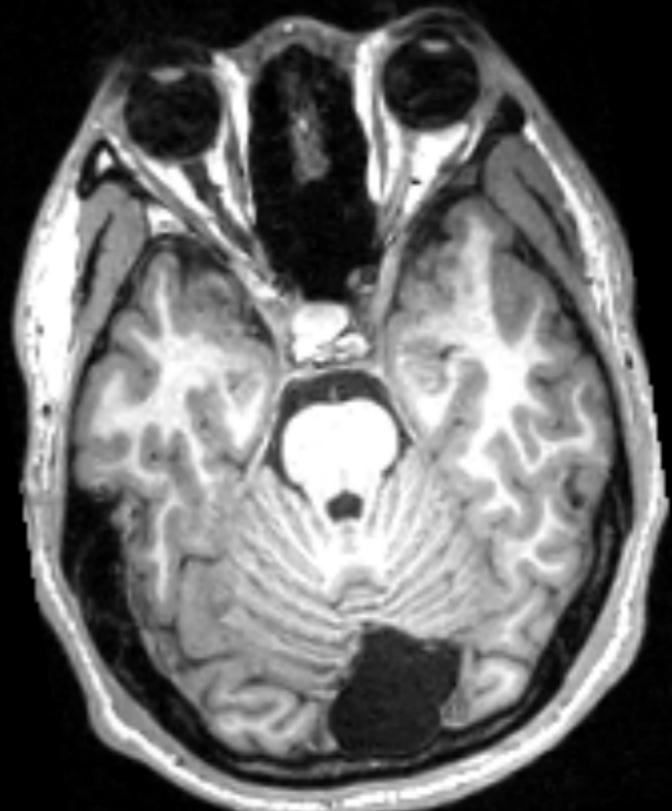
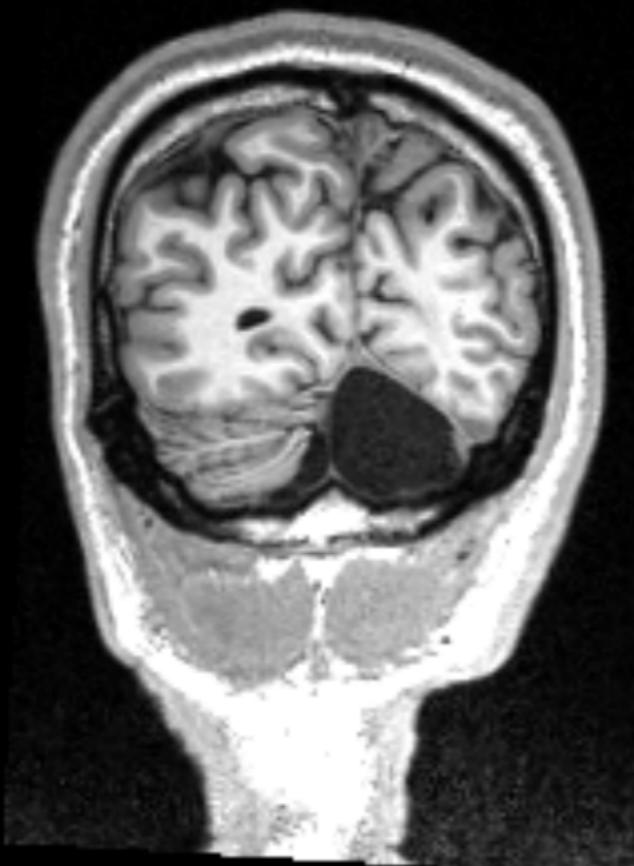
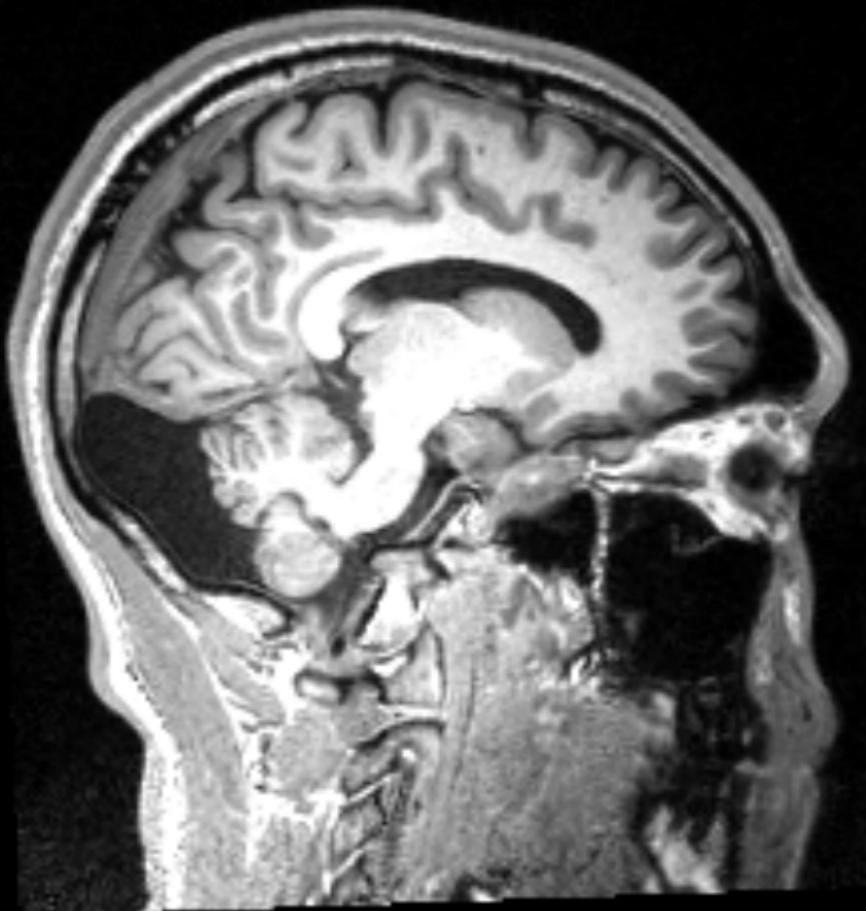


Analyzing a large neuroimaging dataset with cloud-based tools

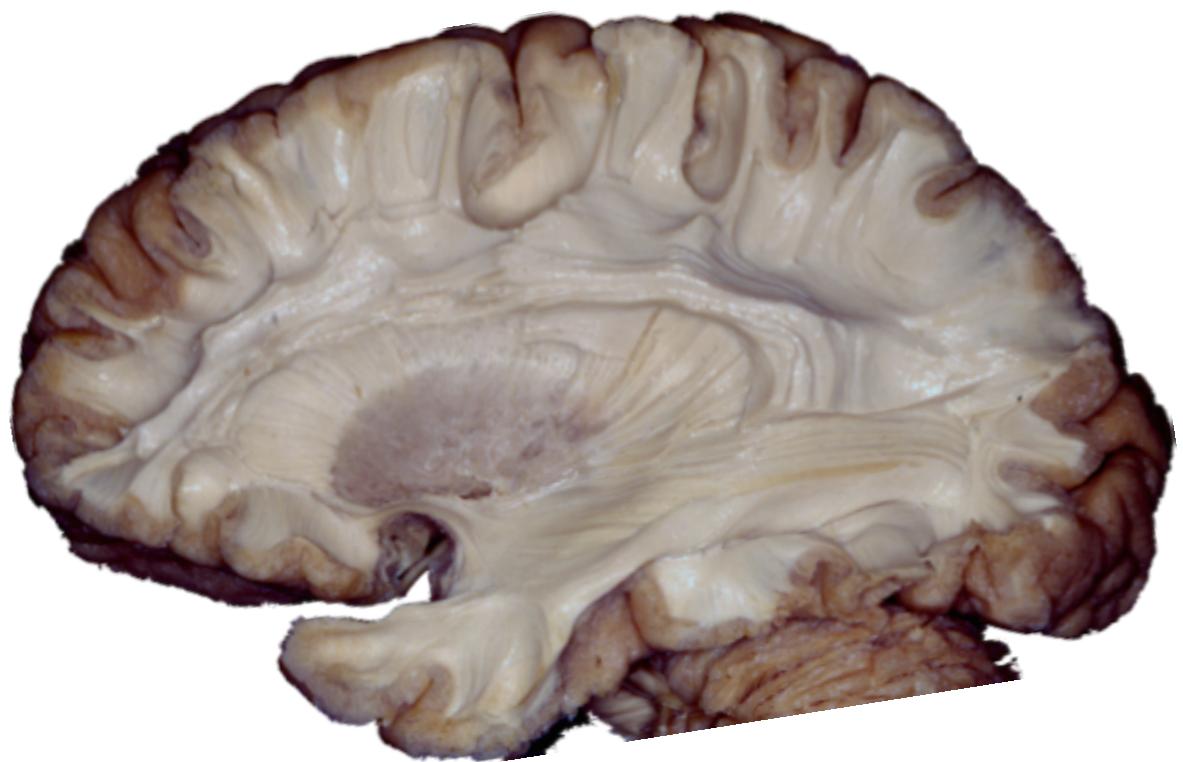
by Josiah Leong
Indiana University Bloomington
2019 July 29

