Brain & Cognitive Sciences

University of Wisconsin
SCHOOL OF MEDICINE AND PUBLIC HEALTH

Topological characterization of brain connectivity using white matter fiber bundles

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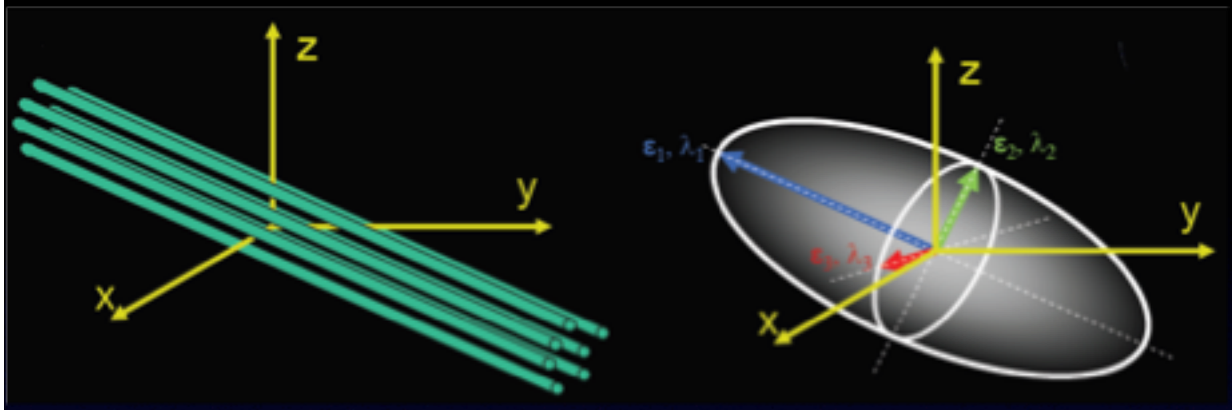
Abstract

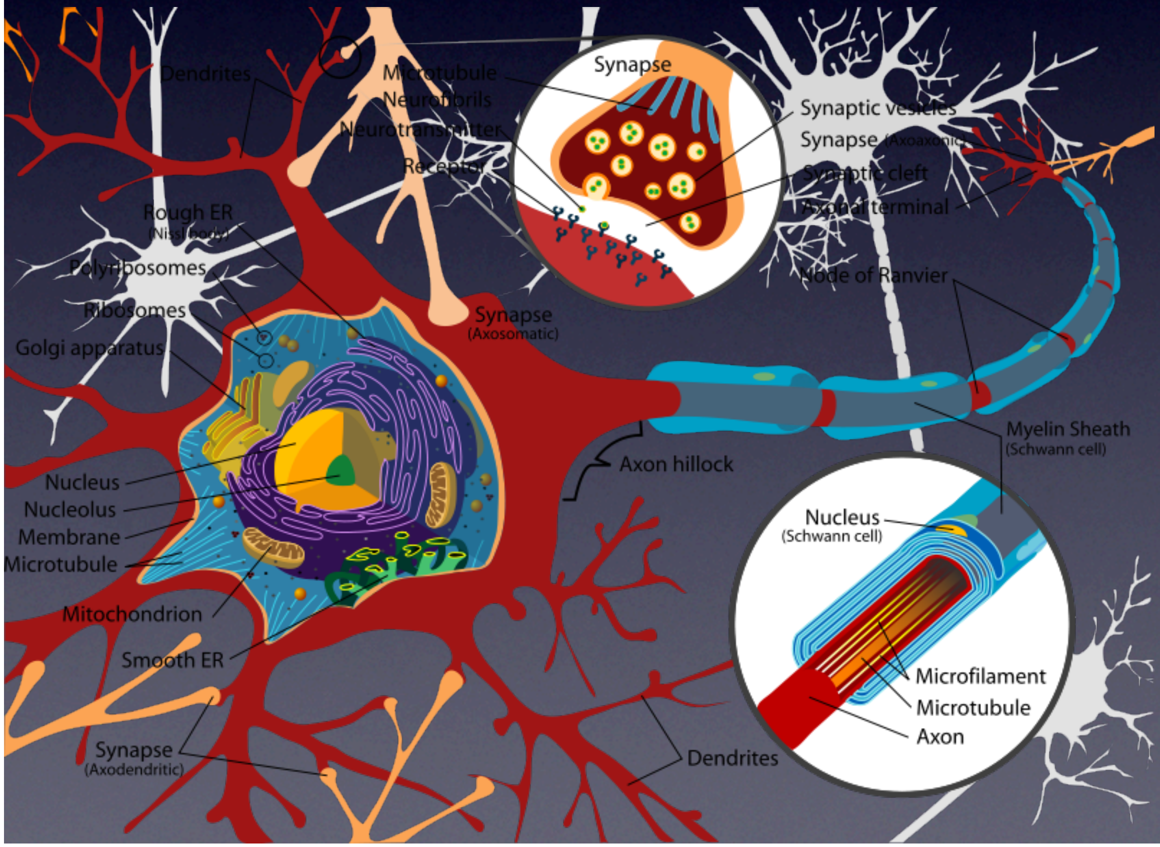
Structural brain connectivity has been mainly modeled as a network graph using white matter fiber tracts in DTI. The whole gray matter has been traditionally parcellated into disjoint regions. Fiber tracts provide information of how one gray matter region is connected to another via a connectivity matrix. The connectivity matrix is then thresholded to produce a binarized adjacency matrix, which is further used in constructing a graph. However, there is no gold standard for gray matter parcellation, which makes the identification of node, depends on the choice of parcellation. Depending on the scale of parcellation, the parameters of graph, which characterize graph topology, varies considerably. Another problem of the parcellation is the arbitrariness of thresholding the connectivity matrix. The topological parameters such as degree, sparsity and clustering coefficients change significantly depending on the level of threshold. The problems of parcellation and the subsequent arbitrary thresholding can be avoided if we do not use any parcellation in building the network. So the question is whether if it is possible to construct a network graph without the usual parcellation scheme. We present a novel topological network graph construction technique called the epsilon-neighbor method that avoids parcellation and the subsequent connectivity matrix thresholding. The method is applied in quantifying abnormal connectivity in autism.

