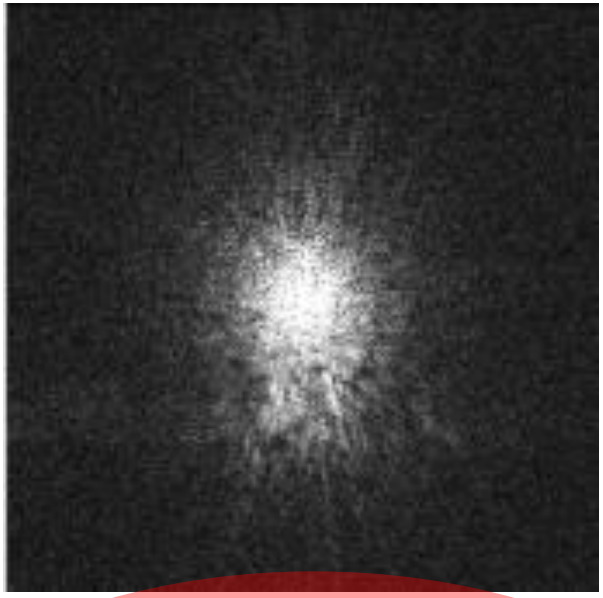
Lab session 3:
FMRI data preprocessing

Andrew Bauer

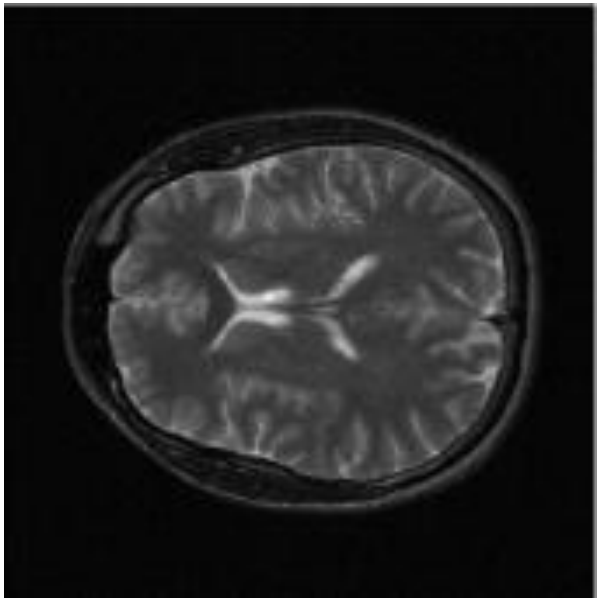
01/27/16

Session no.	Date (all Wednesday)	Topic/activity	Topic of quiz that day	Topic of lab write-up (assignment) due that day
1	13-Jan	Lab overview		
2	20-Jan	Brain anatomy		
3	27-Jan	Data preprocessing	Brain anatomy (no. 1)	
4	3-Feb	Set up GLM model	Functional brain anatomy (no. 2)	
5	10-Feb	Single-subject SPM contrasts	Data preprocessing and GLM model (no. 3)	Brain anatomy (no. 1)
6	17-Feb	Within-subject MVPA		Single-subject SPM contrasts (no. 2)
7	24-Feb	SIBR tour and review for mid-term exam		Within-subject MVPA (no. 3)
No lab	2-Mar	No lab (mid-term exam)		
No lab	9-Mar	No lab (spring break)		
8	16-Mar	Group-level SPM contrasts		
9	23-Mar	Between-subjects MVPA		Group-level SPM contrasts (no. 4)
10	30-Mar	Voxel-wise modeling		Between-subjects MVPA (no. 5)
11	6-Apr	Functional connectivity analysis (*no assignment*)		
12	13-Apr	Review for final exam		Voxel-wise modeling (no. 6)
No lab	20-Apr	No lab		
No lab	27-Apr	No lab (final exam)		

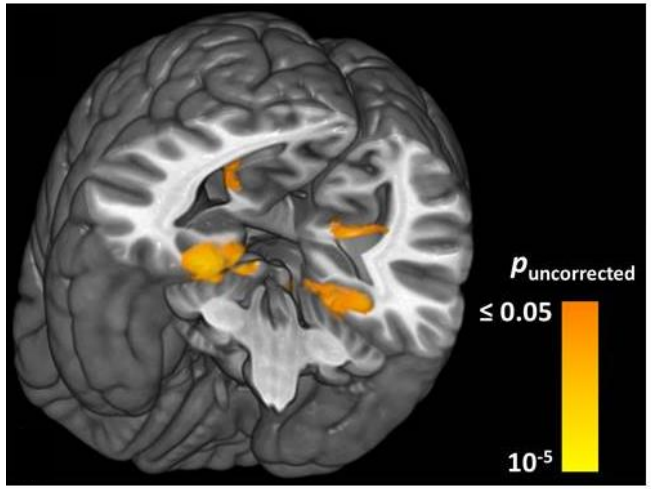
Raw, raw data (*k*-space)



Reconstructed raw data

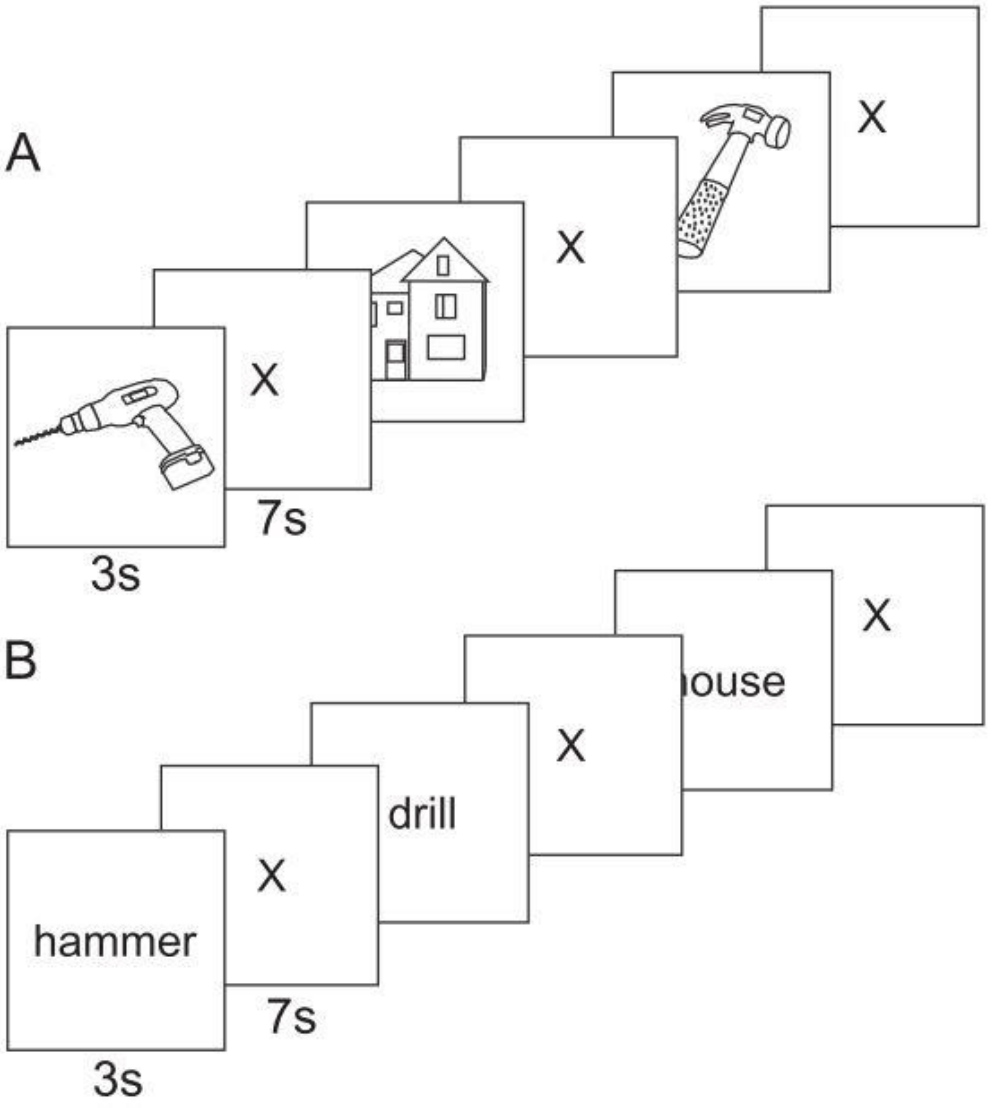


Data preprocessing pipeline



Data analysis & results

Introducing our dataset



(A) Mitchell et al. (2008):
"Think of properties of depicted objects"
(w/nouns underneath too)

(B) Just et al. (2010):
"Think of properties of referred-to objects"
(nouns *only*)

We are analyzing set **B**
("purer" brain activity due to conceptual thought, no pics)

Data preprocessing sequence

1. Motion correction
    - Ensures that brain activity of voxel *i* corresponds to the same volume of brain tissue throughout whole experiment

2. Slice-time correction
    - Brain slices are not collected simultaneously each image acquisition

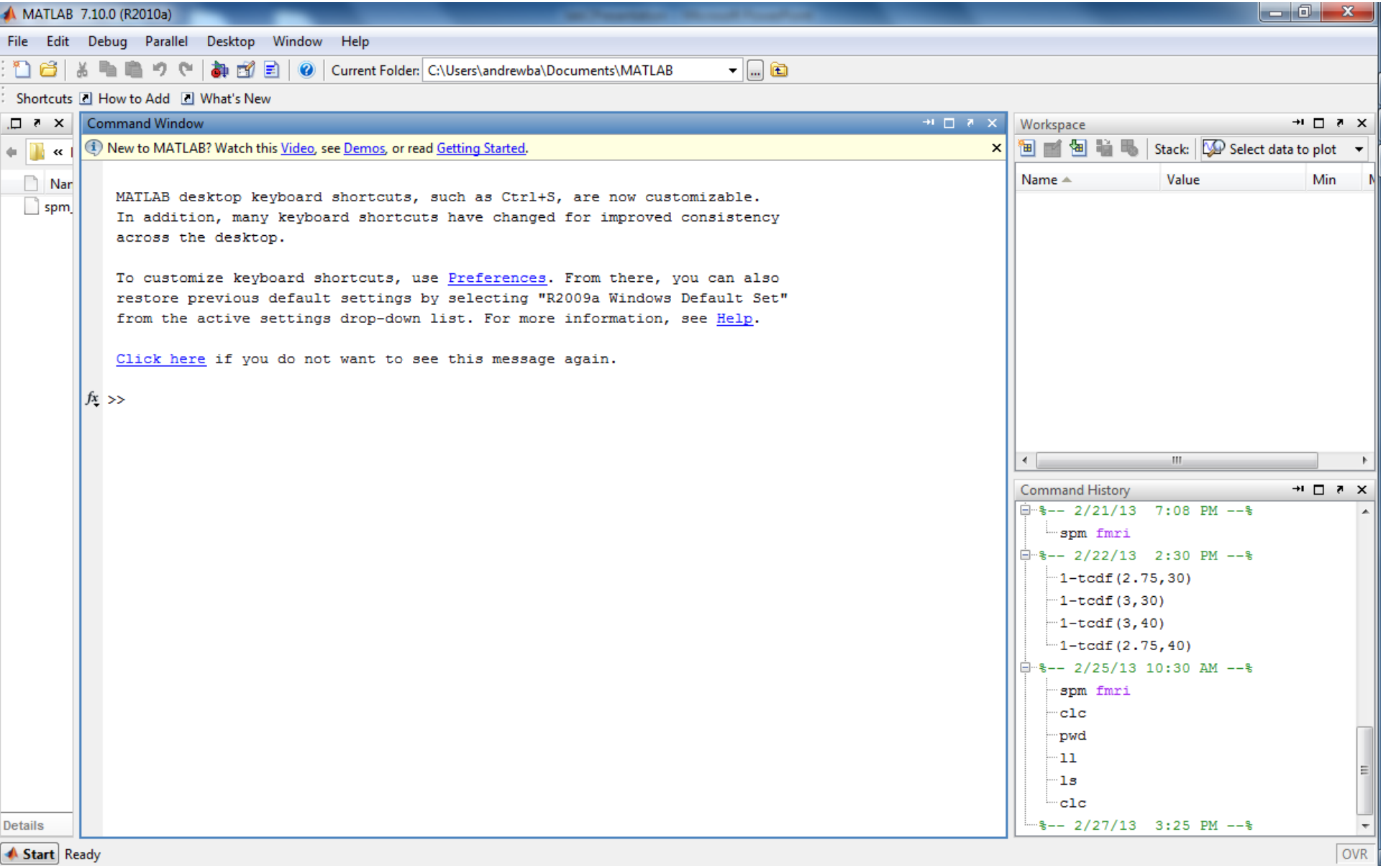
3. Spatial normalization
    - Morphs each subject's brain to a common/template brain

