# Lab session 10:

# Voxel-wise modeling (within-subject)

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03/30/16

| 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) | | |

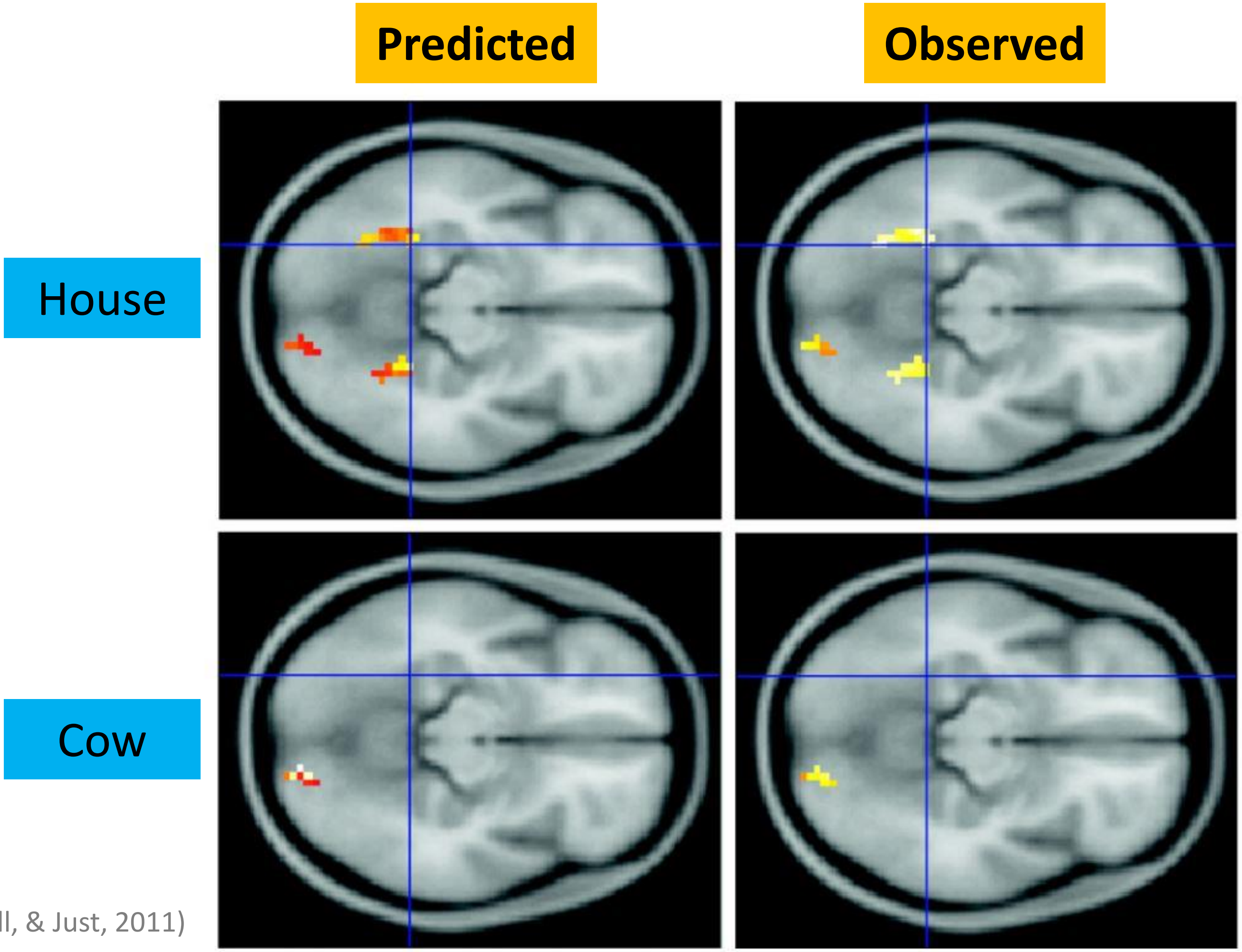
## Upon successful completion of this lab course, you should be able to…

- Process raw fMRI data in preparation for statistical data analysis;
- Visualize brain activation to discover which brain regions are active, or inactive, in a given cognitive or behavioral task;
- Conduct “mind-reading” to infer what a person is thinking about based on distributed brain activation patterns; and
- *Predict the brain activation pattern associated with thinking about a specific concept (the inverse of “mind-reading”)*
  - If we can make precise predictions, then we could be on the right track to an understanding of the phenomenon
  - (E.g. the ability of physics to make precise quantitative predictions, a hallmark of success in science)

# Predictive voxel-wise modeling

- Predict the multi-voxel activation pattern of a concept…

  based on a model of how different voxels encode the concept's features
  - E.g. **house**: is used for shelter, is made of wood or brick, etc.




(Chang, Mitchell, & Just, 2011)

# How & why do voxel-wise modeling?

- We first estimate a model of how each voxel responds to a set of features that define object concepts
  - E.g. one particular voxel activates to thinking about motion (one possible feature), but not about color (another feature)

- We can then predict the brain activation pattern of a concept based on:
  - The feature decomposition of that concept
  - The estimated model of how each voxel responds to these features

- This analysis determines:
  - *What* types of information (features) of concepts are represented in the brain
  - *Where* these features are represented in the brain

# Step 1: Break down a concept into constituent features (e.g. recruit subjects to)

**HOUSE**

Used for shelter

Is warm

Is large

Rectangular shaped

Made of wood

# Step 2: Categorize the features

## HOUSE

| | |
|---|---|
| Used for shelter | ***Function*** |
| Is warm | ***Tactile*** |
| Is large | ***Visual surface*** |
| Rectangular shaped | ***Visual surface*** |
| Made of wood | ***Visual surface*** |

# Step 3: Weight each feature category
## (based on proportion its features)

**HOUSE**

| | |
|---|---|
| ***Function*** | **1/5** |
| ***Tactile*** | **1/5** |
| ***Visual surface*** | **3/5** |

We are using the set of feature categories called the *Brain Region Encoding Scheme*; this includes primarily sensorimotor feature categories (useful in defining object concepts)

Cree and McRae (2003)'s Brain Region (BR) Encoding Scheme

(Chang, Mitchell, & Just, 2011)

| Class | **Feature Category** | Example |
|---|---|---|
| Visual | Visual color | Celery<is green> |
| | Visual form and surface properties | House<is made of bricks> |
| | Visual motion | Cow<eat grass> |
| Other primary sensory-processing | Smell | Barn<is smelly> |
| | Sound | Cat<behavior—meows> |
| | Tactile | Bed<is soft> |
| | Taste | Corn<tastes sweet> |
| Functional | Function | Hammer <used for pounding> |
| Miscellaneous | Taxonomic | Skirt<clothing> |
| | Encyclopedic | Car<requires gasoline> |

After defining concepts by constituent features…

Step 4: Run subjects in the scanner, asking them to think about the concepts

# Step 5: Estimate how each of *n* feature categories affects a voxel's activation, using training data

(multiple linear regression)

*(E.g. the 1/5 and 3/5 weights for "house" in Step 3)*

***f(w)*: Weight of feature category *i* for word *w***

$$a_v = \sum_{i=1}^{n} \beta_{vi} f_i(w) + \varepsilon_v$$

**Total activation of voxel *v***

**The estimated effect (β) of feature category *i* on voxel *v***

**The error ("leftover activation") of voxel *v***

- ***Initially known* (i.e. before doing regression)**
- ***Initially unknown* (but computed using regression)**

## Step 6: Plug the estimated beta values and feature category weights into the regression equation to predict the activation pattern of each TEST concept; then evaluate predictions

