Lab session 9:

Between-subjects multi-voxel pattern classification analysis (MVPA)

Andrew Bauer

03/23/16

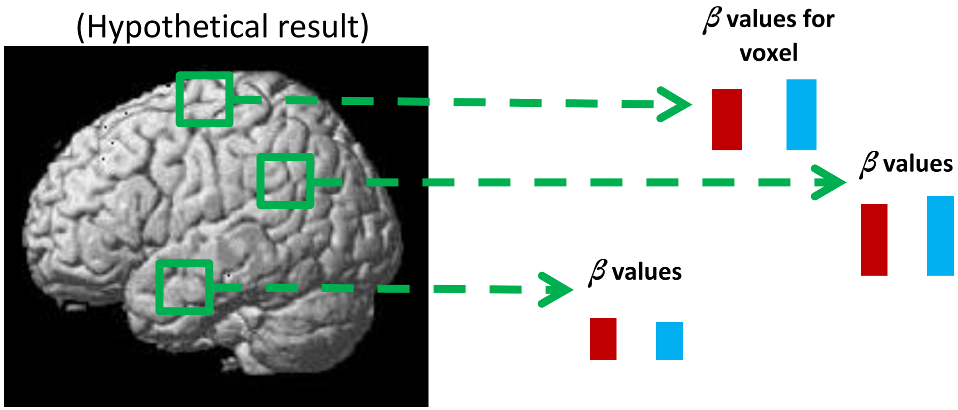
Session no.	Date (all Wednesday)	Topic/activity	Topic of quiz that day	Topic of lab write-up (assignment) due that day
1	13-Jan	Lab overview		
2	20-Jan	Brain anatomy		
3	27-Jan	Data preprocessing	Brain anatomy (no. 1)	
4	3-Feb	Set up GLM model	Functional brain anatomy (no. 2)	
5	10-Feb	Single-subject 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)		

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

Tools vs. other object categories

(Hypothetical result)

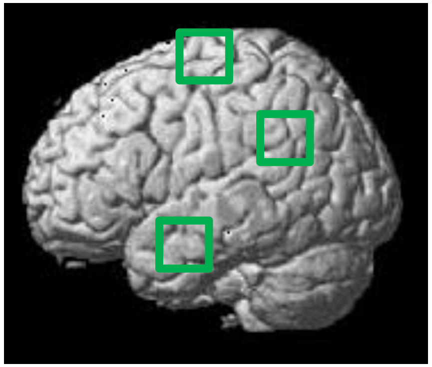
GLM contrast in each voxel



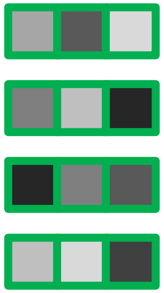
- GLM considers each single voxel *in isolation*
- Within a voxel, GLM compares conditions' activation *levels* (β)
- On the left: It appears **Tools** does not activate the brain differently, compared to **other** categories, in each voxel (see the three voxels)

MVPA using pattern of 3 voxels

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



Object concept	**Voxel activation pattern (3 voxels)**
hammer:	
saw:	
church:	
butterfly:	
. . .	. . .



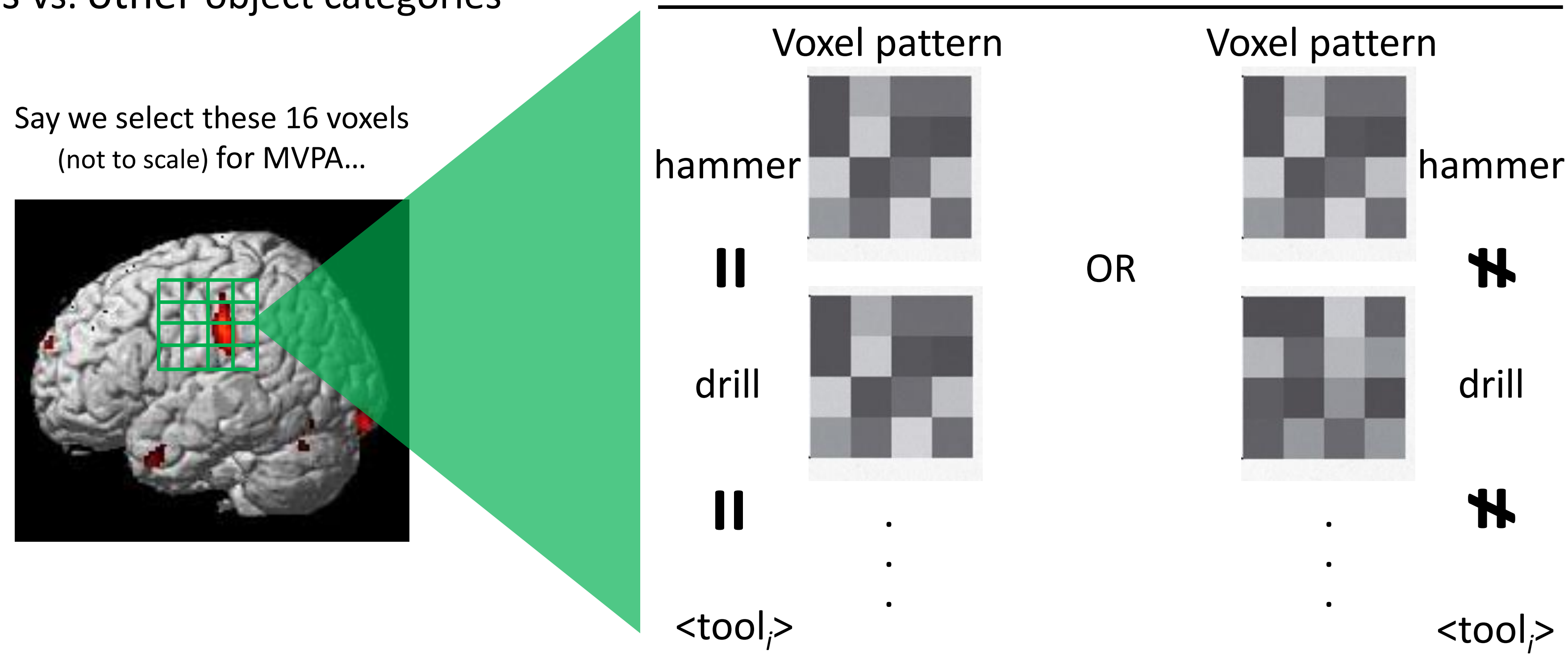
- MVPA considers *interactions* of voxels, and compares *patterns*; it uses the data to a fuller extent, and is thus more sensitive, than GLM
- On the left: Although GLM (above) shows no significant difference in activation *levels* in any single voxel for **Tools** vs. **others**, the voxel activation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

Two possible MVPA results:
Representation of tool concepts?

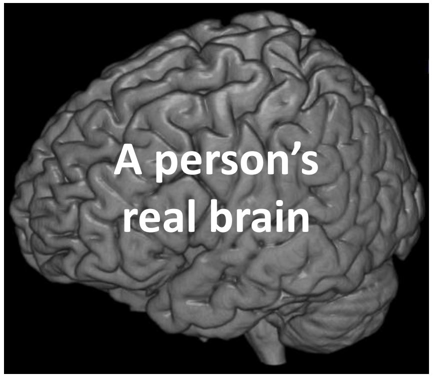
GLM contrast (our actual result):
Tools vs. other object categories



We can also use MVPA to ask:

Are neural representations similar between different people?

… where each person’s brain is spatially normalized:



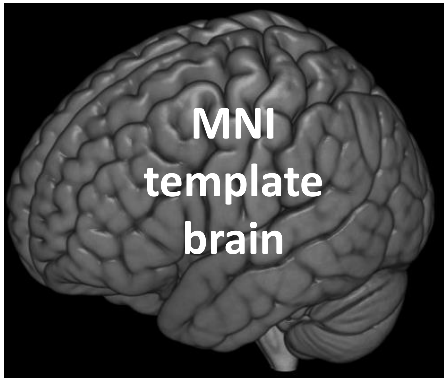
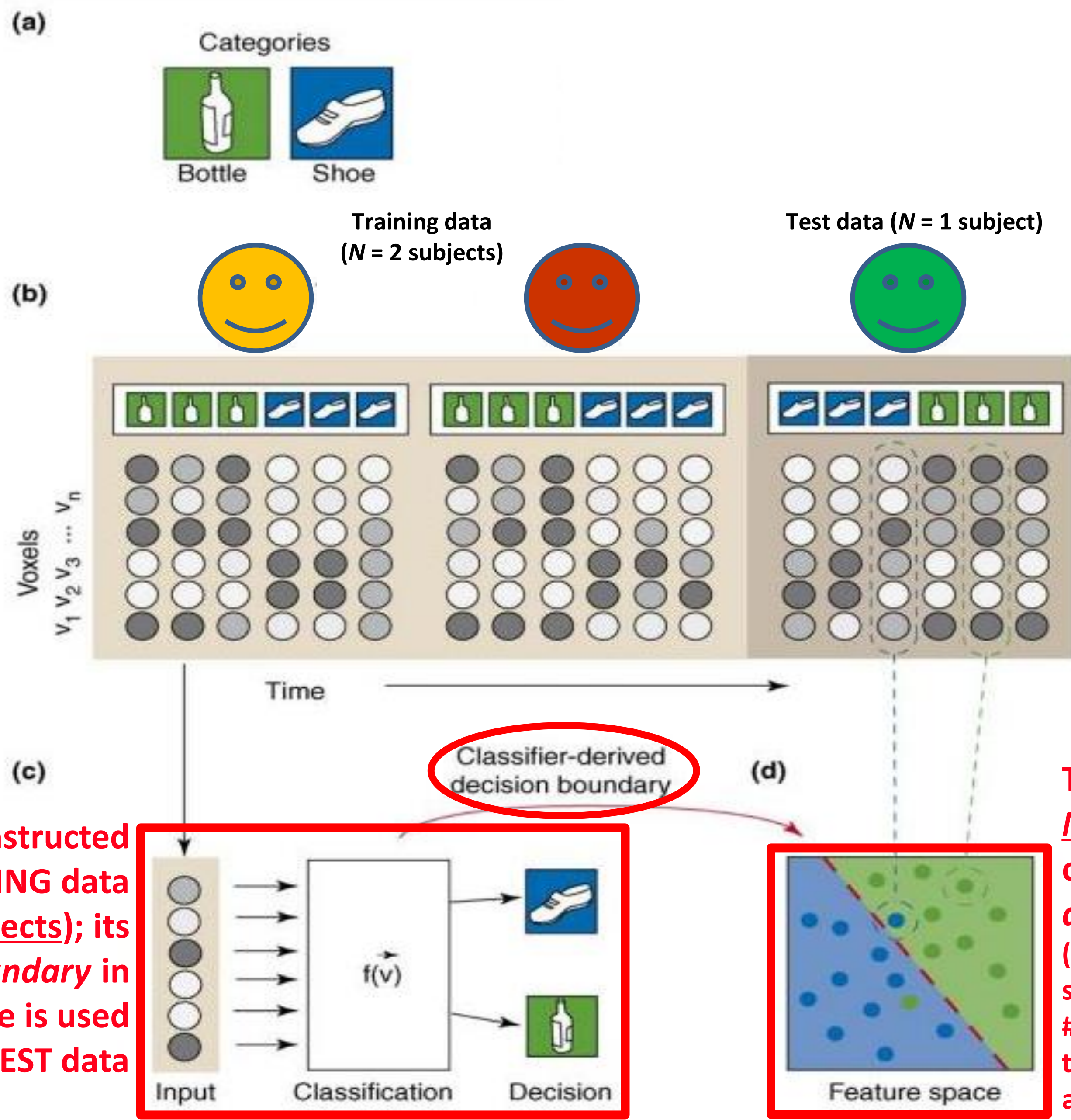