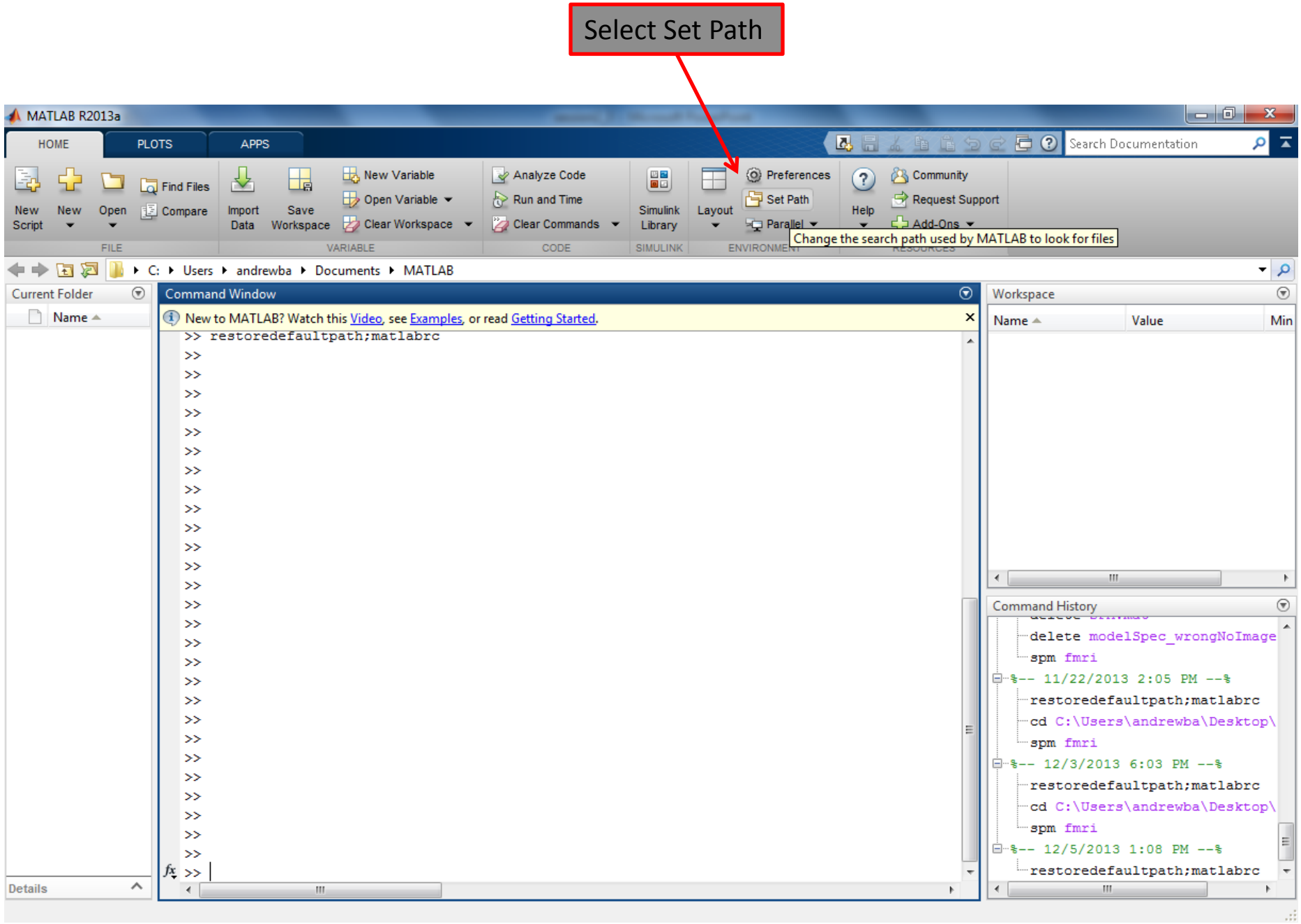
4. Smoothing
    - Reduces amount of noise per voxel by averaging over nearby voxels

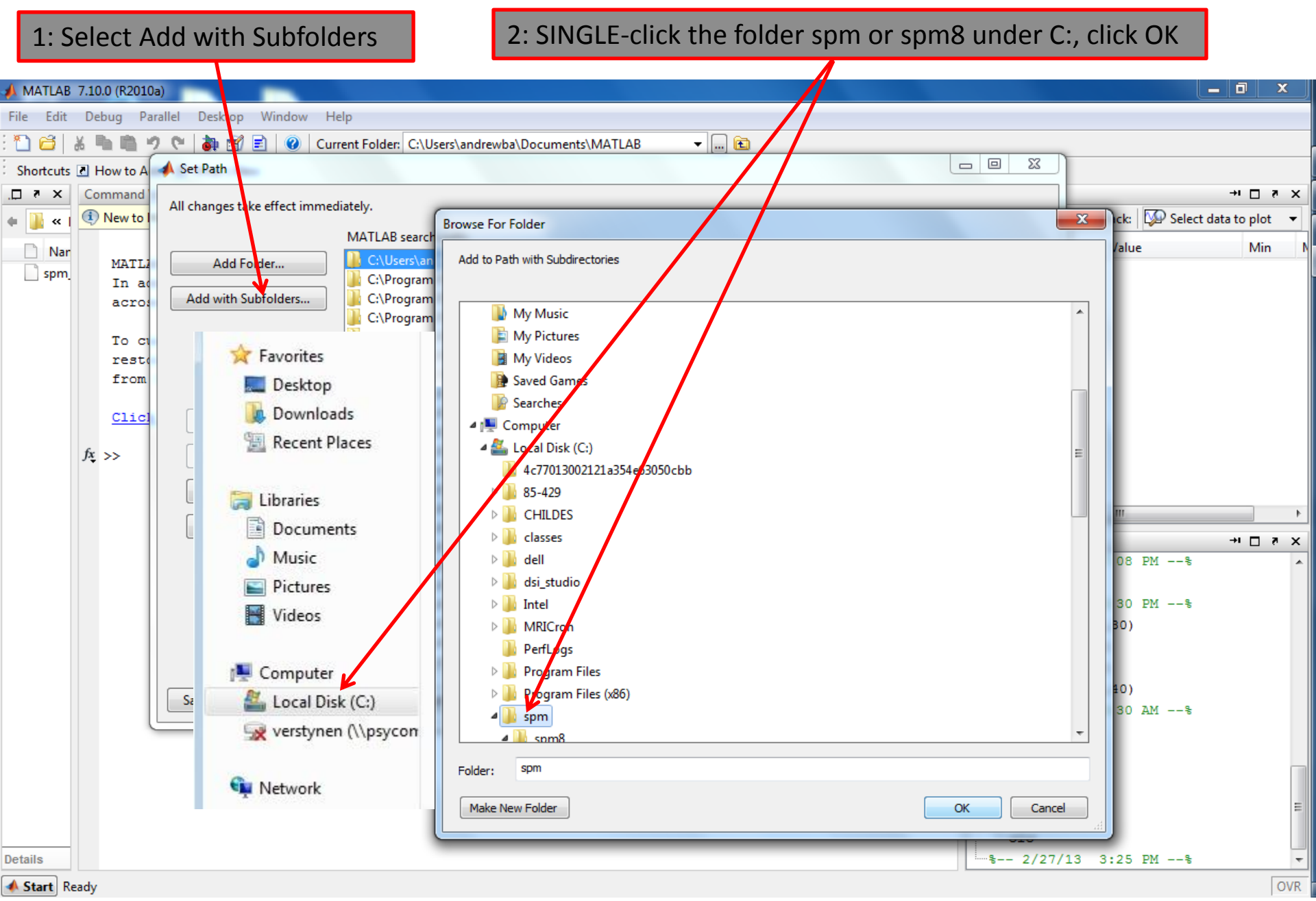
End of session: Revisit functions of brain regions (Quiz no. 2)

Start Matlab 2012b (on desktop, or type “matlab” in Start menu to find it)

NOTE: You MUST select Matlab 2012b, do NOT select 2014b




Select Set Path
MATLAB R2013a
HOME
PLOTS
APPS
Search Documentation
New Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Simulink Library
Layout
Preferences
Set Path
Parallel
Help
Community
Request Support
Add-Ons
Change the search path used by MATLAB to look for files
FILE
VARIABLE
CODE
SIMULINK
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ andrewba ▸ Documents ▸ MATLAB
Current Folder
Name
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
>> restoredefaultpath;matlabrc
Workspace
Name
Value
Min
Command History
delete modelSpec_wrongNoImage
spm fmri
%-- 11/22/2013 2:05 PM --%
restoredefaultpath;matlabrc
cd C:\Users\andrewba\Desktop\
spm fmri
%-- 12/3/2013 6:03 PM --%
restoredefaultpath;matlabrc
cd C:\Users\andrewba\Desktop\
spm fmri
%-- 12/5/2013 1:08 PM --%
restoredefaultpath;matlabrc
Details


1: Select Add with Subfolders
2: SINGLE-click the folder spm or spm8 under C:, click OK
MATLAB 7.10.0 (R2010a)
File Edit Debug Parallel Desktop Window Help
Current Folder: C:\Users\andrewba\Documents\MATLAB
Set Path
All changes take effect immediately.
Add Folder...
Add with Subfolders...
MATLAB search
Browse For Folder
Add to Path with Subdirectories
My Music
My Pictures
My Videos
Saved Games
Searches
Computer
Local Disk (C:)
4c77013002121a354e83050cbb
85-429
CHILDES
classes
dell
dsi_studio
Intel
MRICron
PerfLogs
Program Files
Program Files (x86)
spm
spm8
Favorites
Desktop
Downloads
Recent Places
Libraries
Documents
Music
Pictures
Videos
Computer
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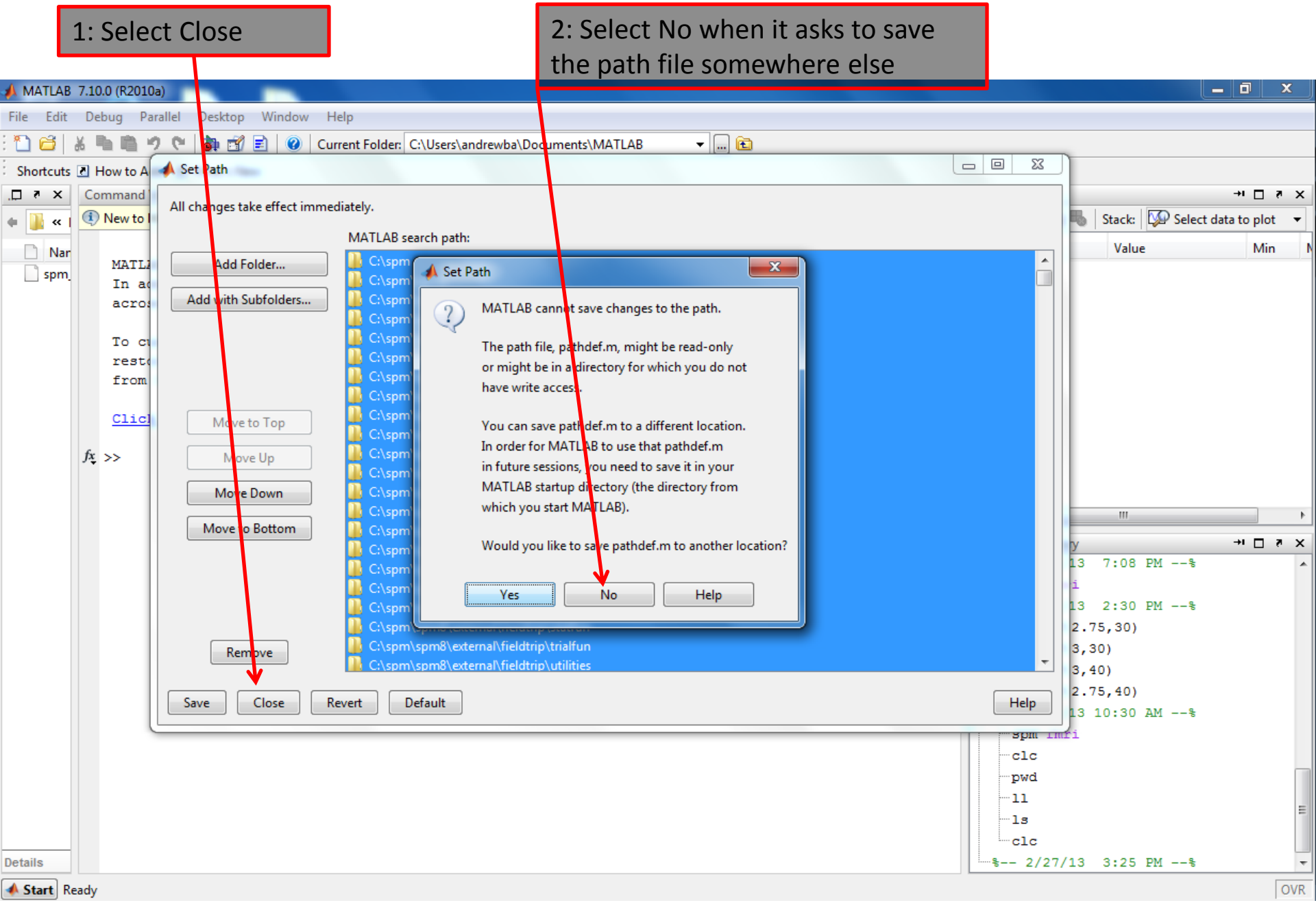
verstynen (\\psycon
Network
Folder: spm
Make New Folder
OK
Cancel
Select data to plot
Start
Ready
OVR