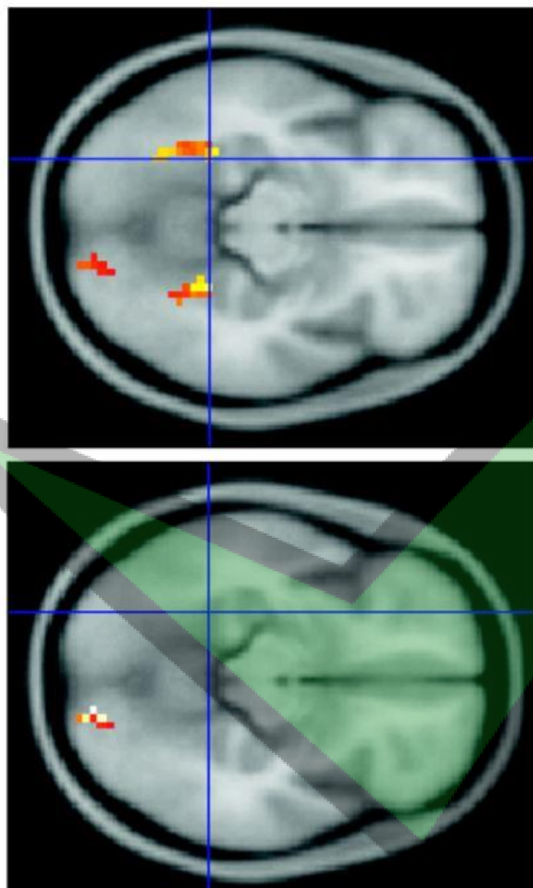
| Model | All | Frontal | Temporal | Parietal | Occipital | Fusiform | Hippocampus |
|---|---|---|---|---|---|---|---|
| *(d) Ability to distinguish between the activation of two previously unseen words (accuracy)* | | | | | | | |
| BR | 0.65 | 0.60 | 0.57 | 0.66 | 0.62 | 0.69 | 0.49 |

Mean proportion correct using BR encoding scheme

**Observed**

House

Cow

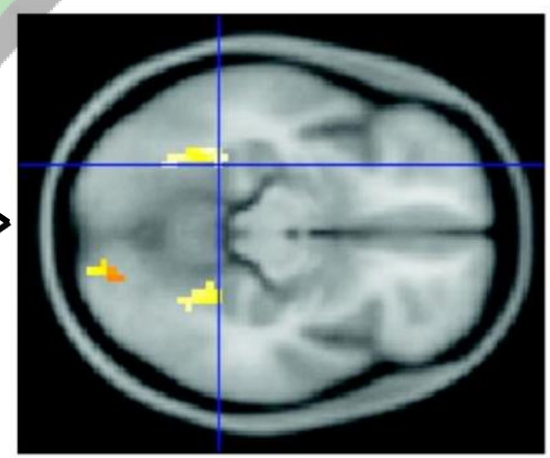


Correlation between observed and predicted activation patterns

*r* = 0.72

*r* = 0.19

**Predicted**



House

# Voxel-wise modeling is often called *generative* (vs. *discriminative*) *classification*

- It can generate/predict the activation pattern for *any* unseen concept, as long as the concept can be decomposed into the model's feature categories

**_Generative_ classifier**

| TRAIN on: | | TEST on: |
|---|---|---|
| Car | TRAINING stimuli | House |
| Hammer | can be ≠ | Cow |
| Apple | TEST stimuli | Tree |

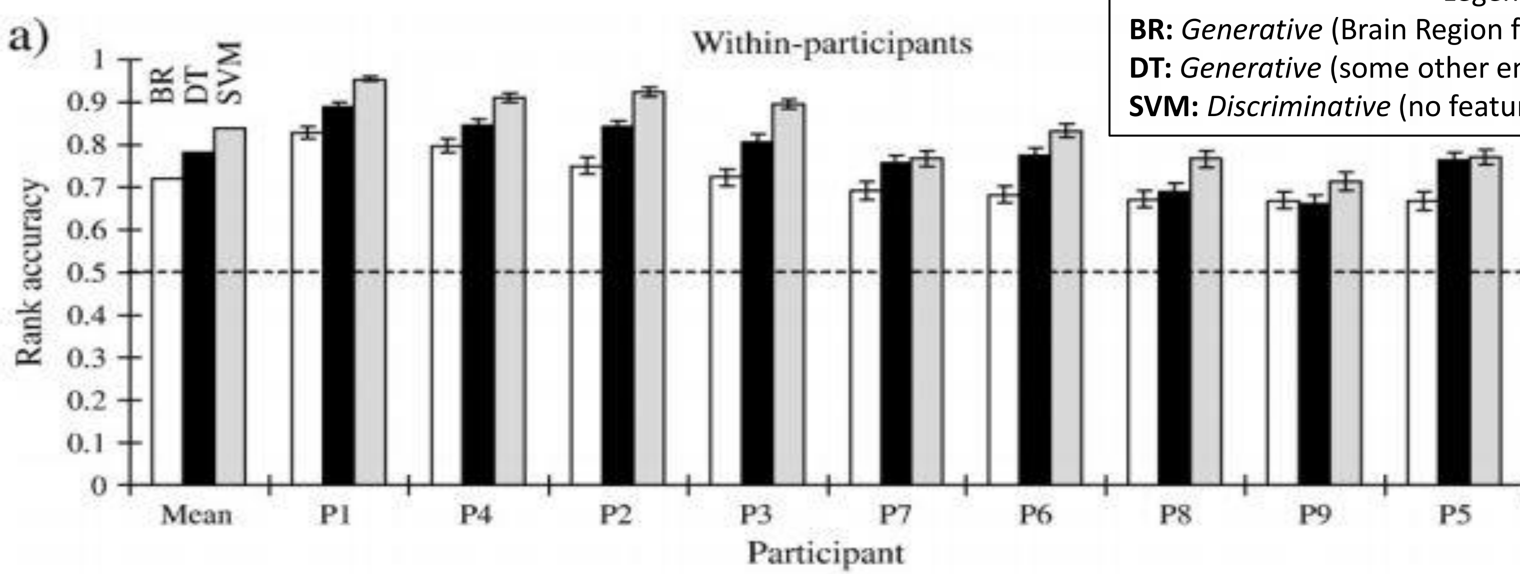
**_Discriminative_ classifier (MVPA)**

| TRAIN on: | | TEST on: |
|---|---|---|
| Car | TRAINING stimuli | Car |
| Hammer | must be = | Hammer |
| Apple | TEST stimuli | Apple |

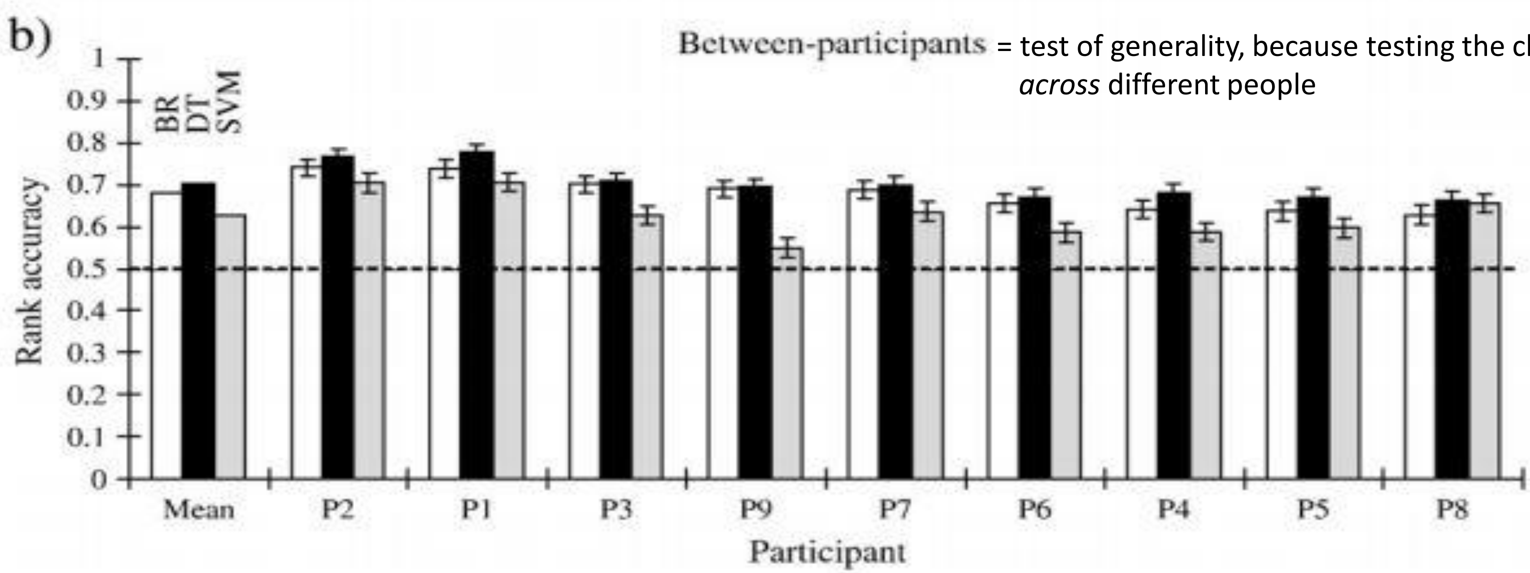
# *Generative* generalizes better than *discriminative*

