Vulnerability of the structural connectome to stroke in older adults

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Background

- Lesions in particular locations have disproportionate effects on brain function
- Strategic infarctions – lesions of critical points in functional networks for movement and cognition
- Strategic lesions might disrupt global properties of the brain's connectome

The brain as a network

Graph theory tools allow us to investigate complex properties of brain networks (Rubinov & Sporns, 2010)

Connectome – the wiring diagram of the brain

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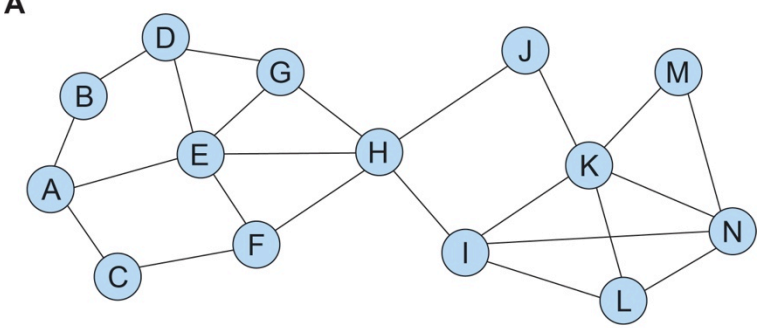

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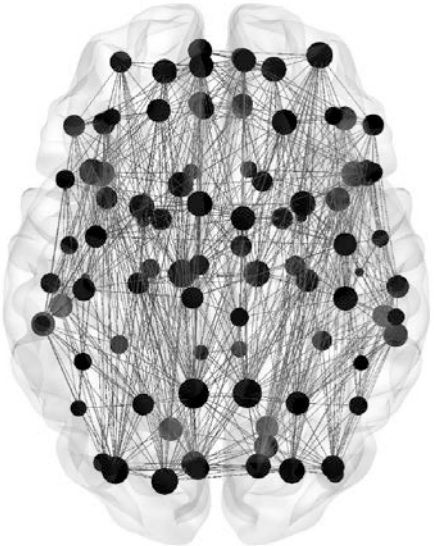
The brain as a network

Network elements:

- Nodes
- Edges

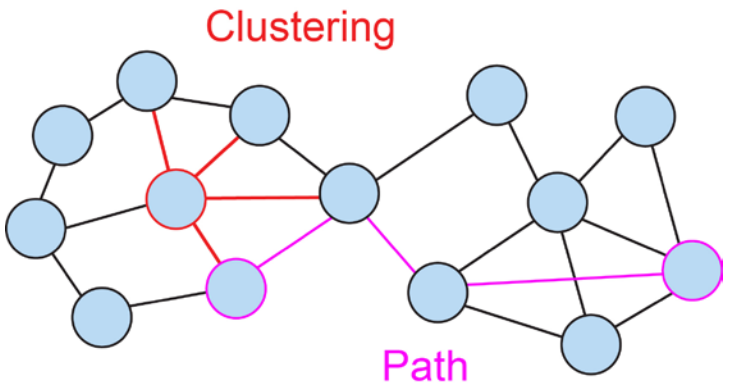


Two groups of network measures:

- Measures of network integration

- Measures of network segregation

  (Rubinov & Sporns, 2010)



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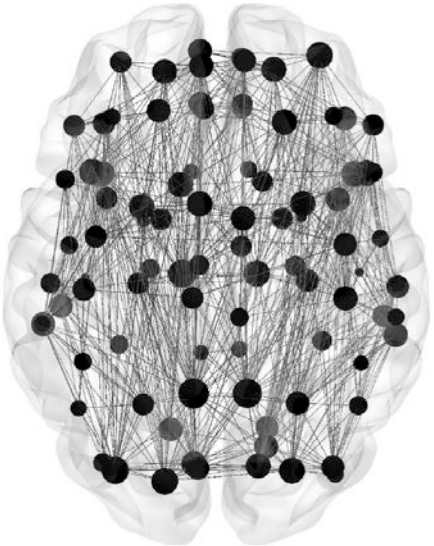

