Lab session 11: Functional connectivity analysis (FCA)

(No assignment)

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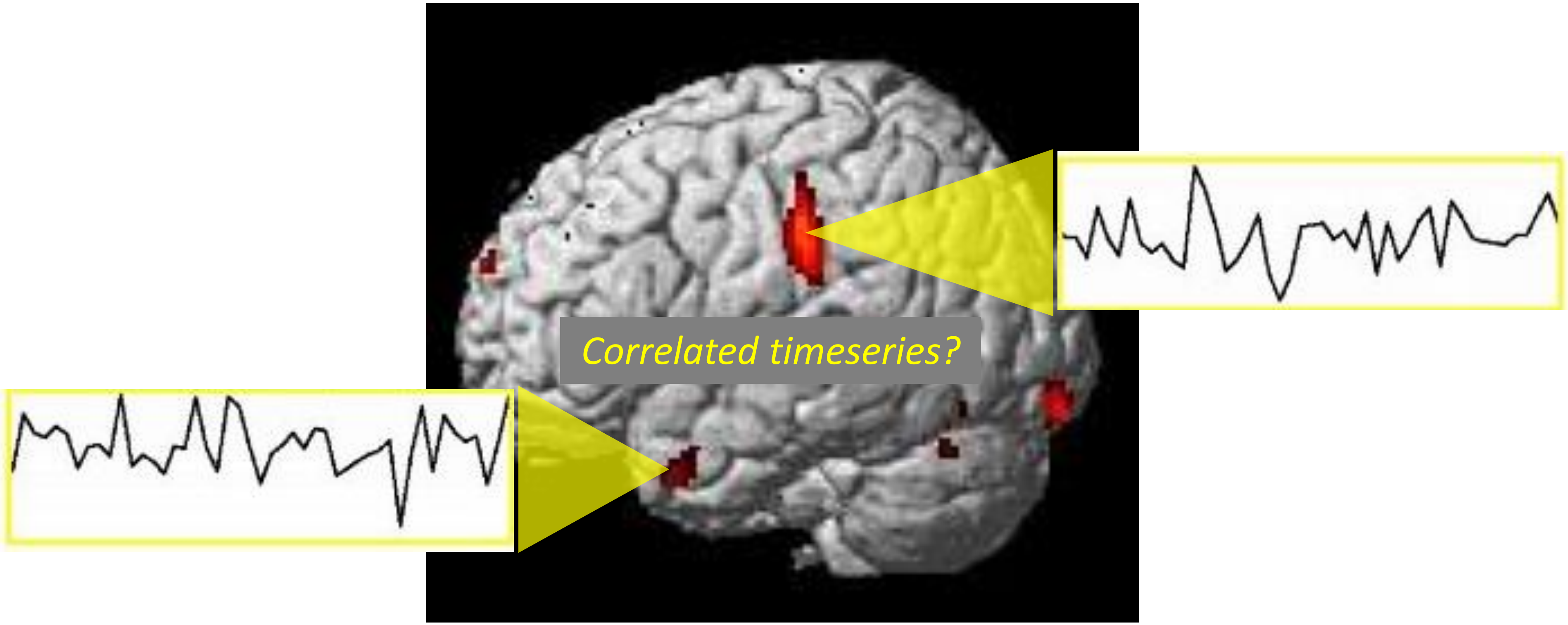
04/06/16

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)		

So far, we've inferred an interaction or cooperation between brain regions if they're *co-active*…