My brain

R



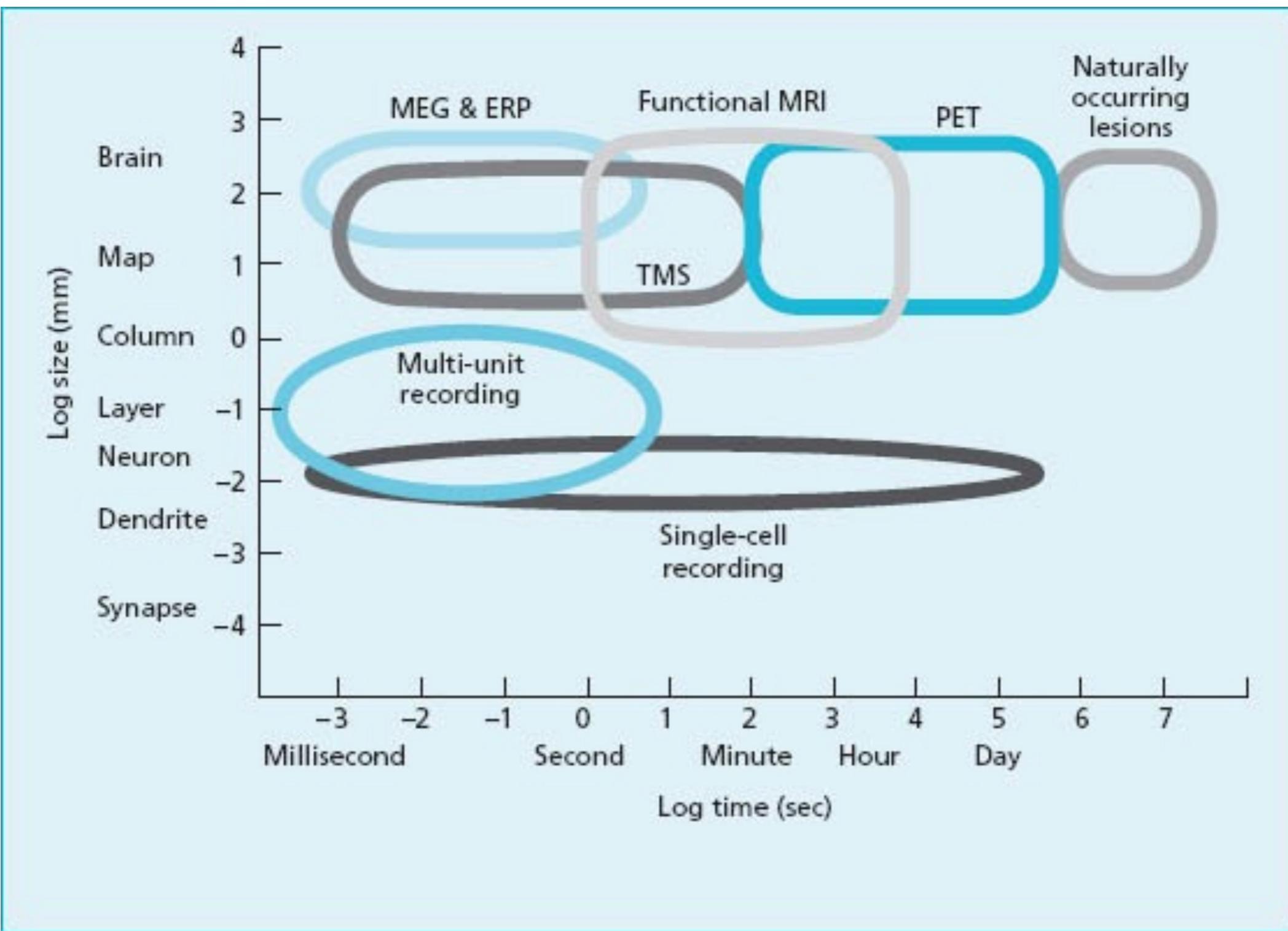
Raw brain



Why study the brain?



How to measure the brain?



Processing brain data

Code Data Computing

NEW APPS	
Shape Signature watchdog-free signature  SHAPE SIGNATURE	
SHAPE SIGNATURE SHAPE SIGNATURE SHAPE SIGNATURE	Trachography equality check watchdog-free trachography check  TRACHOGRAPHY EQUALITY CHECK
SHAPE SIGNATURE SHAPE SIGNATURE SHAPE SIGNATURE	
SHAPE SIGNATURE SHAPE SIGNATURE SHAPE SIGNATURE	Barcode/QR code reader watchdog-free barcode reader  BARCODE/QR CODE READER
SHAPE SIGNATURE SHAPE SIGNATURE SHAPE SIGNATURE	
ANALYSIS	
Brainreader 6.0 brain analysis pro  BRAINREADER 6.0	
BRAINREADER 6.0 BRAINREADER 6.0 BRAINREADER 6.0	LIFC with diffLR brain training pro  LIFC WITH DIFFLR
LIFC WITH DIFFLR LIFC WITH DIFFLR LIFC WITH DIFFLR	
LIFC WITH DIFFLR LIFC WITH DIFFLR LIFC WITH DIFFLR	WIC (Linear Inverse Covariance) practice brain training pro  WIC (LINEAR INVERSE COVARIANCE) PRACTICE
WIC (LINEAR INVERSE COVARIANCE) PRACTICE WIC (LINEAR INVERSE COVARIANCE) PRACTICE WIC (LINEAR INVERSE COVARIANCE) PRACTICE	
WIC (LINEAR INVERSE COVARIANCE) PRACTICE WIC (LINEAR INVERSE COVARIANCE) PRACTICE WIC (LINEAR INVERSE COVARIANCE) PRACTICE	Mathematical Brain Test brain training pro  MATHEMATICAL BRAIN TEST
MATHEMATICAL BRAIN TEST MATHEMATICAL BRAIN TEST MATHEMATICAL BRAIN TEST	
MATHEMATICAL BRAIN TEST MATHEMATICAL BRAIN TEST MATHEMATICAL BRAIN TEST	AIQ Train Classifications with L-BE brain training pro for brain test  AIQ TRAIN CLASSIFICATIONS WITH L-BE
AIQ TRAIN CLASSIFICATIONS WITH L-BE AIQ TRAIN CLASSIFICATIONS WITH L-BE AIQ TRAIN CLASSIFICATIONS WITH L-BE	
AIQ TRAIN CLASSIFICATIONS WITH L-BE AIQ TRAIN CLASSIFICATIONS WITH L-BE AIQ TRAIN CLASSIFICATIONS WITH L-BE	White Matter Segmentation brain training pro  WHITE MATTER SEGMENTATION
WHITE MATTER SEGMENTATION WHITE MATTER SEGMENTATION WHITE MATTER SEGMENTATION	
WHITE MATTER SEGMENTATION WHITE MATTER SEGMENTATION WHITE MATTER SEGMENTATION	Diffusion Tensor Classification brain training pro  DIFFUSION TENSOR CLASSIFICATION
DIFFUSION TENSOR CLASSIFICATION DIFFUSION TENSOR CLASSIFICATION DIFFUSION TENSOR CLASSIFICATION	
DIFFUSION TENSOR CLASSIFICATION DIFFUSION TENSOR CLASSIFICATION DIFFUSION TENSOR CLASSIFICATION	Quantitative Brain Metrics brain training pro  QUANTITATIVE BRAIN METRICS
QUANTITATIVE BRAIN METRICS QUANTITATIVE BRAIN METRICS QUANTITATIVE BRAIN METRICS	

Detail	Datasets	Processes	Pipelines	Publications
941 Subjects	10671 Datasets			
SUBJECT	DATATYPE		DESCRIPTION	CREATE DATE
A00008326	 session  task  task  task  task  task CHECKERSBOARD  task CHECKERSBOARD  task  task  task BREATHHOLD		output from FreeSurfer	9/7/2017, 1:35
			sesion:DS2 task:rest acq:CAP	11/02/2016, 12
			sesion:DS2 task:rest acq:645	11/02/2016, 12
			sesion:DS2 task:rest acq:1400	11/02/2016, 12
			sesion:DS2 task:CHECKERSBOARD	11/02/2016, 12
			sesion:DS2 task:CHECKERSBOARD	11/02/2016, 12
			DS2	11/02/2016, 12
			DS2	11/02/2016, 12
			sesion:DS2 task:BREATHHOLD acq	11/02/2016, 12
A00008398	 session  task  task CHECKERSBOARD  task CHECKERSBOARD  task  task  task BREATHHOLD		sesion:DS2 task:rest acq:CAP	11/02/2016, 12
			sesion:DS2 task:rest acq:1400	11/02/2016, 12
			sesion:DS2 task:CHECKERSBOARD	11/02/2016, 12
			sesion:DS2 task:CHECKERSBOARD	11/02/2016, 12
			DS2	11/02/2016, 12
			sesion:DS2 task:BREATHHOLD acq	11/02/2016, 12
A00018683	 session  task  task  task  task CHECKERSBOARD  task CHECKERSBOARD		output from FreeSurfer	9/7/2017, 1:35
			sesion:DS2 task:rest acq:CAP	11/02/2016, 12
			sesion:DS2 task:rest acq:645	11/02/2016, 12
			sesion:DS2 task:rest acq:1400	11/02/2016, 12
			sesion:DS2 task:CHECKERSBOARD	11/02/2016, 12
			sesion:DS2 task:CHECKERSBOARD	11/02/2016, 12

COMPUTING RESOURCES	
This App can run on the following resources.	
 gpu1-pestillilab	
Cloud Providers	SCORE 12
 js-slurm2 (shared)	
Cloud Providers	SCORE 10
 az-slurm1 (shared)	
Cloud Providers	SCORE 10
 iu-carbonate (shared)	
HPC Systems	
 iu-karst (shared)	
IU / Karst (deprecate)	
 bridges (psc)	
HPC Systems	

