



Coupling during COVID

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I.E. Inter-modal coupling project completed during COVID-19!



A brief history of Inter-modal coupling



April 2021,
I present
at lab
meeting!

2015: Simon's structural coupling work – on the surface... Simon goes to Vanderbilt

2017 - 2018 Lauren Beard attempts with asl/rs-fMRI on the surface... Then goes to graduate school

2018 - 2020: Kristin Linn and Ali Valcarcel attempt asl/rs-fMRI in 3D space, writes some of the manuscript but run into a lot of partial voluming issues, and then Ali goes to industry...

August 2020: I pick up the project and we go back to surface work

I replicate surface projection from wikis

Azeez finds the right files and we replicate the coupling (amazing!)

Good riddance fsGLM. I rewrite all the analyses in R

I get stuck on replicating coupling because of freesurfer version differences, file name changes, some wiki confusion

Cheat going down at any minute !!! I move the project to pmacs

Throw in some gams (thx Bart!), some matlab (you da best, Adam!), some R, some bash, and you've got yourself an ImCo project

*

What IS “coupling?”

- Spatially relating two different imaging modalities to each other
- Can be any two modalities, as long as they are in the same space

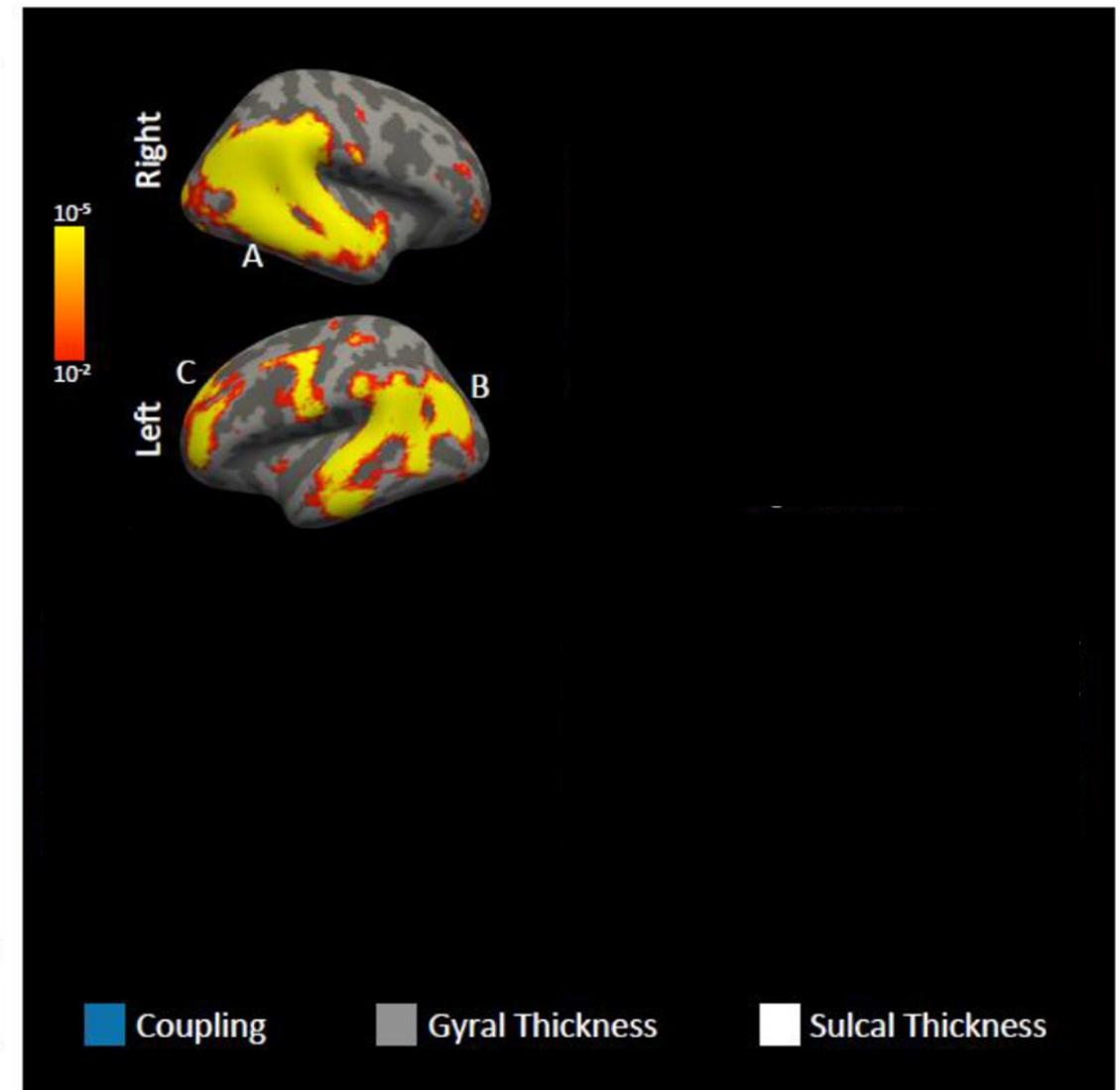
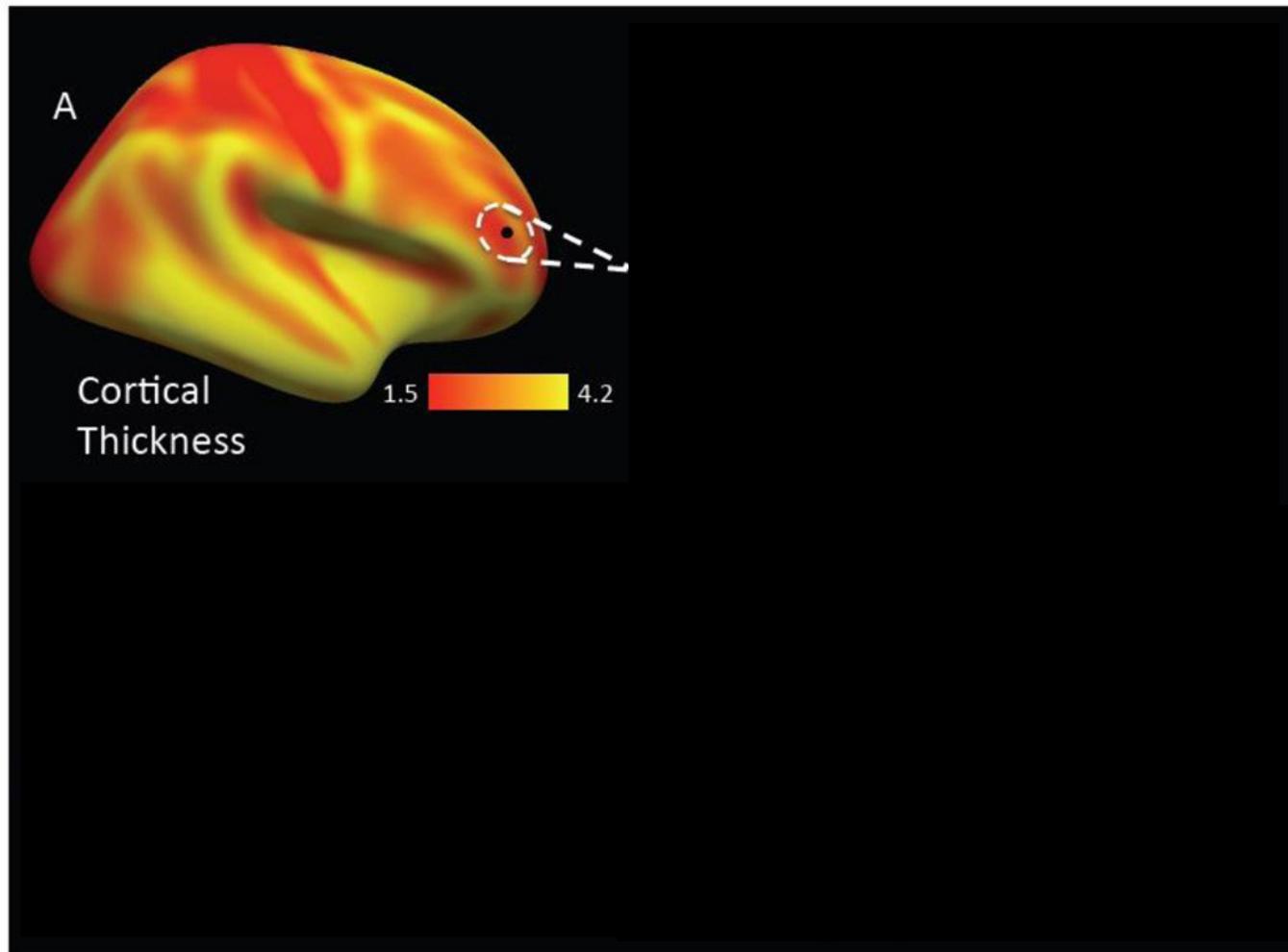


This matters because

- We can gather a lot of info from one modality
- BUT, we get extra if we look at the relationship between the two of them

*** New information ***
structural disparities

Cortical Thickness/Sulcal Depth Coupling Across Development



Vandekar *et al.*, 2016.

A functional coupling metaphor – Philly Traffic



Might this help us think through
coupling of brain function?