## … so it is probably capturing *truer* activation patterns

Legend:
**BR:** *Generative* (Brain Region feature encoding)
**DT:** *Generative* (some other encoding)
**SVM:** *Discriminative* (no feature encoding)




Result:
***Discriminative***
**>** *generative*




= test of generality, because testing the classifier *across* different people

Result:
***Generative***
**>** *discriminative*

# Summary: *Generative* vs. *discriminative classification* approaches to studying multi-voxel activation patterns

- *Discriminative*
  - Does *not* model feature encodings of concepts
  - High classification accuracy can result from overfitting data ← no model of constituent features to "guide" classification
  - Still useful in determining *where* in the brain there are multi-voxel neural representations of concepts

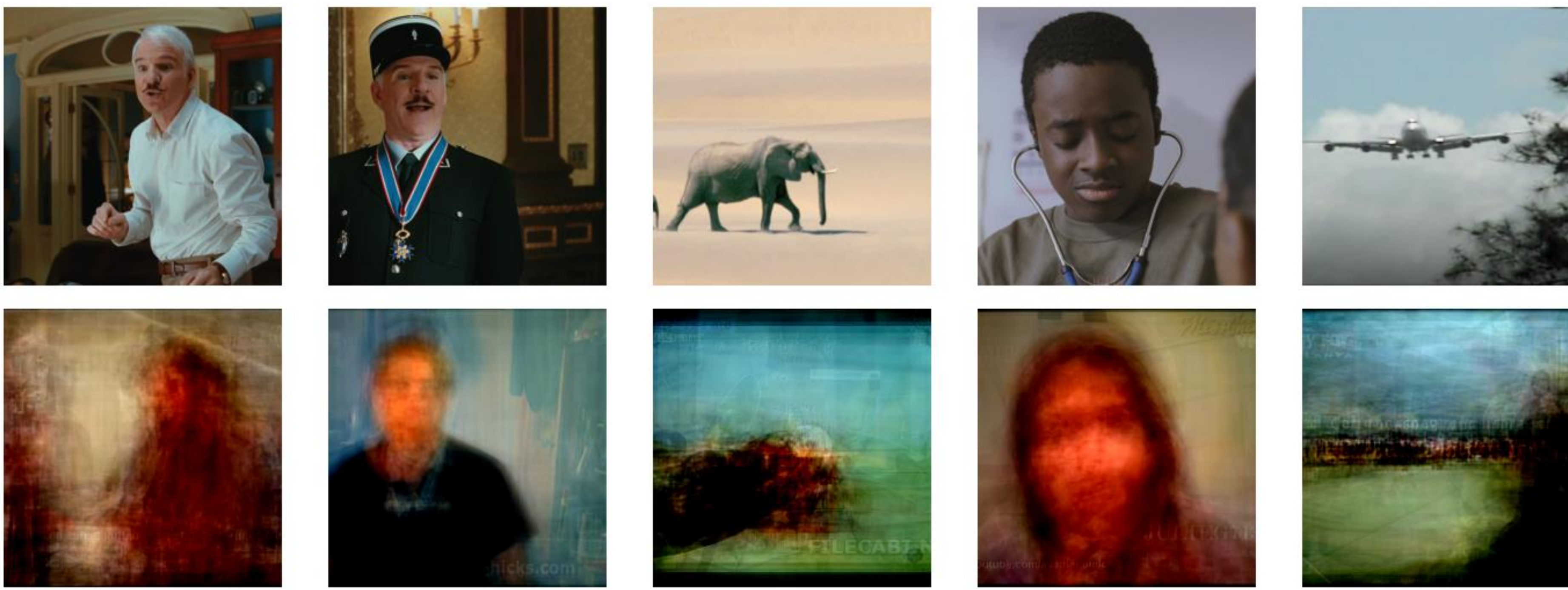
- *Generative (i.e. predictive voxel-wise modeling)*
  - *Does* model feature encodings of concepts
    - Generally truer results (lower classification accuracy, but less overfitting)
  - This analysis determines:
    - *What* types of information (features) of concepts are represented in the brain
    - *Where* these features are represented in the brain