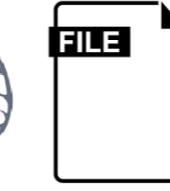
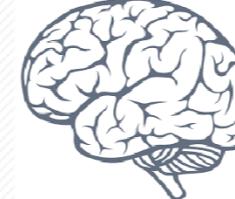
Brainlife

brainlife.io warehouse

Register analyses

Upload data

Choose computing



Brainlife



Container App 1
Container App 2
Python App1
MatLab App2



Google
Azure
Cluster
Cluster 2



brainlife.io warehouse

Register analyses

Upload data

Choose computing



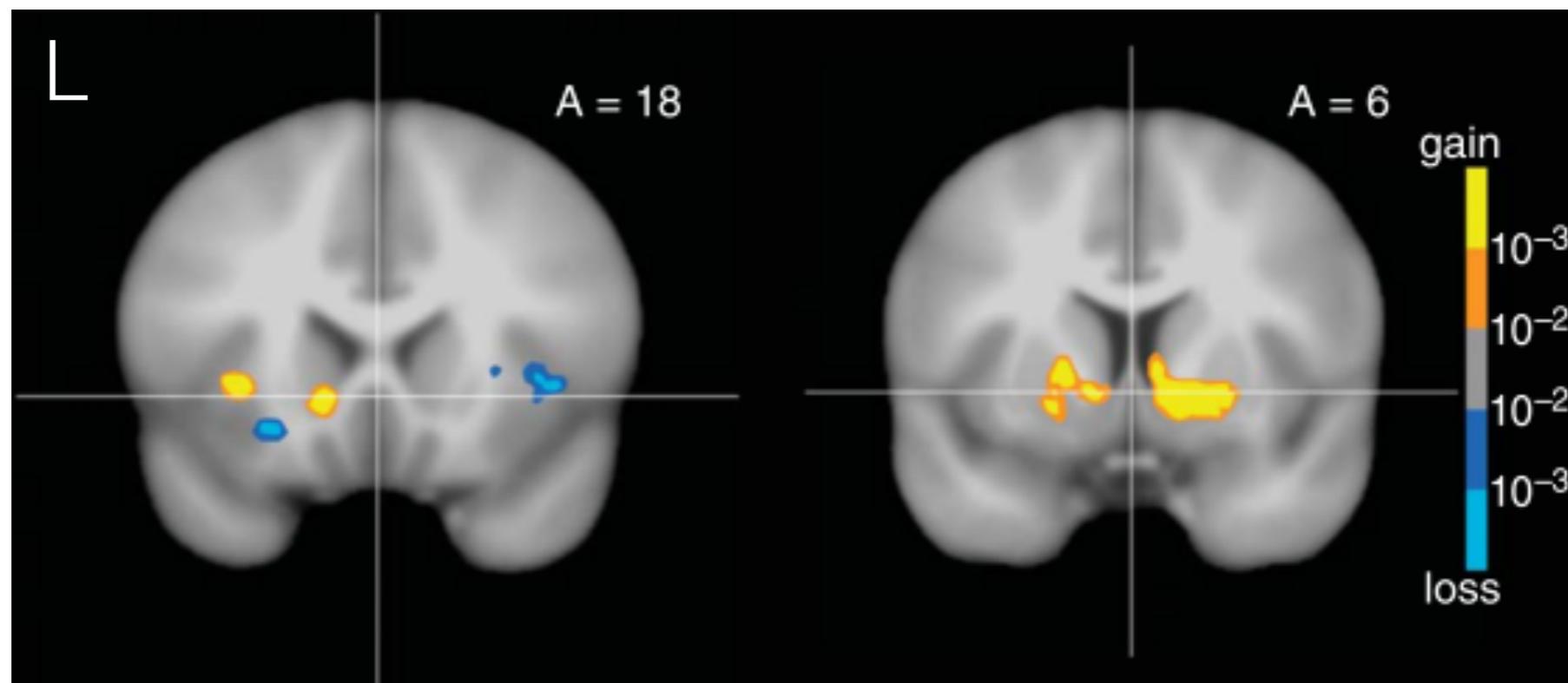
“Incentivized inhibition”



“Incentivized inhibition”

- **Incentive** anticipation
 - brain activity when anticipating incentive
 - activity can predict financial decisions (purchases, gambles)
- Response **inhibition**
 - brain activity when stopping motor actions
- Importance
 - individual differences of ability to inhibit for incentives may be important in short and long terms (survival, health, wealth)

Incentive anticipation

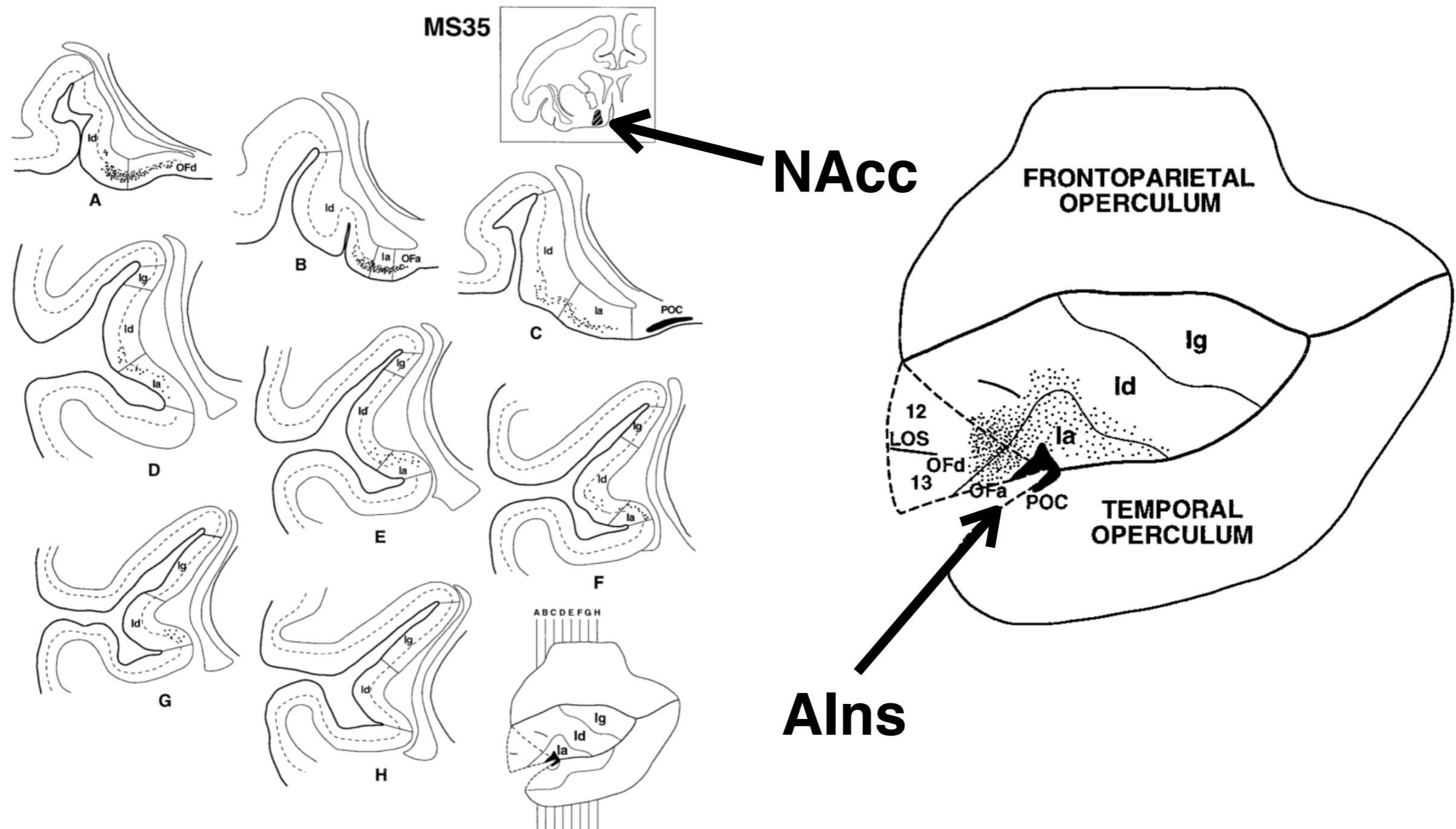


Anterior Insula
(AIns)

Nucleus accumbens
(NAcc)

Knutson & Greer (2008), Proc R Soc B

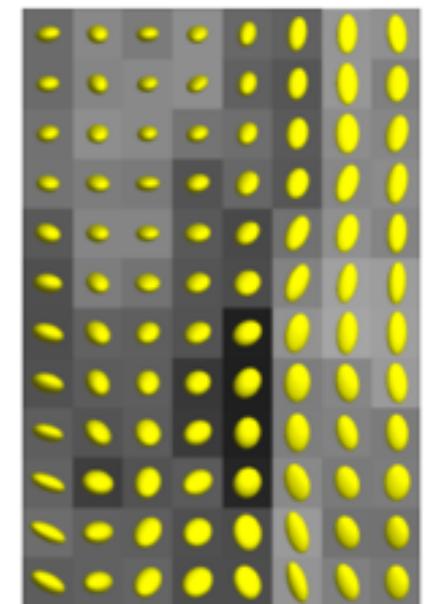
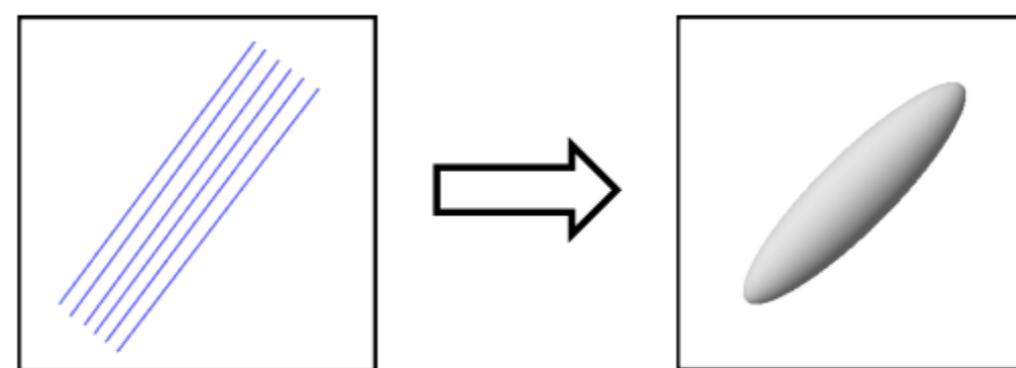
Alns—NAcc connection in monkeys



