



The Waisman Laboratory
for Brain Imaging and Behavior



University of Wisconsin
**SCHOOL OF MEDICINE
AND PUBLIC HEALTH**

Quantifying abnormal white matter connectivity in maltreated children

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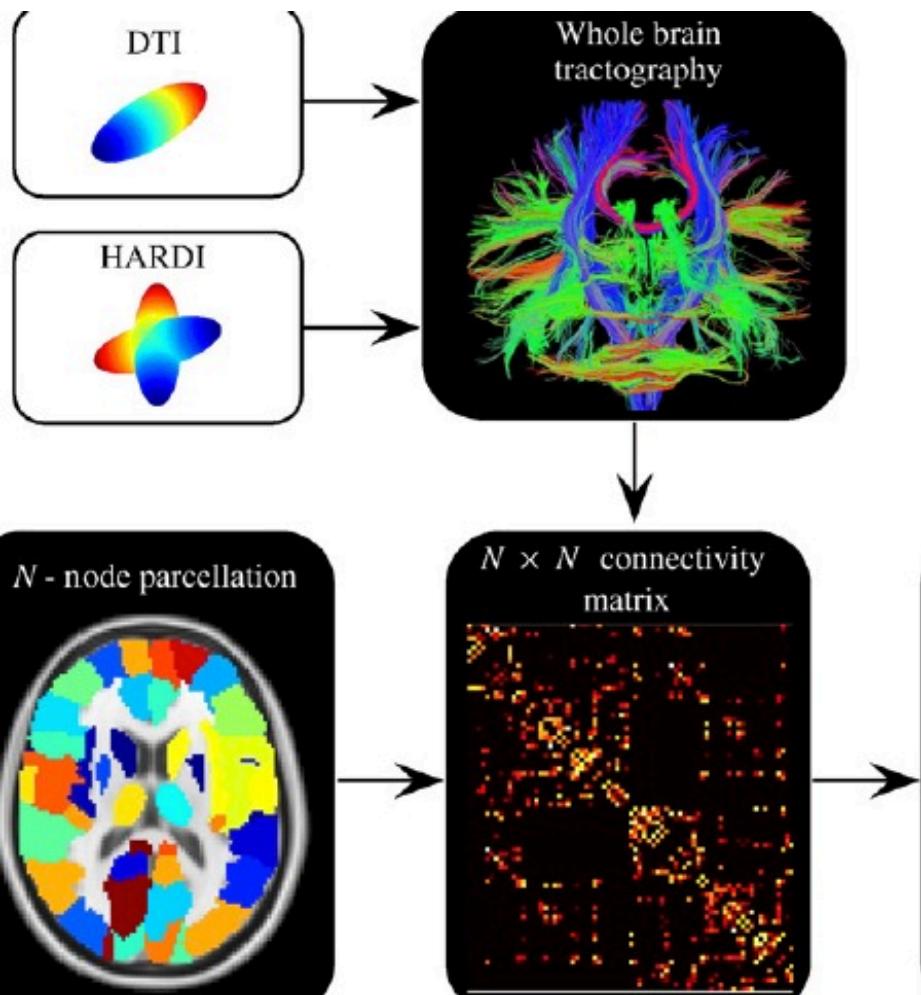
www.stat.wisc.edu/~mchung

Acknowledgement

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Seth Pollack, Richard J. Davidson
University of Wisconsin-Madison

Standard structural connectivity pipeline

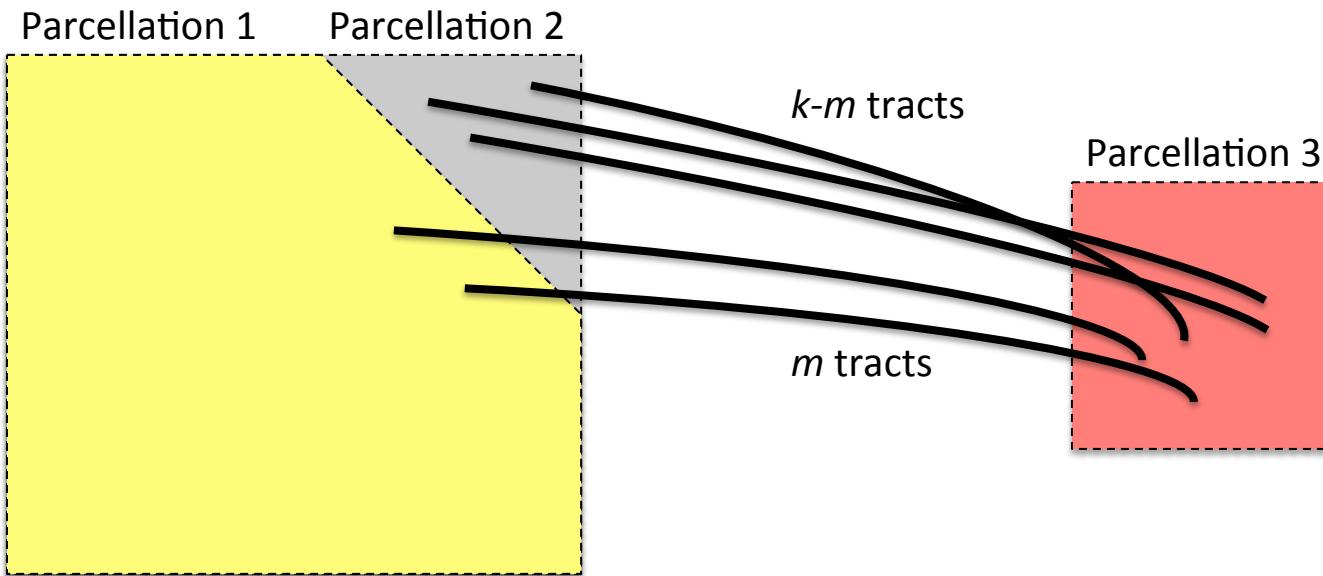


```
1: do whole-brain tractography  
2: for Subject = 1,2,3 do  
3:   for N = 82(AAL), 100, 500, 1000, 2000, 3000, 4000 do  
4:     for 100 random parcellations do  
5:       1. Generate N-node parcellation  
6:       2. Populate  $N \times N$  connectivity matrix  
7:       3. Threshold and binarize  
8:       4. Compute network metrics  
9:     end for  
10:   end for  
11: end for
```

Parcellation
70-120 regions

Zalesky et al. *NeuroImage* 2010

Connectivity based on tract count



$$\begin{pmatrix} 0 & 0 & k-m \\ 0 & 0 & m \\ k-m & m & 0 \end{pmatrix}$$

Electronic Circuit Model for connectivity

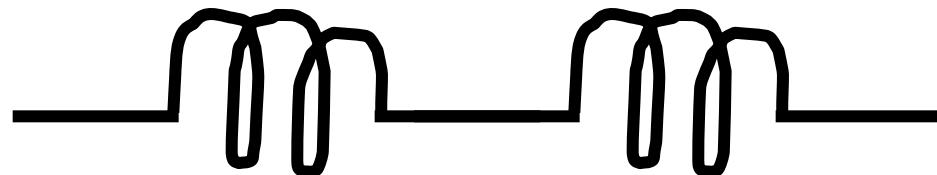
Physics of myelinated neuronal fibers

Myelin sheath increase the speed at which neuronal impulses propagate along the myelinated fiber.

Myelin increases electrical resistance across cell membrane by a factor of 5000 and decreases capacitance by a factor of 50.