# Voxel-wise modeling in fMRI vision research

1. Estimate how each voxel encodes colors, shapes, etc., using training data

2. Reconstruct the images seen in a movie (test data) based on the estimated model

**Real images seen in movie**

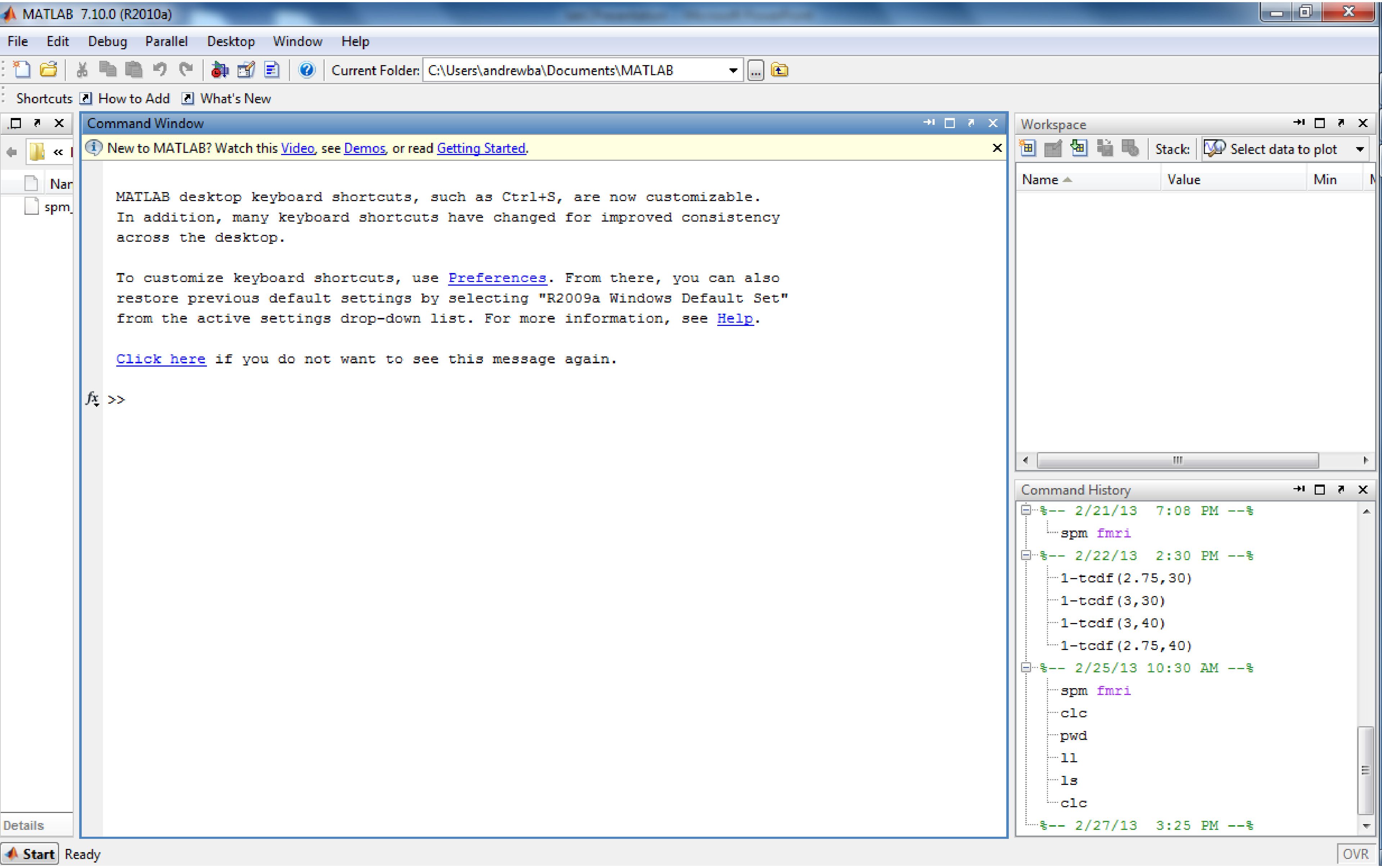


**Reconstructed images**

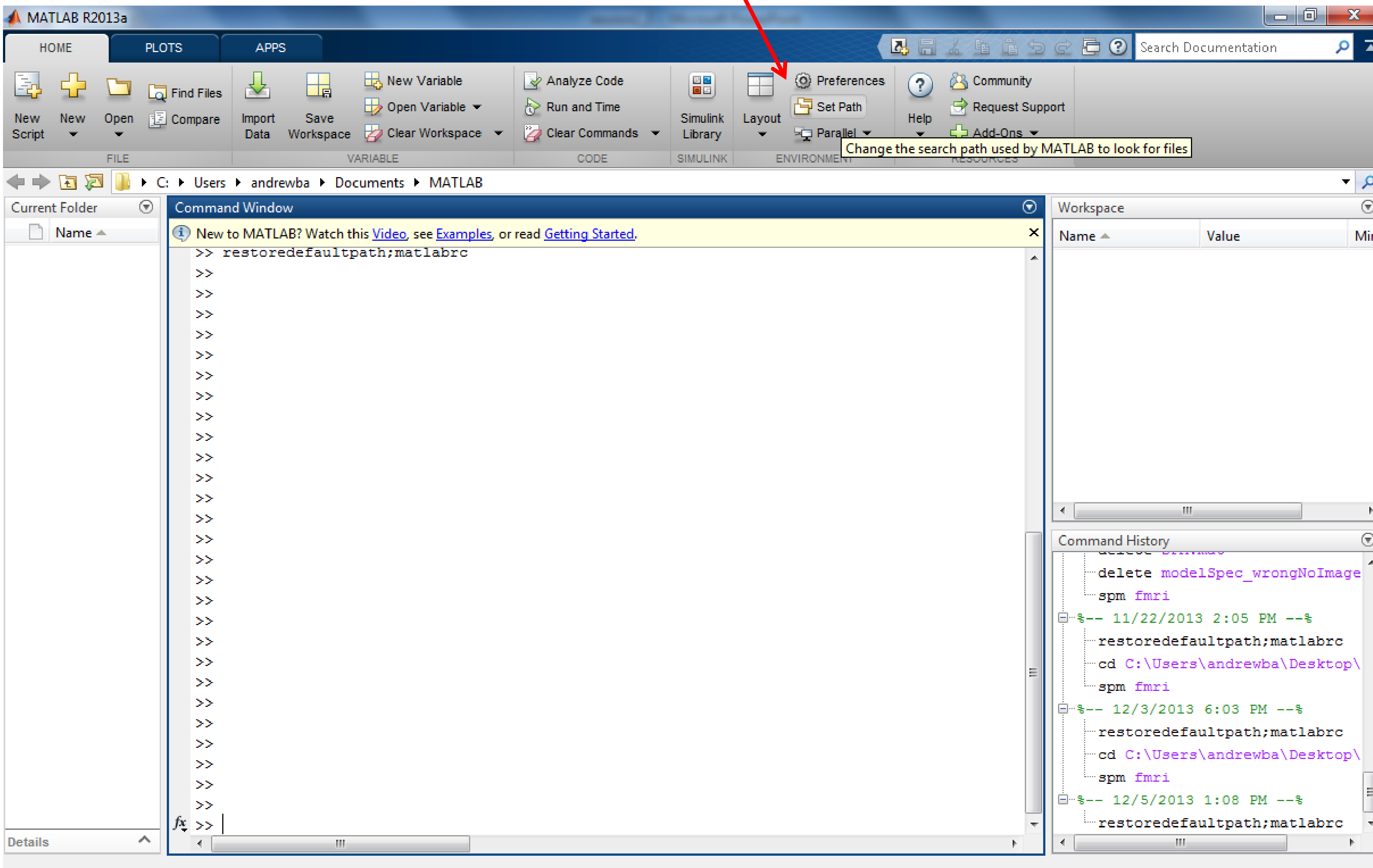
(Nishimoto et al., 2011)