Diffusion Tensor Imaging

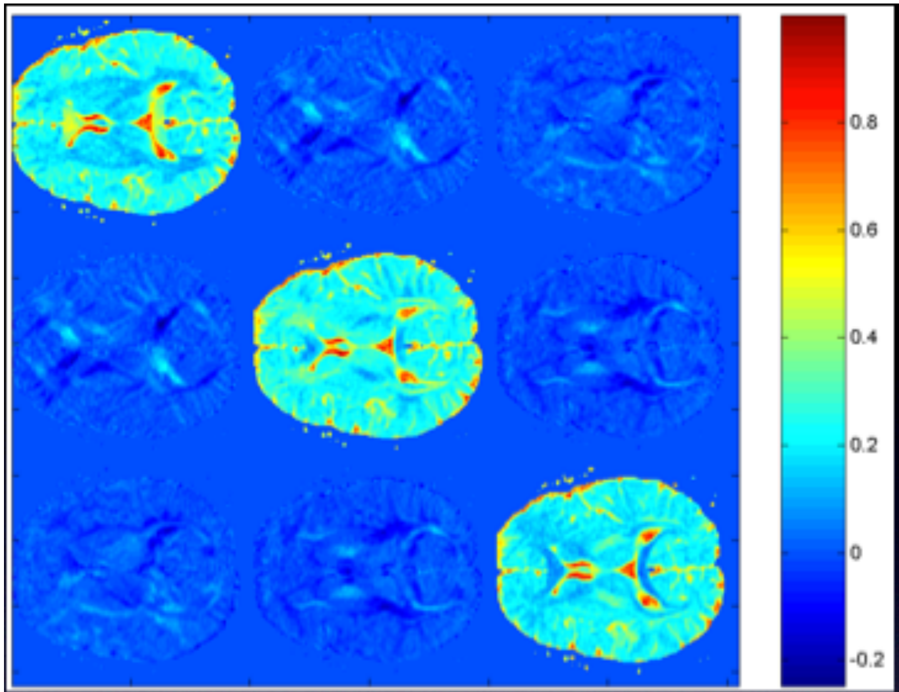
Mori and van Zijl NMR Biomed 2002



The movement of anisotropic water diffusion can be measured using DTI

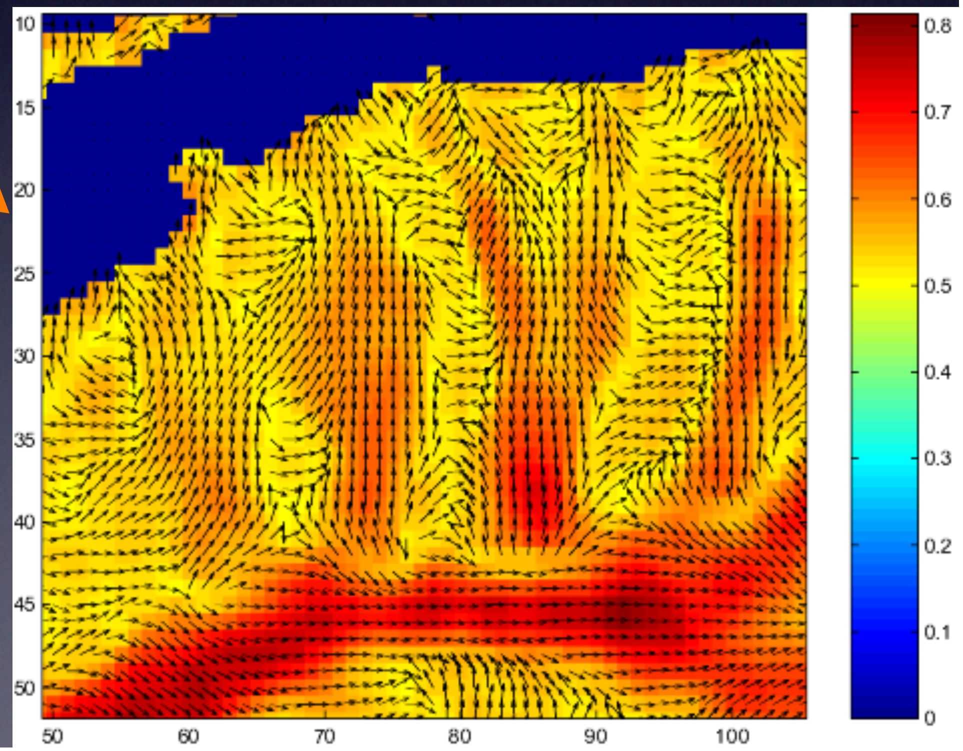


The direction of neuronal filaments in the axon dictates the movement of water diffusion.



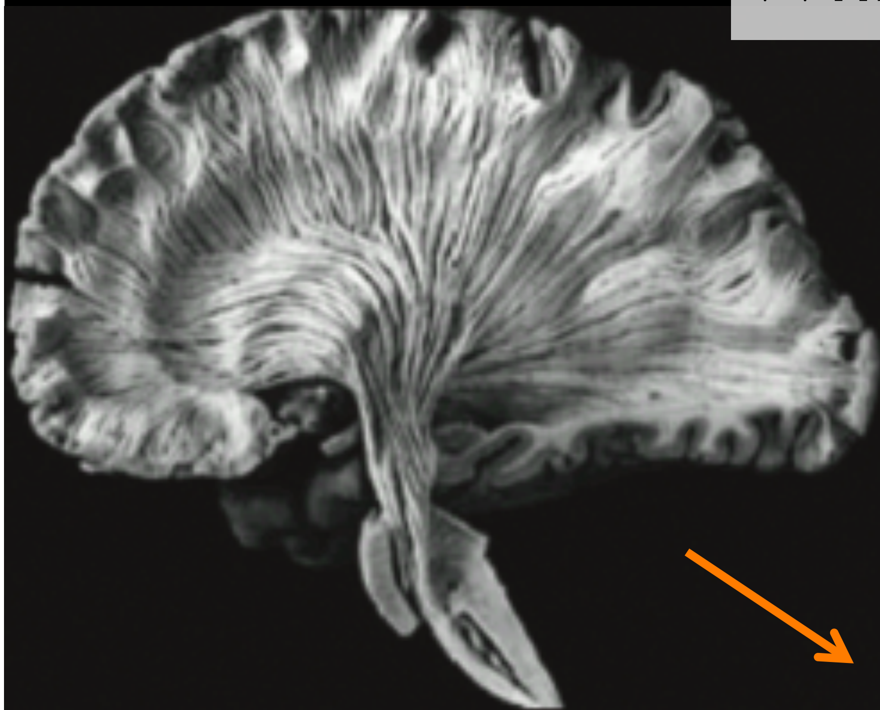
Direction of diffusion is encoded in 3x3 matrix *D* (diffusion tensor)

Principal eigenvector of D

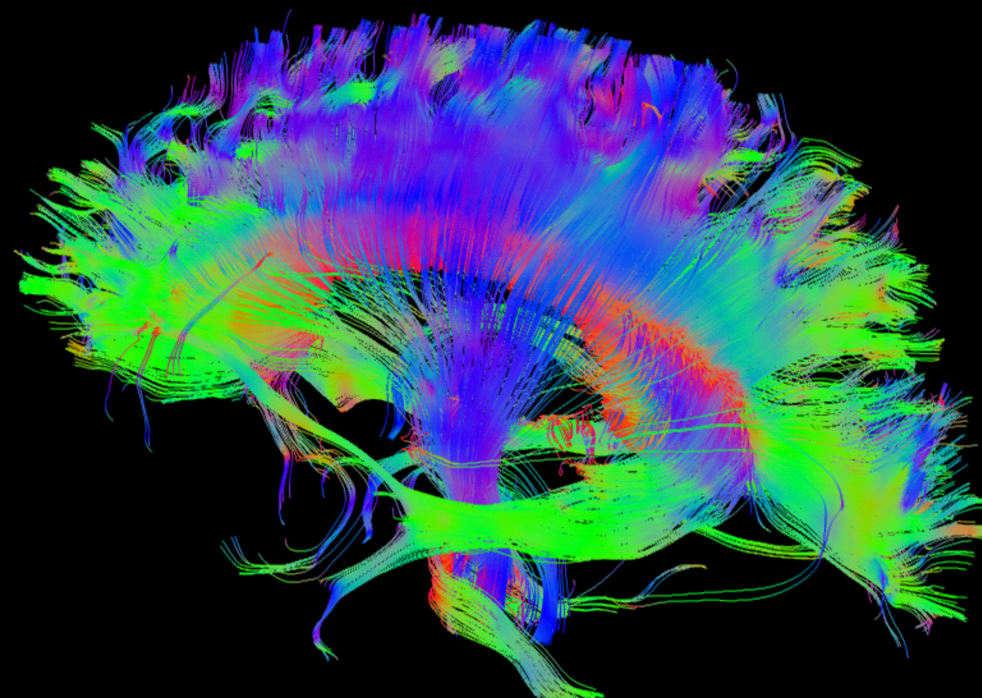


Tractography done using the second order Runge-Kutta algorithm with TEND (Lazar et al., HBM 2003)

