Investigating the Development of Thalamocortical Structural Connections

as told by Alice's adventures in Wonderland

Lab Meeting March 14, 2023

Valerie Sydnor

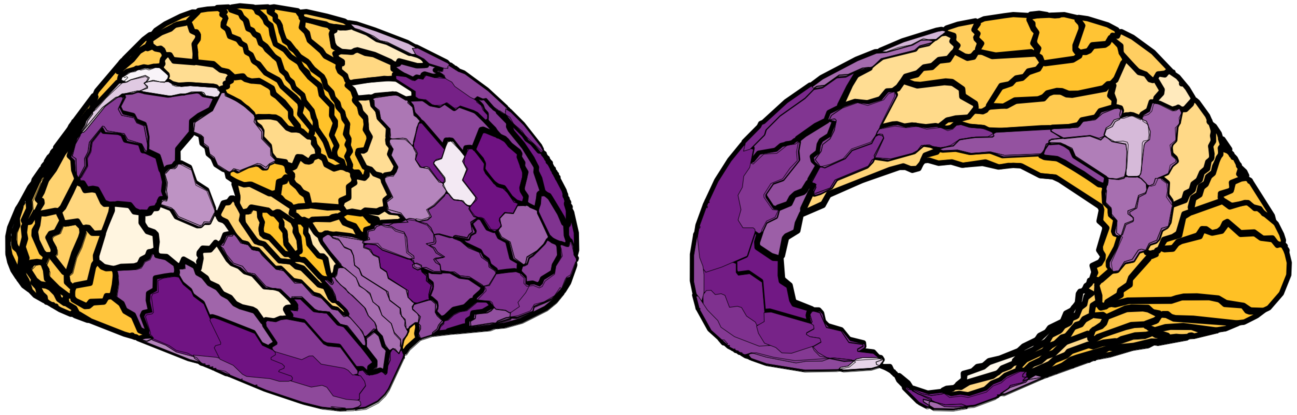
Lifespan Informatics & Neuroimaging Center

Aim 1:

To investigate if the maturation of thalamocortical structural connections drives developmental changes in cortical plasticity

Prior Thesis Work

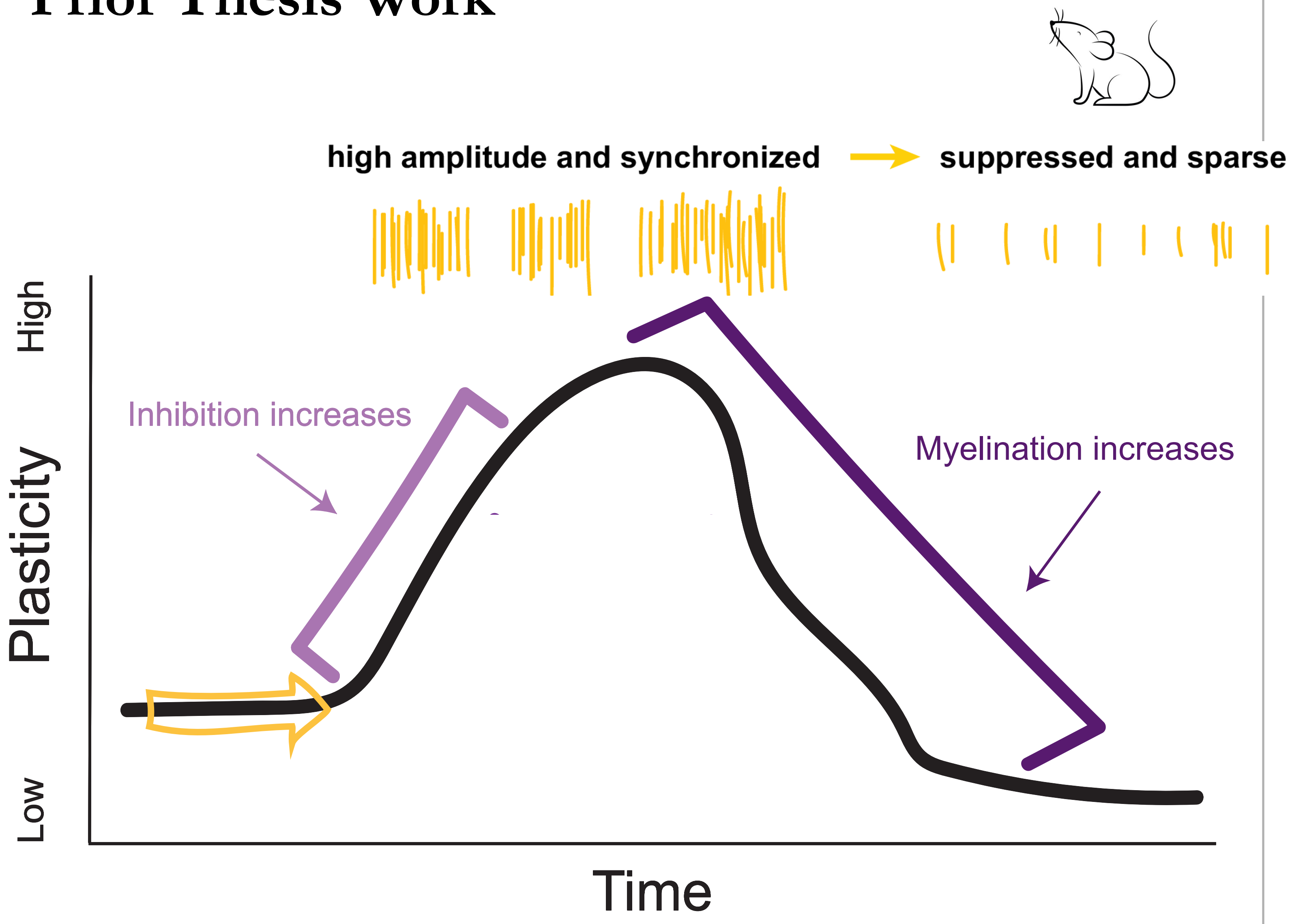
How does developmental plasticity spatially and temporally progress across the human cortex?



Aim 1:

To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

Prior Thesis Work



Aim 1:

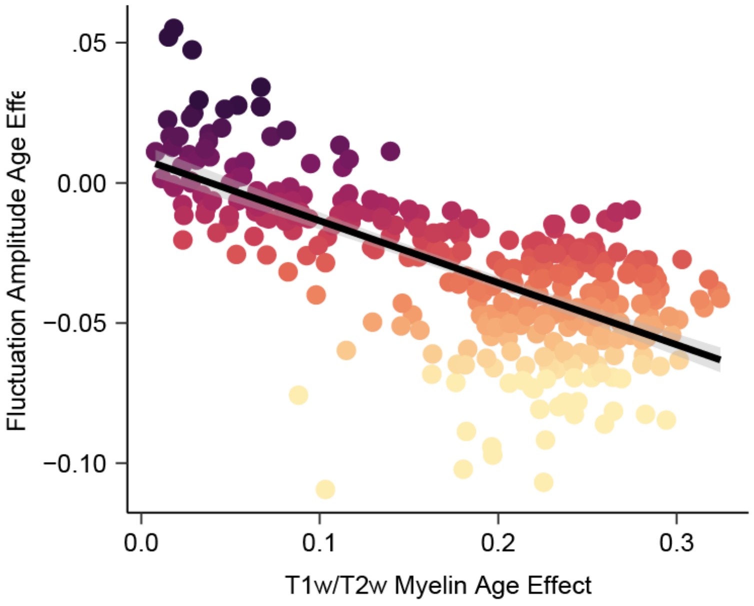
To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

T1w/T2w data from Baum et al., 2021

Prior Thesis Work

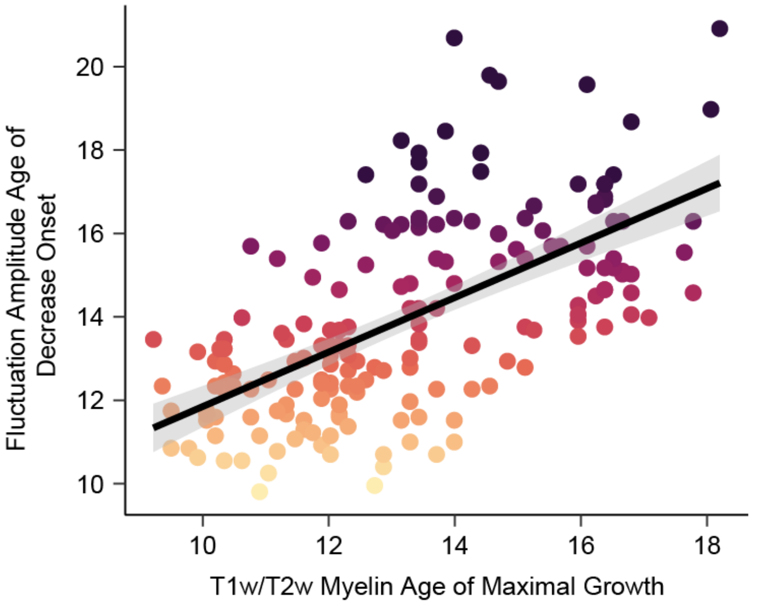
Spatial Relationship

$r = -0.67, p_{spin} < 0.001$



Temporal Relationship

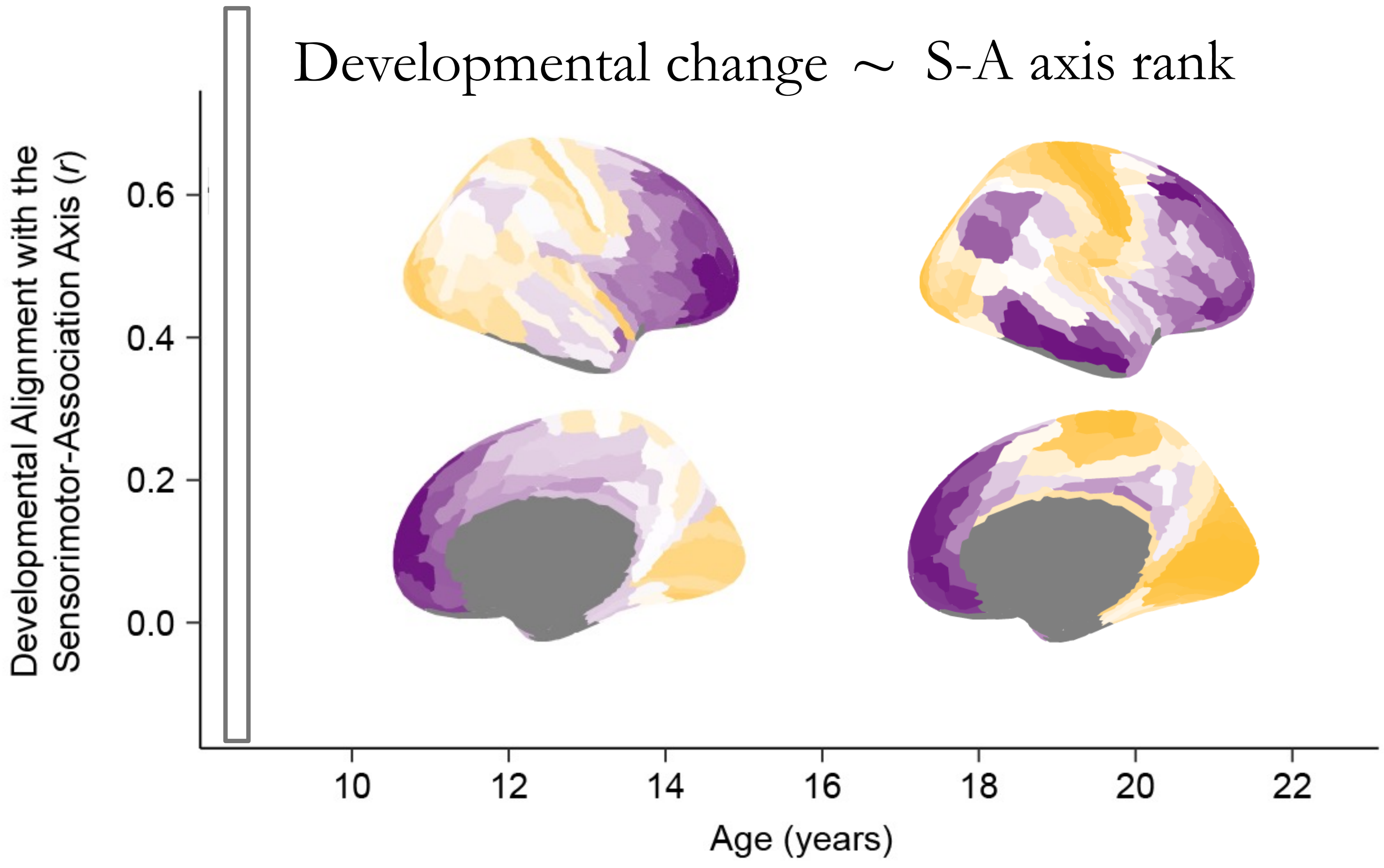
$r = 0.64, p_{spin} = 0.016$



Aim 1:

To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

Prior Thesis Work



Aim 1:

To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

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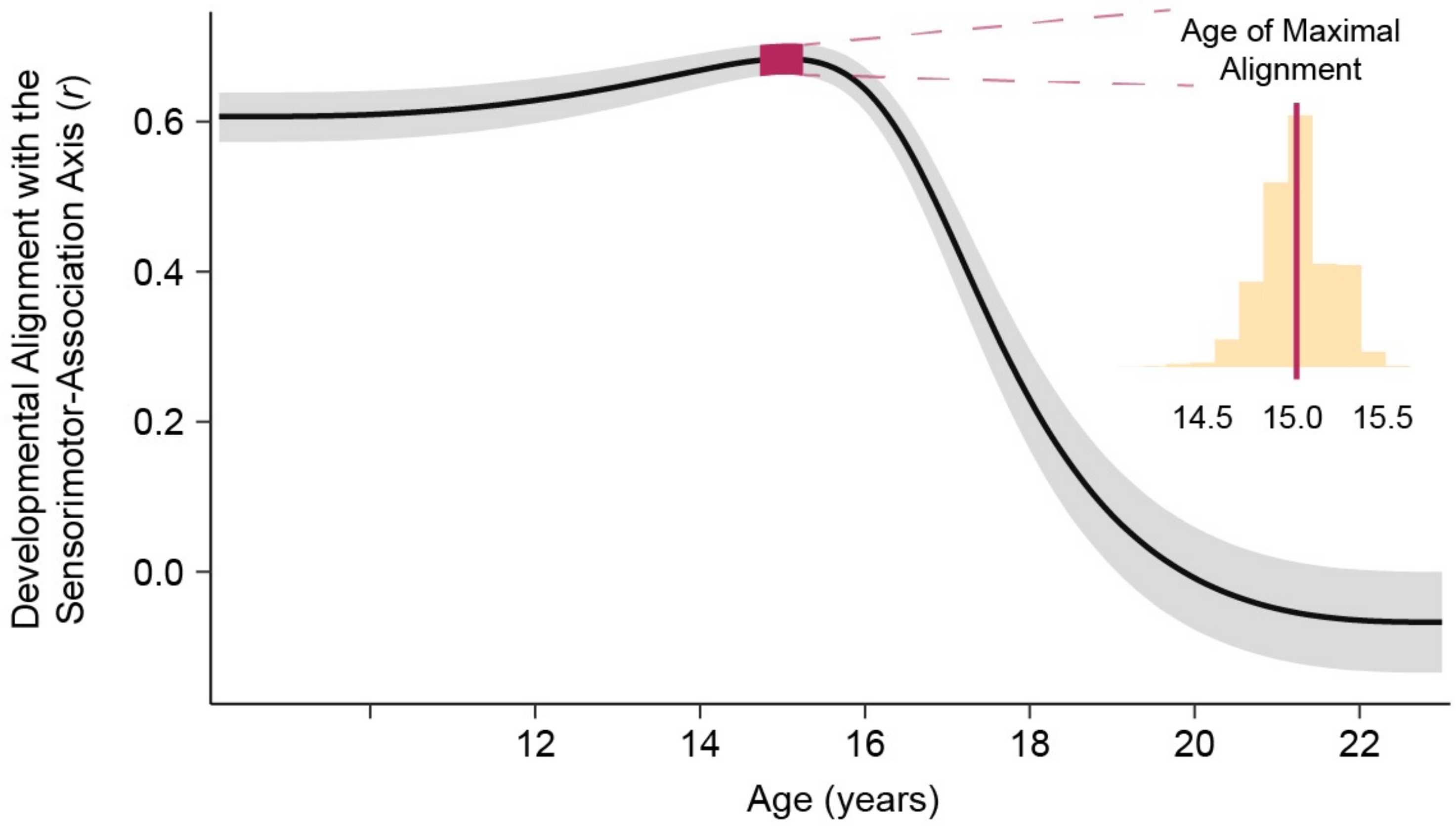

Aim 1:

To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

Outstanding Question: What drives the asynchronous, hierarchical pattern of cortical development along the S-A axis?

