Lab session 6:

Within-subject multi-voxel pattern classification analysis (MVPA)

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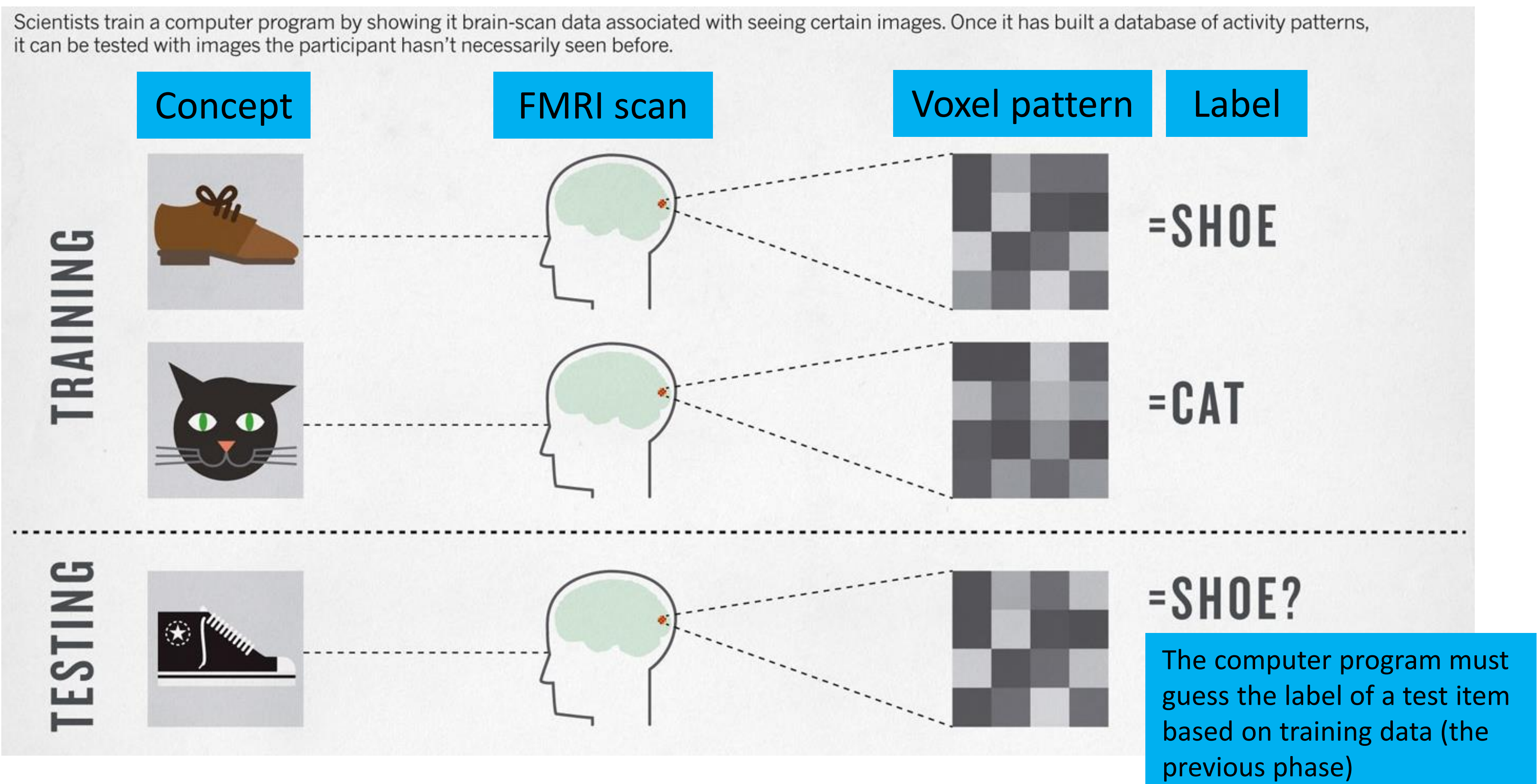
02/17/16

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)		

How MVPA works

- Detects patterns of brain activation – no averaging/smoothing over voxels
- Is a more sensitive tool of brain mapping than standard GLM/SPM analysis
  - Can distinguish between activation patterns of similar concepts

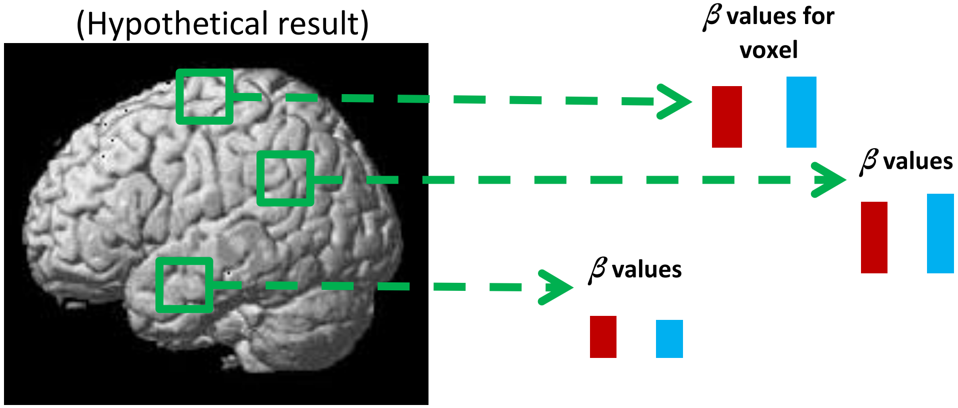


Are there differences in activation between object concepts? GLM and MVPA approach this question differently

Tools vs. other object categories

(Hypothetical result)

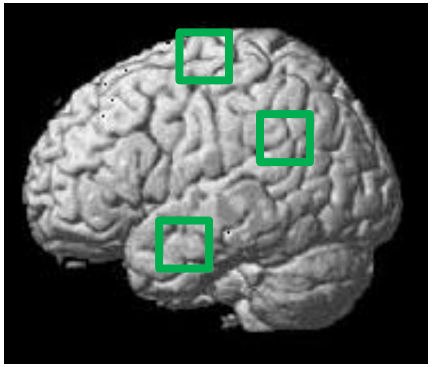
GLM contrast in each voxel

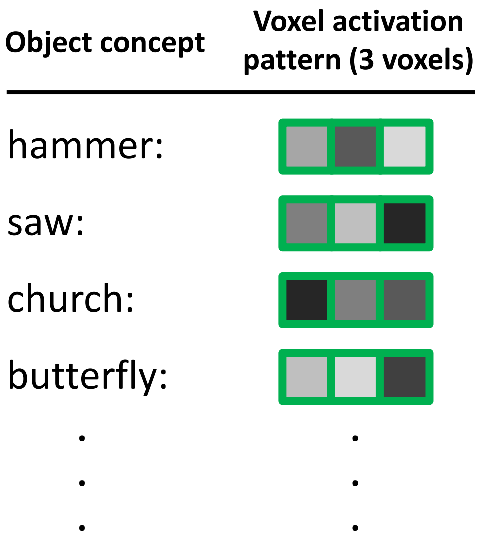


- GLM considers each single voxel *in isolation*
- Within a voxel, GLM compares conditions' activation *levels* (β)
- On the left: It appears **Tools** does not activate the brain differently, compared to **other** categories, in each voxel (see the three voxels)

MVPA using pattern of 3 voxels

Get response signal from each selected voxel (not to scale) for each object concept…





- MVPA considers *interactions* of voxels, and compares *patterns*; it uses the data to a fuller extent, and is thus more sensitive, than GLM
- On the left: Although GLM (above) shows no significant difference in activation *levels* in any single voxel for **Tools** vs. **others**, the voxel activation *patterns* between **Tools** and **other** concepts *are* different (i.e. are reliably distinguishable)

Neural representation/storage of concept meaning

- MVPA asks: Are individual tool concepts represented in some brain areas?
- I.e. are there brain areas that encode rich information about different tool concepts?
  - GLM is not a sensitive enough method

GLM contrast (our actual result):
Tools vs. other object categories

Two possible MVPA results:
Representation of tool concepts?

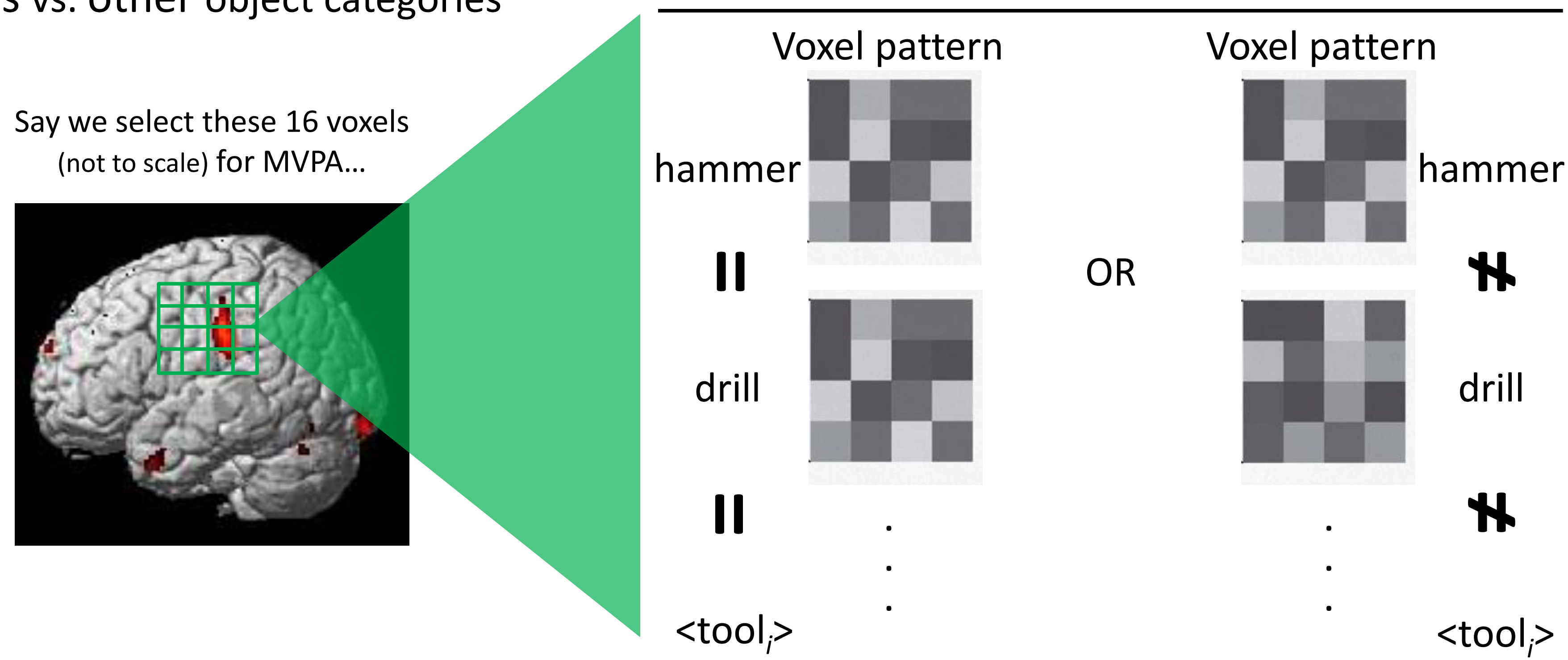


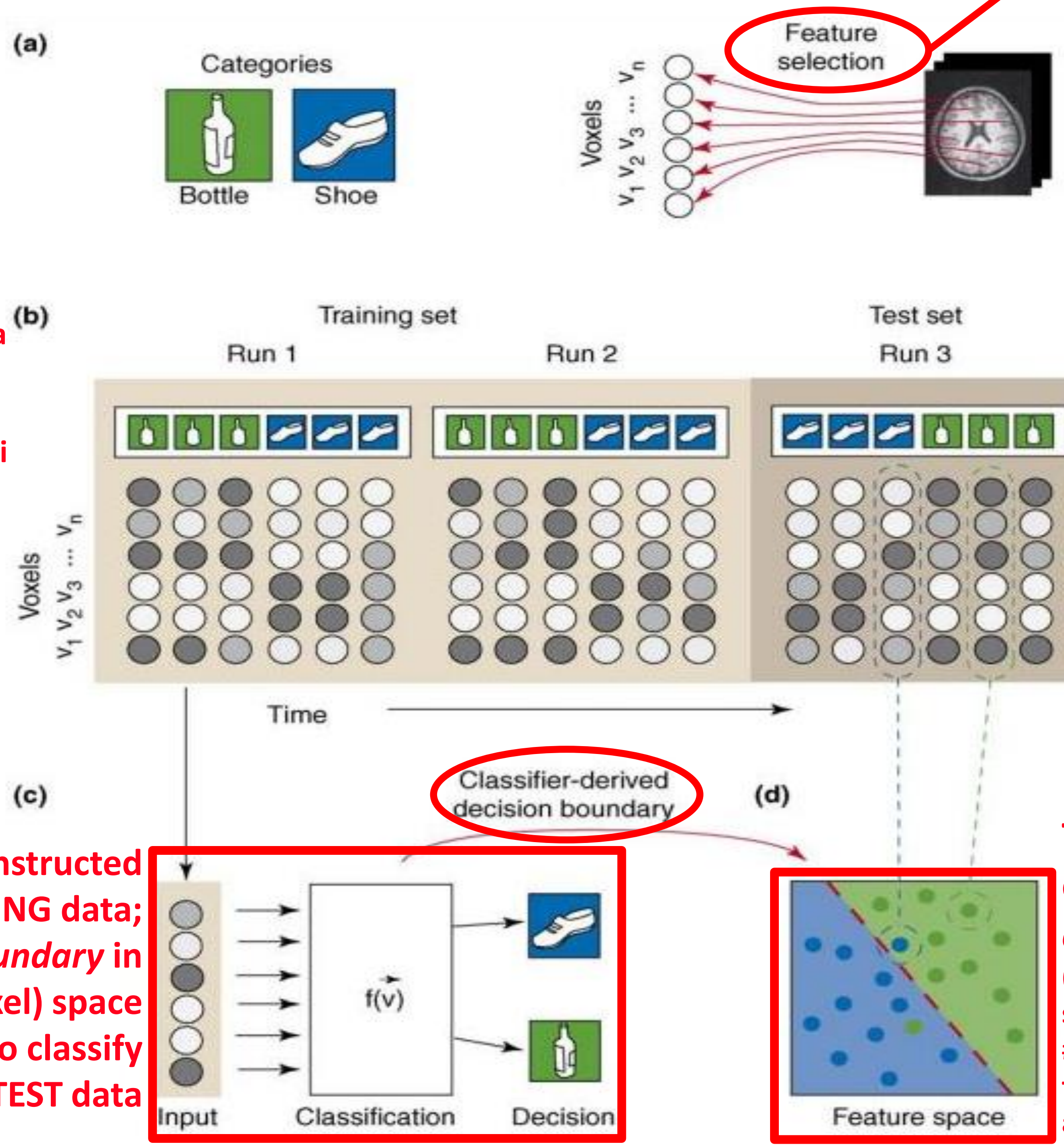
Image from
Norman et al. (2006)