Chikama et al (1997); Reynolds & Zahm (2005), J Neuro

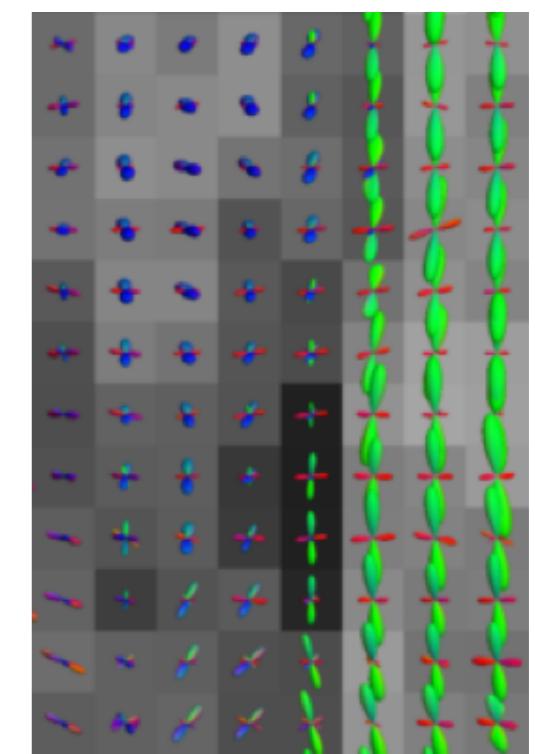
Diffusion MRI models

Tensor model



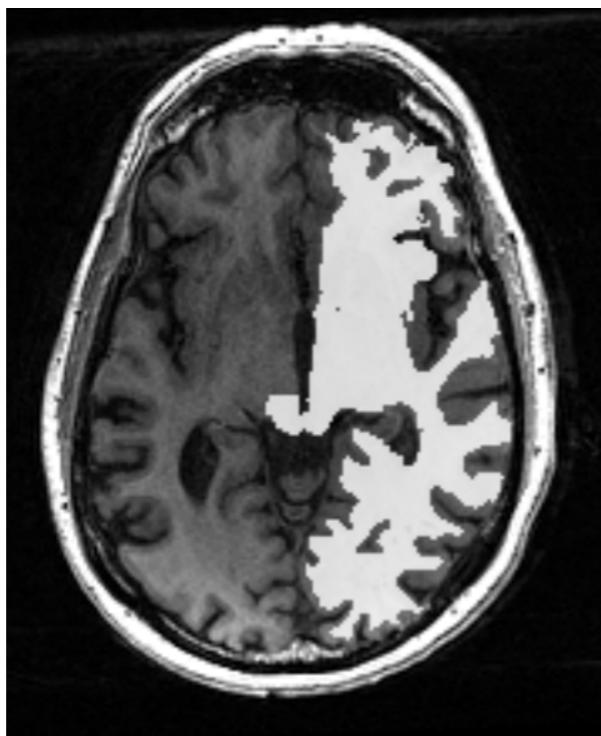
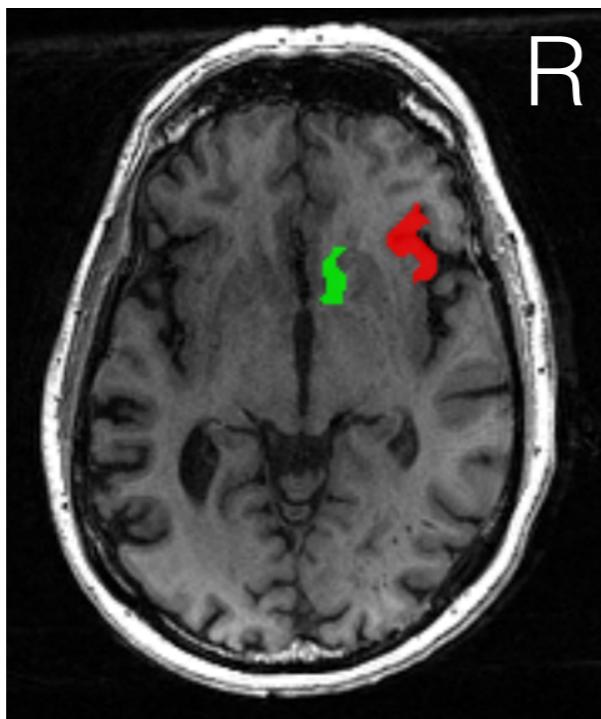
Constrained
spherical
deconvolution

$$\text{Signal} = \text{Kernel} * \text{fODF}$$



Tournier et al (2007), NeuroImage

Diffusion MRI data processing



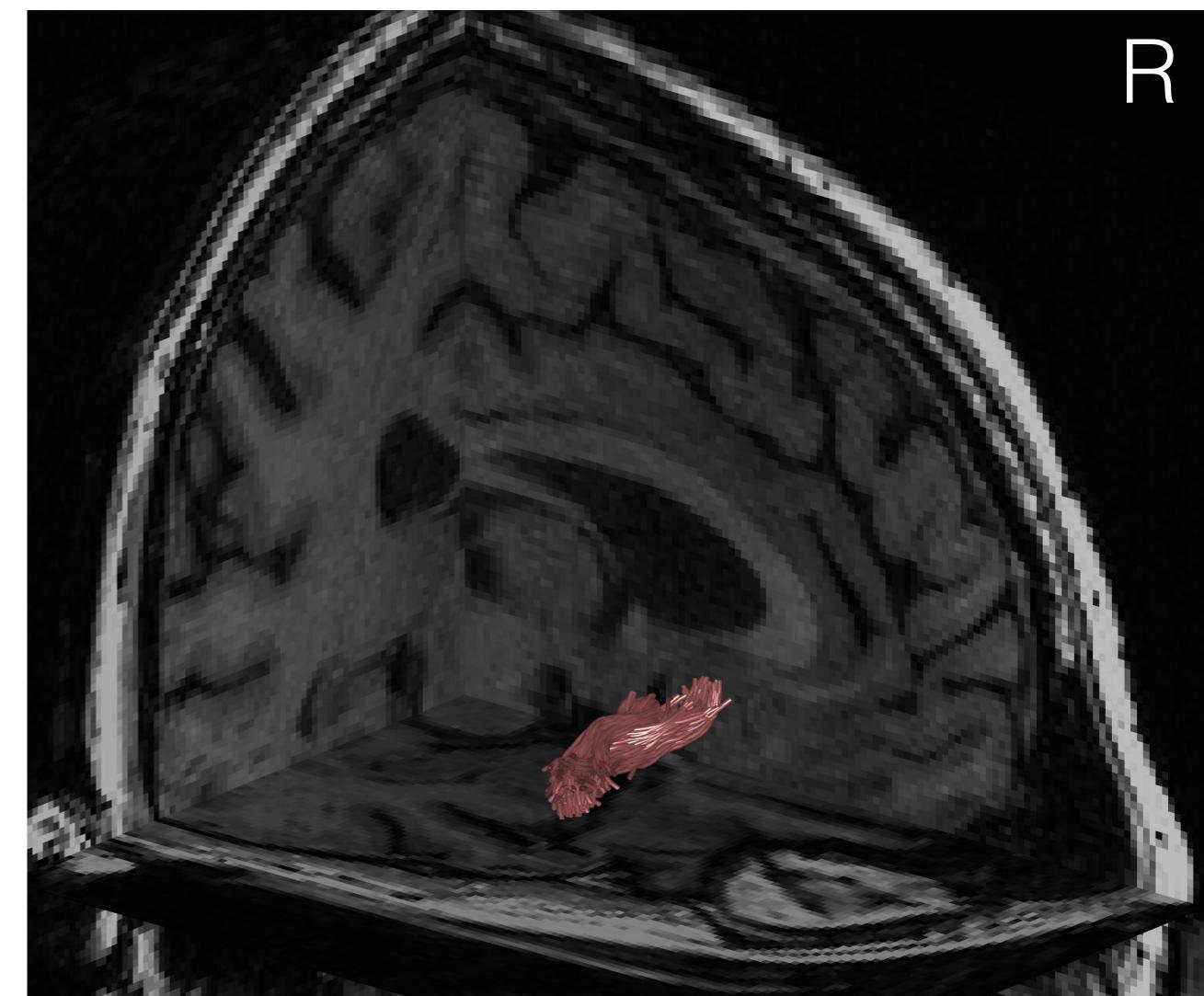
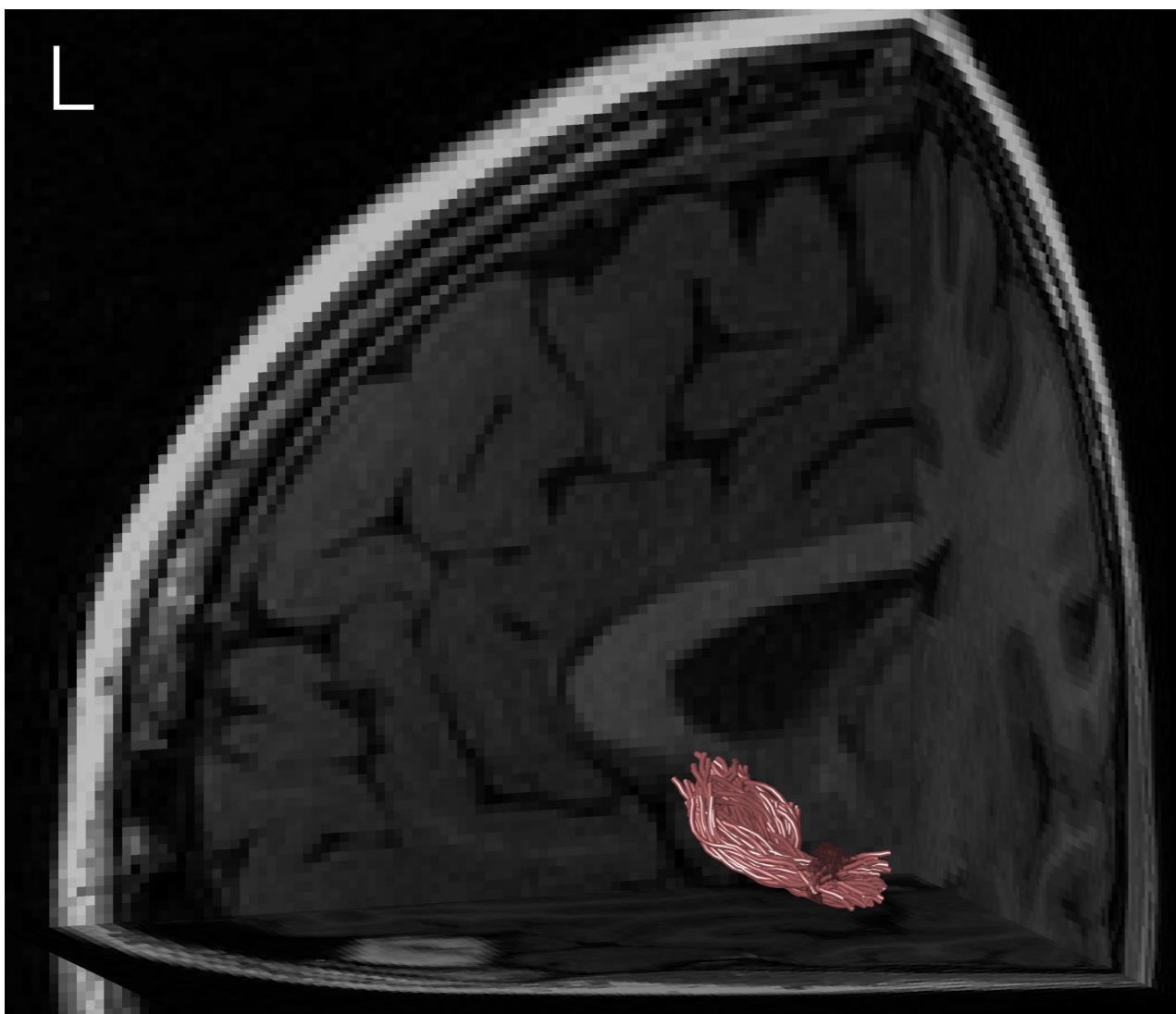
Seed FreeSurfer volumes