Extrinsic influences

- Experience

Intrinsic mechanisms

- Temporally organized gene expression (e.g., circadian genes, epigenetic regulators)
- Circuit dynamics
- **Thalamocortical inputs**

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Thalamocortical axons play critical roles in the developing brain

- Enhance cortical neurogenesis *(Monko et al., 2022)*
- Impact laminar architecture of cortical areas *(Monko et al., 2022; Li et al., 2013)*
- Control cortical area gene expression and identity *(Vue et al., 2013; Pouchelon et al., 2014)*
- Sculpt sensory maps (i.e., retinotopic, tonotopic, somatotopic maps) *(Antón-Bolaños et al., 2019; Li et al., 2013; Chou et al., 2013; Lokmane et al., 2013)*
- Influence the migration and maturation of parvalbumin interneurons *(Larsen et al., 2019; Zechel et al., 2016)*
- Alter the intensity, synchronization, and temporal patterning of cortical activity *(Antón-Bolaños et al., 2019; Benoit et al., 2021)*

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Science

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HOME > SCIENCE > VOL. 364, NO. 6444 > PRENATAL ACTIVITY FROM THALAMIC NEURONS GOVERNS THE EMERGENCE OF FUNCTIONAL CORTICAL MAPS IN MICE

REPORT

Prenatal activity from thalamic neurons governs the emergence of functional cortical maps in mice

NOELIA ANTÓN-BOLAÑOS, ALEJANDRO SEMPERE-FERRÀNDEZ, TERESA GUILLAMÓN-VIVANCOS, FRANCISCO J. MARTINI, [...], AND GUILLERMINA LÓPEZ-BENDITO

+4 authors Authors Info & Affiliations

SCIENCE • 2 May 2019 • Vol 364, Issue 6444 • pp. 987-990 • DOI: 10.1126/science.aav7617

nature

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Article | Published: 03 August 2022

Modular strategy for development of the hierarchical visual network in mice

Tomonari Murakami, Teppei Matsui, Masato Uemura & Kenichi Ohki

Nature **608**, 578–585 (2022) | Cite this article

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

nature neuroscience

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Article | Published: 19 May 2022

Adolescent thalamic inhibition leads to long-lasting impairments in prefrontal cortex function

Laura J. Benoit, Emma S. Holt, Lorenzo Posani, Stefano Fusi, Alexander Z. Harris, Sarah Canetta & Christoph Kellendonk

Development of Thalamocortical Structural Connectivity in Typically Developing and Psychosis Spectrum Youths

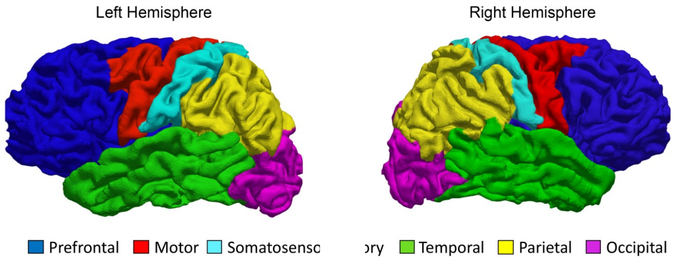
Suzanne N. Avery, Anna S. Huang, Julia M. Sheffield, Baxter P. Rogers, Simon Vandekar, Alan Anticevic, and Neil D. Woodward

Methods

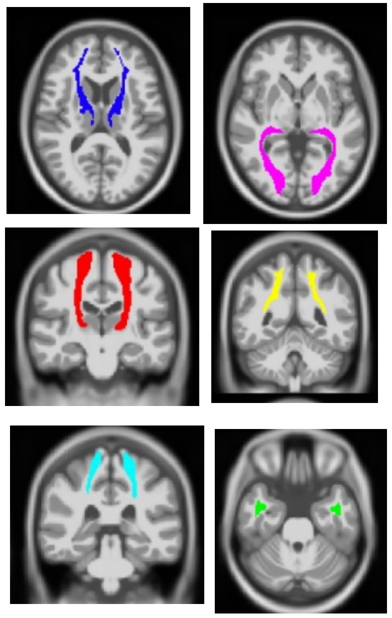
PNC (n = 1144)

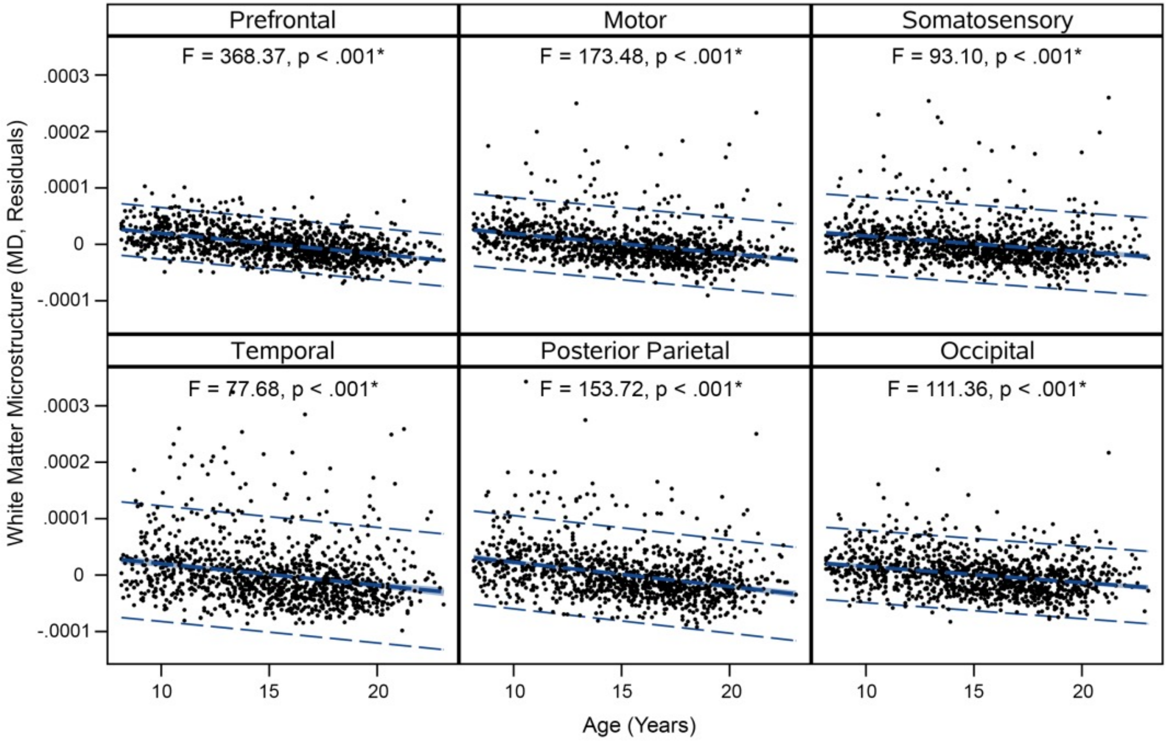
Probabilistic tractography

FA of group-overlap tracts connecting thalamus to 6 cortical territories



Supplementary Figure S1. Six bilateral cortical re gions were included as thalamic targets for the probabilistic tractography analysis.





Avery et al., 2022, Bio Psych: CNNI

Thalamocortical Connectivity Predicts Cognition in Children Born Preterm

Gareth Ball[1,†], Libuse Pazderova[2,†], Andrew Chew[1], Nora Tusor[1], Nazakat Merchant[1], Tomoki Arichi[1], Joanna M. Allsop[1], Frances M. Cowan[2], A. David Edwards[1], and Serena J. Counsell[1]

Methods

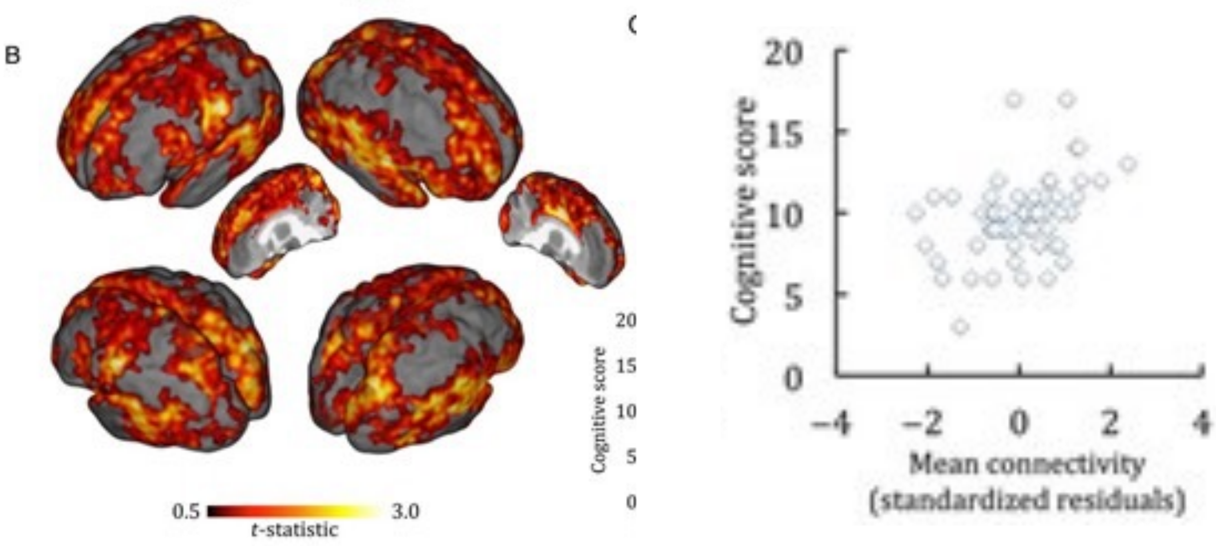
57 preterm infants

Probabilistic tractography

Voxel-wise thalamocortical connectivity maps

Results

Cognitive scores at 2 years of age were positively correlated with thalamocortical connectivity at birth across much of cortex



Ball et al., 2015, Cerebral Cortex

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Project 5 (Current project): Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Background: During childhood and adolescence, cortical maturation temporally progresses along a hierarchical, sensorimotor-association (S-A) axis (Baum et al., 2022; Pines et al., 2022; Reh et al., 2020; Sydnor et al., 2021). This S-A developmental sequence facilitates prolonged plasticity within higher-order association cortices, thereby allowing association cortex-supported cognitive functions to be enhanced over an extended developmental window. While this spatiotemporal developmental pattern has been observed across biological scales and species, the intrinsic mechanisms driving asynchronous cortical maturation and protracted association cortex development in humans are poorly understood. Animal studies have shown that axonal inputs from the thalamus to the cortex robustly influence cortical plasticity, arealization, and identity during post-natal development (Benoit et al., 2022; Pouchelon et al., 2014; Shibata et al., 2021; Sugiyama et al., 2008; Vue et al., 2013); cortical sculpting by thalamocortical inputs has been observed in both sensory and association cortex. Despite a potentially fundamental role for thalamocortical structural connections in determining cortical malleability, size, and function during development, a mechanistic developmental model that relates thalamocortical connectivity maturation to the advancement of cortical development and developmental outcomes along the S-A axis has yet to be tested in humans. This project will leverage innovations in diffusion MRI acquisition and analysis techniques, large N youth datasets, and cortical maps of plasticity marker maturation to examine the impact of thalamocortical structural connectivity maturation on cortical developmental patterns and biobehavioral developmental outcomes.

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Aim 1: To investigate if the maturation of thalamocortical structural connections drives developmental changes in cortical plasticity.

Aim 2: To determine whether thalamocortical connectivity strength is associated with local cortical scaling during youth.

Aim 3: To identify relationships between thalamocortical connectivity strength and individual variability in general cognition.

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Aim 1:

To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

Thalamocortical Axons Influence Plasticity in Primary and Association Areas

- Ocular dominance plasticity in V1 coincides with reorganization of thalamic inputs *(Coleman et al., 2010)* and requires OD plasticity in the thalamus LGN *(Sommeijer et al., 2010)*
- Thalamocortical inputs from the LGN to V1 transfer the Otx2 homeoprotein to visual cortex, allowing for Otx2-dependent maturation of PV interneurons and the onset of CP plasticity *(Sugiyama et al., 2008)*
- PNN degradation in V1 increases the strength of thalamic synapses onto PV interneurons, the power of spontaneous gamma oscillations, and cortical plasticity *(Faini et al., 2018)*

Aim 1:

To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development

Thalamocortical Axons Influence Plasticity in Primary and Association Areas

- Thalamocortical inputs to the medial PFC regulate maturation of PV interneurons via thalamus-associated signaling molecules *(Larsen et al., 2019)*
- Inhibiting mediodorsal and midline thalamus in mice during adolescence (but not adulthood) leads to long-lasting decreases in thalamo-prefrontal projection density, E:I balance alterations, and persistent impairments in circuit function *(Benoit et al., 2022)*

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Aim 1: To investigate if the maturation of thalamocortical structural connections drives developmental changes in cortical plasticity.

Thalamocortical structural connections will develop along the S-A axis during childhood and adolescence, influencing the hierarchical maturation of cortical plasticity markers.

Aim 1:

To investigate if the maturation of thalamocortical structural connections drives developmental changes in cortical plasticity

Specific Hypotheses

1a. Developmental changes in thalamocortical structural connectivity will progress along the S-A axis, with higher-order association cortices exhibiting larger and later increases in thalamic connectivity.

1b. Later increases in thalamocortical structural connectivity will be associated with protracted cortical plasticity, as revealed by delayed changes in functional and structural markers of declining plasticity.

1c. Spatiotemporal changes in thalamocortical structural connectivity will be maximally organized along the S-A axis in early adolescence.

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Aim 1: To investigate if the maturation of thalamocortical structural connections drives developmental changes in cortical plasticity.

Aim 2: To determine whether thalamocortical connectivity strength is associated with local cortical scaling during youth.

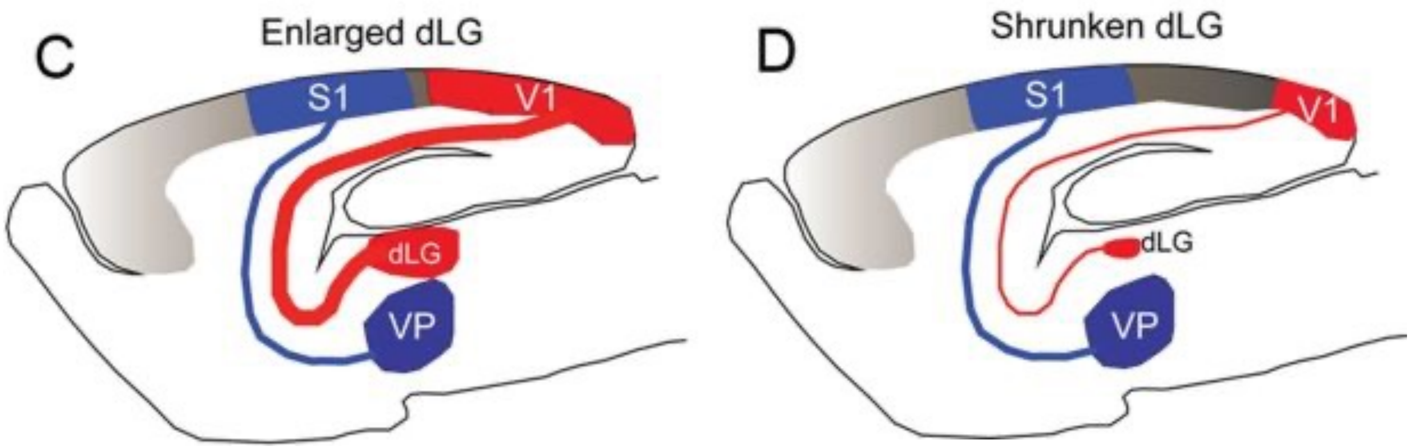
Aim 3: To identify relationships between thalamocortical connectivity strength and individual variability in general cognition.

Aim 2:

To determine whether thalamocortical connectivity strength is associated with local cortical scaling during youth

Thalamocortical Inputs Regulate Cortical Area Size in Primary and Association Areas

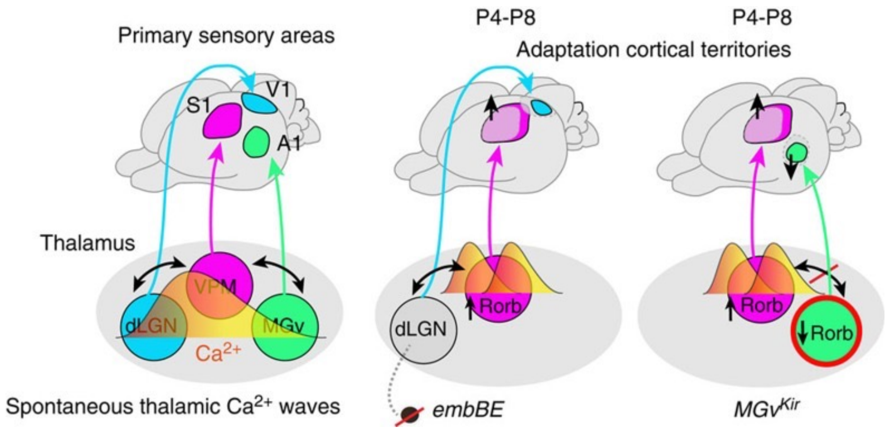
- Genetically increasing or decreasing the size of the LGN results in a corresponding expansion or reduction in 1) the number of thalamocortical axon projections and 2) the size of V1 *(Vue et al., 2013; Mercurio et al., 2019)*



Aim 2:
To determine whether thalamocortical connectivity strength is associated with local cortical scaling during youth

Thalamocortical Inputs Regulate Cortical Area Size in Primary and Association Areas

- Genetically increasing or decreasing the size of the LGN results in a corresponding expansion or reduction in 1) the number of thalamocortical axon projections and 2) the size of V1 *(Vue et al., 2013; Mercurio et al., 2019)*
- Spontaneous thalamic calcium waves propagate among thalamic sensory nuclei, travel up to the cortex, and influence cortical area size *(Moreno-Juan et al., 2017)*



Aim 2:

To determine whether thalamocortical connectivity strength is associated with local cortical scaling during youth

Thalamocortical Inputs Regulate Cortical Area Size in Primary and Association Areas

- Changes in the number of MD-PFC thalamocortical axons precede volumetric alterations in the mouse PFC *(Ferguson and Gao, 2014)*
- Retinoic acid signaling in the PFC facilitates lateral expansion of PFC areas in primates dependent on lateral PFC innervation by the MD nucleus of the thalamus *(Shibata et al., 2021)*

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Aim 2: To determine whether thalamocortical connectivity strength is associated with local cortical scaling during youth.

Greater regional surface area reflects greater connectivity with the thalamus.

Aim 2:

To determine whether thalamocortical connectivity strength is associated with differences in cortical area scaling in youth

Specific Hypotheses

2a. Across individuals, the relative size of each cortical region will scale with the strength of its structural connectivity with the thalamus.

2b. Associations between thalamocortical structural connectivity and regional scaling will be strongest in cortices that show the greatest degree of nonlinear scaling with scaling of overall brain size.

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Aim 1: To investigate if the spatiotemporal maturation of thalamocortical connections drives asynchronous cortical development.

Aim 2: To determine whether thalamocortical connectivity strength is associated with differences in cortical area scaling in youth.

Aim 3: To study the influence of inter-individual differences in thalamocortical connectivity strength on individual variability in cognition.

Aim 3:

To study the influence of inter-individual differences in thalamocortical connectivity strength on individual variability in cognition

Thalamocortical Inputs to Higher-order Association Cortices are Important for Cognition

- Slow, deliberative, serial processing is facilitated by integrative, associative thalamic nuclei. Thalamocortical connections with association cortex modulate large-scale brain dynamics and distributed processing during complex cognition *(Bell and Shine, 2016; Shine et al., 2022).*

- Transiently inhibiting mediodorsal and midline thalamus during adolescence leads to cognitive deficits (WM, attentional set shifting) in adulthood *(Benoit et al., 2022)*

- The thalamus is implicated in disorders characterized by severe cognitive deficits (e.g., schizophrenia)

Investigating the Influence of Thalamocortical Structural Connections on Cortical Plasticity and Cognition in Youth

Aim 3: To study the influence of inter-individual differences in thalamocortical connectivity strength on individual variability in cognition.

Stronger structural connectivity between the thalamus and transmodal association regions higher on the S-A axis will be associated with better general cognition, particularly in adolescence.

