Lab session 4: Set up General Linear Model (GLM)

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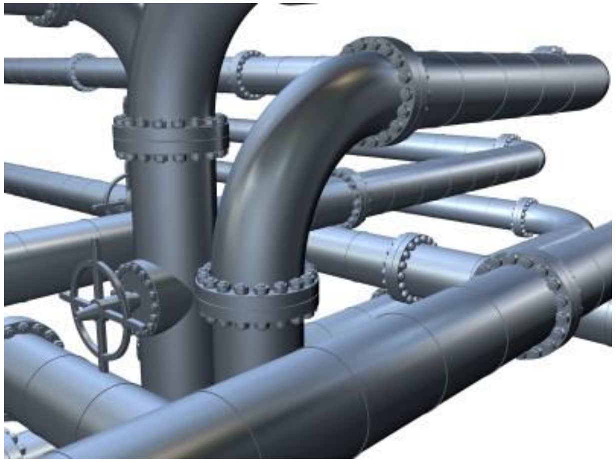
02/03/16

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)		

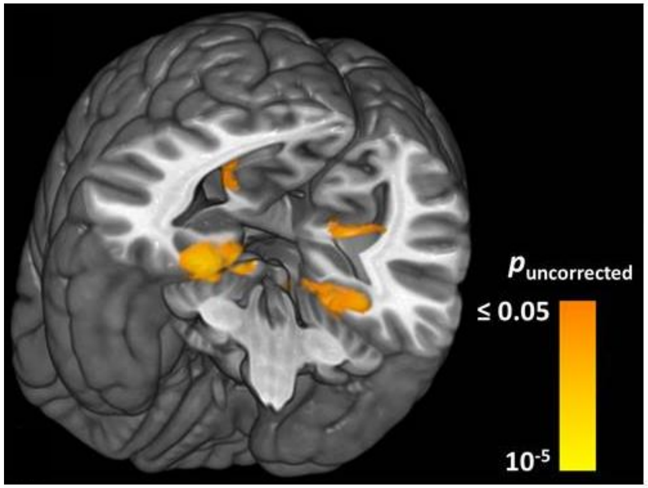
Study slides 6, 19, 20 below

Data preprocessing pipeline



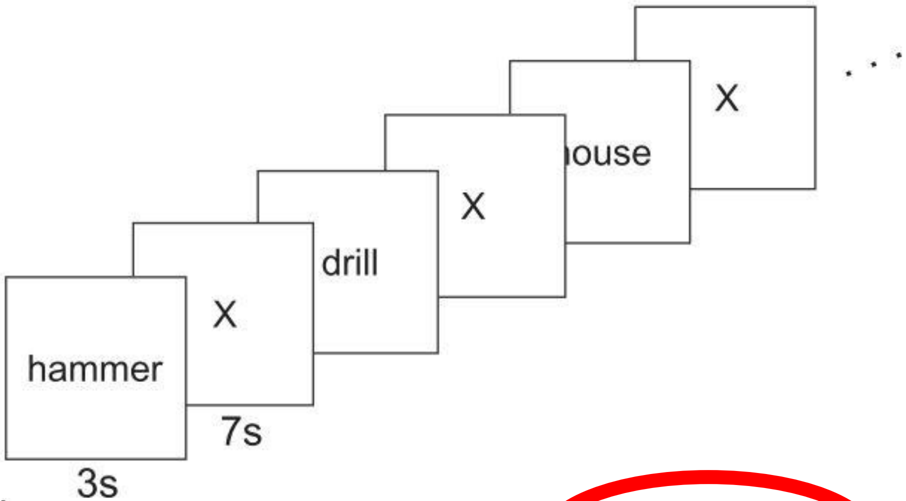
Generalized Linear Model (GLM)

Setting up analysis



Data analysis & results

Our analysis: Discover the brain areas that are associated with thinking about different object concept *categories*



<u>Instructions to subjects</u>:
"Think of the main properties of each named object"

Table 1. 60 stimulus words grouped into 12 semantic categories.

Category	Exemplar 1	Exemplar 2	Exemplar 3	Exemplar 4	Exemplar 5
body parts	leg	arm	eye	foot	hand
furniture	chair	table	bed	desk	dresser
vehicles	car	airplane	train	truck	bicycle
animals	horse	dog	bear	cow	cat
kitchen utensils	glass	knife	bottle	cup	spoon
tools	chisel	hammer	screwdriver	pliers	saw
buildings	apartment	barn	house	church	igloo
building parts	window	door	chimney	closet	arch
clothing	coat	dress	shirt	skirt	pants
insects	fly	ant	bee	butterfly	beetle
vegetables	lettuce	tomato	carrot	corn	celery
man-made objects	refrigerator	key	telephone	watch	bell

doi:10.1371/journal.pone.0008622.t001

(Just et al., 2010)

The *H*emodynamic *R*esponse *F*unction of the BOLD MRI signal

- MRI signal in the brain increases by a few % points after there are increases in neural activity