White Matter Fiber Tractography



Postmortem

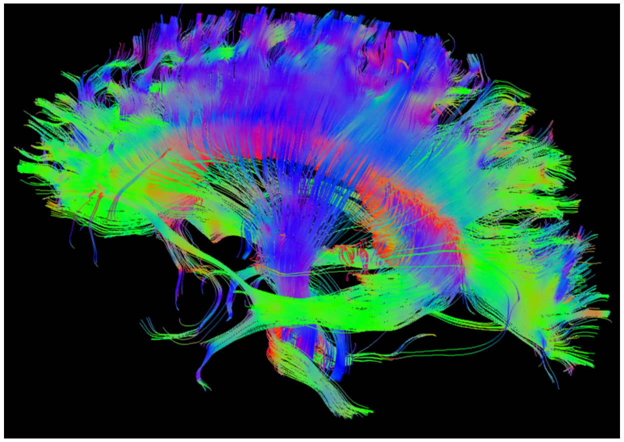


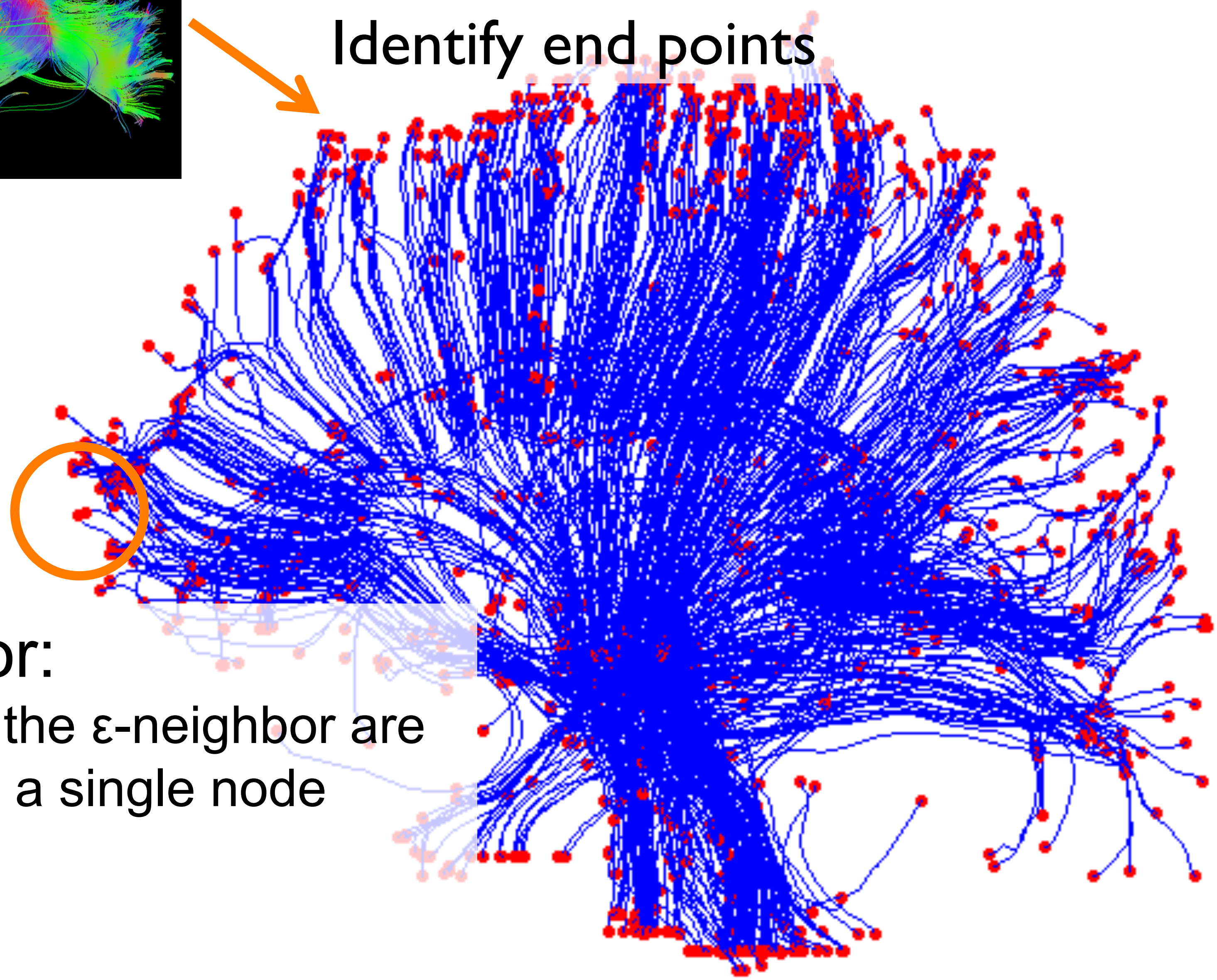
Reconstructed
0.5 million tracts

Structural connectivity in DTI:

Structural connectivity will be explored using graph theoretic approaches.

Graph construction

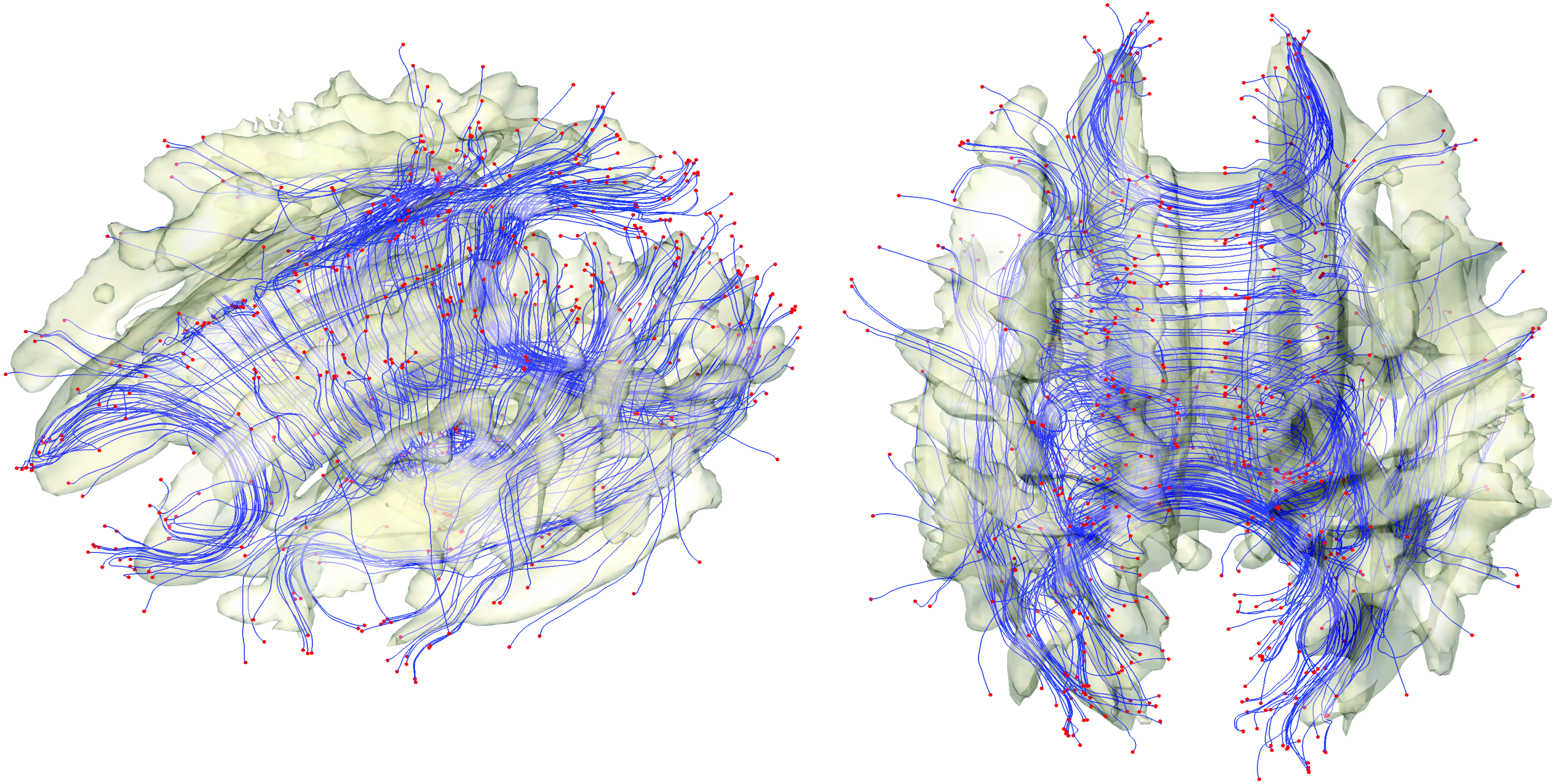




ε-neighbor:

All points in the ε-neighbor are identified as a single node in a graph

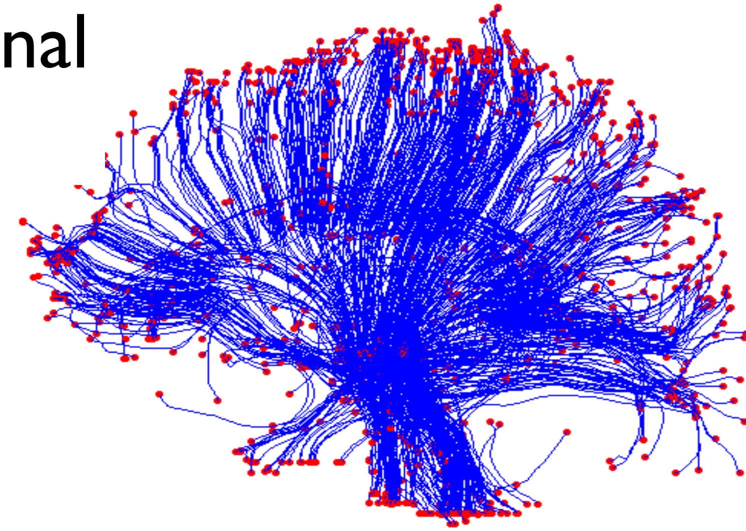
End points of tracts



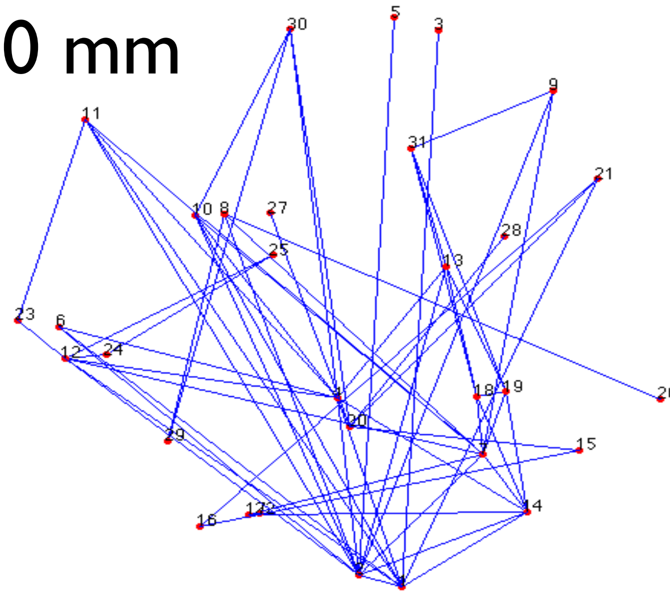
Surface: white matter boundary

ε-neighbor graphs with different ε

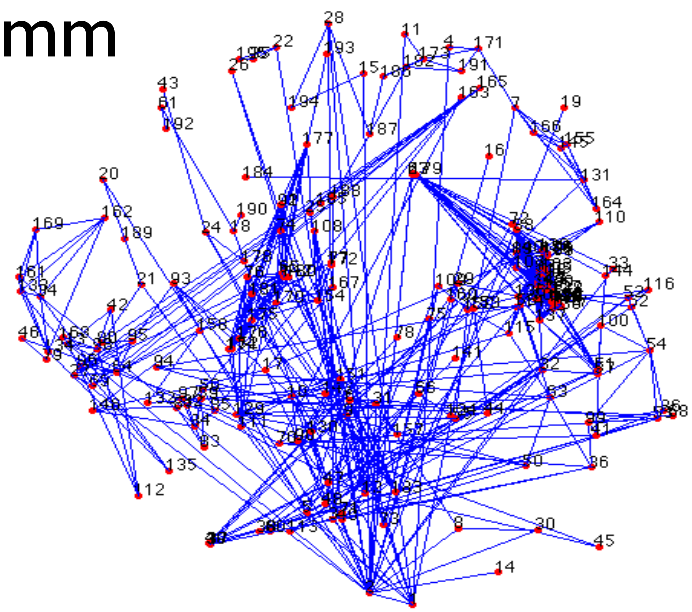
original data



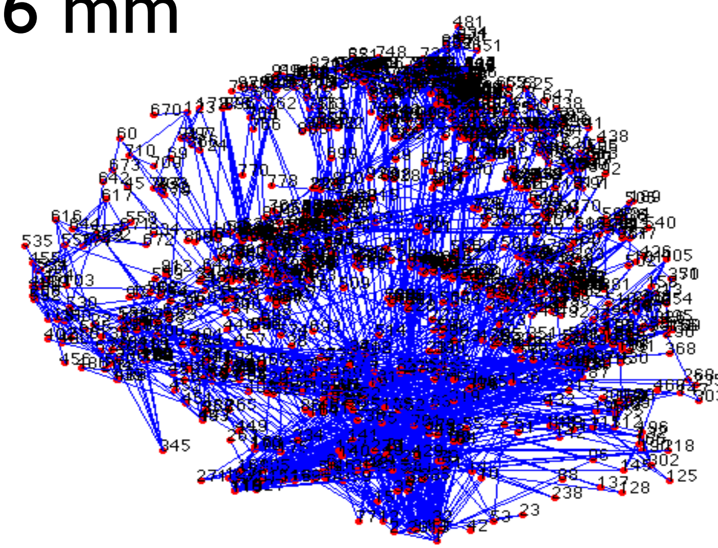
20 mm



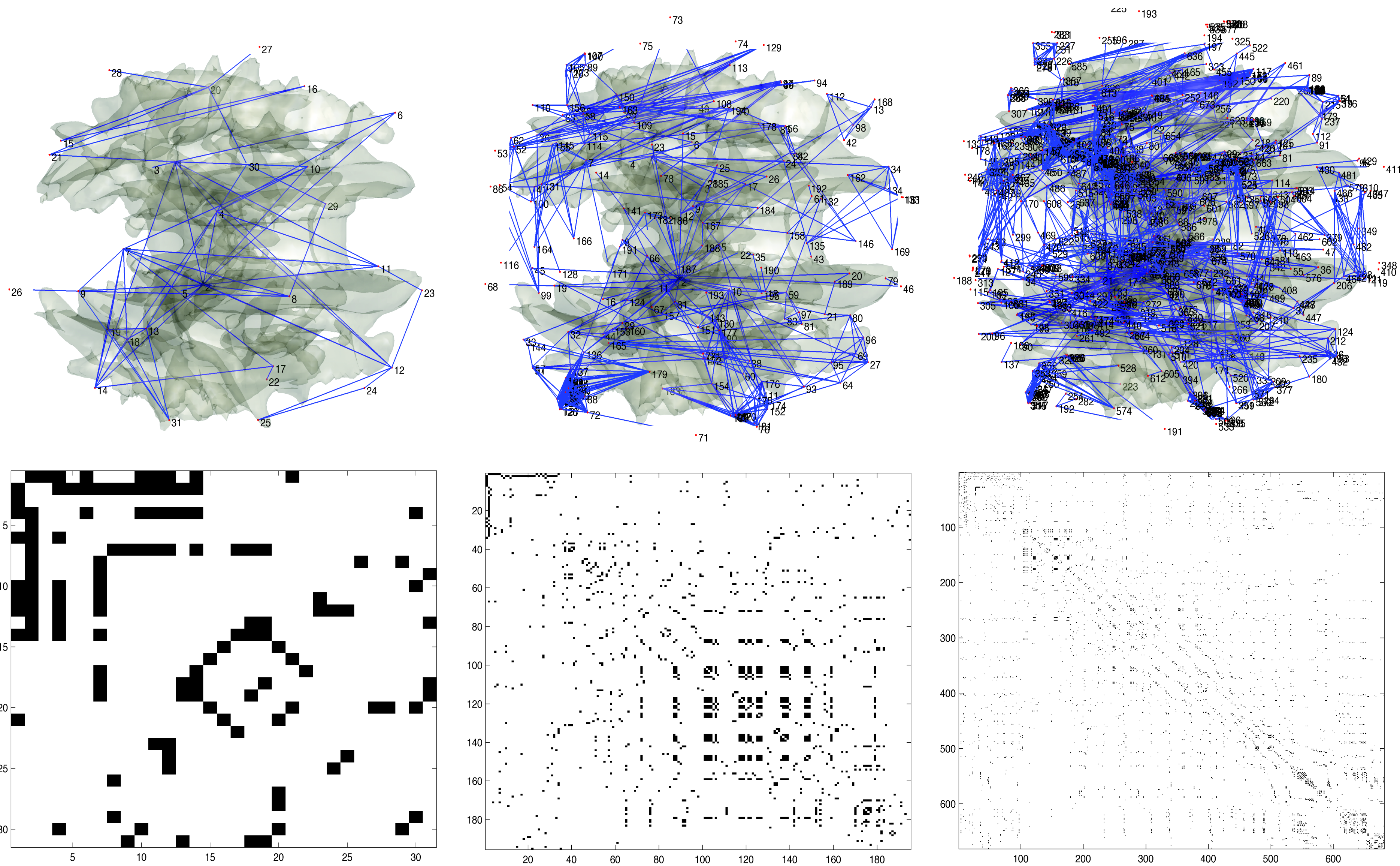
10 mm



6 mm



Adjacency matrix



Application to autism

Autistic children (n=17)