Aim 3:

To study the influence of inter-individual differences in thalamocortical connectivity strength on individual variability in cognition

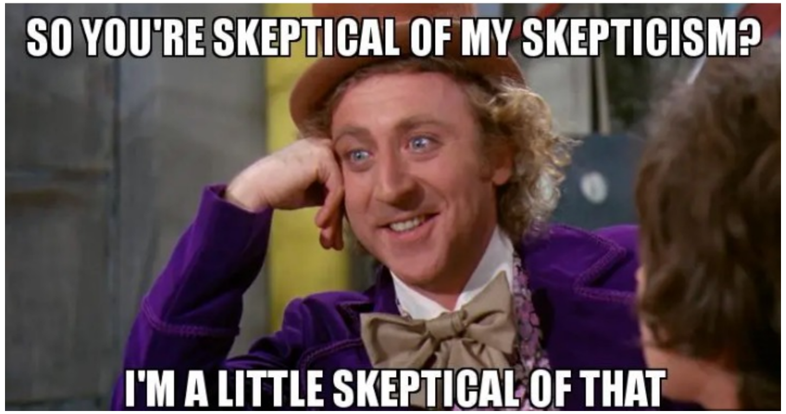
Specific Hypotheses

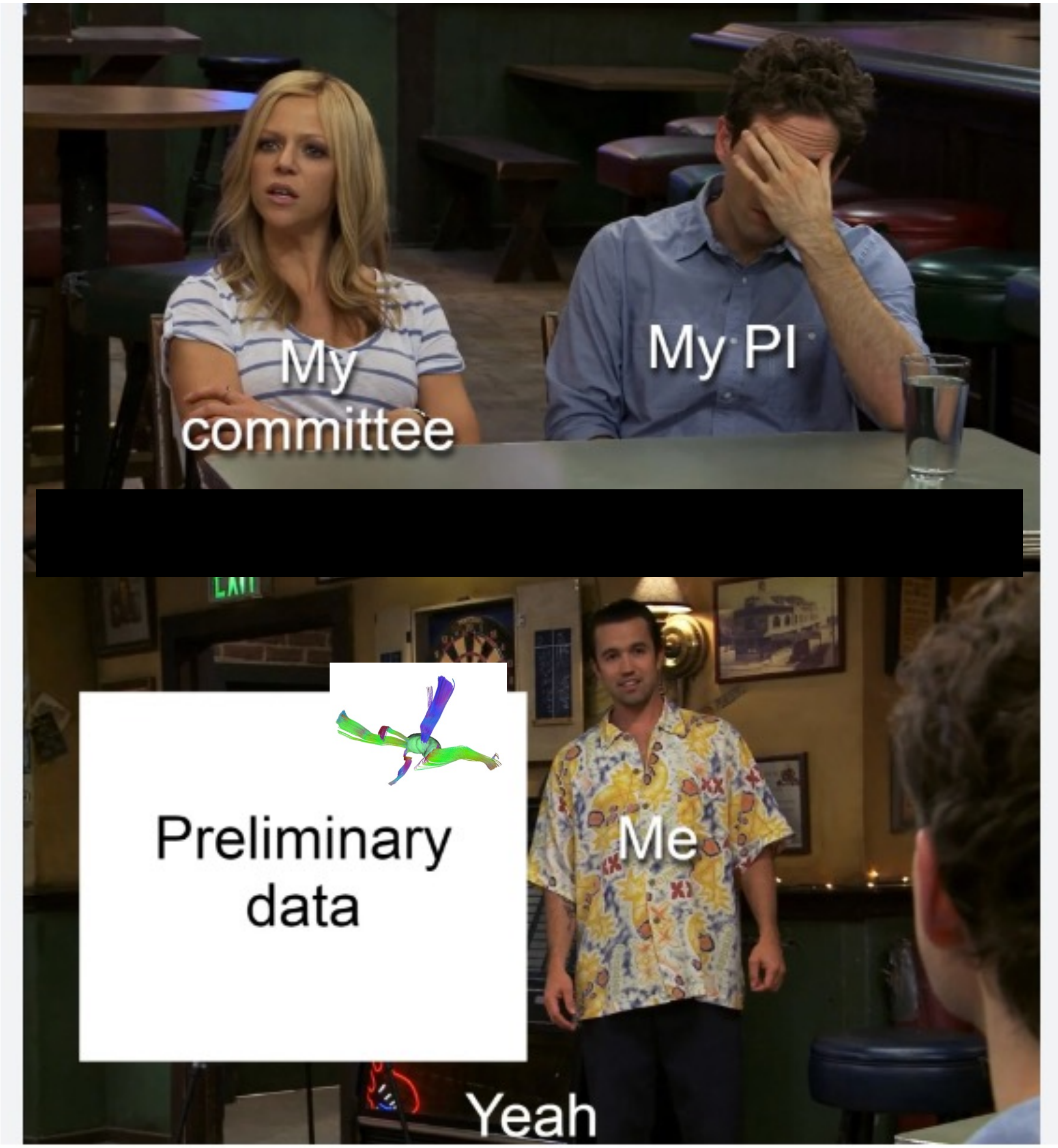
3a. Greater thalamocortical connectivity with association regions will be associated with better general cognition.

3b. Associations between thalamocortical connectivity strength and general cognition will increase in magnitude up the S-A axis.

3c. Associations between association cortex thalamocortical connectivity and cognition will be strongest in adolescence.

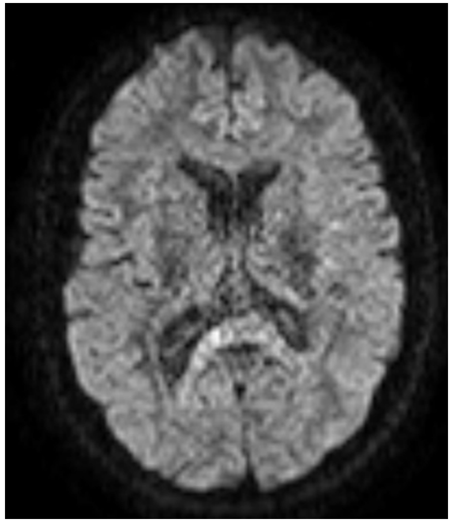

You cannot track connections between the thalamus and the entire cortex
CHANGE MY MIND

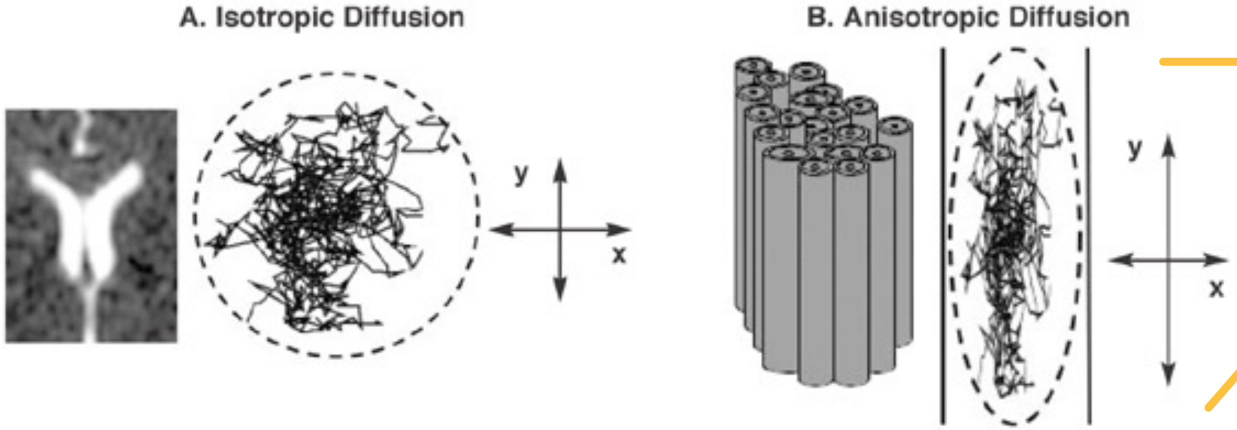

SO YOU'RE SKEPTICAL OF MY SKEPTICISM?
I'M A LITTLE SKEPTICAL OF THAT

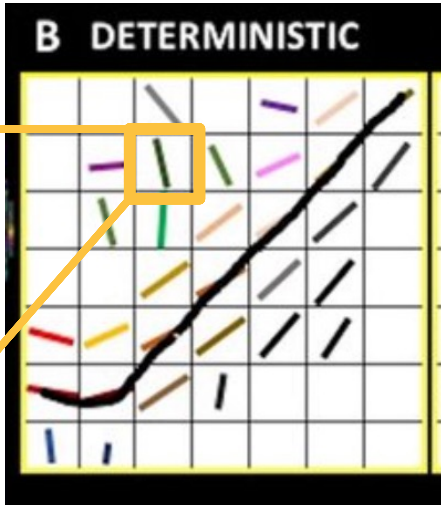

My committee
My PI
[redacted]
Preliminary data
Me
Yeah

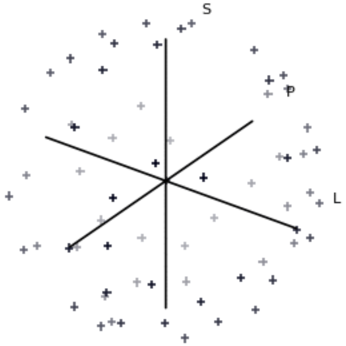

Curiosity often leads to trouble.

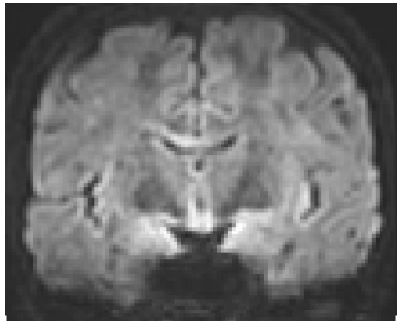
METHODS: Delineating thalamocortical connections with tractography











METHODS: Delineating thalamocortical connections with tractography

nature neuroscience

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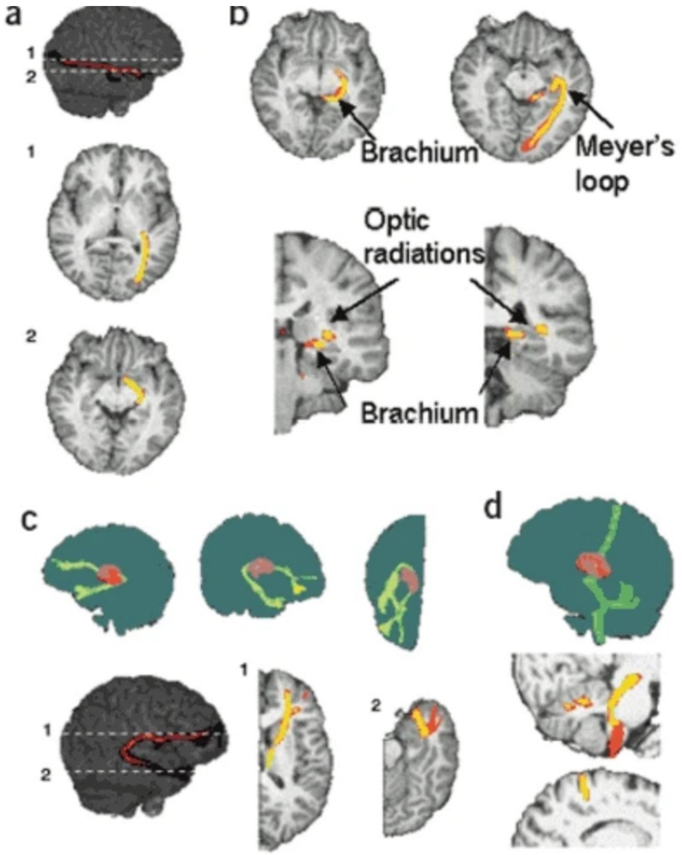
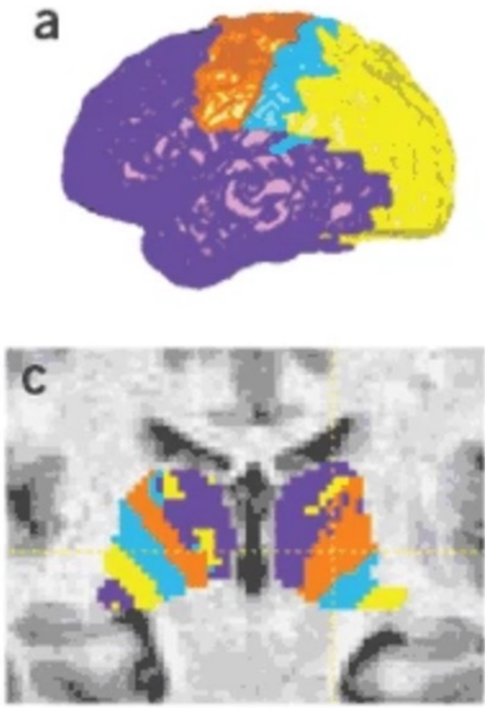
Published: 15 June 2003

Non-invasive mapping of connections between human thalamus and cortex using diffusion imaging

T E J Behrens, H Johansen-Berg ✉, M W Woolrich, S M Smith, C A M Wheeler-Kingshott, P A Boulby, G J Barker, E L Sillery, K Sheehan, O Ciccarelli, A J Thompson, J M Brady & P M Matthews

Nature Neuroscience **6**, 750–757 (2003) | Cite this article





METHODS: Delineating thalamocortical connections with tractography

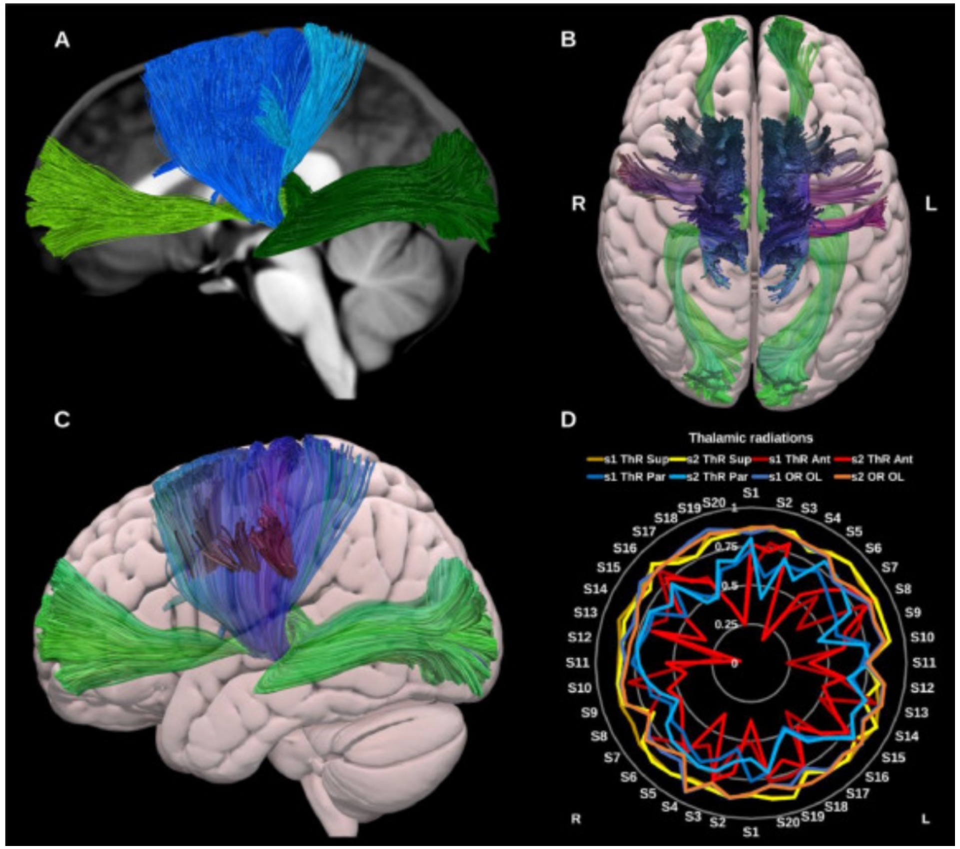
ELSEVIER

NeuroImage

Volume 254, 1 July 2022, 119029

An atlas of white matter anatomy, its variability, and reproducibility based on constrained spherical deconvolution of diffusion MRI

Ahmed M. Radwan [a b], Stefan Sunaert [a b c], Kurt Schilling [d], Maxime Descoteaux [e], Bennett A. Landman [f], Mathieu Vandenbulcke [b g h], Tom Theys [b i j], Patrick Dupont [b k], Louise Emsell [a b g h]



METHODS: Delineating thalamocortical connections with tractography

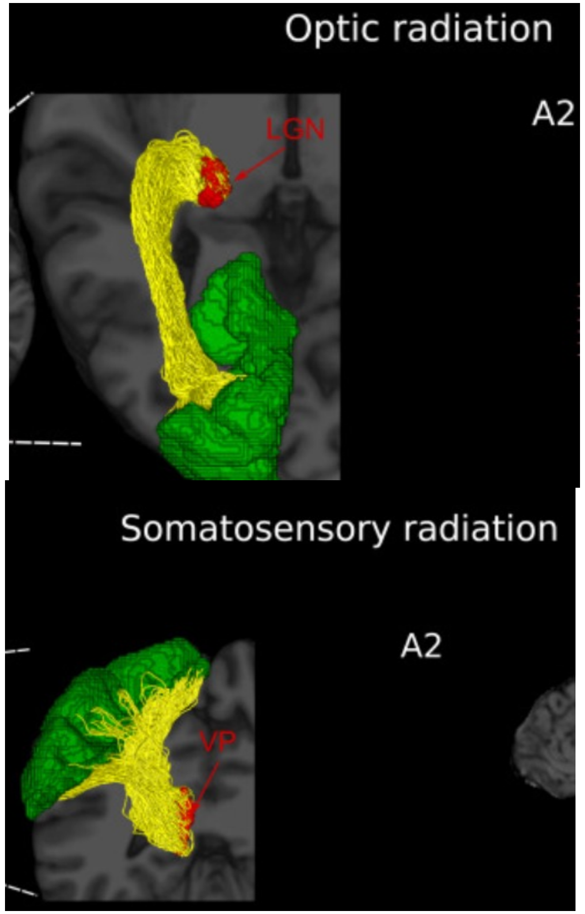
ELSEVIER

NeuroImage

Volume 262, 15 November 2022, 119558

Reproducible protocol to obtain and measure first-order relay human thalamic white-matter tracts

Mengxing Liu [a], Garikoitz Lerma-Usabiaga [a c], Francisco Clascá [b], Pedro M. Paz-Alonso [a c]



METHODS: Delineating thalamocortical connections with tractography

ORIGINAL RESEARCH article

Front. Neuroanat., 17 April 2018
Volume 12 - 2018 |
https://doi.org/10.3389/fnana.2018.00024

This article is part of the Research Topic
Organization of the White Matter Anatomy in the Human Brain
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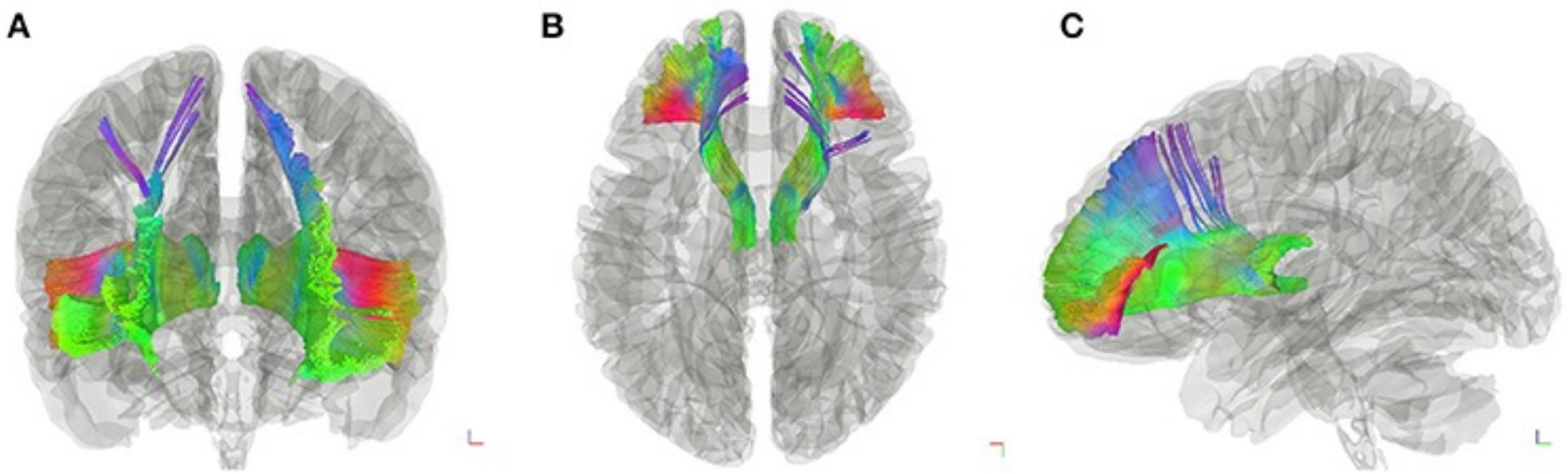
Human Thalamic-Prefrontal Peduncle Connectivity Revealed by Diffusion Spectrum Imaging

Chuanqi Sun[1], Yibao Wang[2], Xinguo Li[2], Yue Bao[2] and



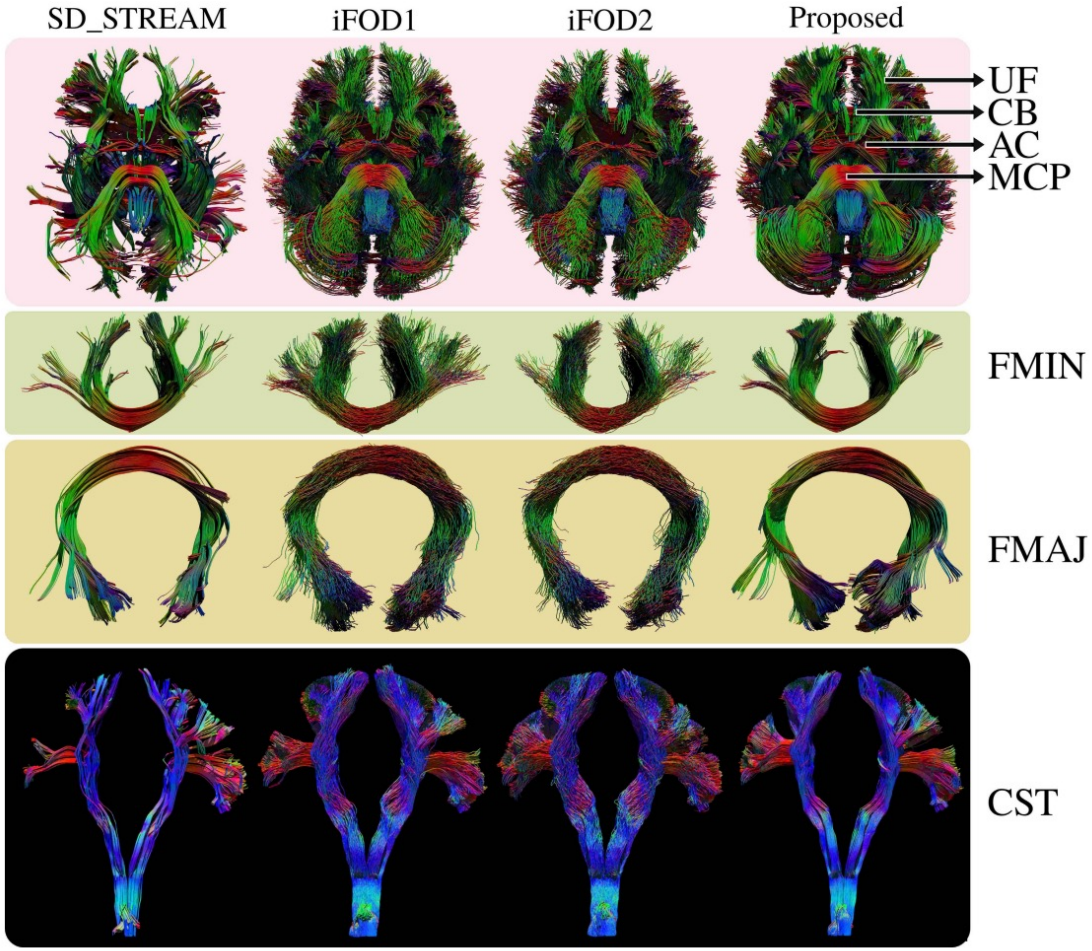
METHODS: Delineating thalamocortical connections with trekker

IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 40, NO. 2, FEBRUARY 2021 635

Parallel Transport Tractography

Dogu Baran Aydogan, *Member, IEEE*, and Yonggang Shi, *Member, IEEE*

Our experiments on FiberCup and ISMRM 2015 challenge datasets as well as on 56 subjects of the Human Connectome Project show highly promising results both visually and quantitatively.