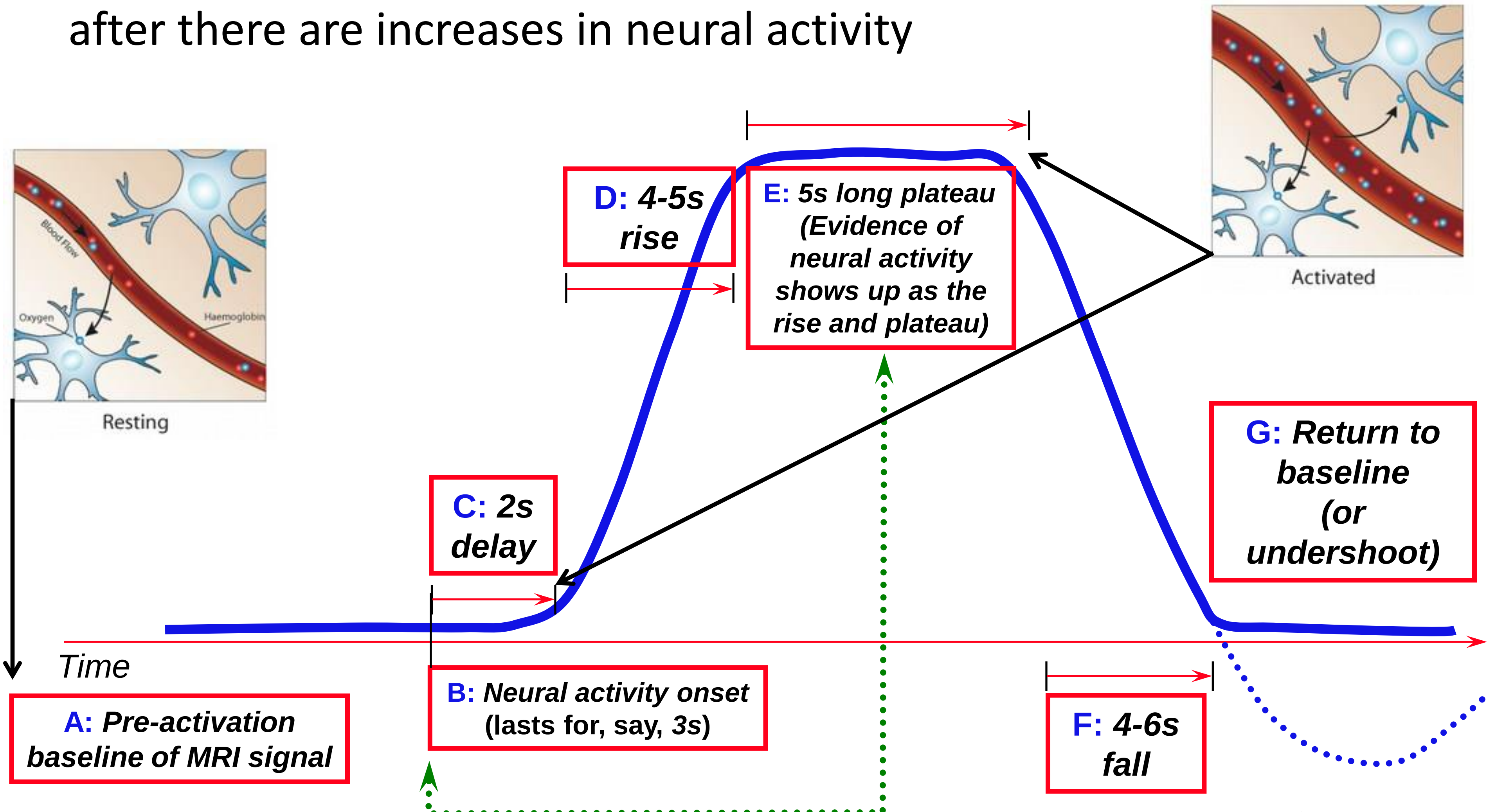
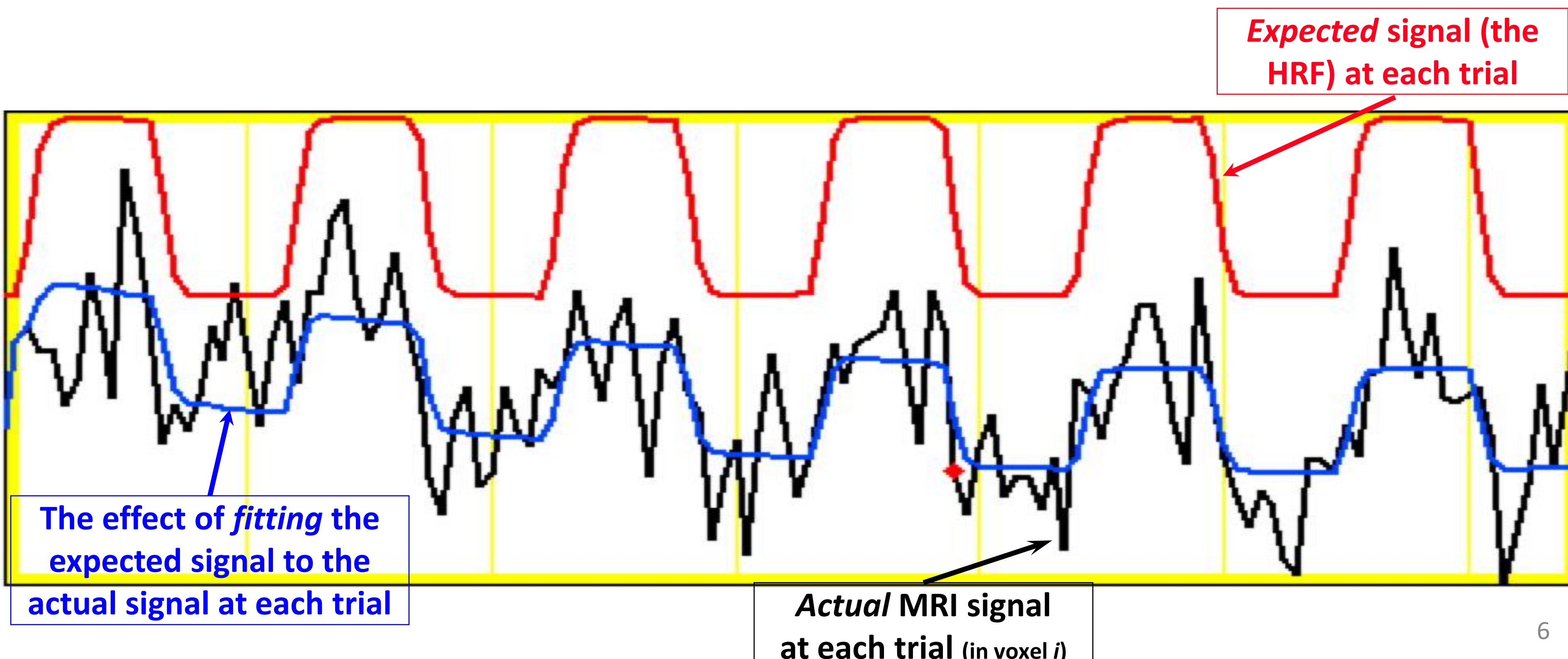


Image adapted from AFNI web site

Fitting the HRF to actual MRI signal (Quiz no. 3 slides 6, 19, 20)

- If a voxel is active, we expect its MRI signal to take the *same* HRF shape, regardless of the brain region it's in or which subject's data it is
- "Brain activation level" of condition *x* in voxel *i* = how well the HRF *fits* (and the magnitude/height of the fitted waveforms) to the actual MRI signal during that condition's trials



What is "brain activation level" in fMRI?

- Voxel-wise GLM regression model: $y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_n x_n + \varepsilon$