Coupling in the brain via the neurovascular unit



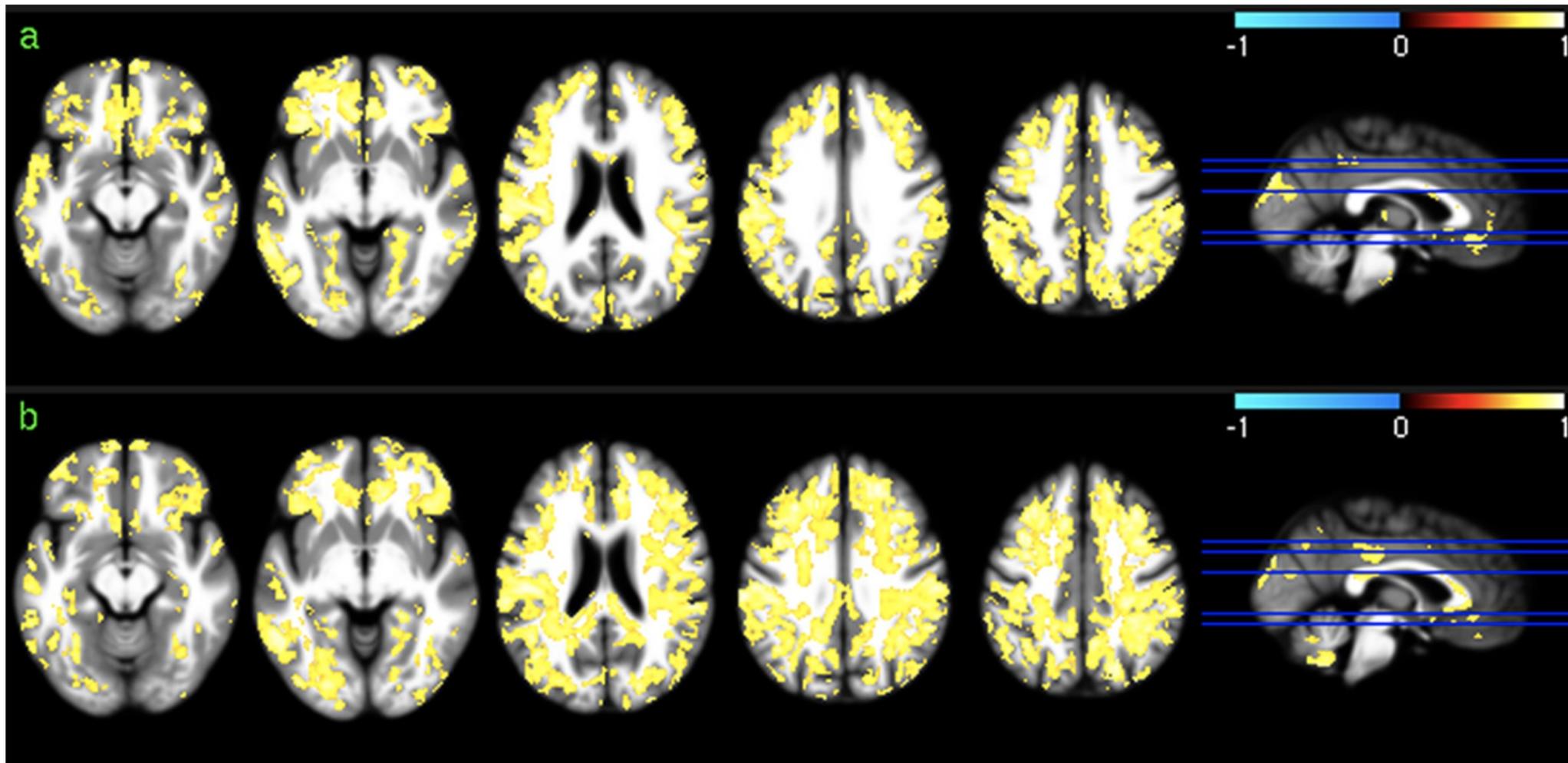
Relations between BOLD fMRI-Derived Resting Brain Activity and Cerebral Blood Flow

Zhengjun Li, Yisheng Zhu, Anna Rose Childress, John A. Detre, Ze Wang

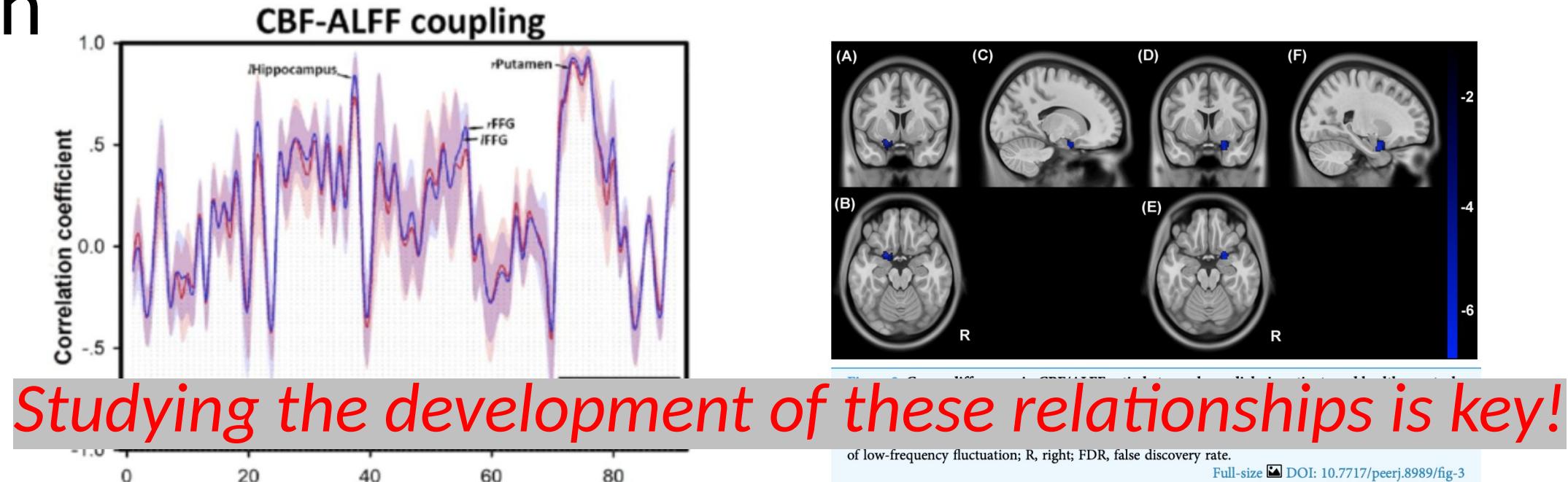
PLOS ONE

Figure 7

ALFF vs regional CBF correlation maps for a) session 1 and b) session 2 thresholded at $p < 0.005$ (uncorrected).

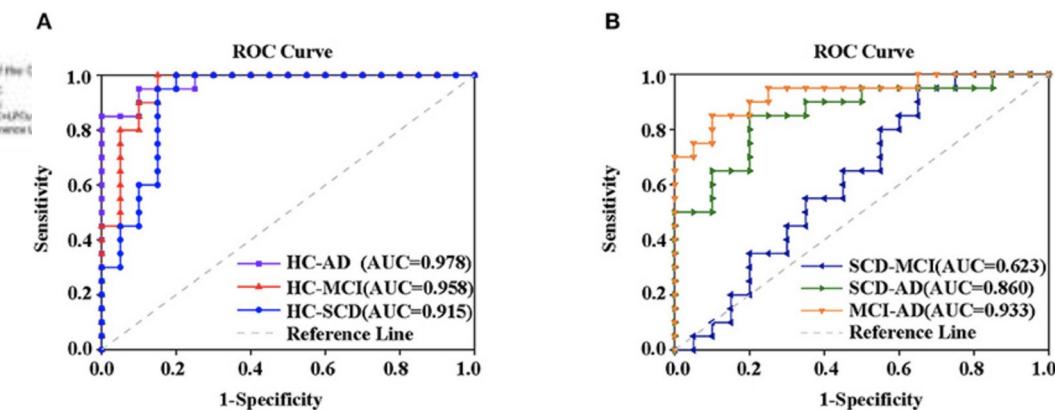
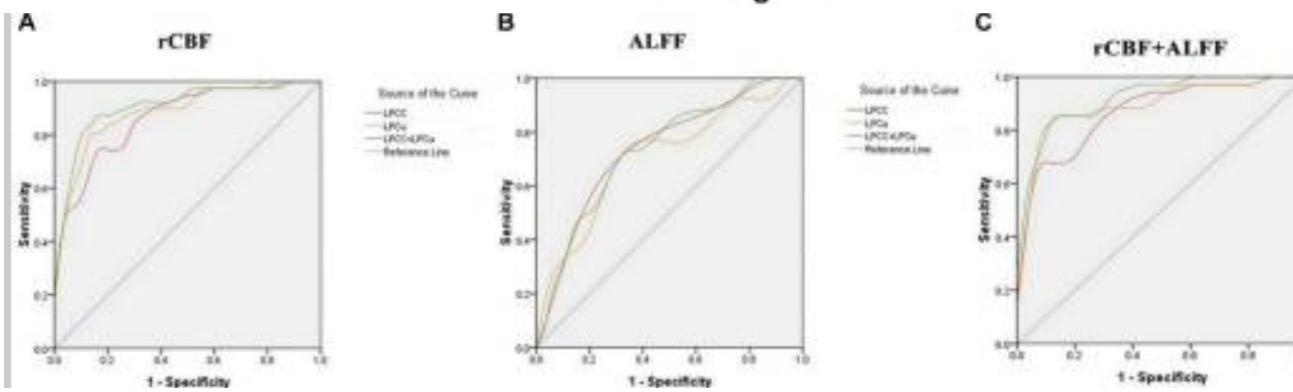


Variations in CBF/ALFF coupling seen in path

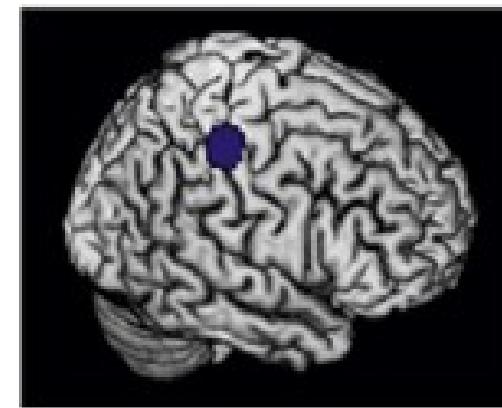
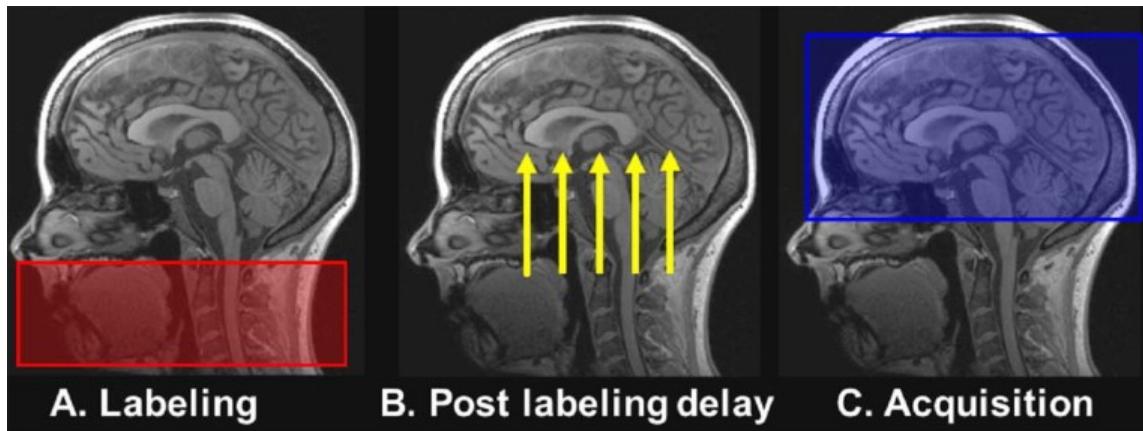


of low-frequency fluctuation; R, right; FDR, false discovery rate.

[Full-size](#) DOI: 10.7717/peerj.8989/fig-3



ASL and rs-fMRI as input data



ASL to measure cerebral blood flow (CBF)

rs-fMRI to measure amplitude of low frequency fluctuations (ALFF)

Hypotheses

- Coupling will be TIGHT
- It will change with age
 - Tighter to looser?
- Sex differences
- Exploratory after that!