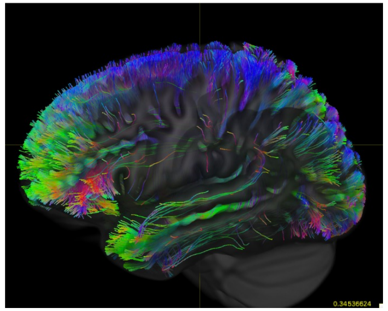
METHODS: Delineating thalamocortical connections with trekker

Testing whole-brain trekker in HCP template

Default parameters in trekker

wholebrain-trekker-2mil-noCSF-nomidli… 2 kB

TRACKER OPTIONS
algorithm : parallel transport tracker (PTT)
stepSize : 0.025 mm
minRadiusOfCurvature : 0.5 mm
probeLength : 0.25 mm
probeRadius : 0 mm
probeCount : 1
probeQuality : 4
minFODamp : 0.05
ignoreWeakLinks : 0
maxEstInterval : 1
dataSupportExponent : 1
minLength : 0
maxLength : infinite mm
atMaxLength : discard
writeInterval : 20
directionality : two_sided
maxSamplingPerStep : 1000
initMaxEstTrials : adaptive



Testing trekker versus ifod2

Testing and comparing

1. trekker with thalamus seeded tractography and cortical ROI inclusions
2. whole-brain trekker with post-hoc thalamus-cortical ROI tract extraction
3. iFOD2 with thalamus seeded tractography and cortical ROI inclusions
4. whole-brain iFOD2 with post-hoc thalamus-cortical ROI tract extraction

Results of thalamocortical tractography testing

thalamus_cortical_connectivity_tracto… 74 MB

Trekker's default parameter combinations generally result with good coverage of fiber bundles with well organized streamlines. However by adjusting the parameters you can improve the results. Basically you can go towards two directions:

A. make the streamlines more organized, this could come with loss of bundle coverage
B. cover more of the bundle, then you could lose the organization of streamlines
To go towards direction A:

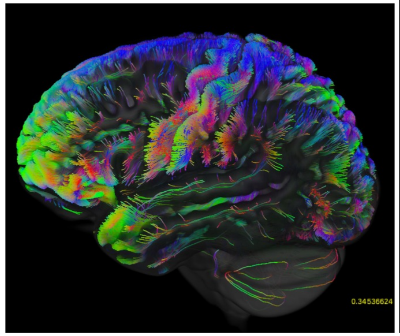
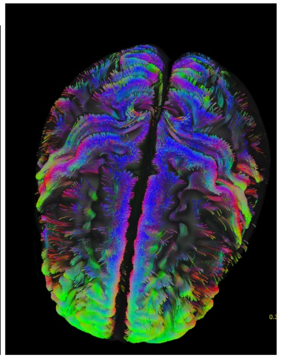
1. **decrease *stepSize***
2. **increase *probeLength***
3. **increase *minRadiusOfCurvature***
4. **increase *minFODamp***

Changing to not end in WM and increasing streamline number

wholebrain-trekker-3mil-noWM-nomidli… 2 kB

Can increasing streamline number and/or not ending in WM get better coverage of lateral surface of the brain? YES! But which was more important (streamline # or discard if ends inside WM)

singularity run --cleanenv --no-home -B ~/thalamocortical_connectivity/:/mnt ~/thalamocortical_connectivity/software/trekker-latest-120122.sif -numberOfThreads 10 -fod /mnt/HCP_templates/FOD.nii -seed_image /mnt/HCP_templates/T1w-tissuesegmentation-WM.nii **-seed_count 3000000** -pathway=discard_if_enters /mnt/HCP_templates/midline-ROI.nii **-pathway=discard_if_ends_inside /mnt/HCP_templates/T1w-tissuesegmentation-WM.nii**

METHODS: Delineating thalamocortical connections with autotrack

DSI Studio

Automatic Fiber Tracking (AutoTrack)

Create an atlas of thalamocortical white matter connections

Use the atlas to parcellate thalamocortical tracts in subject-specific data

Quantify indexes of connection strength/coherence in each tract

METHODS: Delineating thalamocortical connections with autotrack

NeuroImage
Volume 178, September 2018, Pages 57-68

Population-averaged atlas of the macroscale human structural connectome and its network topology

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Article | Open Access | Published: 22 August 2022

Population-based tract-to-region connectome of the human brain and its hierarchical topology

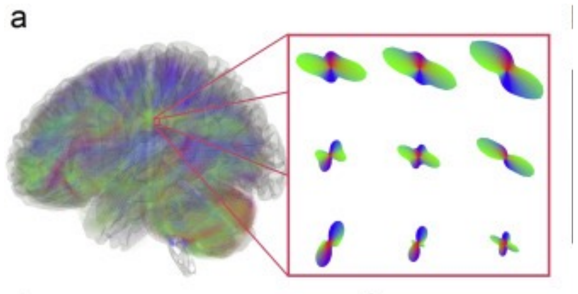
Fang-Cheng Yeh

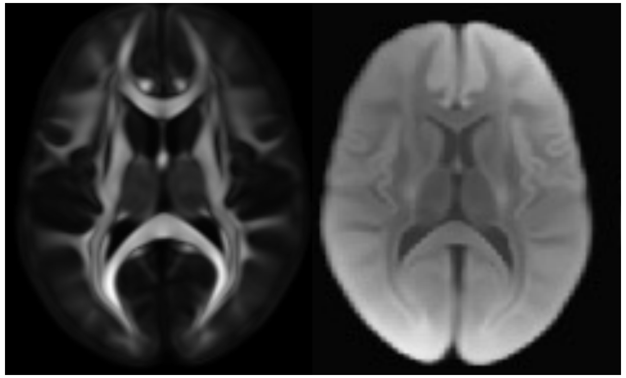
Nature Communications **13**, Article number: 4933 (2022) | Cite this article

3786 Accesses | **1** Citations | **52** Altmetric | Metrics

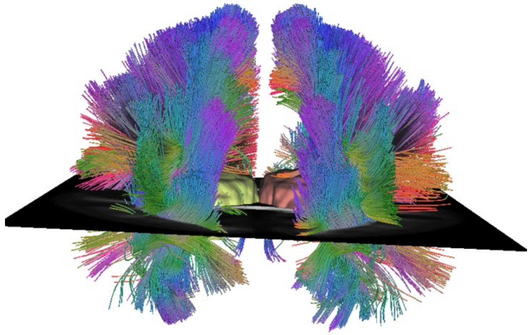
Create an atlas of thalamocortical white matter connections

HCP young adult GQI template





Thalamocortical bundles template

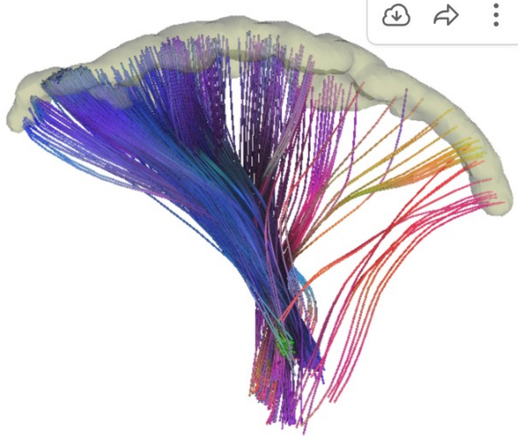


METHODS: Delineating thalamocortical connections with autotrack

Create an atlas of thalamocortical white matter connections

Wednesday, January 18th

Valerie Sydnor 5:40 PM
look at this thalamus parachute
Screen Shot 2023-01-18 at 5.40.13 PM.png



Matt Cieslak 5:52 PM
whoa
is it real?

Valerie Sydnor 5:54 PM
yes
5:54 part of primary somatosensory cortex strip
things are looking prettyy pretty good
pretty pretty good (1 MB)

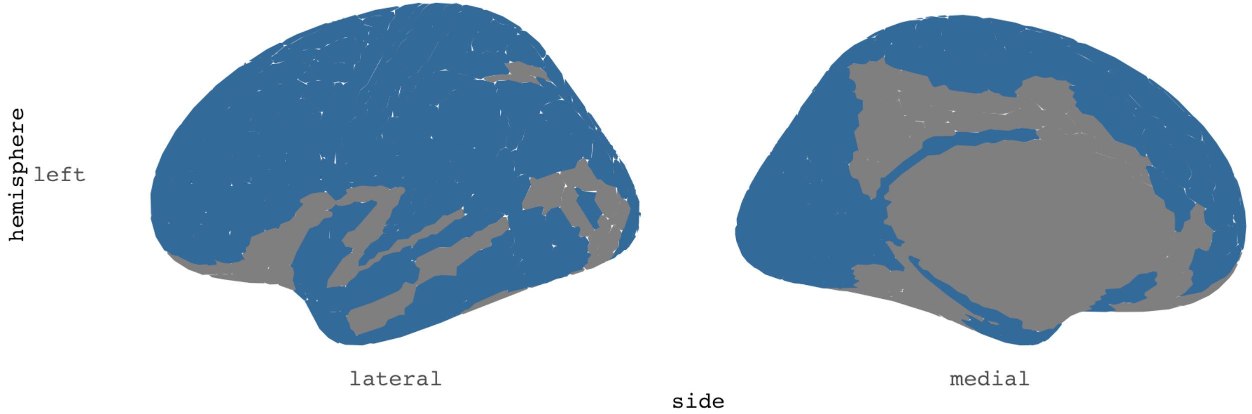
Posted using /giphy | GIF by Curb Your Enthusiasm

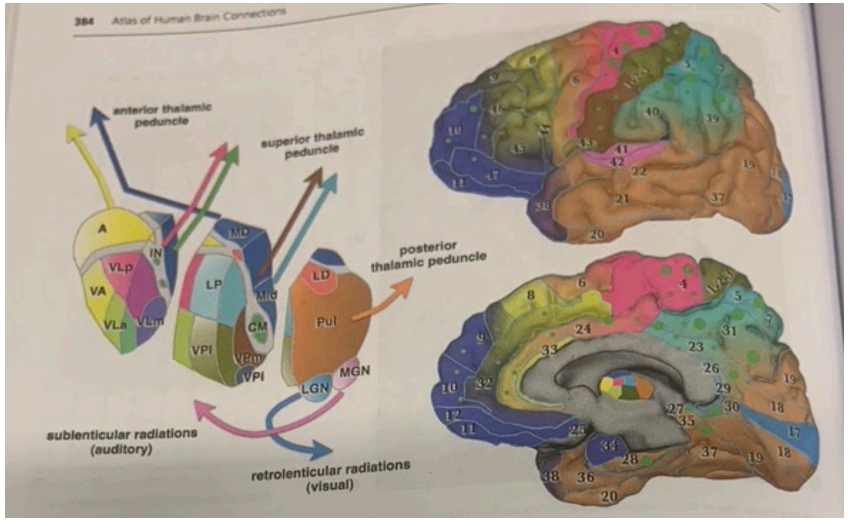
Matt Cieslak 6:44 PM
this is so cool

Ted Satterthwaite 7:51 PM
SOOOO COOOOL

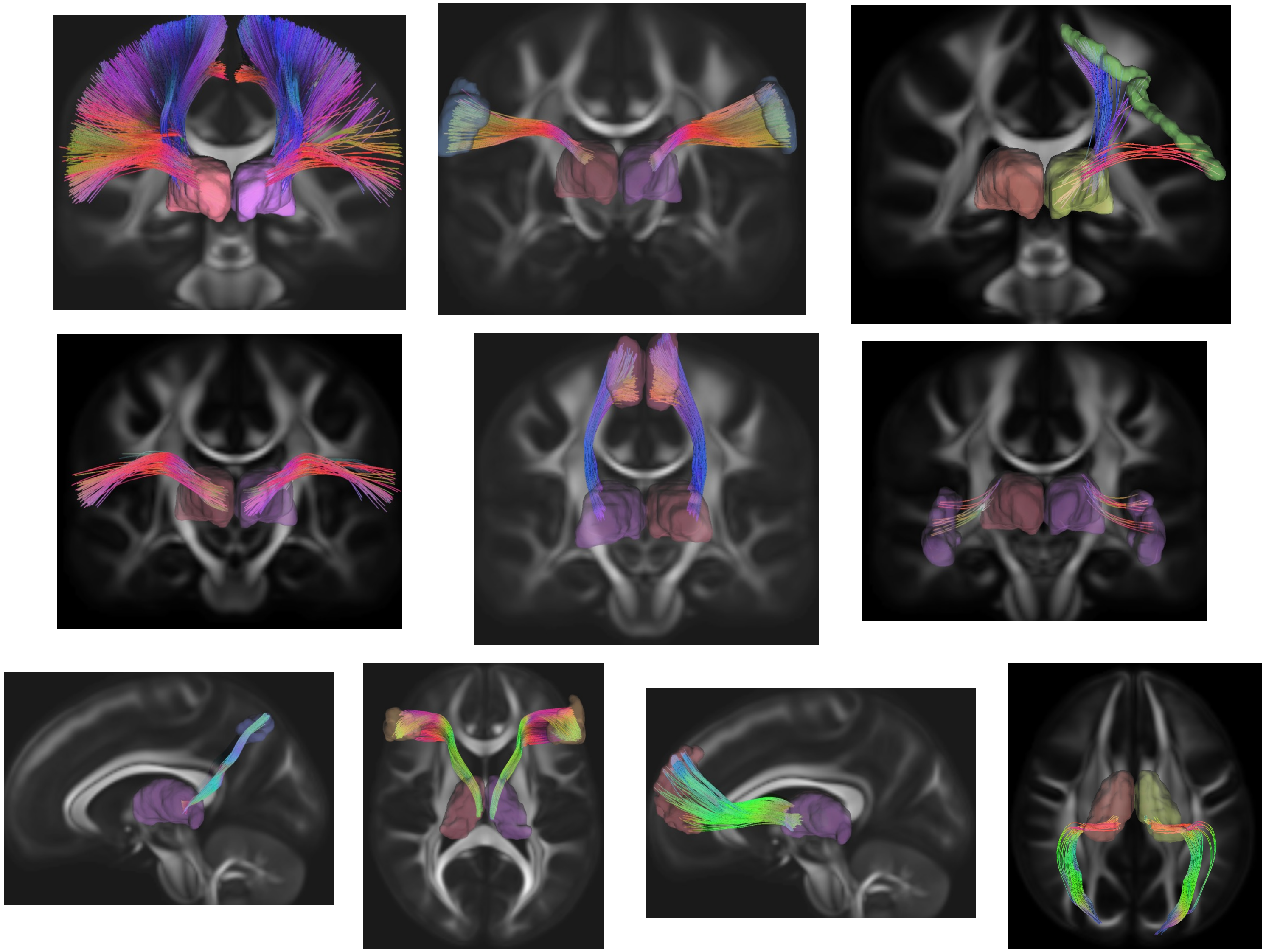
METHODS: Delineating thalamocortical connections with autotrack

Create an atlas of thalamocortical white matter connections





METHODS: Delineating thalamocortical connections with autotrack




A Very Merry Un-Birthday to you!