  y: MRI signal (time series) at a voxel – **different** across voxels

  x: independent variables/conditions (regressors) – **same** across voxels

  β: regression coefficients (HRF fits/magnitudes) – **different** across voxels

  ε: residuals (data unaccounted for by model) – **different** across voxels

We are measuring this

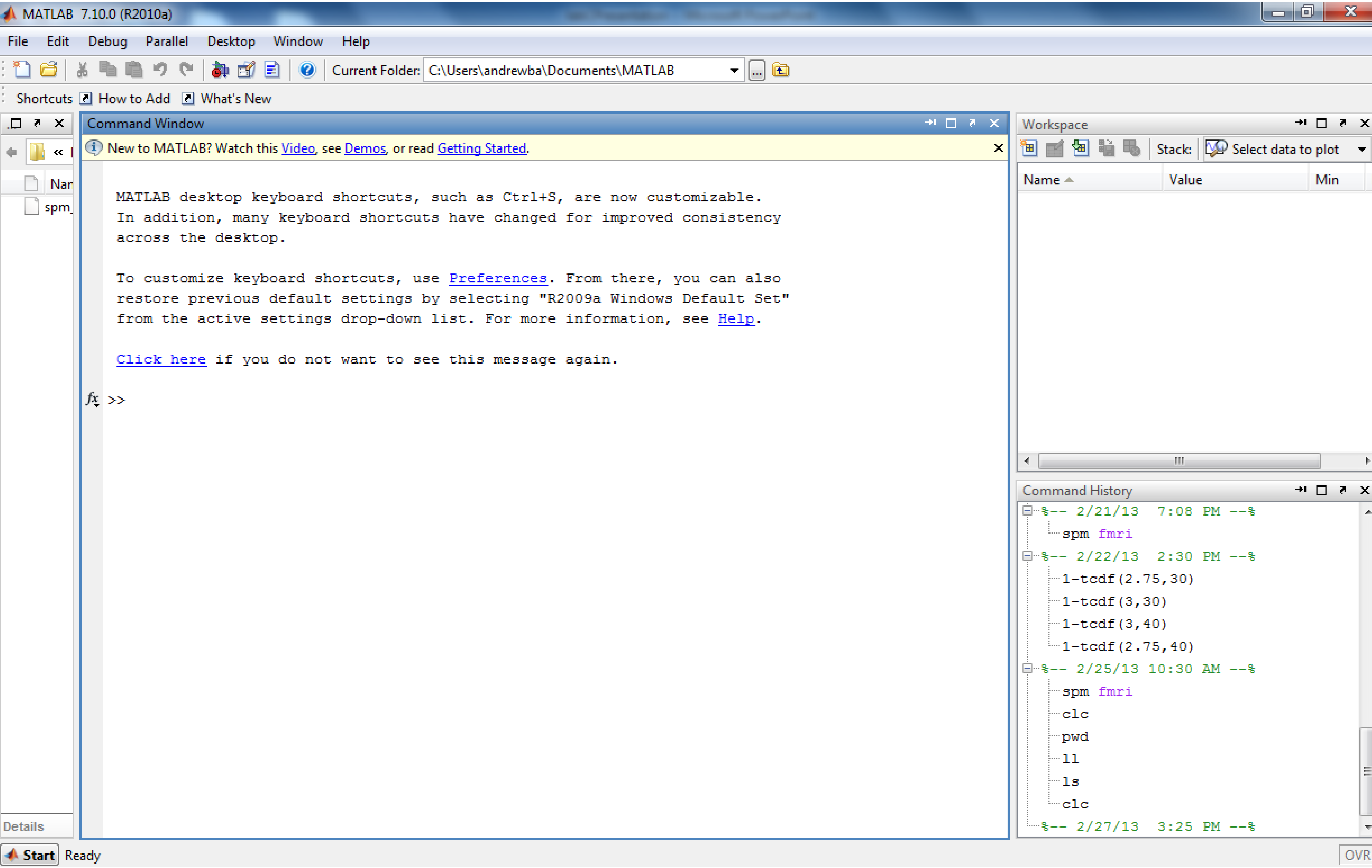
- So the β coefficient is the ***brain activation level*** associated with a particular condition x

  - In our case, the conditions are the different object concept *categories*

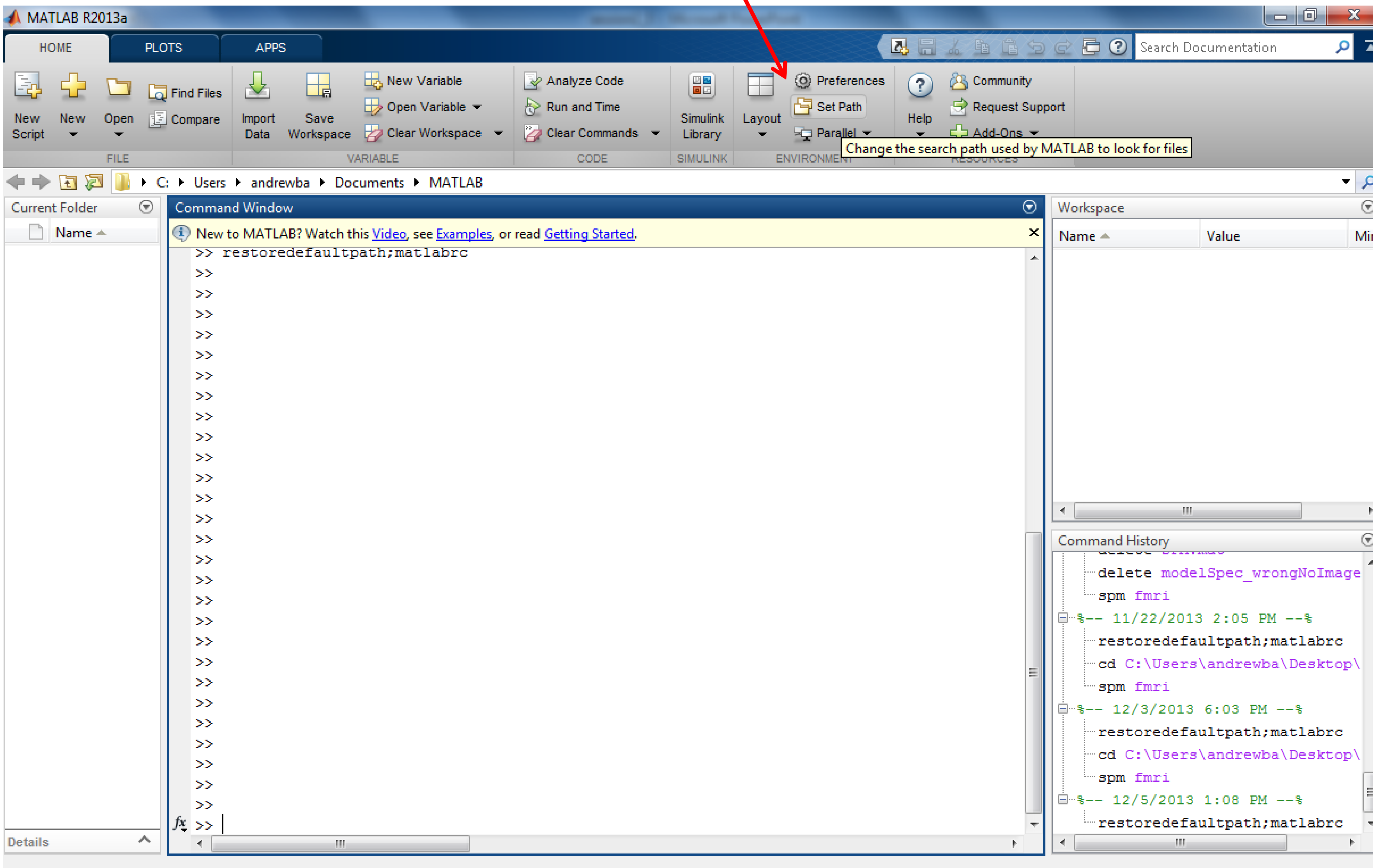
  - The model estimates the β value for each condition by how well the HRF fits (and its magnitude) the MRI signal over all a given condition's trials