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

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

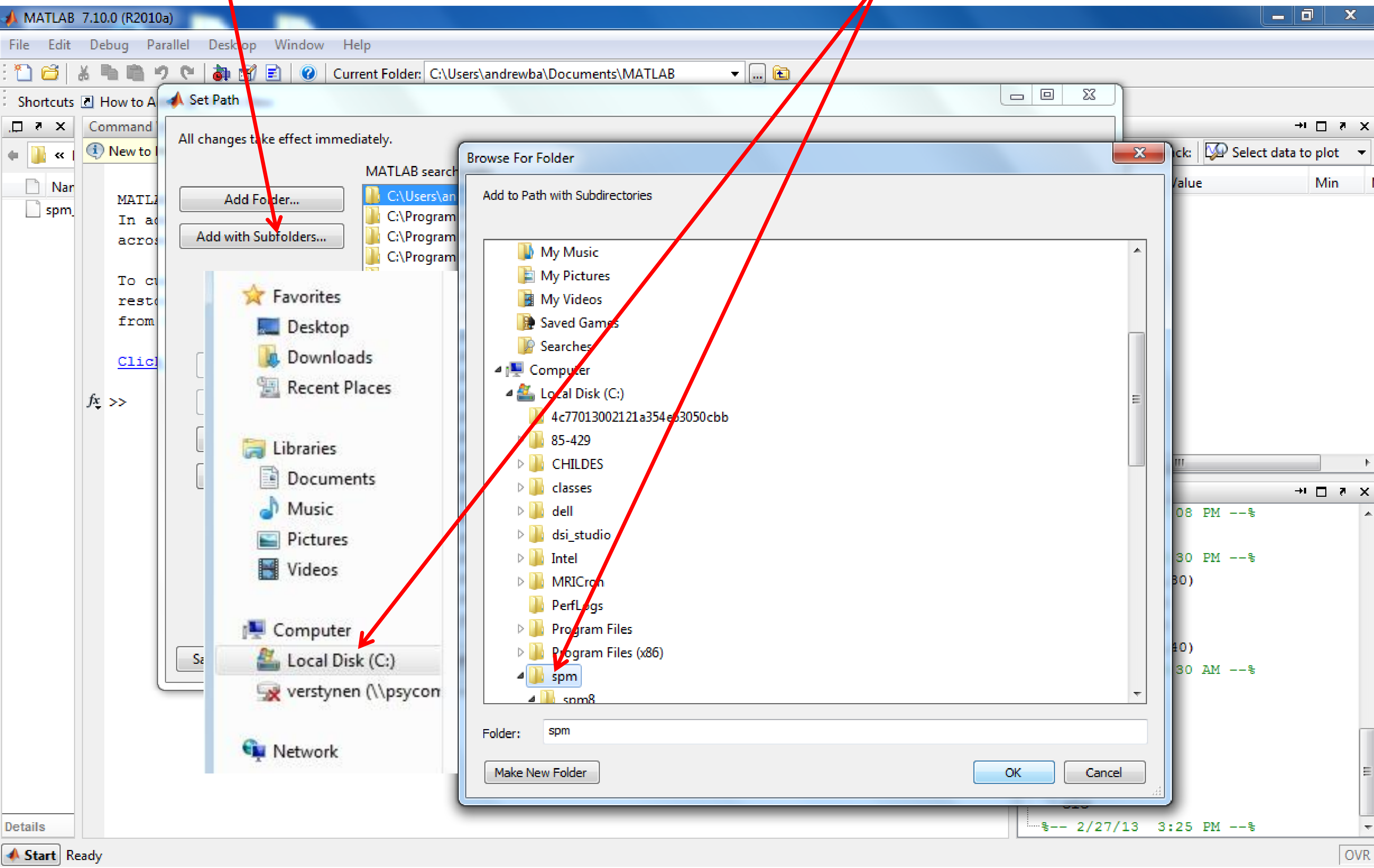


Select Set Path

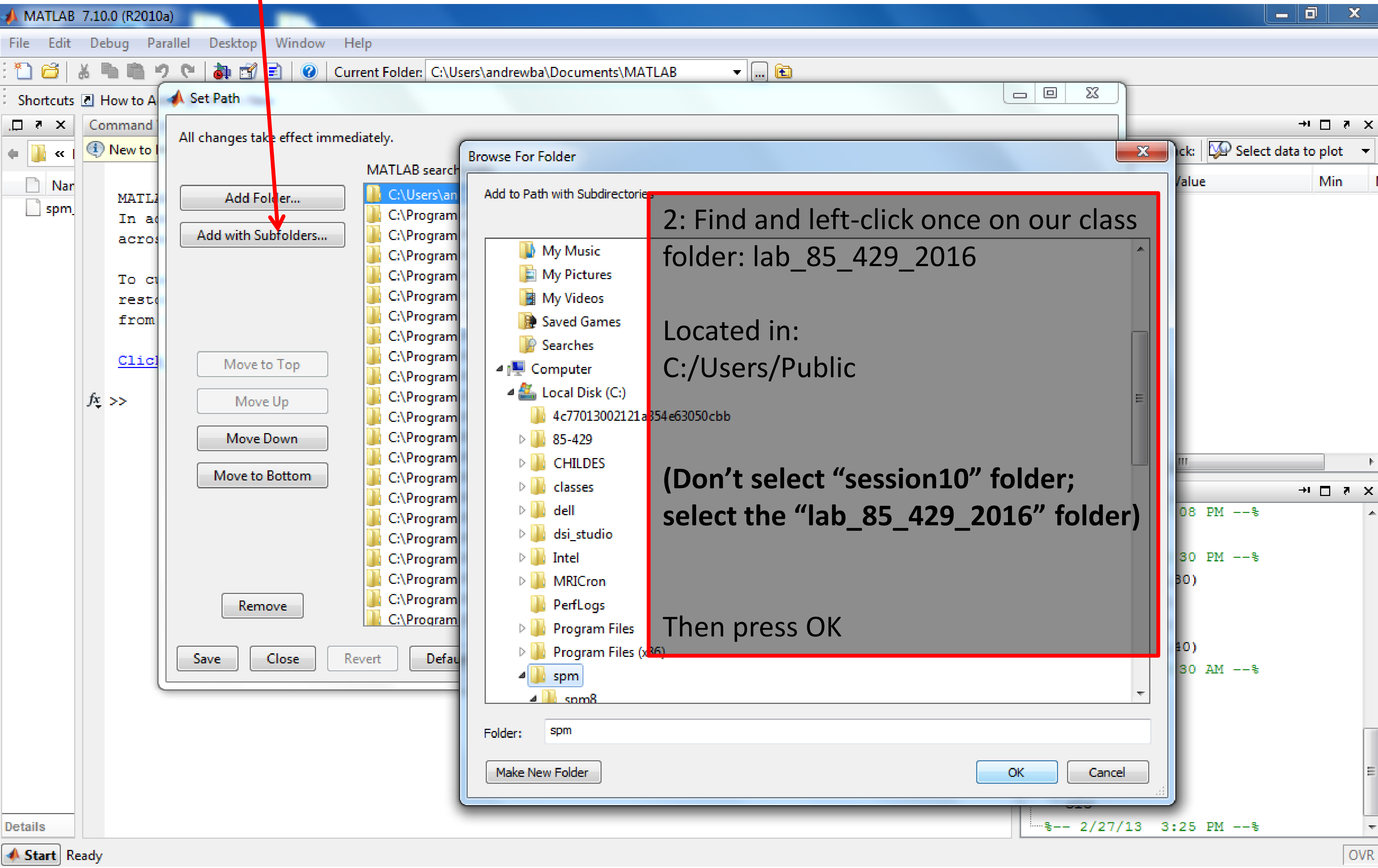


1: Select Add with Subfolders

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

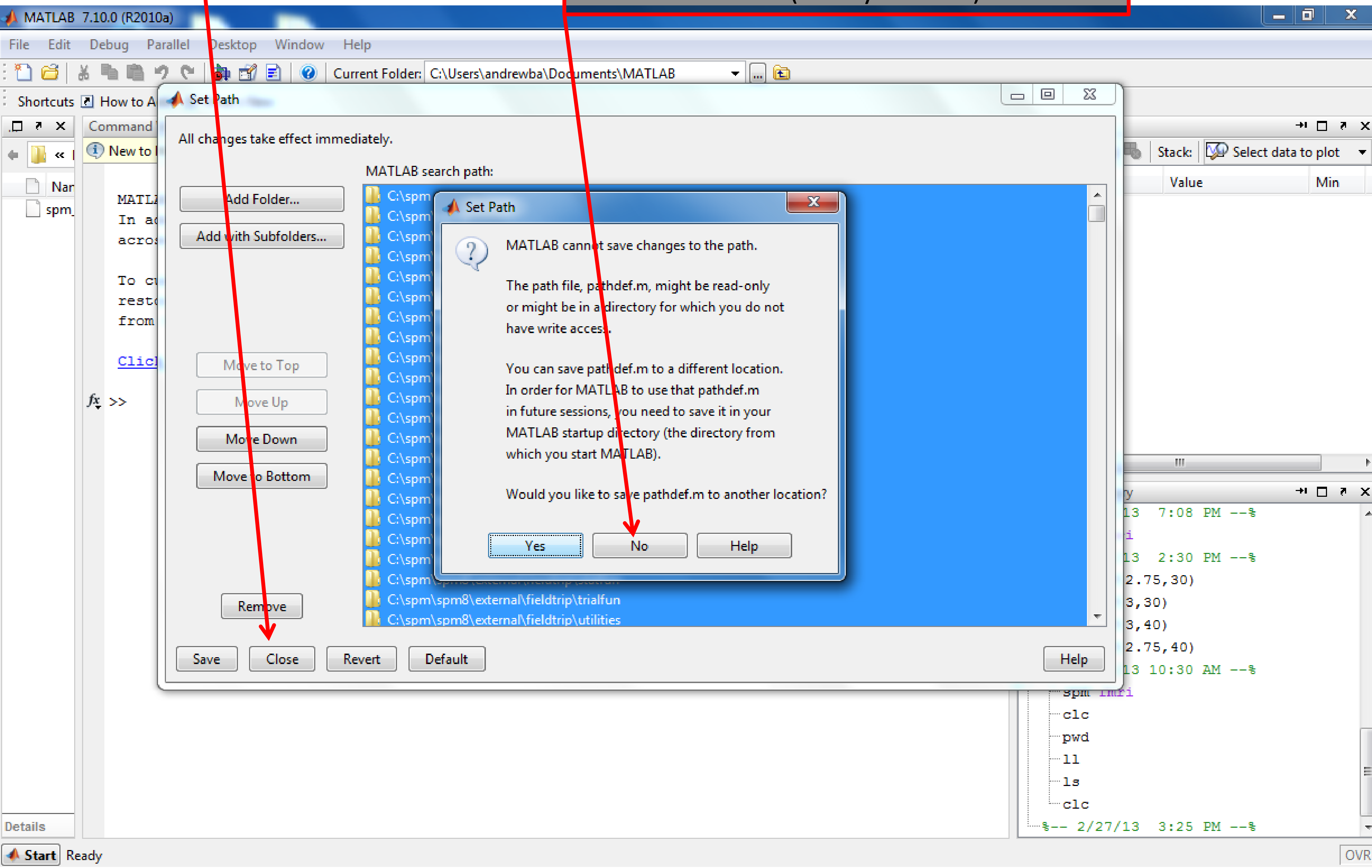


1: Select Add with Subfolders again



1: Select Close

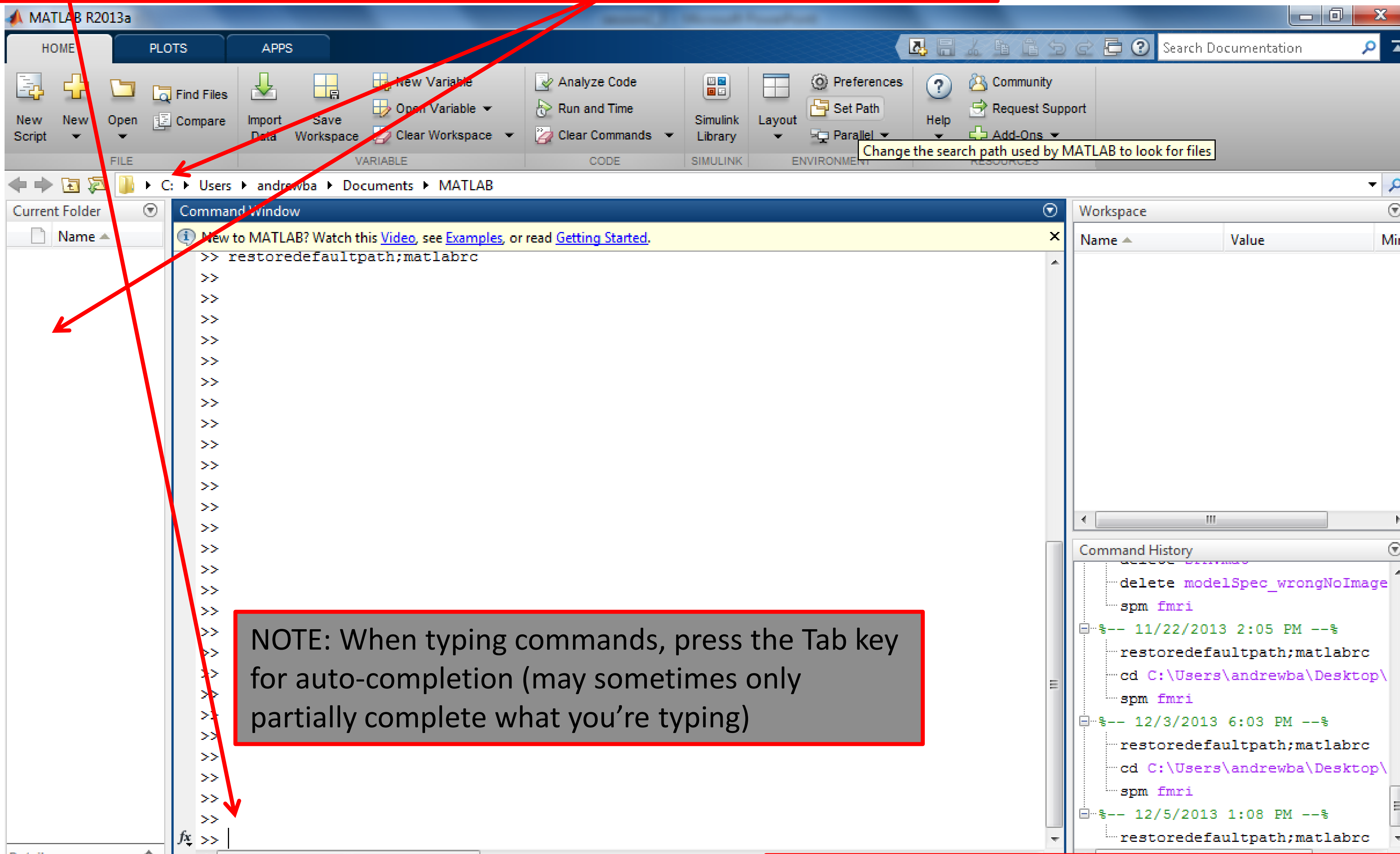
2: Select No if it asks to save the path file somewhere else (it may not ask)



1: Go to the Matlab Command Window and type:

*cd C:/Users/Public/lab_85_429_2016/session10*

…(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: See the next slide for remaining instructions

# Assignment instructions

- Problem 1: Run script “do_VM_accuracy”, which you do ***not*** edit
  - Just type `do_VM_accuracy` in Matlab command prompt and press the enter/return key

- Other problems ask you to run the “do_VM_activations” script, which you also do ***not*** edit