Image from
Norman et al. (2006)

How between-subjects MVPA works (assume N = 3 subjects)

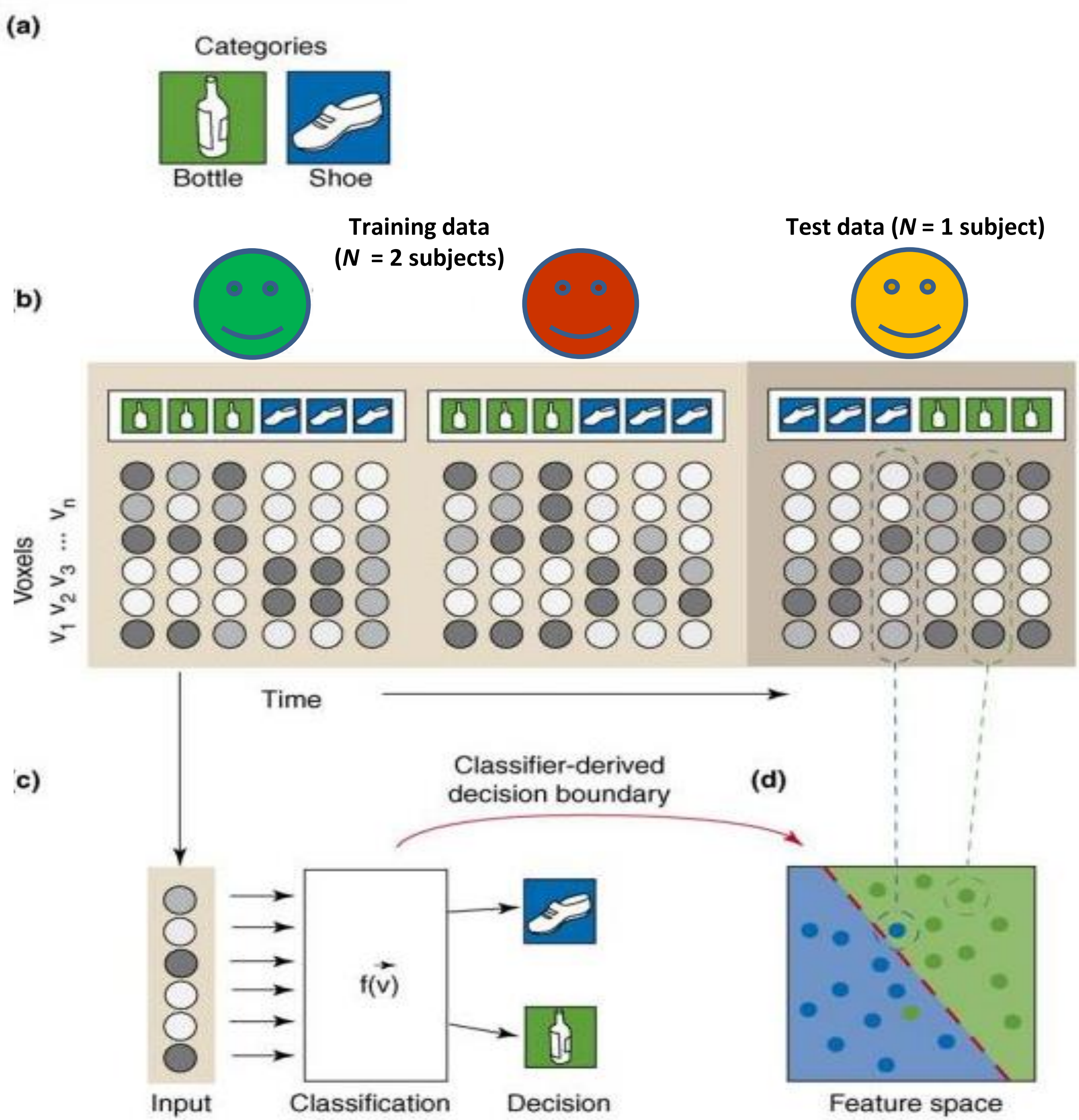


The classifier is constructed from TRAINING data (<u>from *N* = 2 subjects</u>); its *decision boundary* in feature (voxel) space is used to classify the TEST data

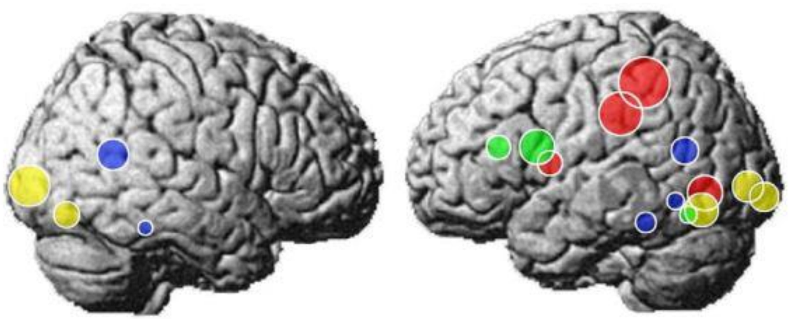
The TEST data (<u>from *N* = 1 subject</u>) are compared to the *decision boundary*
(feature space is simplified to 2D here; # dimensions = # voxels that make up the activation patterns)

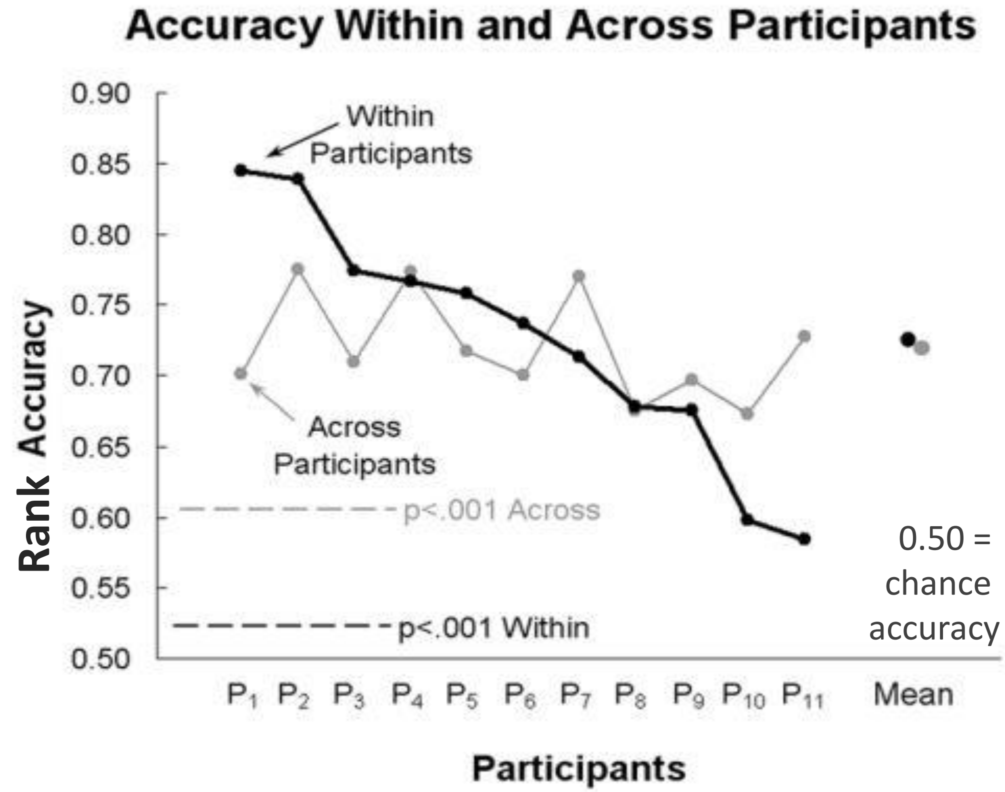
The process goes through many iterations, or “folds”, partitioning the data into TRAINING and TEST sets differently every time (<u>each subject is used as the TEST data once</u>)

The final output is the classification accuracy averaged over each subject (i.e. how well the subjects’ data were labeled)



We can classify each subject's data using a classifier trained on all the *other* subjects (gray line to the right)
(Just et al., 2010's study on object concepts)





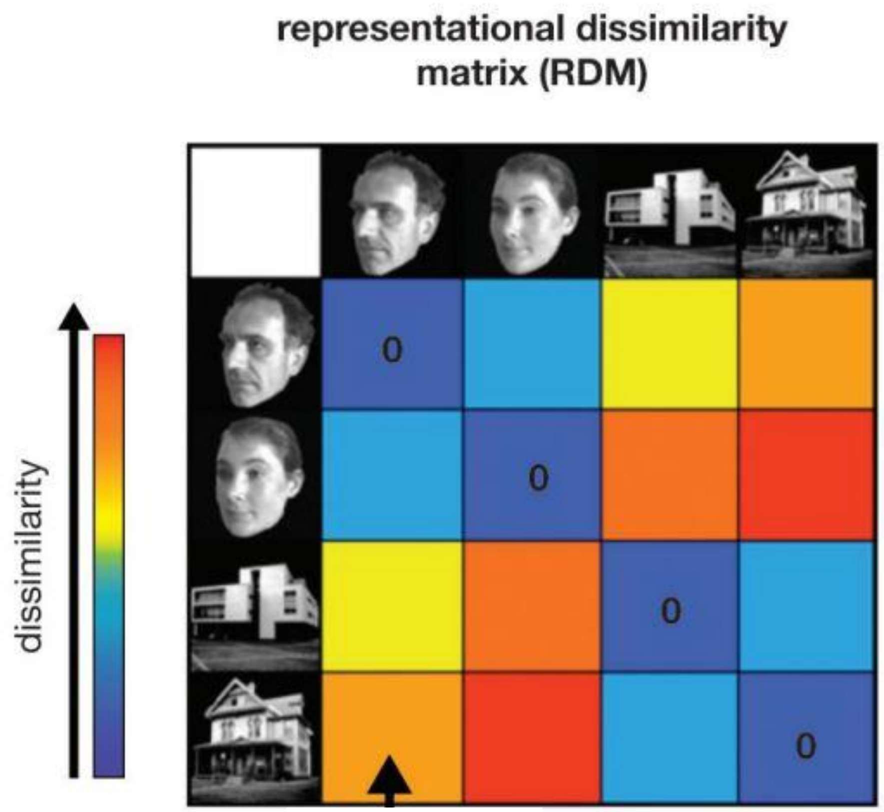
Category	Exemplar 1	Exemplar 2	Exemplar 3	Exemplar 4	Exemplar 5
body parts	leg	arm	eye	foot	hand
furniture	chair	table	bed	desk	dresser
vehicles	car	airplane	train	truck	bicycle
animals	horse	dog	bear	cow	cat
kitchen utensils	glass	knife	bottle	cup	spoon
tools	chisel	hammer	screwdriver	pliers	saw
buildings	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