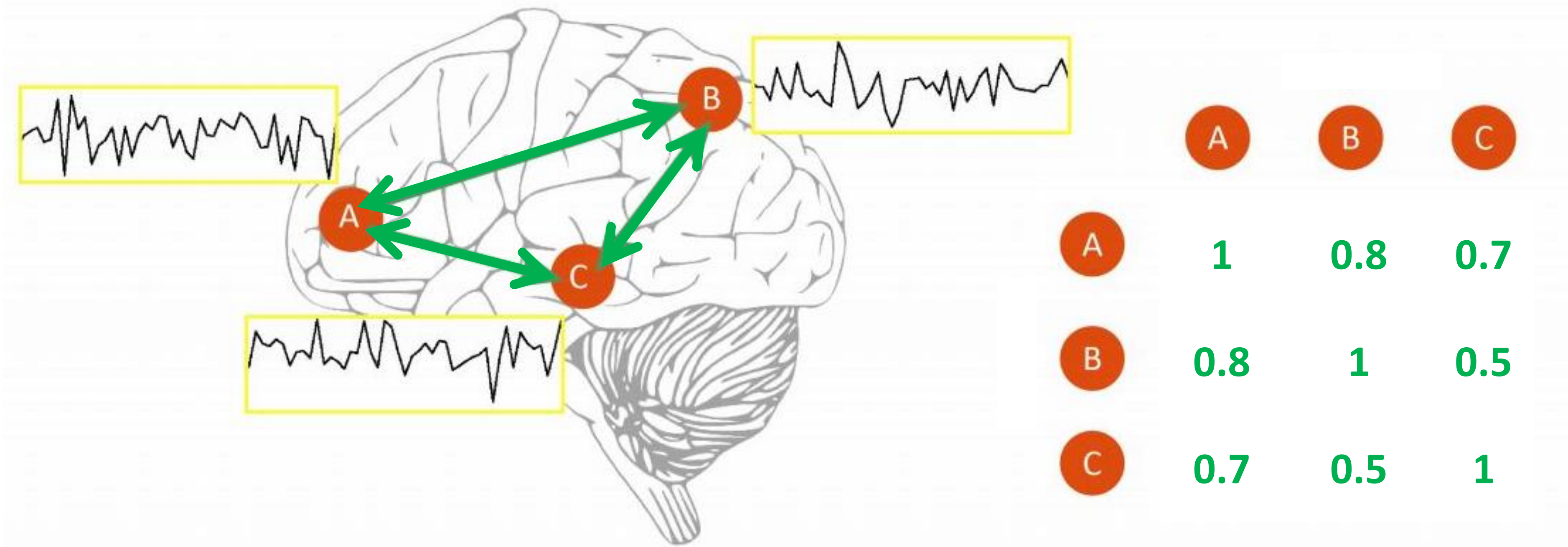


… but we can make our inference stronger by examining whether different brain regions' activity is *correlated over time*

Types of FCA

- Basic correlational approach
  - Does brain region A's activity correlate with brain region B's over time? If so: *probably working together*

Basic correlational FCA:
Pairwise correlations between nodes



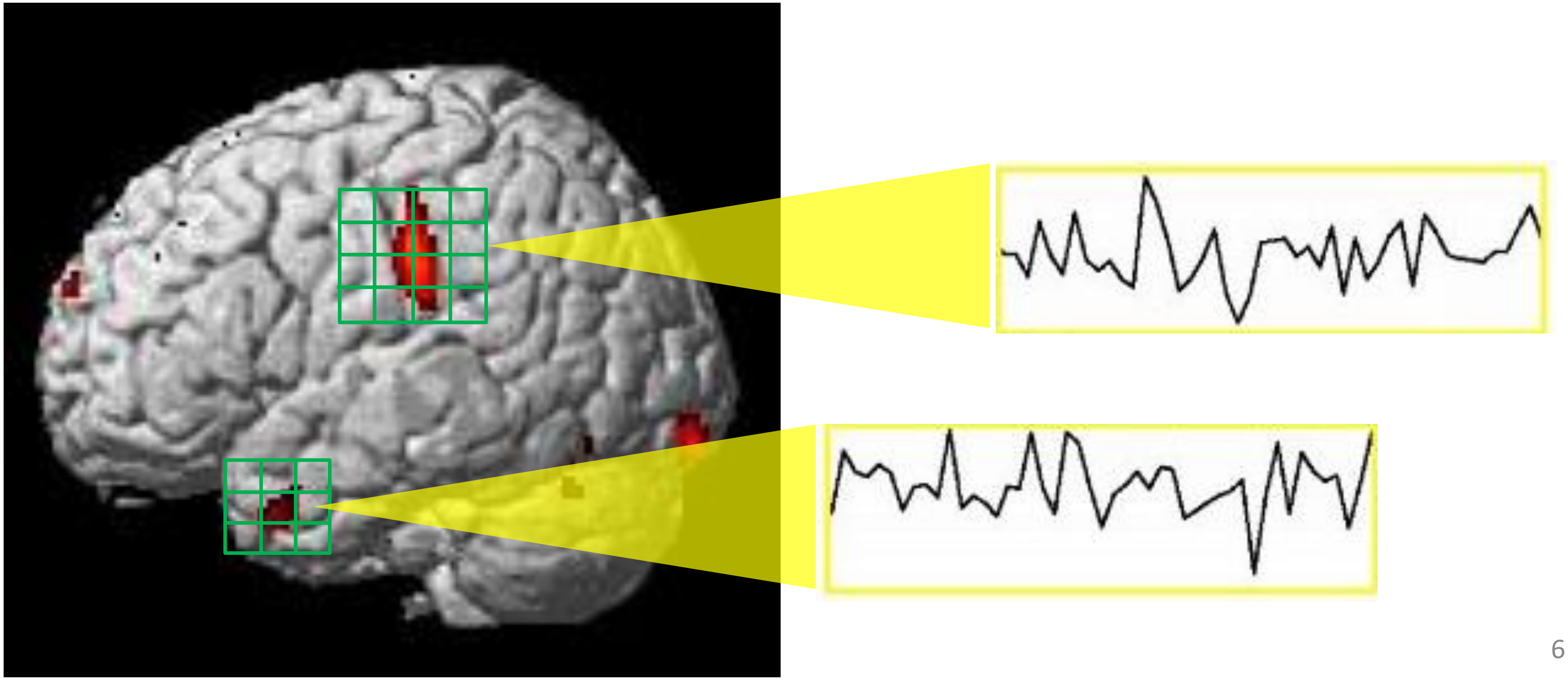
- Define network *nodes* (spatial coordinates or regions of interest)
- Identify a timeseries associated with each node
- Estimate the *edge strengths*, or connections between the nodes
    - For example, correlate each timeseries with every other timeseries

(Image from Smith et al., 2013)