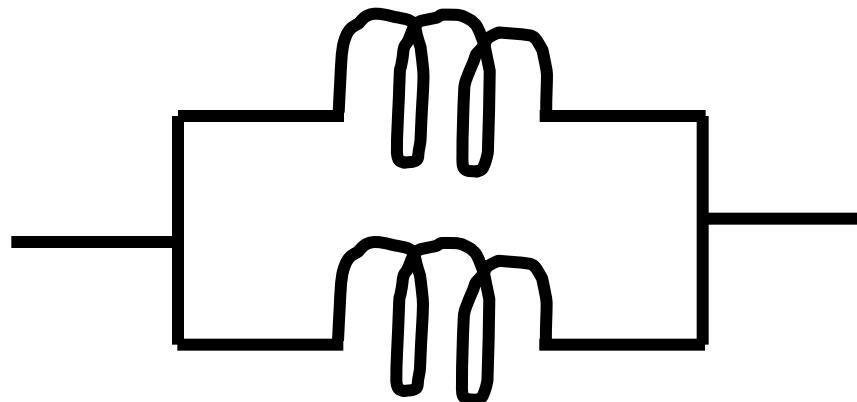
Basic circuit physics: Ohm's law

Series circuit



$$R = R_1 + R_2$$

Parallel circuit



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

Resistance for parallel tracts

(length = 10cm)



$$R = 10$$

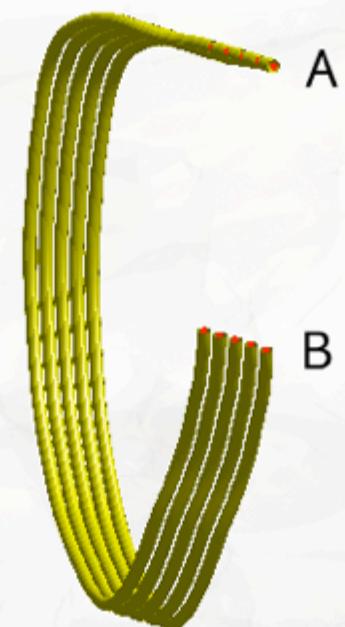
$$\frac{1}{R} = \frac{1}{10} + \frac{1}{10}$$

$$R = 5$$



$$\frac{1}{R} = \frac{1}{10} + \frac{1}{10} + \frac{1}{10} + \frac{1}{10} + \frac{1}{10}$$

$$R = 2$$

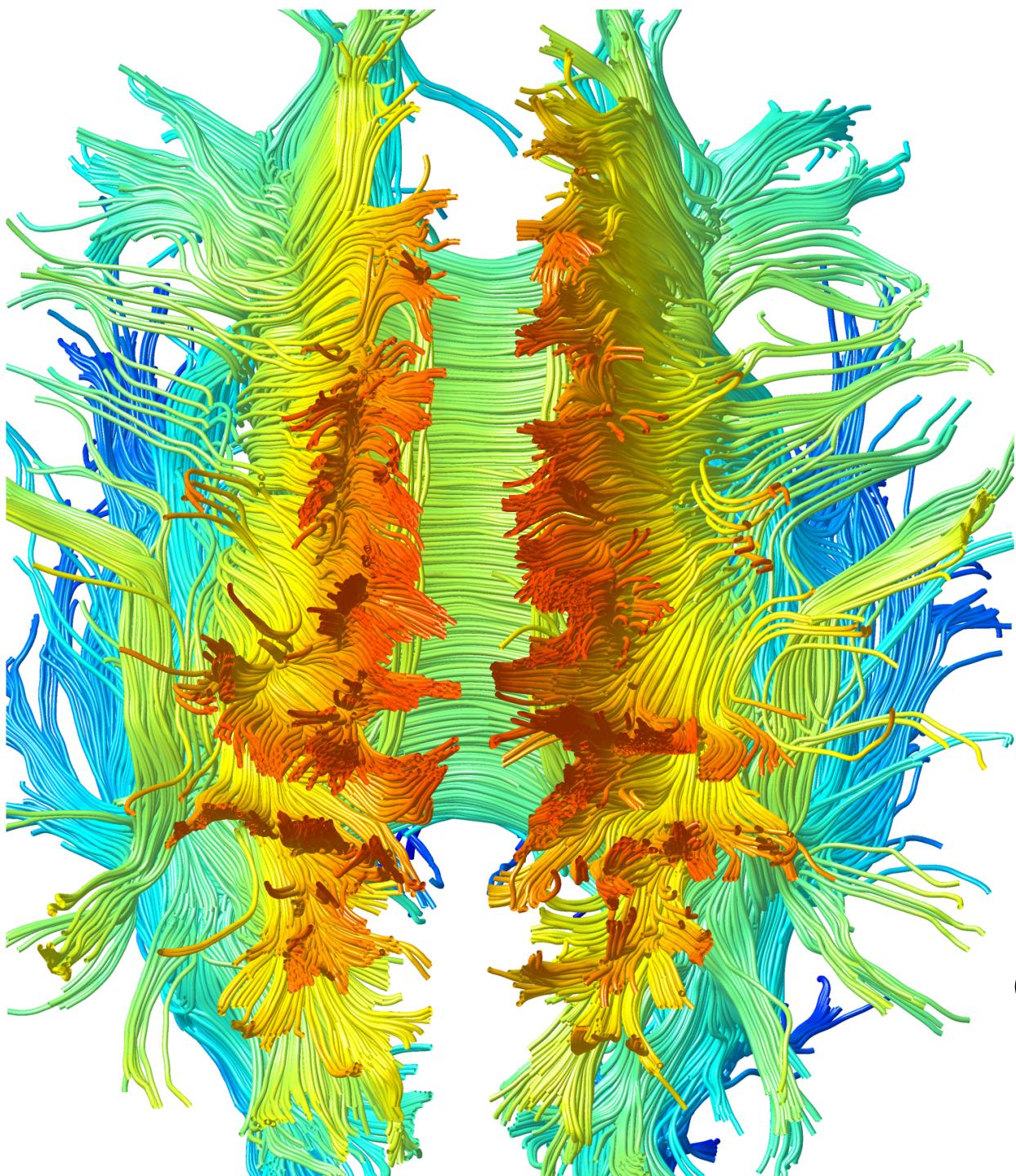


More tracts = less resistance

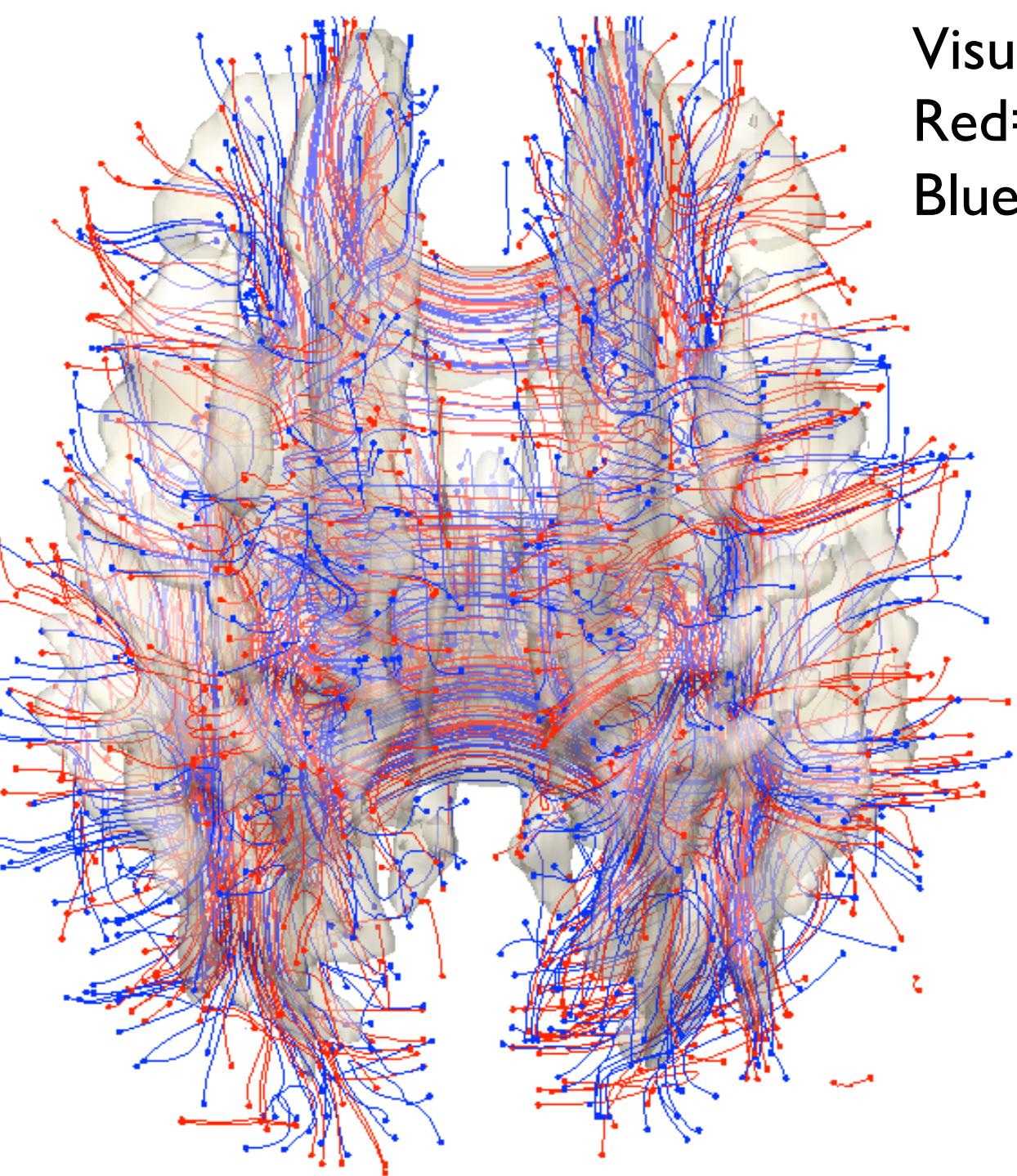
DTI study on maltreated children

- 3T DTI: $2 \times 2 \times 3$ mm resolution
- 23 maltreated children who have been post-institutionalized (PI) in orphanages but later adopted to the families in US.
- Age-matched 31 normal control subjects.
- Age distribution
 - PI : 11.26 ± 1.71
 - Controls : 11.58 ± 1.61 years