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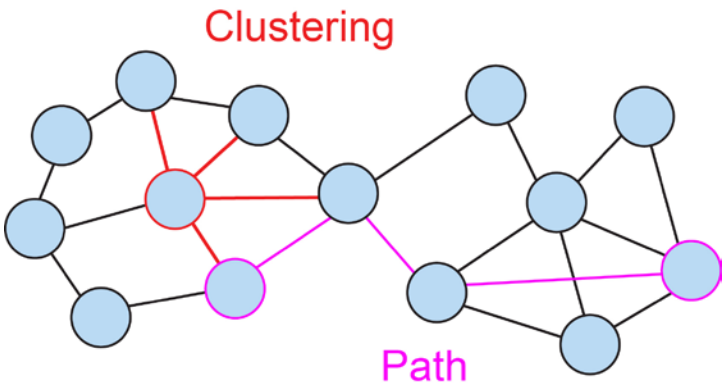

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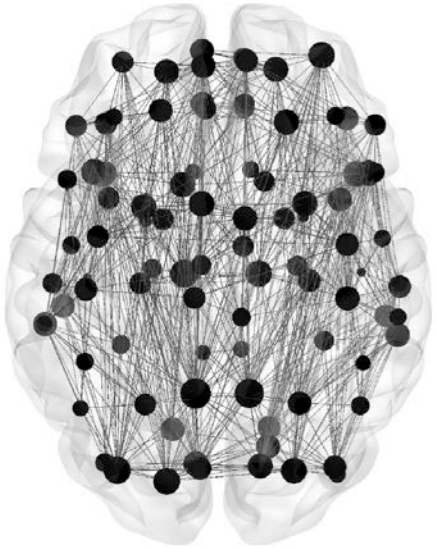

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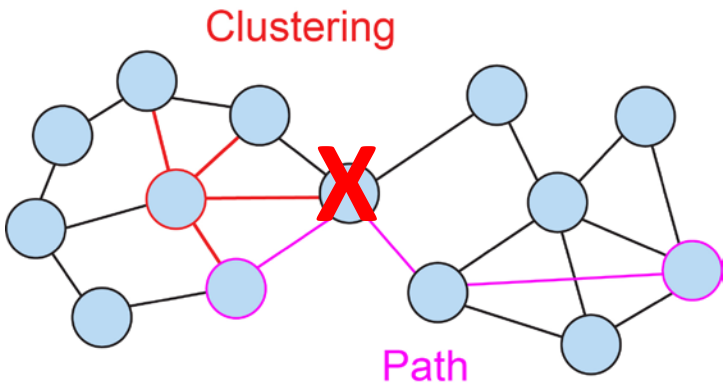

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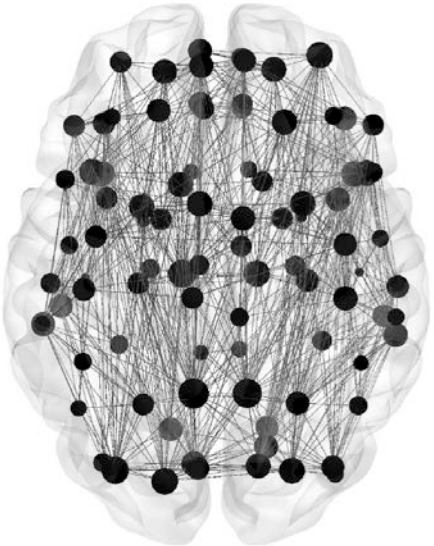