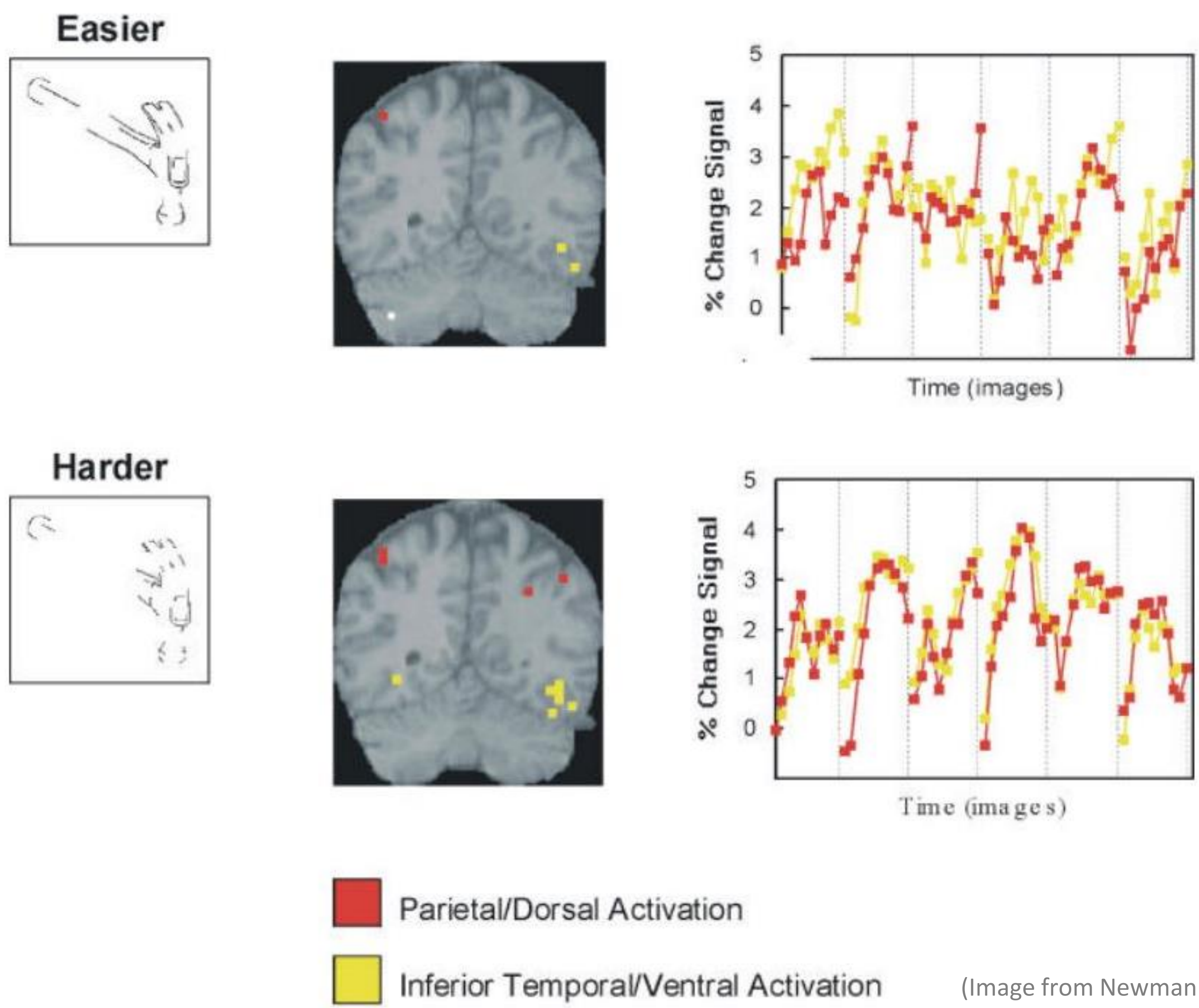
First must define regions of interest (ROI), a.k.a. nodes

1. Define a cube (your ROI, below) around a statistically significant cluster

2. In this cube, average the timeseries *only* from the voxels that are statistically significant



Spatial (parietal) and visual (inf. temporal) brain activity synchronize *more* during the *harder* object recognition task



(Image from Newman & Just, 2005)