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

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

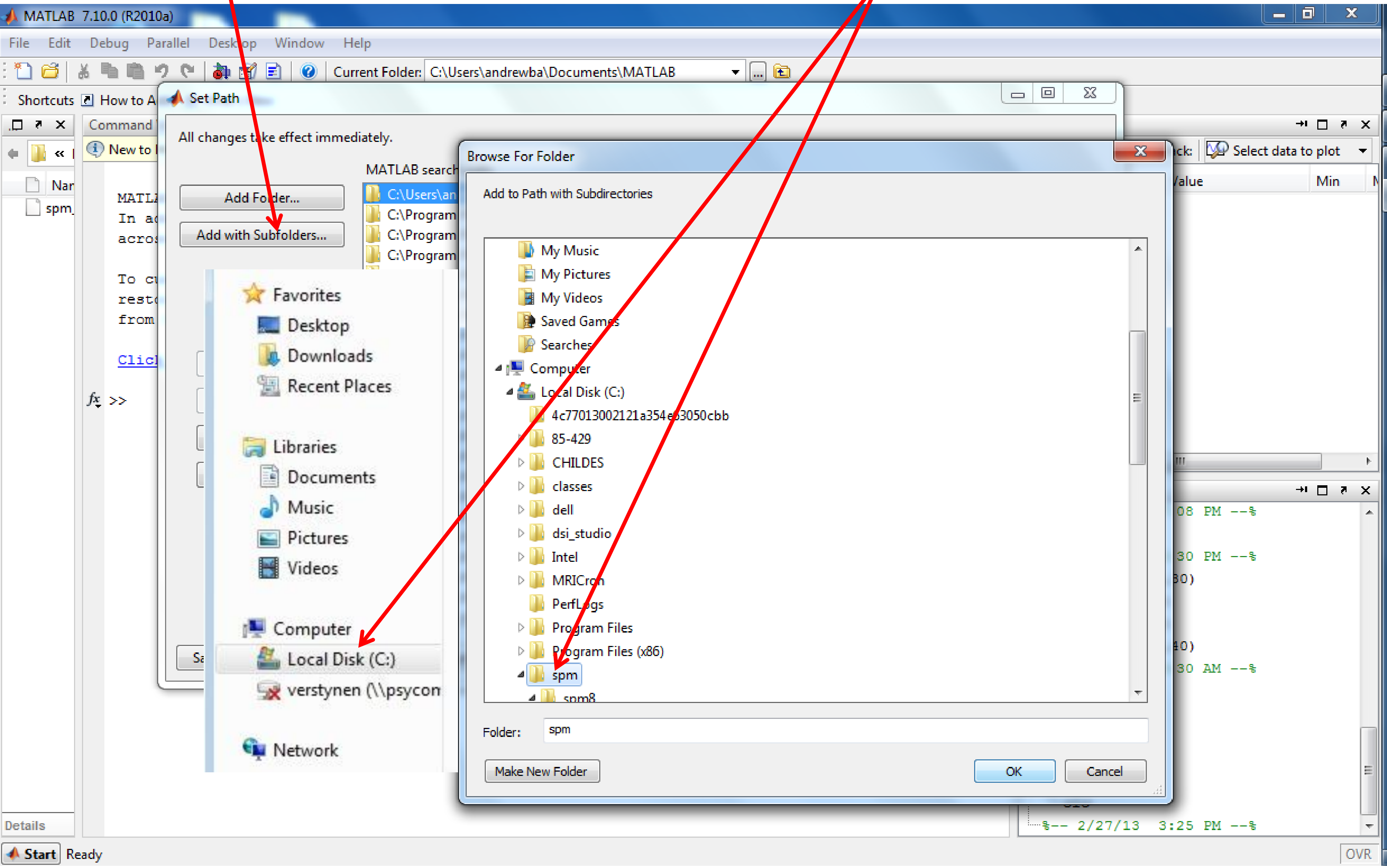


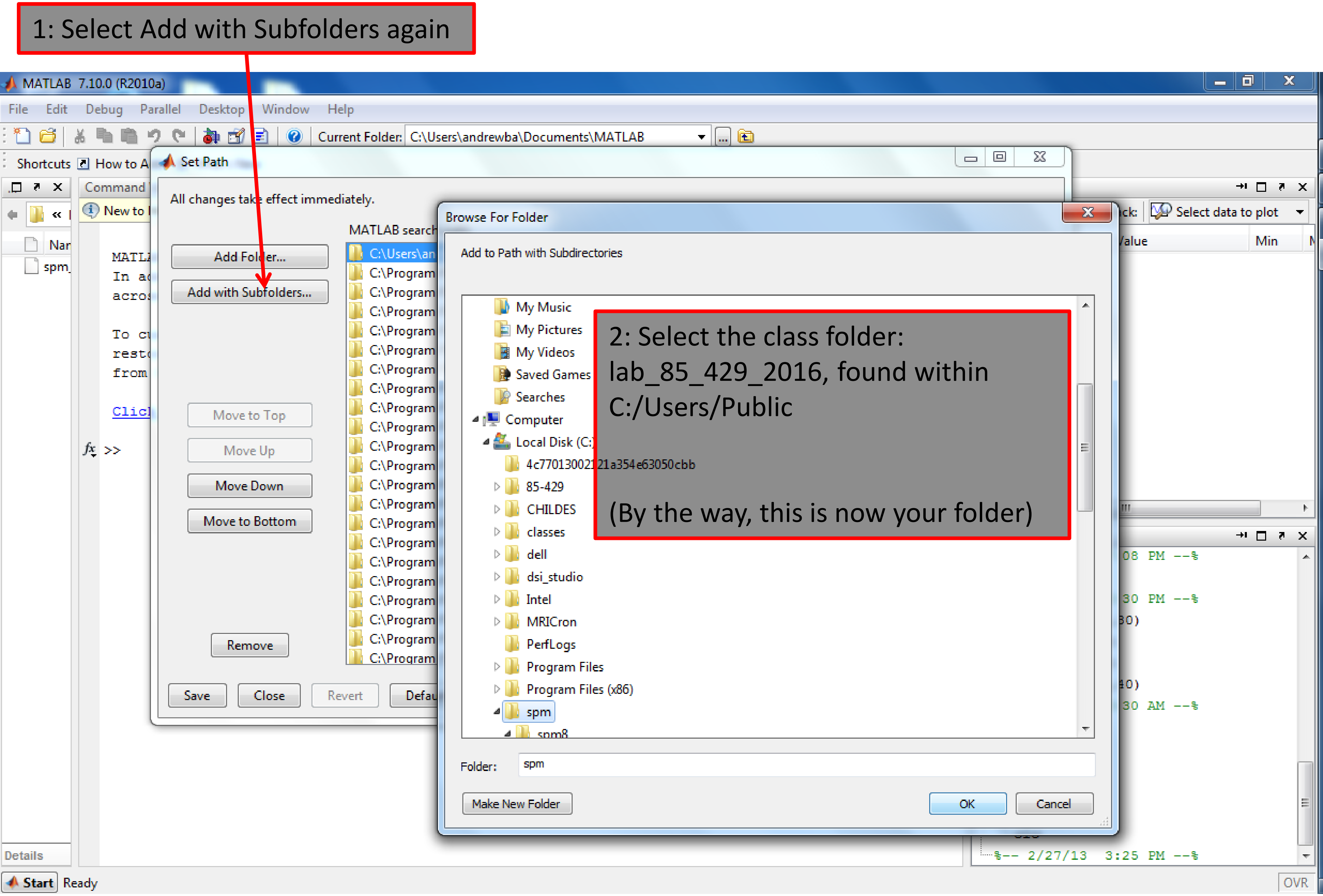
Select Set Path



1: Select Add with Subfolders

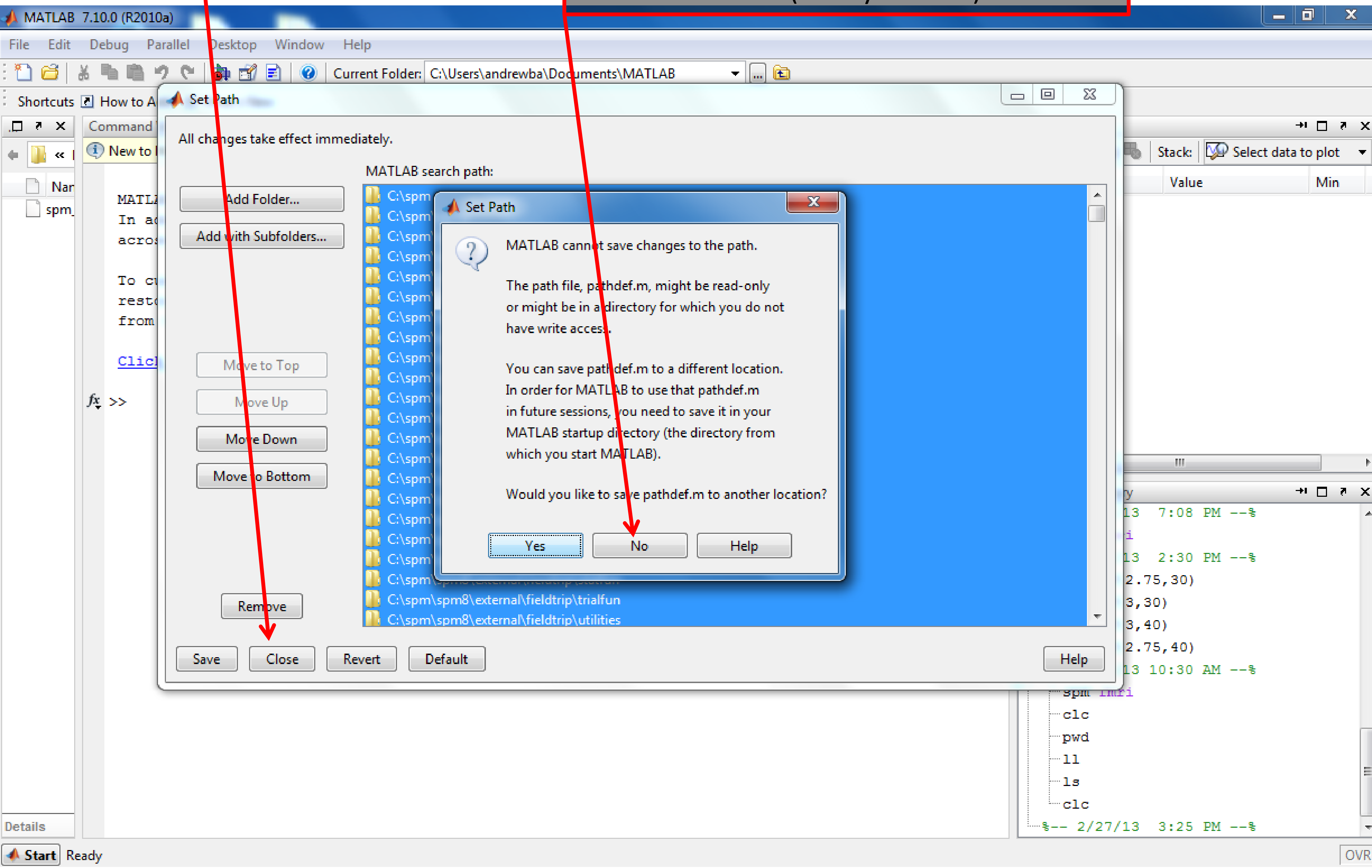
2: SINGLE-click the folder spm or spm8 under C:, click OK




1: Select Add with Subfolders again
2: Select the class folder: lab_85_429_2016, found within C:/Users/Public