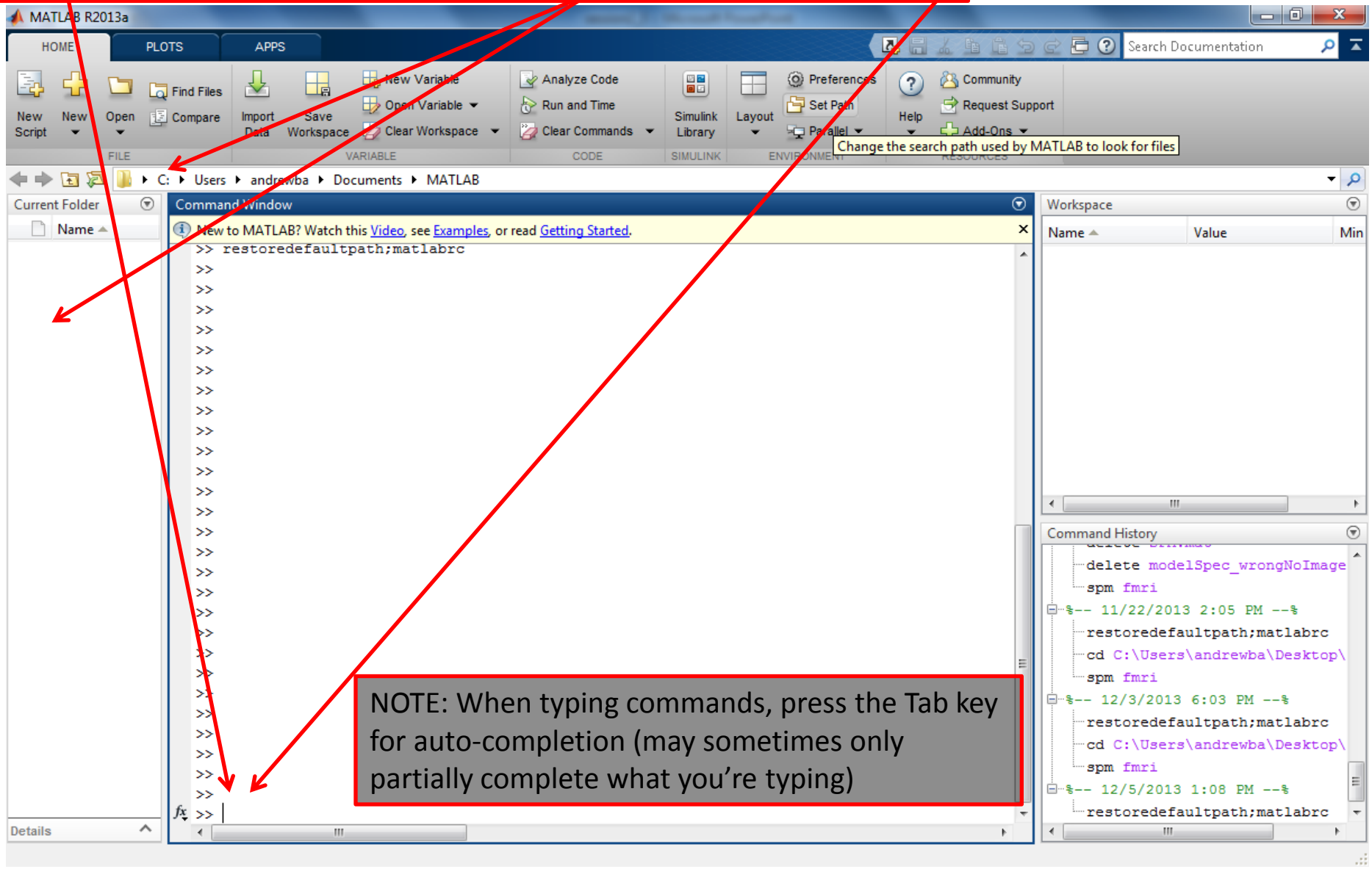

1: Select Close
2: Select No when it asks to save the path file somewhere else
MATLAB 7.10.0 (R2010a)
File Edit Debug Parallel Desktop Window Help
Current Folder: C:\Users\andrewba\Documents\MATLAB
Set Path
All changes take effect immediately.
MATLAB search path:
Add Folder...
Add with Subfolders...
Move to Top
Move Up
Move Down
Move to Bottom
Remove
Save
Close
Revert
Default
Help
Set Path
MATLAB cannot save changes to the path.
The path file, pathdef.m, might be read-only or might be in a directory for which you do not have write access.
You can save pathdef.m to a different location. In order for MATLAB to use that pathdef.m in future sessions, you need to save it in your MATLAB startup directory (the directory from which you start MATLAB).
Would you like to save pathdef.m to another location?
Yes
No
Help
C:\spm\spm8\external\fieldtrip\trialfun
C:\spm\spm8\external\fieldtrip\utilities
Start
Ready
OVR

1: Go to the Matlab Command Window and type:

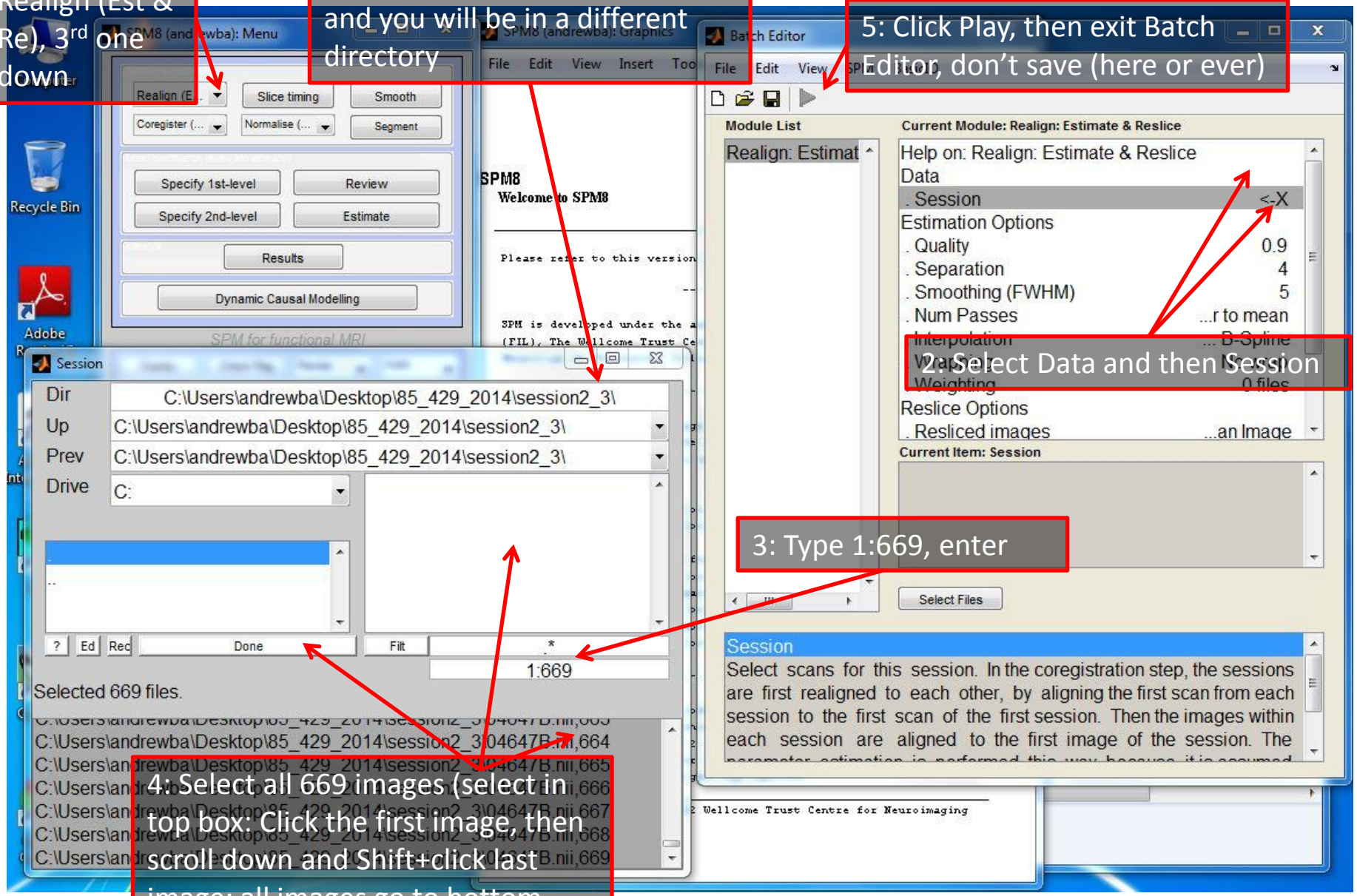
cd C:/Users/Public/lab_85_429_2016/session3

…(OR navigate there using the browser)

2: Then type: spm fmri



NOTE: When typing commands, press the Tab key for auto-completion (may sometimes only partially complete what you're typing)