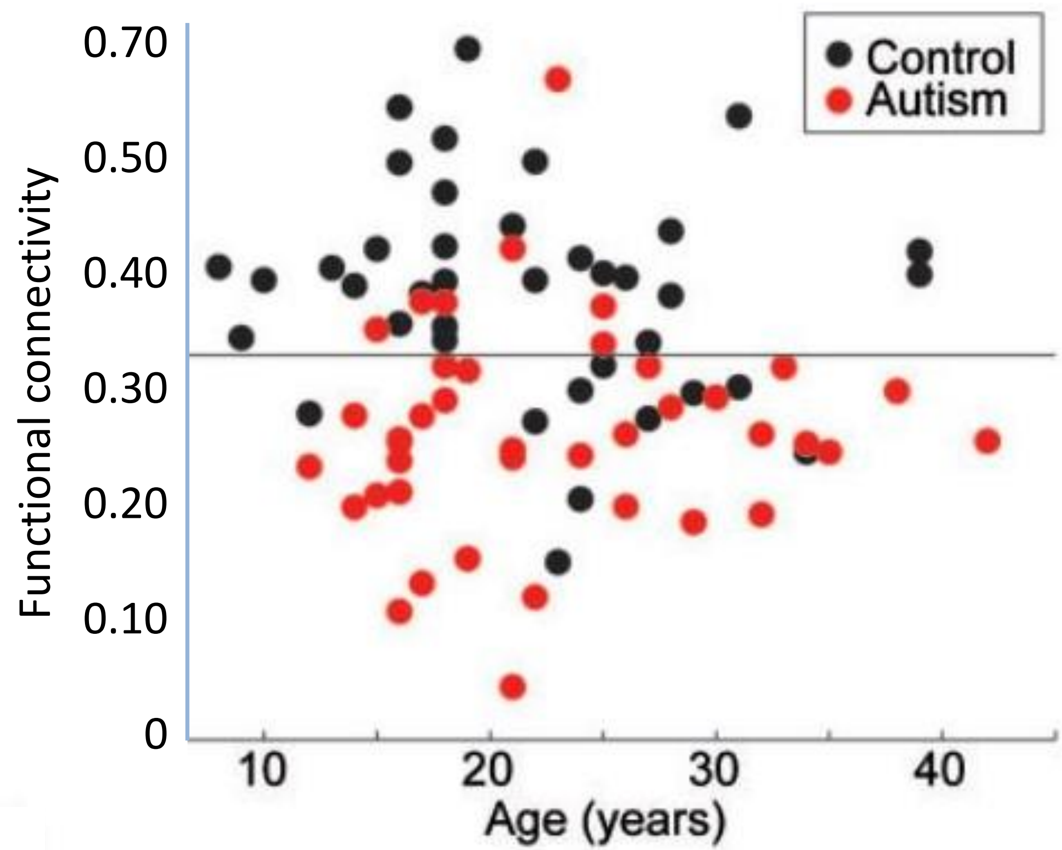
Can diagnose a subject based on functional connectivity as either: Autistic or Neurotypical (control)

Functional connectivity between frontal and parietal areas	
subj1	0.19
subj2	0.74
subj3	0.32
subj4	0.63
subj5	0.17
subj6	0.64
subj7	0.39

Neurotypical (control)?

Classifier's decision for each subject

Autistic?

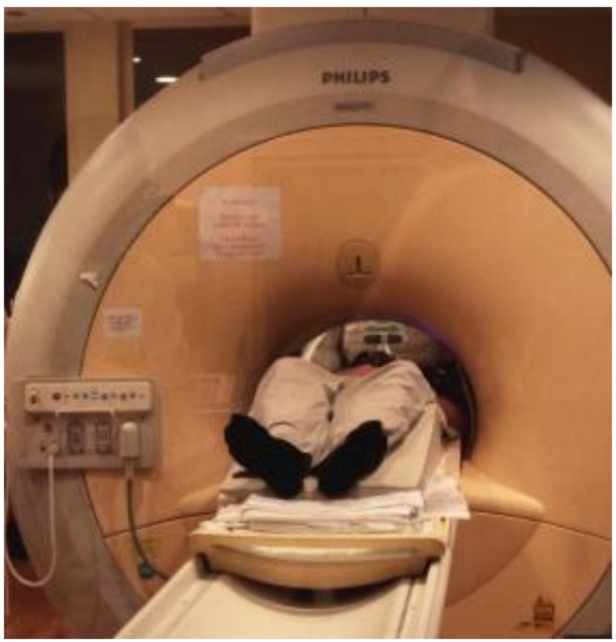


(Image from Anderson et al., 2011)

Resting-state functional connectivity networks

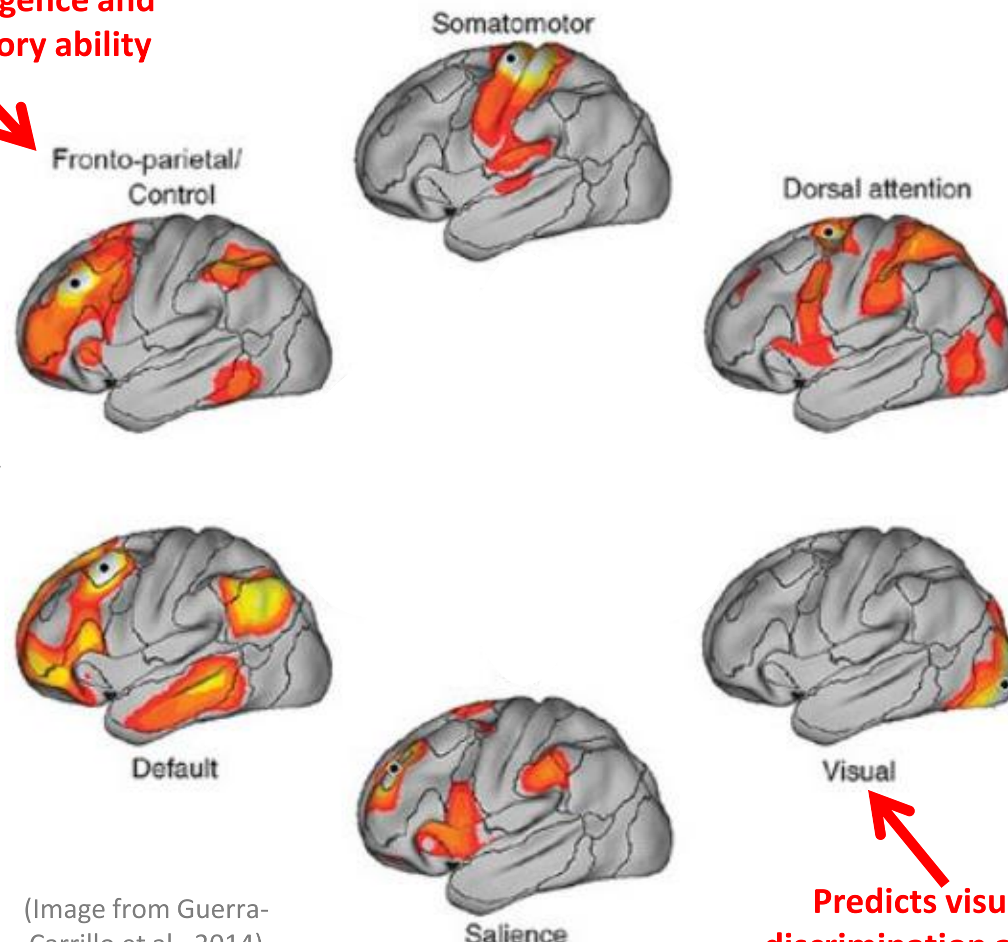
Taking functional neuroanatomy to the spatio**<u>temporal</u>** level