How MVPA works (detailed level)

The bottle and shoe pictures are presented 3 times in each run (or *scan*); there are 3 runs

We select only a subset of voxels; we choose active voxels that come from sensible brain regions ("feature selection" is a general term in machine learning)

We separate the data into TRAINING and TEST sets. We presented our stimuli multiple times so that we could train a classifier on some repetitions, and test it on the remaining repetitions



The classifier is constructed from the TRAINING data; its *decision boundary* in feature (voxel) space is used to classify the TEST data

The TEST data are compared to the *decision boundary*
(feature space is simplified to 2D here; # dimensions = # voxels that make up the activation patterns)

Full image and caption, Norman et al. (2006)

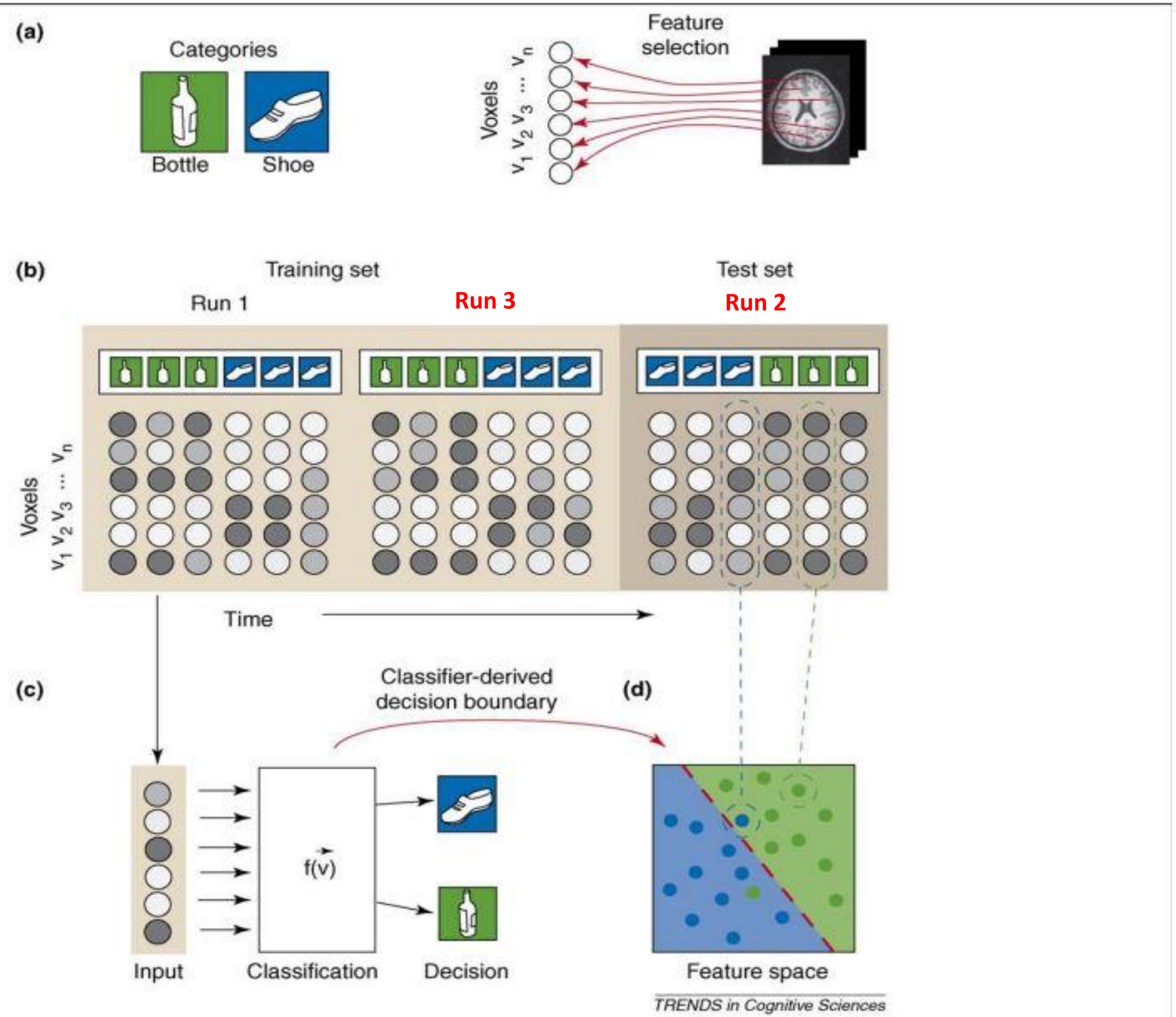
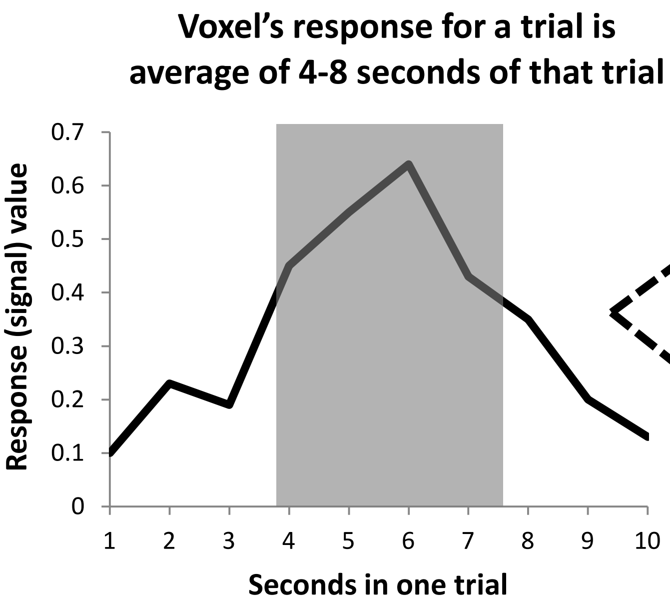


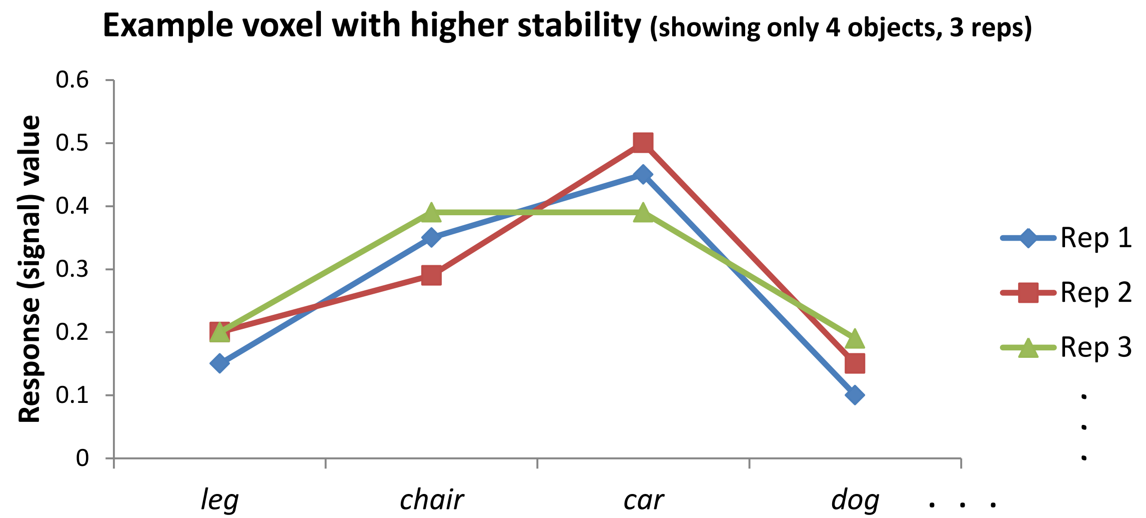
Figure 1. Illustration of a hypothetical experiment and how it could be analyzed using MVPA. **(a)** Subjects view stimuli from two object categories (bottles and shoes). A 'feature selection' procedure is used to determine which voxels will be included in the classification analysis (see Box 1). **(b)** The fMRI time series is decomposed into discrete brain patterns that correspond to the pattern of activity across the selected voxels at a particular point in time. Each brain pattern is labeled according to the corresponding experimental condition (bottle versus shoe). The patterns are divided into a training set and a testing set. **(c)** Patterns from the training set are used to train a classifier function that maps between brain patterns and experimental conditions. **(d)** The trained classifier function defines a decision boundary (red dashed line, right) in the high-dimensional space of voxel patterns (collapsed here to 2-D for illustrative purposes). Each dot corresponds to a pattern and the color of the dot indicates its category. The background color of the figure corresponds to the guess the classifier makes for patterns in that region. The trained classifier is used to predict category membership for patterns from the test set. The figure shows one example of the classifier correctly identifying a bottle pattern (green dot) as a bottle, and one example of the classifier misidentifying a shoe pattern (blue dot) as a bottle.

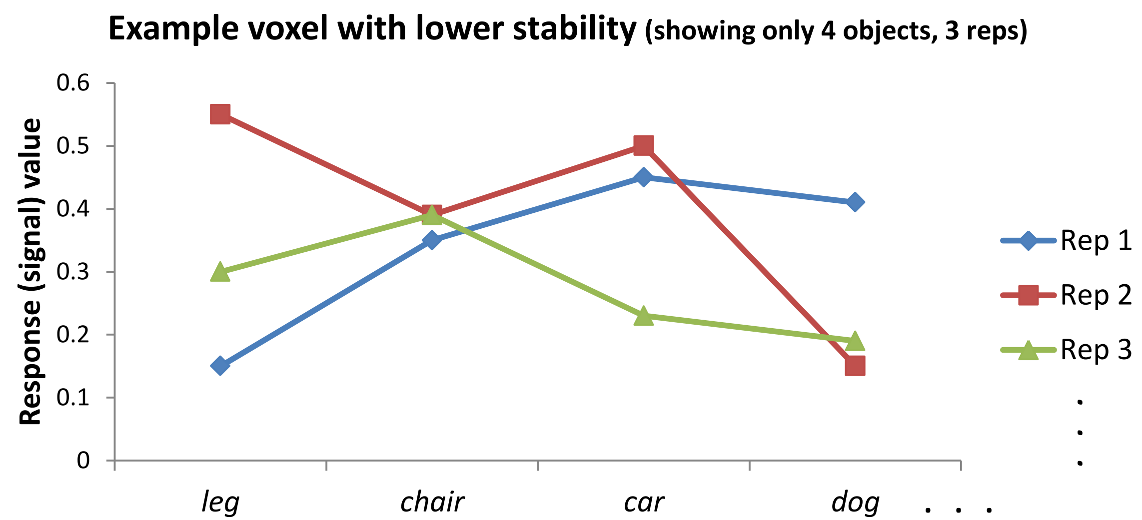
The process goes through many iterations, or "folds", partitioning the data into TRAINING and TEST sets differently every time

The final output is the classification accuracy (i.e. how well did it label the TEST data?) averaged over all the iterations of separating the TRAINING and TEST data

For our experiment, *voxel (feature) selection* picks the most stable voxels (<u>stability</u>: the consistency of a voxel's response profile to all 60 words over the 6 trial repetitions)







Interpreting MVPA results

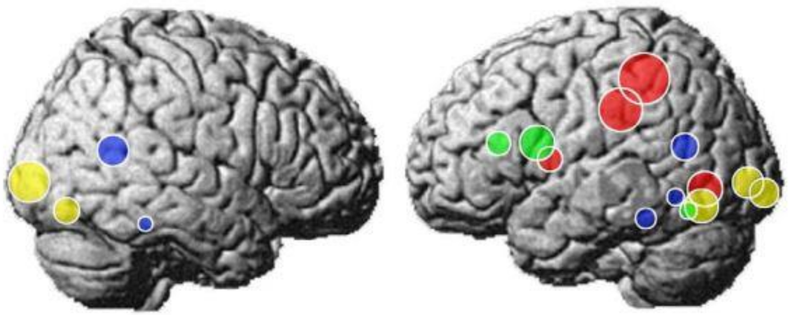
- Say that we can classify all the object concepts *very well* using *all* voxels, in *all* brain areas
  - Not an interesting result because we are not specific enough… which brain areas contribute most to the classification?, which are noise?, etc.
- Say that we can classify all the object concepts *very well* using voxels from the brainstem, or from white matter
  - Not a plausible or interpretable result, given what we know about the functions of the brainstem and white matter
    - Either this result *really is* due to chance
    - Or result *not* due to chance, but there is a problem with our stimuli or stimulus presentation method, e.g. stimuli not randomized properly