1: Select Realign (Est & Re), 3rd one down
NOTE: Your screen will say "session3", not "session2_3", and you will be in a different directory
5: Click Play, then exit Batch Editor, don't save (here or ever)
2: Select Data and then Session
3: Type 1:669, enter
4: Select all 669 images (select in top box: Click the first image, then scroll down and Shift+click last image; all images go to bottom box), then click Done
SPM8 (andrewba): Menu
Realign (E...
Slice timing
Smooth
Coregister (...
Normalise (...
Segment
Specify 1st-level
Review
Specify 2nd-level
Estimate
Results
Dynamic Causal Modelling
SPM for functional MRI
SPM8 (andrewba): Graphics
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SPM8
Welcome to SPM8
Please refer to this version
SPM is developed under the a
(FIL), The Wellcome Trust Ce
Batch Editor
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Help on: Realign: Estimate & Reslice
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Current Item: Session
Select Files
Session
Select scans for this session. In the coregistration step, the sessions are first realigned to each other, by aligning the first scan from each session to the first scan of the first session. Then the images within each session are aligned to the first image of the session. The
Session
Dir C:\Users\andrewba\Desktop\85_429_2014\session2_3\
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1:669
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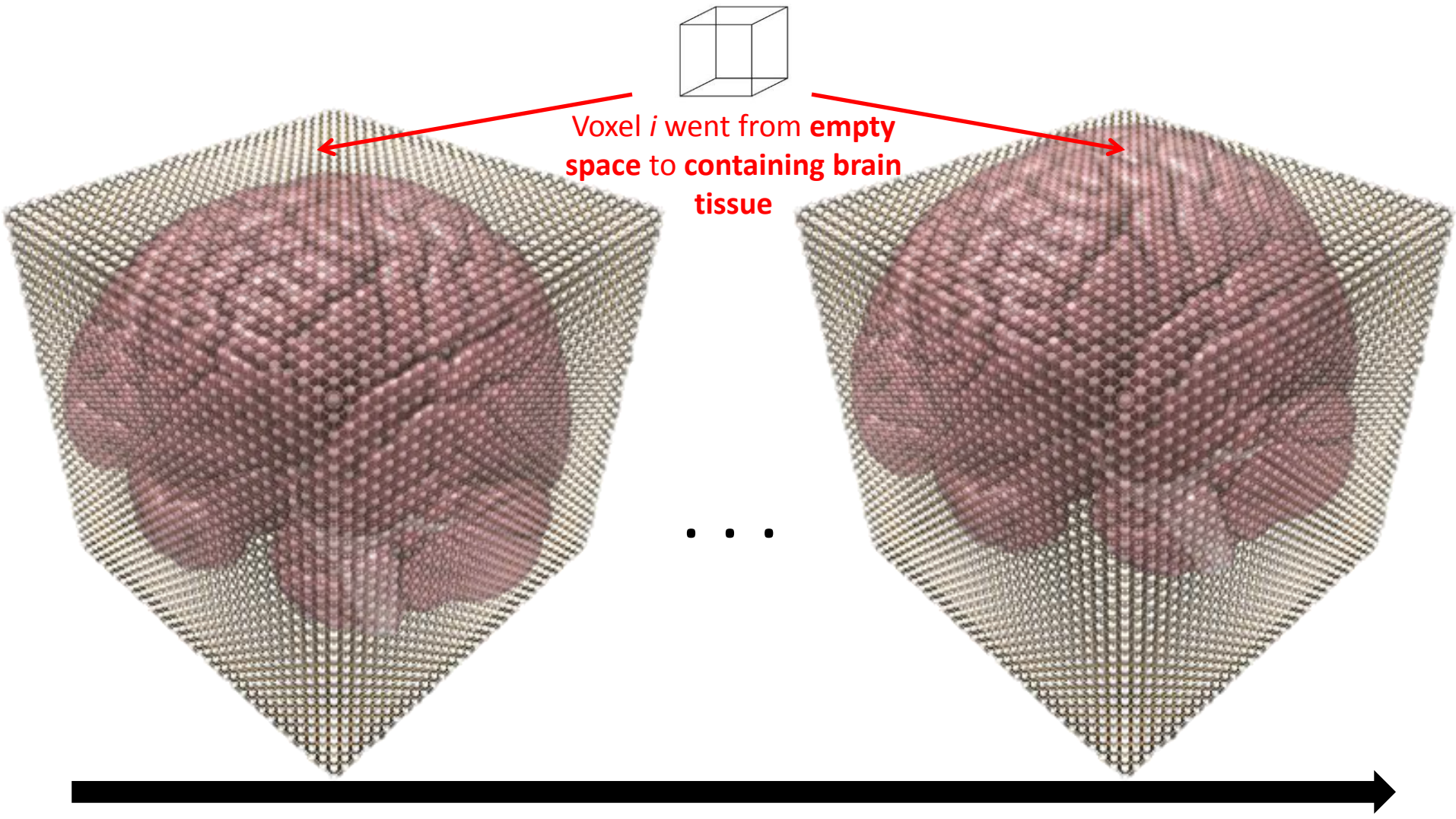
C:\Users\andrewba\Desktop\85_429_2014\session2_3\04647B.nii,669
Wellcome Trust Centre for Neuroimaging

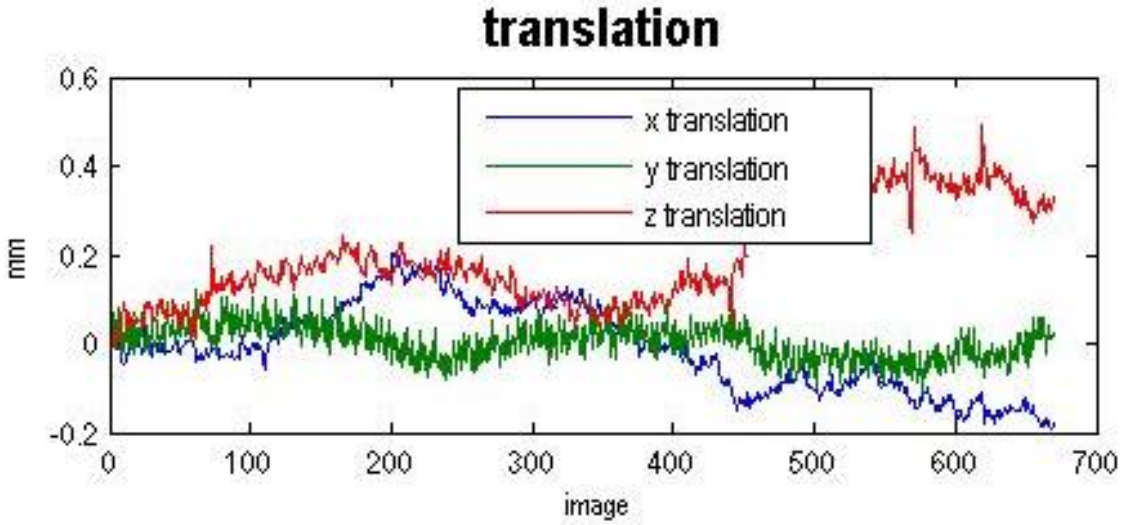
Need to correct for head motion
For example:



Viewing head motion

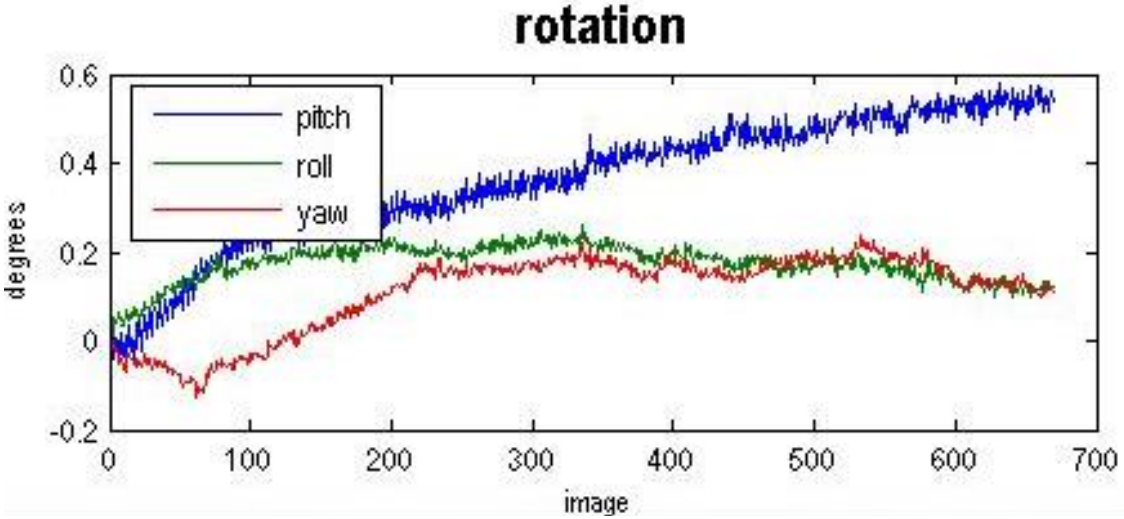
Translation:

Deviation in space for each dimension



Rotation:

Deviation in angle/degree for each direction



Spatial rotation terms

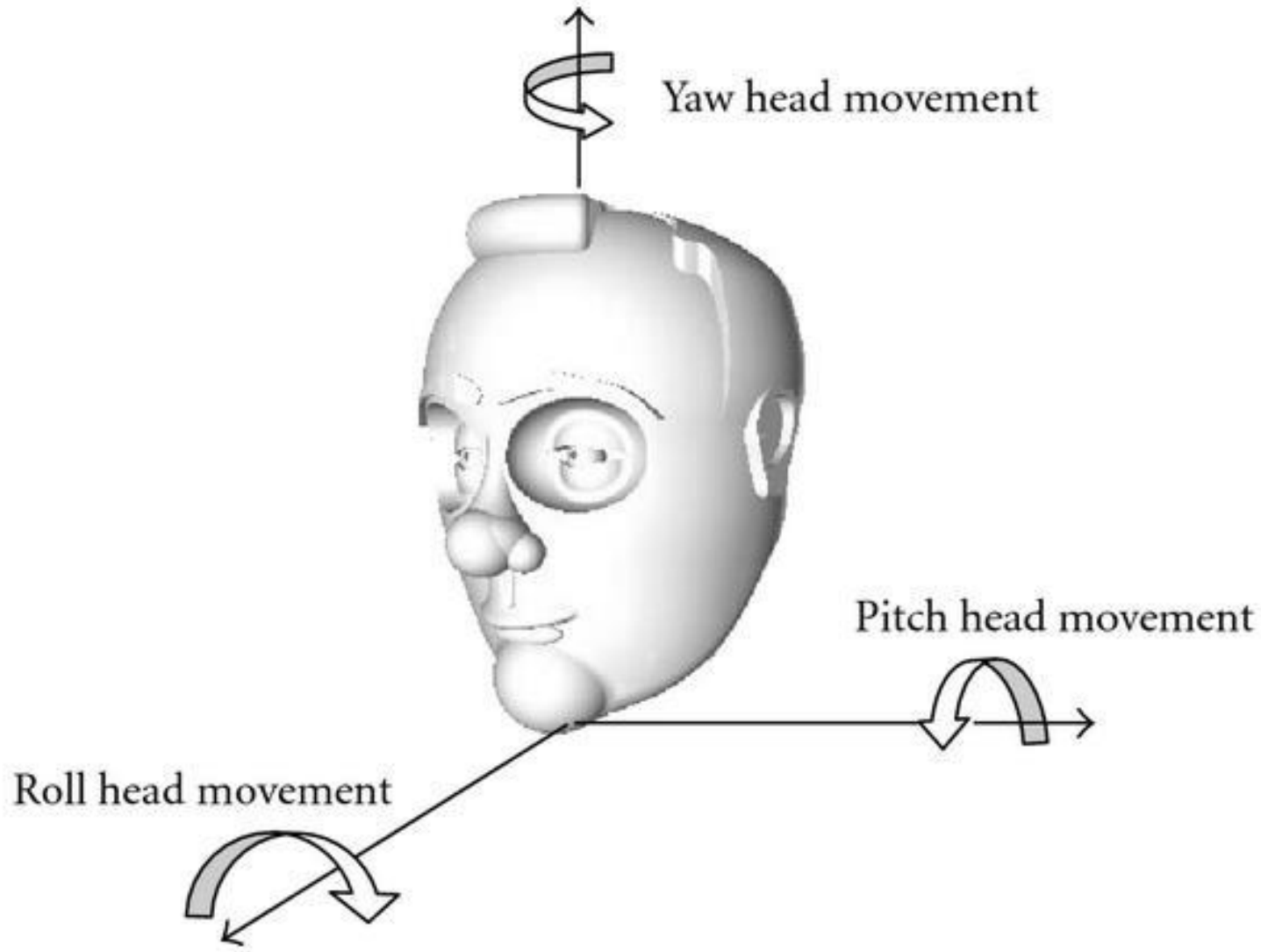


Image: http://www.hindawi.com/journals/mse/2009/245606/fig7/

Data preprocessing sequence

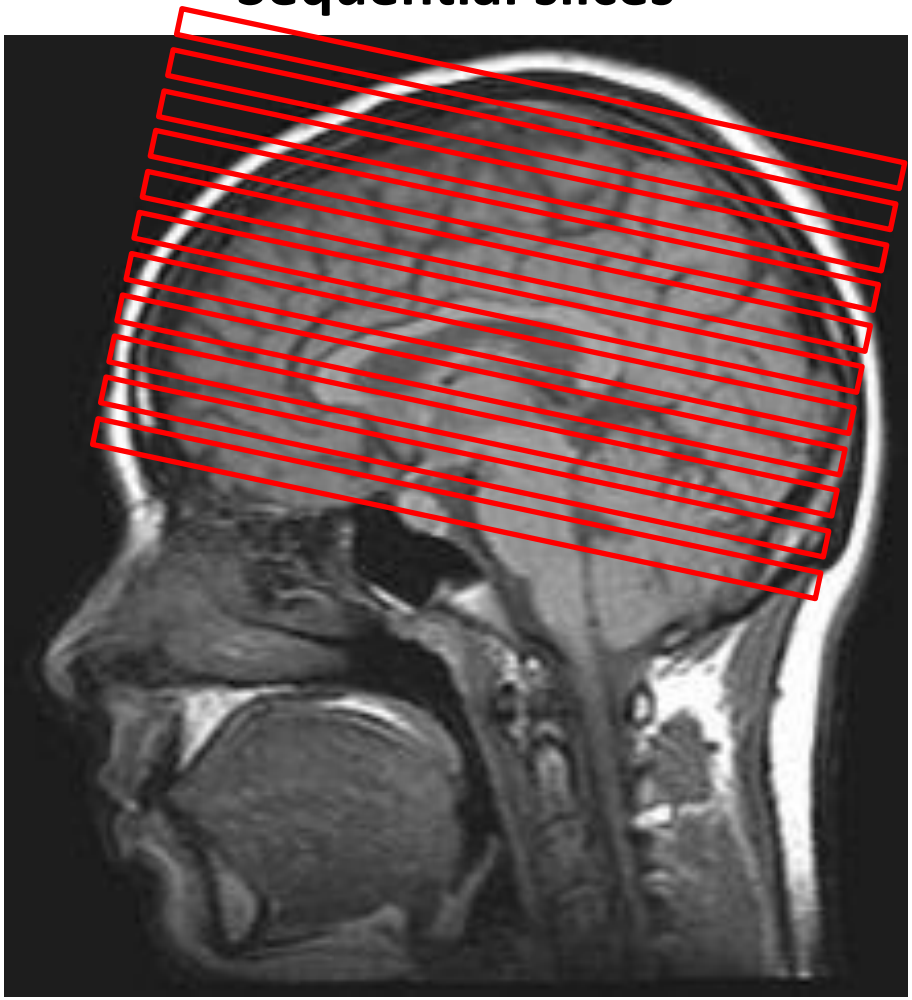
1. Motion correction
    - Ensures that brain activity of voxel *i* corresponds to the same volume of brain tissue throughout whole experiment

2. Slice-time correction
    - Brain slices are not collected simultaneously each image acquisition

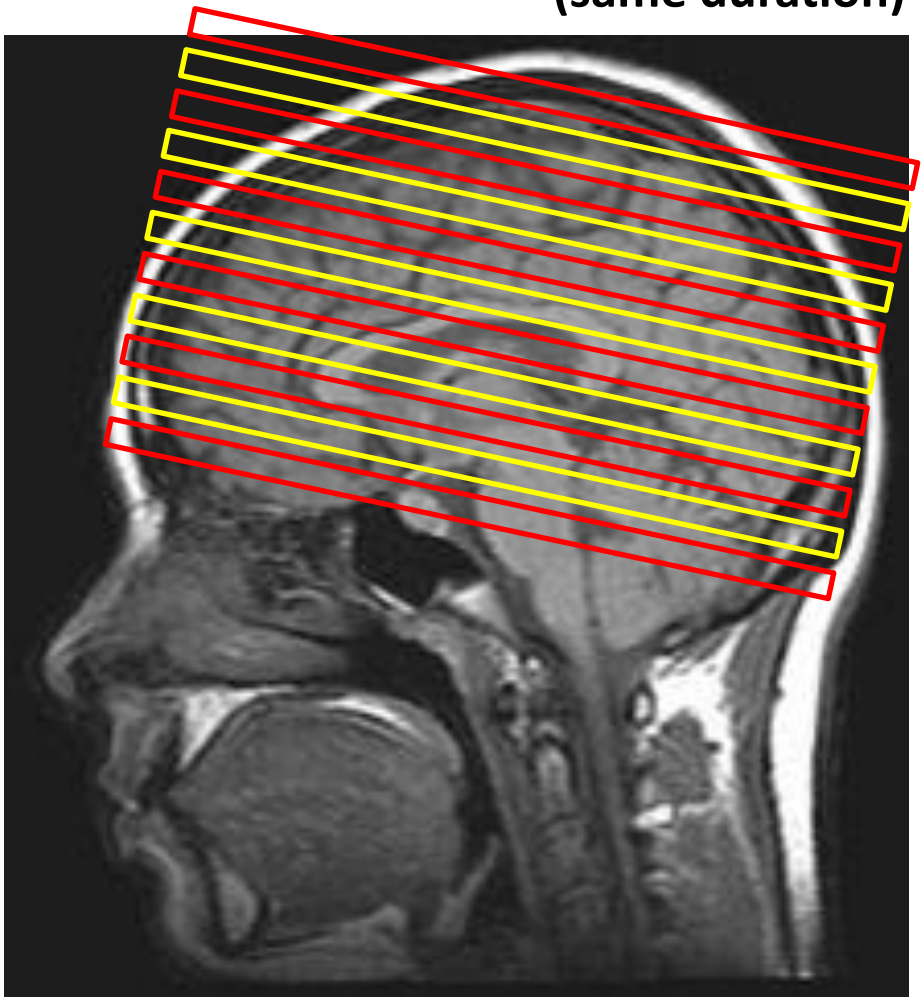
How do we acquire one whole picture of the brain?

- Read individual “slices” and put them together
- Typical acquisition time (TR) of reading slices over the whole brain is 1 sec
- TR depends on voxel size & amount of brain coverage

Sequential slices



… or Interleaved slices (same duration)

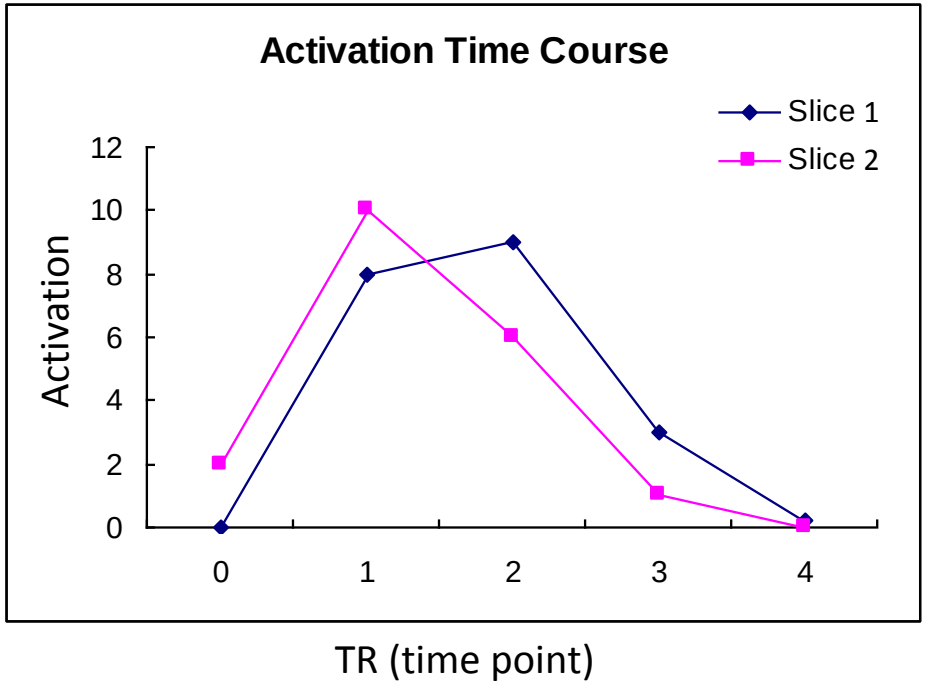


Adjust slice activation to correct for slice asynchrony

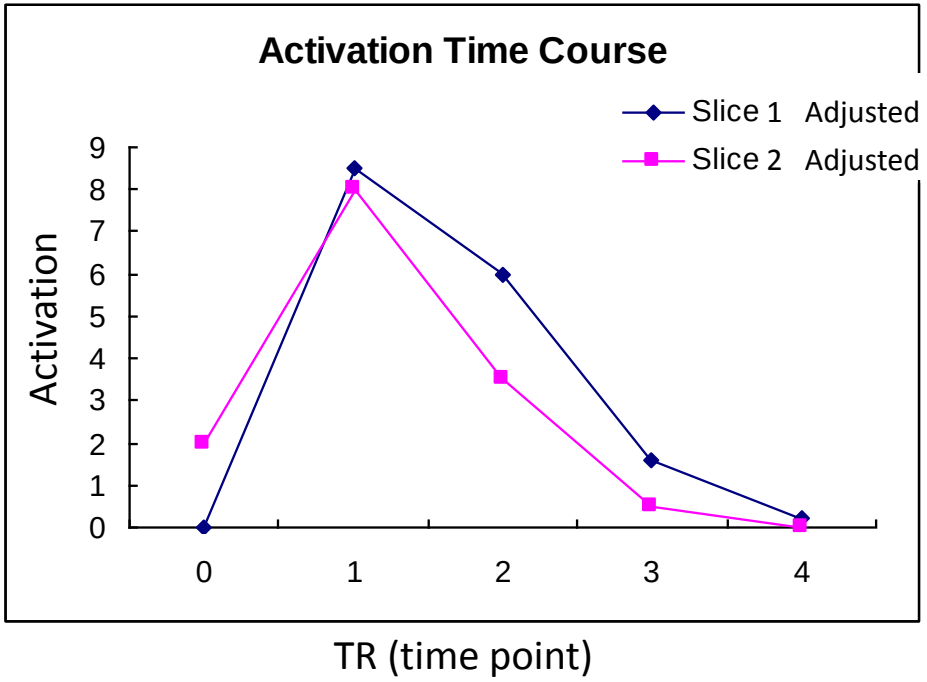
- Notice that Slice 2 activation appears to peak earlier, and to decrease earlier
  - Why? Slice 2 is acquired *after* Slice 1; Slice 2's activation waveform at TR = 0 is *really* at around TR = 0 *plus* that extra delay time, during which its activation has increased a bit