Fiber tractography

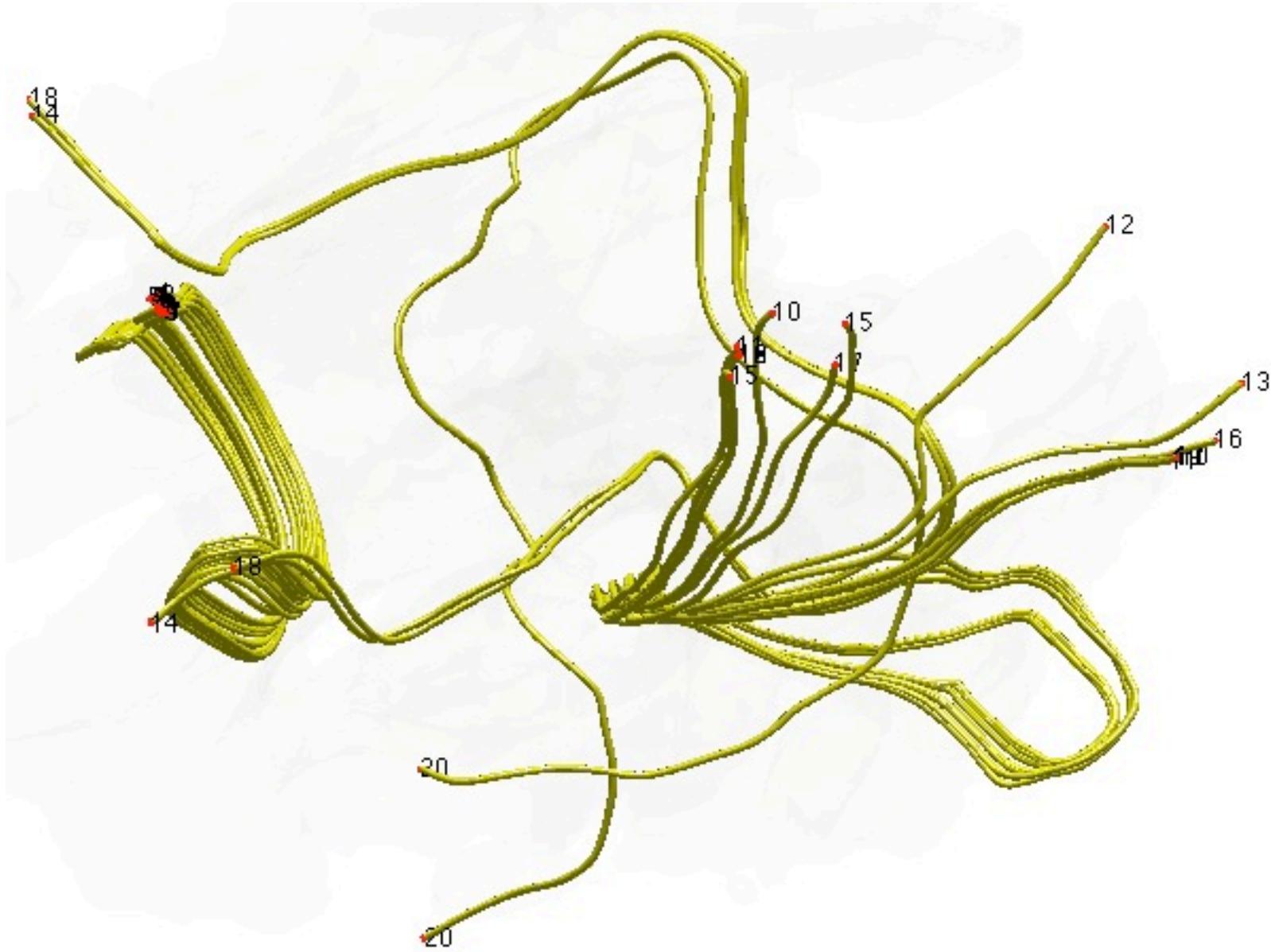


Only showing about
3000 tracts out of
100000 tracts



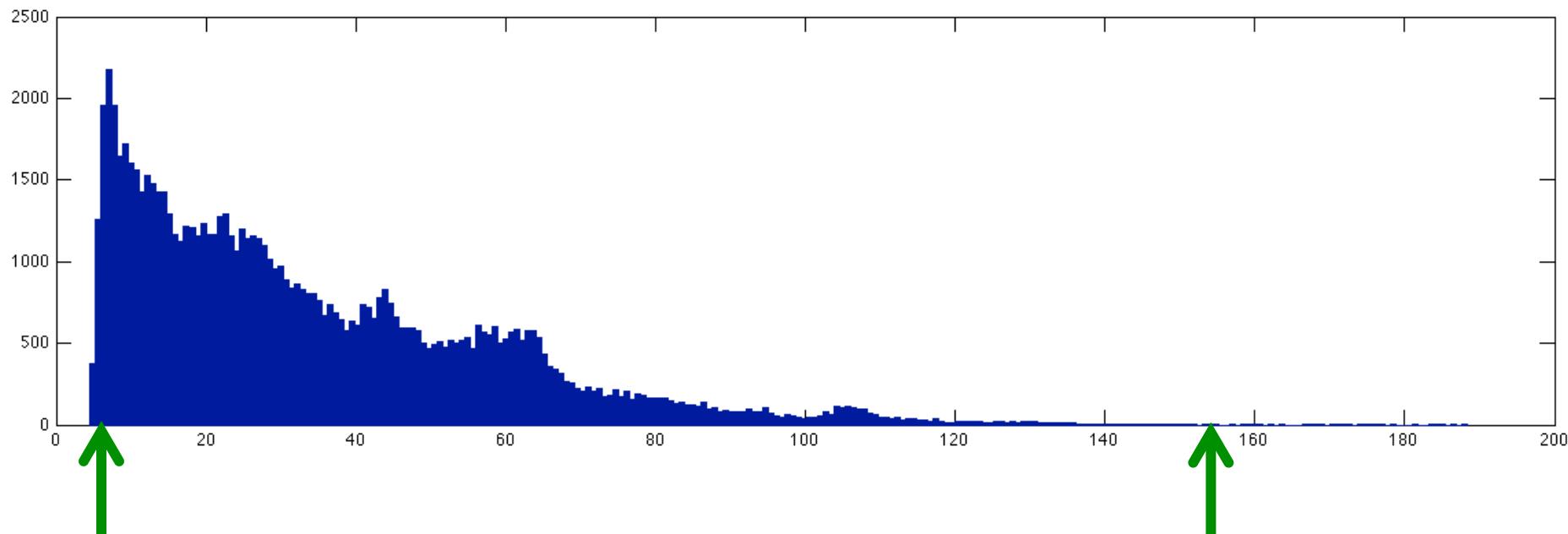
Visualizing tract alignment
Red= subject 1
Blue= subject 2