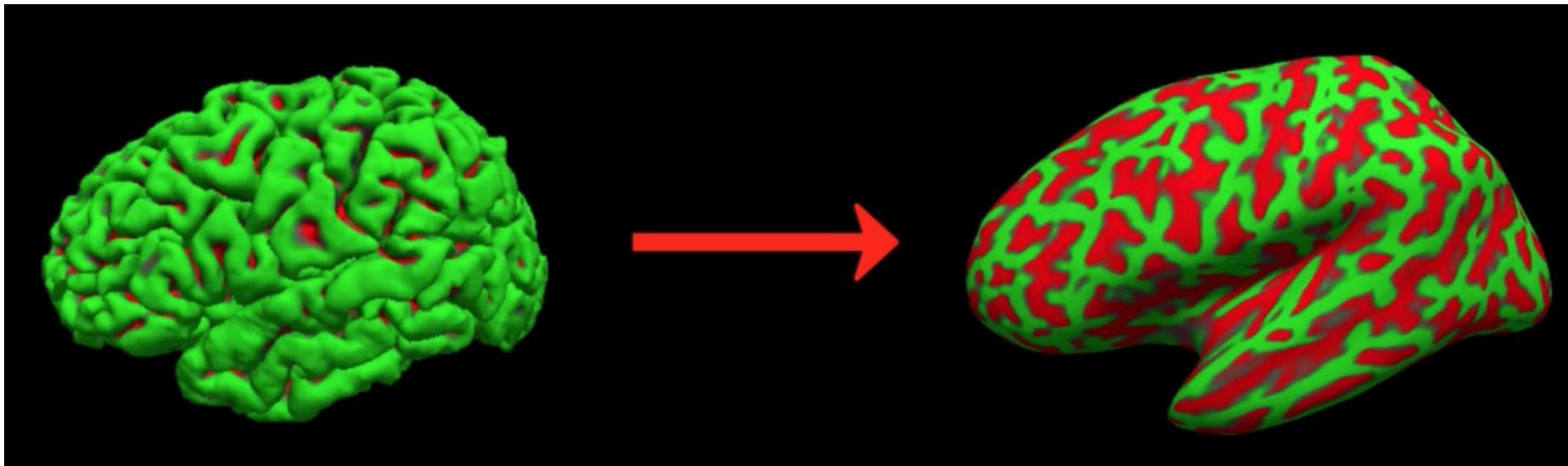
Sample

- PNC
 - Imaging: T1, ASL, rs-fMRI
 - Clinical – KSADS
 - Cognitive - CNB
- Exclusions
 - LTN (low threshold normal)
 - Medical illnesses affecting the brain
 - Psychiatric disorders
 - Imaging
 - Bad T1
 - CBF/ALFF Motion

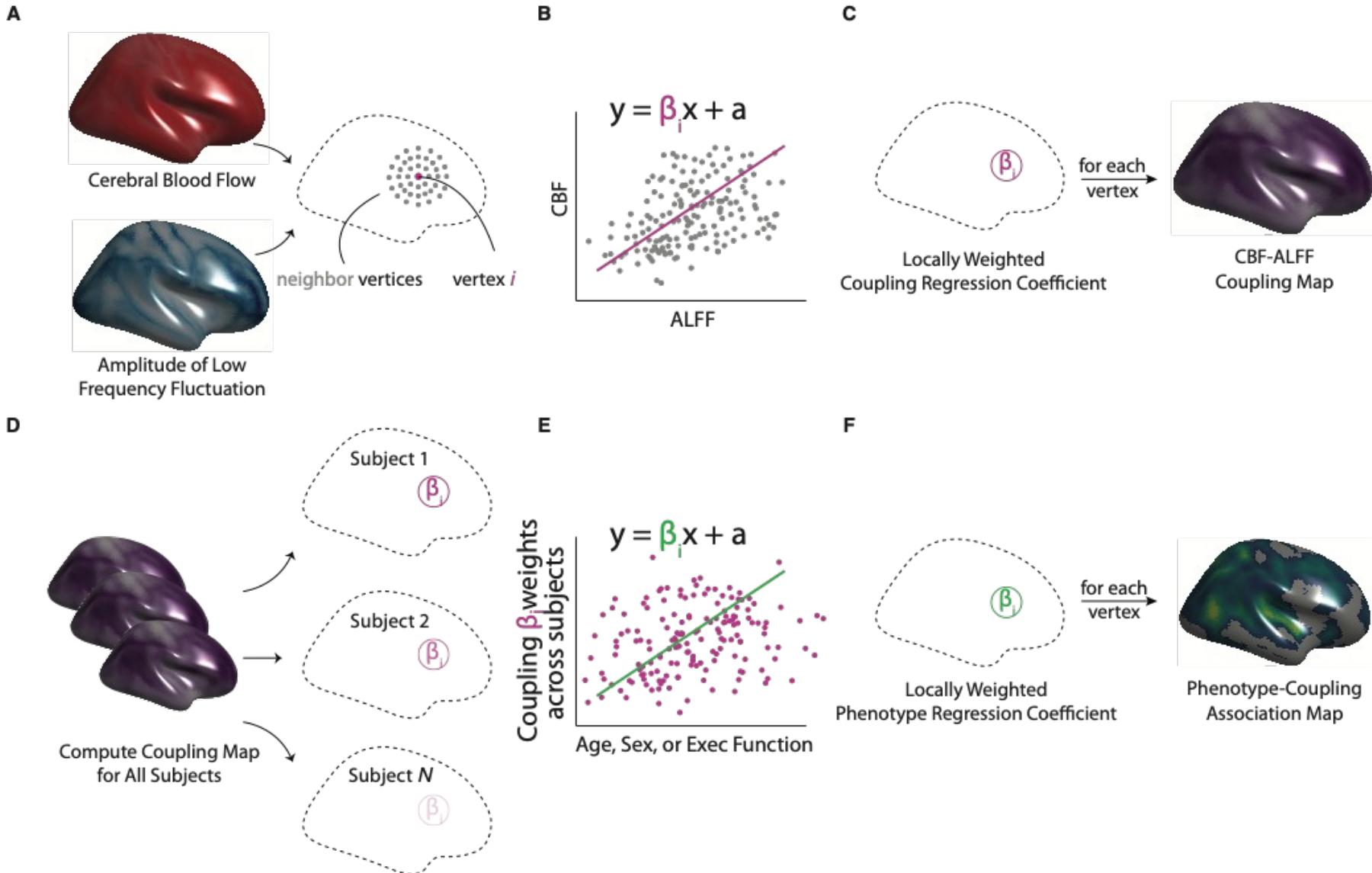
Characteristic ¹	N = 831
Sex	
Male	353 (42%)
Female	478 (58%)
Race	
White	366 (44%)
Non-White	465 (56%)
Age (years)	15.6 (3.4)
Maternal Education	14.3 (2.5)