- NAcc
- Anterior insula
- white matter mask

MRtrix probabilistic tractography

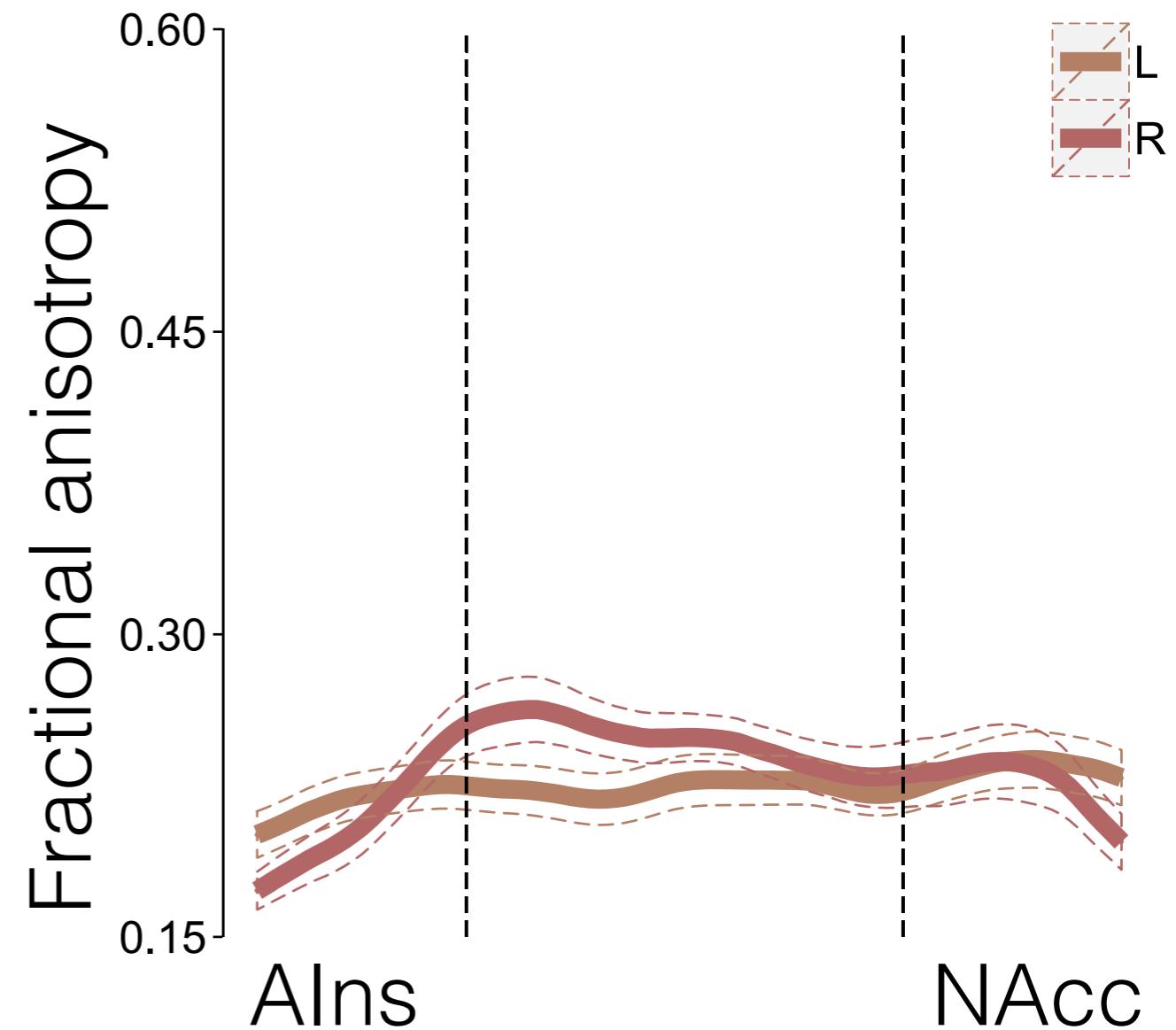
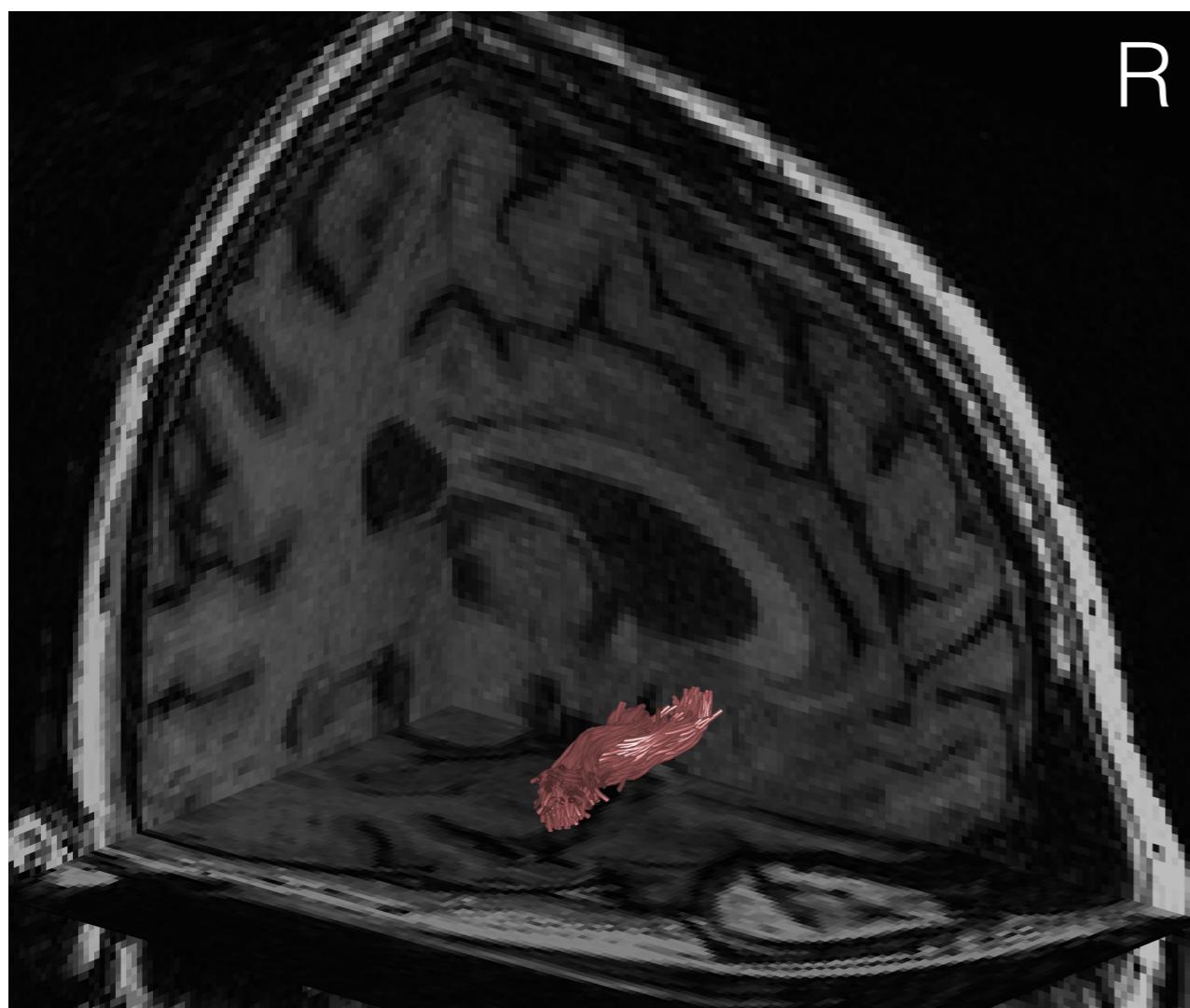
- CSD $L_{\max} = 10$
- 0.05 FA cutoff
- 60° curvature
- 5,000 fibers
- 500,000 max