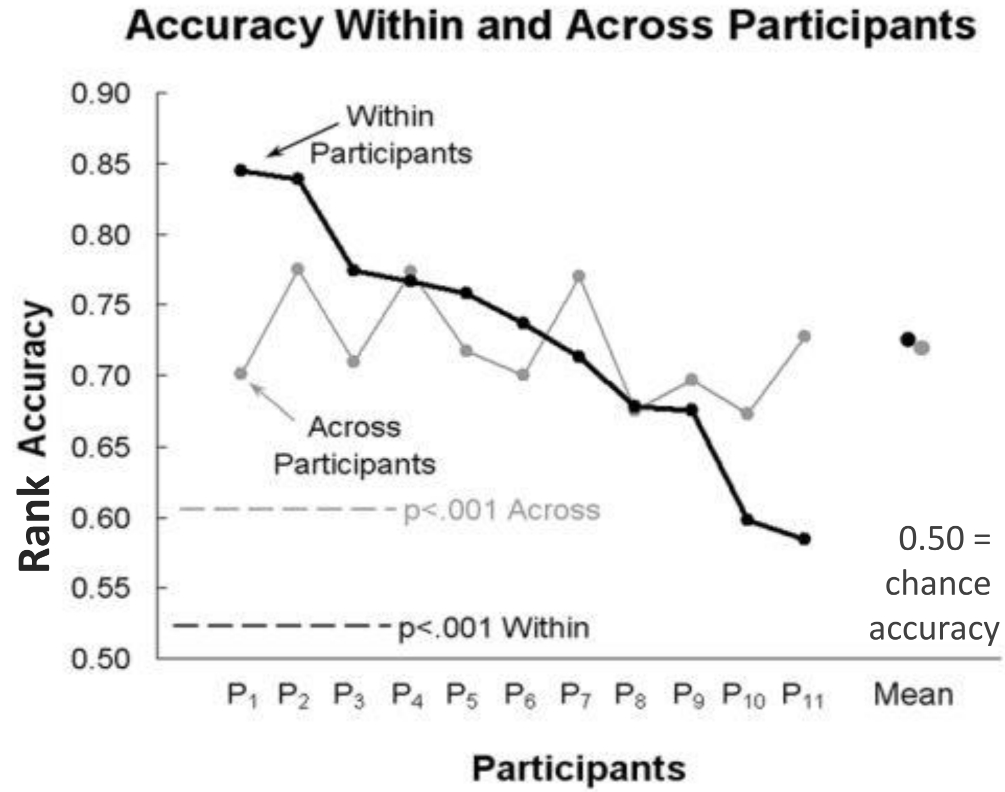
Interpreting MVPA results cont.

- Only when we successfully classify using voxels from (*i*) *specific* and (*ii*) *functionally interpretable* brain areas…

- … can we suggest that those activation patterns are the neural codes by which object concept meaning is *represented* (i.e. stored, processed) in the brain

We can classify individual object concepts using a small number of functionally interpretable voxels (Just et al., 2010)

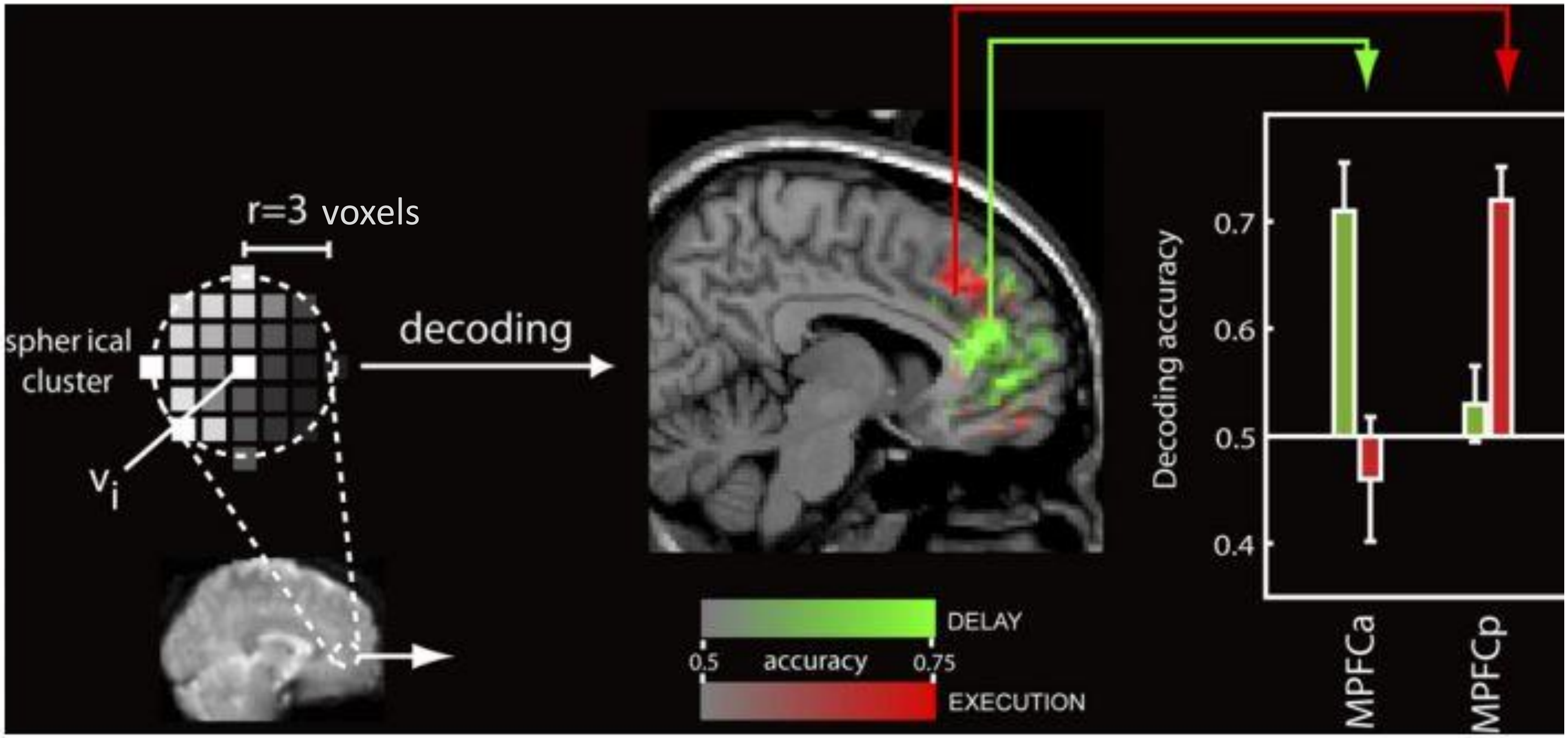




0.50 = chance accuracy

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

… but we can also classify covert intentions to execute actions



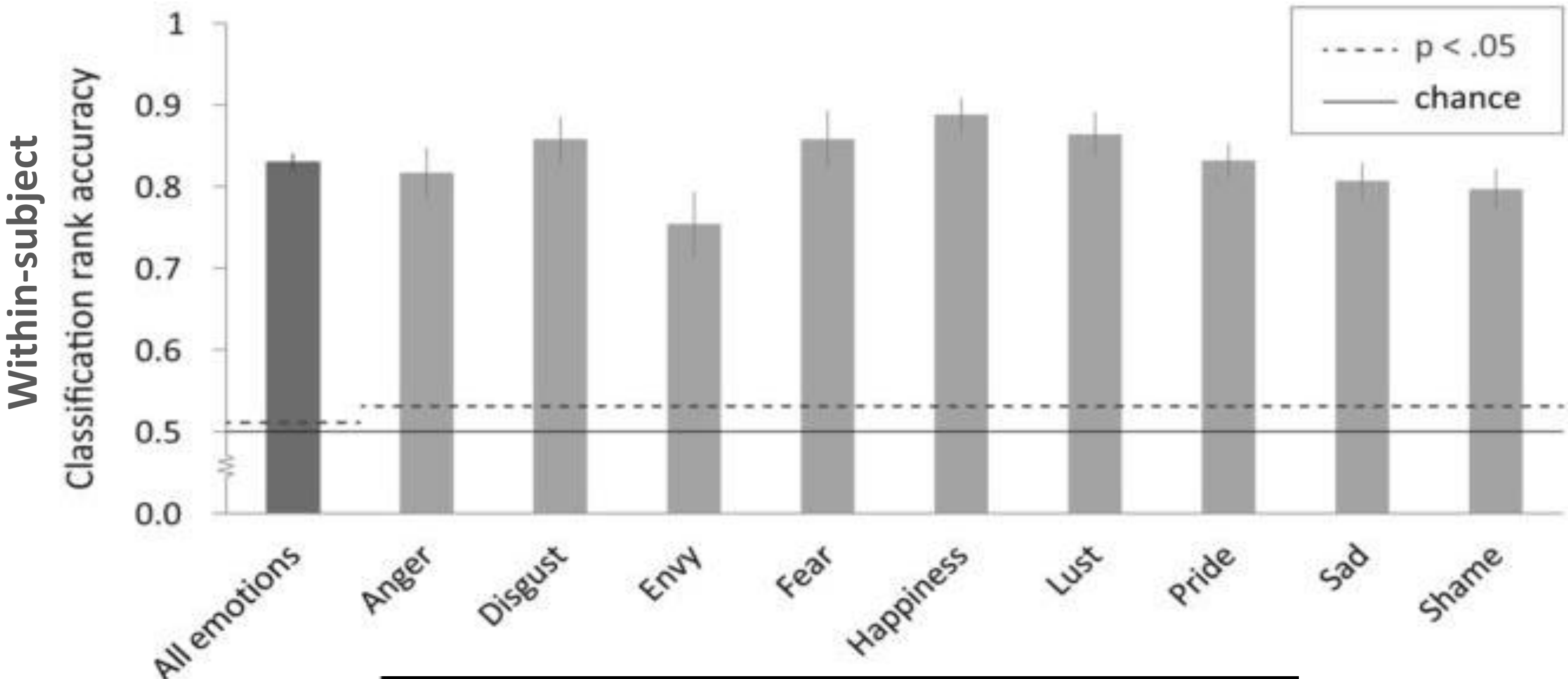
0.5 = chance accuracy

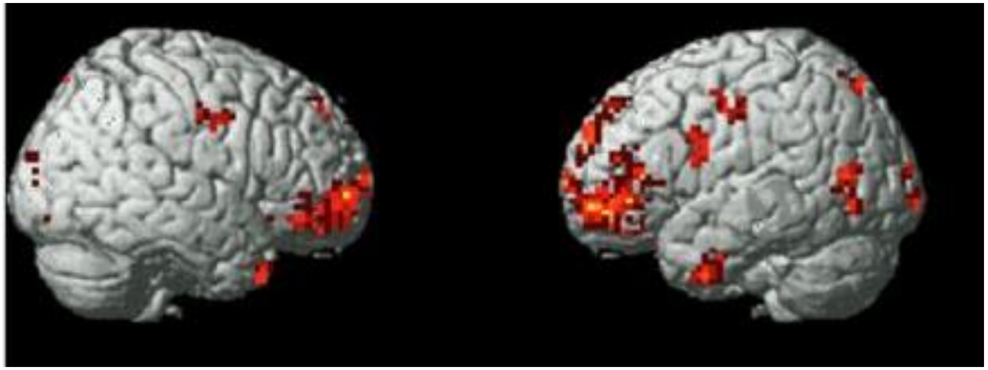
DELAY: **Covertly maintaining intention in mind (but doing nothing physically)**

EXECUTION: **At end of delay, actually carrying out the intended action**

Haynes et al. (2007)

… and we can classify emotions (feeling or thinking about them)





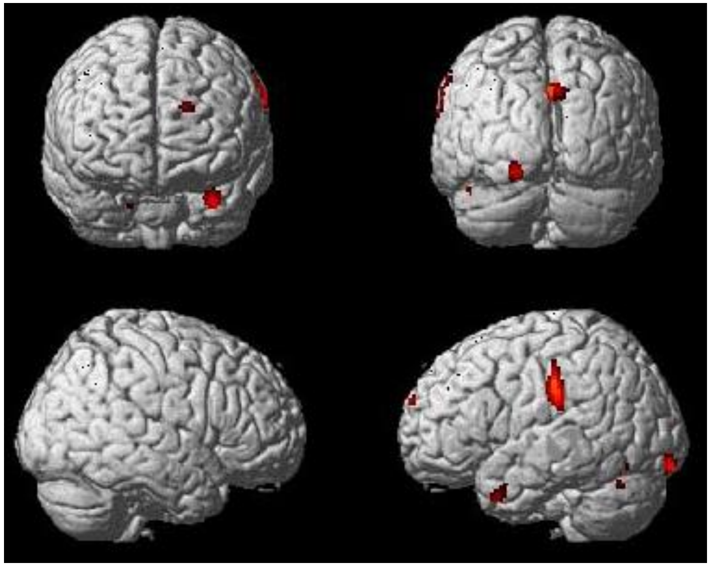
Kassam al. (2013)

MVPA in action: Brain activity while thinking about tools

(Class activity to practice for assignment)

- There is only a little bit of GLM activation for the *Tools vs. others* contrast in the frontal lobe (see below image)…
  1. Does this mean that the Tools activation in the frontal lobe does *not* differ from activation of the other categories? *Test with MVPA*
  2. MVPA tells us if any conceptual meaning about different tools is stored in this lobe (answer is *yes* if can classify above chance level)