Surface Projection

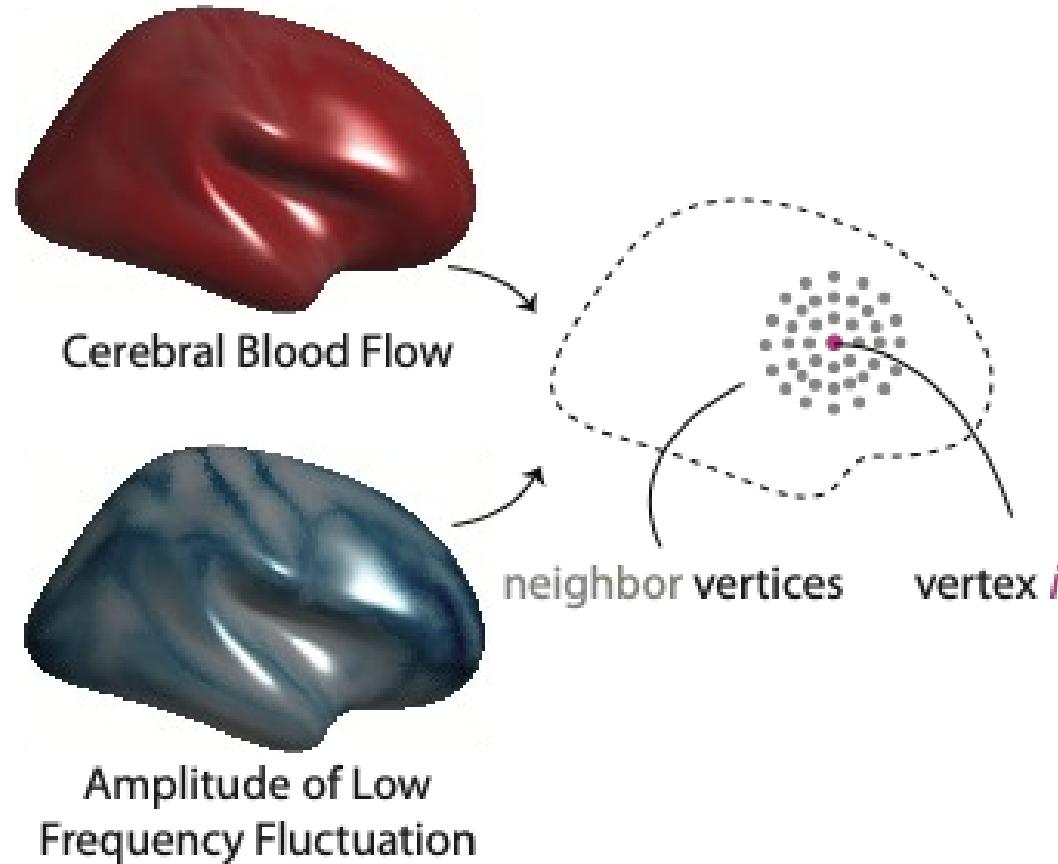
fsaverage5



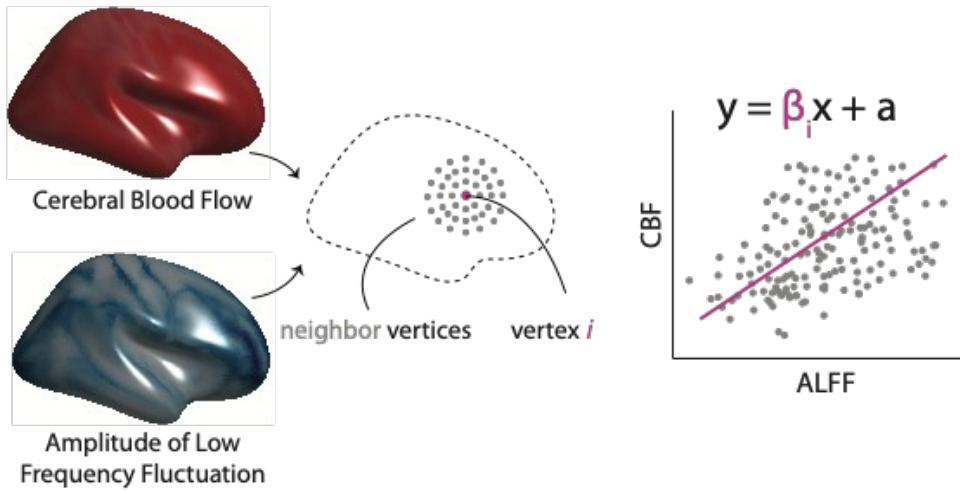
Coupling Algorithm



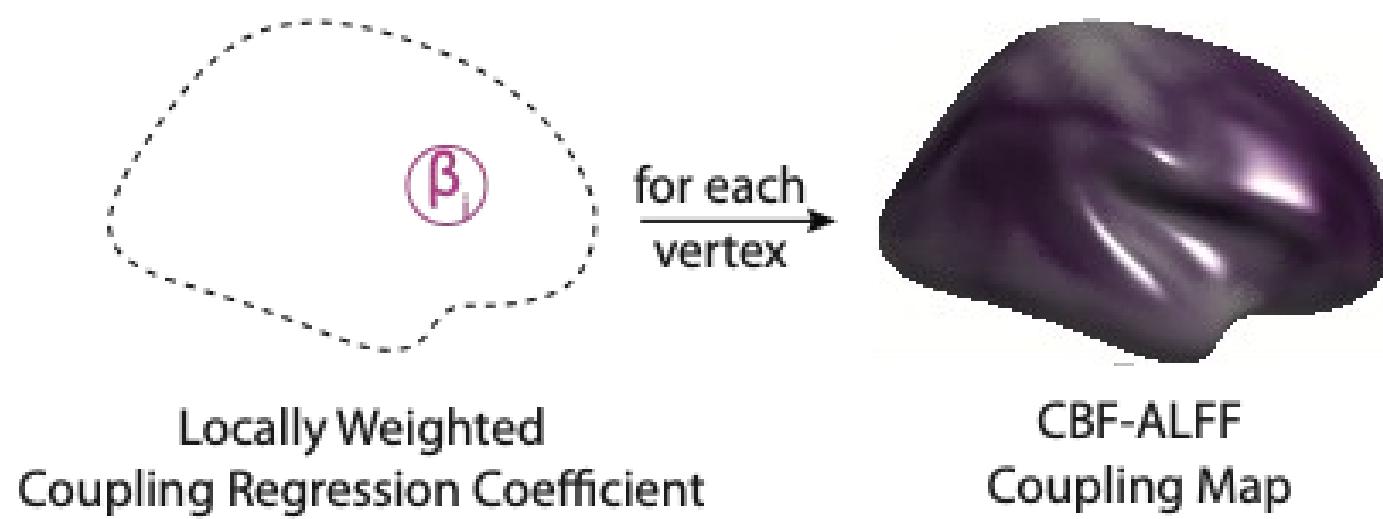
Identify the neighborhood



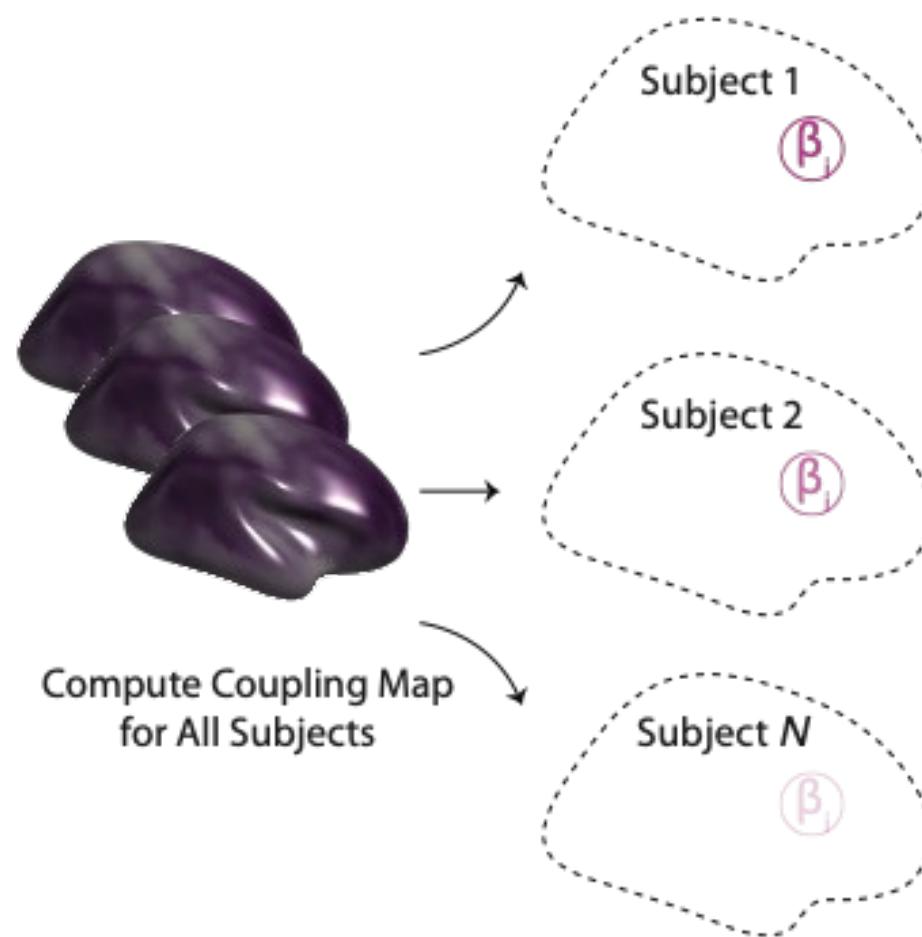
Locally weighted regression



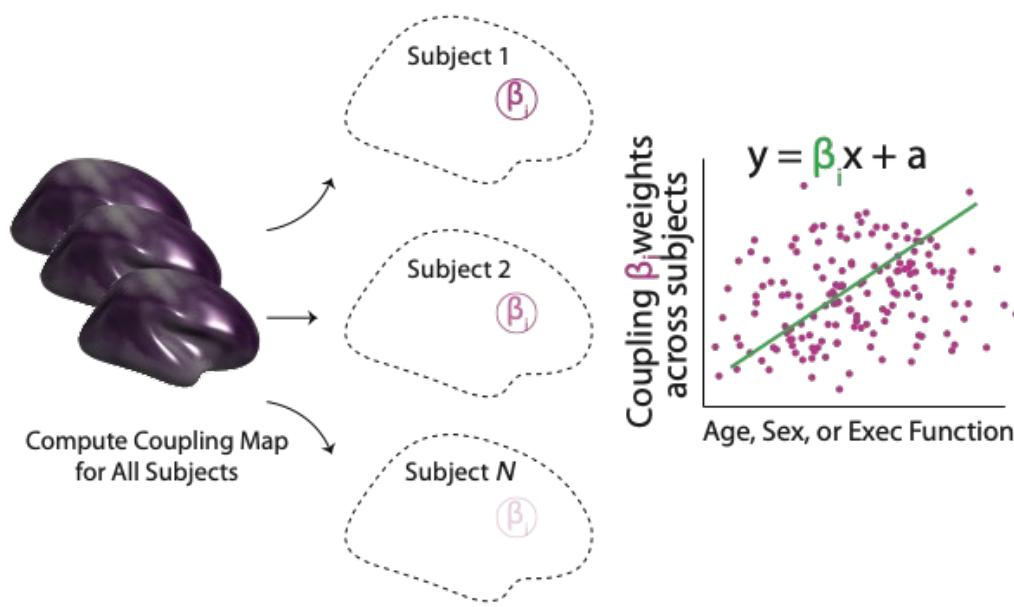
Coupling map



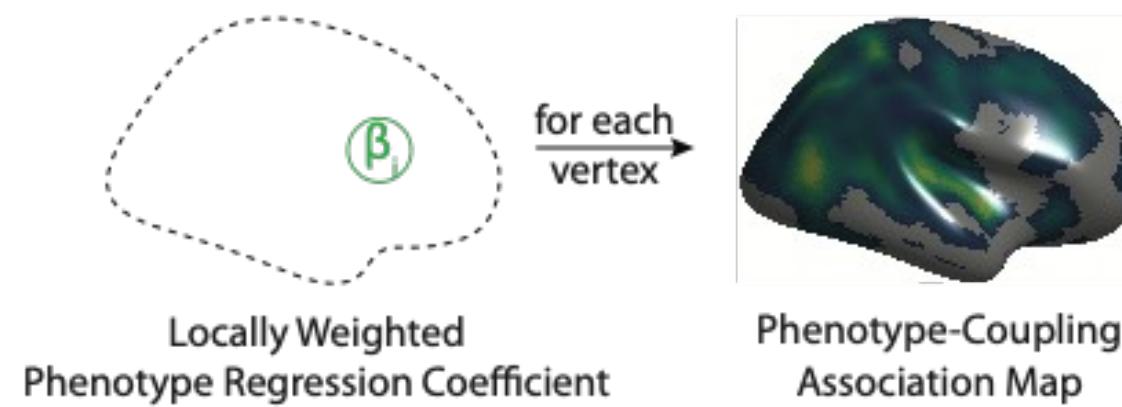
Compute maps for each subject

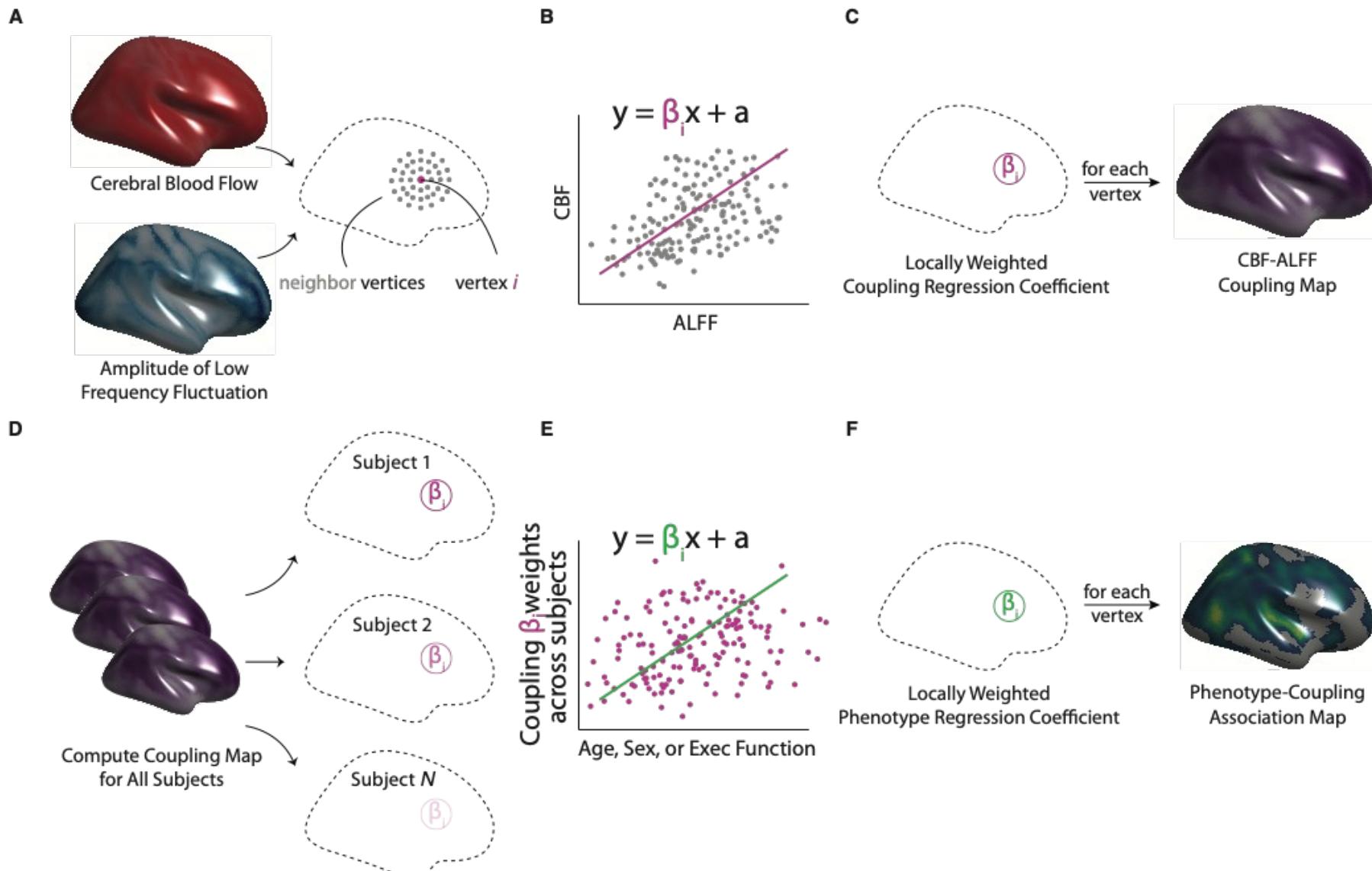


Perform age, sex, executive accuracy regressions



Compute at each vertex





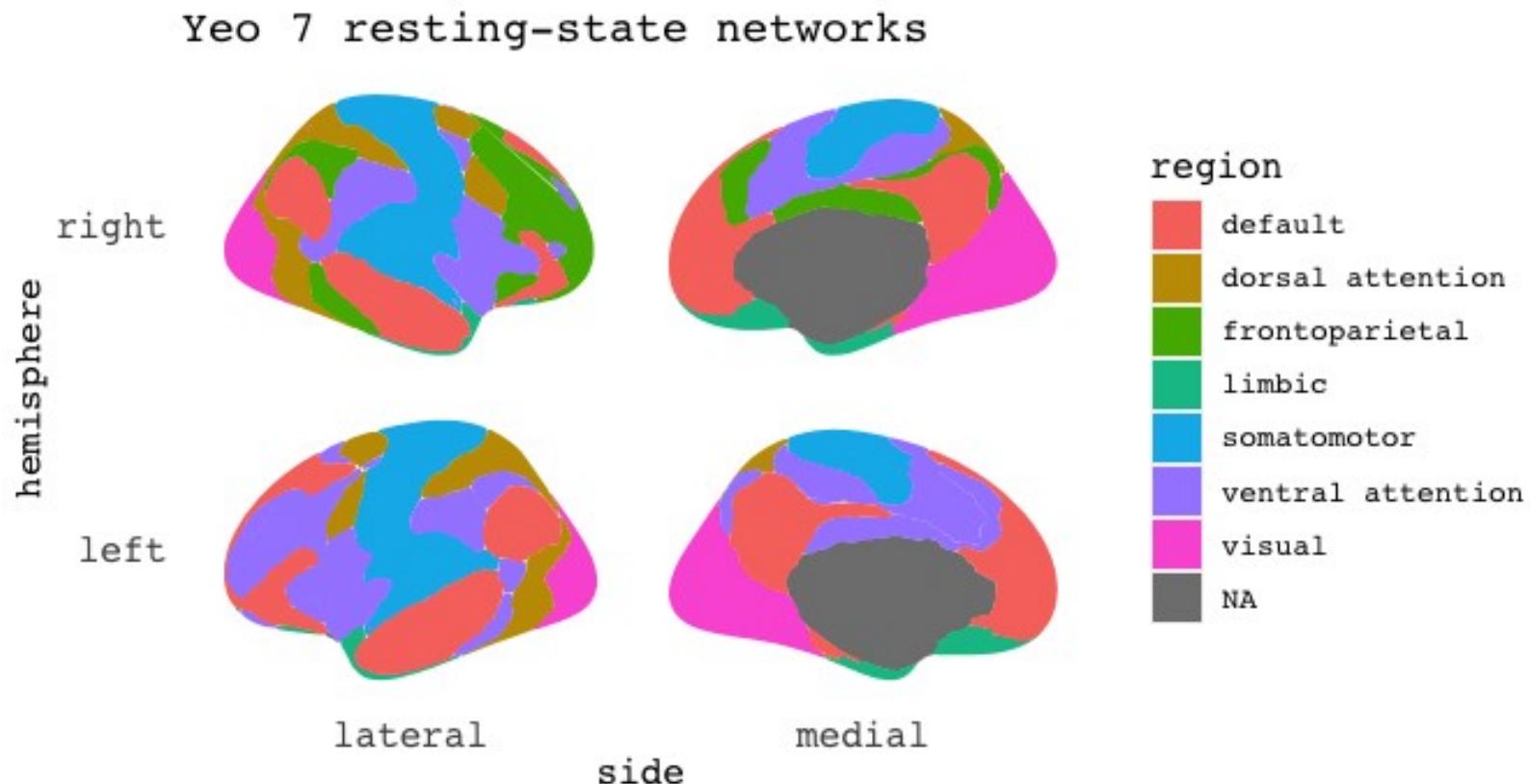
General Additive Models with penalized splines

Age and sex: $\text{gam}(\text{ImCo}(v) \sim \text{CBF_motion} + \text{ALFF_motion} + s(\text{age}) + \text{sex})$