Control subjects (n=14)

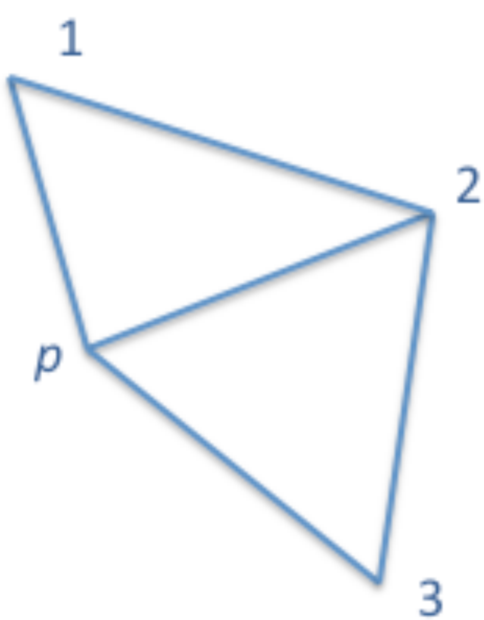
Matched for age, handedness, IQ and head size

Clustering coefficient

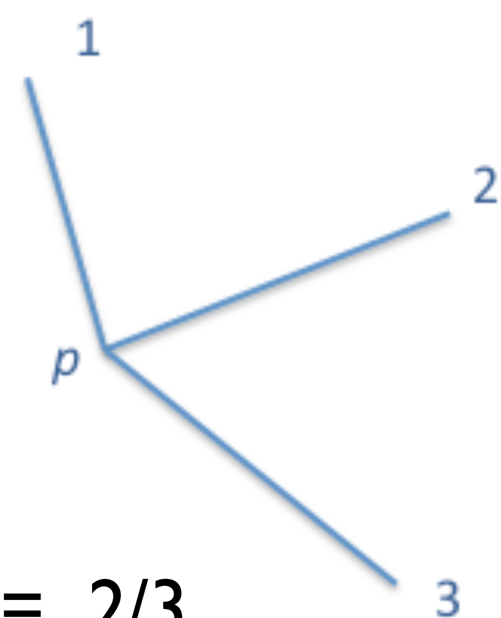
Newman et al., (2001)

At a given node *p*, there are *k* number of neighboring nodes.