METHODS: Delineating thalamocortical connections with autotrack

Use the atlas to parcellate thalamocortical tracts in subject-specific data

- Generate subject QA map and register to template QA map
- Seed in atlas tract volume
- “Parameter saturation” tracking
- Select streamlines based on distance from the template bundle
- Discard unmatched streamlines

METHODS: Delineating thalamocortical connections with autotrack

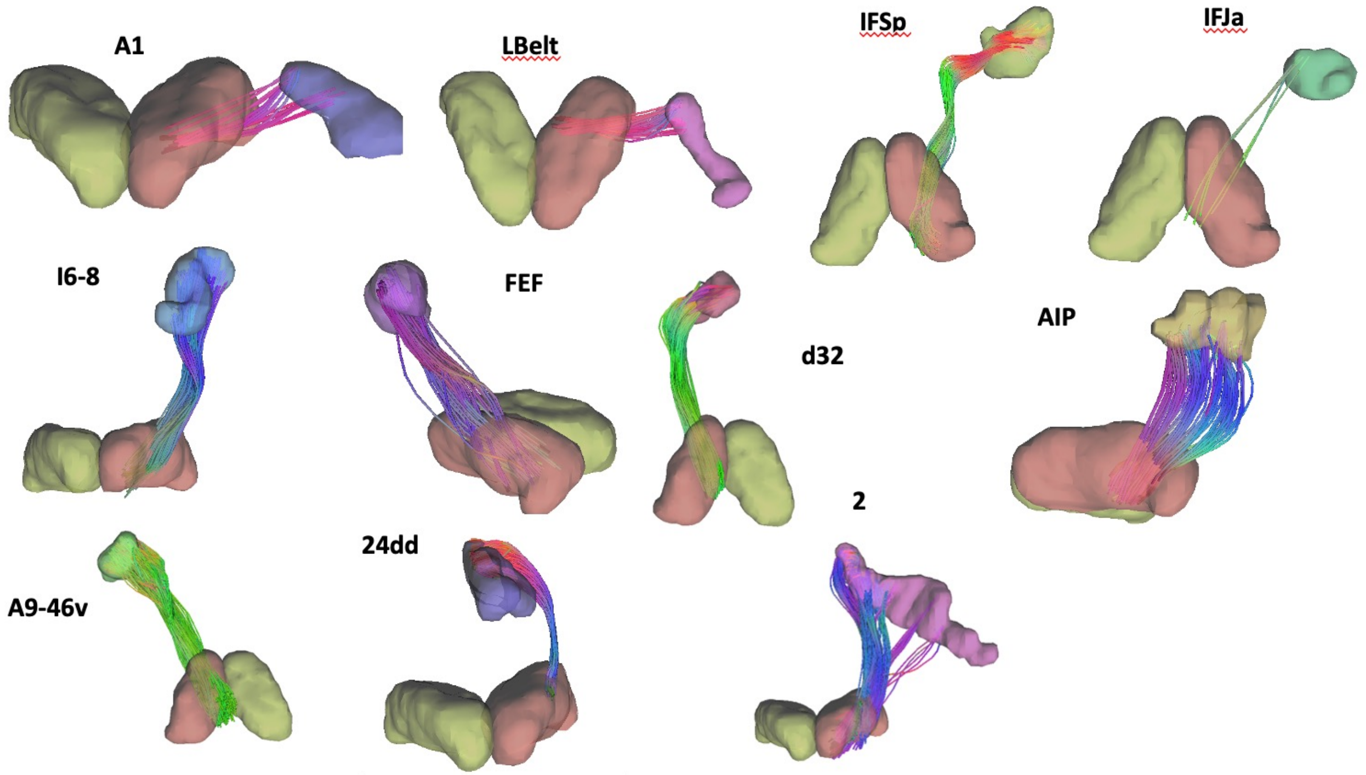
Datasets

PNC	HCP-D
Ages 8-23	Ages 5-21
N = ~1,000	N = ~850
single-shell	multi-shell
b = 1000	b = 1500, 3000

METHODS: Delineating thalamocortical connections with autotrack

PNC

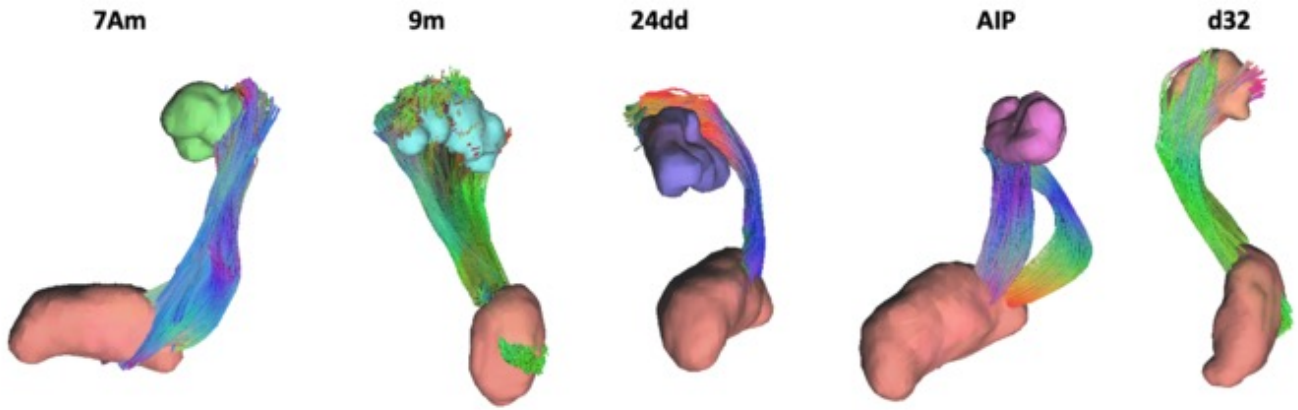
Use the atlas to parcellate thalamocortical tracts in subject-specific data



METHODS: Delineating thalamocortical connections with autotrack

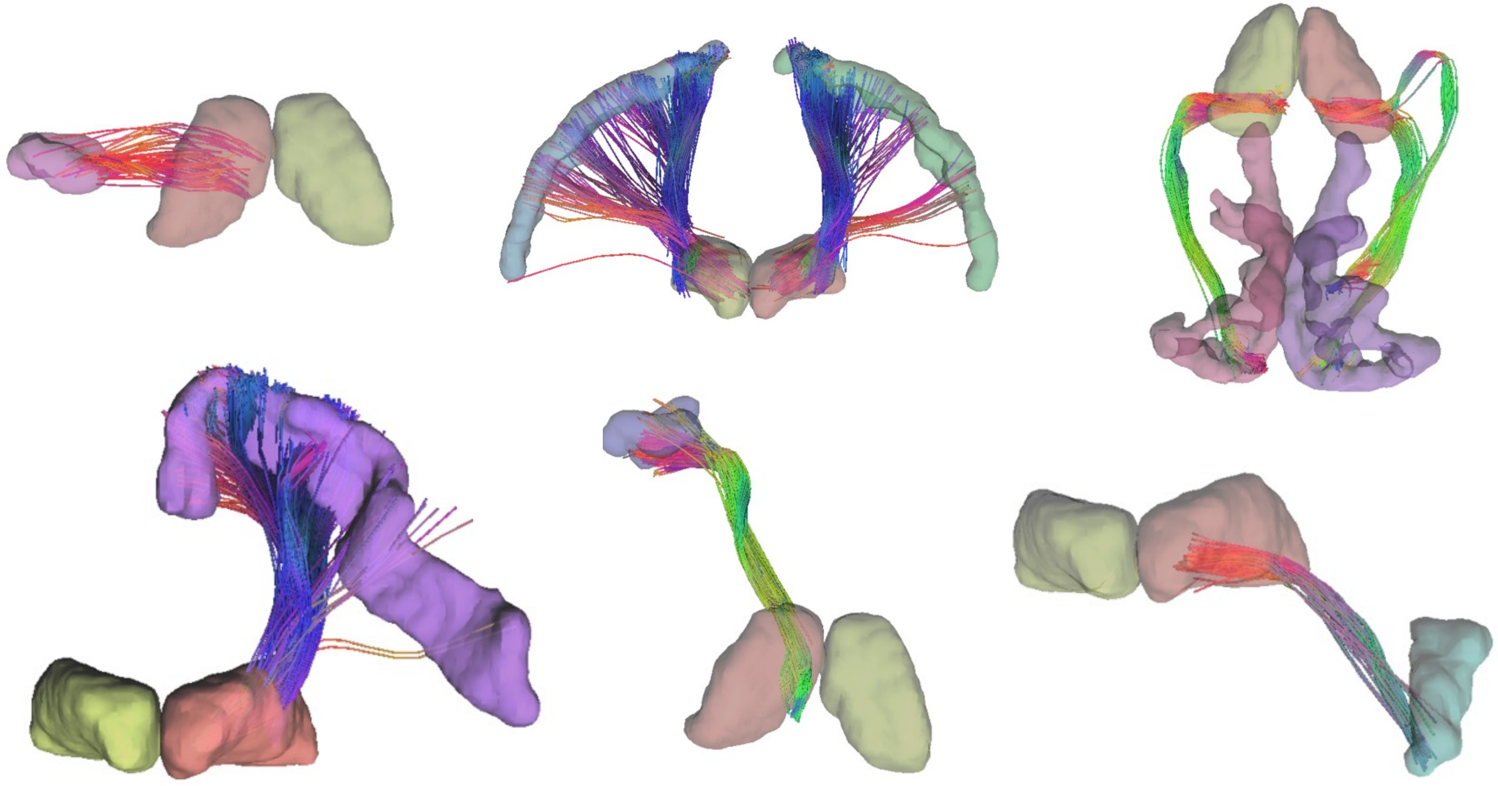
PNC

Use the atlas to parcellate thalamocortical tracts in subject-specific data



METHODS: Delineating thalamocortical connections with autotrack

Use the atlas to parcellate thalamocortical tracts in subject-specific data



Valerie Sydnor 12:05 PM

I cant believe how well this is working

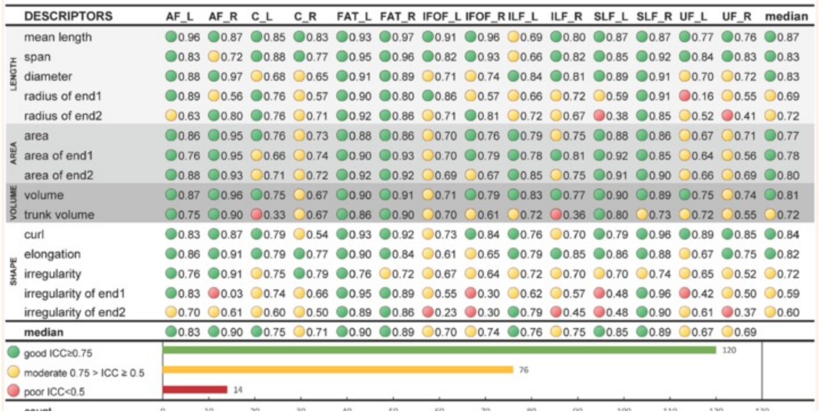
Also they look like a bunch of mini dinosaurs

the ones with the looooong necks

METHODS: Delineating thalamocortical connections with autotrack

Quantify indexes of connection strength/coherence in each tract

number of tracts	17259
mean length(mm)	118.086
span(mm)	76.2074
curl	1.54953
elongation	16.9568
diameter(mm)	6.96392
volume(mm^3)	4497.75
trunk volume(mm^3)	3963.5
branch volume(mm^3)	534.25
total surface area(mm^2)	15924.2
total radius of end regions(mm)	21.9439
total area of end regions(mm^2)	932.25
irregularity	6.16392
area of end region 1(mm^2)	286.25
radius of end region 1(mm)	7.20835
irregularity of end region 1	0.570265
area of end region 2(mm^2)	646
radius of end region 2(mm)	14.7356
irregularity of end region 2	1.05597
qa	0.244135
nqa	0.316082
dti_fa	0.526664
md	0.000779202
ad	0.00129284
rd	0.000522384
gfa	0.142216
iso	0.320188
rdi	0.42069
nrdi02L	0.279077
nrdi04L	0.0379572
nrdi06L	0

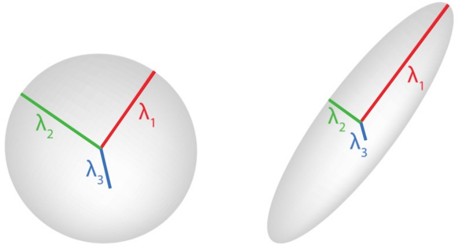


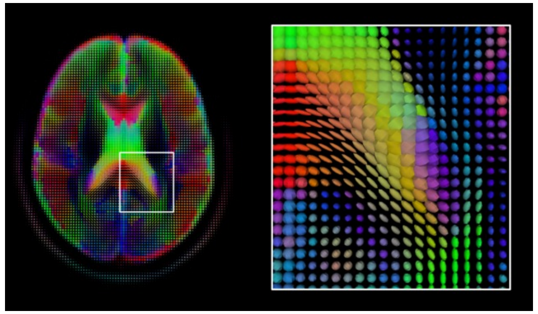
	DESCRIPTORS	AF_L	AF_R	C_L	C_R	FAT_L	FAT_R	IFOF_L	IFOF_R	ILF_L	ILF_R	SLF_L	SLF_R	UF_L	UF_R	median
LENGTH	mean length	0.96	0.87	0.85	0.83	0.93	0.97	0.91	0.96	0.69	0.80	0.87	0.87	0.77	0.76	0.87
	span	0.83	0.72	0.88	0.77	0.95	0.96	0.82	0.93	0.66	0.82	0.85	0.92	0.84	0.83	0.83
	diameter	0.88	0.97	0.68	0.65	0.91	0.89	0.71	0.74	0.84	0.81	0.89	0.91	0.70	0.72	0.83
	radius of end1	0.89	0.56	0.76	0.57	0.90	0.80	0.86	0.57	0.66	0.72	0.59	0.91	0.16	0.55	0.69
	radius of end2	0.63	0.80	0.76	0.71	0.92	0.86	0.71	0.81	0.72	0.67	0.38	0.85	0.52	0.41	0.72
AREA	area	0.86	0.95	0.76	0.73	0.88	0.86	0.70	0.76	0.79	0.75	0.88	0.86	0.67	0.71	0.77
	area of end1	0.76	0.95	0.66	0.74	0.90	0.93	0.70	0.79	0.78	0.81	0.92	0.85	0.64	0.56	0.78
	area of end2	0.88	0.93	0.71	0.72	0.92	0.92	0.69	0.67	0.85	0.75	0.91	0.90	0.66	0.69	0.80
VOLUME	volume	0.87	0.96	0.75	0.67	0.90	0.91	0.71	0.79	0.83	0.77	0.90	0.89	0.75	0.74	0.81
	trunk volume	0.75	0.90	0.33	0.67	0.86	0.90	0.70	0.61	0.72	0.36	0.80	0.73	0.72	0.55	0.72
SHAPE	curl	0.83	0.87	0.79	0.54	0.93	0.92	0.73	0.84	0.76	0.70	0.79	0.96	0.89	0.85	0.84
	elongation	0.86	0.91	0.79	0.77	0.90	0.84	0.61	0.65	0.79	0.85	0.86	0.88	0.67	0.75	0.82
	irregularity	0.76	0.91	0.75	0.79	0.76	0.72	0.67	0.64	0.72	0.70	0.70	0.74	0.65	0.52	0.72
	irregularity of end1	0.83	0.03	0.74	0.66	0.95	0.89	0.55	0.30	0.62	0.57	0.48	0.96	0.42	0.50	0.59
	irregularity of end2	0.70	0.61	0.60	0.50	0.89	0.86	0.23	0.30	0.79	0.45	0.48	0.90	0.61	0.37	0.60
	median	0.83	0.90	0.75	0.71	0.90	0.89	0.70	0.74	0.76	0.75	0.85	0.89	0.67	0.69	

METHODS: Delineating thalamocortical connections with autotrack

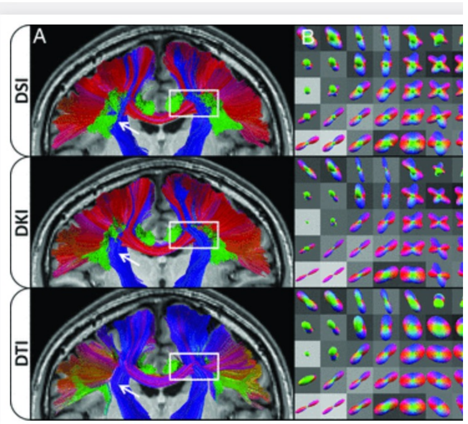
Quantify indexes of connection strength/coherence in each tract: ANISOTROPY

Fractional anisotropy
diffusion tensor

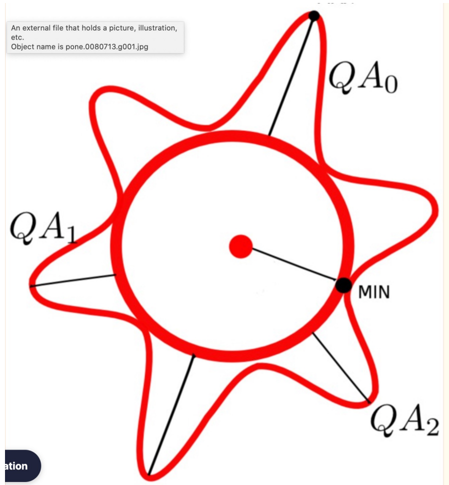




Generalized FA
Orientation distribution function (ODF)