Shown in red: areas of positive *or* negative GLM activation



Questions you will explore in the assignment

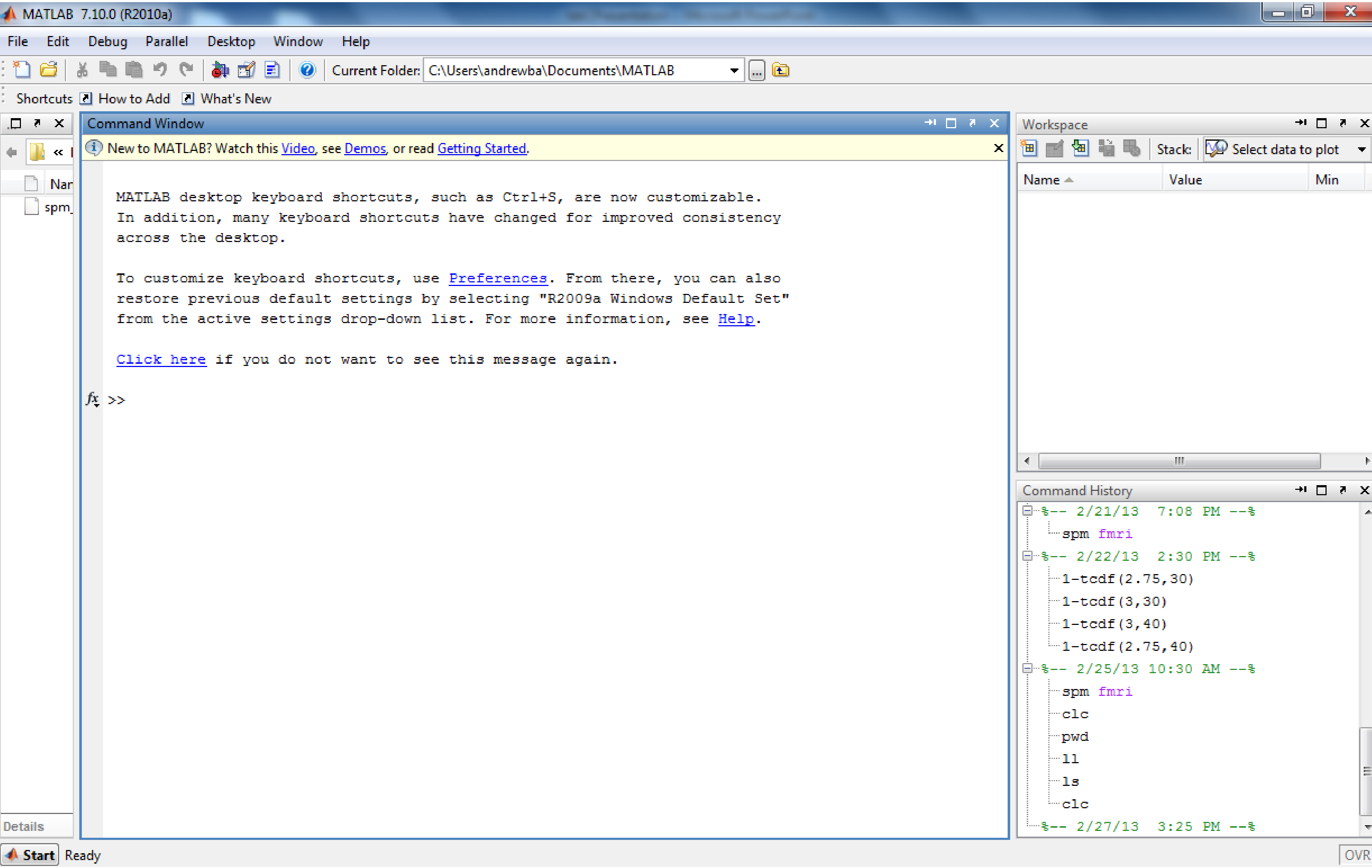
- How does classification accuracy change as a function of the *number* of selected voxels?
  - How should a change (if any) be interpreted in terms of the neural representations of the object concepts?

- Is there a difference in how well *different* brain areas classify the object concepts? Why (if so)?

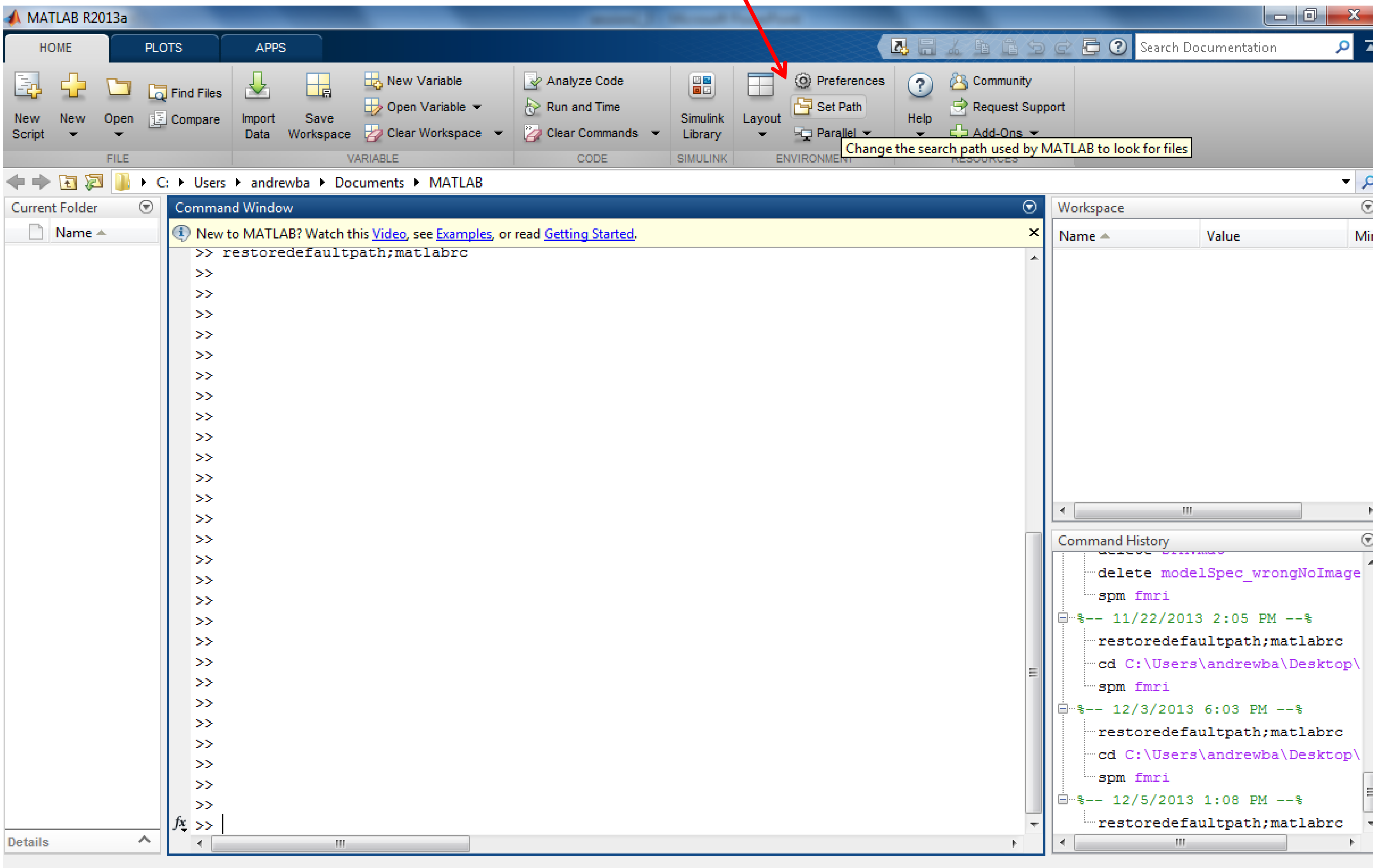
- What happens when *multiple* different brain areas are used for classification vs. just *one* area? What does this say about the neural representations of the object concepts?