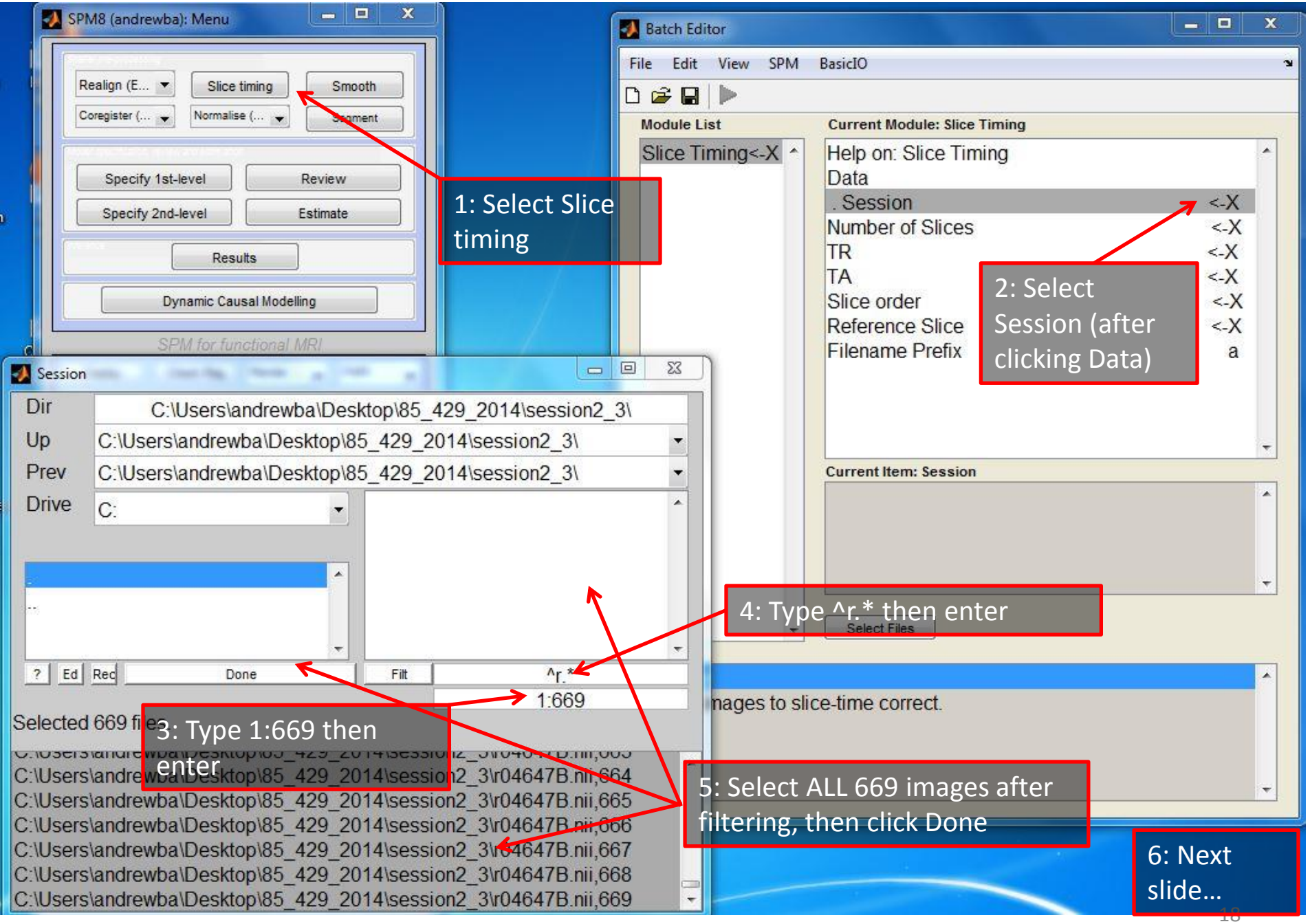
- The solution is temporal interpolation: Estimates new slice activations for each TR; makes slices more synchronous *(can be more accurate for Interleaved slice-reading)*

Before slice-time correction



After slice-time correction




SPM8 (andrewba): Menu
Realign (E...
Slice timing
Smooth
Coregister (...
Normalise (...
Specify 1st-level
Review
Specify 2nd-level
Estimate
Results
Dynamic Causal Modelling
SPM for functional MRI
Batch Editor
File Edit View SPM BasicIO
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Current Module: Slice Timing
Help on: Slice Timing
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Reference Slice <-X
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1: Select Slice timing
2: Select Session (after clicking Data)
Session
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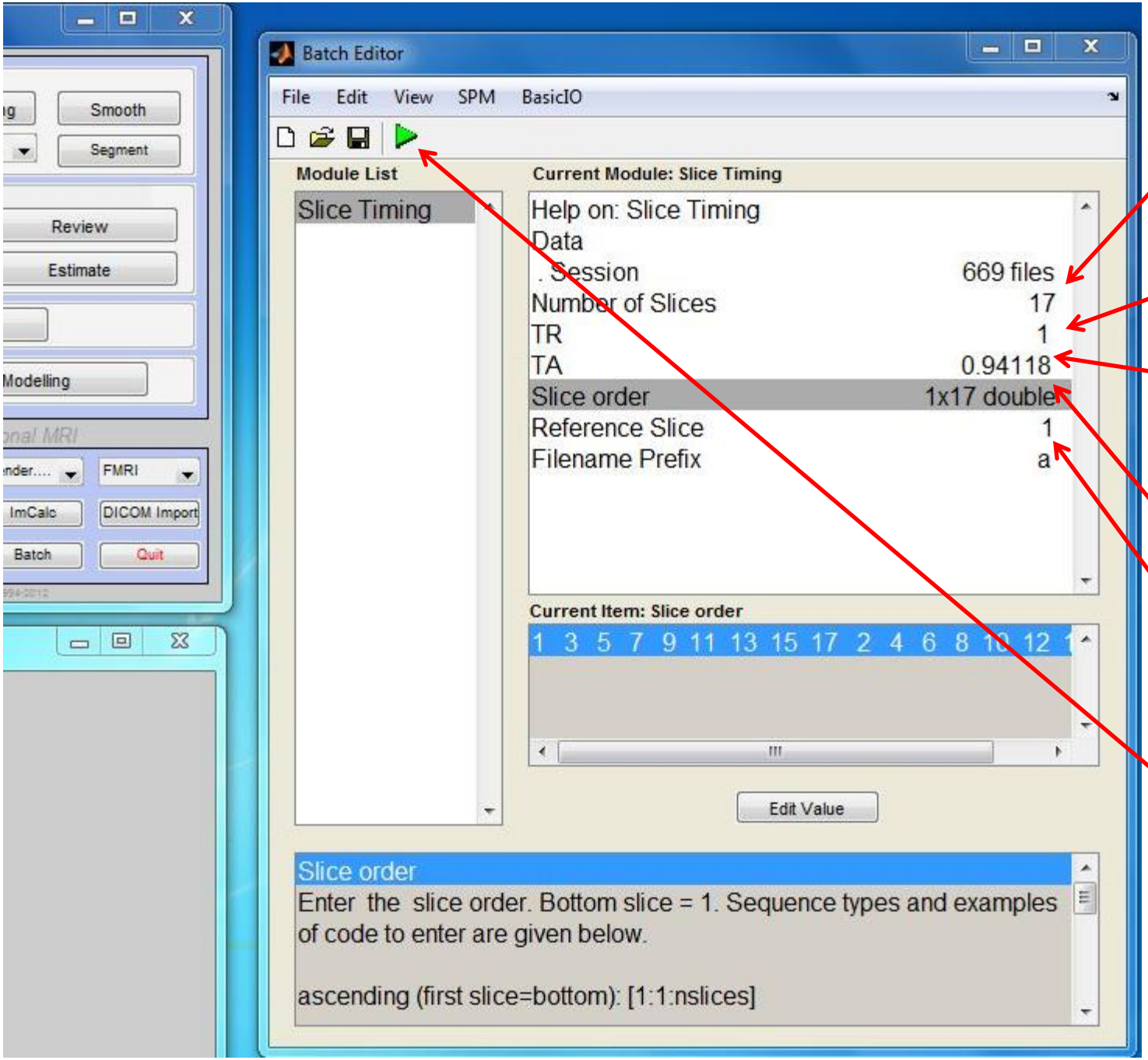
4: Type ^r.* then enter
3: Type 1:669 then enter
5: Select ALL 669 images after filtering, then click Done
nages to slice-time correct.
6: Next slide...



7: No. of slices: 17

8: TR: 1

9: TA: type this: 1-1/17

10: Slice order: [1:2:17 2:2:16] (space between 17 & 2)

11: Reference slice: 1

12: Click Play

Data preprocessing sequence

1. Motion correction
    - Ensures that brain activity of voxel *i* corresponds to the same volume of brain tissue throughout whole experiment

2. Slice-time correction
    - Brain slices are not collected simultaneously each image acquisition

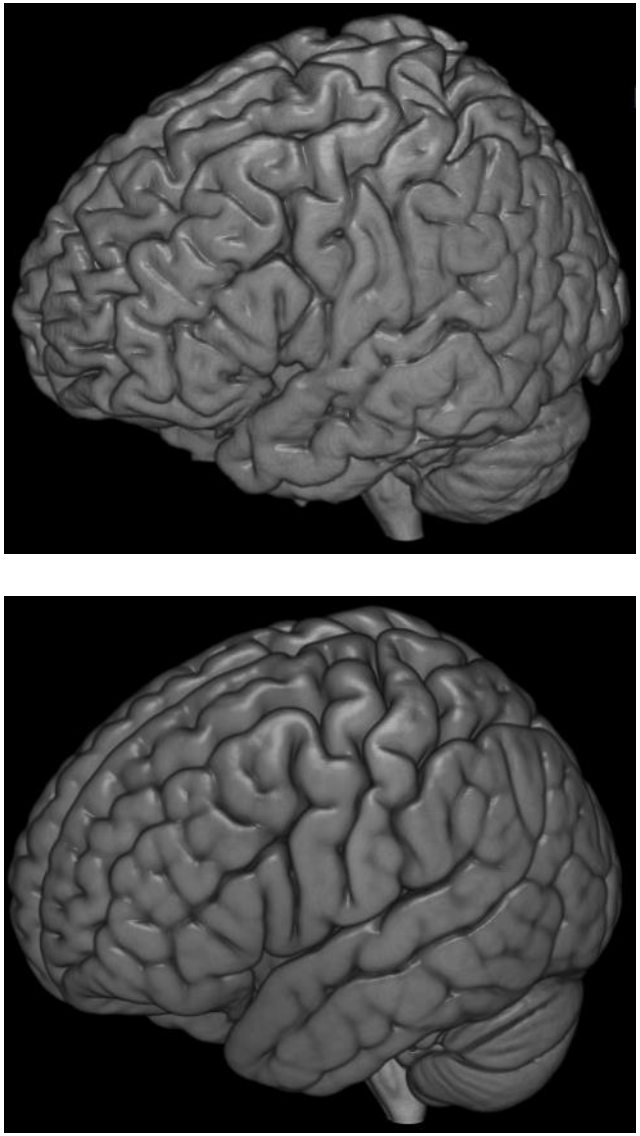
3. Spatial normalization
    - Morphs each subject's brain to a common/template brain

Spatial normalization

Morph an individual's brain to a common template to examine activation in the *same voxels* across subjects

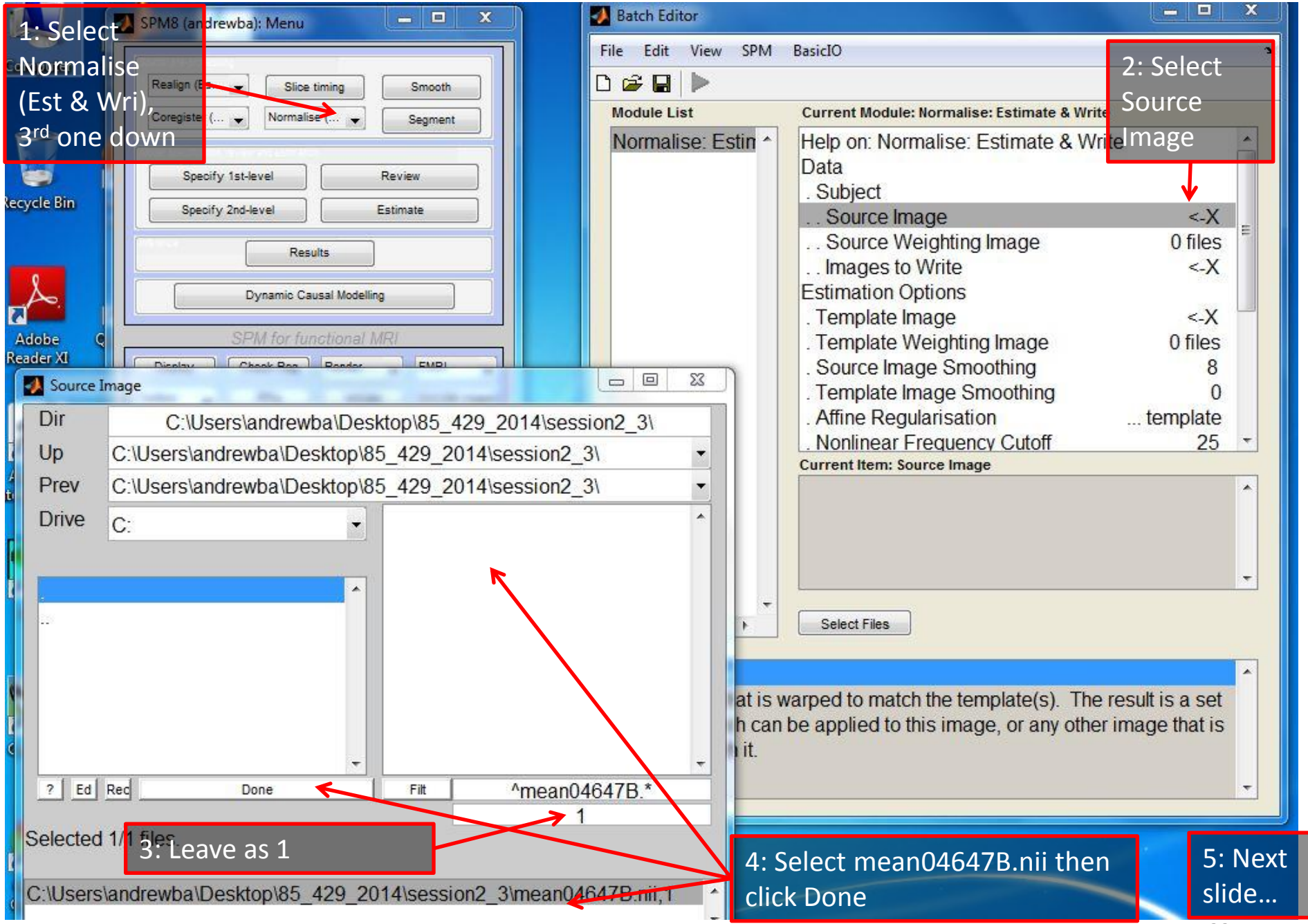
We are using the Montreal Neurological Institute (MNI) template, which is the average of 152 brains