AlIns—NAcc connection in humans



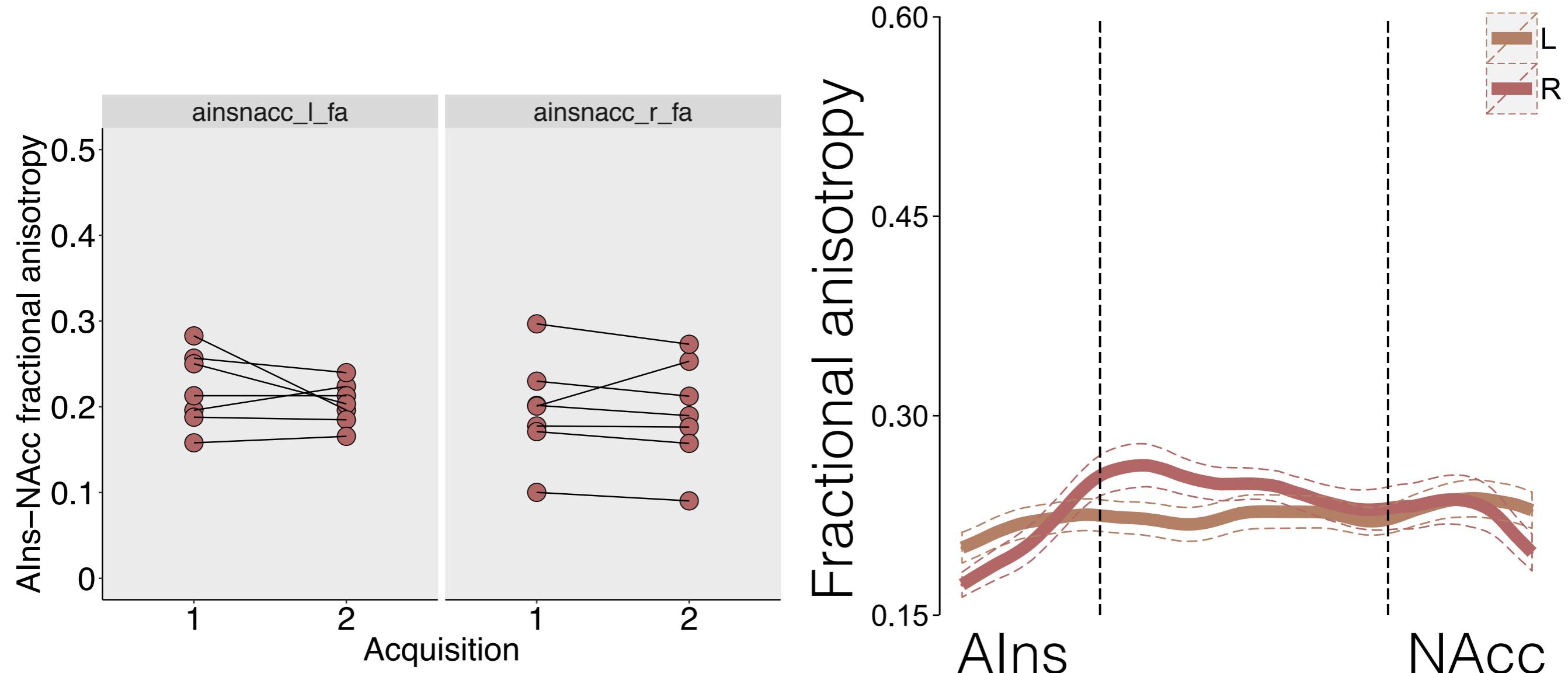
Leong, Pestilli, Wu, Samanez-Larkin, & Knutson (2016), *Neuron*
Leong, MacNiven, Samanez-Larkin, & Knutson (2018), *NeuroImage*

Connection strength



Leong, Pestilli, Wu, Samanez-Larkin, & Knutson (2016), *Neuron*
Leong, MacNiven, Samanez-Larkin, & Knutson (2018), *NeuroImage*

Measurement reliability



ICC_{2k} = 0.96, p < 0.001

Leong, Pestilli, Wu, Samanez-Larkin, & Knutson (2016), Neuron
Leong, MacNiven, Samanez-Larkin, & Knutson (2018), NeuroImage

Adolescent brain development

How neuroimaging measures might be useful?

- Link structure and function of incentive and inhibition circuits in adolescents
- Characterize longitudinal development of brain circuits
- Predict future life outcomes

Adolescent Brain Cognitive Development (ABCD) study

Data

- 11,000 subjects, 9-11 years old
- collect data every 2 years for 10 years
 - structural and functional MRI
 - real-life and laboratory behaviors
 - genetics

Software

- Brainlife

Hardware

- Microsoft Azure (4 customized computing nodes)
- Indiana University high-performance computing clusters
- Open Science Grid