Outlying tracts



Outlier removal

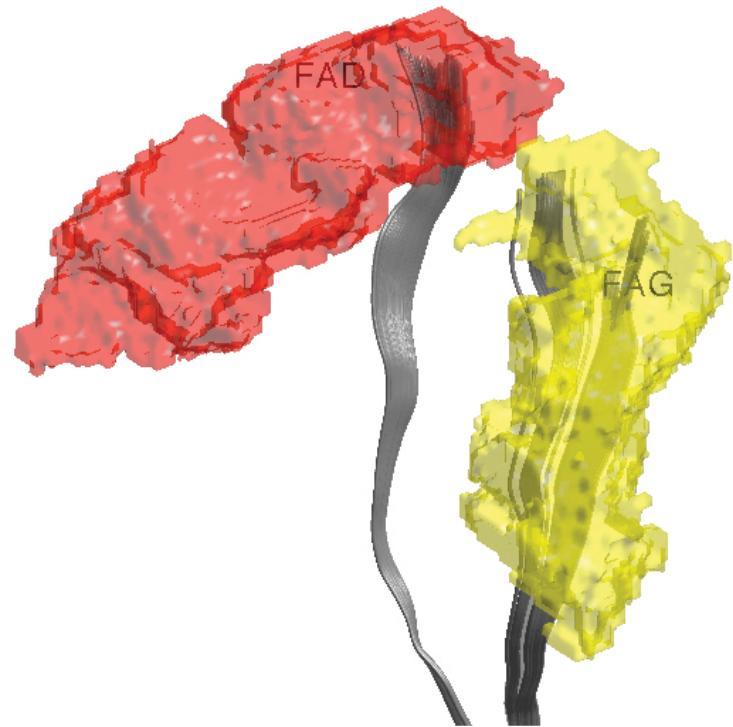
Histogram on tract length



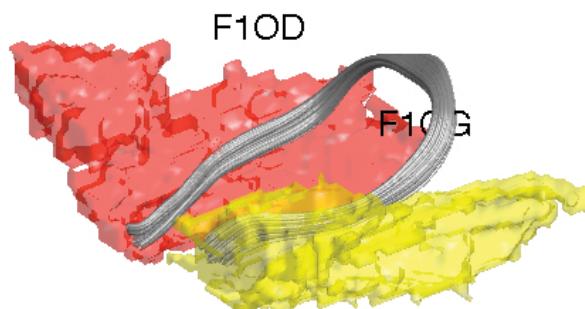
Noise

Noise

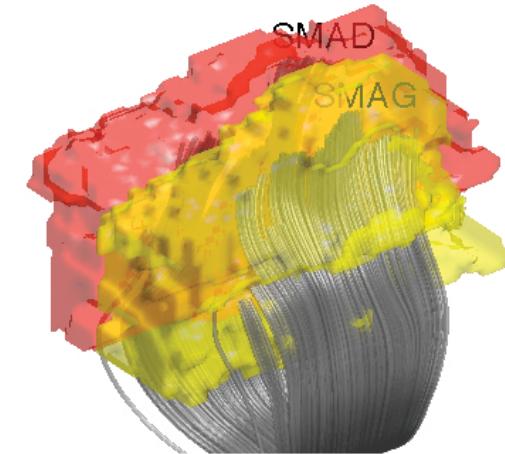
Tracts between parcellations



FAG (left precentral)
FAD (right precentral)

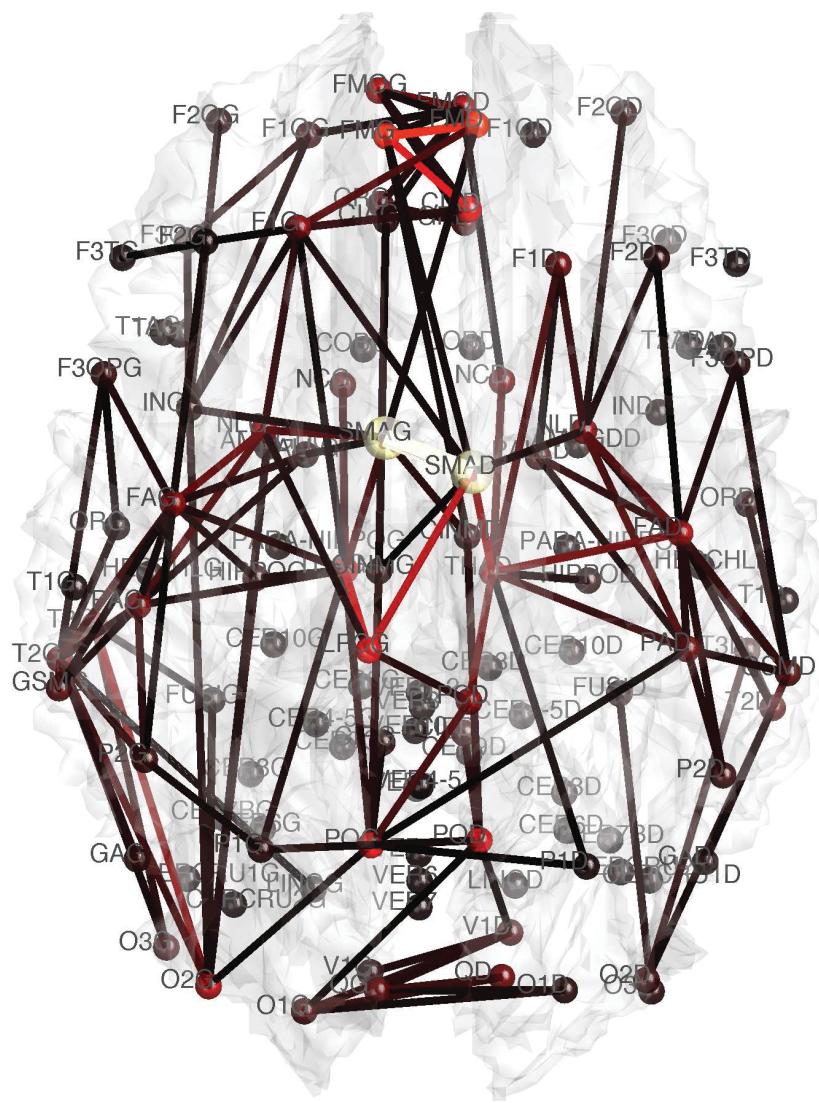


F1OF (left frontal mid orbital)
F1OG (right frontal mid orbital)

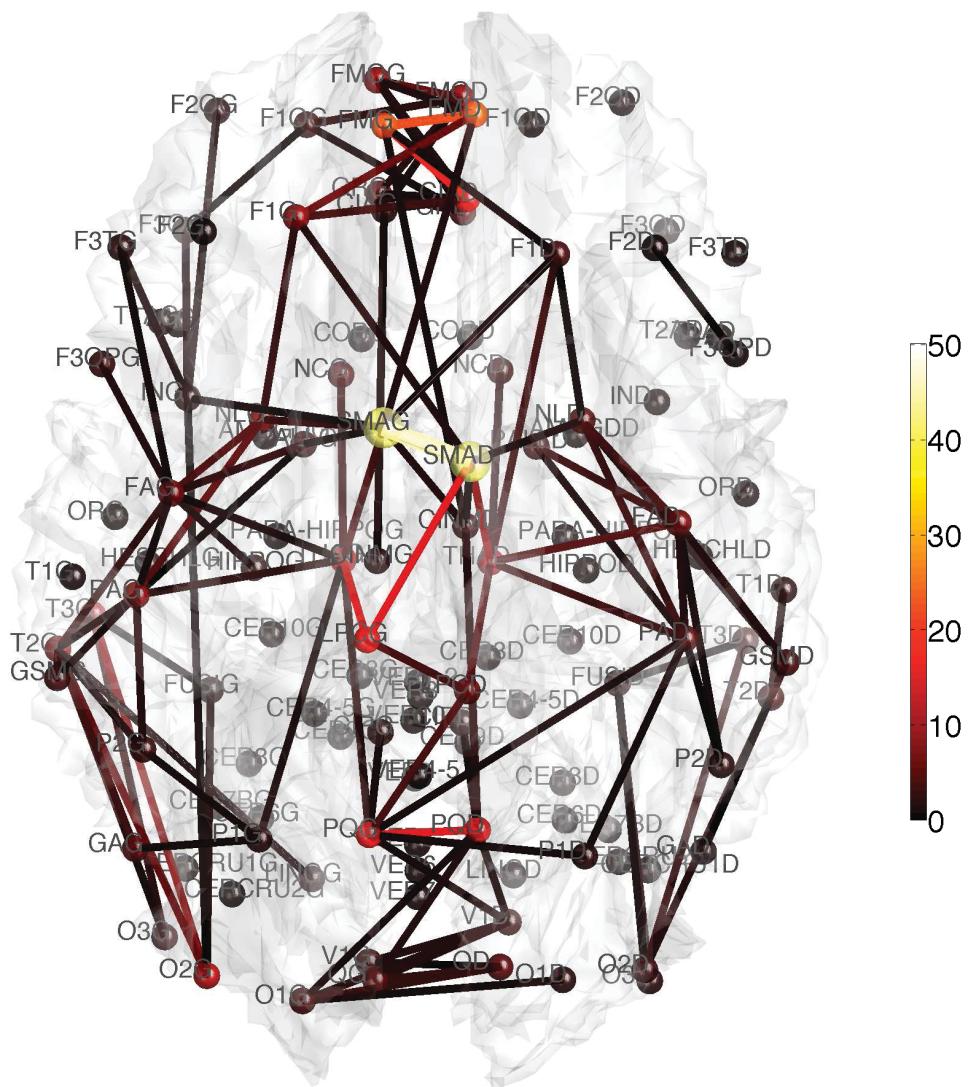


SMAG (left superior motor area)
SMAD (right superior motor area)