- Brain networks at rest reflect the history of interactions between regions during day-to-day activities



Subject in scanner doing… nothing, except staring at fixation cross (i.e. resting-state scan)

Predicts intelligence and working memory ability



Predicts visual discrimination ability

(Image from Guerra-Carrillo et al., 2014)

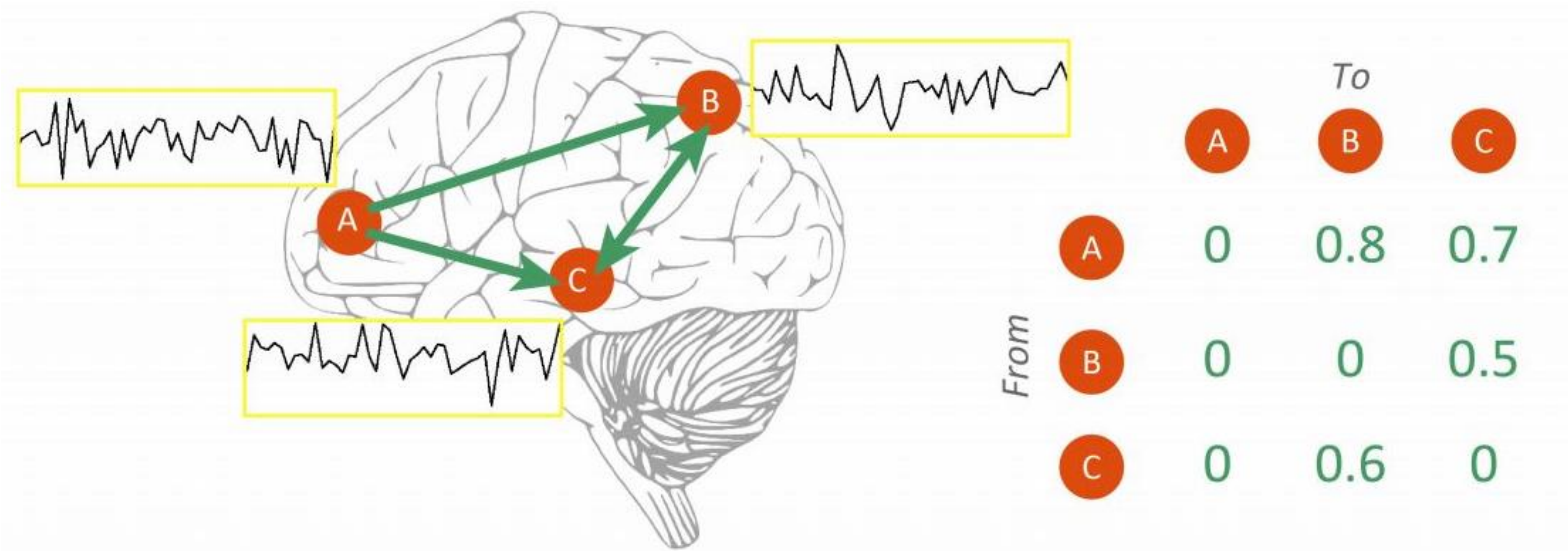
Types of FCA

- Basic correlational approach
  - Does brain region A's activity correlate with brain region B's over time? If so: probably working together

- Causal(-esque) approach (vs. correlational)
  - Does brain region A's activity **cause** brain region B's?
    - More specific interaction than "they might work together"

Going from *correlational* to *causal* FCA (a.k.a. from *functional* to *effective* connectivity)

(note differences here from Slide 5)



- Define network *nodes* (spatial coordinates or regions of interest)
- Identify a timeseries associated with each node
- Estimate the *edge strengths*, or connections between the nodes
  - For example, correlate each timeseries with every other timeseries
  - If the data (and method for estimating edges) permits the estimation of causality, the edges may be uni-directional, resulting in an asymmetric network matrix

(Image from Smith et al., 2013)