AIns—NAcc connection in adolescents

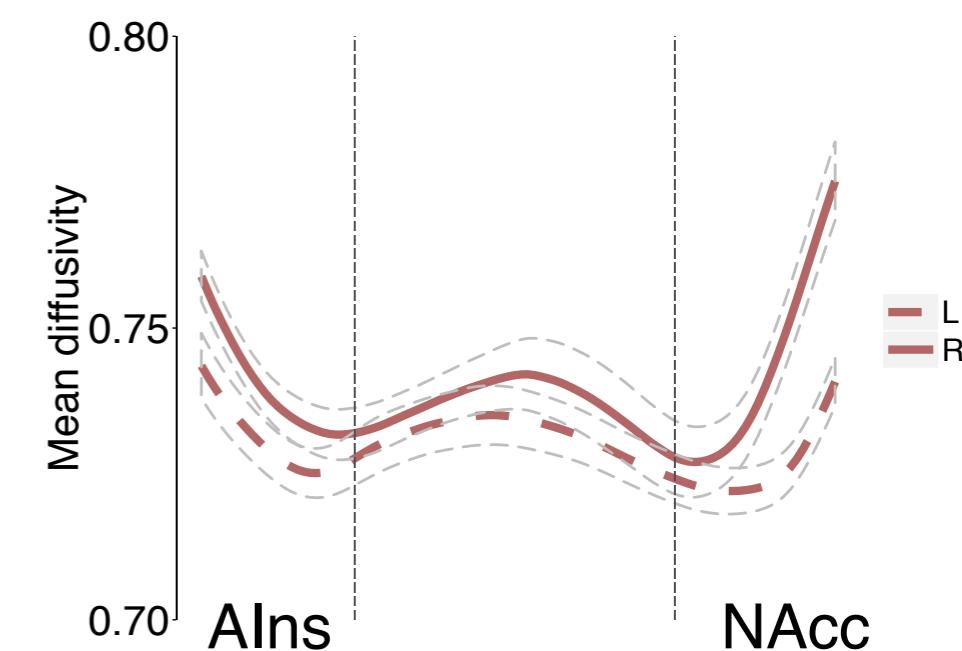
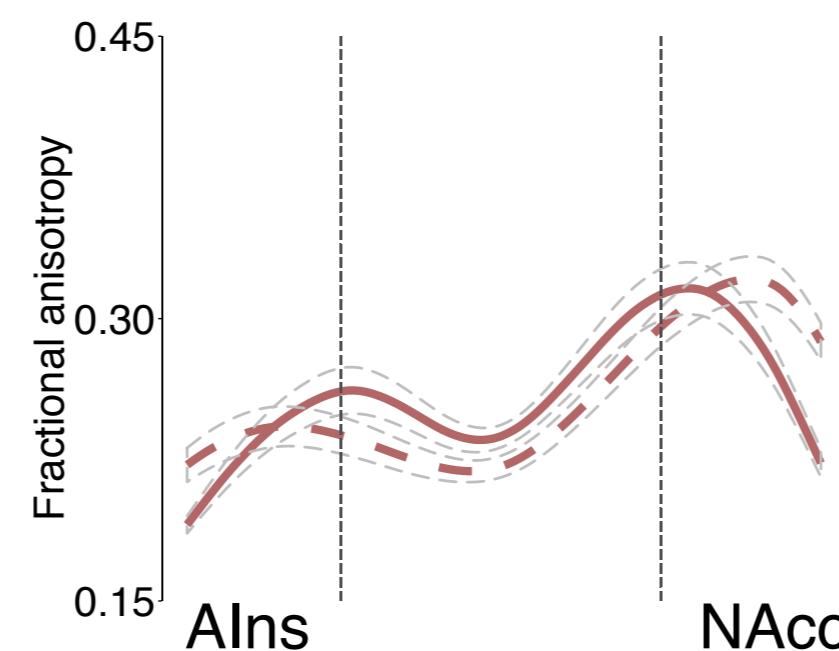
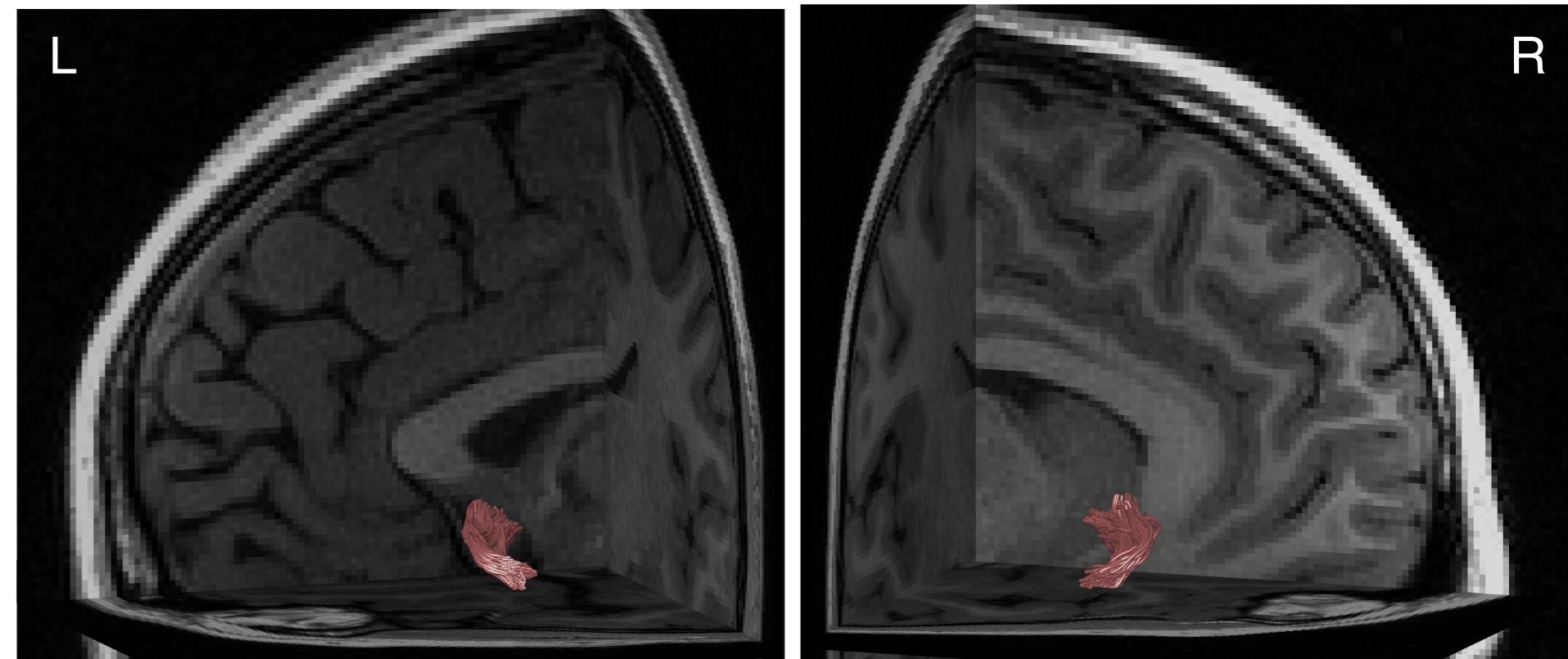
Sample