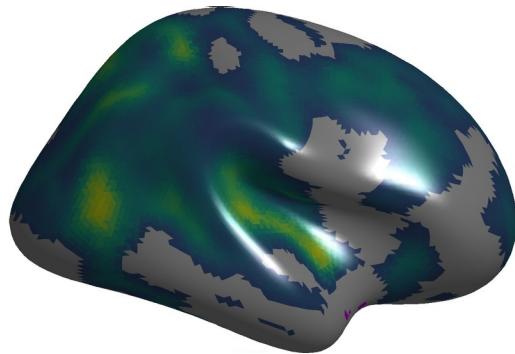
Executive acc: $\text{gam}(\text{ImCo}(v) \sim \text{CBF_motion} + \text{ALFF_motion} + s(\text{age}) + \text{exec_acc})$



Interpreting by projecting results to Yeo -7



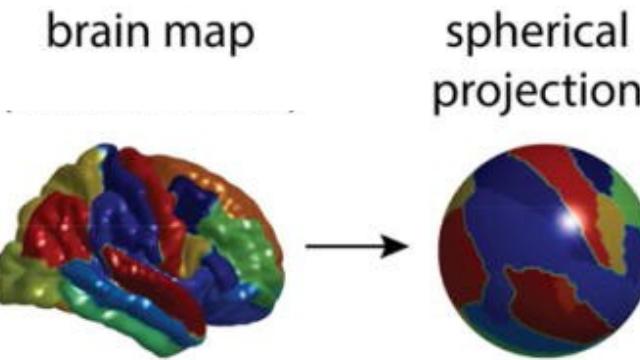
Spin test



trinarize

spin

V	T	Yeo-7	
1	2.45	1	1
2	5.44	5	1
3	0.00	3	0
4	0.00	8	-1
5	0.00	8	-1
...		...	
10242	3.2	6	1



repeat x1000
per hemisphere

Spin continued ...

- For each permutation, calculate:

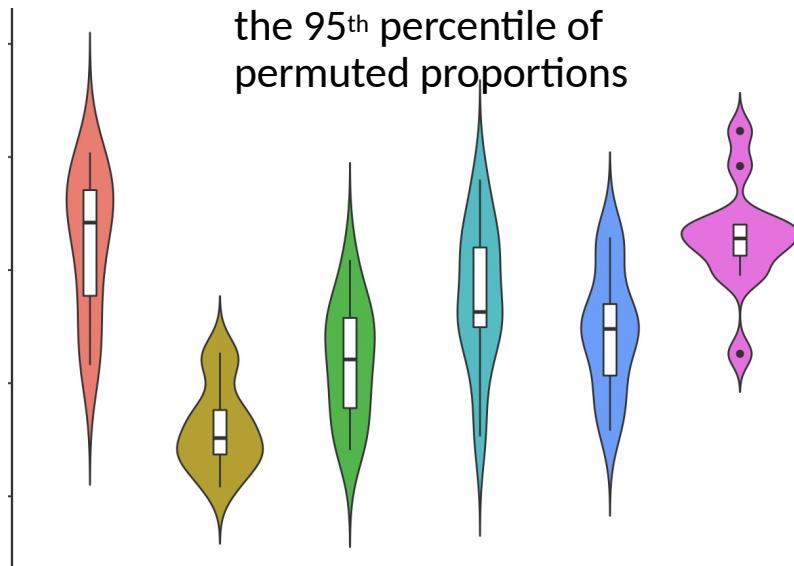
number of significant vertices within a network (i.e. the 1s)

Total # vertices per network - medial wall vertices (-1s)

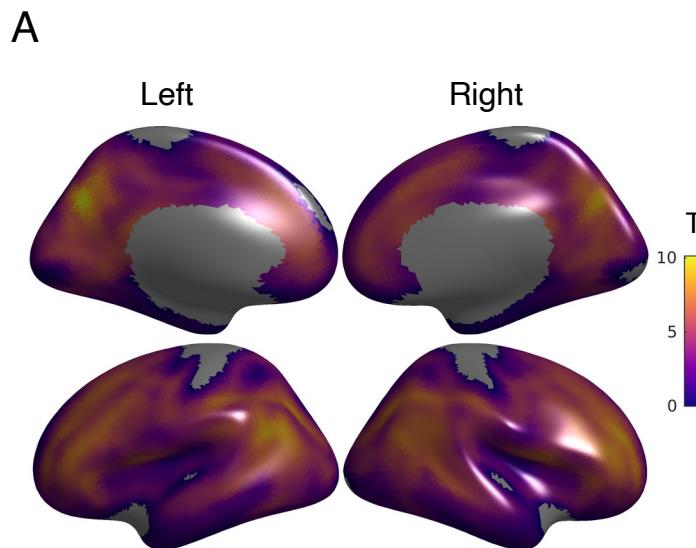
Perm 1	2	3	...	2000
Network 1		0.4	0.1	0.3
2		0.1	0.2	0.8
3	0.8	0.2	0.1	
4		...		
5	...			
6				
7				