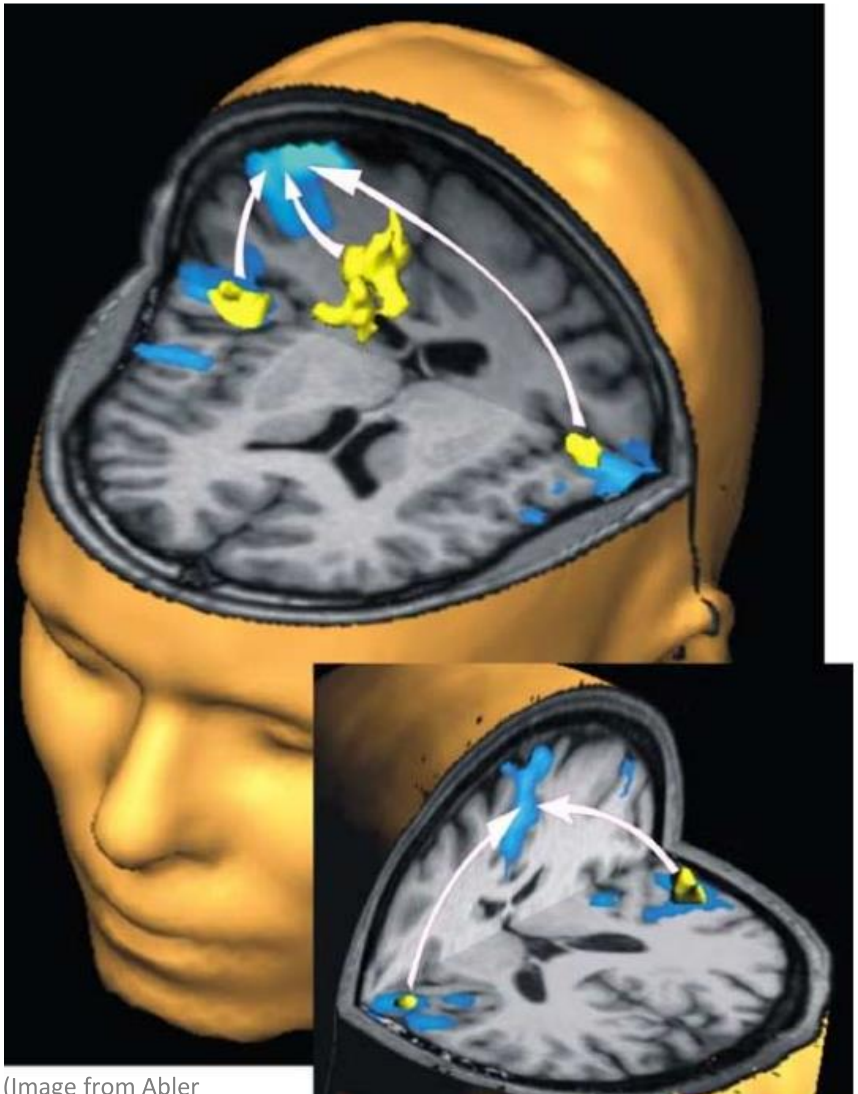
One method of causal(-esque) FCA: *Granger causality*

(Pure causality is hard to measure due to poor fMRI temporal resolution)

If brain region A’s timeseries “Granger-causes” brain region B’s, then:

Past activation values of A should help predict B’s activation *above and beyond* the information contained in past activation of B alone

Granger-causal flow of brain activity following the auditory command: *"press left button"*



(Image from Abler et al., 2006)

Main picture:

Significant Granger causality:

FROM auditory cortex and SMA

TO right motor cortex

Small picture:

Significant Granger causality:

FROM auditory cortex

TO SMA

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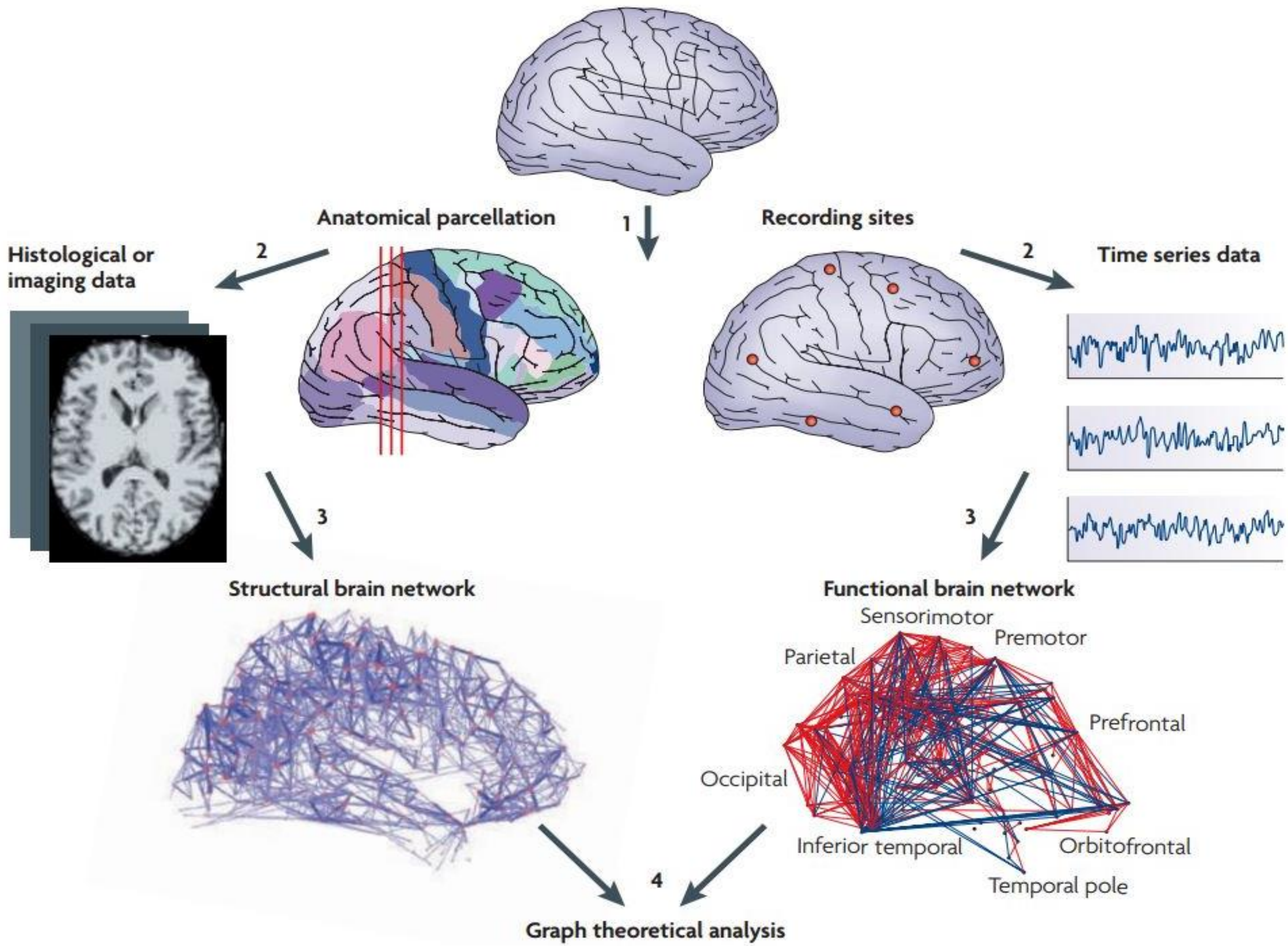
- Comparing functional and **structural** connectivity
  - E.g. diffusion tensor or spectrum imaging (DTI/DSI)