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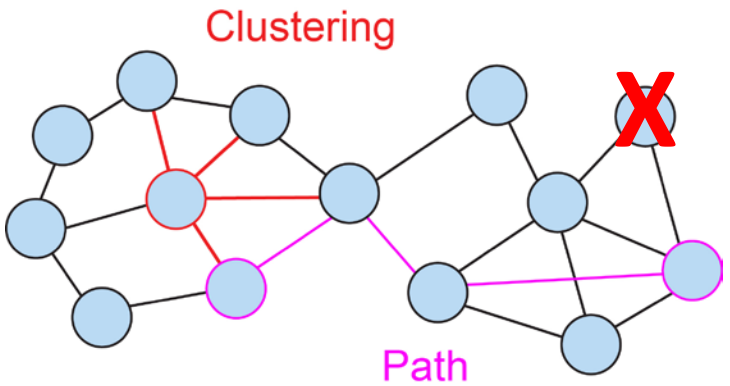
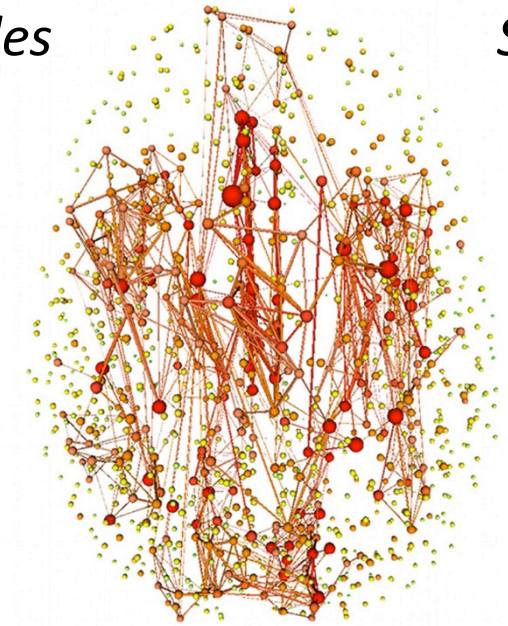


Aim

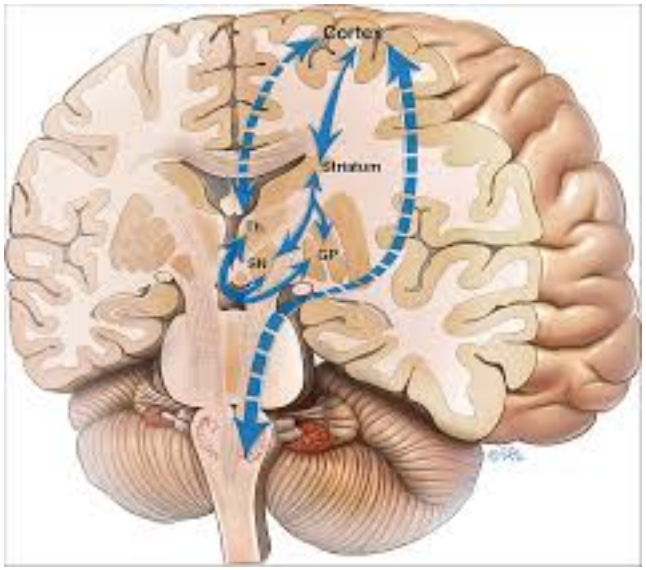
- To examine the effect of simulated lesions on the global properties of the structural connectome

- Effect of lesions in two sets of locations:

Rich-club nodes



Subcortical nodes



Methods

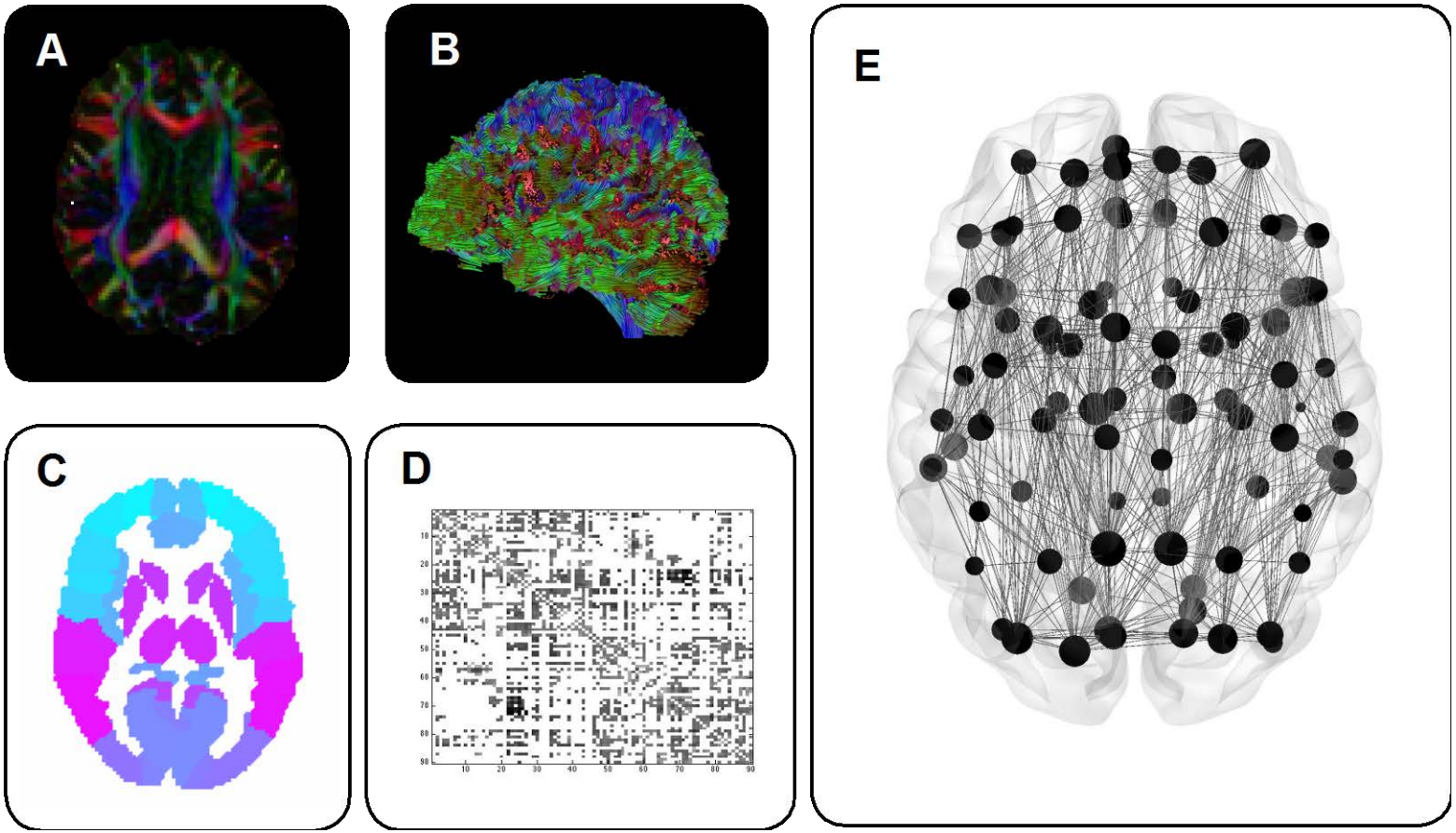
- 39 healthy older adults, aged 53-93 yrs.
- Exclusion criteria: moderate/severe head injury; history of alcohol or drug abuse; previous stroke; known peripheral, cervical or coronary artery disease; heart failure; report of previous memory symptoms; contraindications to MRI

- Diffusion-weighted MRI: 3T GE HDx system, twice refocused spin-echo EPI sequence, 2.4 mm isotropic voxels, TE = 87 ms, b = 1,200 s/mm^2, 30 isotropically distributed directions, 3 non-diffusion-weighted scans

- Whole-brain tractography: deterministic tracking algorithm, step size 1.0 mm, FA threshold 0.15, angle threshold 45°