(By the way, this is now your folder)
MATLAB 7.10.0 (R2010a)
Set Path
All changes take effect immediately.
Add Folder...
Add with Subfolders...
Move to Top
Move Up
Move Down
Move to Bottom
Remove
Save
Close
Revert
Browse For Folder
Add to Path with Subdirectories
Folder:
spm
Make New Folder
OK
Cancel

1: Select Close

2: Select No if it asks to save the path file somewhere else (it may not ask)

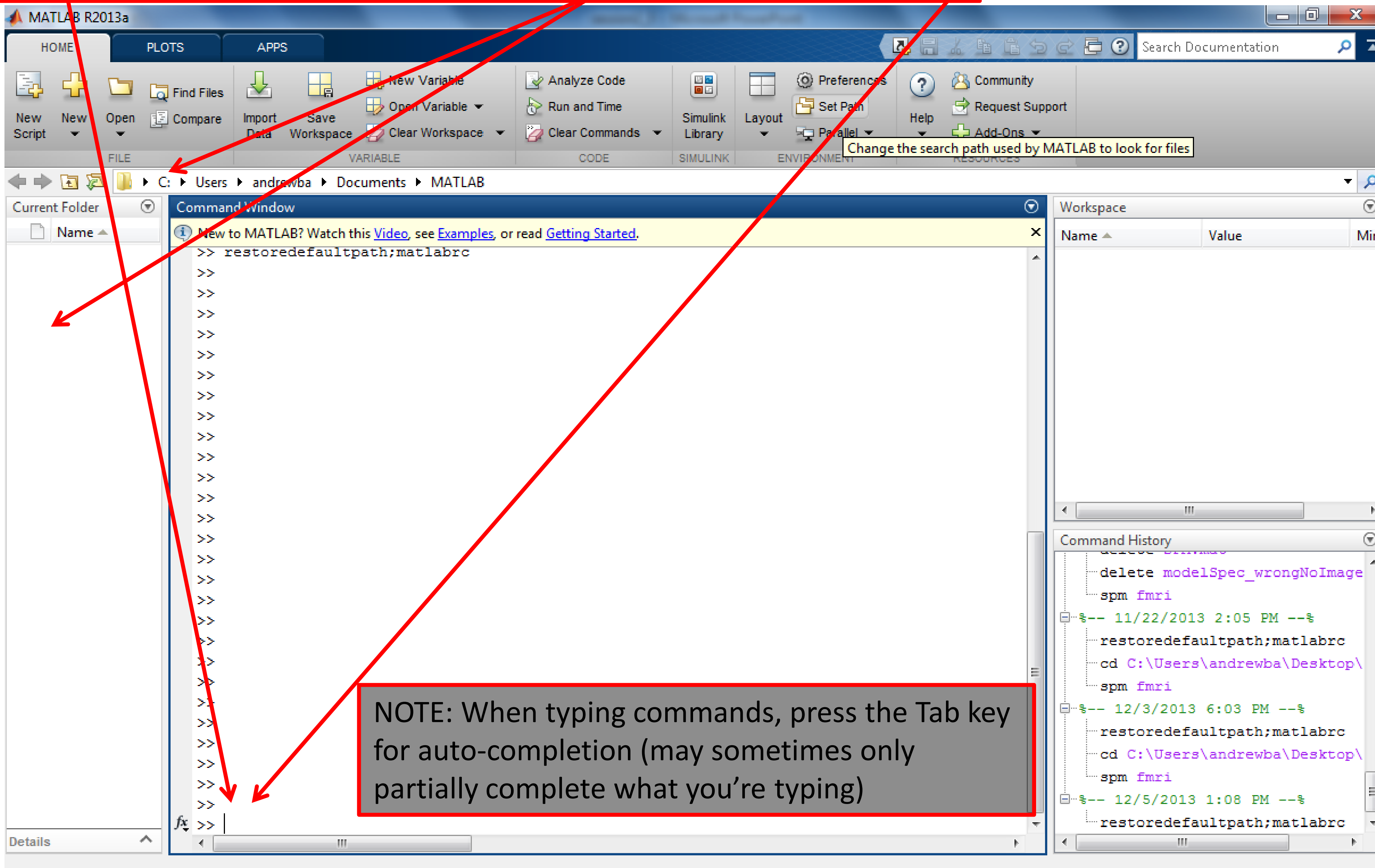


1: Go to the Matlab Command Window and type:

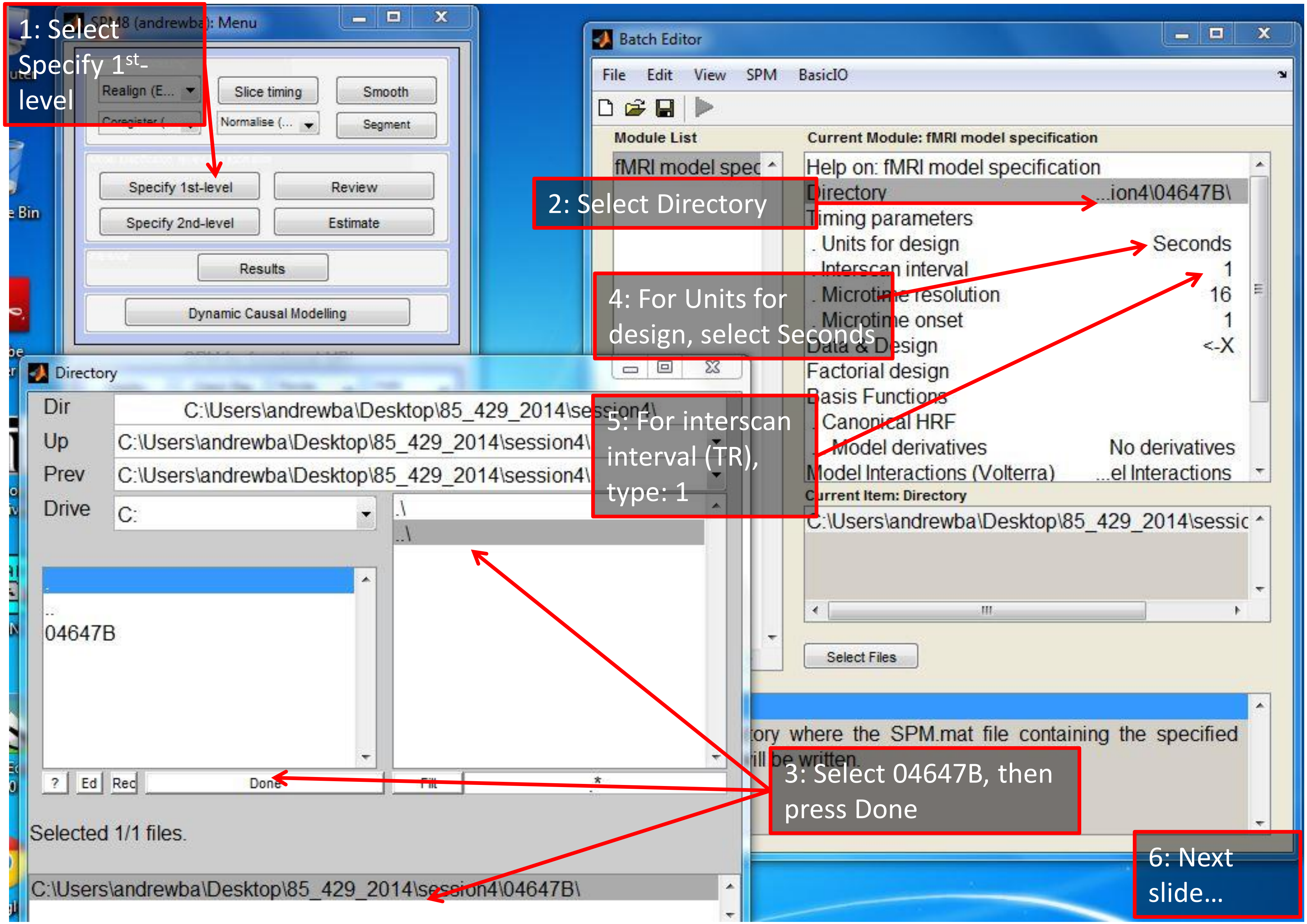
cd C:/Users/Public/lab_85_429_2016/session4

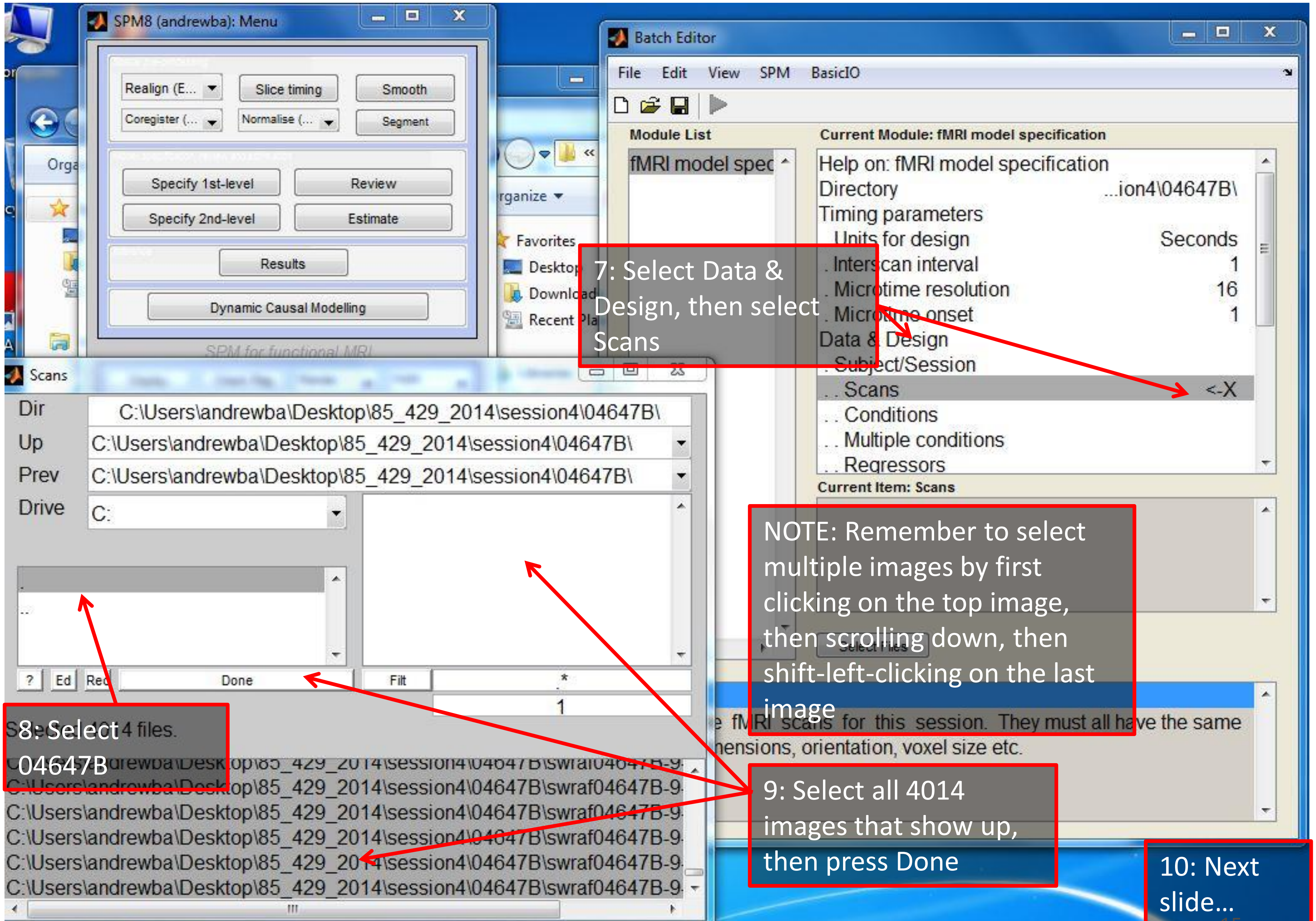
…(OR navigate there using the browser)