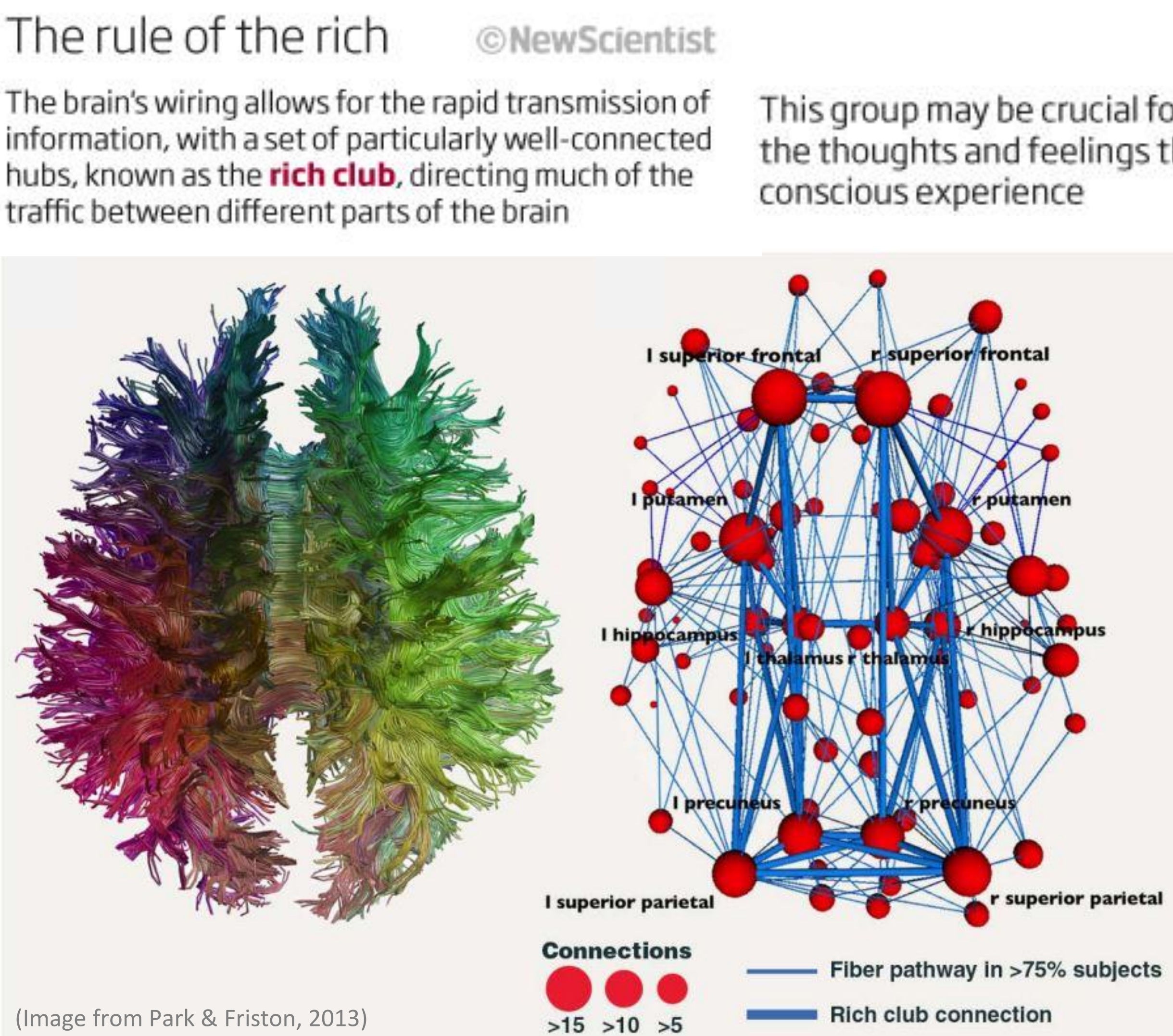
Can compare *structural* (left) and *functional* (right) connectivity measures



