule in acquired images)

# SPM: SPMese Decoder Ring

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- “Spatial Normalization”
  - Intersubject registration
- “Coregistration”
  - Intermodality registration (intrasubject)
- “Registration”
  - Intrasubject registration (movement corr)
- “Results”
  - Inference
- “Interscan Interval”
  - TR

# SPM: Perspective

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- SPM tries to be a “sole source”, turn key solution for fMRI
- At this point, *there can be no such thing!*
  - This is impossible in a cutting edge, rapidly evolving field where each dataset has 10's of millions 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' and 'Check Reg' alot.

# SPM: Alternatives

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- VoxBo
  - Started as independent coding (and validation!) of SPM methods in IDL
  - Uses random field theory, etc
  - Easy to do to parallel computing; easy to automate
- FSL
  - Started as extentions to MEDx
  - Best temporal autocorrelation modeling available
    - Regularized ACF fit at every voxel
  - Most sophisticated group modeling available
    - Between and within subj. variance estimated
  - Better design specification UI, easy to automate