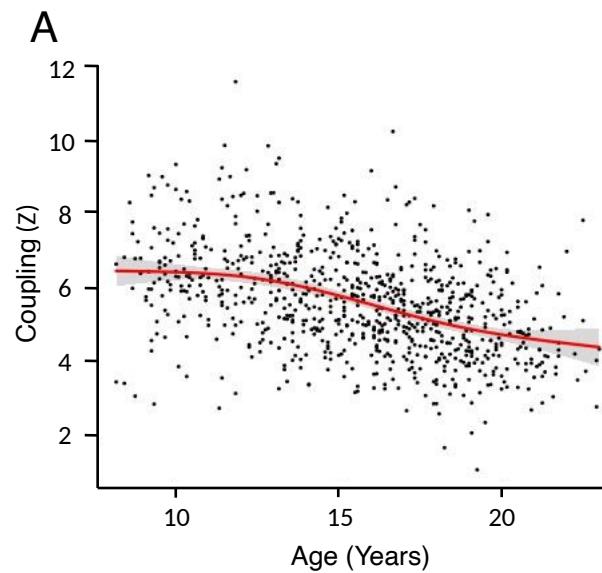
*significant if actual result (proportion) is in the 95th percentile of permuted proportions



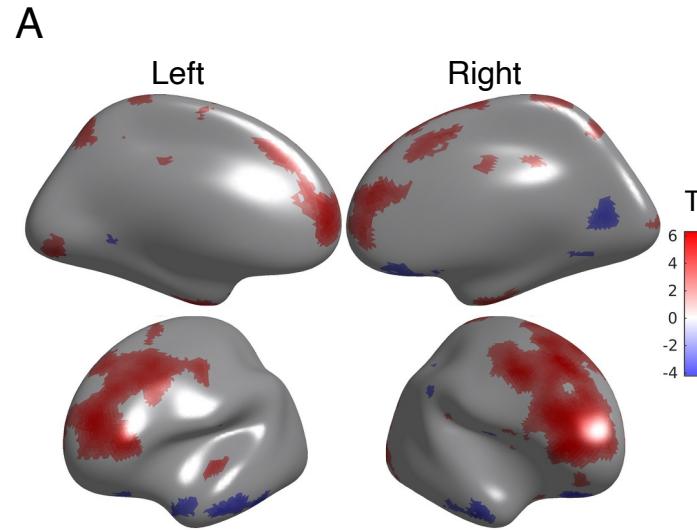
There is tight coupling throughout the cortex



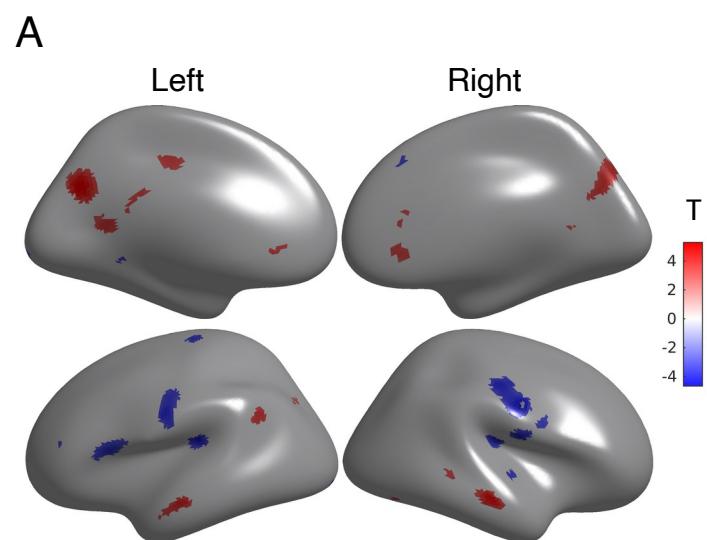
Coupling decreases with age



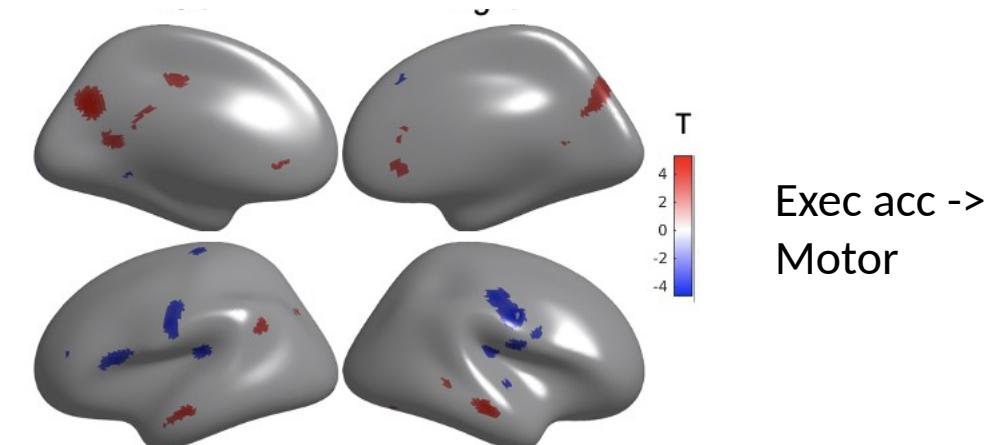
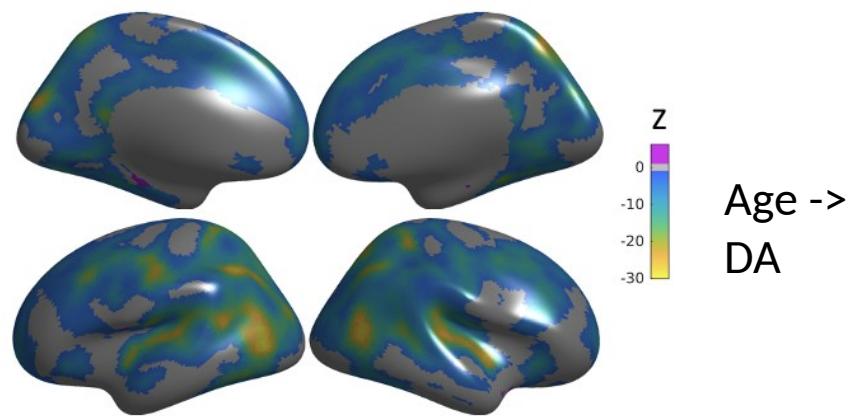
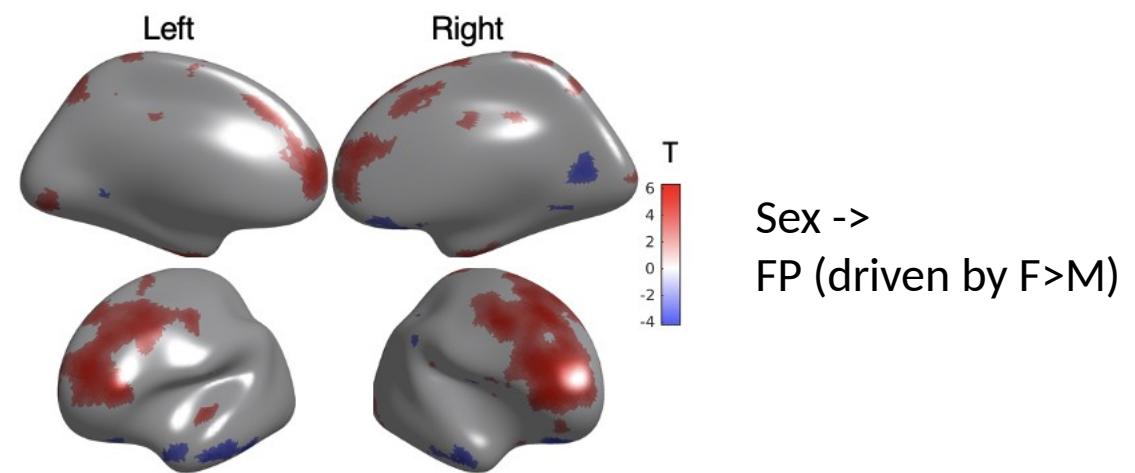
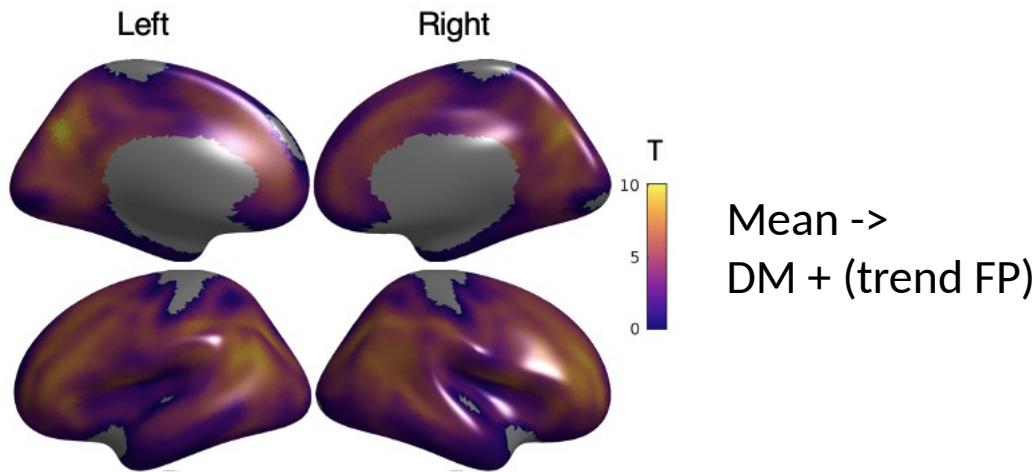
Females have more coupling in the FP network