(Too perfect-looking to be an actual brain…) →



A person's real brain

MNI brain


1: Select Normalise (Est & Wri), 3rd one down
SPM8 (andrewba): Menu
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SPM for functional MRI
Batch Editor
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2: Select Source Image
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Select Files
at is warped to match the template(s). The result is a set
h can be applied to this image, or any other image that is
it.
Source Image
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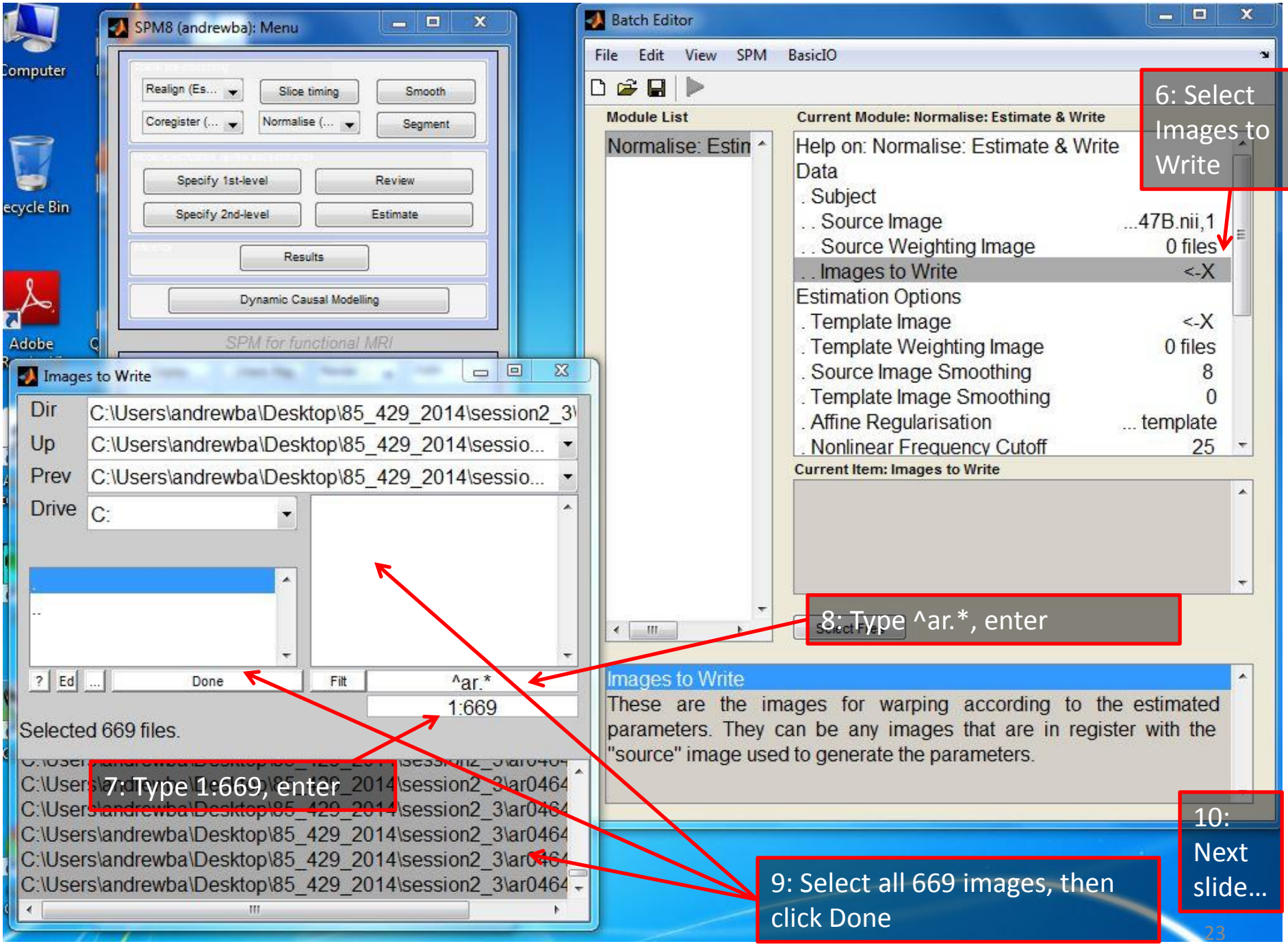
3: Leave as 1
4: Select mean04647B.nii then click Done
C:\Users\andrewba\Desktop\85_429_2014\session2_3\mean04647B.nii,1
5: Next slide...
Recycle Bin
Adobe Reader XI


SPM8 (andrewba): Menu
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Slice timing
Smooth
Coregister (...
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Dynamic Causal Modelling
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Batch Editor
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Module List
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Estimation Options
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. Source Image Smoothing 8
. Template Image Smoothing 0
. Affine Regularisation ... template
. Nonlinear Frequency Cutoff 25
Current Item: Images to Write
Images to Write
These are the images for warping according to the estimated parameters. They can be any images that are in register with the "source" image used to generate the parameters.
Images to Write
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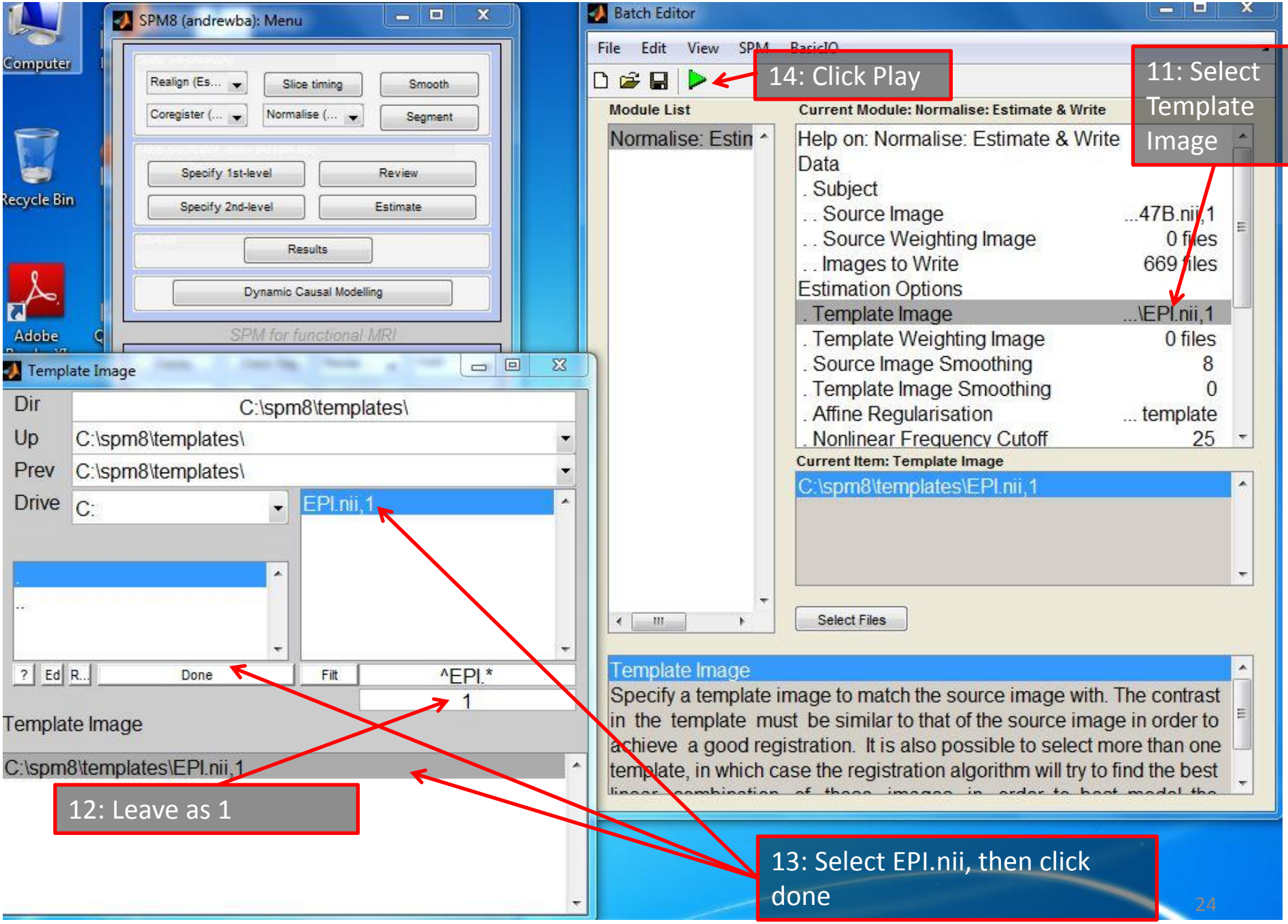
C:\Users\andrewba\Desktop\85_429_2014\session2_3\ar0464
6: Select Images to Write
7: Type 1:669, enter
8: Type ^ar.*, enter
9: Select all 669 images, then click Done
10: Next slide…


SPM8 (andrewba): Menu
Realign (Es...
Slice timing
Smooth
Coregister (...
Normalise (...
Segment
Specify 1st-level
Review
Specify 2nd-level
Estimate
Results
Dynamic Causal Modelling
SPM for functional MRI
Batch Editor
File Edit View SPM BasicIO
14: Click Play
11: Select Template Image
Module List
Normalise: Estin
Current Module: Normalise: Estimate & Write
Help on: Normalise: Estimate & Write
Data
. Subject
. . Source Image ...47B.nii,1
. . Source Weighting Image 0 files
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Estimation Options
. Template Image ...\EPI.nii,1
. Template Weighting Image 0 files
. Source Image Smoothing 8
. Template Image Smoothing 0
. Affine Regularisation ... template
. Nonlinear Frequency Cutoff 25
Current Item: Template Image
C:\spm8\templates\EPI.nii,1
Select Files
Template Image
Specify a template image to match the source image with. The contrast in the template must be similar to that of the source image in order to achieve a good registration. It is also possible to select more than one template, in which case the registration algorithm will try to find the best
Template Image
Dir C:\spm8\templates\
Up C:\spm8\templates\
Prev C:\spm8\templates\
Drive C:
EPI.nii,1
? Ed R... Done
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Template Image
C:\spm8\templates\EPI.nii,1
12: Leave as 1
13: Select EPI.nii, then click done