Representational similarity analysis (RSA):

Between-subjects MVPA *without needing* spatial normalization

<u>Step 1, for each subject's data:</u> After selecting a set of voxels, calculate the correlation distance (i.e. dissimilarity) between the activation patterns of each pair of concepts

- The dissimilarities among the concepts reveal what kinds of information are represented in their activation patterns (e.g. visual information on the right)
- Each element in the RDM =
  1 – correlation between
  activation pattern of concept_1
  and activation pattern of concept_2
- Dissimilarity between two faces or two buildings is low; dissimilarity between a face and building is high
- The dissimilarity between a stimulus and itself is 0



Step 2: Calculate how well each subject's RDM correlates with the other subjects' RDMs

- Then, assess whether the average correlation between different subjects is high (and statistically significant)
  - (To see this analysis in use, see Raizada & Connolley, 2012)

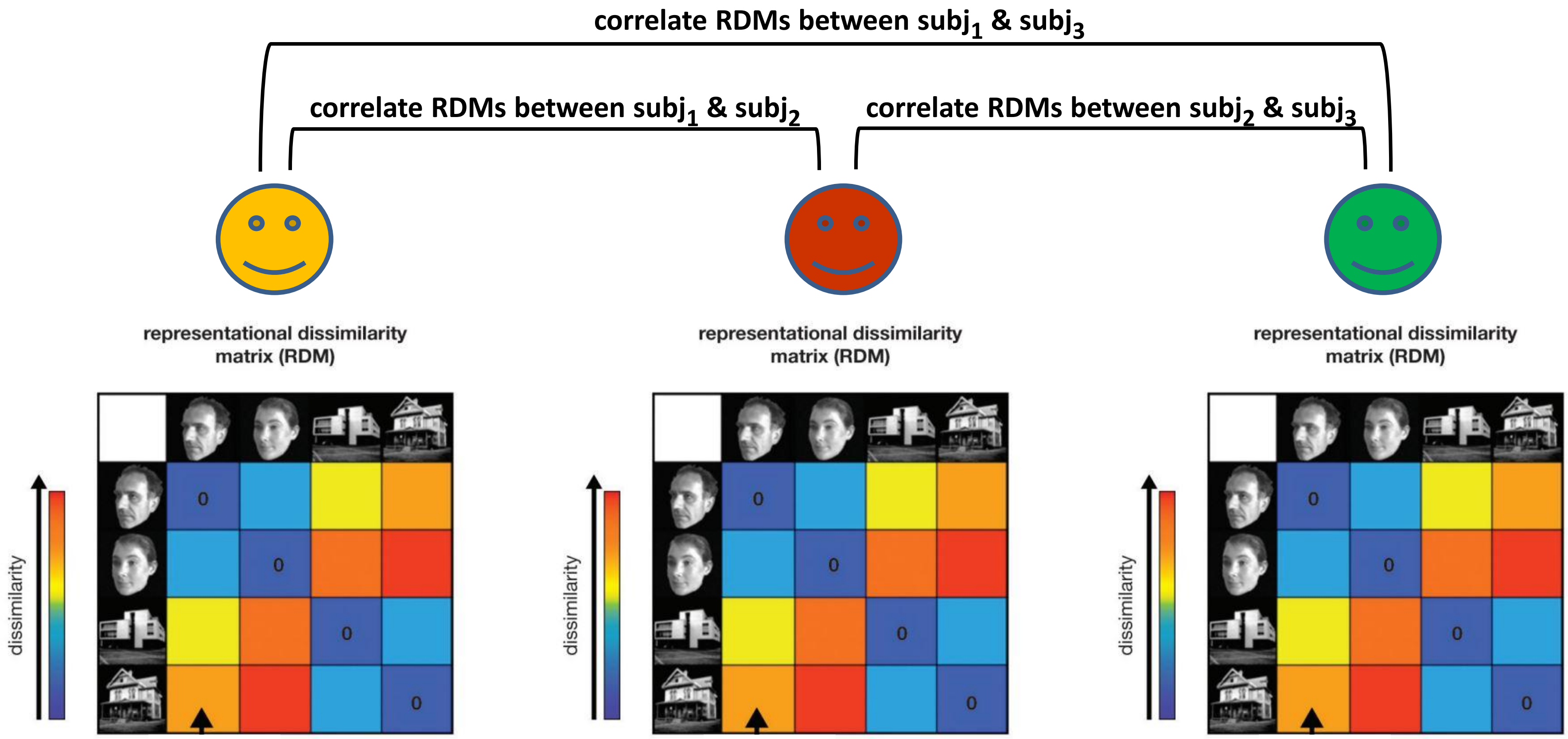


Image from Kriegeskorte et al. (2008)

Take-home points about representational similarity analysis

- A form of between-subjects MVPA that assesses the similarity between different people's neural representations *without needing* spatial normalization

- This analysis compares different subjects' RDMs; it does NOT compare the same activation patterns between subjects

- Thus, this analysis abstracts away from the unique brain of each subject; the voxels selected from each subject can be different

Representational similarity analysis can determine how similar the neural representations are between humans and monkeys!

(impossible to do using MVPA that requires spatial normalization)

Legend:

Face
Body
Natural object
Unnatural object

NOTE: Thick connecting lines mean “less alike“ between monkey and human

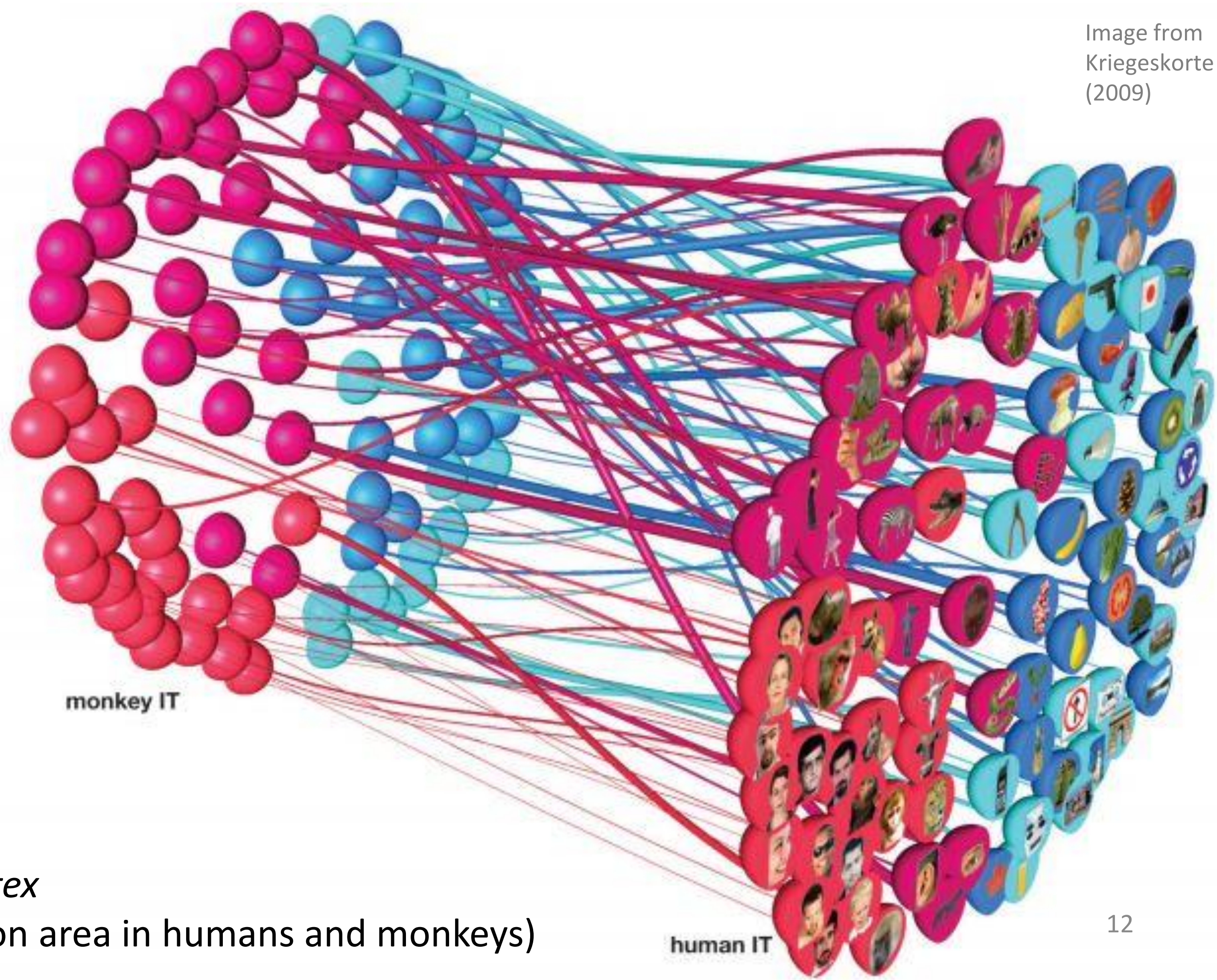
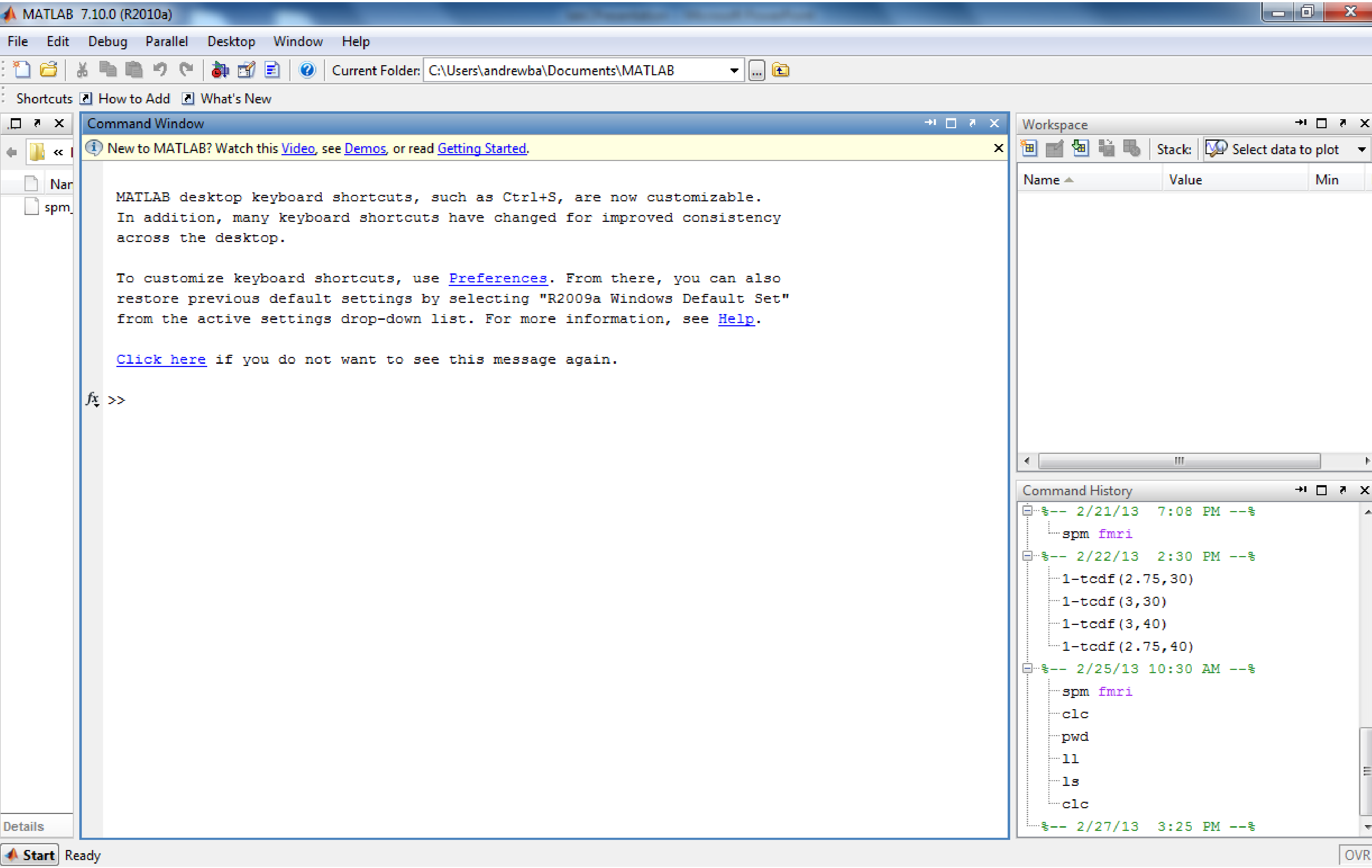