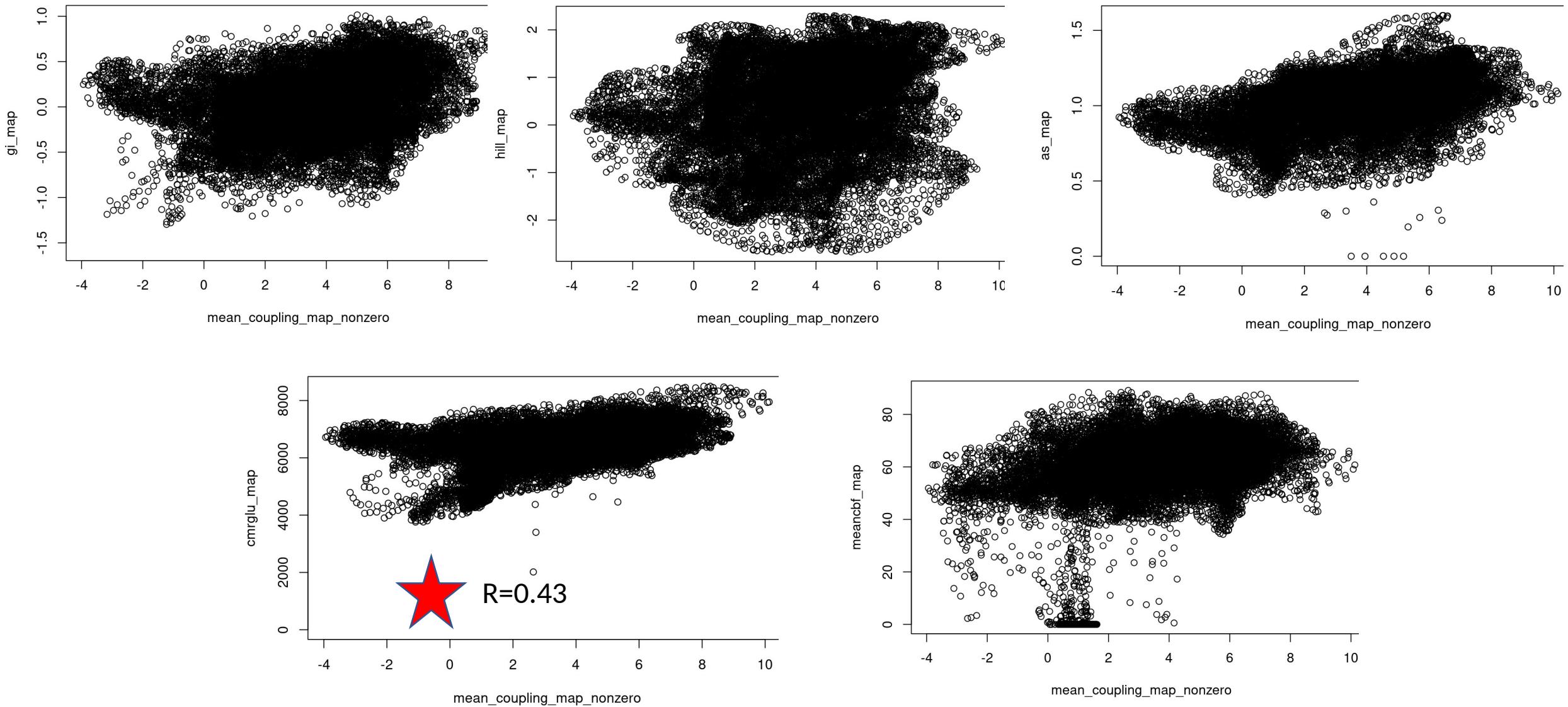
Better accuracy associated with less motor coupling



Summary:



Coupling map relates to other maps



Conclusions

- A few take-homes
 - Functional coupling algorithm works
 - It tells us new things
 - Differential coupling patterns across domains that map onto yeo networks suggests functional importance
- Open to interpretation -> would love everyone's thoughts!



Next steps

- Poster in 2 weeks (eek)
- Write the paper
- Psychopathology in the future?



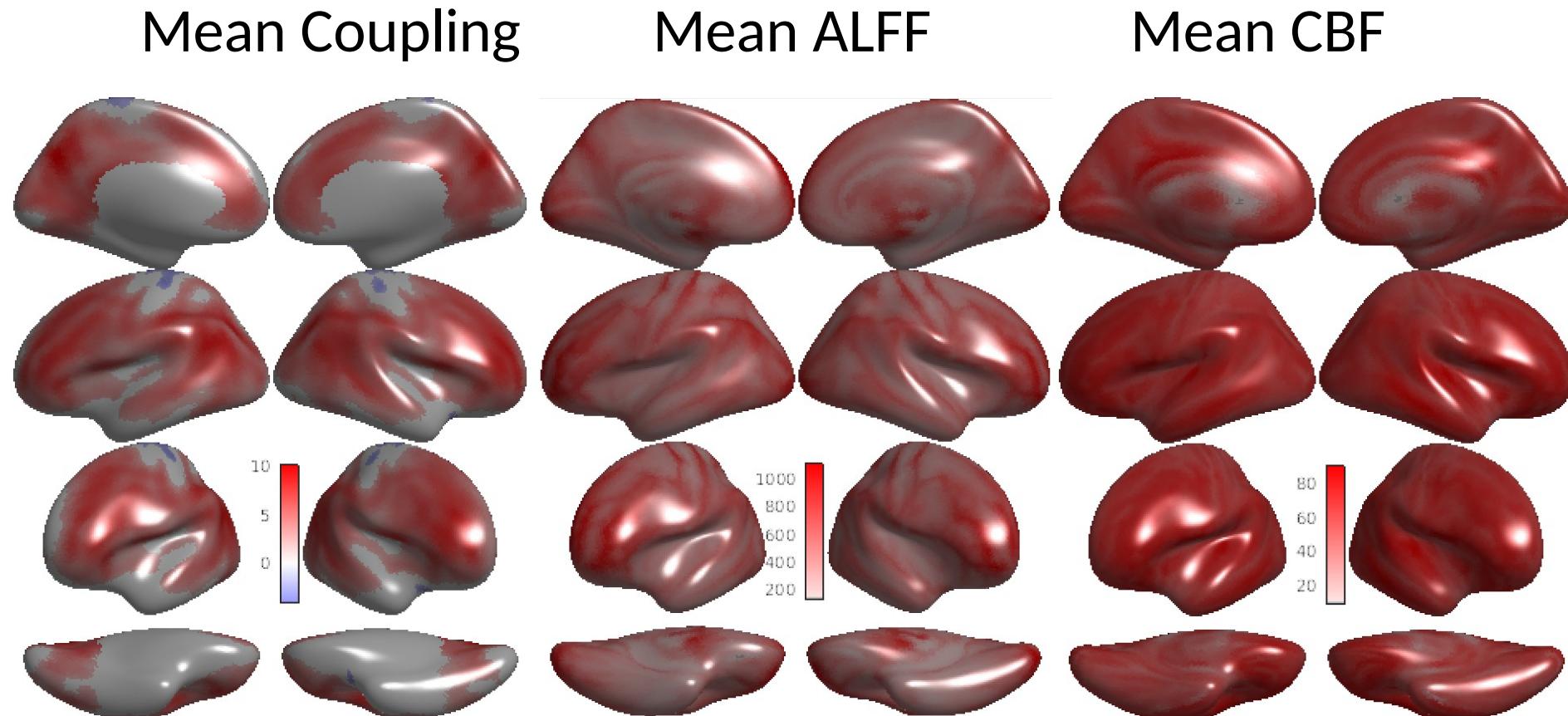
THANK YOU!!!!!!

- **AZEEZ Adebimpe**

- Adam Pines
- Bart Larsen
- Cedric Xia
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- Taki Shinohara
- John Detre
- And amazing co-authors/collaborators
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 - Zaixu Cui
 - Raquel Gur
 - Ruben Gur
 - Kristin Linn
 - Carly O'Donnell
 - Armin Raznahan
 - David Roalf
 - Tinashe Tapera
 - Simon Vandekar