Methods

- Construction of the connectome



Methods

- Lesion simulation: removing a node and its connections from the graph

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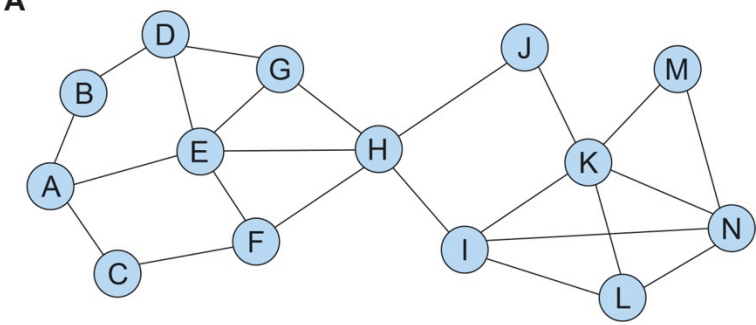

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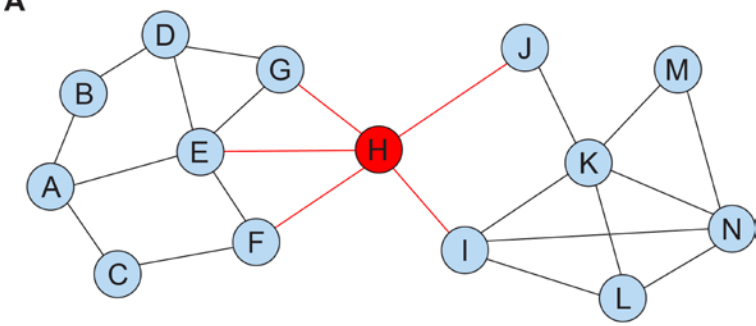

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Methods

- Lesion simulation: removing a node and its connections from the graph
- Proportional change in global efficiency
- Comparison between sets of nodes and correlation with age

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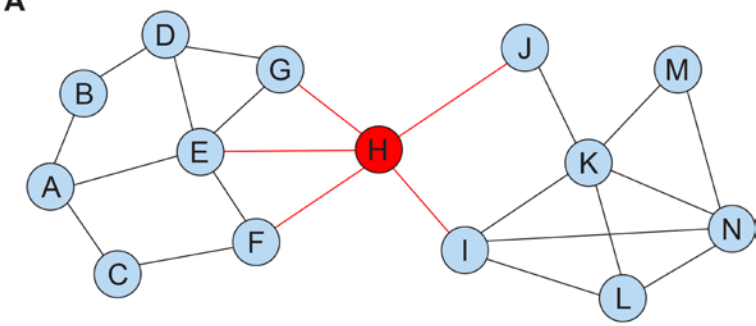