Image from Kriegeskorte (2009)

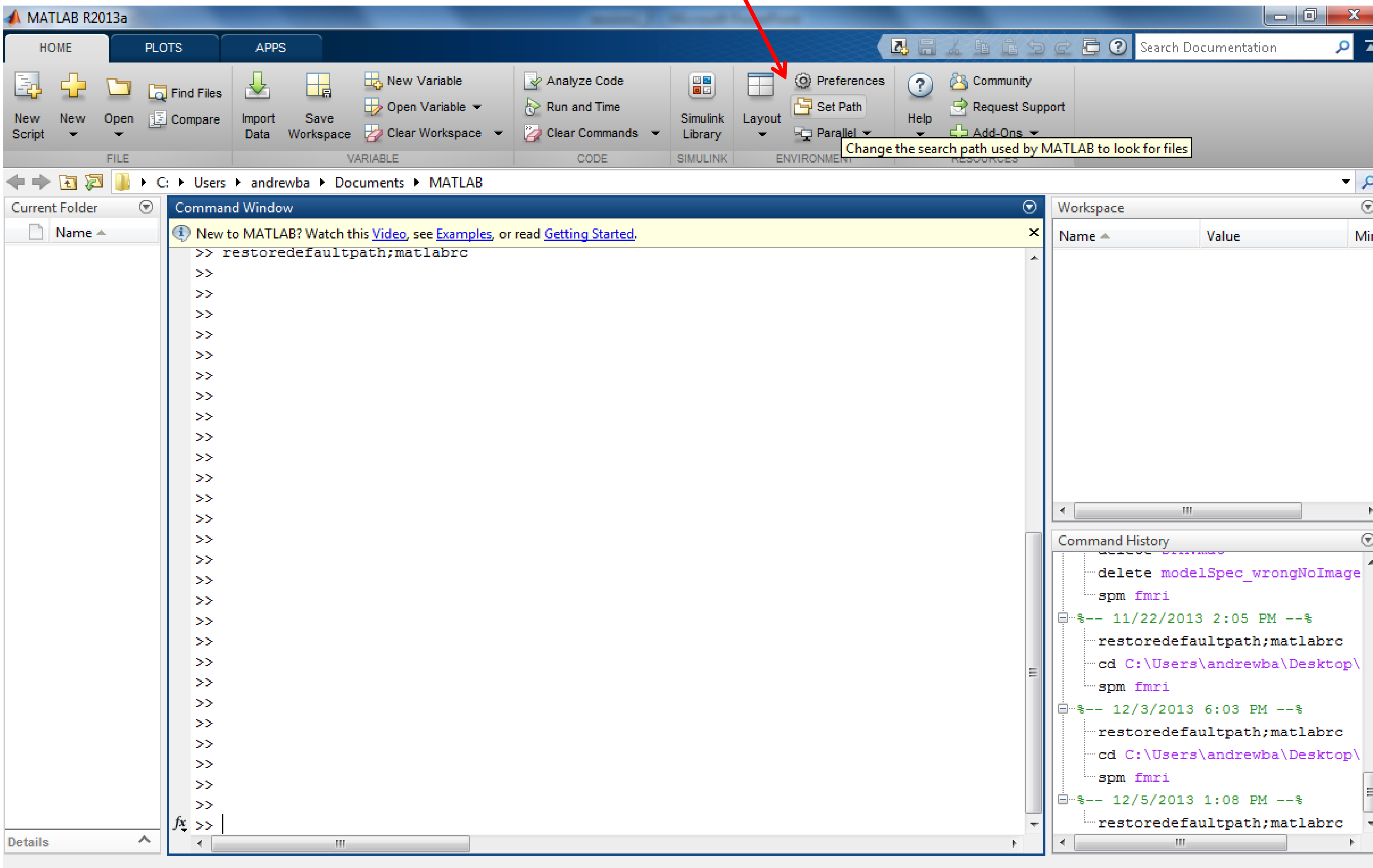
IT = inferotemporal cortex
(visual object recognition area in humans and monkeys)

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

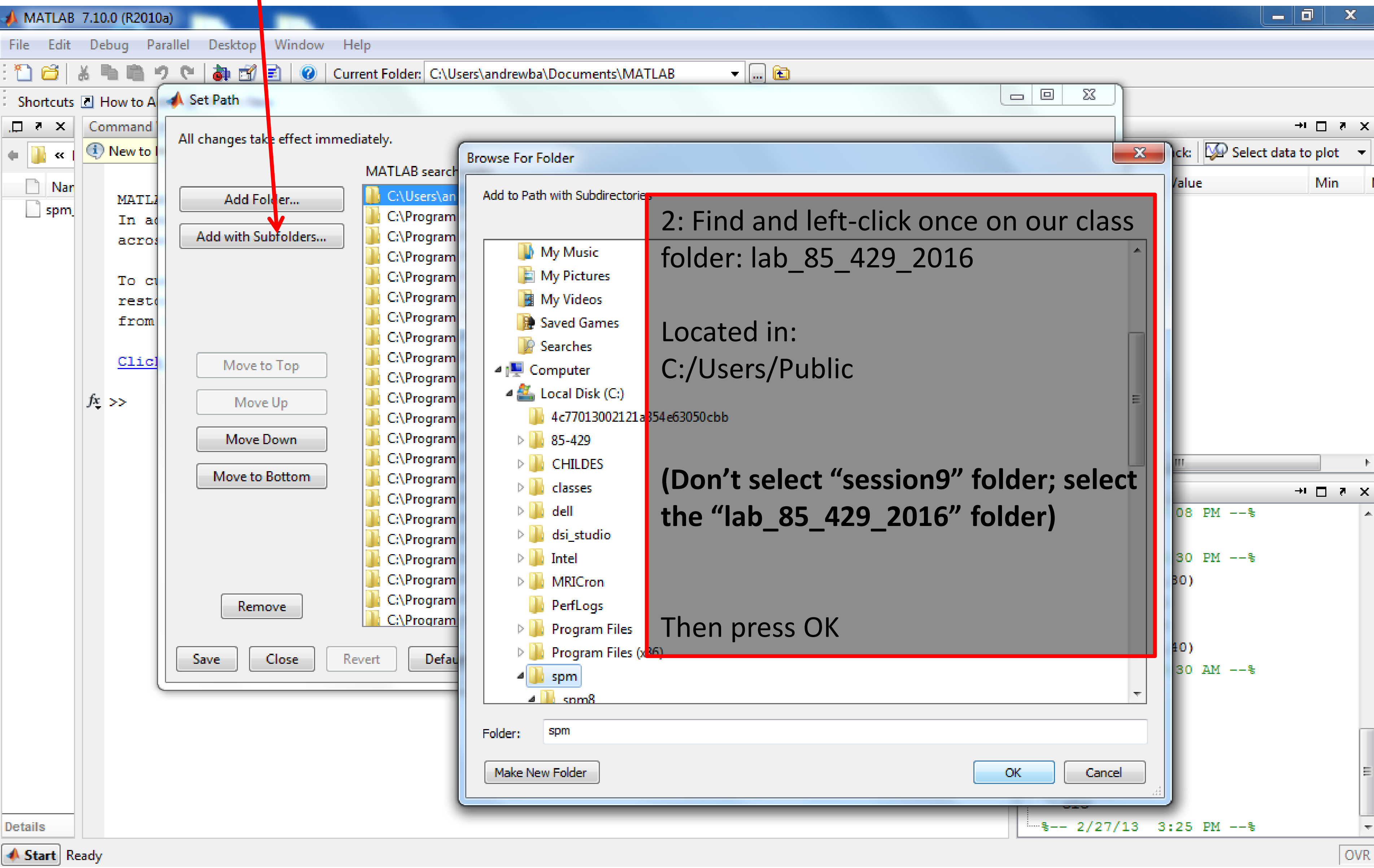
NOTE: You MUST select Matlab 2012b, do NOT select 2014b