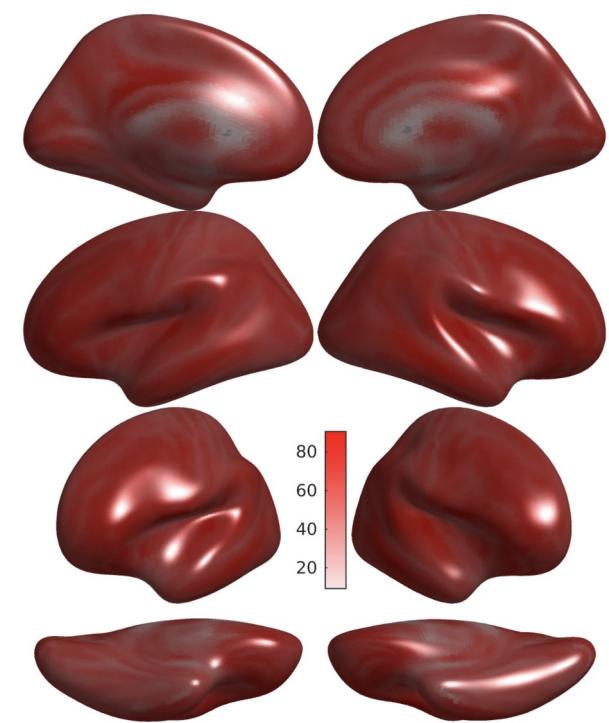


Coupling/Alff/CBF next to each other

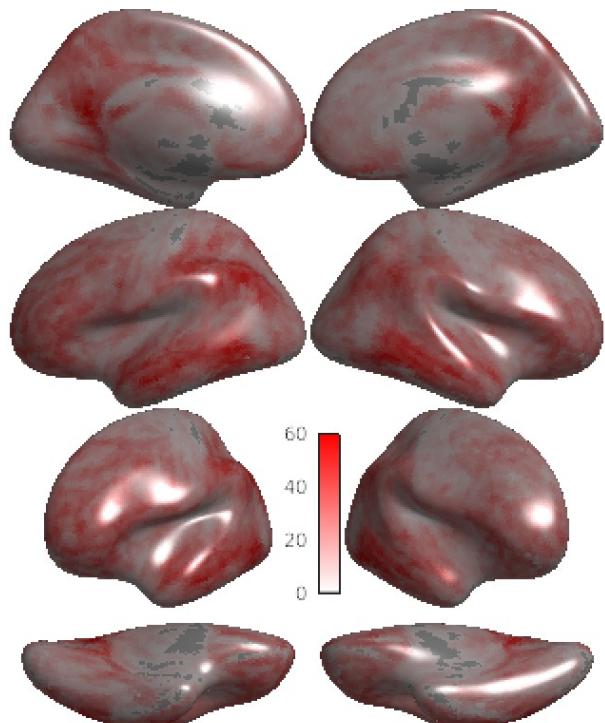


CBF analyses

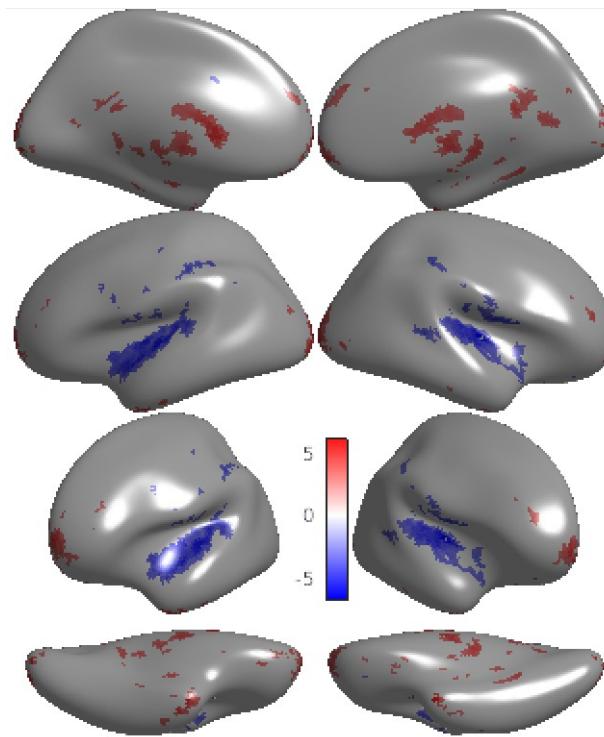
CBF Mean



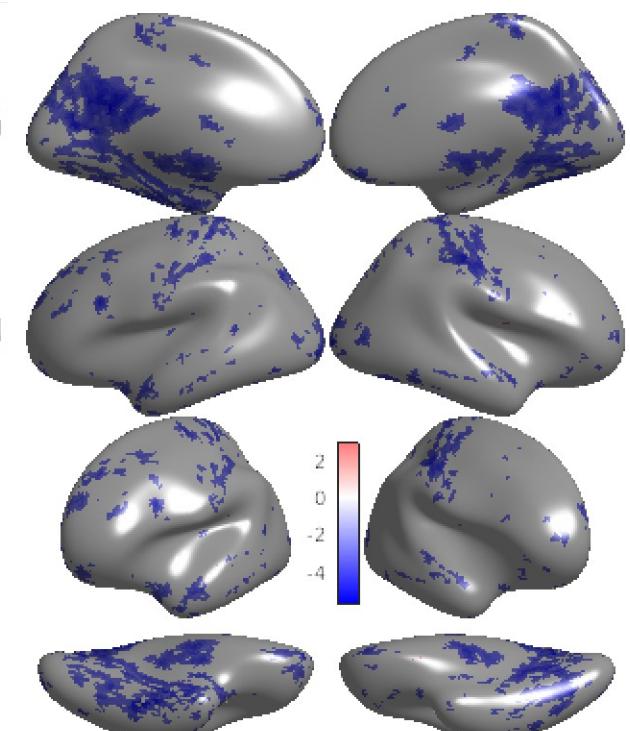
CBF Age p<0.05 FDR



CBF Sex p<0.05 FDR

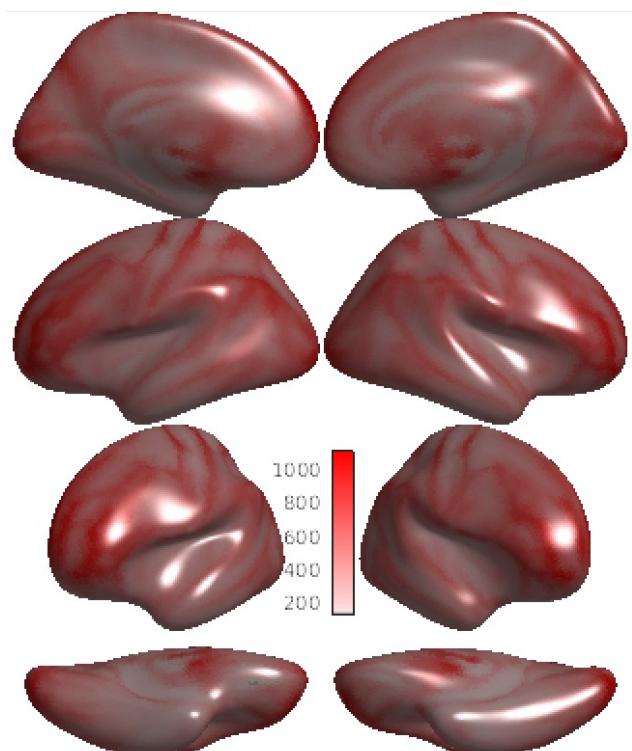


CBF exec accuracy
p<0.05 FDR

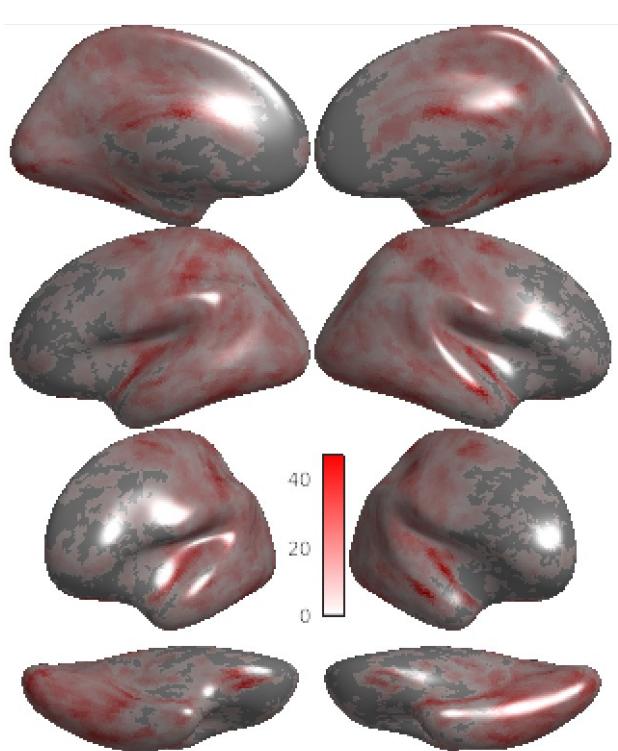


Alff analyses

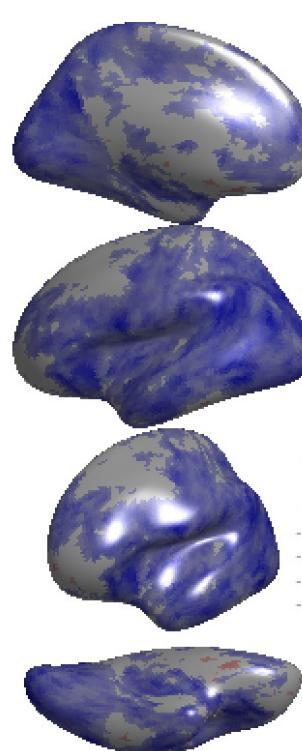
Mean ALFF



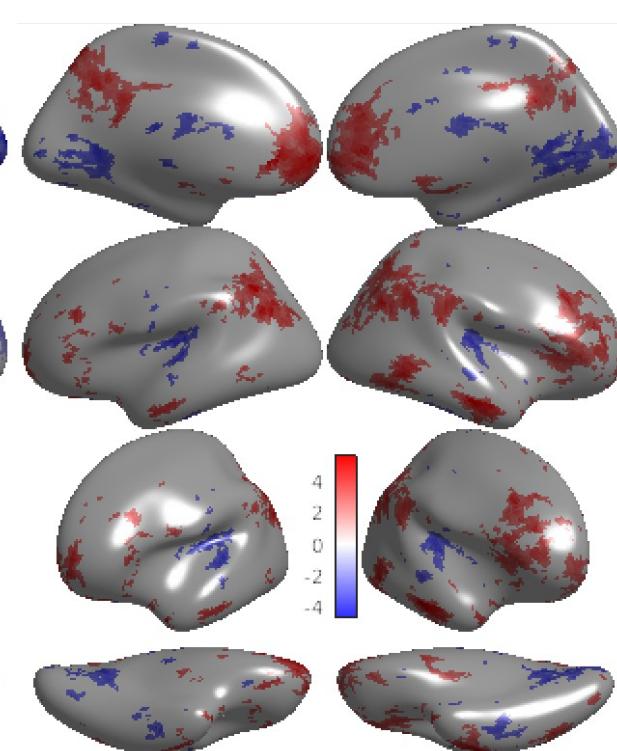
Alff Gam Age p<0.05 FDR



ALFF LM Sex p<0.05
FDR

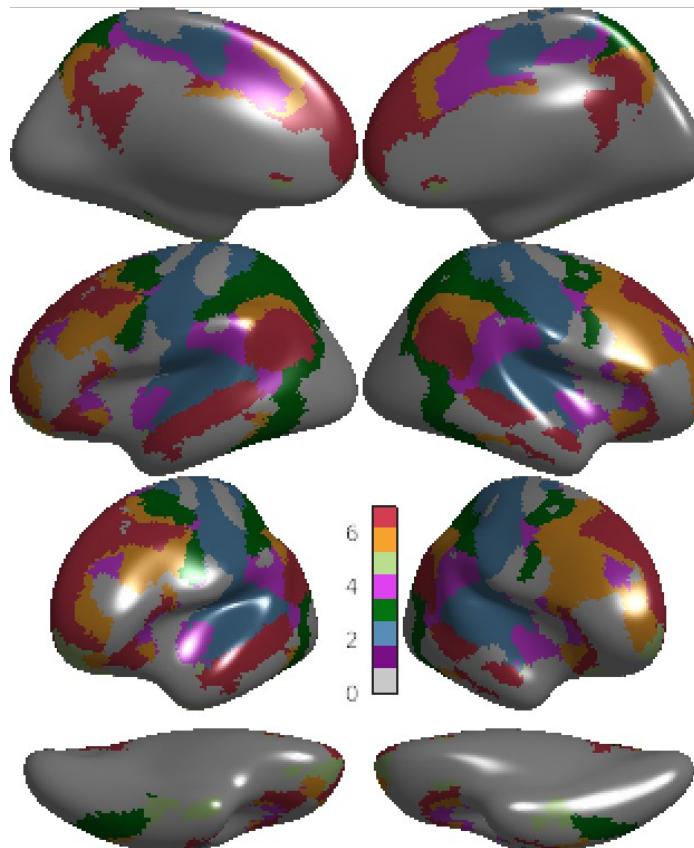


ALFF LM exec accuracy
p<0.05 FDR

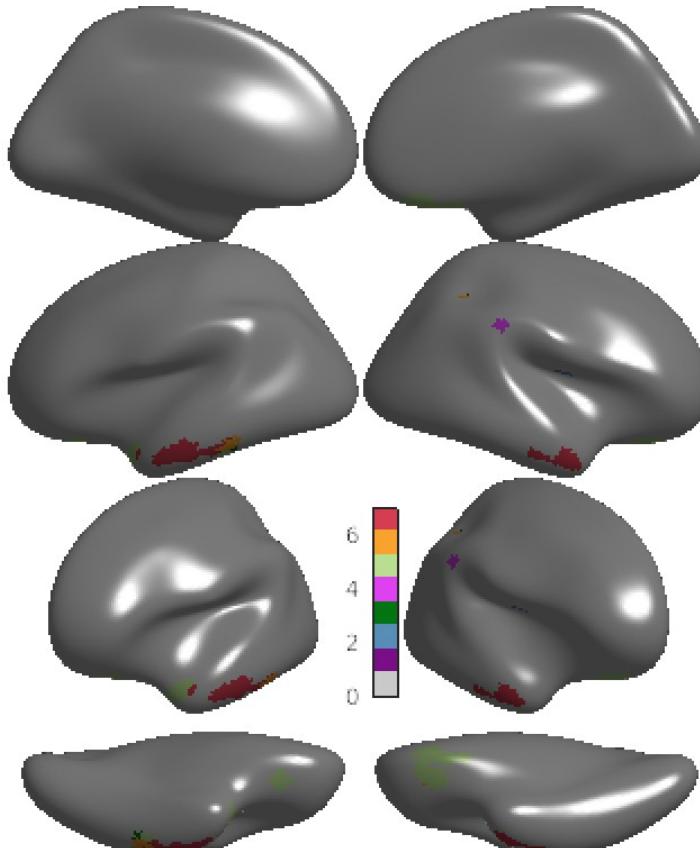


Yeo mapping

Coupling Im Age p<0.05
FDR



Coupling LM Sex
p<0.05 FDR



Coupling LM exec
accuracy p<0.05 FDR