  - `do_VM_activations` in Matlab command prompt
    - You will then be asked to type an object concept name

- Use xjview to view resulting observed and predicted activation patterns; these files are found in folder “voxelwiseModel_results”
  - Files are named either “observed” or “predicted” and by the object concept
  - Use these xjview parameters ***always*** whenever you load a file
    - Select “Old” (not “New”) and checkmark next to “Render”
    - pThreshold: 1
    - Voxel cluster size: 2
    - Toggle “Only +”, *not* “All” or “Only -”

**(NOTE: You may need to squint at the monitor to see xjview activation!)**

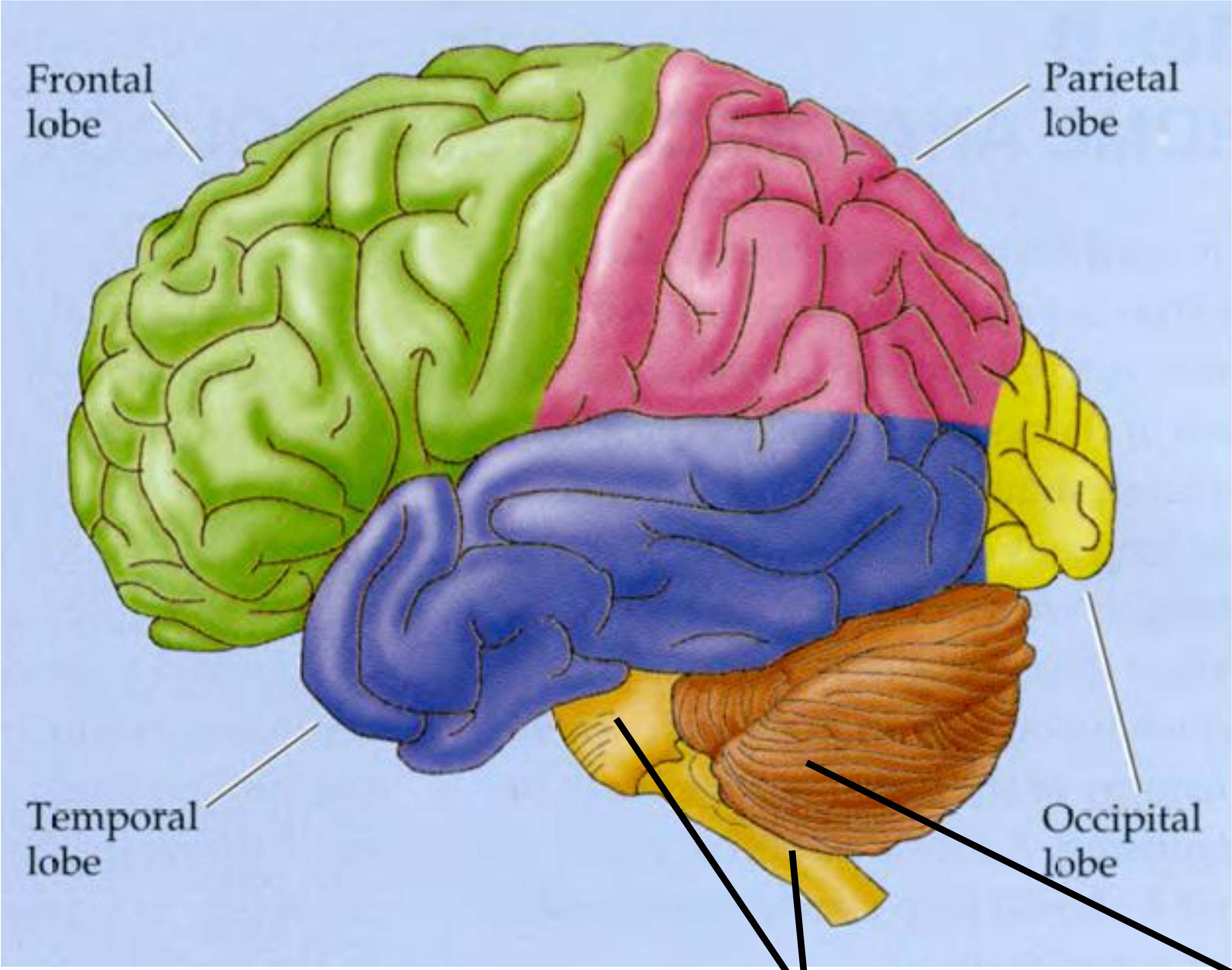
- This is all the guidance/information that you should need to do this session's assignment

- If you must restart MATLAB for whatever reason, after you restart MATLAB ***be sure to set the paths again (just our lab folder)*** *and* ***cd back to the "session10" directory*** *(see beginning slides)*