Select Set Path



1: Select Add with Subfolders



2: Find and left-click once on our class folder: lab_85_429_2016

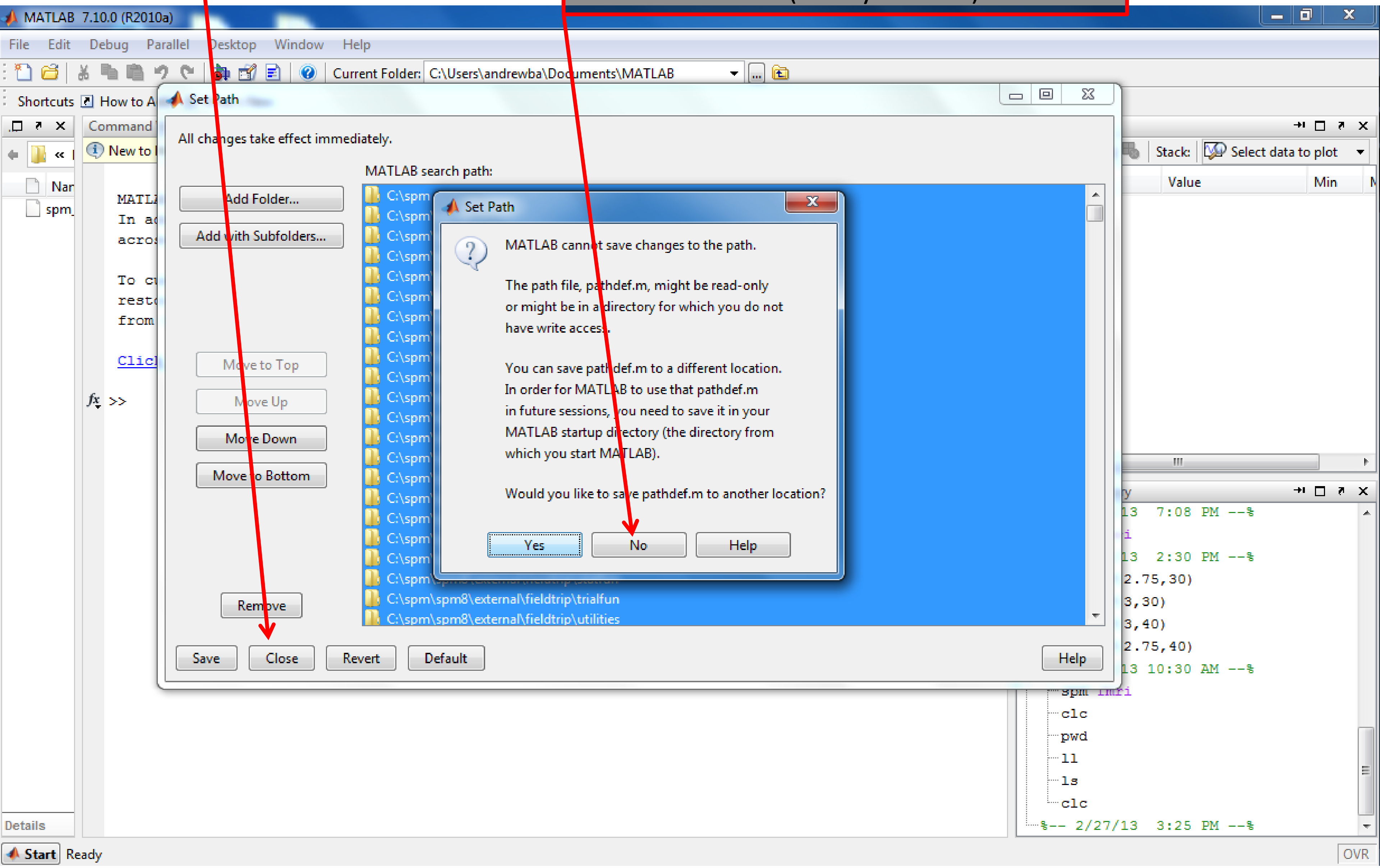
Located in:
C:/Users/Public

(Don't select "session9" folder; select the "lab_85_429_2016" folder)

Then press OK

1: Select Close

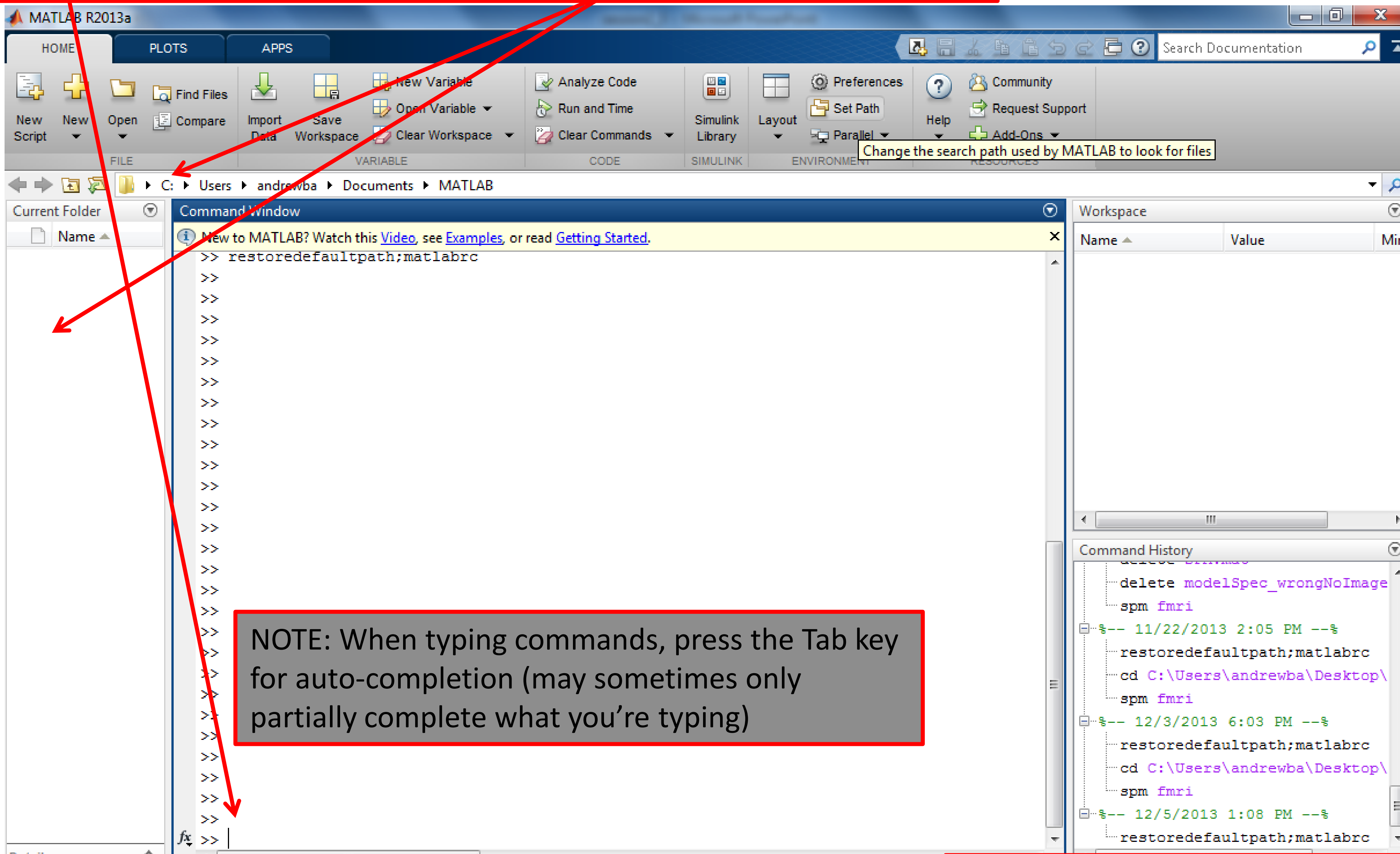
2: Select No if it asks to save the path file somewhere else (it may not ask)



1: Go to the Matlab Command Window and type:

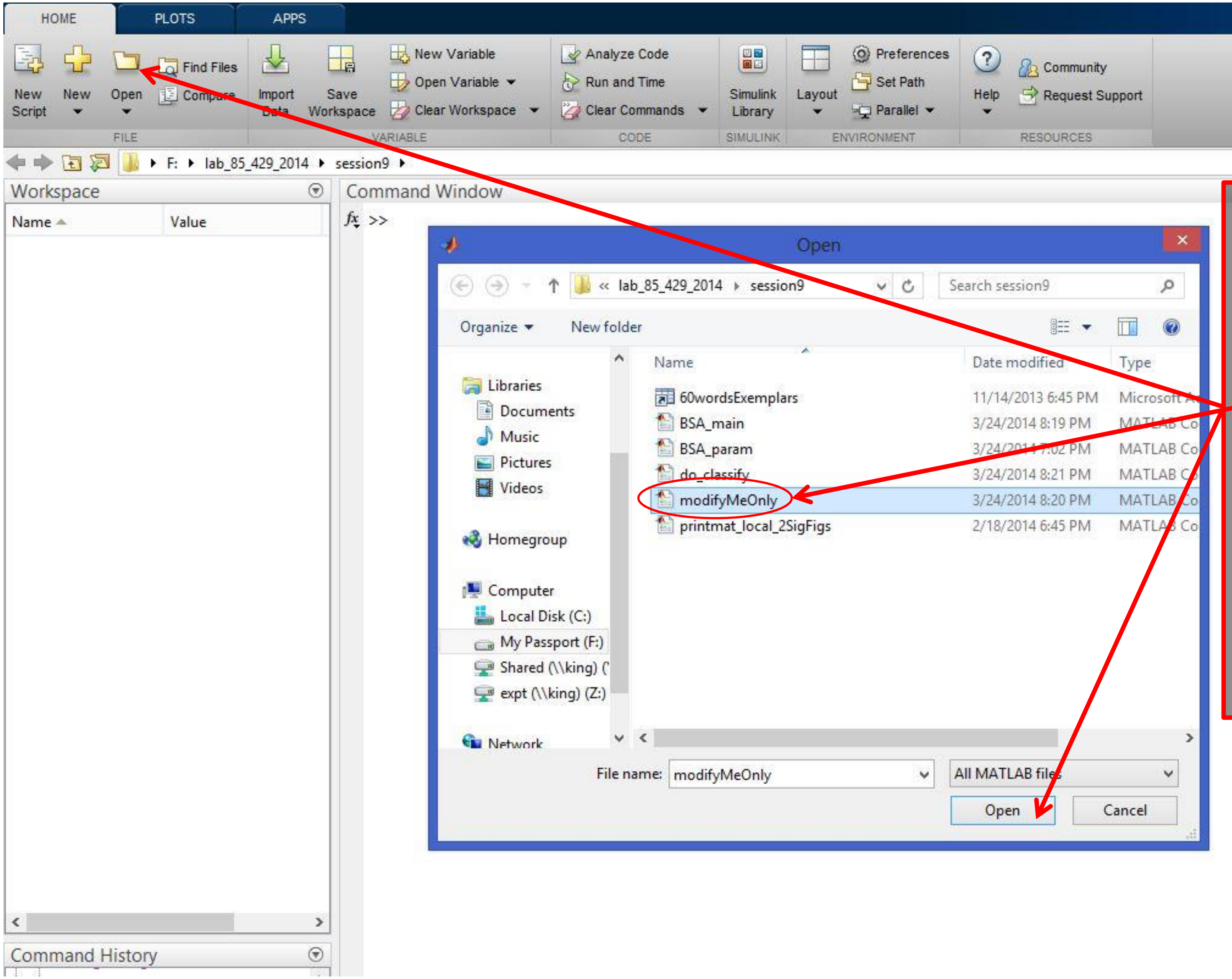
cd C:/Users/Public/lab_85_429_2016/session9