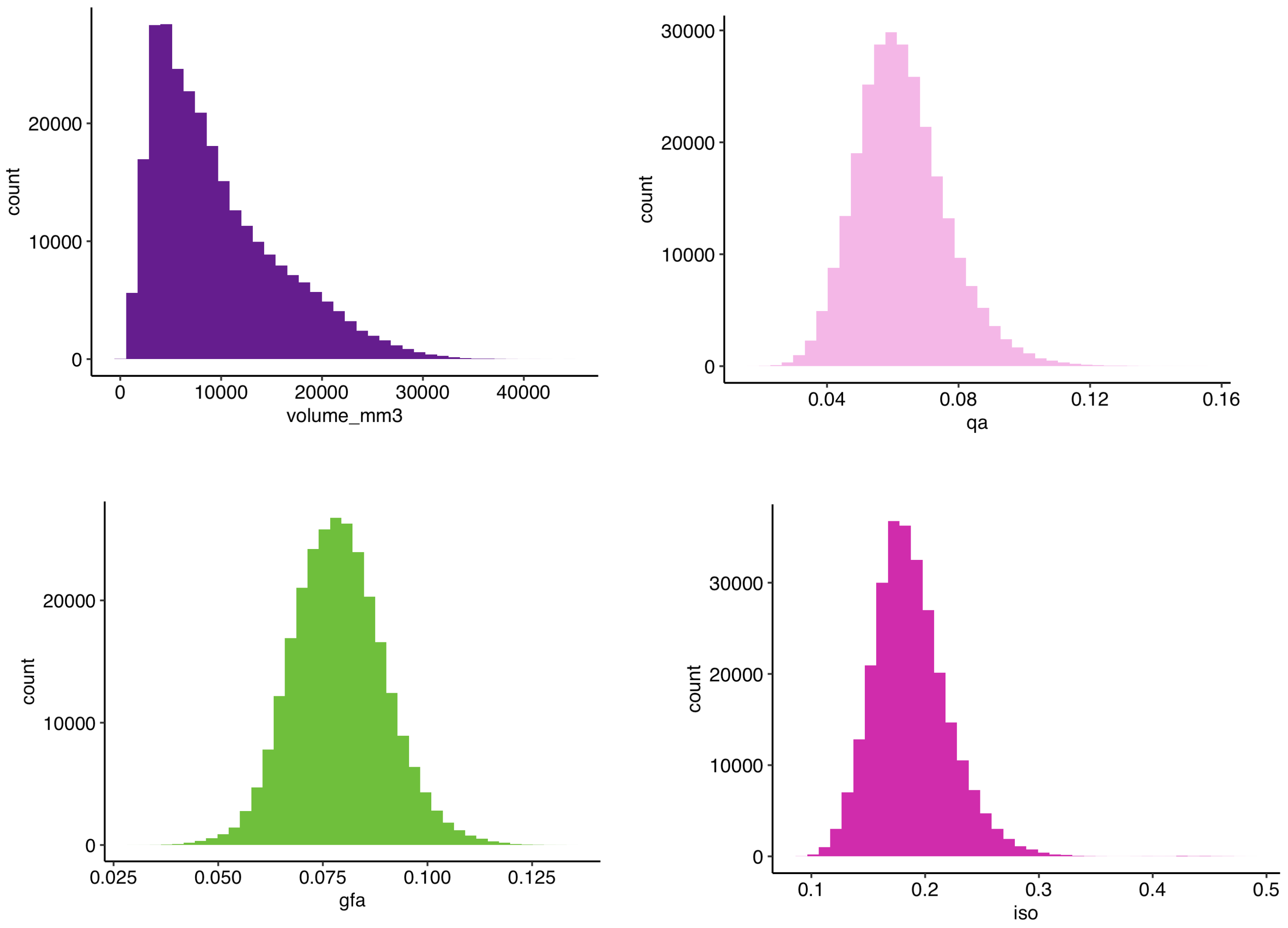


Quantitative Anisotropy
spin density function



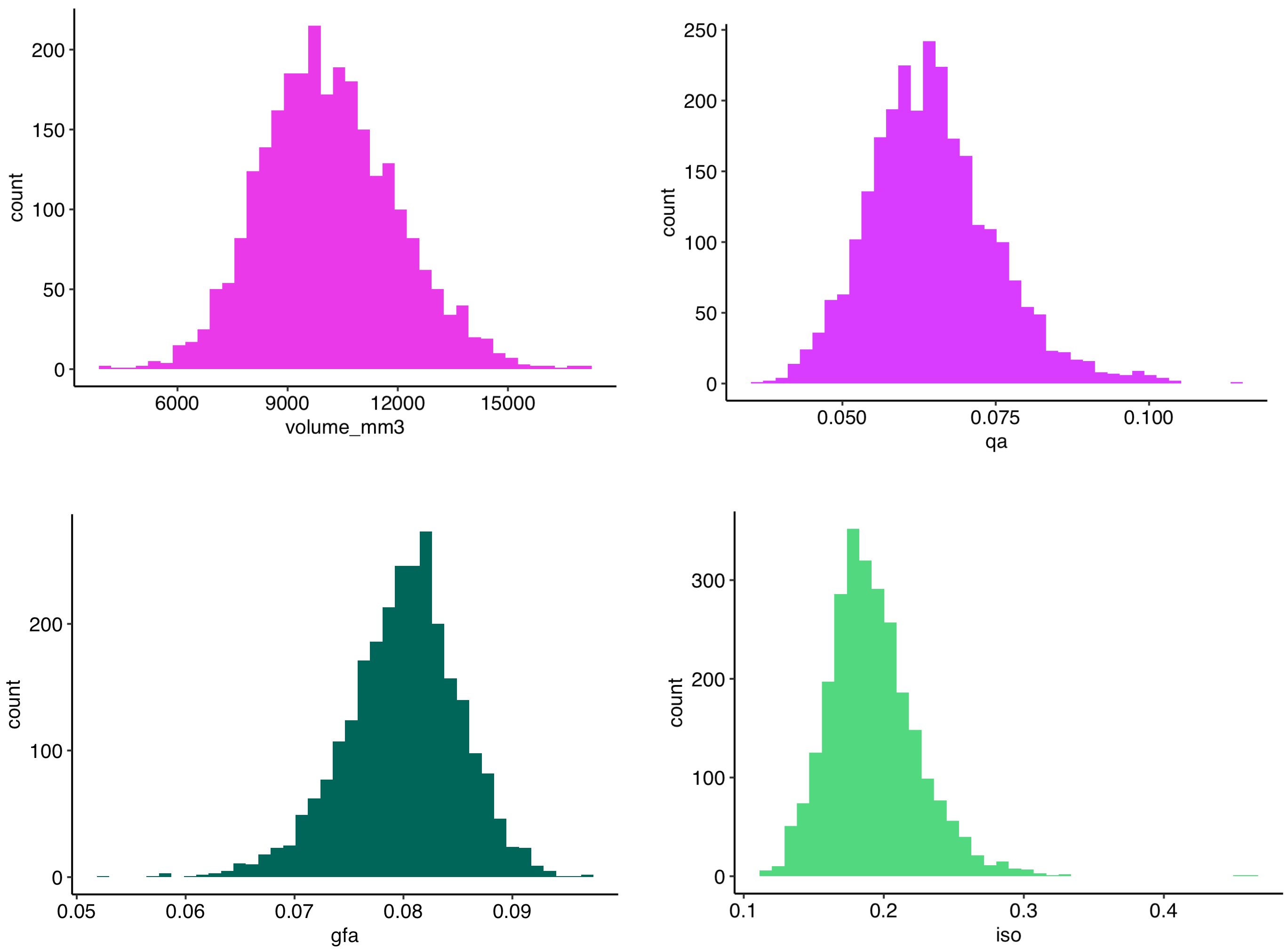
METHODS: Delineating thalamocortical connections with autotrack

Measure distributions across all bundles



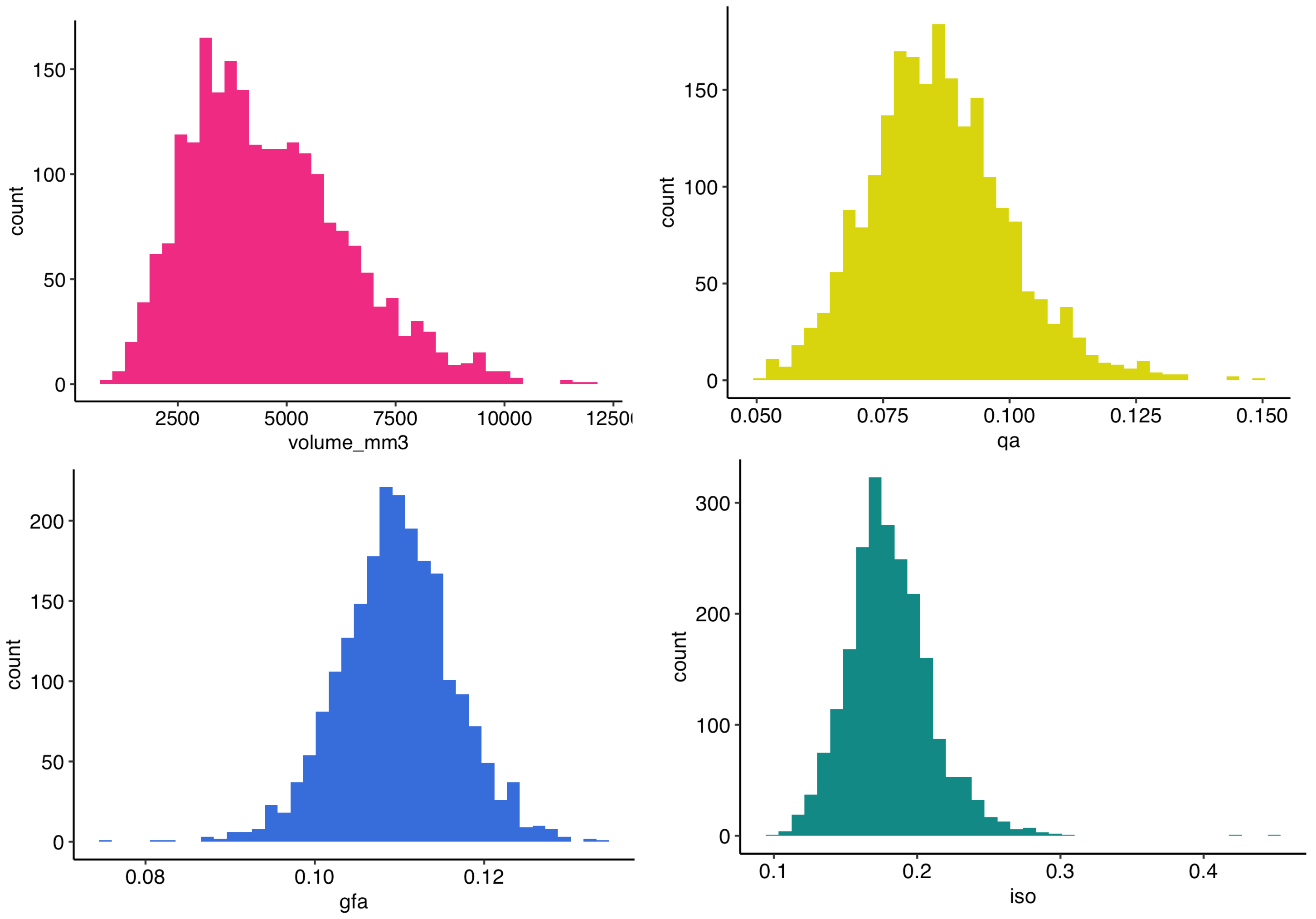
METHODS: Delineating thalamocortical connections with autotrack

Measure distributions in thalamus- lateral PFC bundle



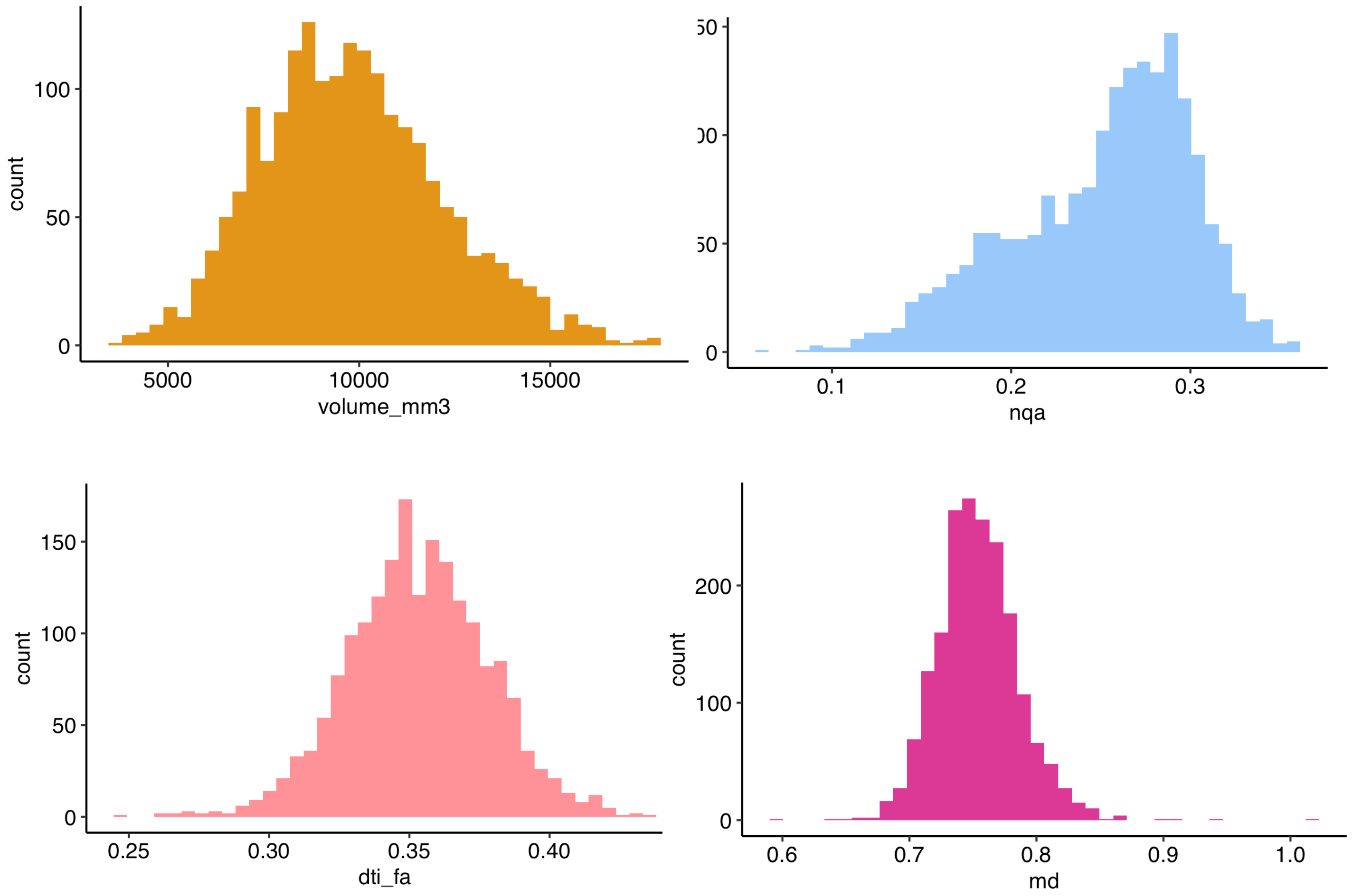
METHODS: Delineating thalamocortical connections with autotrack

Measure distributions in thalamus-V1 bundle



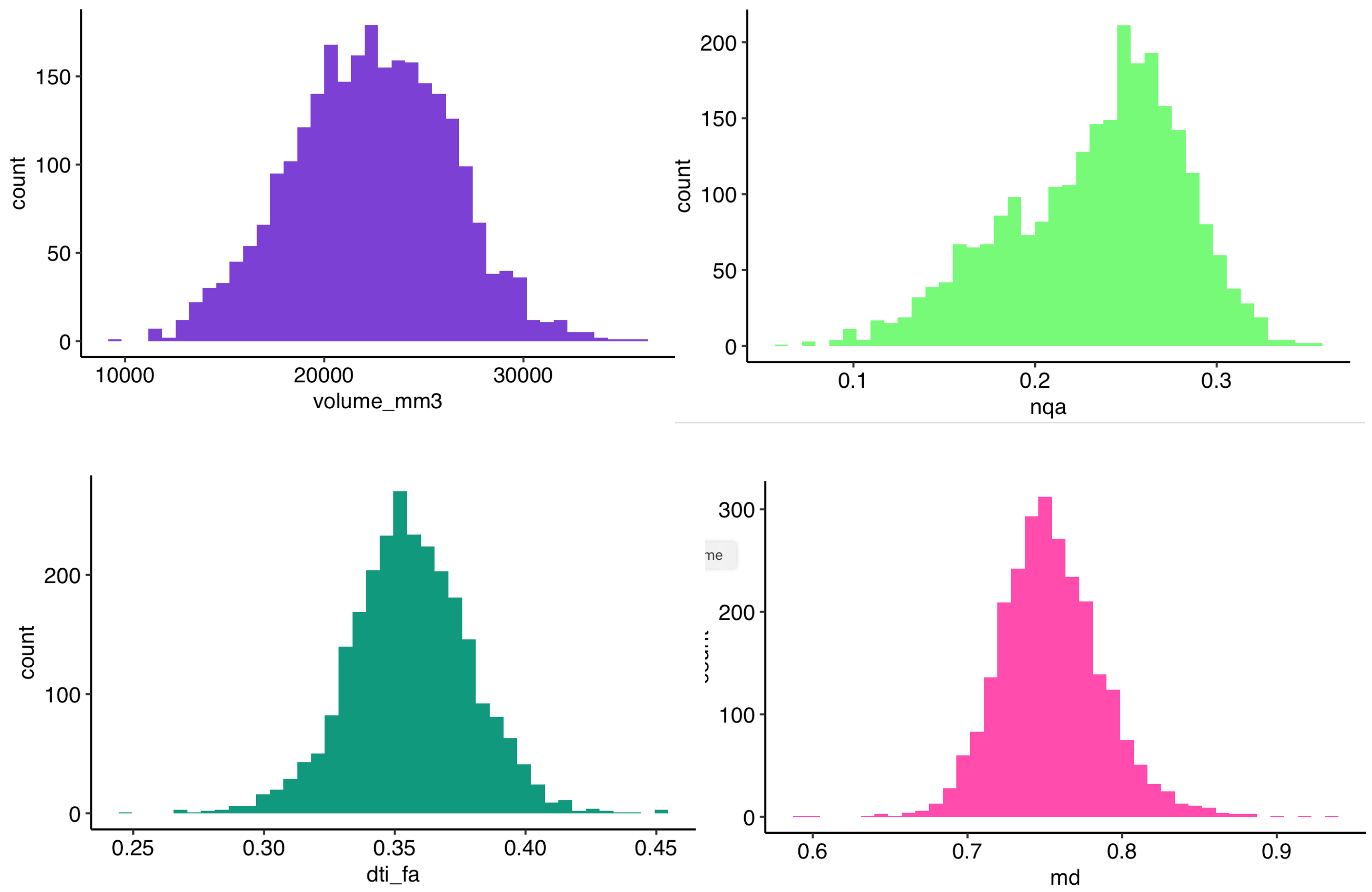
METHODS: Delineating thalamocortical connections with autotrack

Measure distributions in thalamus- SFG bundle



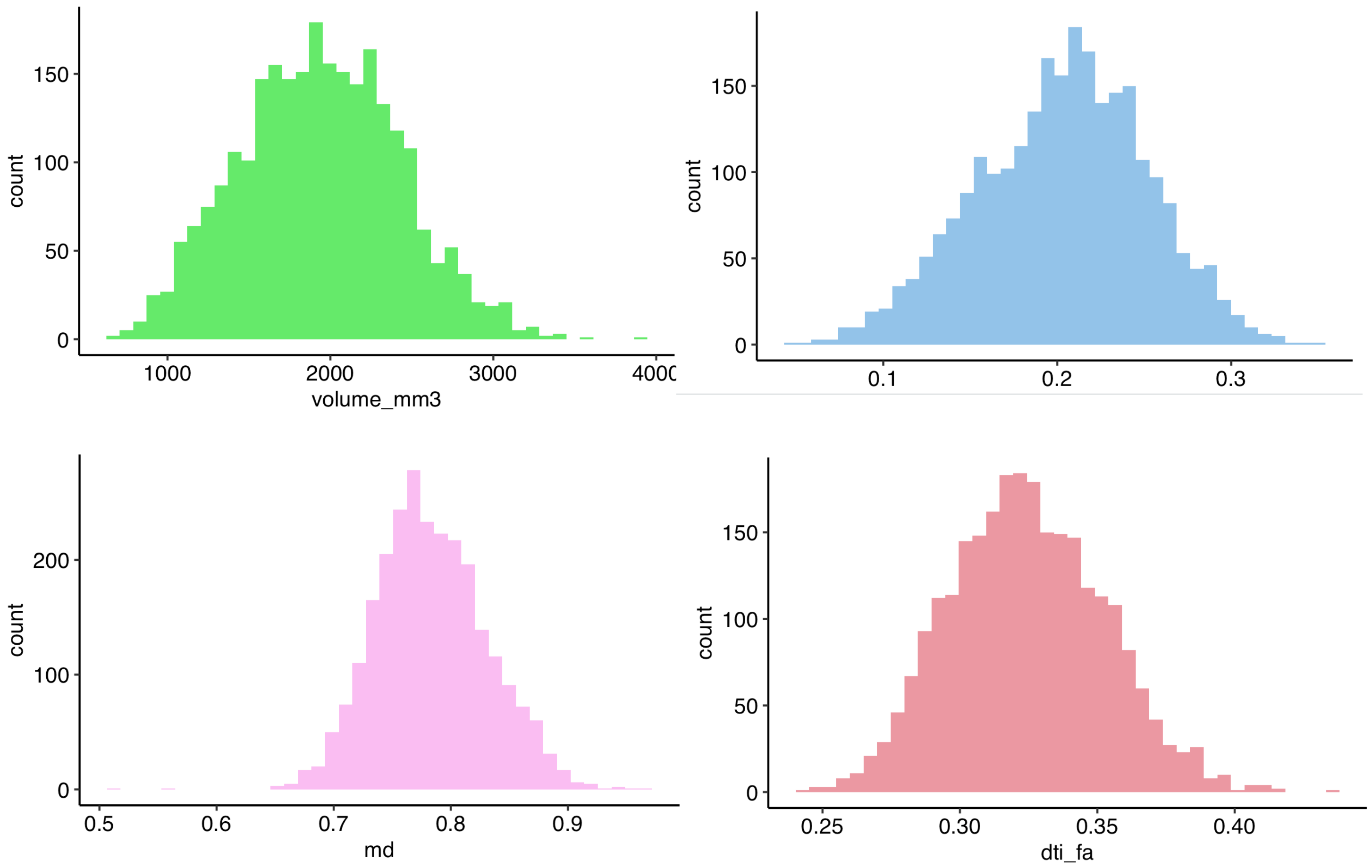
METHODS: Delineating thalamocortical connections with autotrack