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 Specify 1st-level
SPM8 (andrewba): Menu
Realign (E...
Slice timing
Smooth
Coregister (
Normalise (...
Segment
Specify 1st-level
Review
Specify 2nd-level
Estimate
Results
Dynamic Causal Modelling
Batch Editor
File Edit View SPM BasicIO
Module List
fMRI model spec
Current Module: fMRI model specification
Help on: fMRI model specification
Directory ...ion4\04647B\
Timing parameters
. Units for design Seconds
. Interscan interval 1
. Microtime resolution 16
. Microtime onset 1
Data & Design <-X
Factorial design
Basis Functions
. Canonical HRF
. . Model derivatives No derivatives
Model Interactions (Volterra) ...el Interactions
Current Item: Directory
C:\Users\andrewba\Desktop\85_429_2014\sessic
Select Files
2: Select Directory
4: For Units for design, select Seconds
5: For interscan interval (TR), type: 1
Directory
Dir C:\Users\andrewba\Desktop\85_429_2014\session4\
Up C:\Users\andrewba\Desktop\85_429_2014\session4\
Prev C:\Users\andrewba\Desktop\85_429_2014\session4\
Drive C:
04647B
? Ed Rec Done Filt
Selected 1/1 files.
C:\Users\andrewba\Desktop\85_429_2014\session4\04647B\
3: Select 04647B, then press Done
6: Next slide...


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
Batch Editor
File Edit View SPM BasicIO
Module List
fMRI model spec
Current Module: fMRI model specification
Help on: fMRI model specification
Directory ...ion4\04647B\
Timing parameters
Units for design Seconds
Interscan interval 1
Microtime resolution 16
Microtime onset 1
Data & Design
Subject/Session
Scans <-X
Conditions
Multiple conditions
Regressors
Current Item: Scans
7: Select Data & Design, then select Scans
NOTE: Remember to select multiple images by first clicking on the top image, then scrolling down, then shift-left-clicking on the last image
fMRI scans for this session. They must all have the same dimensions, orientation, voxel size etc.
Scans
Dir C:\Users\andrewba\Desktop\85_429_2014\session4\04647B\
Up C:\Users\andrewba\Desktop\85_429_2014\session4\04647B\
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1
8: Select 04647B
4 files.
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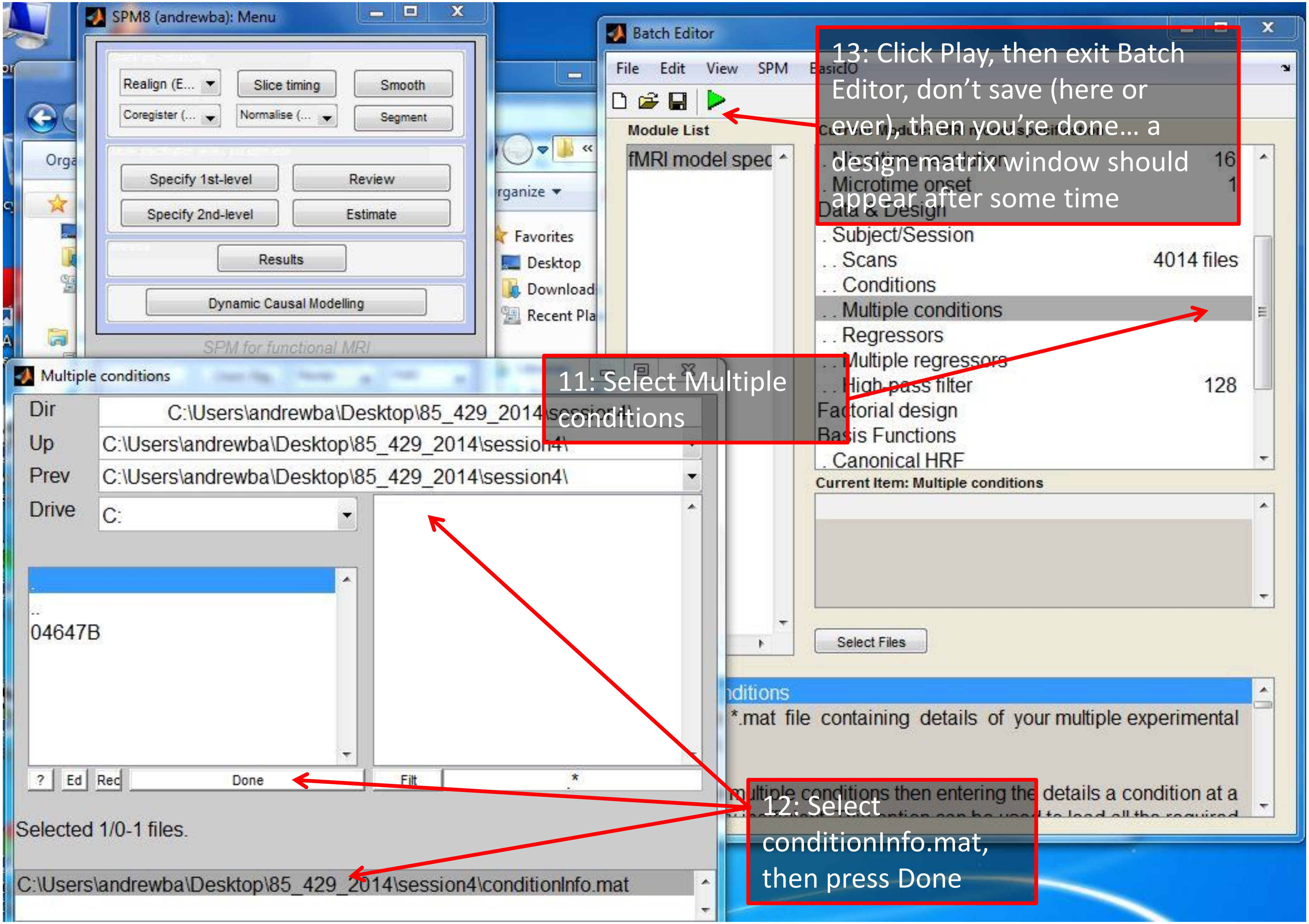
C:\Users\andrewba\Desktop\85_429_2014\session4\04647B\swraf04647B-9
C:\Users\andrewba\Desktop\85_429_2014\session4\04647B\swraf04647B-9
9: Select all 4014 images that show up, then press Done
10: Next slide…