$$c(p) = \frac{\text{actual number of edges}}{k(k-1)/2}$$

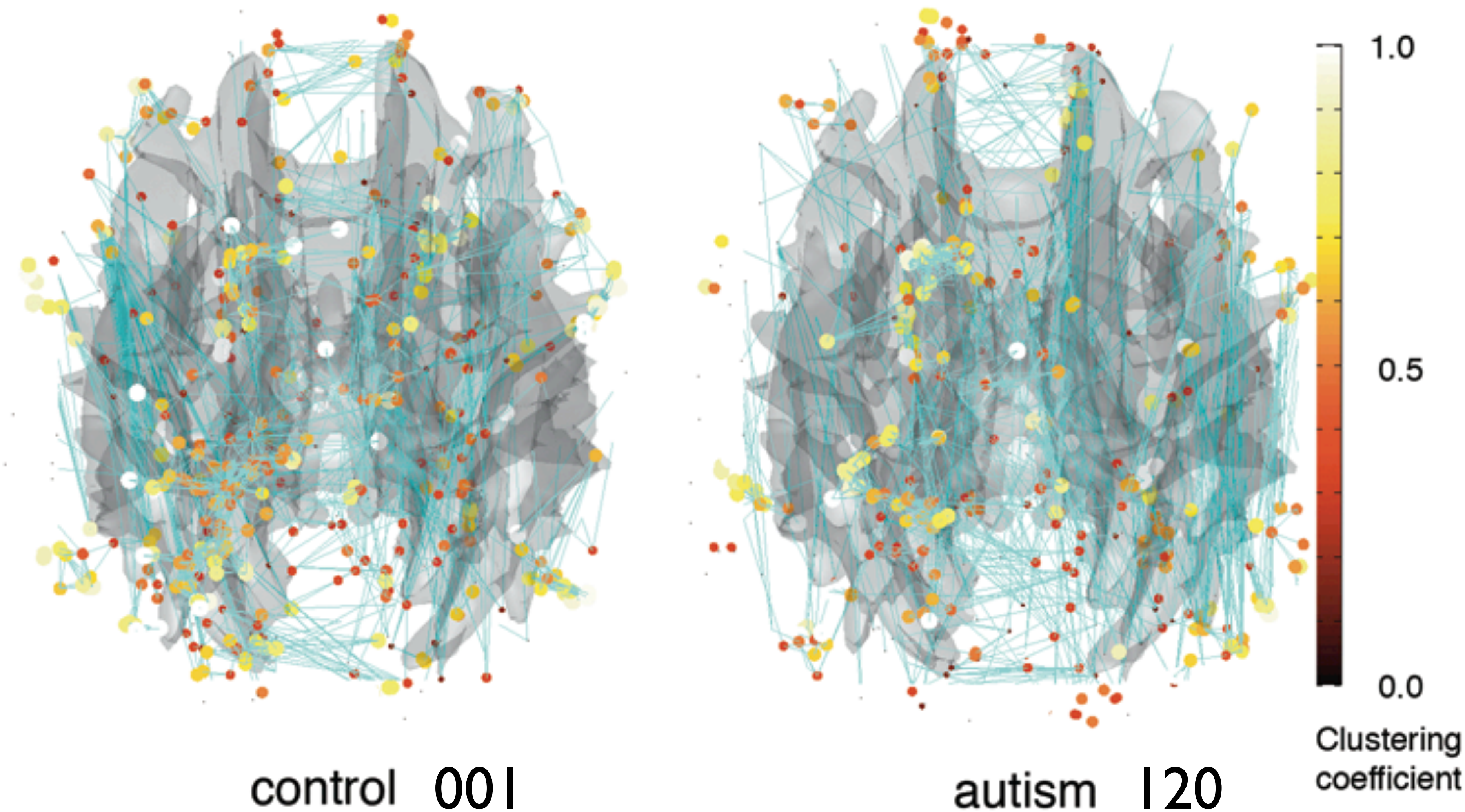


C(p)= 2/3

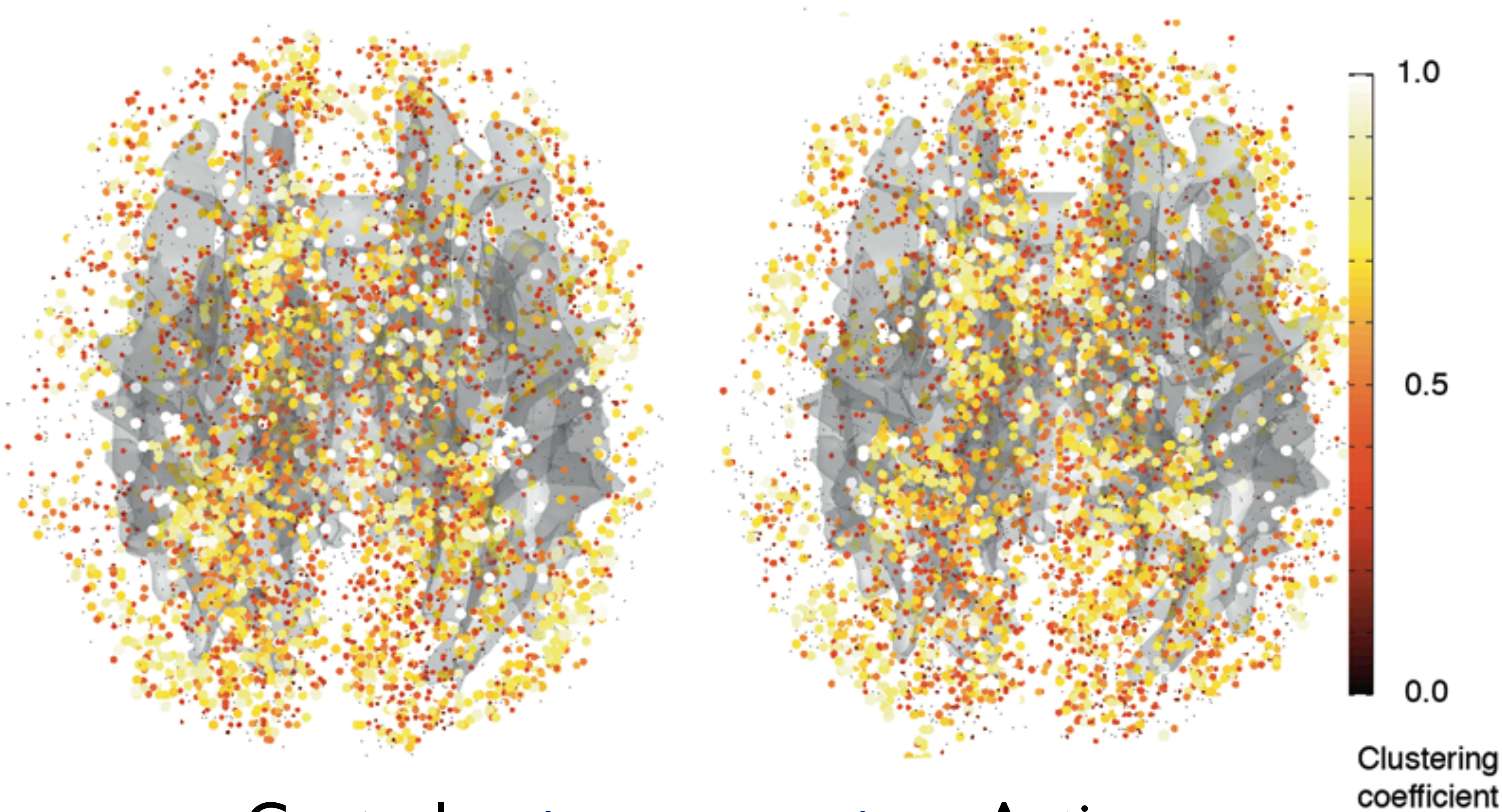


C(p)=0/3

Clustering coefficient



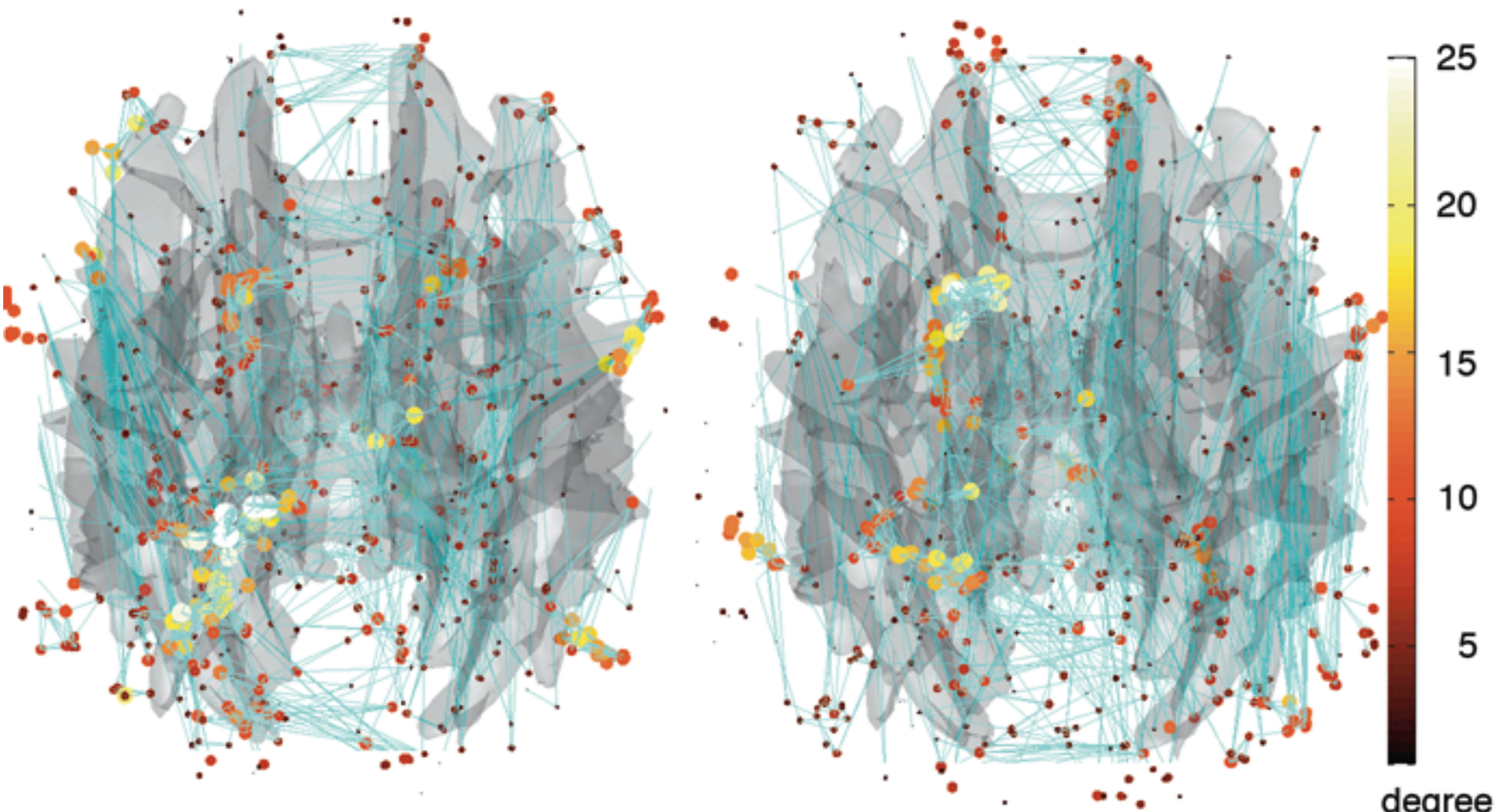
Clustering coefficients for all subjects