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

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

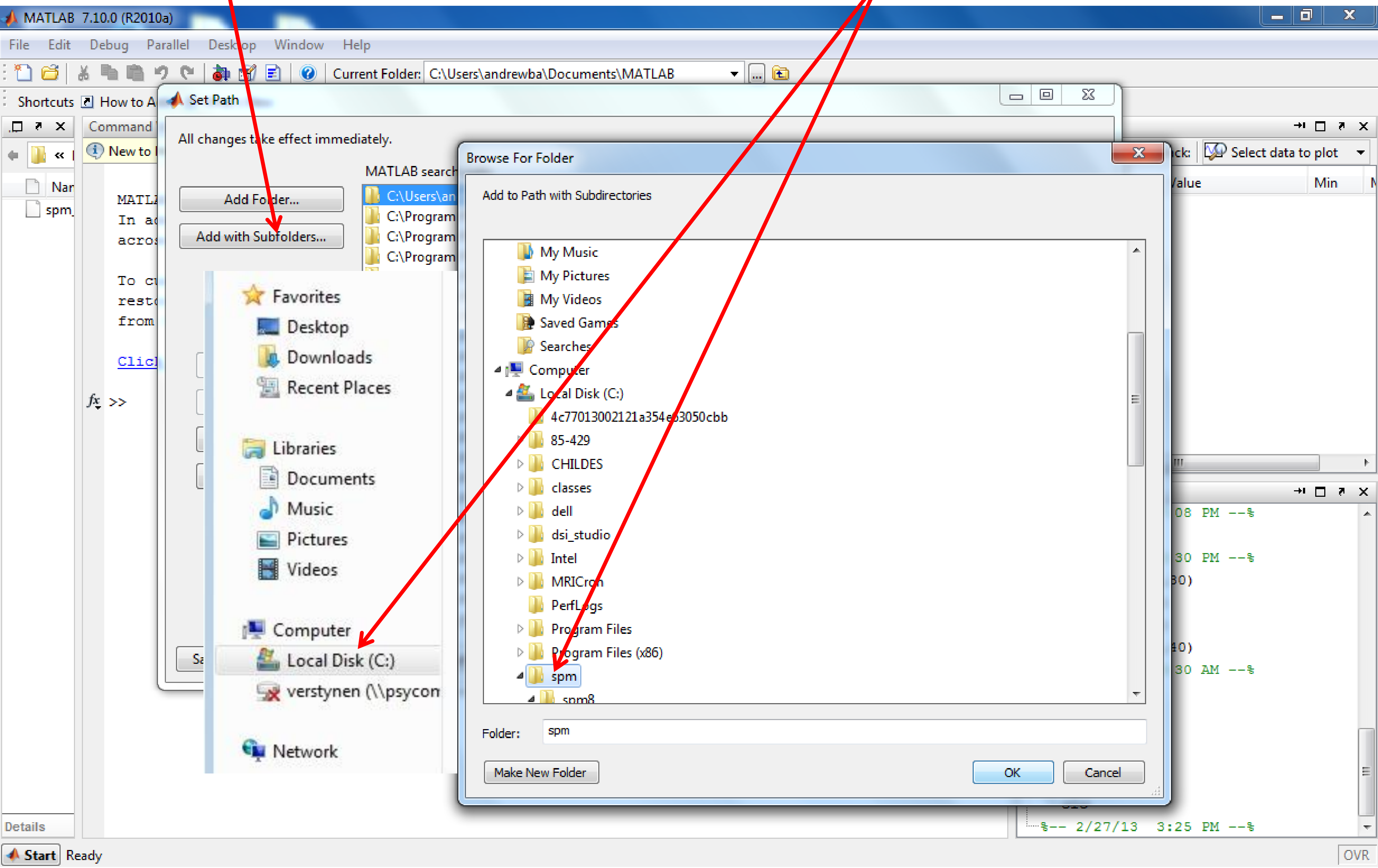


Select Set Path

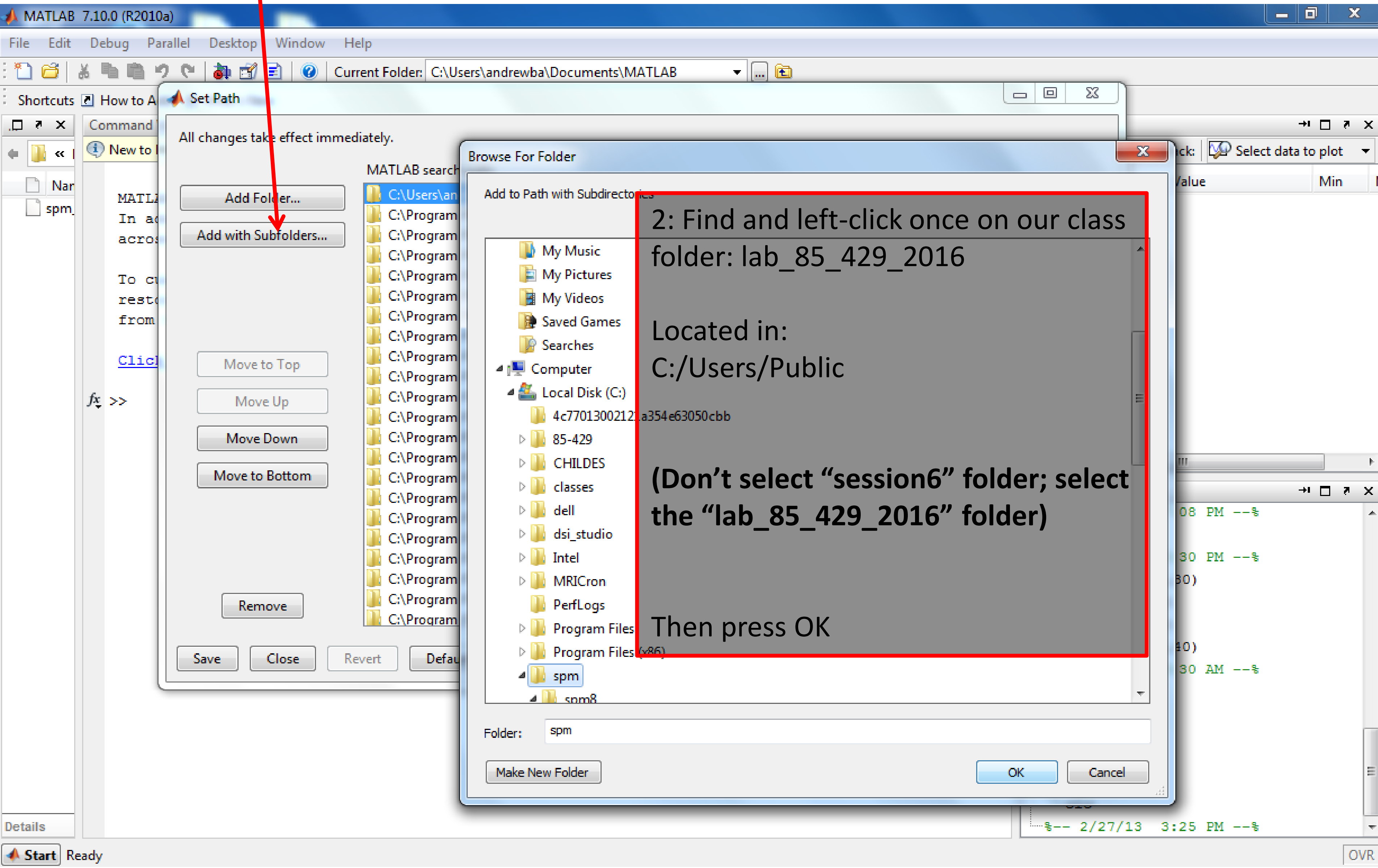


1: Select Add with Subfolders

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

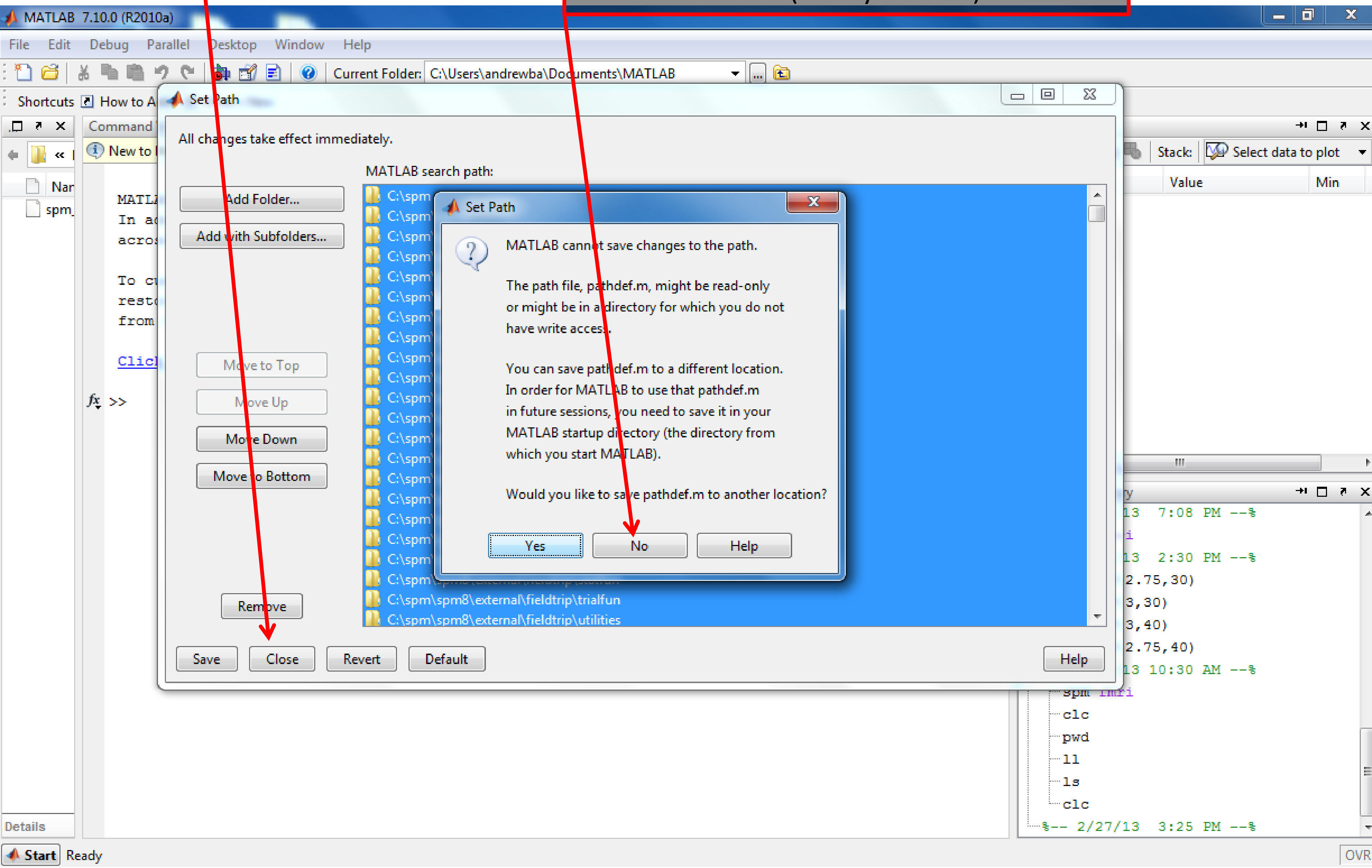


1: Select Add with Subfolders again



1: Select Close

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

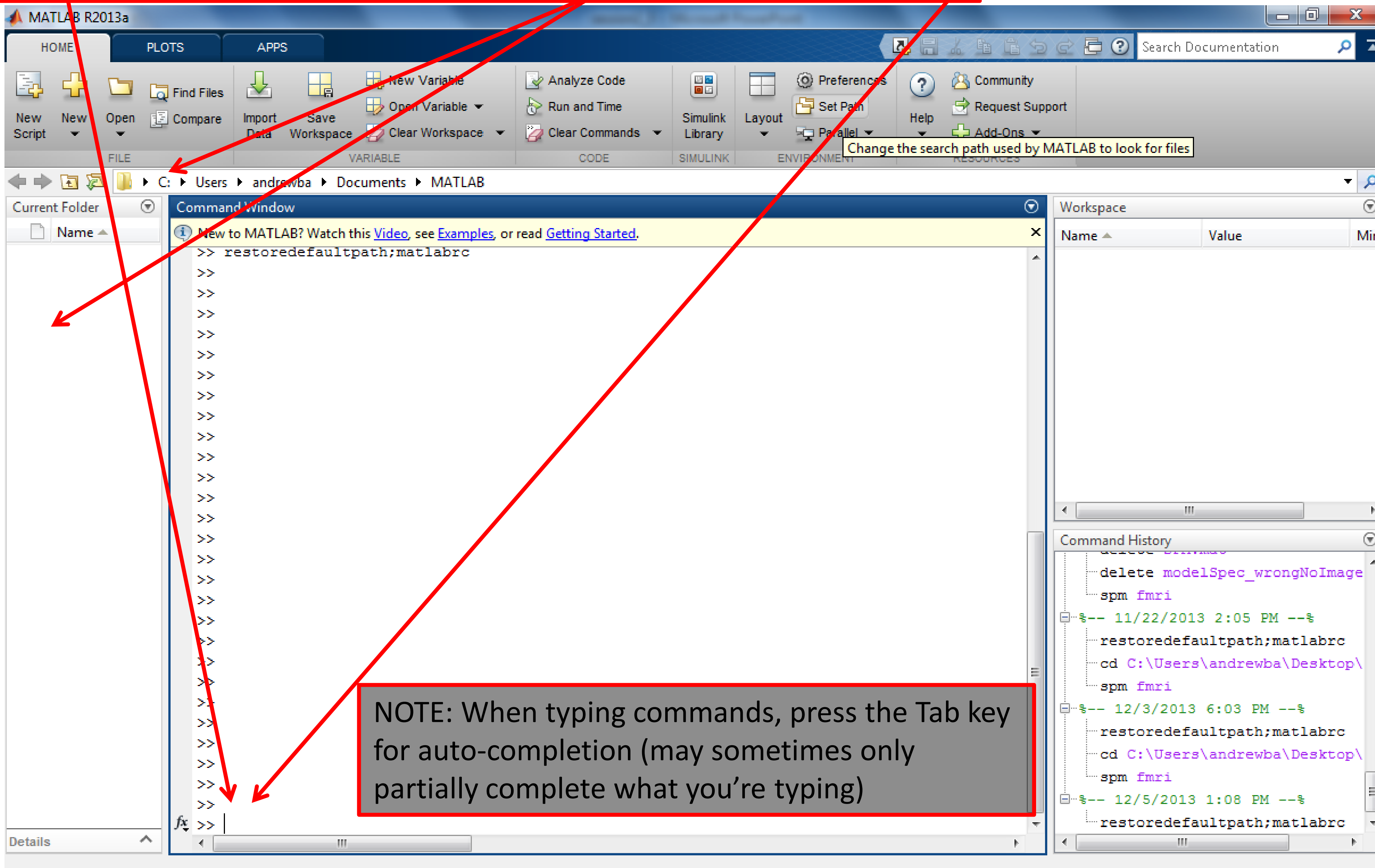


1: Go to the Matlab Command Window and type:

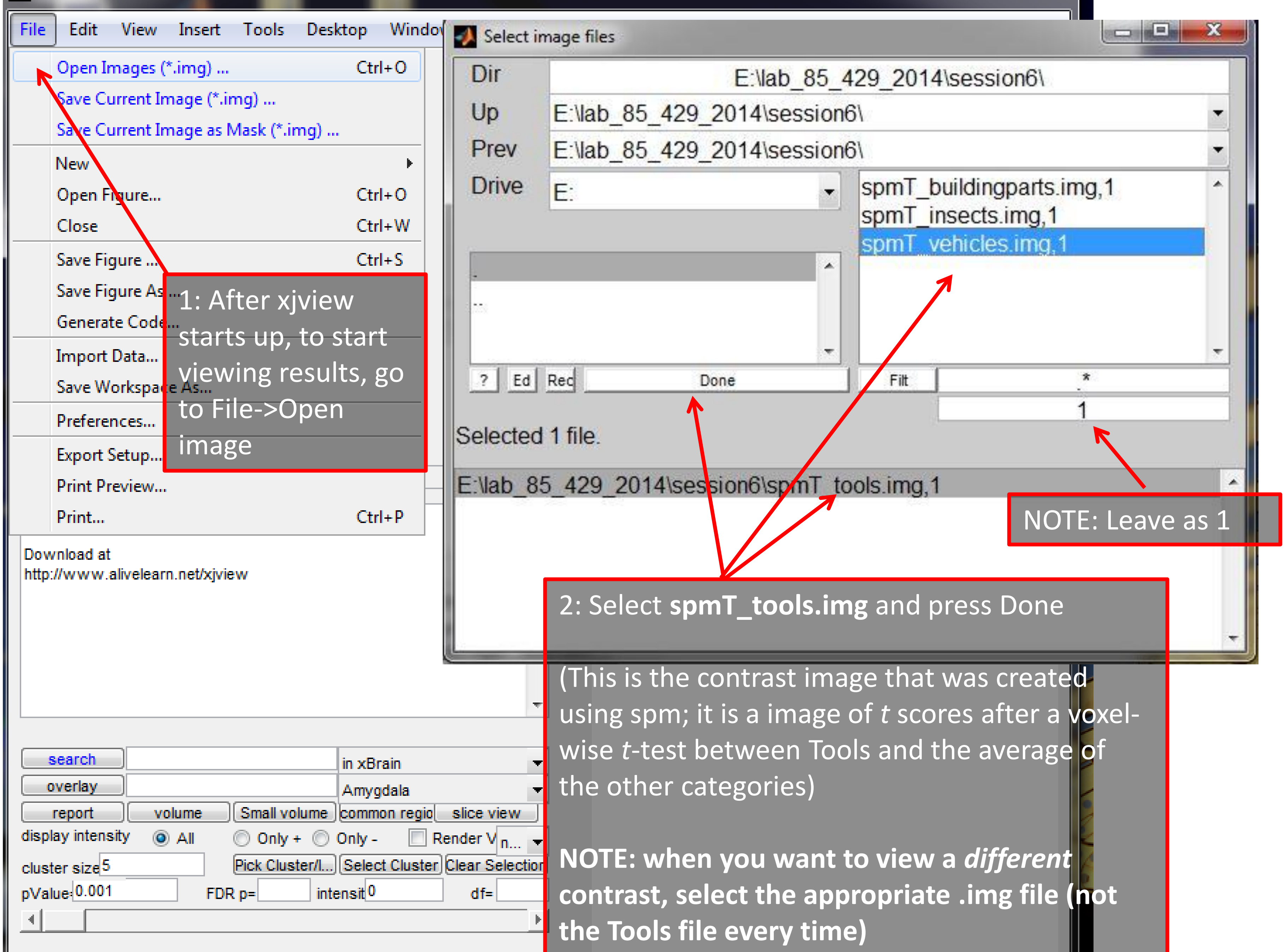
cd C:/Users/Public/lab_85_429_2016/session6