SPM8 (andrewba): Menu
Realign (E...
Slice timing
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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
fMRI model spec
13: Click Play, then exit Batch Editor, don't save (here or ever), then you're done… a design matrix window should appear after some time
Microtime onset
Data & Design
. Subject/Session
. . Scans
4014 files
. . Conditions
. . Multiple conditions
. . Regressors
. . Multiple regressors
. . High-pass filter
128
Factorial design
Basis Functions
. Canonical HRF
Current Item: Multiple conditions
Select Files
*.mat file containing details of your multiple experimental
Multiple conditions
11: Select Multiple conditions
Dir
Up
C:\Users\andrewba\Desktop\85_429_2014\session4\
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C:\Users\andrewba\Desktop\85_429_2014\session4\
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04647B
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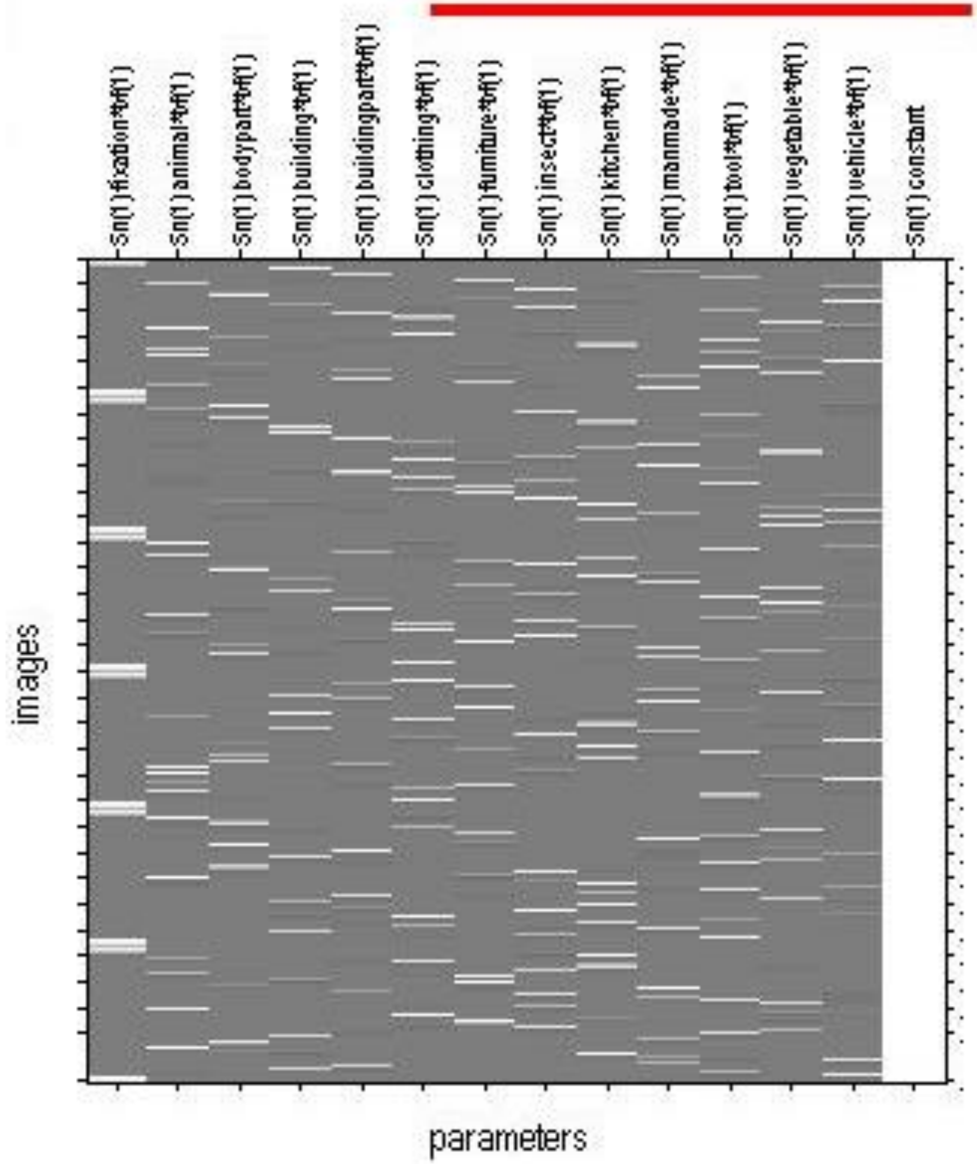
*
Selected 1/0-1 files.
C:\Users\andrewba\Desktop\85_429_2014\session4\conditionInfo.mat
12: Select conditionInfo.mat, then press Done

Statistical analysis: Design



Sn(1) fixation*bf(1)	=	Baseline
Sn(1) animal*bf(1)		Animal
Sn(1) bodypart*bf(1)		Bodypart
Sn(1) building*bf(1)		Building
Sn(1) buildingpart*bf(1)		Buildingpart
Sn(1) clothing*bf(1)		Clothing
Sn(1) furniture*bf(1)		Furniture
Sn(1) insect*bf(1)		Insect
Sn(1) kitchen*bf(1)		Kitchen
Sn(1) manmade*bf(1)		Manmade
Sn(1) tool*bf(1)		Tool
Sn(1) vegetable*bf(1)		Vegetable
Sn(1) vehicle*bf(1)		Vehicle
Sn(1) constant		Constant

Programming statistical β contrasts to compare…

- Activation of one condition vs. Baseline ("Resting")
- Activation between two different conditions
  - Baseline cancels out (see below)

Contrast	Baseline multiplier	Tools multiplier	Buildings multiplier	Statistical result (*t-stat and p-value*) in <u>each</u> voxel
$\beta_{Tools} - \beta_{Baseline}$	-1	1	0	*Tools activation that is > "Resting"*
$\beta_{Buildings} - \beta_{Baseline}$	-1	0	1	*Buildings activation that is > "Resting"*
$\beta_{Tools} - \beta_{Buildings}$ *i.e. (Tools - Baseline) - (Buildings - Baseline)*	0	1	-1	*(Tools > "Resting") that is > (Buildings > "Resting")*
$\beta_{Buildings} - \beta_{Tools}$ *i.e. (Buildings - Baseline) - (Tools - Baseline)*	0	-1	1	*(Buildings > "Resting") that is > (Tools > "Resting")*

Data preprocessing sequence (Quiz no. 3 slides 6, 19, 20)

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
   - Need to correct for fact that brain slices are not collected simultaneously each image acquisition (TR)
3. Spatial normalization
   - Morphs each subject's brain to a common/template brain to examine activation in same locations across subjects
4. Smoothing
   - Reduces amount of noise per voxel by averaging over nearby voxels

Final notes about data preprocessing

(Quiz no. 3: Slides 6, 19, 20)

- In brain imaging <u>and other fields</u>, data processing can result in ***loss*** or ***artificial creation*** of data
  - Smoothing (you control how much)
    - ***Lose*** small fluctuations in data that might be real
    - 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, ***creating an artificial*** cluster of activation
  - Spatial normalization
    - ***Lose*** data due to the normalization algorithm tampering with the original data
    - ***Lose*** individual quirks of a person's data

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