…(OR navigate there using the browser)



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

2: Next slide…



3. Open the following file found in the session9 folder (you should already be there):

modifyMeOnly.m

NOTE: Never modify any other file but this one

```
%%    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
%     only subcortical areas ID = 5
%     anywhere EXCEPT occipital lobe ID = 6

%     NOTE: every lobe refers to both right and left lobes combined

voxelsID = 5
```

Change to “1” if it’s not already

```
%% (2)How many voxels? Type the number in directly after "noVoxels = "

noVoxels = 80


%% (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)
```

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

(1) Select where to draw voxels from;

(2) Set how many voxels to select;

(3) Type “do_classify” (without quotes) into the MATLAB command prompt to start the classification

1: To acquaint yourself with how to do the classification, you will run classification on the frontal lobe only. Type “1” (without quotes) directly after “voxelsID = “; this is the numerical ID associated with the frontal lobe

(See the typed instructions in this file too)

NOTE: For the assignment, you will have to change the voxelsID value… do *not* choose “1” every time

2: Next slide…

```
%% 	Andrew Bauer
% 	brainImagingLabSpring2014

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% 	only occipital lobe ID = 4
% 	only subcortical areas ID = 5
% 	anywhere EXCEPT occipital lobe ID = 6

% 	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
```

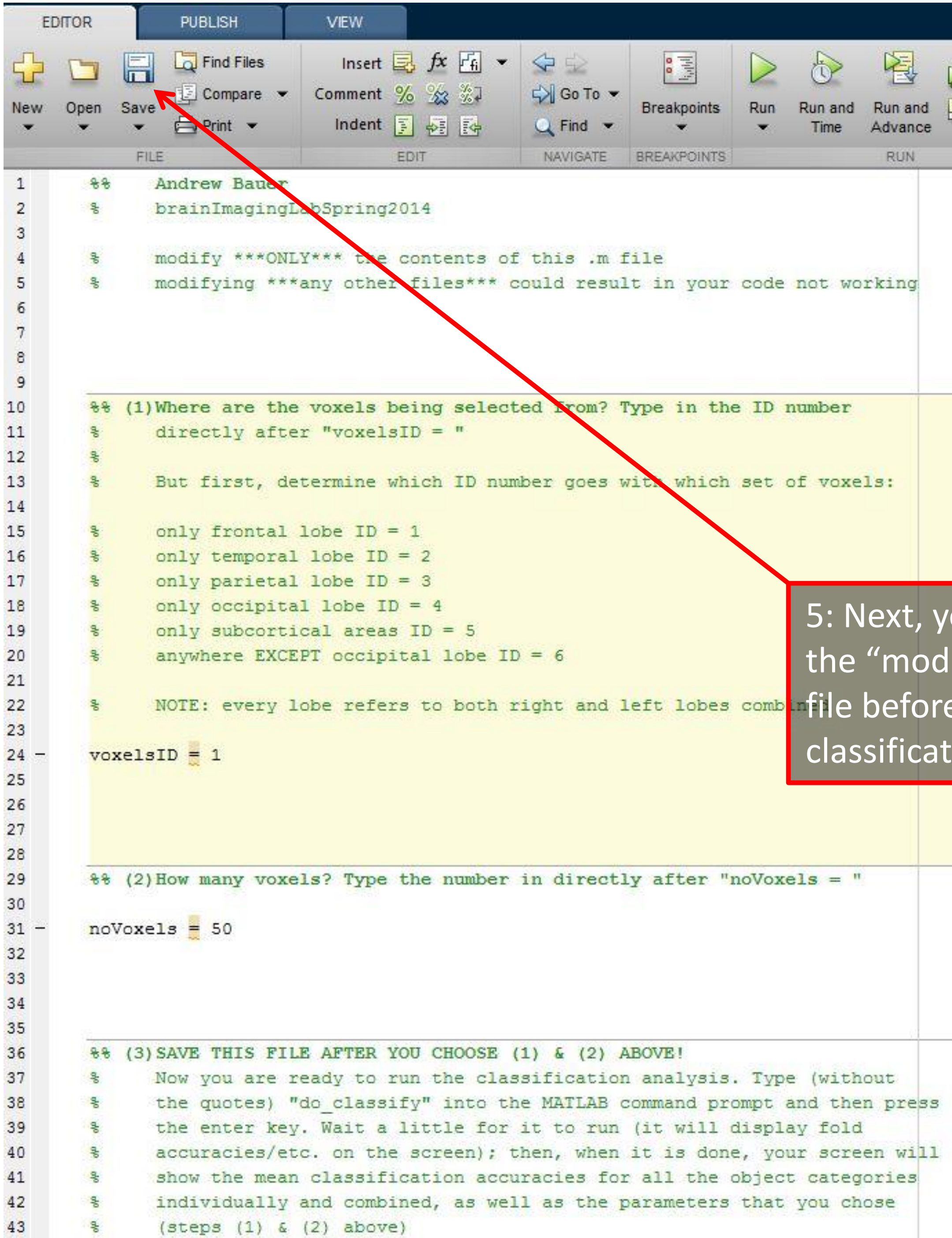
Change to “50” if it’s not already

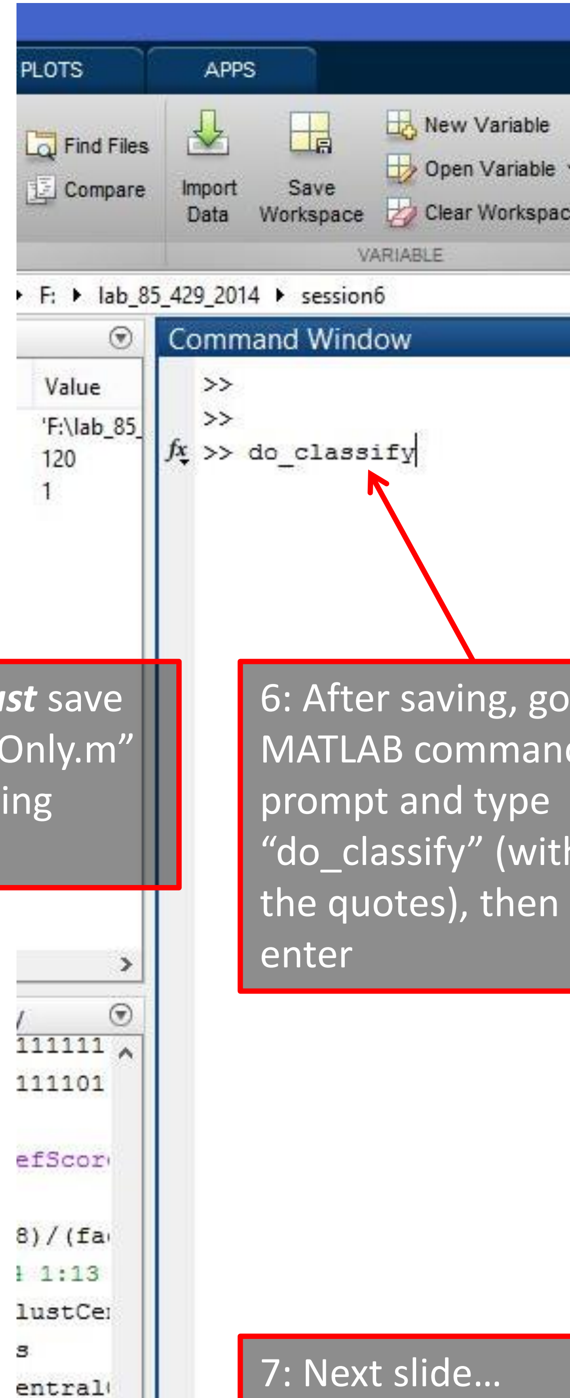
```
%% (3)SAVE THIS FILE AFTER YOU CHOOSE (1) & (2) ABOVE!
% 	Now you are ready to run the classification analysis. Type (without
% 	the quotes) "do_classify" into the MATLAB command prompt and then press
% 	the enter key. Wait a little for it to run (it will display fold
% 	accuracies/etc. on the screen); 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)
```

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

4: Next slide…





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…

MVPA report: Object category BY subject accuracy (%) =

	04383B	04408B	04550B	04647B	04564B
MEAN_categry	61.69	59.94	56.44	55.82	55.65
animals	47.80	55.59	62.37	67.46	68.81
bodyparts	63.73	57.29	33.90	67.12	34.58
buildings	51.86	24.75	63.05	61.02	46.78
buildprts	61.02	46.78	63.73	55.93	42.71
clothing	63.39	47.12	51.53	60.00	53.22
frniture	67.80	81.02	70.85	22.71	68.47
insects	49.83	73.56	58.98	57.29	67.46
kitchen	69.49	61.02	62.71	55.25	47.12
manmade	62.71	83.05	77.63	64.07	50.17
tools	65.76	51.86	42.71	42.03	56.61
vegetbles	82.37	61.02	35.59	68.81	71.19
vehicles	54.58	76.27	54.24	48.14	60.68

	04619B	04480B	04639B	04597B	04605B
MEAN_categry	54.32	53.33	53.08	52.40	51.72
animals	50.17	28.81	48.47	66.44	68.81
bodyparts	64.07	60.00	57.63	56.95	35.59
buildings	44.07	60.00	72.54	43.05	46.44
buildprts	48.47	61.69	60.68	52.20	38.64
clothing	46.78	50.17	51.86	25.08	44.75
frniture	52.20	27.12	73.22	66.10	50.85
insects	62.03	80.34	65.76	53.90	51.86
kitchen	54.24	48.14	46.78	57.63	49.15
manmade	48.14	43.73	46.78	32.54	82.03
tools	66.44	73.22	50.17	62.71	34.24
vegetbles	47.80	43.73	22.03	57.97	73.90
vehicles	67.46	63.05	41.02	54.24	44.41