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

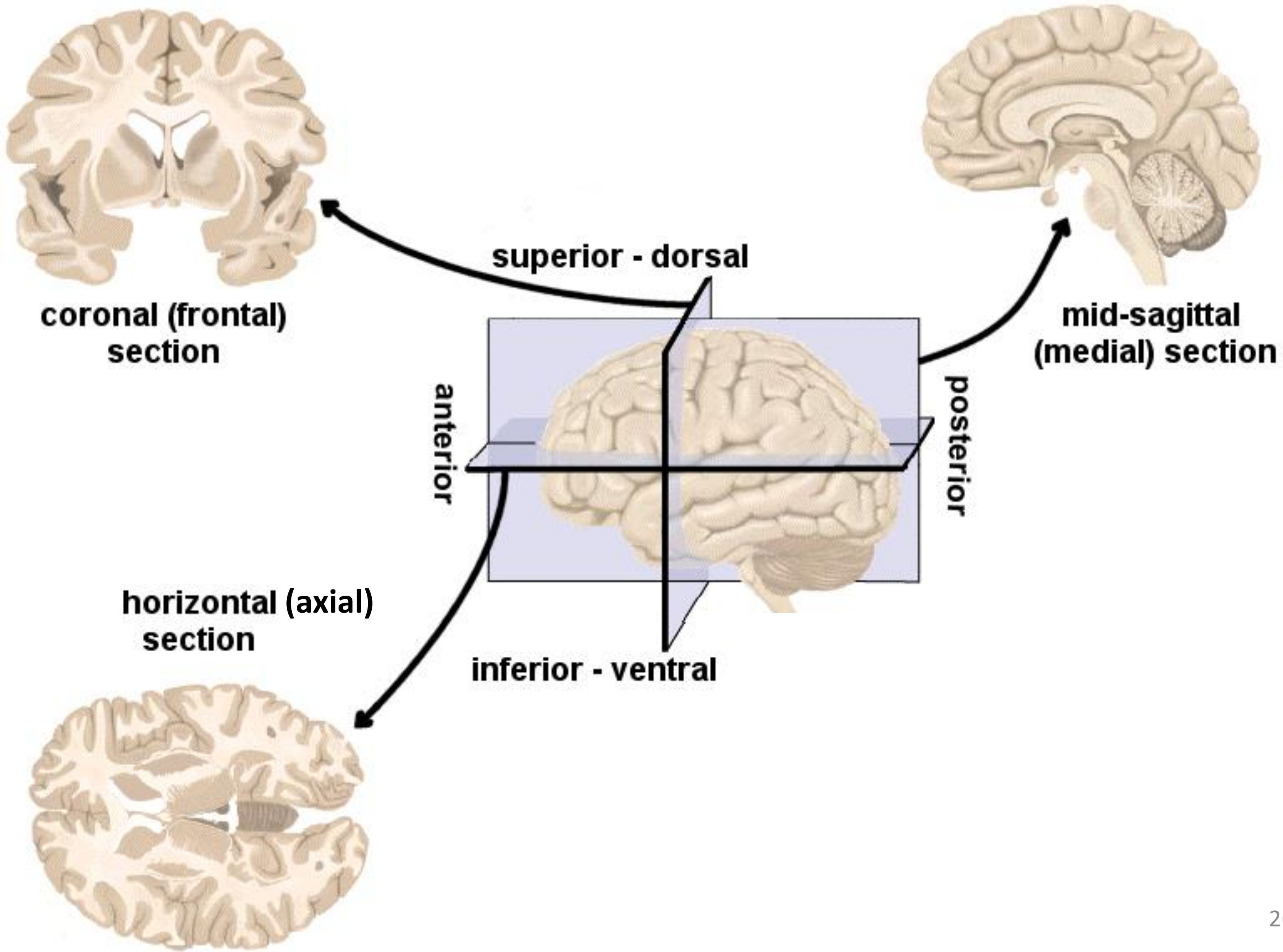
# Brain partitioned into four lobes

(… plus some extra regions)