n=91

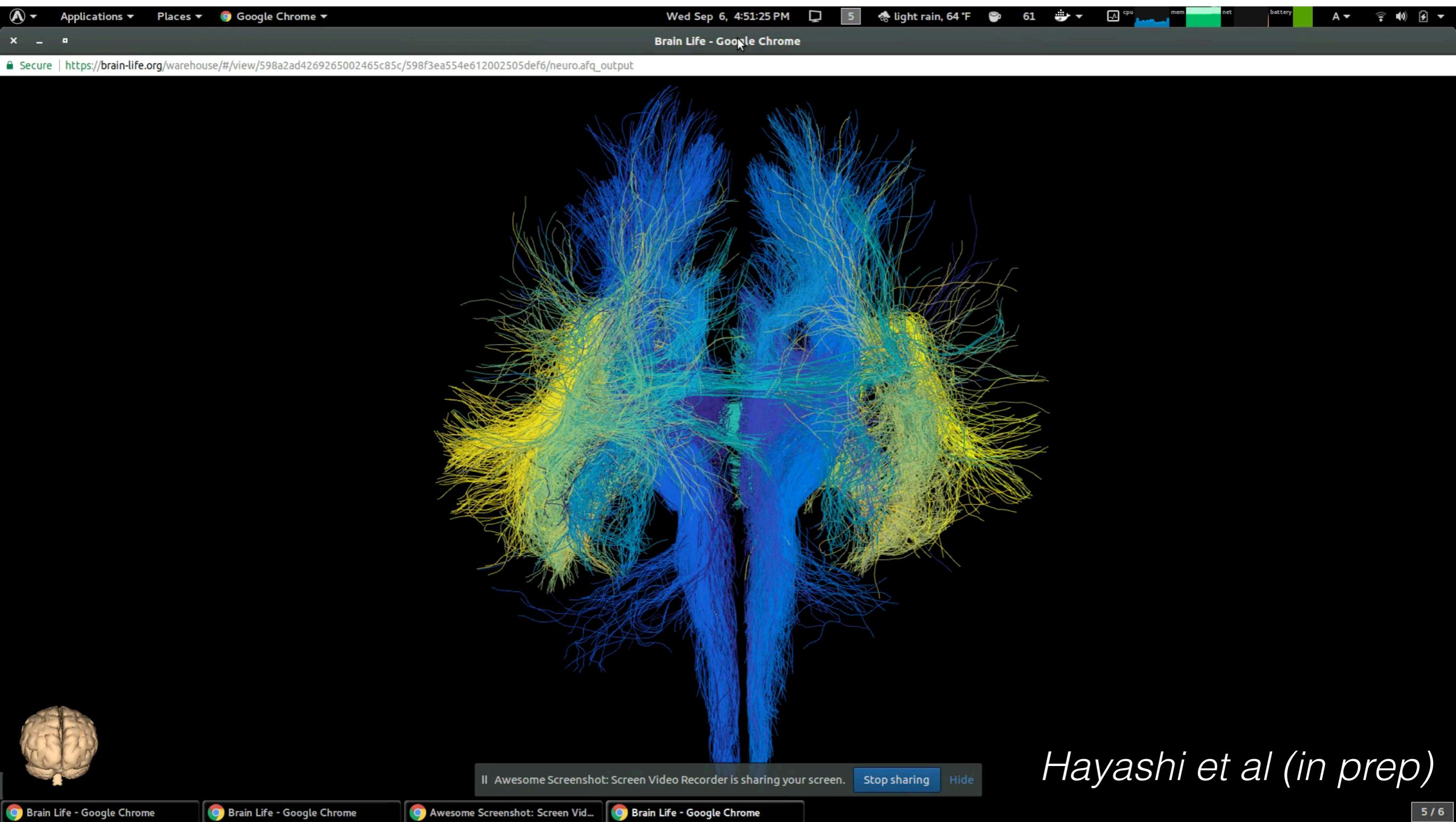
age mean=11

range = 9-13

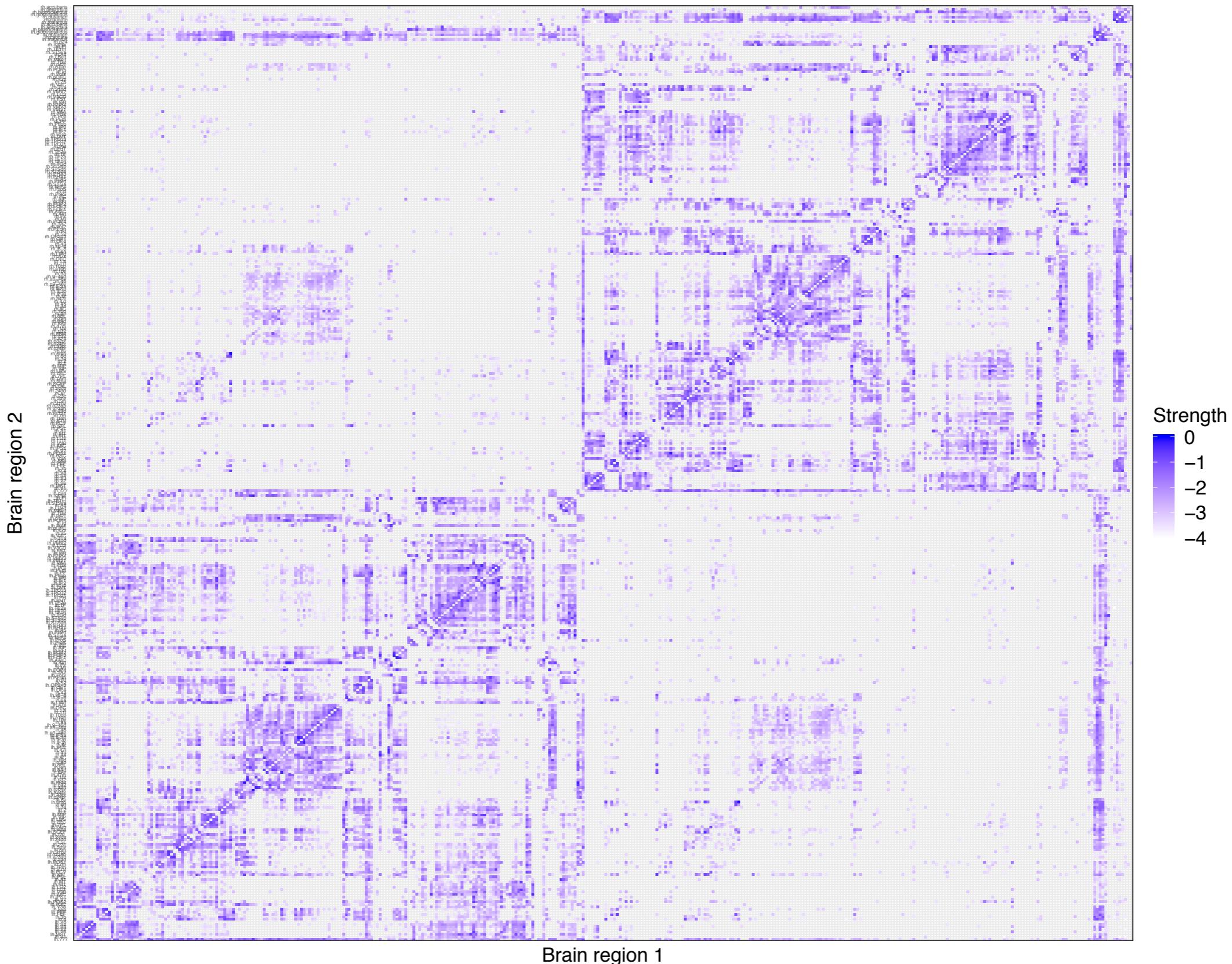
59 females



Whole-brain structural connectivity



Whole-brain structural connectivity



Processing pipeline

brainlife <  ABCD 

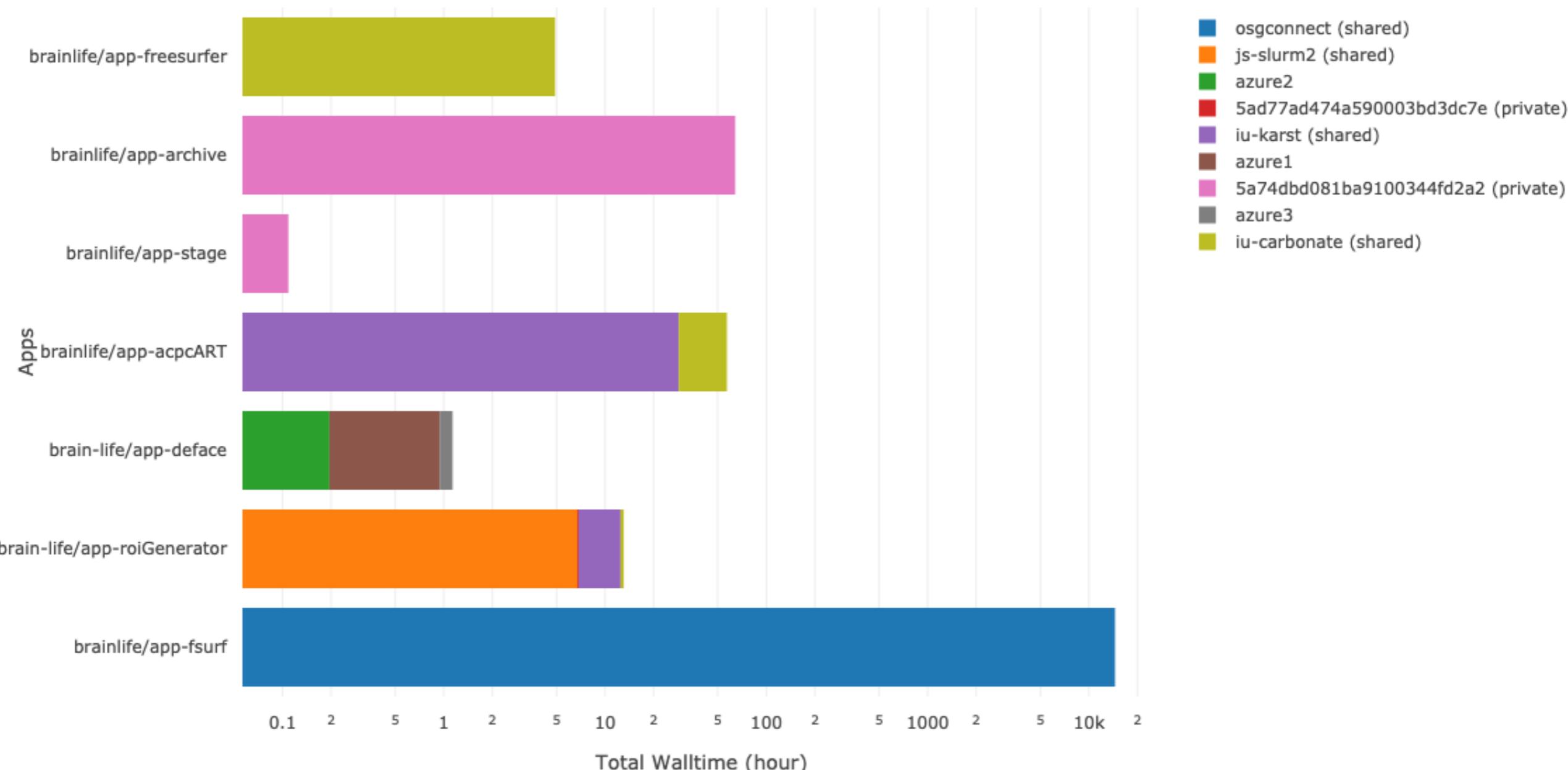
Apps Projects Publications Datatypes Settings Josiah Leong Contact us (slack) Documentation +

Detail Archive Processes Pipelines Publications

9 Pipeline Rules Order by `create_date` ▾

	Jobs	Create Date	Update Date
<input type="checkbox"/> Offline	Freesurfer 6.0 freesurfer	11 hours ago	5 hours ago
<input checked="" type="checkbox"/> Online	Network Matrices netmat	1 199	3 days ago 1 hour ago
<input checked="" type="checkbox"/> Online	mrtrix3 act act	8 1207	3 days ago 1 hour ago
<input checked="" type="checkbox"/> Online	Freesurfer Deface deface	29 1579	4 days ago 1 hour ago
<input checked="" type="checkbox"/> Online	Multi-Atlas Transfer Tool maTT	273	4 days ago 1 hour ago
<input checked="" type="checkbox"/> Online	ROI Generation rois aparc2009	123 169	5 days ago 1 hour ago
<input checked="" type="checkbox"/> Online	Freesurfer on OSG freesurfer osg	1109 20273	6 days ago 1 hour ago
<input checked="" type="checkbox"/> Online	mrtrix3 preprocess mrtrix preproc 	435 1443	7 days ago 1 hour ago
<input type="checkbox"/> Offline	ACPC alignment via ART t1w-acpc 		1 week ago 6 days ago

Hardware usage



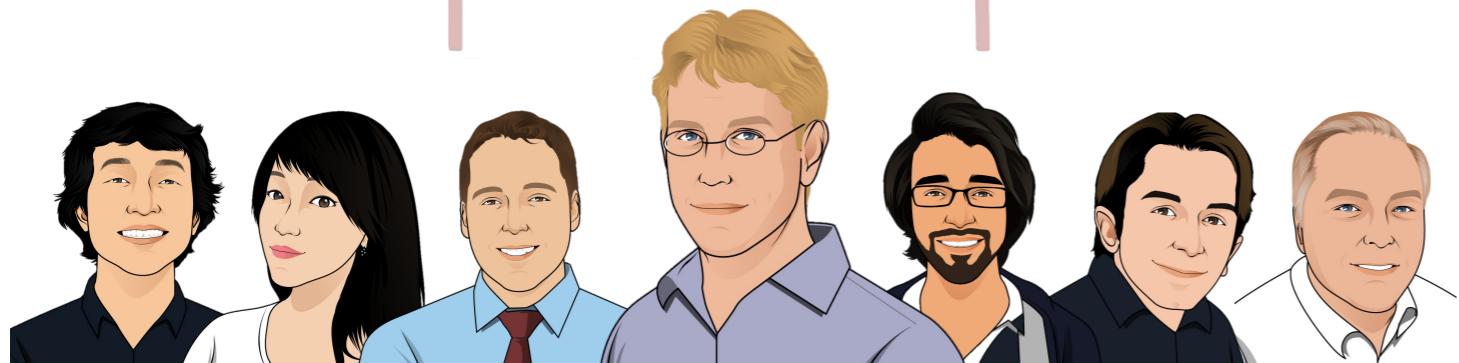
Summary

- Brainlife platform allows neuroscientists to process large datasets on any computing resource (e.g., Microsoft Azure)
- Visualized and measured specific white-matter connections and whole-brain structural connectivity

What next?

- Analyze more subjects ($n \sim 10,000$)
- Link brain to behaviors and genetics
- Predict future behaviors (e.g., problematic drug use, neuropsychiatric disorders)

Thank you! Questions?



brainlife.io

Funding

Indiana University Pervasive
Technology Institute
Stanford NeuroChoice Initiative
NIMH Affective Science Program