Measure distributions in thalamus-inf. parietal lobule bundle

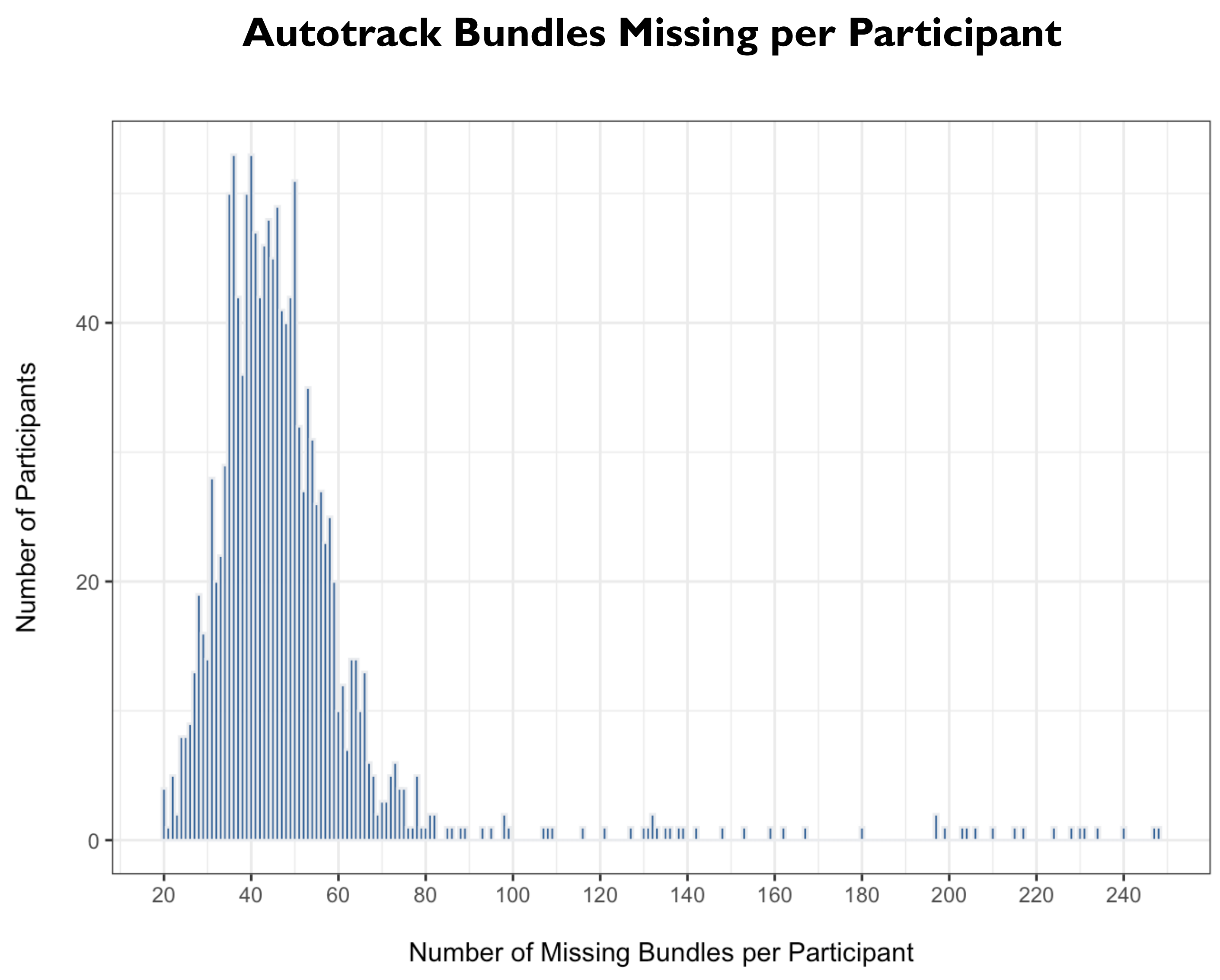


METHODS: Delineating thalamocortical connections with autotrack

Measure distributions in thalamus-A1 bundle

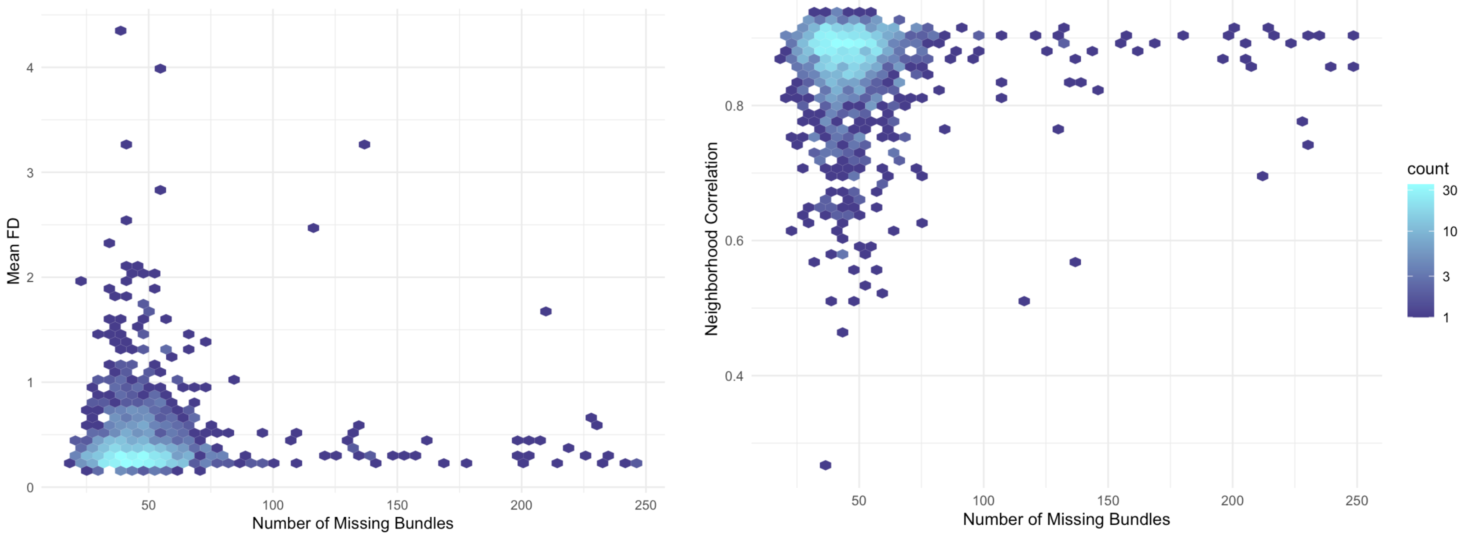


METHODS: Delineating thalamocortical connections with autotrack



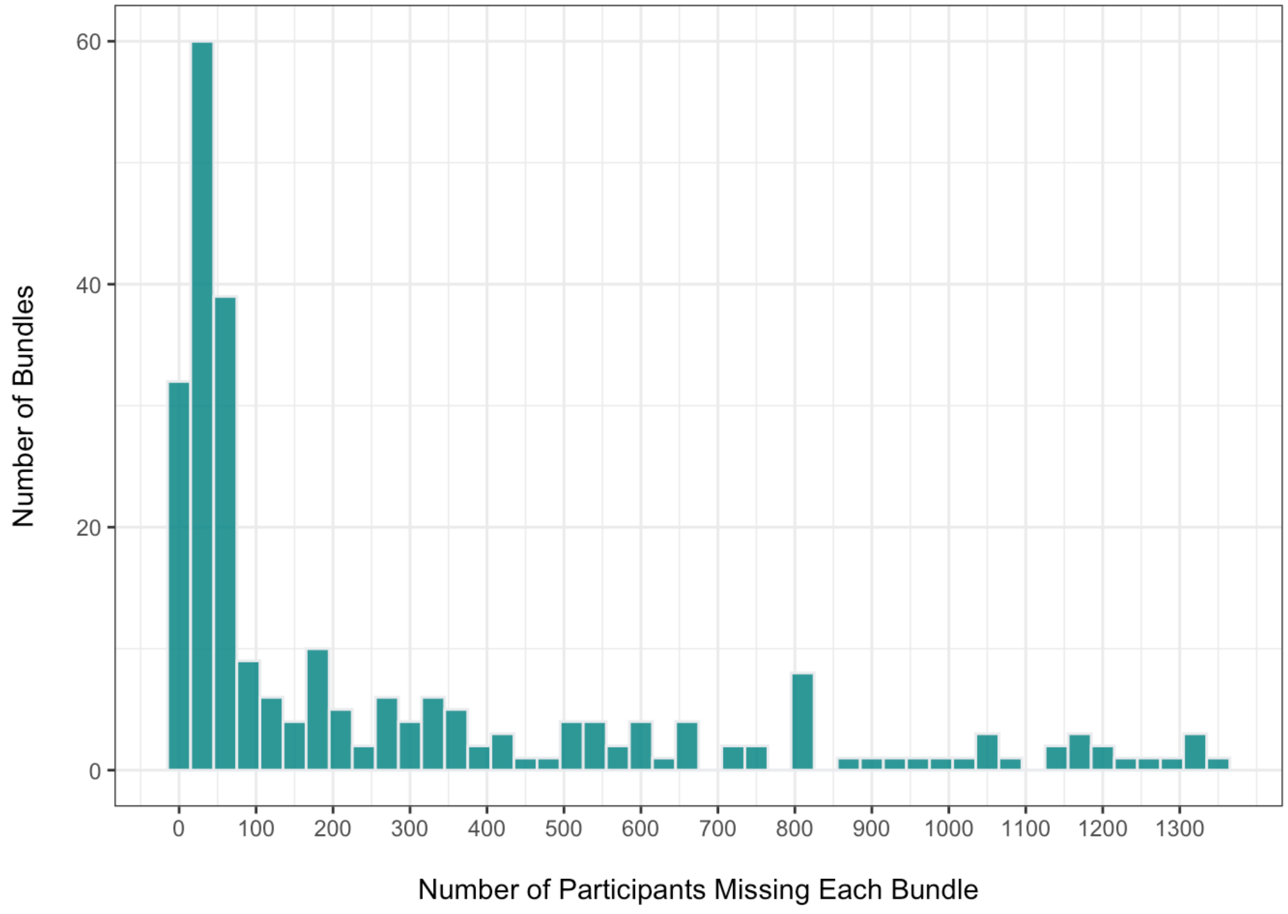
METHODS: Delineating thalamocortical connections with autotrack

Autotrack Bundles Missing per Participant



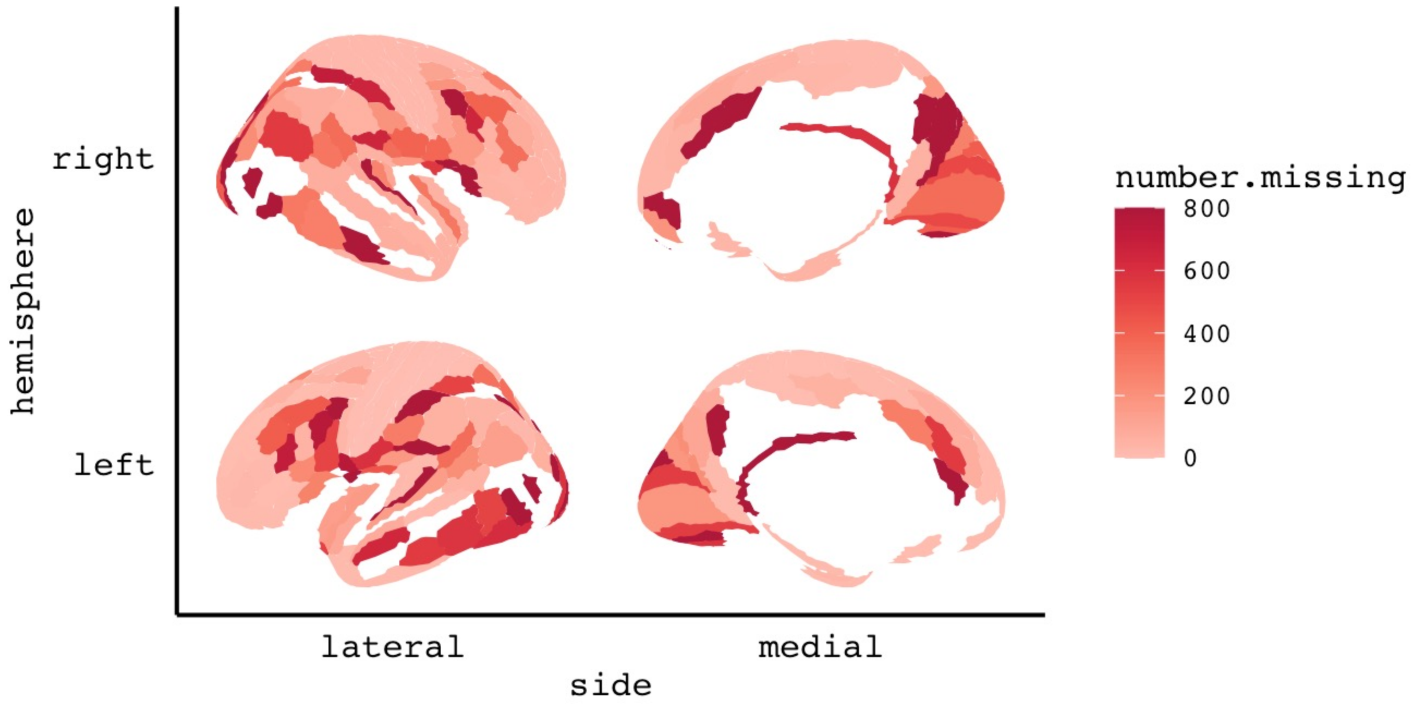
METHODS: Delineating thalamocortical connections with autotrack

Autotrack Participants Missing per Bundle



METHODS: Delineating thalamocortical connections with autotrack

Autotrack Participants Missing per Bundle




Oh dear, I do wish I hadn't cried so much.

METHODS: Delineating thalamocortical connections with autotrack

METHODS NEXT STEPS:

- Change yield rate/length of time termination threshold for autotrack
- Test a more liberal distance threshold for autotrack
- Test autotrack success in multi-shell, higher b-value diffusion data (HCP-D, etc.)
- Use a less fine-grained cortical atlas to divide the cortex (Schaefer? Suggestions?)

VERY EARLY RESULTS

Sample Construction

- Health exclusion
- T1 quality exclusion
- DWI motion exclusion: Mean FD > 0.45
- Bundle missingness exclusion: missing > 75 bundles

Bundle Exclusions

- Removing bundles where > 350 participants are missing data

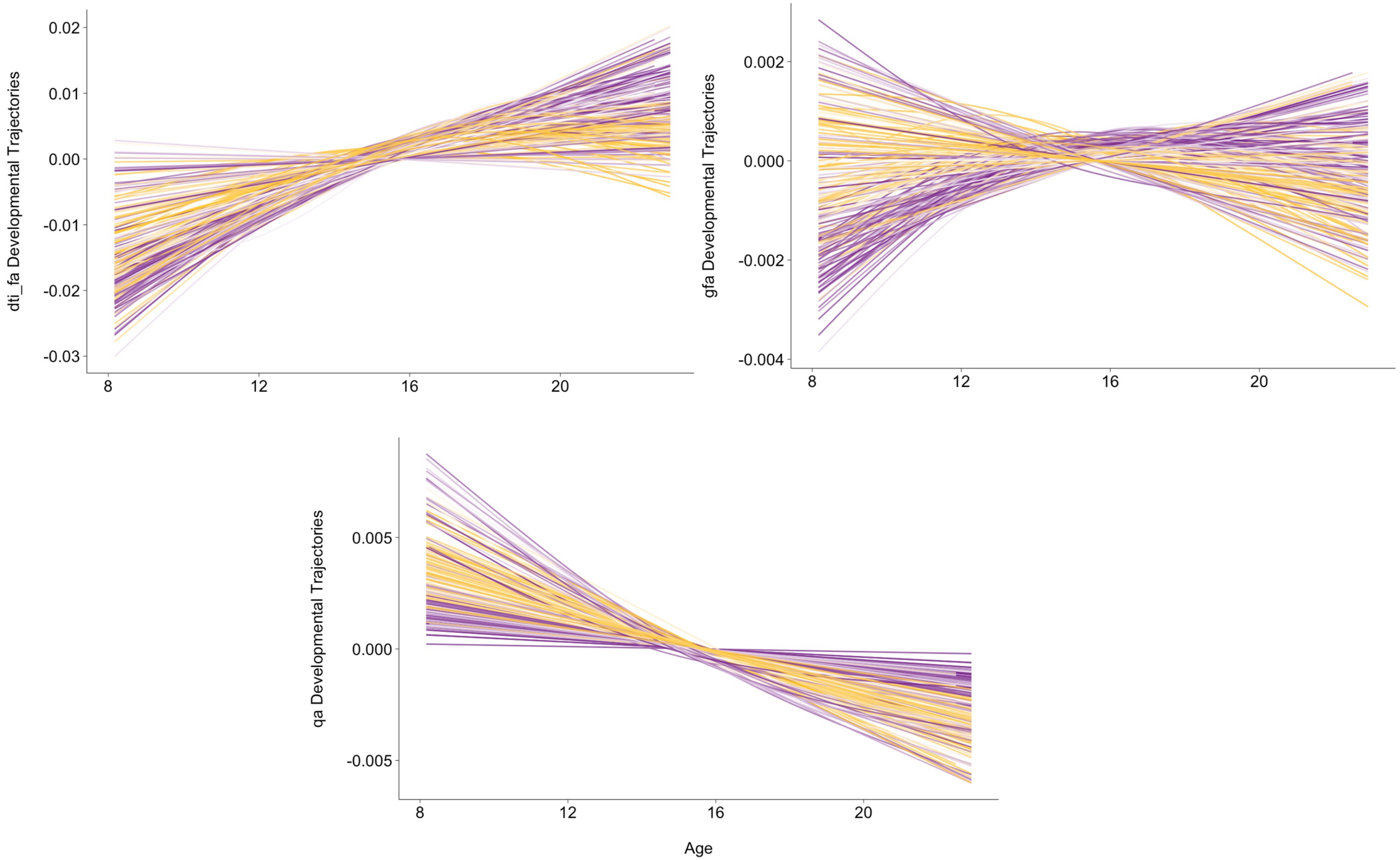
GAM

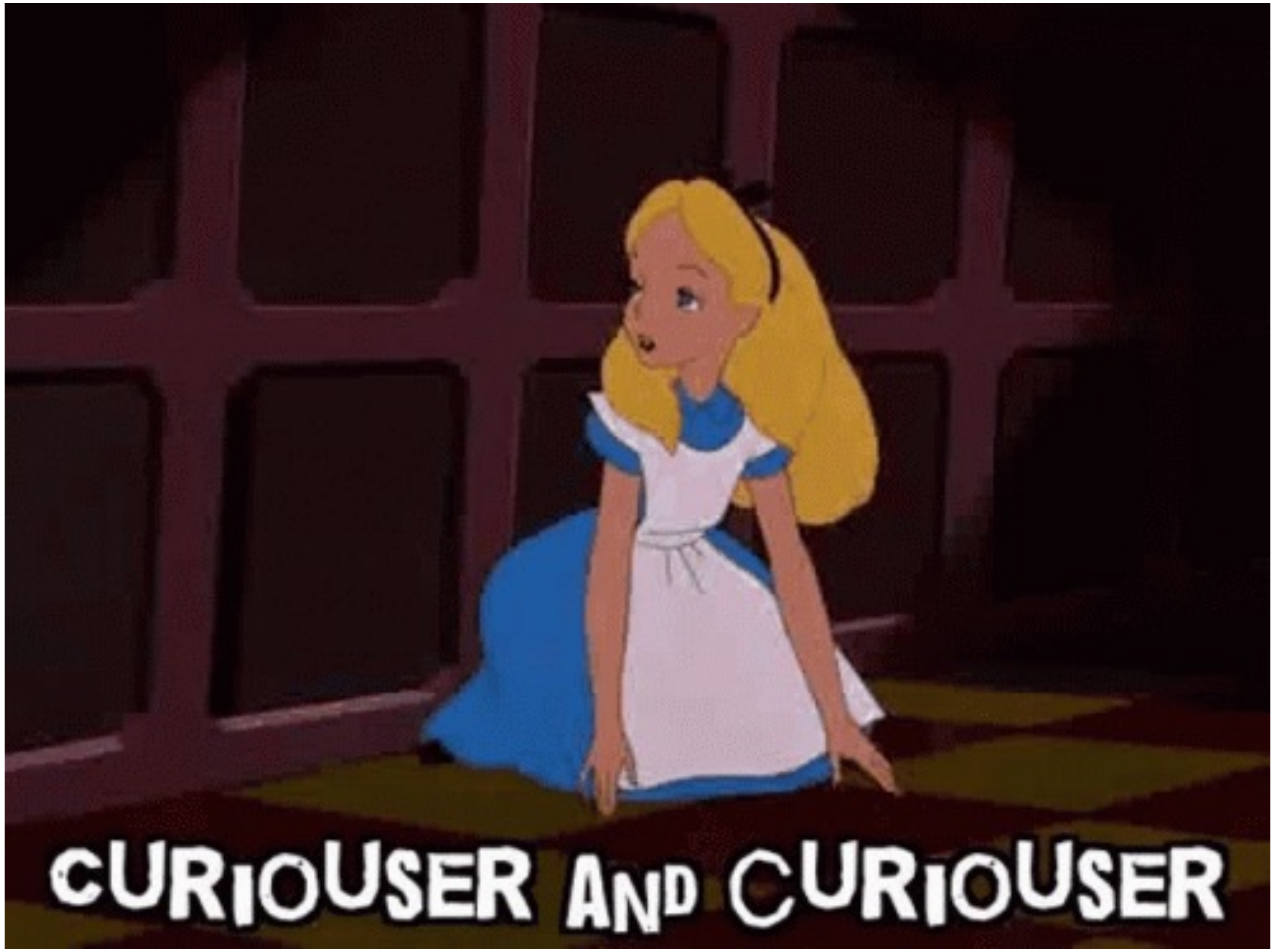
- bundle measure ~ s(age, k=4, fx=F) + sex + mean_FD