NOT “lobes”: Some subcortical brain regions & cerebellum

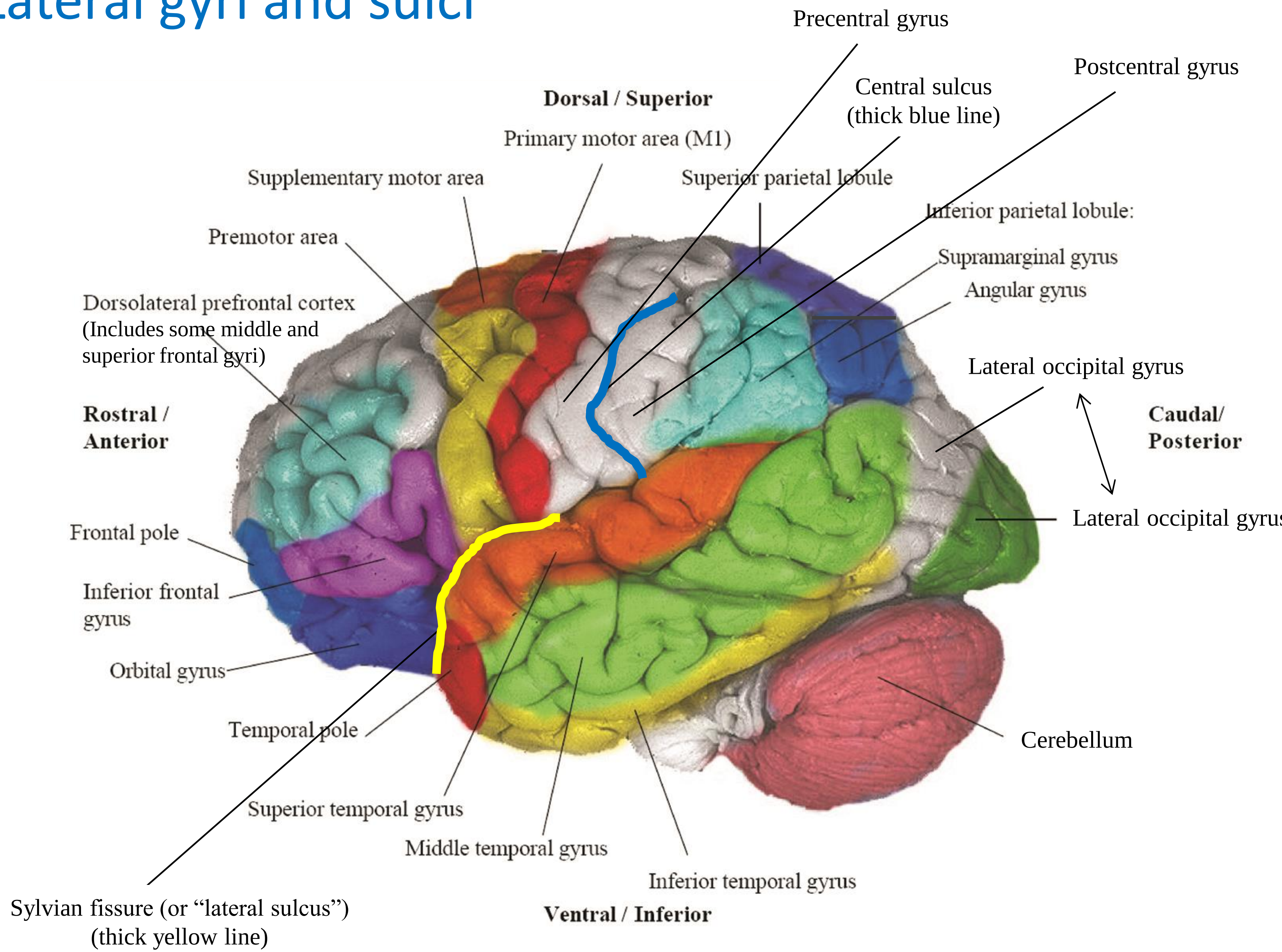
# Orientation terms and planes



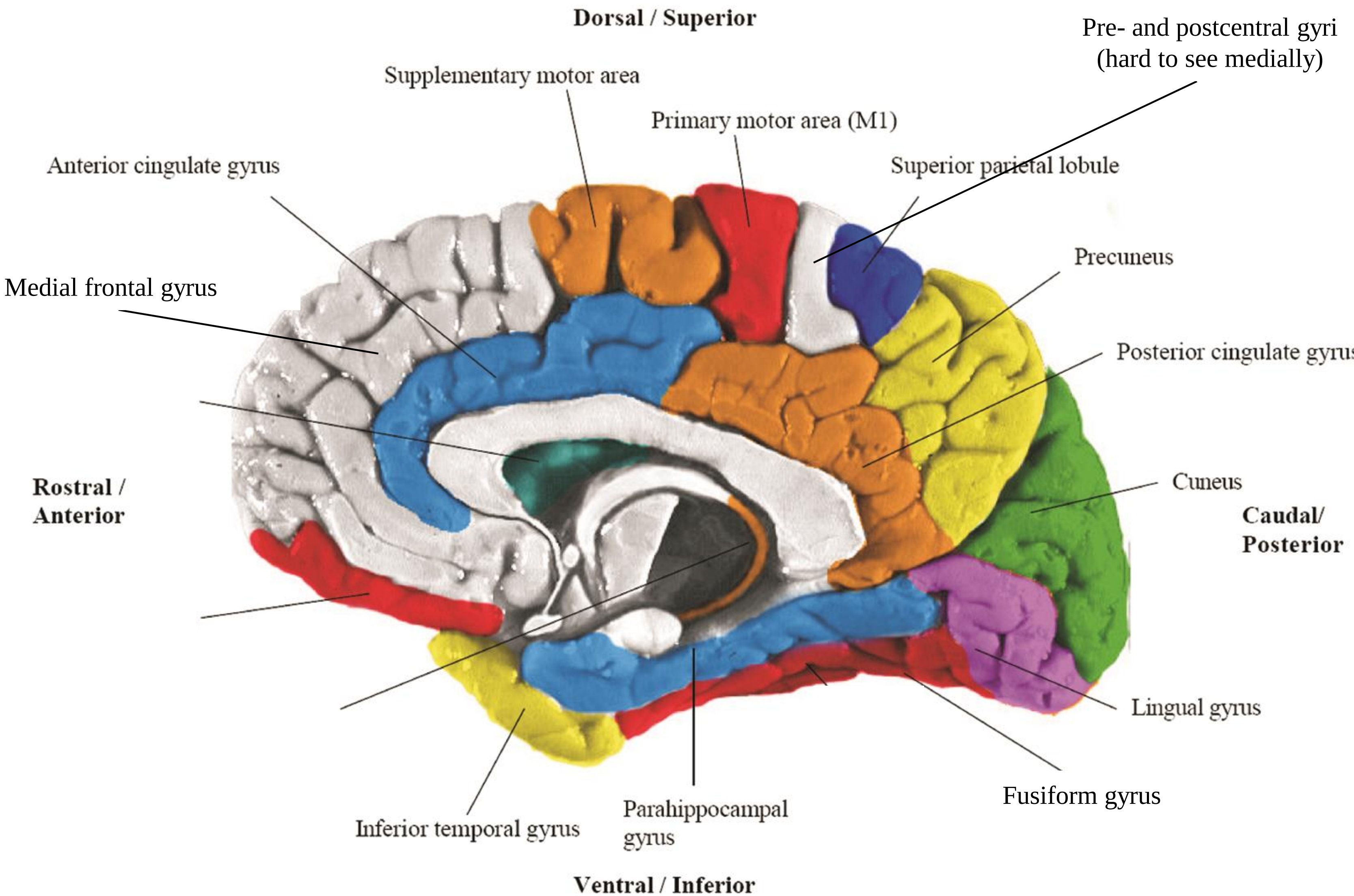
# We are using the Automated Anatomical Labeling (AAL) atlas in this lab (very similar to the atlases of your two quizzes)

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

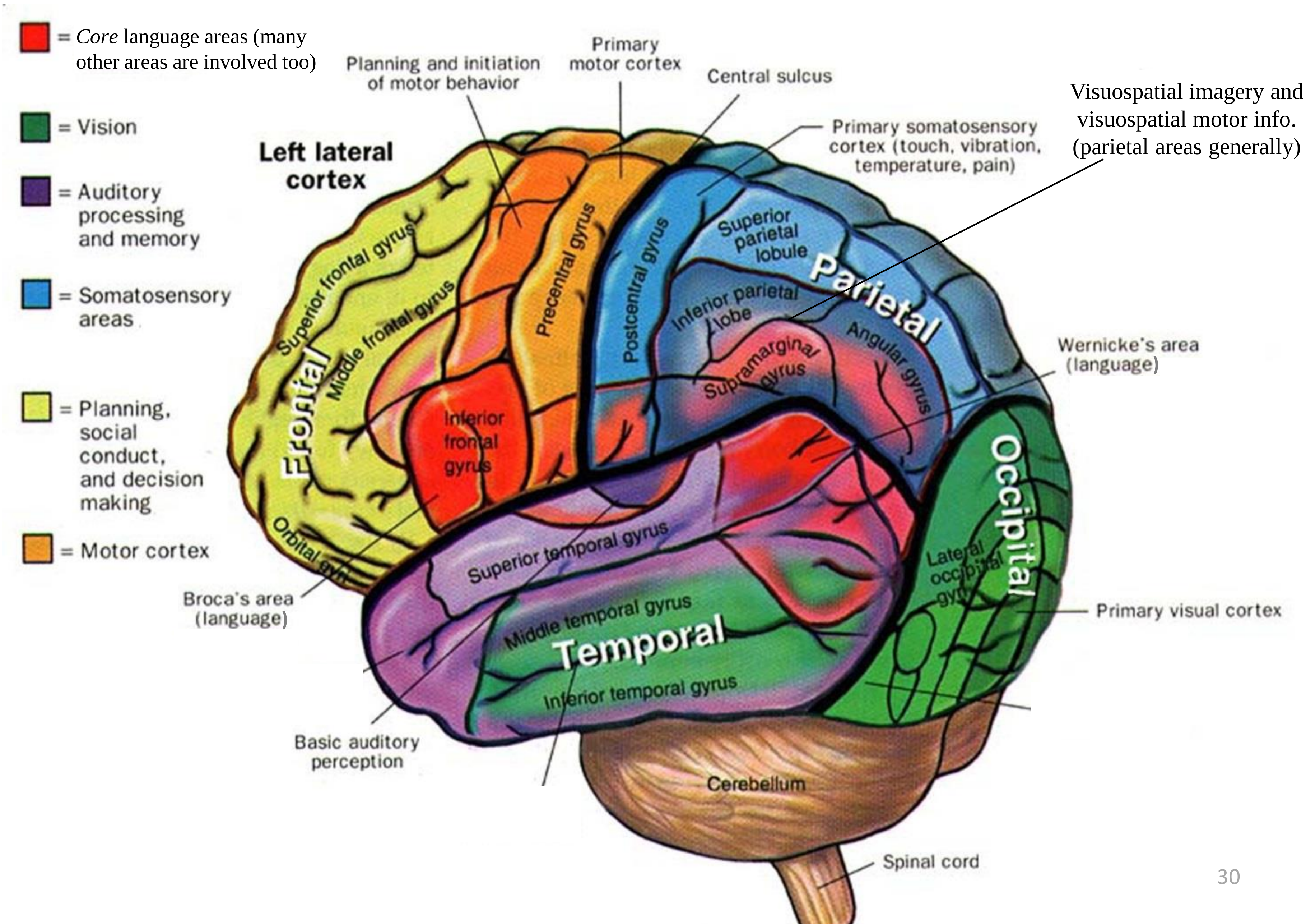
# Lateral gyri and sulci



# Medial gyri (some redundancy w/previous slide)



# General functional neuroanatomy



# References

Chang, K. K., Mitchell, T., & Just, M. A. (2011). Quantitative modeling of the neural representation of objects: how semantic feature norms can account for fMRI activation. *NeuroImage*, *56*(2), 716–27. doi:10.1016/j.neuroimage.2010.04.271

Nishimoto, S., Vu, A. T., Naselaris, T., Benjamini, Y., Yu, B., & Gallant, J. L. (2011). Reconstructing visual experiences from brain activity evoked by natural movies. *Current Biology : CB*, *21*(19), 1641–6. doi:10.1016/j.cub.2011.08.031