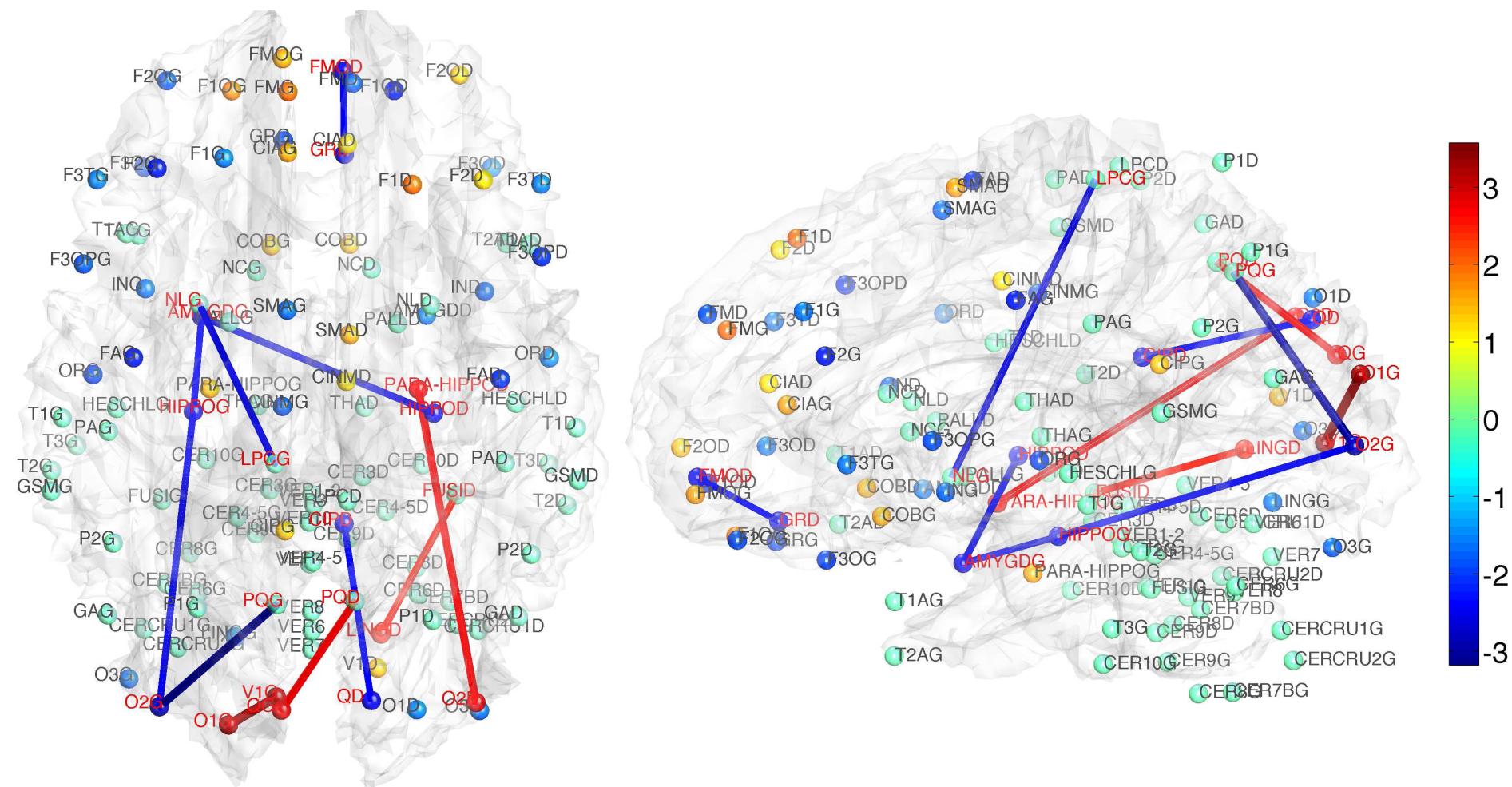
Normal Controls



Maltreated Children



T-stat (maltreated – controls)



Uncorrected pvalue < 0.01

FDR < 0.04

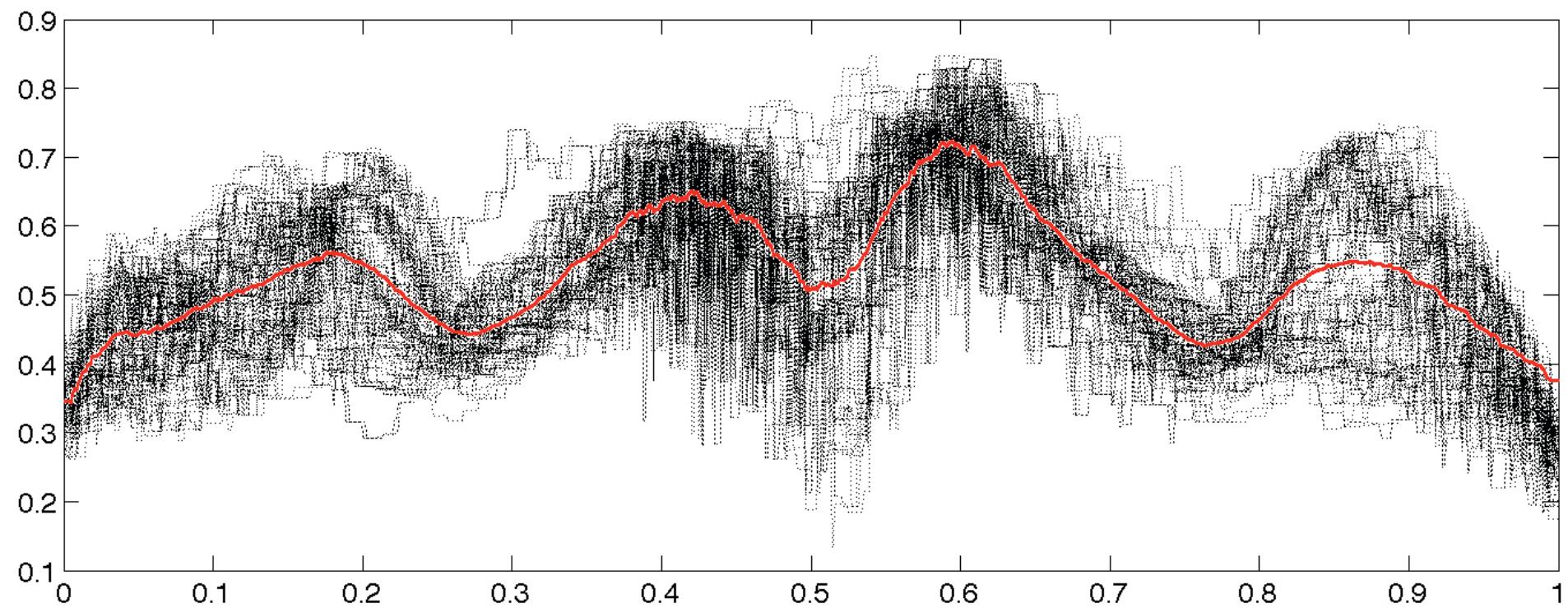
Affected connection nodes

AAL Node Labels

FMOD	Frontal-Med-Orb-R
GRD	Rectus-R
CIPD	Cingulum-Post-R
HIPPOG	Hippocampus-L
HIPPOD	Hippocampus-R
PARA-HIPPOD	ParaHippocampal-R
AMYGDG	Amygdala-L
VIG	Calcarine-L
QG	Cuneus-L
QD	Cuneus-R
LINGD	Lingual-R
OIG	Occipital-Sup-L
O2G	Occipital-Mid-L
O2D	Occipital-Mid-R
FUSID	Fusiform-R
PQG	Precuneus-L
PQD	Precuneus-R
LPCG	Paracentral-Lobule-L
NLG	Putamen-L