	04617B	MEAN_subj
MEAN_categry	49.49	54.90
animals	39.32	54.92
bodyparts	49.15	52.73
buildings	51.53	51.37
buildprts	63.73	54.14
clothing	55.93	49.98
frniture	54.58	57.72
insects	27.46	58.95
kitchen	47.12	54.42
manmade	57.63	58.95
tools	49.83	54.14
vegetbles	33.56	54.36
vehicles	64.07	57.10

no. of voxels: 50
voxels are from: only frontal

8: After the classification is finished, you will see an “MVPA report” that lists the 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 at the top (called “MEAN_category”)

You will also see a column of accuracies for each subject. The last column is the mean subject (mean over all subjects)

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

- This is all the guidance/information that you should need to do this session's assignment

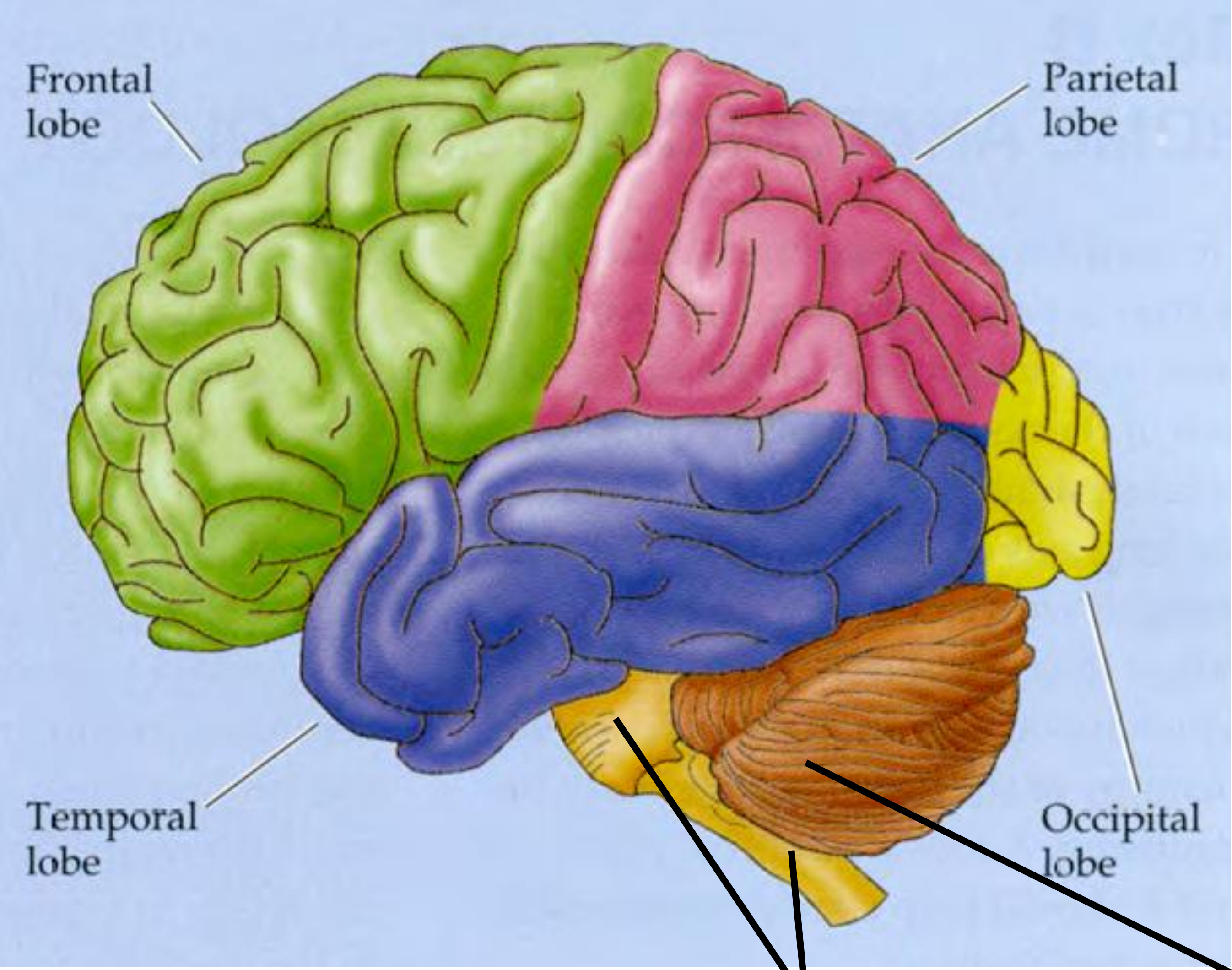
- **You do not need to start up spm or xjview for this assignment**

- If you must restart MATLAB for whatever reason, after you start MATLAB ***be sure to set the path again (just our lab folder)*** *and* ***cd back to the "session9" directory*** *(see beginning slides)*

- See the slides below for any help with orientation terms and planes, brain anatomy, and general functional neuroanatomy

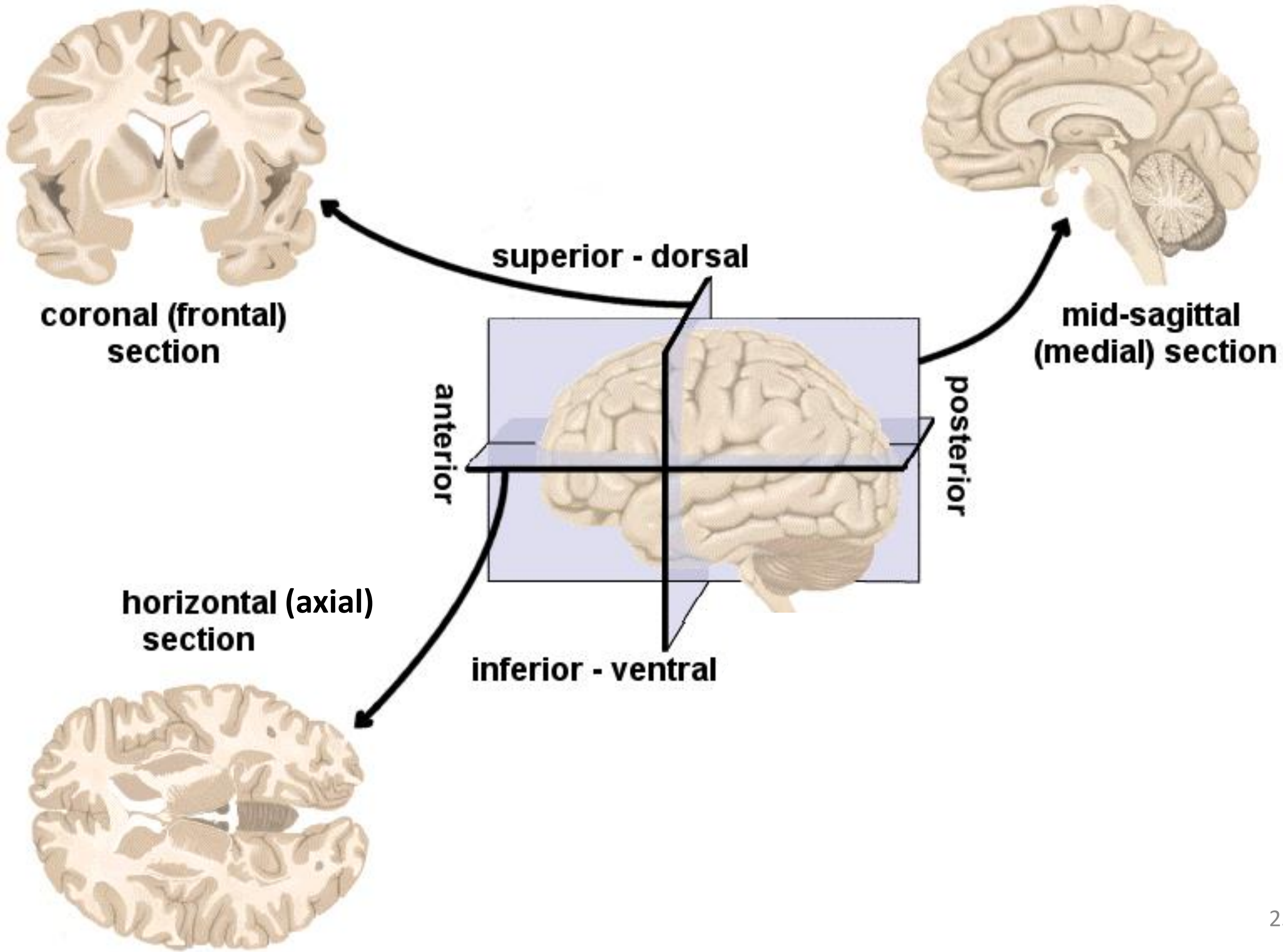
Brain partitioned into four lobes

(… plus some extra regions)