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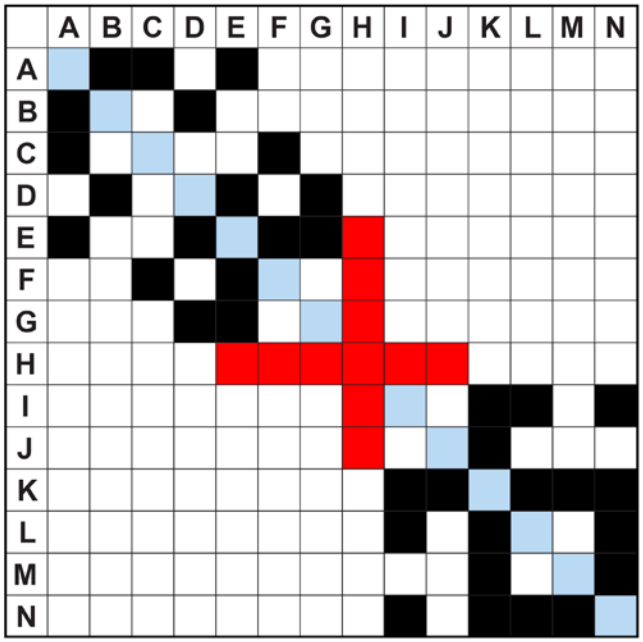
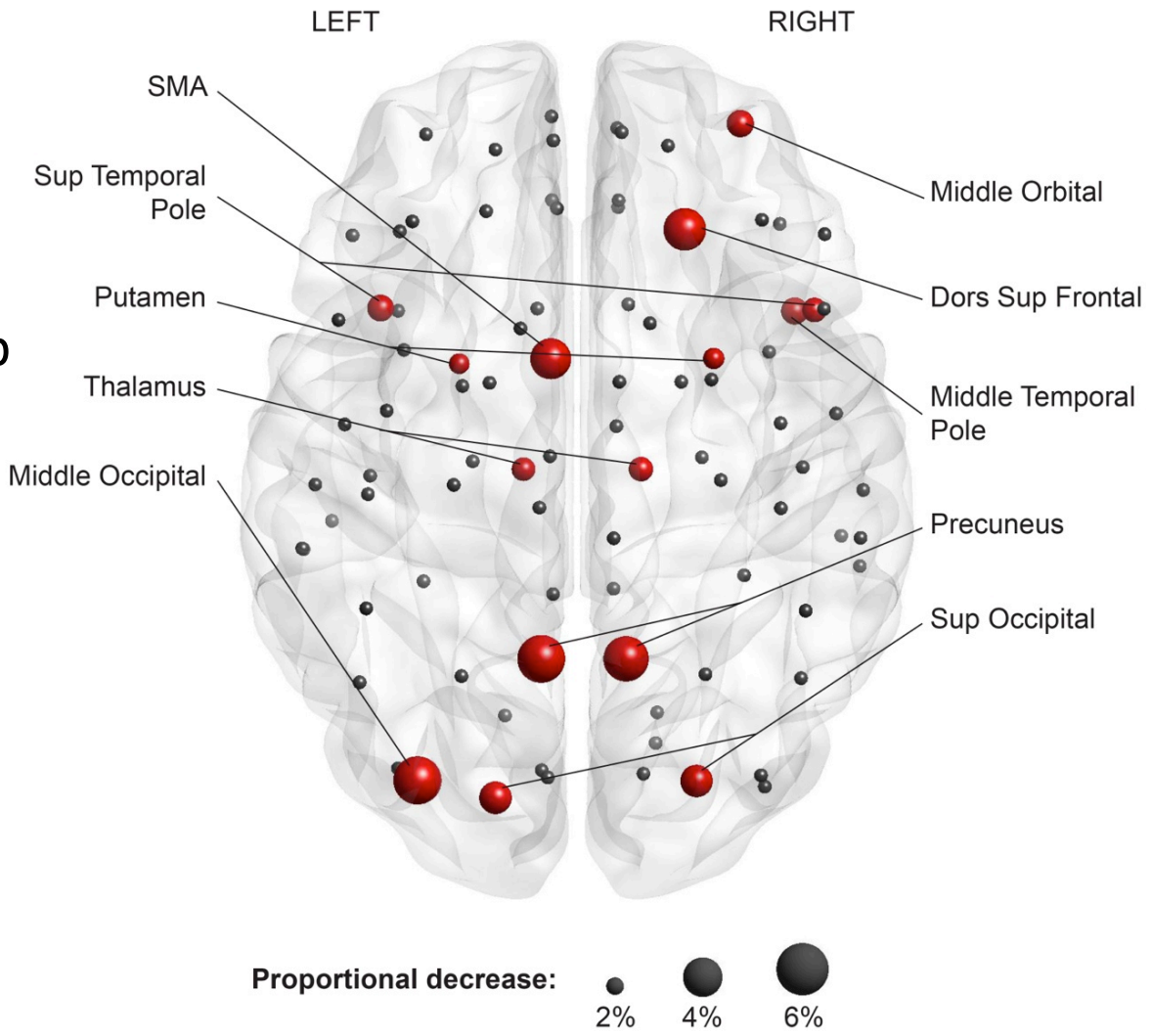


Results

Lesions of rich-club nodes lead to **larger reductions** in global efficiency than lesions outside the rich club (t=21.0, p < .001).