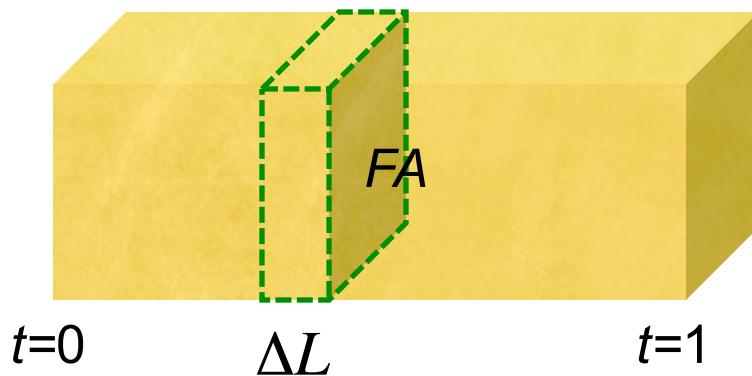
How to integrate FA values to connectivity

FA values over tracts between SMAG to SMAD



Resistance of a tract segment

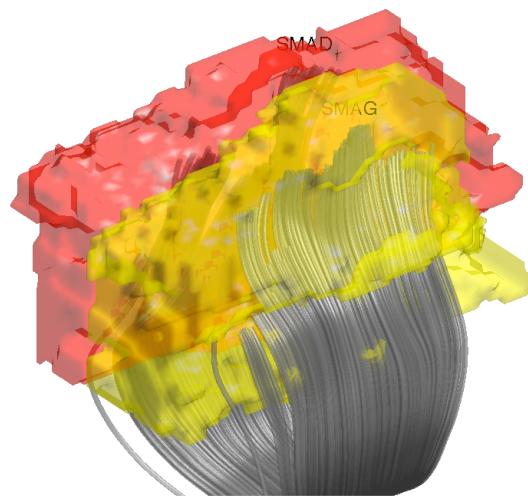
$$\Delta R = \frac{\Delta L}{FA}$$



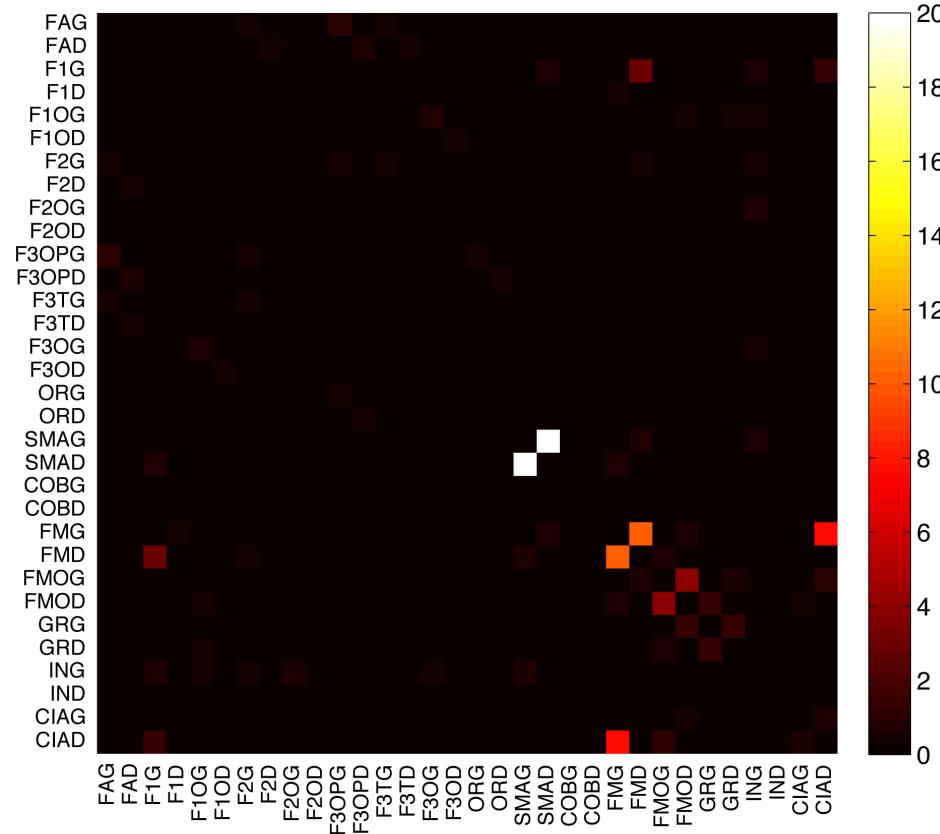
$$R = \int_0^1 \frac{dL}{FA(t)}$$

Mean connectivity matrix

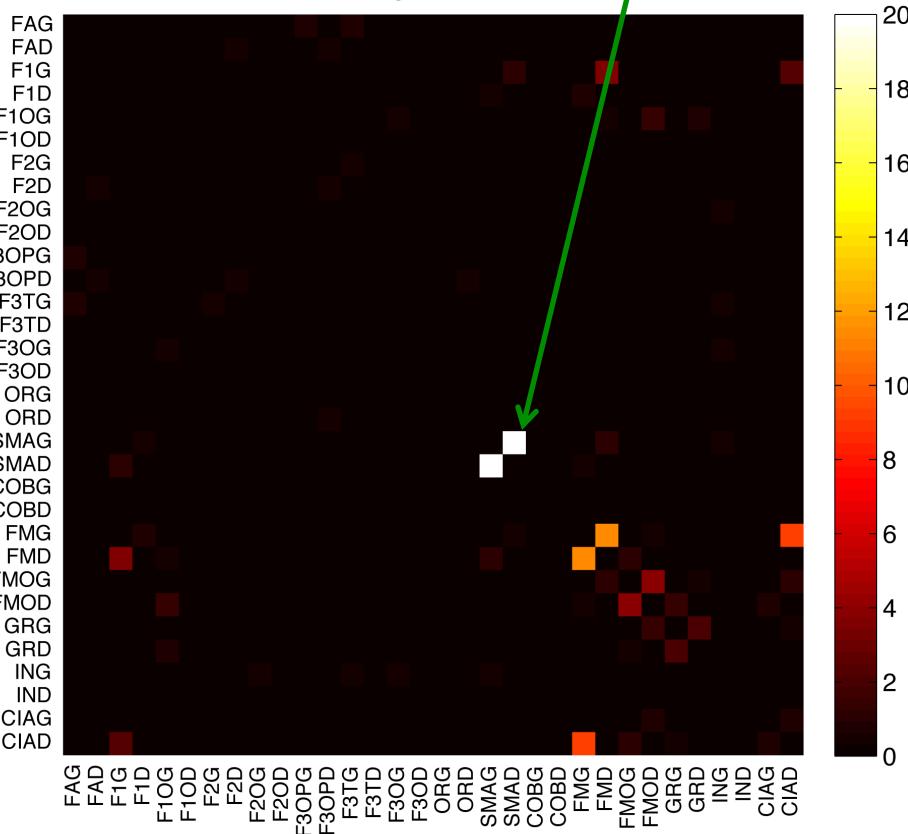
SMAG (left superior motor area) to
SMAD (right superior motor area)