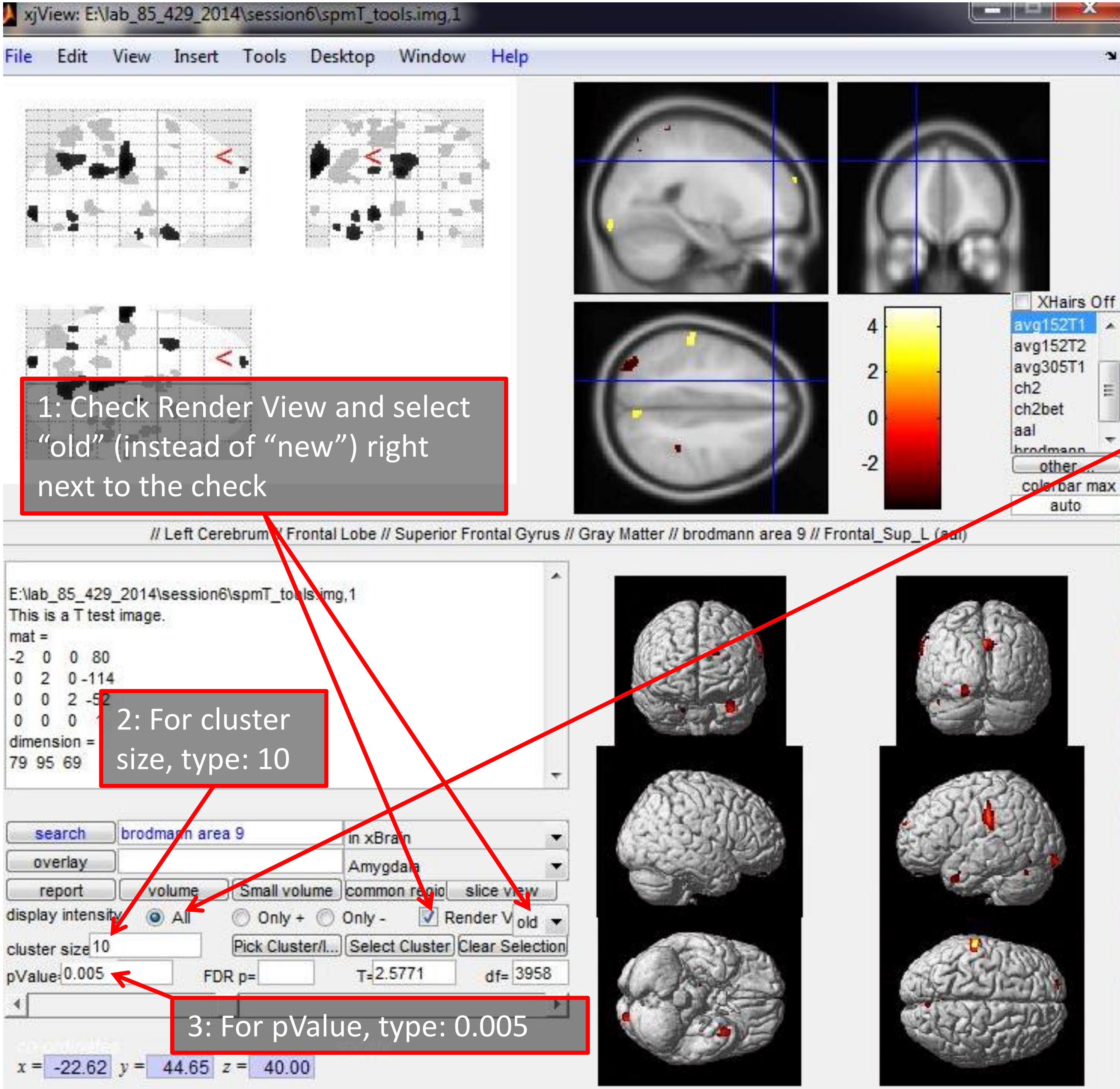
...(OR navigate there using the browser)

2: Then type: xjview



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


1: After xjview starts up, to start viewing results, go to File->Open image
2: Select **spmT_tools.img** and press Done
(This is the contrast image that was created using spm; it is a image of *t* scores after a voxel-wise *t*-test between Tools and the average of the other categories)
NOTE: when you want to view a *different* contrast, select the appropriate .img file (not the Tools file every time)
NOTE: Leave as 1



1: Check Render View and select “old” (instead of “new”) right next to the check

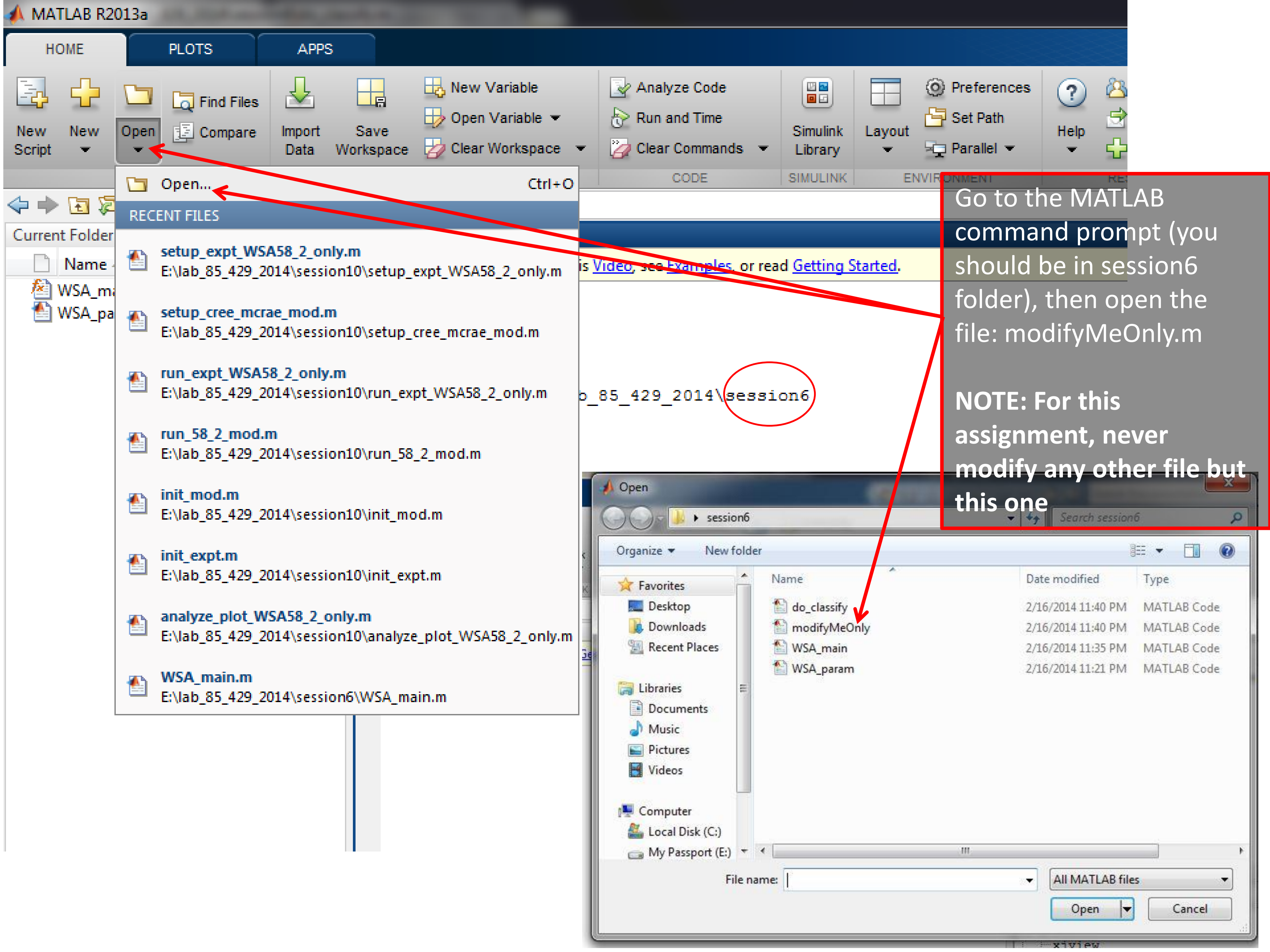
2: For cluster size, type: 10

3: For pValue, type: 0.005

NOTE: For the question in the assignment that requires the use of xjview, you will follow the steps up to this slide to look at positive or negative activation for a contrast

4: Select: All
The images indicate that there is only a little bit of Tools activation (vs. other categories) in the frontal lobe, *whether positive or negative*

We now will run MVPA using voxels from the frontal lobe to see if MVPA detects any differences between Tools and other object concepts in the frontal lobe… next slide



MATLAB R2013a
HOME
PLOTS
APPS
New Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
CODE
Simulink Library
SIMULINK
Layout
Preferences
Set Path
Parallel
Help
Open... Ctrl+O
RECENT FILES
setup_expt_WSA58_2_only.m
E:\lab_85_429_2014\session10\setup_expt_WSA58_2_only.m
setup_cree_mcrae_mod.m
E:\lab_85_429_2014\session10\setup_cree_mcrae_mod.m
run_expt_WSA58_2_only.m
E:\lab_85_429_2014\session10\run_expt_WSA58_2_only.m
run_58_2_mod.m
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init_mod.m
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init_expt.m
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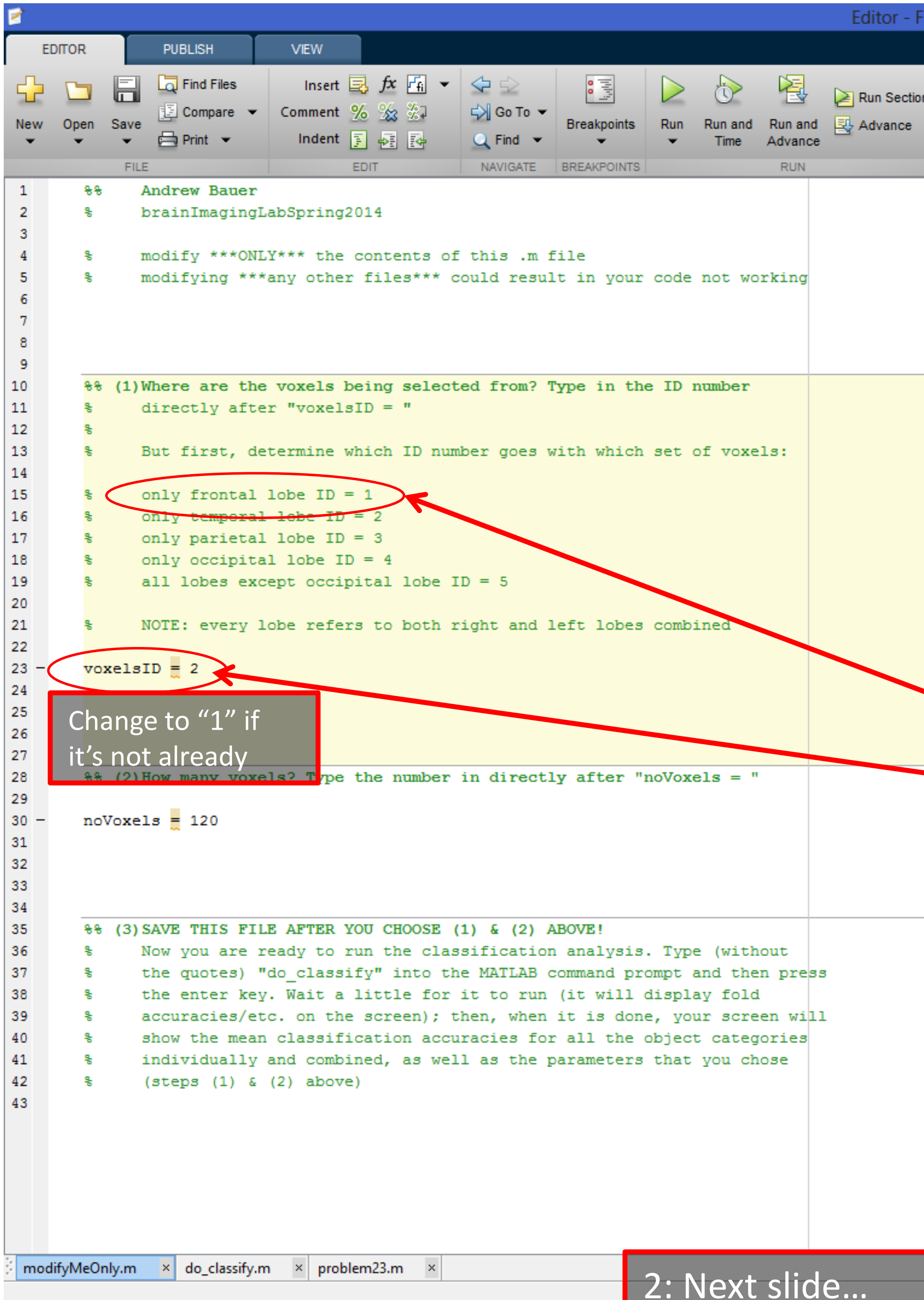
analyze_plot_WSA58_2_only.m
E:\lab_85_429_2014\session10\analyze_plot_WSA58_2_only.m
WSA_main.m
E:\lab_85_429_2014\session6\WSA_main.m
Current Folder
Name
or read Getting Started.
session6
Go to the MATLAB command prompt (you should be in session6 folder), then open the file: modifyMeOnly.m
NOTE: For this assignment, never modify any other file but this one
Open
Organize
New folder
Favorites
Desktop
Downloads
Recent Places
Libraries
Documents
Music
Pictures
Videos
Computer
Local Disk (C:)
My Passport (E:)
Name
Date modified
Type
do_classify 2/16/2014 11:40 PM MATLAB Code
modifyMeOnly 2/16/2014 11:40 PM MATLAB Code
WSA_main 2/16/2014 11:35 PM MATLAB Code
WSA_param 2/16/2014 11:21 PM MATLAB Code
File name:
All MATLAB files
Open
Cancel