Control ⟷ Autism

No group difference

Degree of nodes: measure of local network complexity

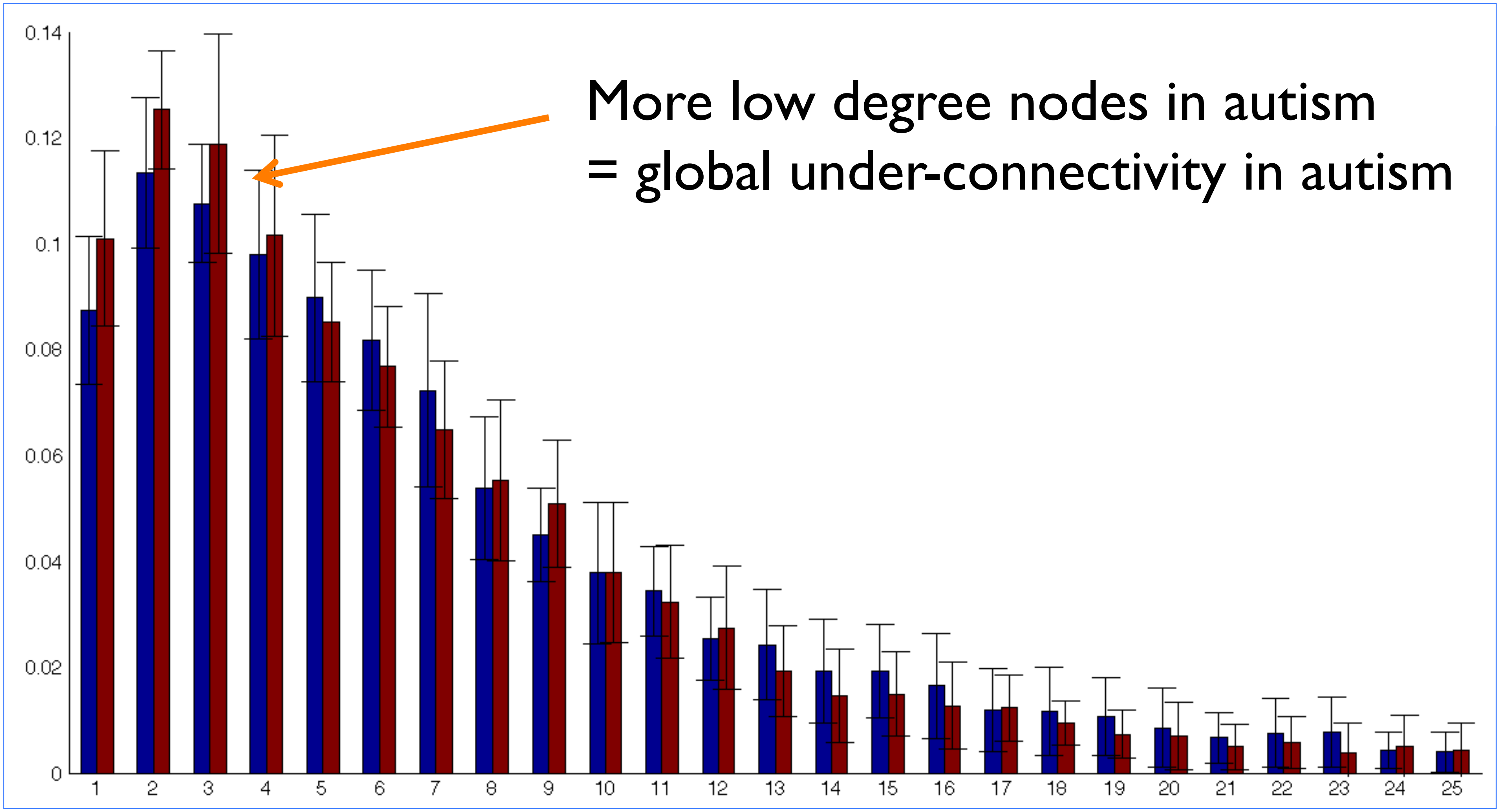


control #001

autism #120

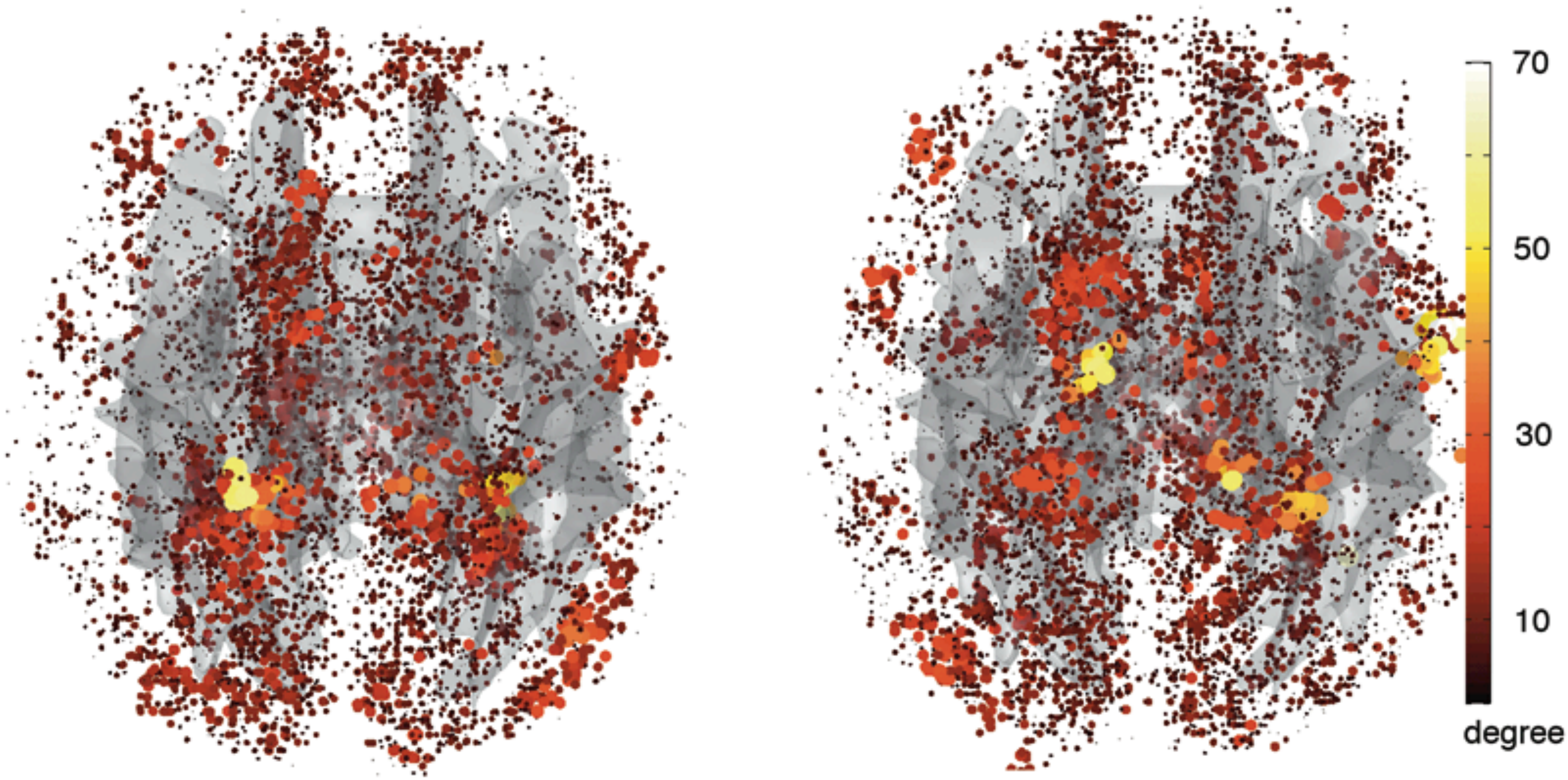
Global degree distribution

red: autism
blue: control



pvalues = 0.024, 0.015 and 0.080 for degrees 1, 2 and 3.

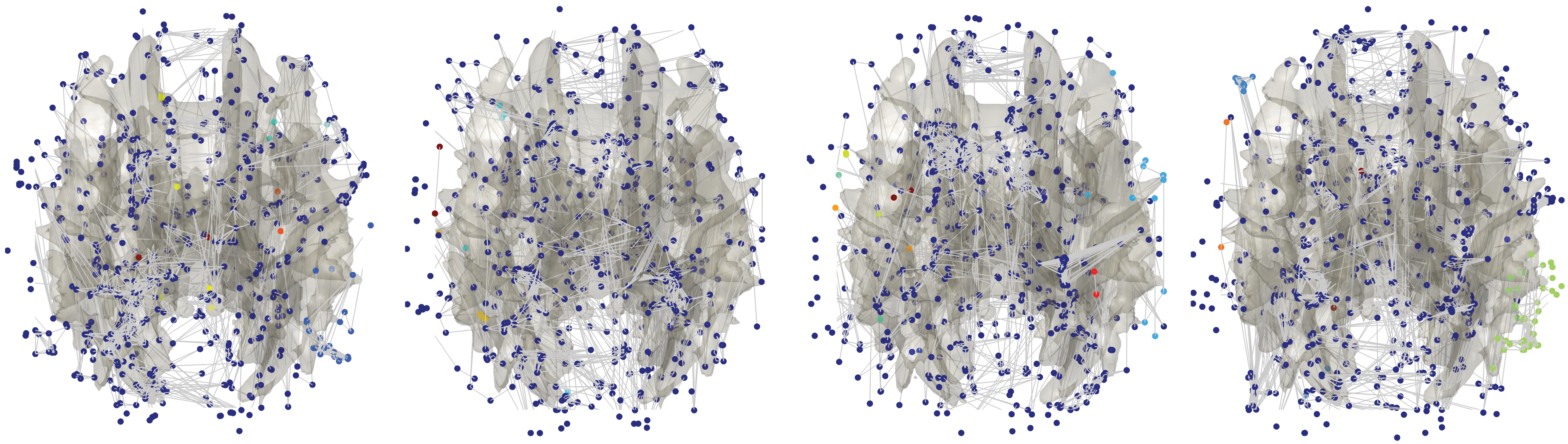
Local degree distribution for all subjects