Mean Connectivity: Normal Controls

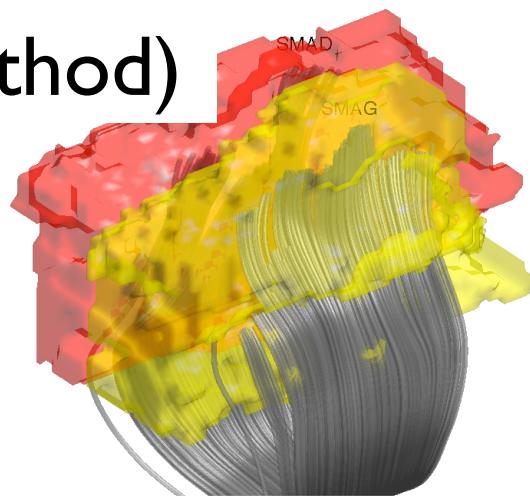


Mean Connectivity: Maltreated Children

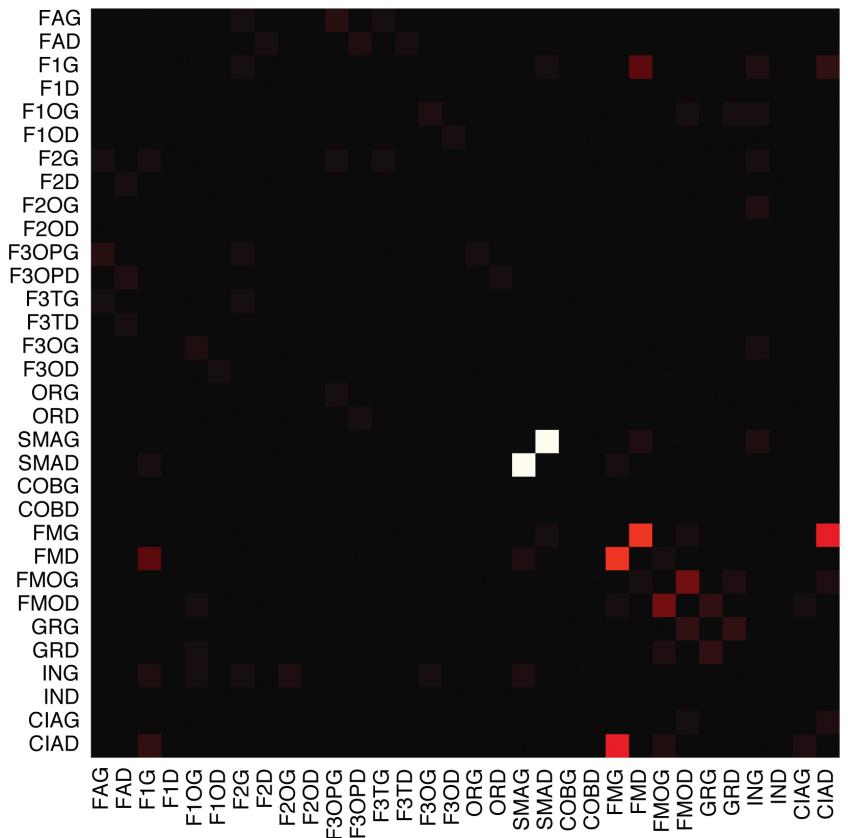


Mean connectivity matrix (previous method)

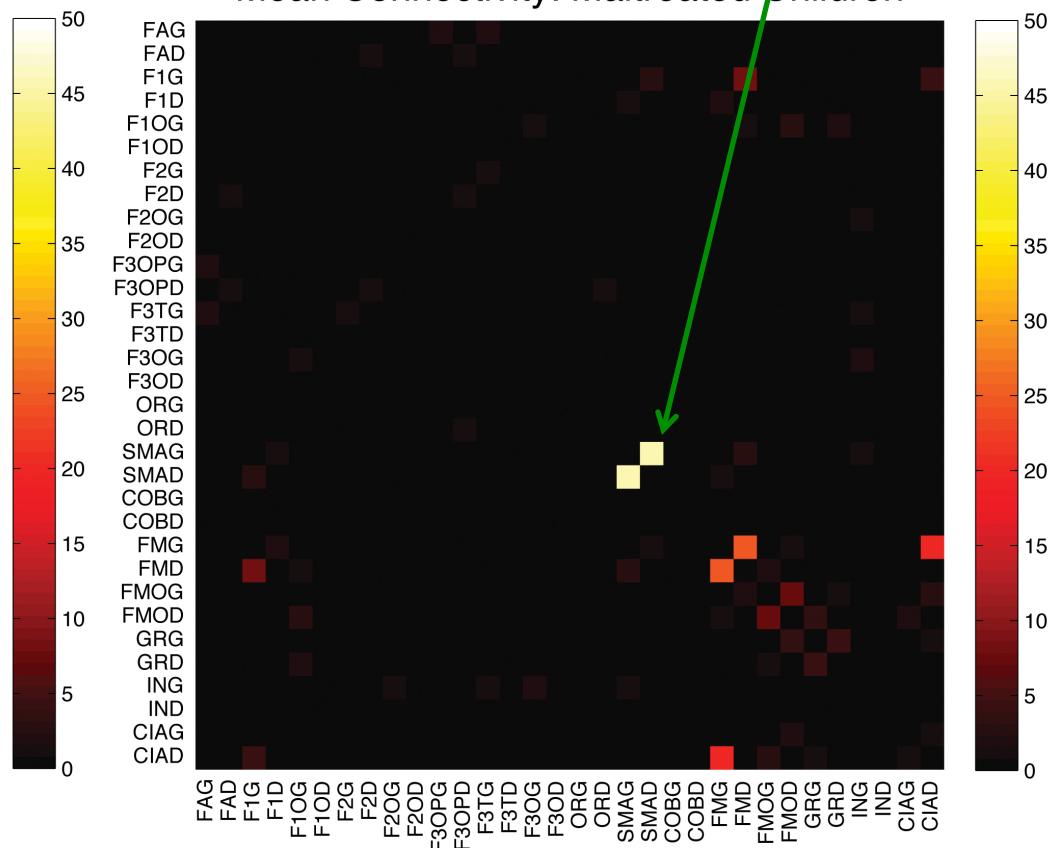
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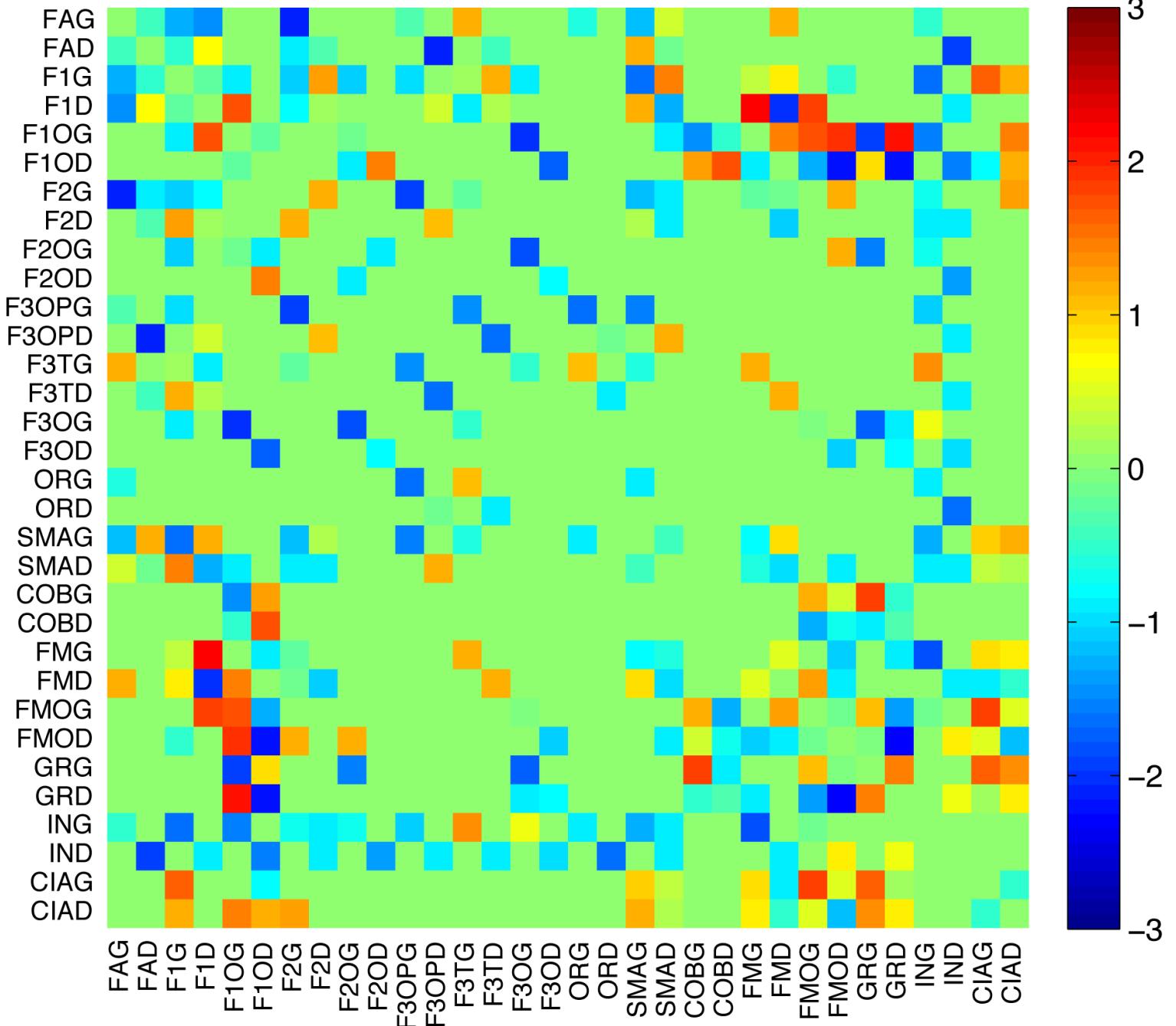
Mean Connectivity: Normal Controls