Change to "1" if it's not already

2: Next slide…

NOTE: There are three steps every time you will run MVPA:

a) Select where to draw voxels from;

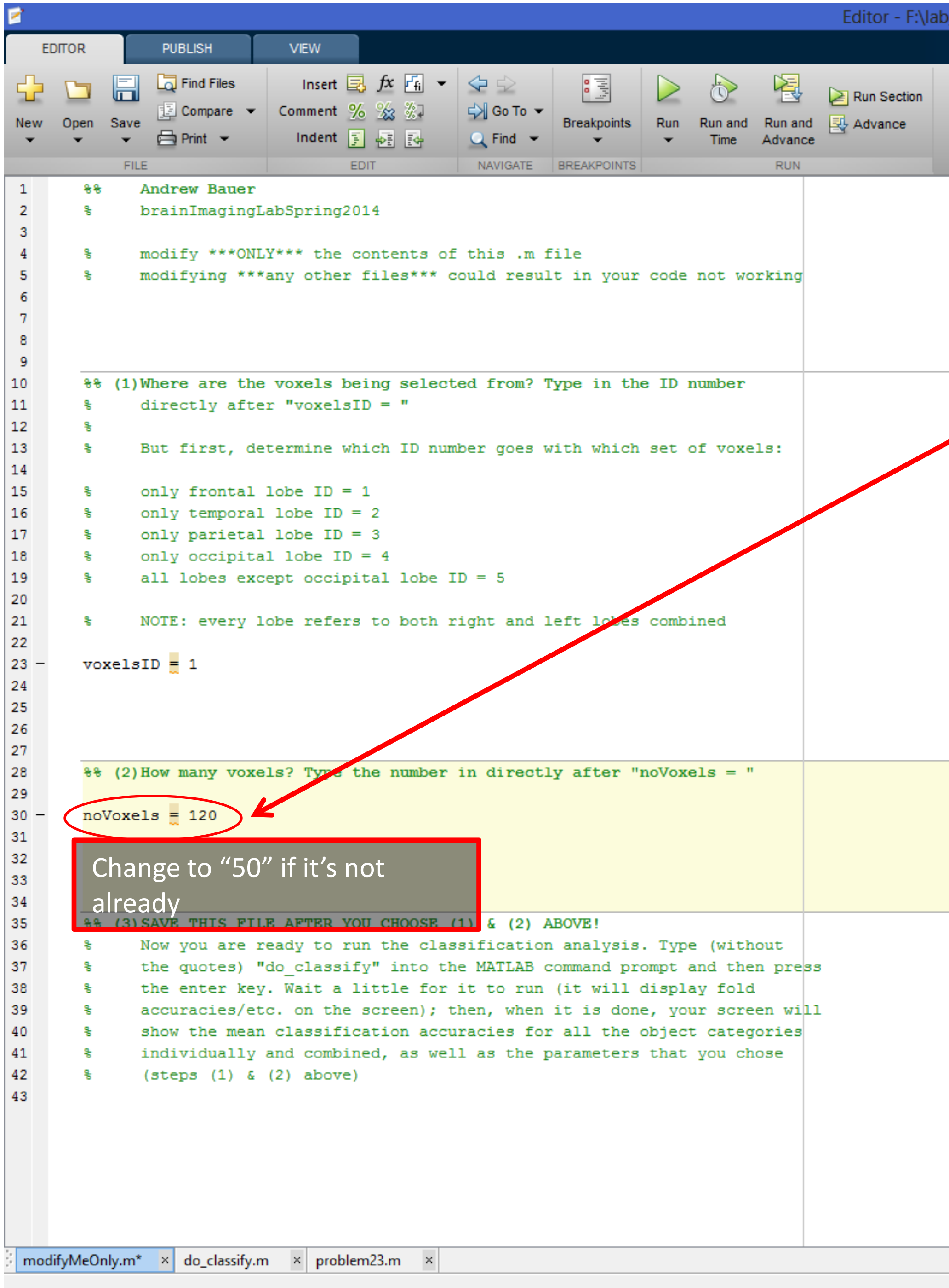
b) Set how many voxels to select;

c) Type "do_classify" (without quotes) into the MATLAB command prompt to run the classification

1: First, since we are (as a class) investigating the frontal lobe, type "1" (without quotes) directly after "voxels ID = "; this is the numerical ID associated with the frontal lobe

(See the typed instructions in the file too)

NOTE: For the assignment, you will have to change the voxels ID value… do *not* choose "1" every time



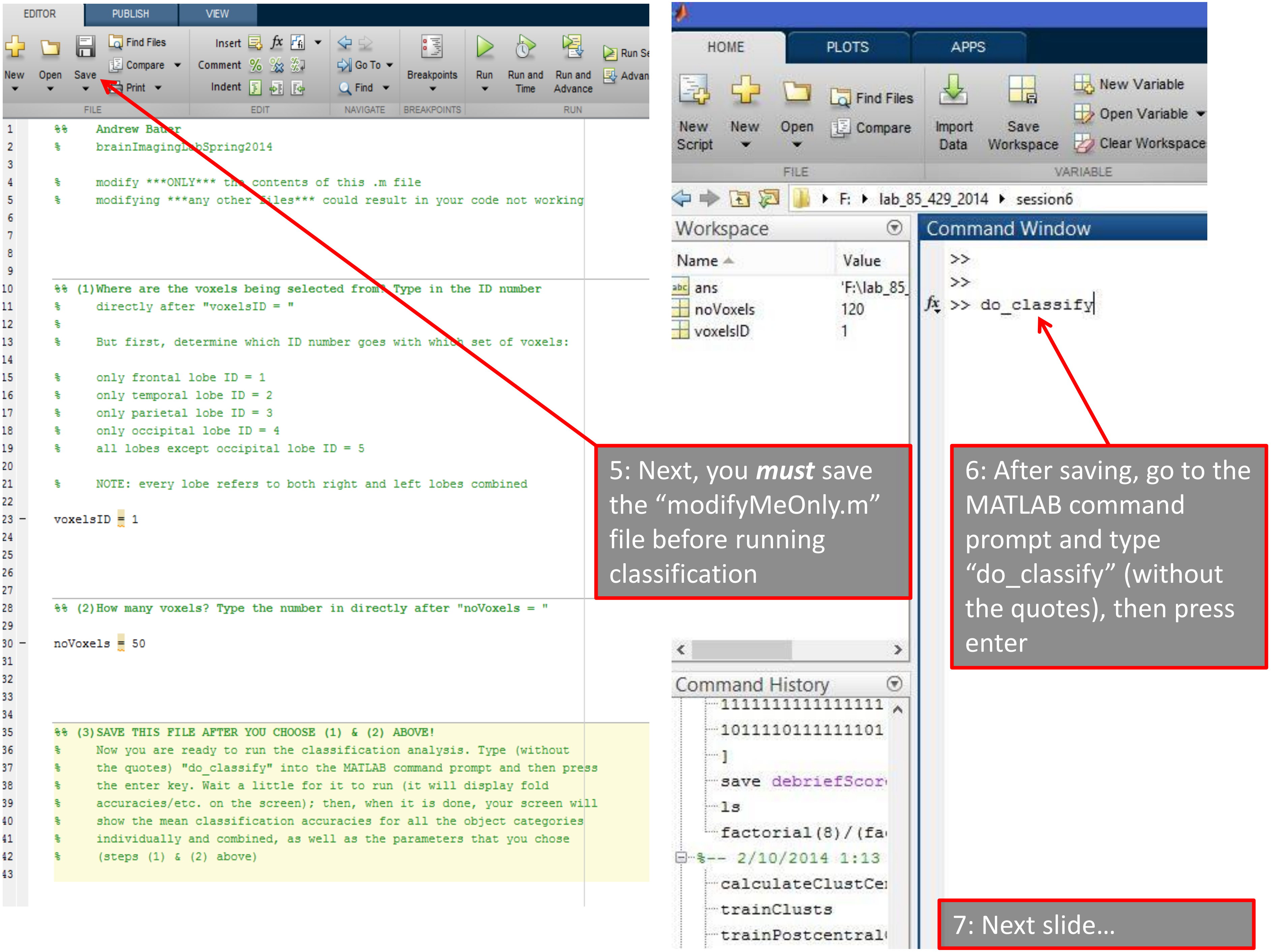
Change to “50” if it’s not already

3: Now we will set the number of voxels. In the PLoS One paper (the study that published these data), 80 voxels were drawn from the whole brain; so we should use fewer than 80 if we are focusing on just one lobe of the brain

NOTE: For the assignment, you will have to change the noVoxels value… do *not* choose “50” every time

NOTE: In the GLM analysis, the voxels were converted to a smaller size during preprocessing; however, for MVPA, the voxels are kept at their original bigger size

4: Next slide…



EDITOR
PUBLISH
VIEW
New
Open
Save
Find Files
Compare
Print
FILE
Insert
Comment
Indent
EDIT
Go To
Find
NAVIGATE
Breakpoints
BREAKPOINTS
Run
Run and Time
Run and Advance
RUN
%% Andrew Bauer
% brainImagingLabSpring2014
% modify ***ONLY*** the contents of this .m file
% modifying ***any other files*** could result in your code not working
%% (1)Where are the voxels being selected from? Type in the ID number
% directly after "voxelsID = "
%
% But first, determine which ID number goes with which set of voxels:
% only frontal lobe ID = 1
% only temporal lobe ID = 2
% only parietal lobe ID = 3
% only occipital lobe ID = 4
% all lobes except occipital lobe ID = 5
% NOTE: every lobe refers to both right and left lobes combined
voxelsID = 1
%% (2)How many voxels? Type the number in directly after "noVoxels = "
noVoxels = 50
%% (3)SAVE THIS FILE AFTER YOU CHOOSE (1) & (2) ABOVE!
% Now you are ready to run the classification analysis. Type (without
% the quotes) "do_classify" into the MATLAB command prompt and then press
% the enter key. Wait a little for it to run (it will display fold
% accuracies/etc. on the screen); then, when it is done, your screen will
% show the mean classification accuracies for all the object categories
% individually and combined, as well as the parameters that you chose
% (steps (1) & (2) above)
HOME
PLOTS
APPS
New Script
New
Open
Find Files
Compare
FILE
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
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F: ▸ lab_85_429_2014 ▸ session6
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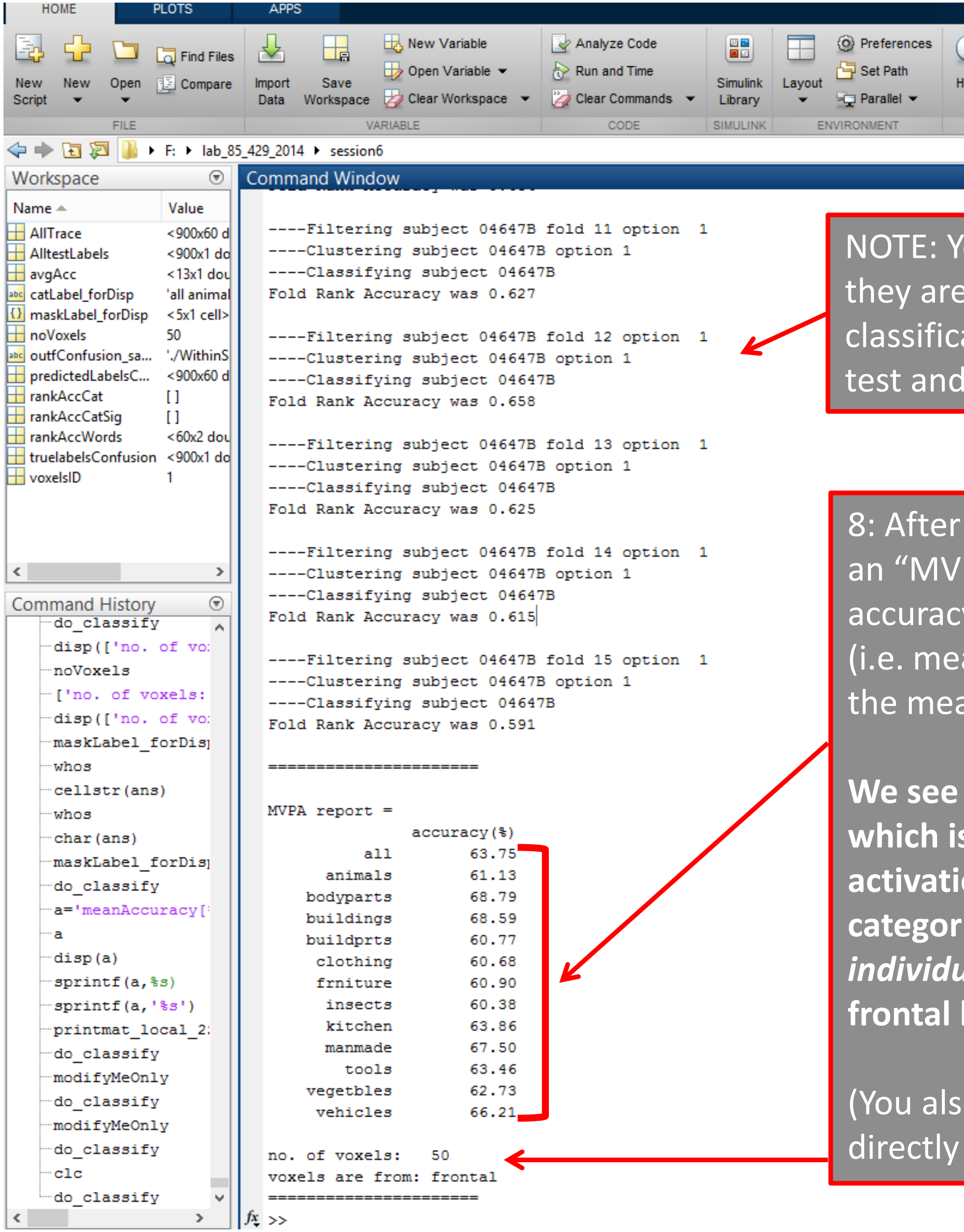
%-- 2/10/2014 1:13
calculateClustCe
trainClusts
trainPostcentral
5: Next, you *must* save the “modifyMeOnly.m” file before running classification
6: After saving, go to the MATLAB command prompt and type “do_classify” (without the quotes), then press enter
7: Next slide…