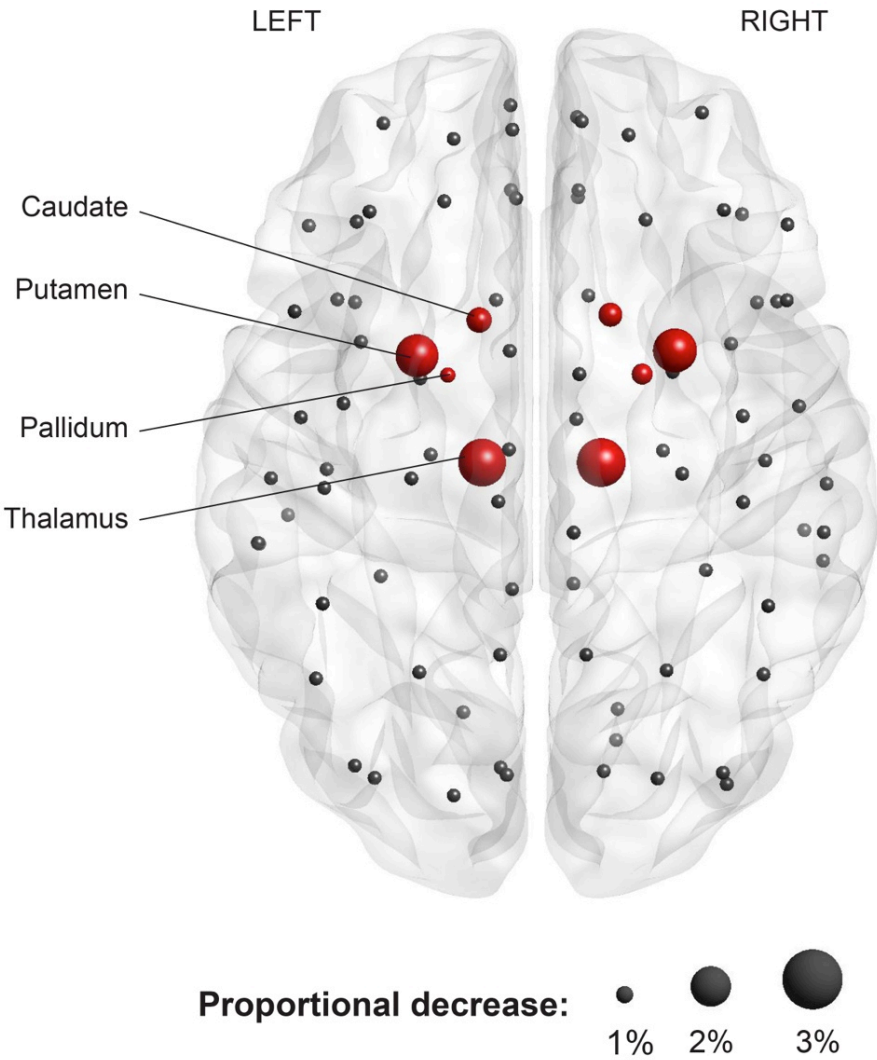
Lesions of both **precunei** produce the largest effect.



Results

Lesions of both **thalami** produce the largest effect of the subcortical nodes examined.

Their effect is smaller than for cortical hubs (2.7% vs 6.2% for precunei).