Control

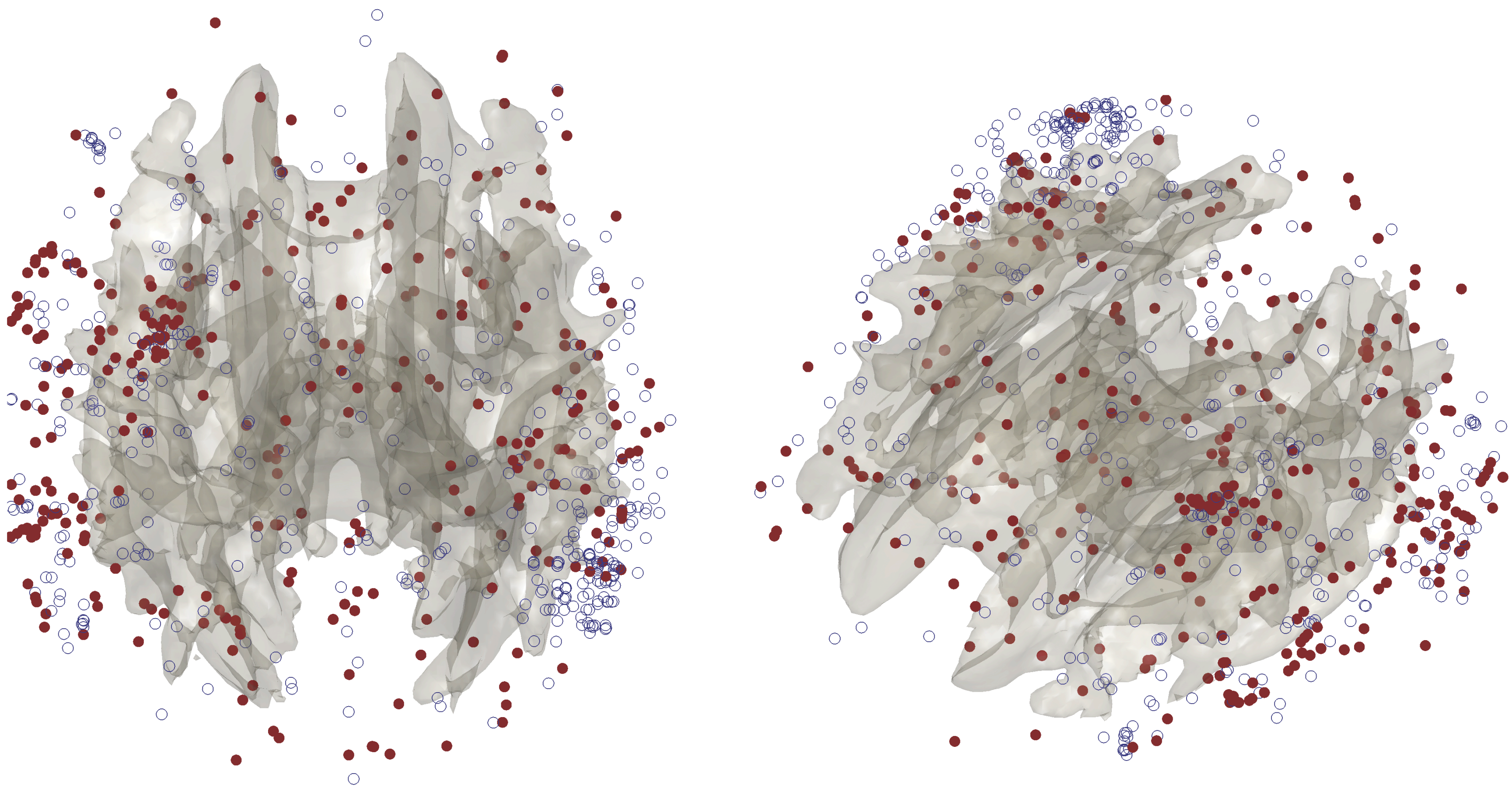
Autism

Largest connected component



In average 96% of all nodes are connected to each other. We believe 100% of all nodes are supposed to be connected. 4% is a processing noise caused by weak connections.

Group difference in disconnected components



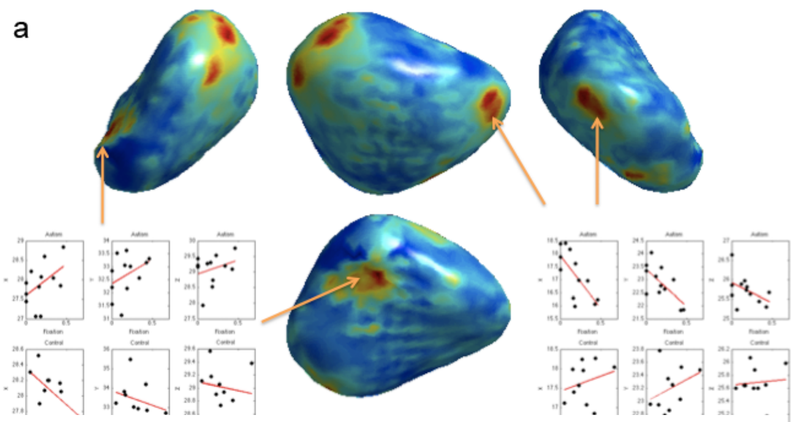
Control=blue
Autism=red

high clustering on the right parietal lobe
(pvalue = 0.01)

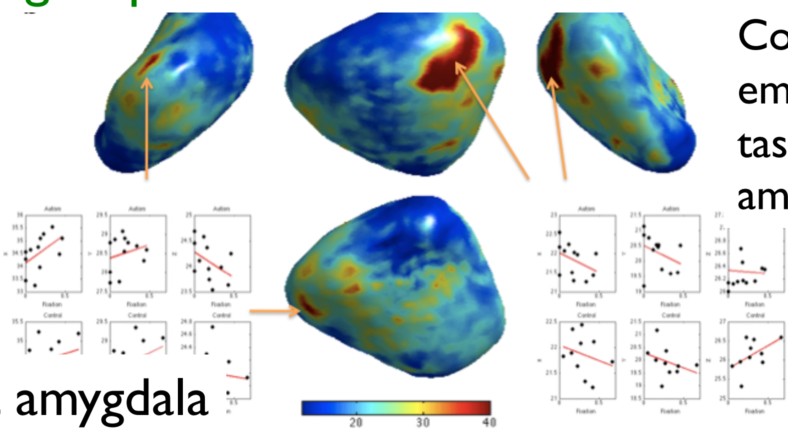
Discussion

Chung et al., Neuroimage 2010

Left amygdala

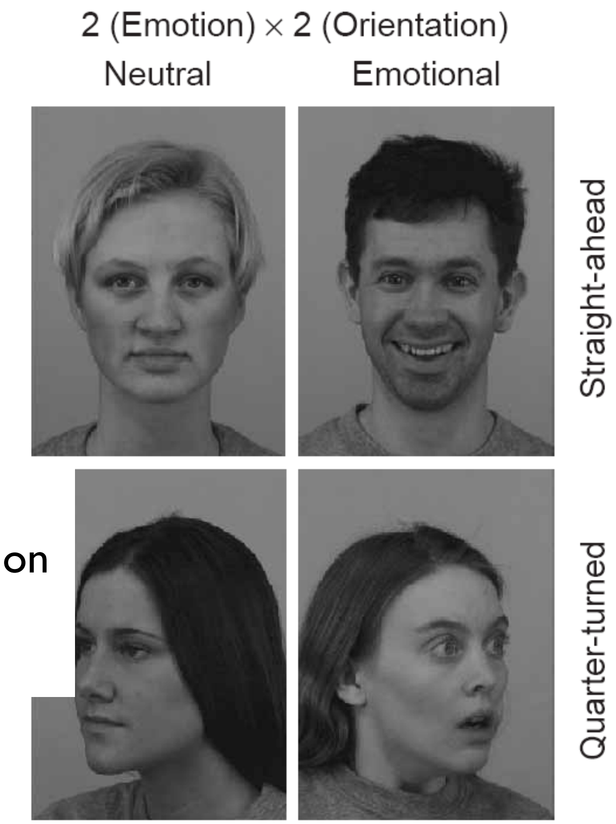


group difference at lateral nuclei



Right amygdala

Correlating facial emotion discrimination task response and amygdala shape



Amygdala networks correlated with behavioral measures

Thank you