Data preprocessing sequence

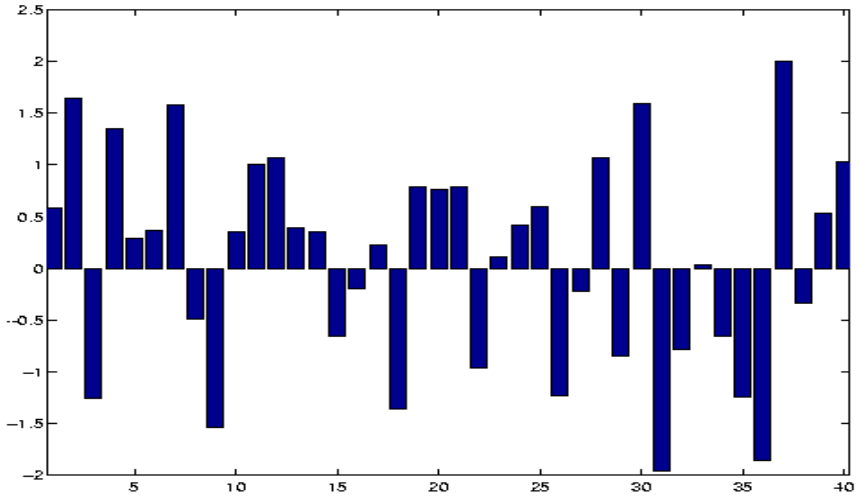
1. Motion correction
   - Ensures that brain activity of voxel *i* corresponds to the same volume of brain tissue throughout whole experiment
2. Slice-time correction
   - Brain slices are not collected simultaneously each image acquisition
3. Spatial normalization
   - Morphs each subject's brain to a common/template brain
4. Smoothing
   - Reduces amount of noise per voxel by averaging over nearby voxels

Smoothing

- Assumes (reasonably) that adjacent voxels contain neurons that have same or very similar functions

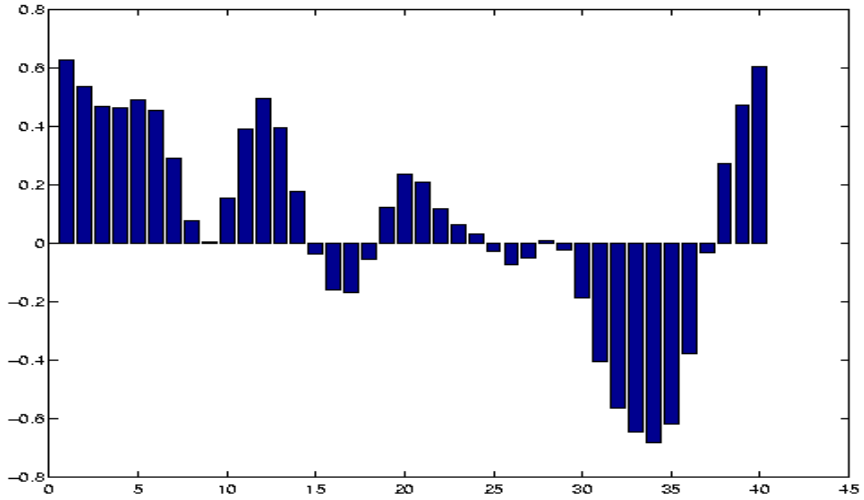
- Averages signals of neighboring voxels to filter out “noise” and boost “real” activation

Before smoothing

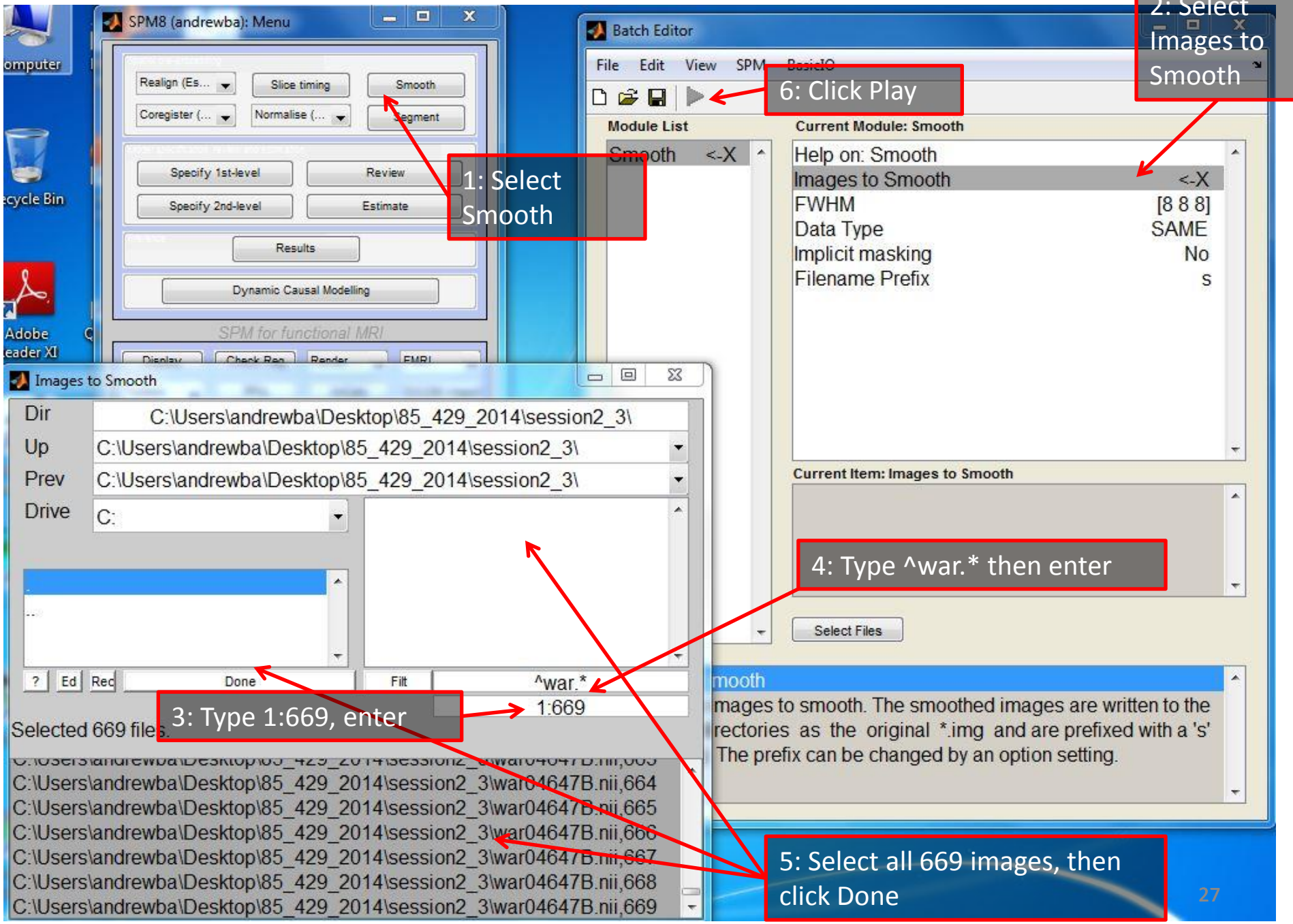


Voxel ID (voxels 4 &5 close together, etc.)

After smoothing



Voxel ID (voxels 4 &5 close together, etc.)


SPM8 (andrewba): Menu
Realign (Es...
Slice timing
Smooth
Coregister (...
Normalise (...
Segment
Specify 1st-level
Review
Specify 2nd-level
Estimate
Results
Dynamic Causal Modelling
SPM for functional MRI
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]
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Select Files
Images to Smooth
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1:669
Selected 669 files.
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mages to smooth. The smoothed images are written to the
rectories as the original *.img and are prefixed with a 's'
The prefix can be changed by an option setting.
1: Select Smooth
2: Select Images to Smooth
3: Type 1:669, enter
4: Type ^war.* then enter
5: Select all 669 images, then click Done
6: Click Play

Final notes about data preprocessing

- Although some preprocessing always necessary, all steps can result in *loss* of data
  - Smoothing (previous slide) is vulnerable to this
    - Lose small fluctuations in data that might be real
      - Some techniques can address this problem (later in lab)
  - Another vulnerable step is spatial normalization
    - Lose individual quirks of a person's data

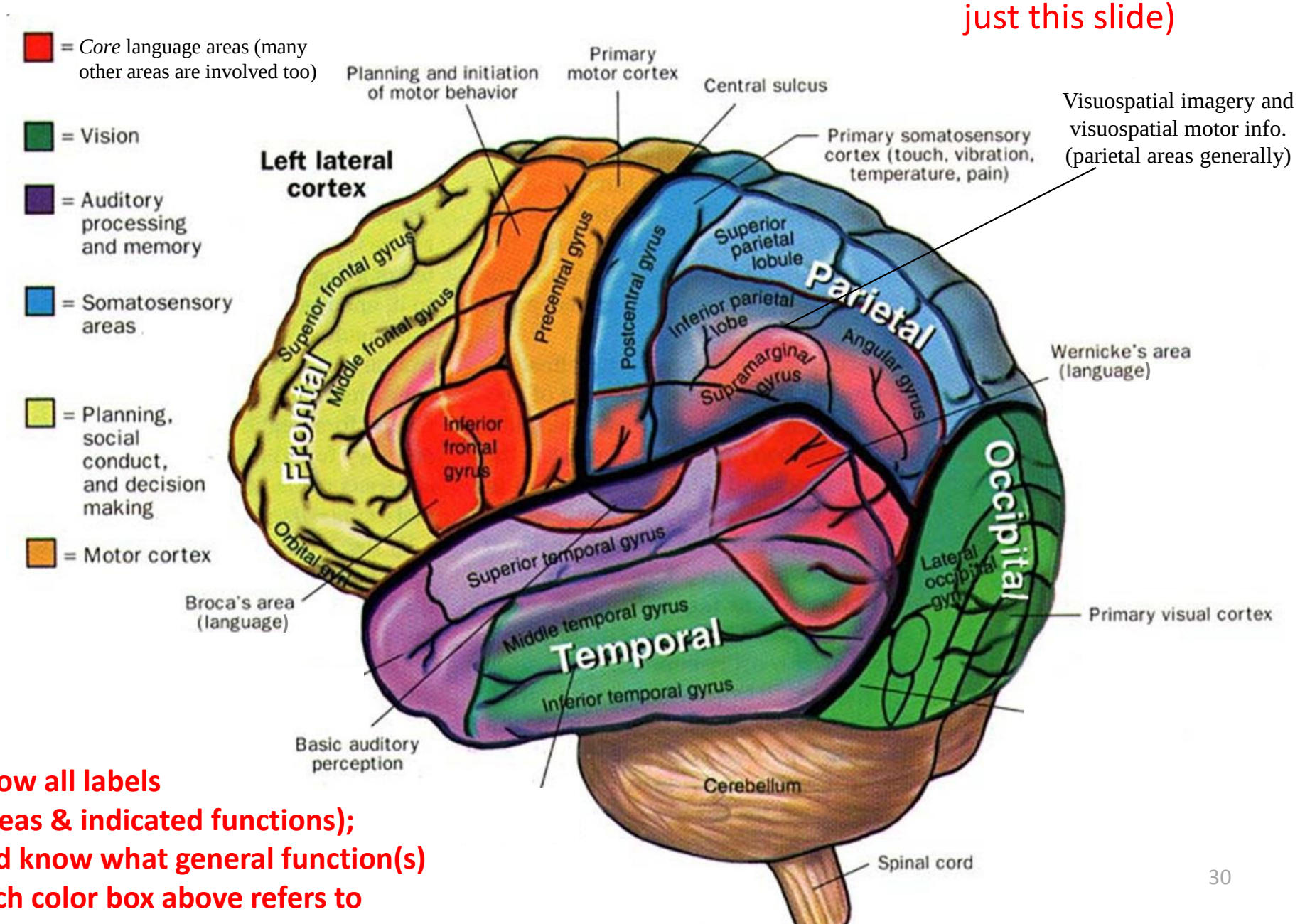
Final notes about data preprocessing

- All steps can also result in artificial *creation* of seemingly real data

  - Again, smoothing is vulnerable to this
    - If one voxel's activation level is high due to error/random chance, then averaging it in with other voxels will spread this error to other voxels, leading to a *false* cluster of activation

General functional neuroanatomy (Quiz no. 2

just this slide)



Know all labels
(areas & indicated functions);
and know what general function(s)
each color box above refers to

References

Just, M. A., Cherkassky, V. L., Aryal, S., & Mitchell, T. M. (2010). A neurosemantic theory of concrete noun representation based on the underlying brain codes. *PLoS One*, *5*(1), e8622. doi:10.1371/journal.pone.0008622

Mitchell, T. M., Shinkareva, S. V, Carlson, A., Chang, K. M., Malave, V. L., Mason, R. A, & Just, M. A. (2008). Predicting human brain activity associated with the meanings of nouns. *Science* (New York, N.Y.), 320(5880), 1191–5. doi:10.1126/science.1152876