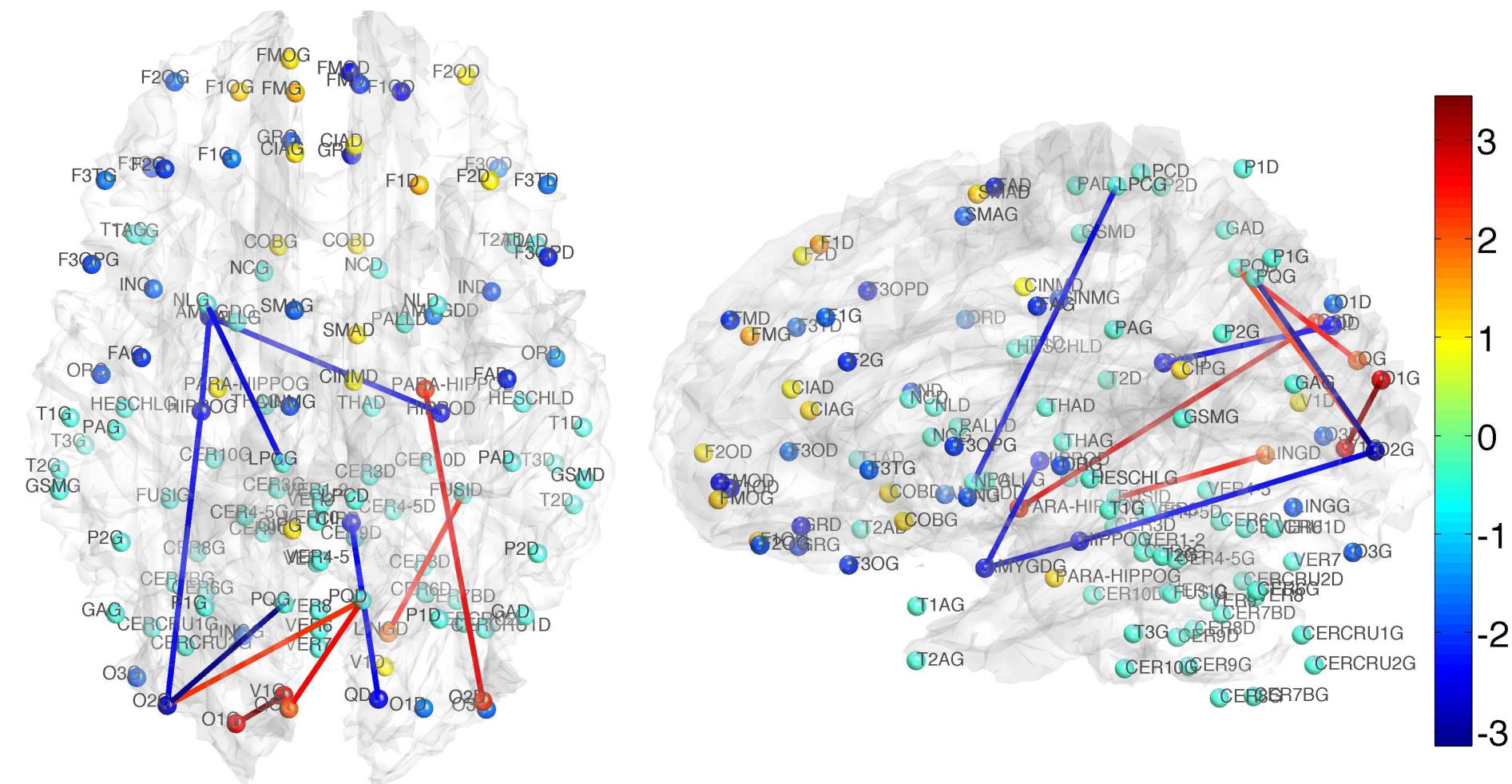
Mean Connectivity: Maltreated Children



T-stat (Maltreated – Controls)



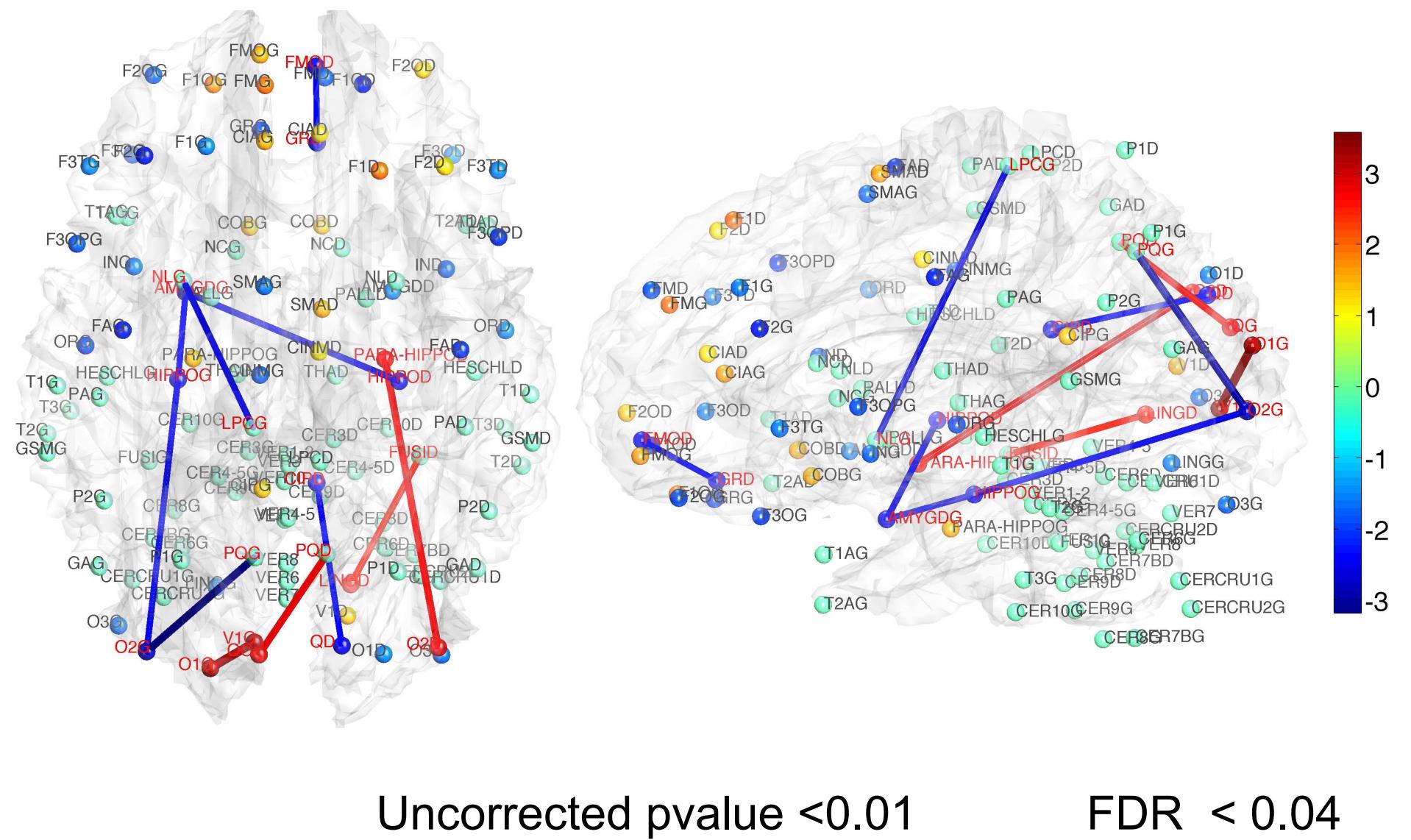
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The electrical circuit
model is very robust.

What next?