NOT “lobes”: Some subcortical brain regions & cerebellum

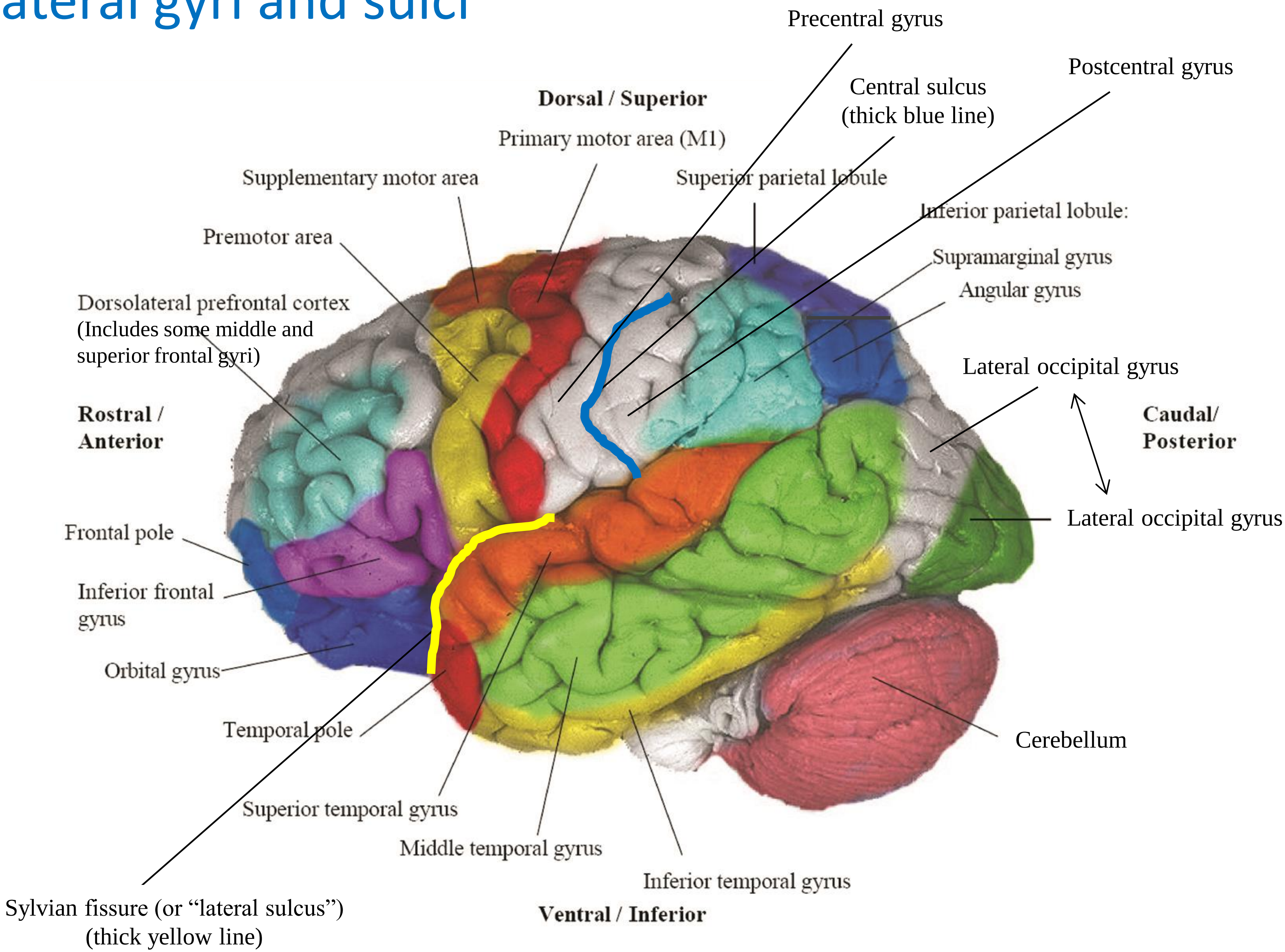
Orientation terms and planes



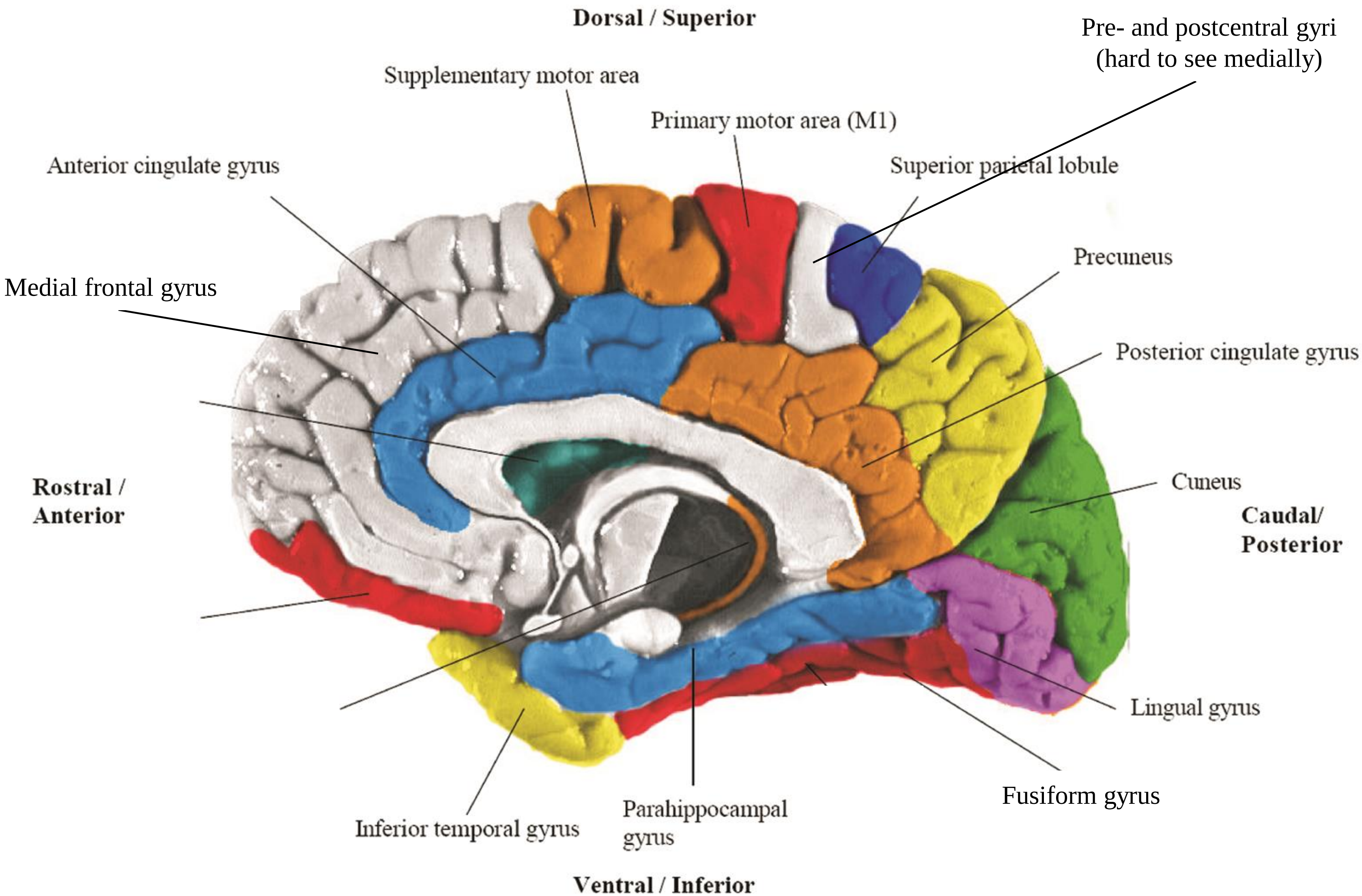
We are using the Automated Anatomical Labeling (AAL) atlas in this lab (very similar to the atlases of your two quizzes)

Images: http://www.frontiersin.org/Journal/10.3389/fnhum.2013.00845/full

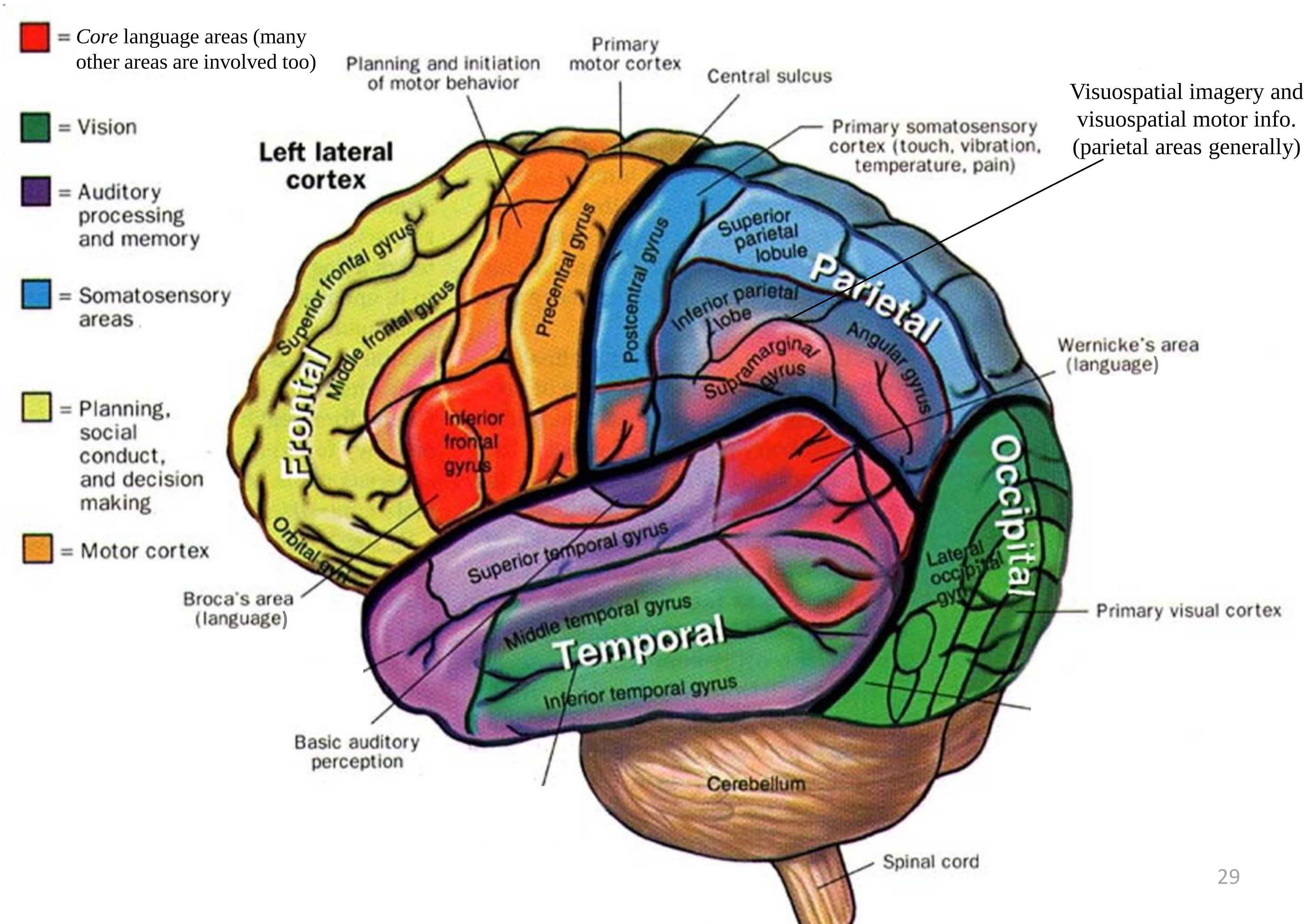
Lateral gyri and sulci



Medial gyri (some redundancy w/previous slide)



General functional neuroanatomy



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

Kriegeskorte, N., Mur, M., & Bandettini, P. (2008). Representational similarity analysis - connecting the branches of systems neuroscience. Frontiers in Systems Neuroscience, *2*(November), 4. doi:10.3389/neuro.06.004.2008

Kriegeskorte, N. (2009). Relating Population-Code Representations between Man, Monkey, and Computational Models. Frontiers in Neuroscience, 3(3), 363–73. doi:10.3389/neuro.01.035.2009

Norman, K. A., Polyn, S. M., Detre, G. J., & Haxby, J. V. (2006). Beyond mind-reading: multi-voxel pattern analysis of fMRI data. Trends in Cognitive Sciences, 10(9), 424–30. doi:10.1016/j.tics.2006.07.005

Raizada, R. D. S., & Connolly, A. C. (2012). What Makes Different People's Representations Alike : Neural Similarity Space Solves the Problem of Across-subject fMRI Decoding. Journal of Cognitive Neuroscience, 24(4), 868–877.