(Image from Bullmore & Sporns, 2009)

(e.g. structural data can identify what the <u>intermediate regions</u> are between two functionally connected regions)

The "rich club" (left; discovered *structurally*) partially overlaps with the intelligence/control network (right; discovered *functionally*)



(Image from Park & Friston, 2013)

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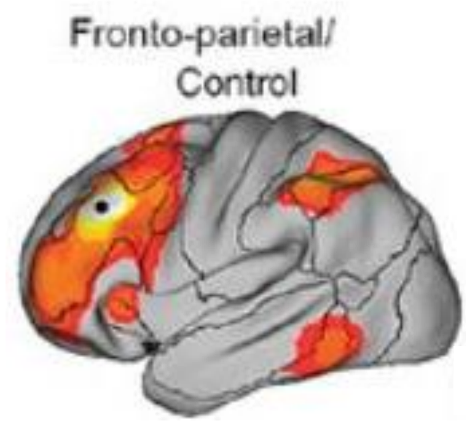
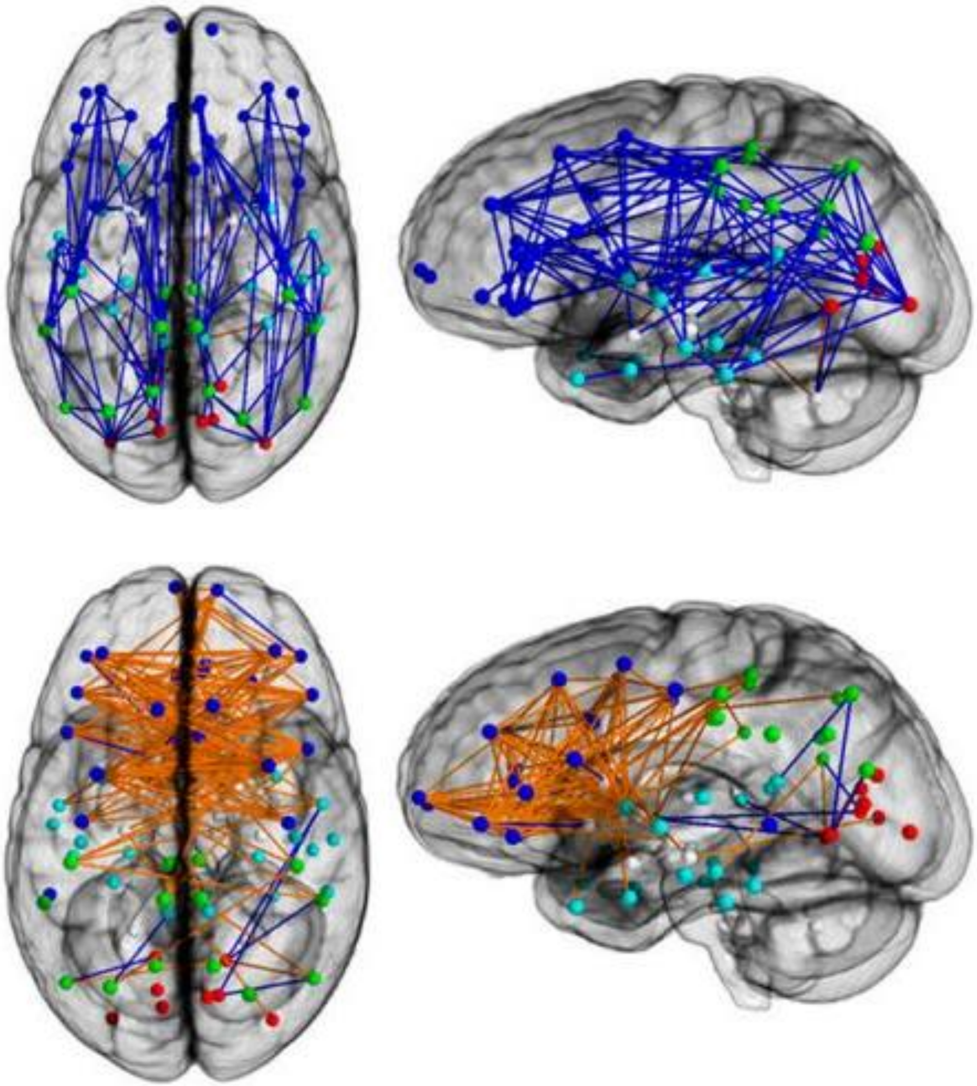


(Image from Guerra-Carrillo, 2014)

Sex differences in major structural connectivity

(Image from Ingalhalikar et al., 2013)



Male

Greater *within*-hemisphere connectivity

Female

Greater *across*-hemisphere connectivity

… but what do these results mean in terms of brain function and behavior?

References

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