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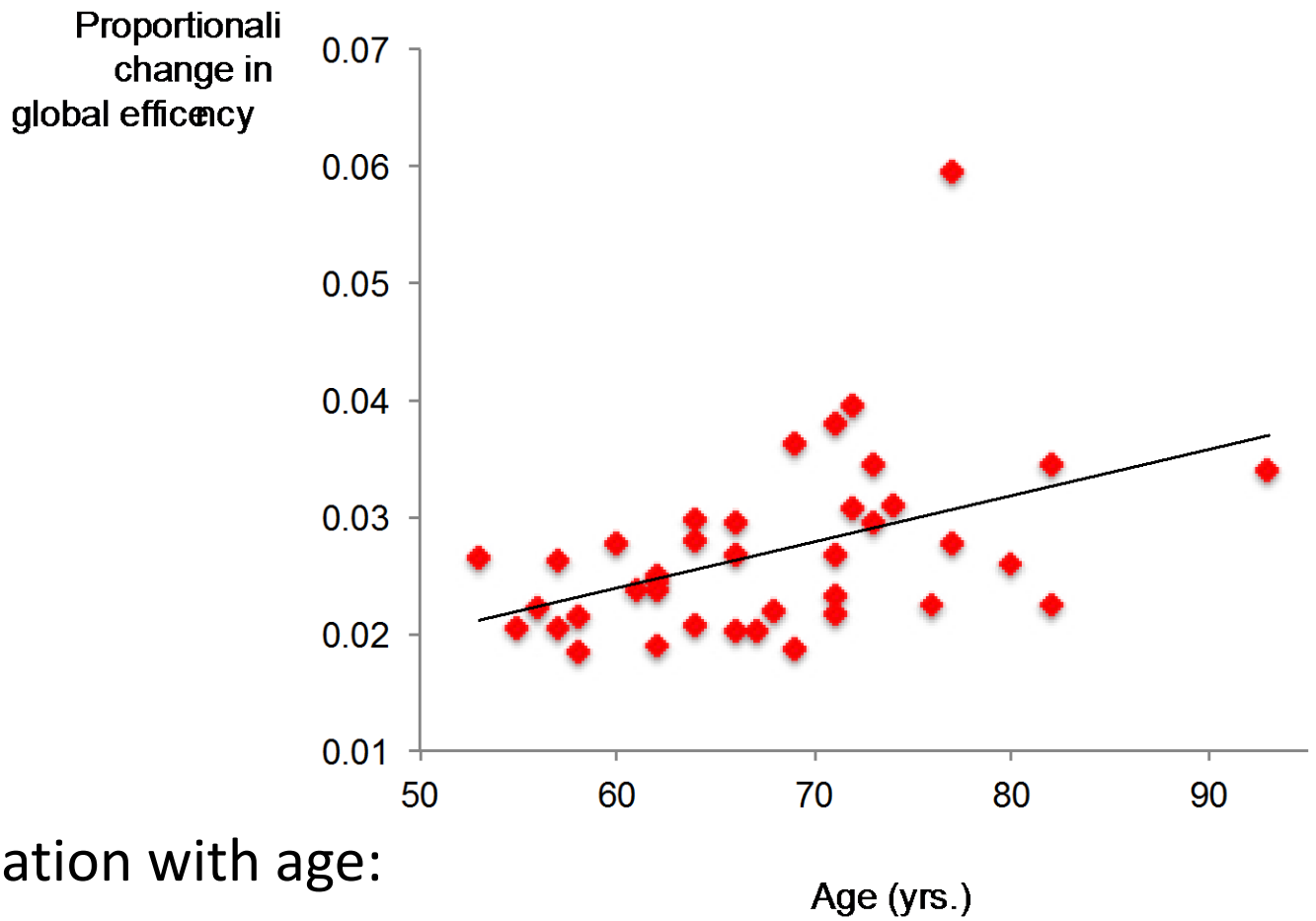

Positive correlation with age:

- right thalamus (r = .463, p = .003)
- left thalamus (r = .337, p = .036)
- right temporal superior pole (r = .363, p = .023)

Discussion

- Structural connectome of healthy individuals over 50 is vulnerable to strategic lesions of rich-club nodes.
- Some vulnerable sites are rarely affected by stroke in practice.
- Thalamic lesions have a large global impact that increases with age. This is likely a factor in the influence of age on stroke outcome.

Acknowledgments

Michael J O'Sullivan

Nicola J Ray

Claudia Metzler – Baddeley

Derek K Jones

Zvezdan Pirtošek

Blaž Koritnik

members of the Research Unit

THANK YOU FOR YOUR ATTENTION!