** Tested with participant-level exclusion of > 50 bundles missing and group-level exclusion of removing bundles where > 100 participants are missing data. Patterns are very similar*

VERY EARLY RESULTS

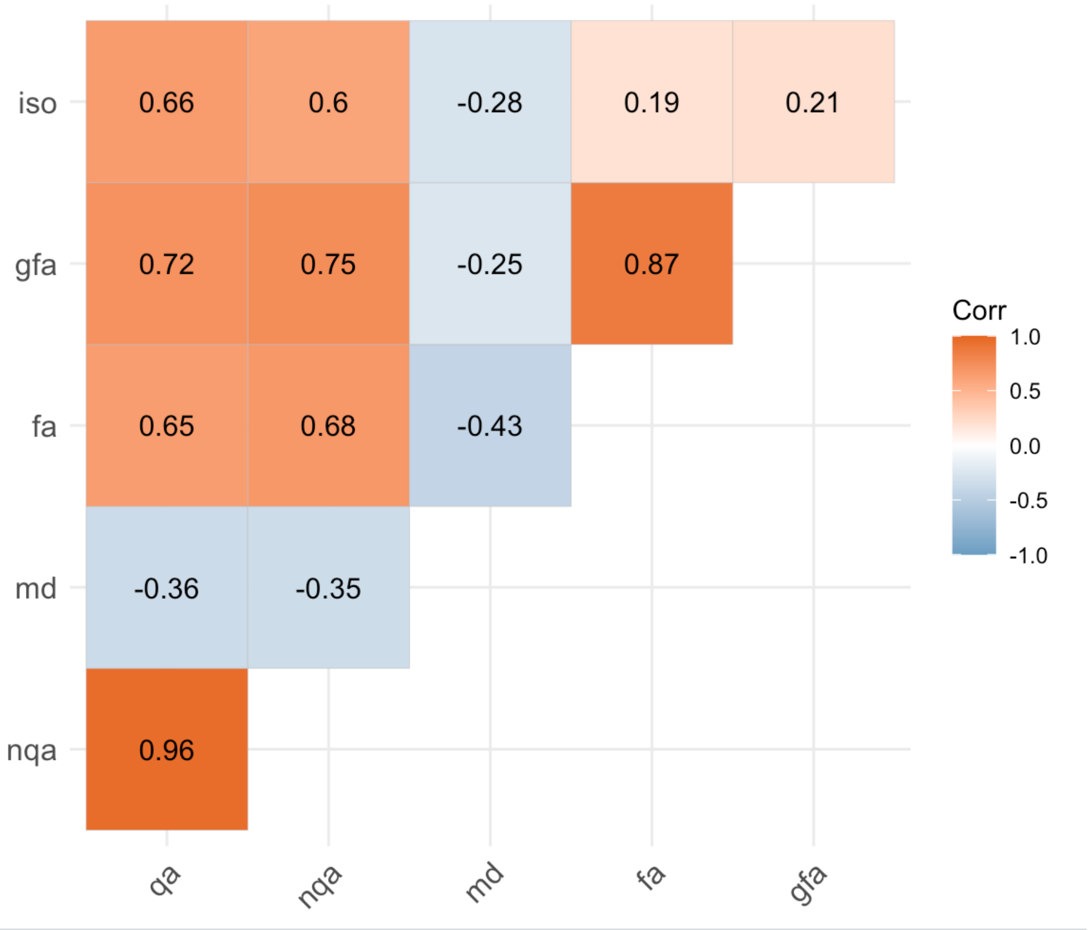
Thalamocortical Developmental Trajectories



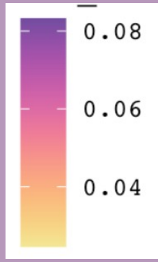

CURIOUSER AND CURIOUSER

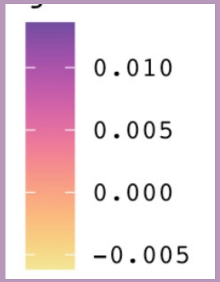
VERY EARLY RESULTS

Correlation Between Age Effects

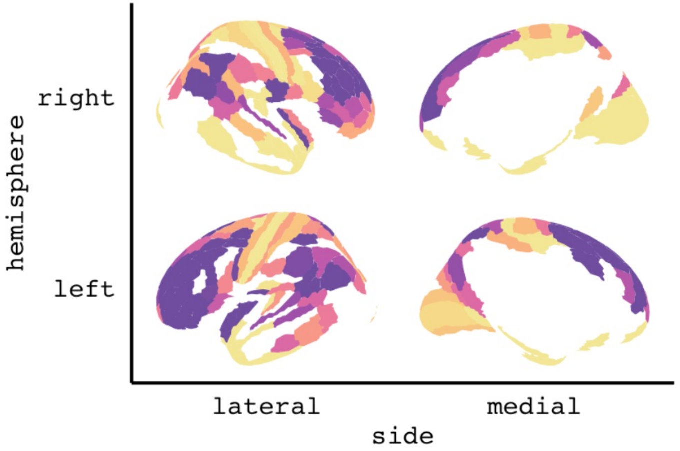


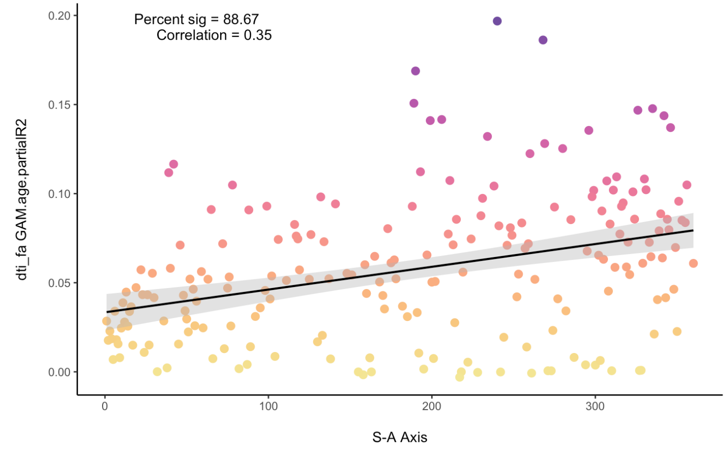
VERY EARLY RESULTS

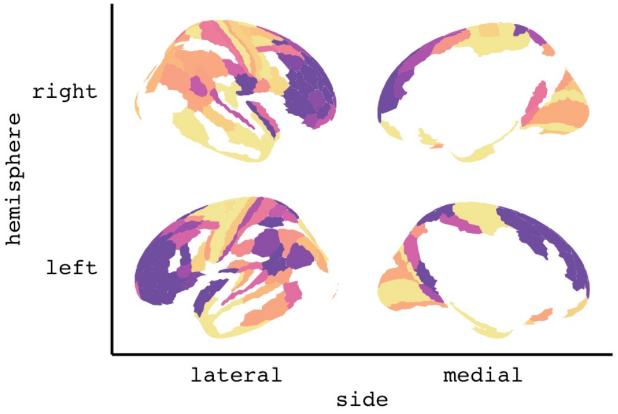


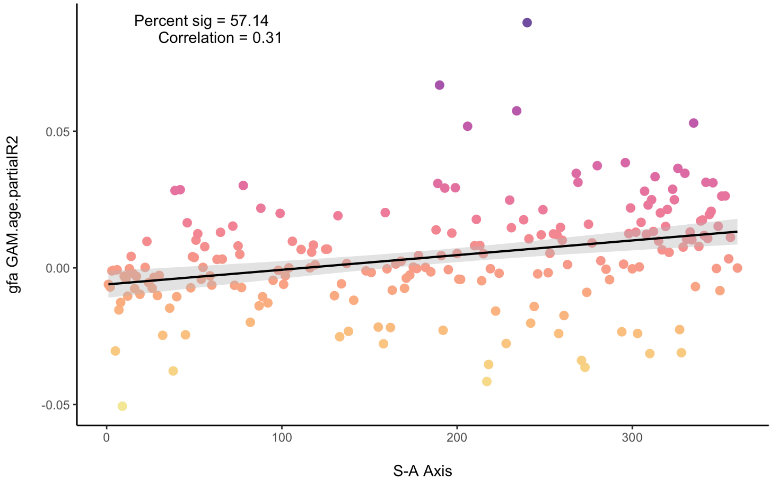


Age Effects

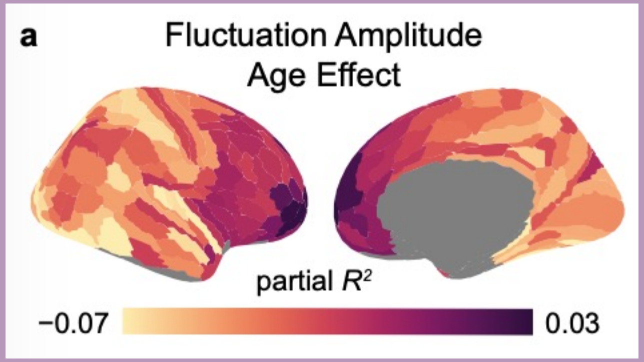




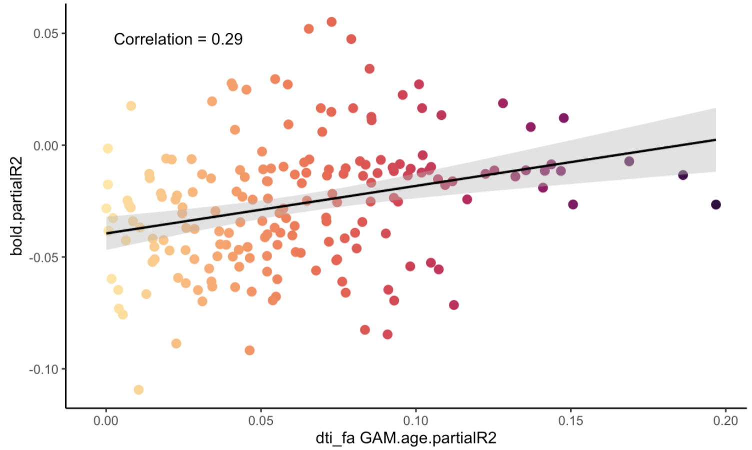


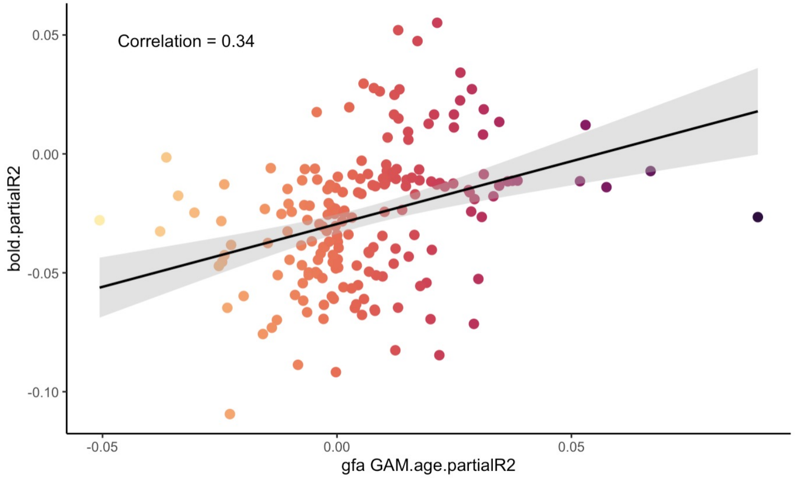


VERY EARLY RESULTS

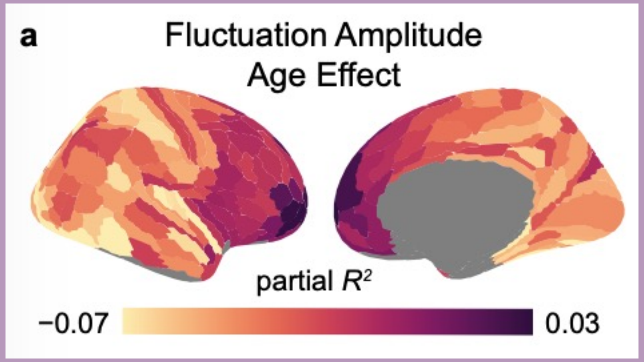


Relationship to Plasticity Markers: Alff Age Effect

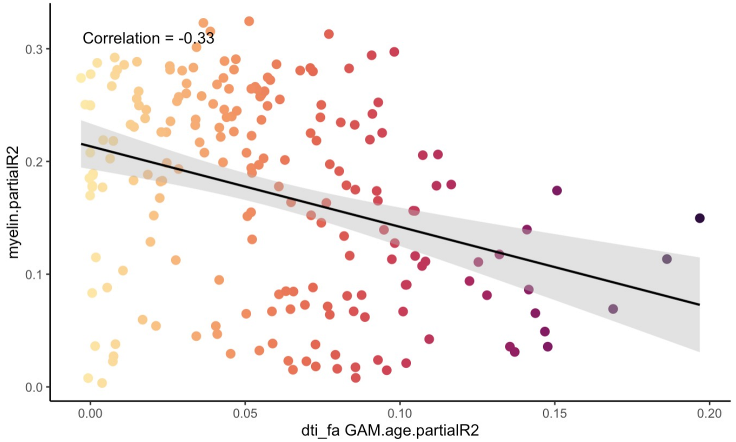


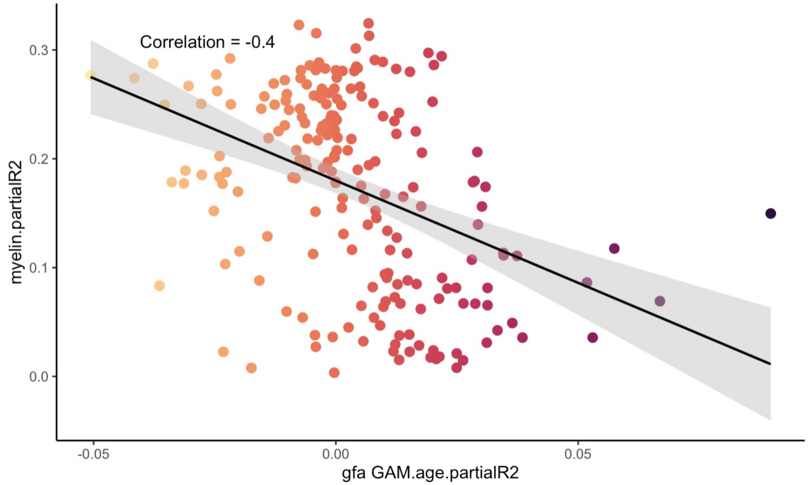


VERY EARLY RESULTS



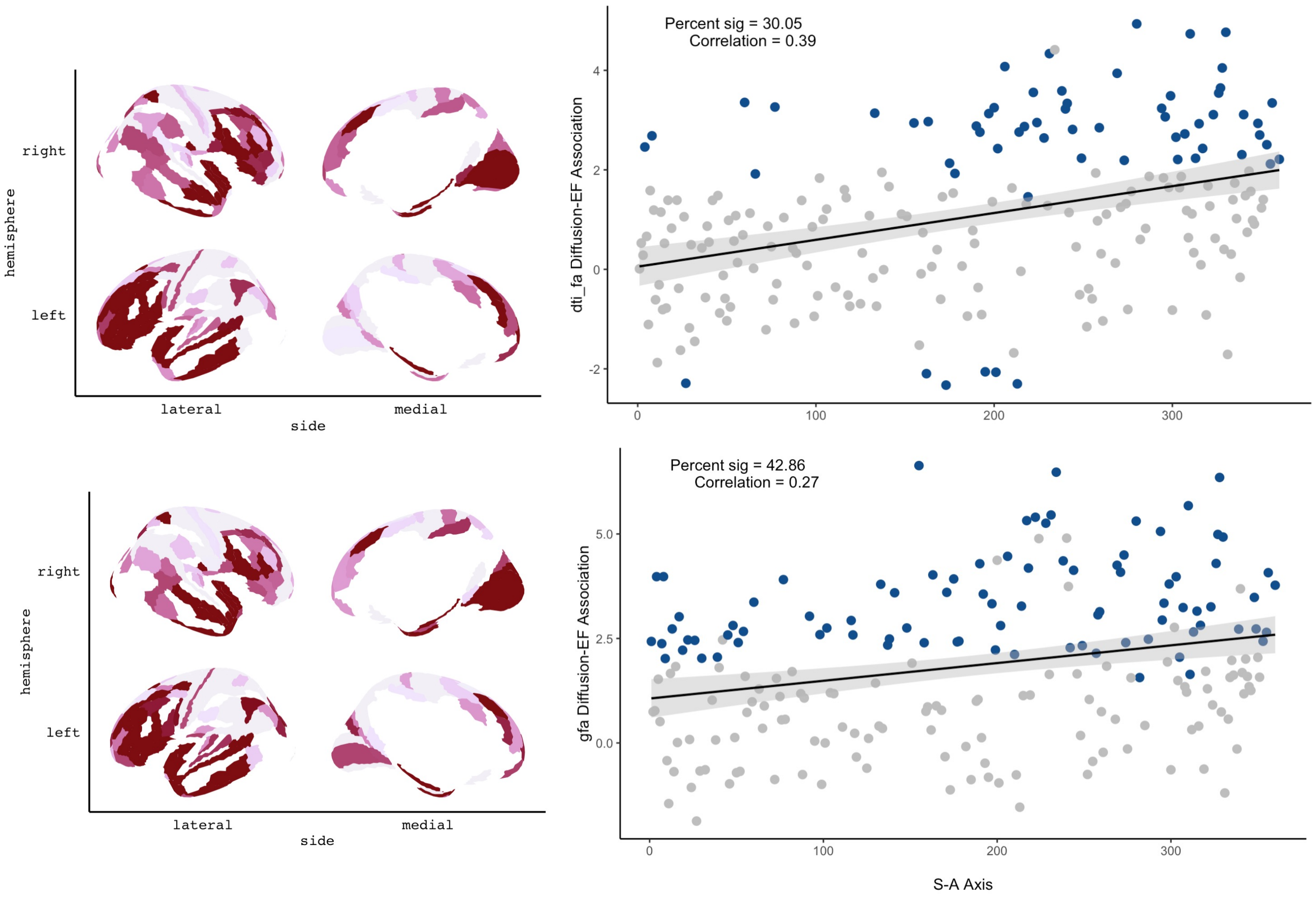
Relationship to Plasticity Markers: Myelin Age Effect





VERY EARLY RESULTS

Cognition Associations



DEVELOPMENT NEXT STEPS:


Well, that depends on where you
want to get to