NOTE: You can disregard these "fold" accuracies; they are the accuracy each iteration of classification, where the data are partitioned into test and training data differently

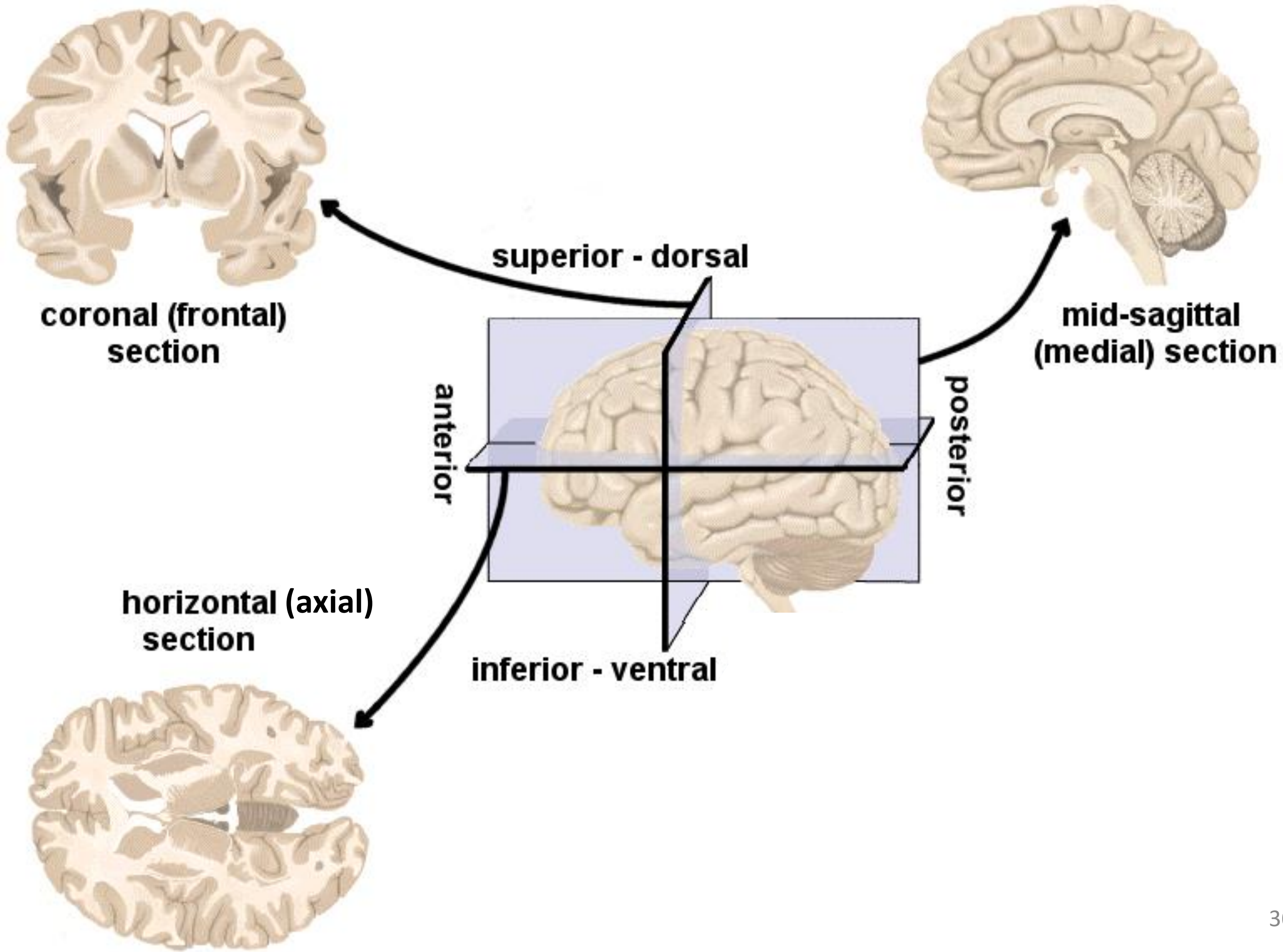
8: After the classification is finished, you will see an "MVPA report" that lists the mean classification accuracy for each of the twelve object categories (i.e. mean over the five items per category); and the mean accuracy over all categories

We see that "tools" yields 63.46% accuracy, which is higher than the 50% chance level. So activation for Tools *is* different from that of other categories, *and* some conceptual meaning of *individual* tools is stored in voxels patterns of the frontal lobe (probably motor information?)

(You also see the two parameters that you set directly before classification)

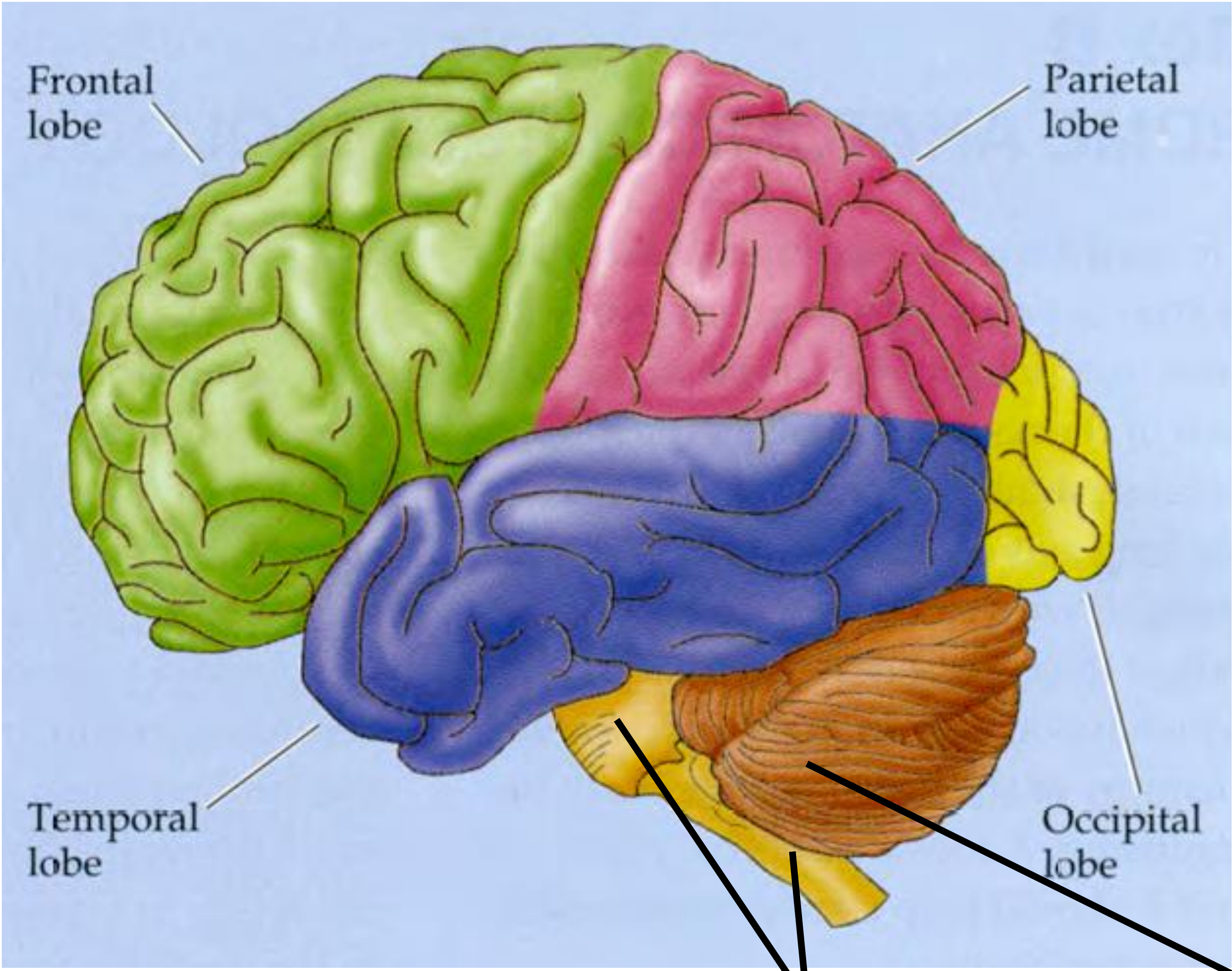
- This is all the guidance/information that you should need to do this session’s assignment
- **You do not need to start and use spm for this assignment, at all**
- If something goes wrong with xjview, just exit the program and restart it from MATLAB as usual. You don’t have to exit out of MATLAB to restart xjview
- If you must restart MATLAB for whatever reason, after you start MATLAB ***be sure to set the path again (our lab folder)*** *and* ***cd back to the “session6” directory*** *(see beginning slides!)*
- See the slides below for any needed help with orientation terms, identifying brain lobes, and general functional neuroanatomy

Orientation terms and planes



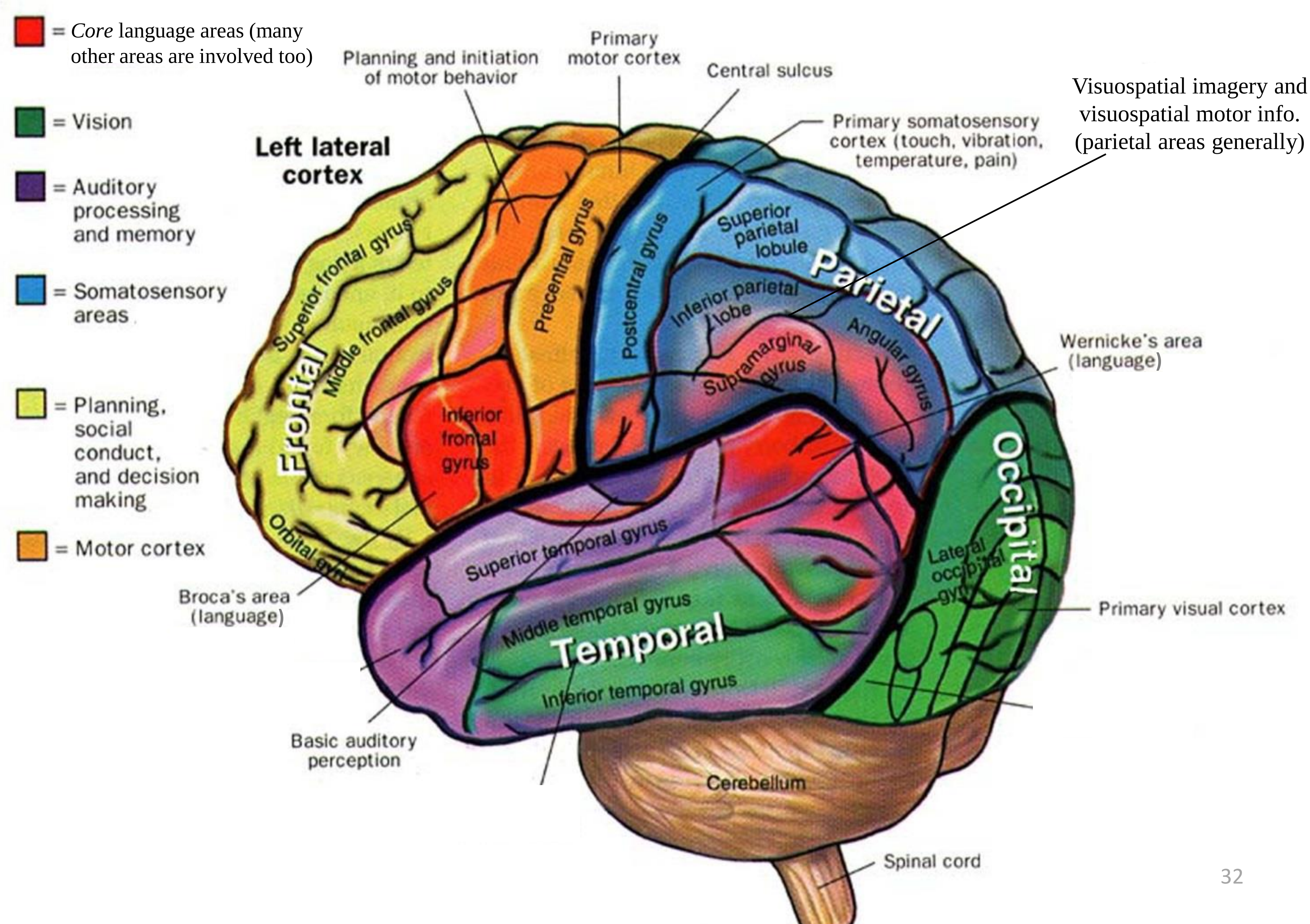
Brain partitioned into four lobes

(… plus some extra regions)



NOT “lobes”: Some subcortical brain regions & cerebellum

General functional neuroanatomy



References

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