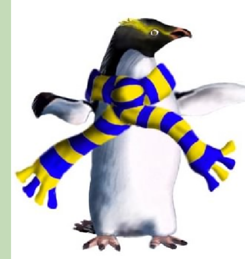
Effect of aging and dementia on functional connectivity: graph theoretical analysis of fMRI data

Paul McCarthy, Lubica Benuskova and Elizabeth Franz
University of Otago, Dunedin, New Zealand

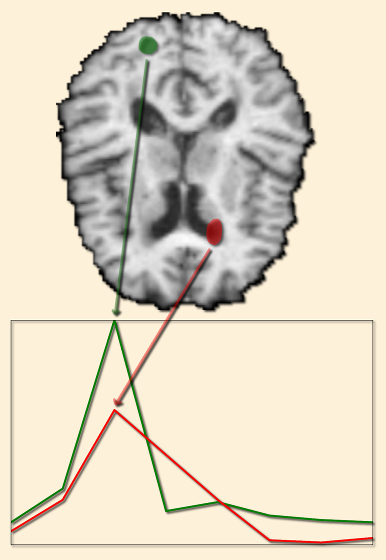


Introduction

Graph theory is becoming a popular approach for the analysis of functional connectivity in the brain. In this poster we present our approach to the analysis of functional connectivity in fMRI data, and results from such an analysis, comparing healthy young and aged subjects with subjects suffering from mild Alzheimer's disease.

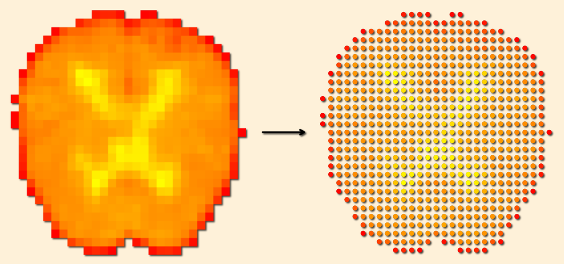
Functional connectivity

fMRI allows us to measure the ratio of oxygenated to deoxygenated blood throughout the brain. From this ratio, we may infer neural cell metabolism and thus overall neural activity. If two areas of the brain exhibit similar neural behaviour over a period of time, they are said to be *functionally connected*.



Graph creation

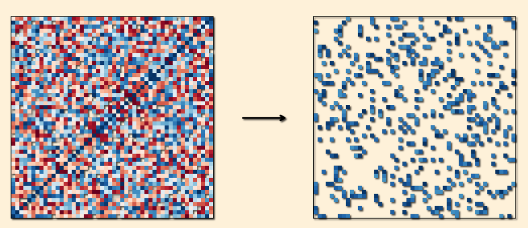
Every voxel in the fMRI volume is included as a node in a graph:



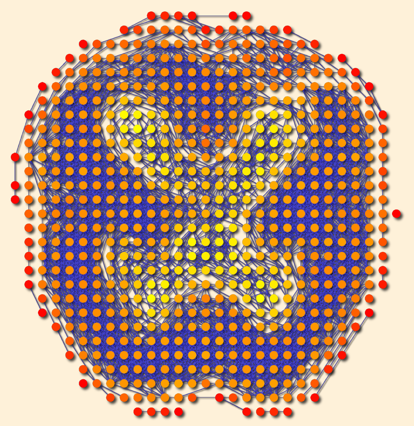
Pearson's Correlation Coefficient is calculated upon the time series for every pair of voxels:

$$r(x,y) = \frac{\sum(x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2\,\sum(y_i - \bar{y})^2}}$$

The absolute values of the resulting correlation matrix are thresholded to remove any weak relationships:



Edges are added to the graph, representing strong temporal correlation between pairs of voxels:

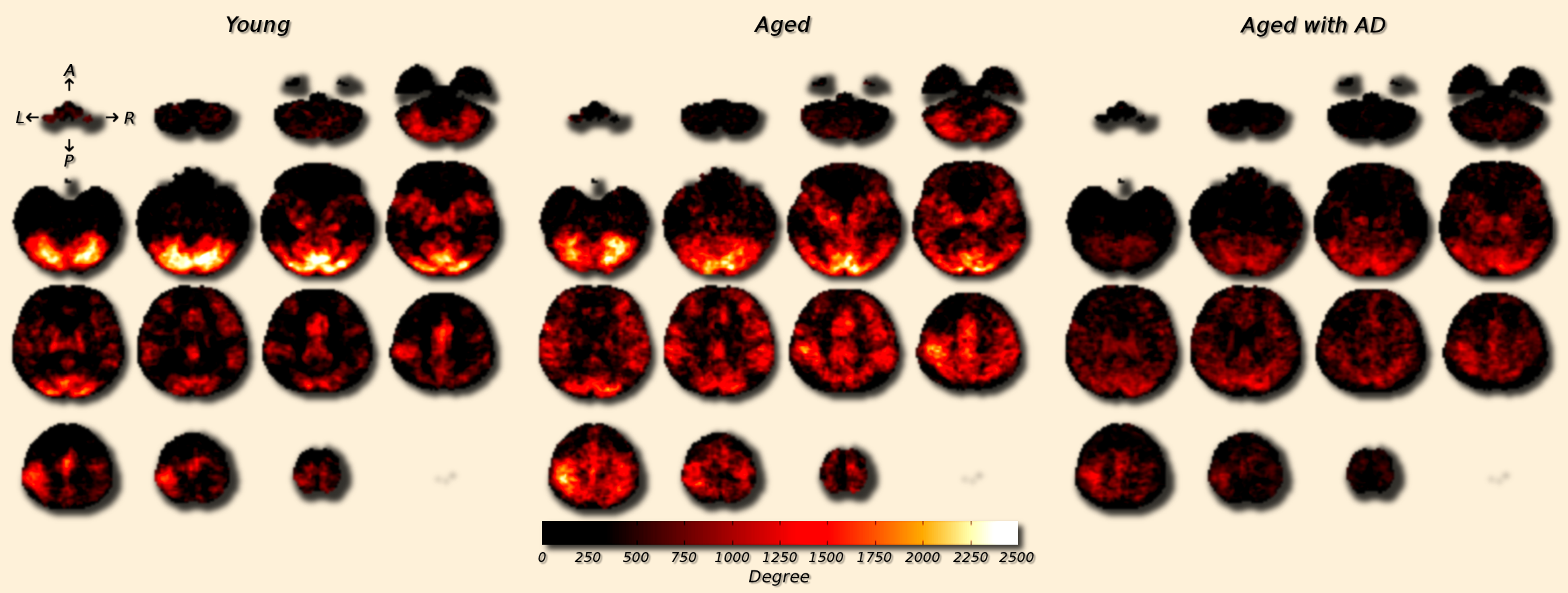


Aging and Alzheimer's disease

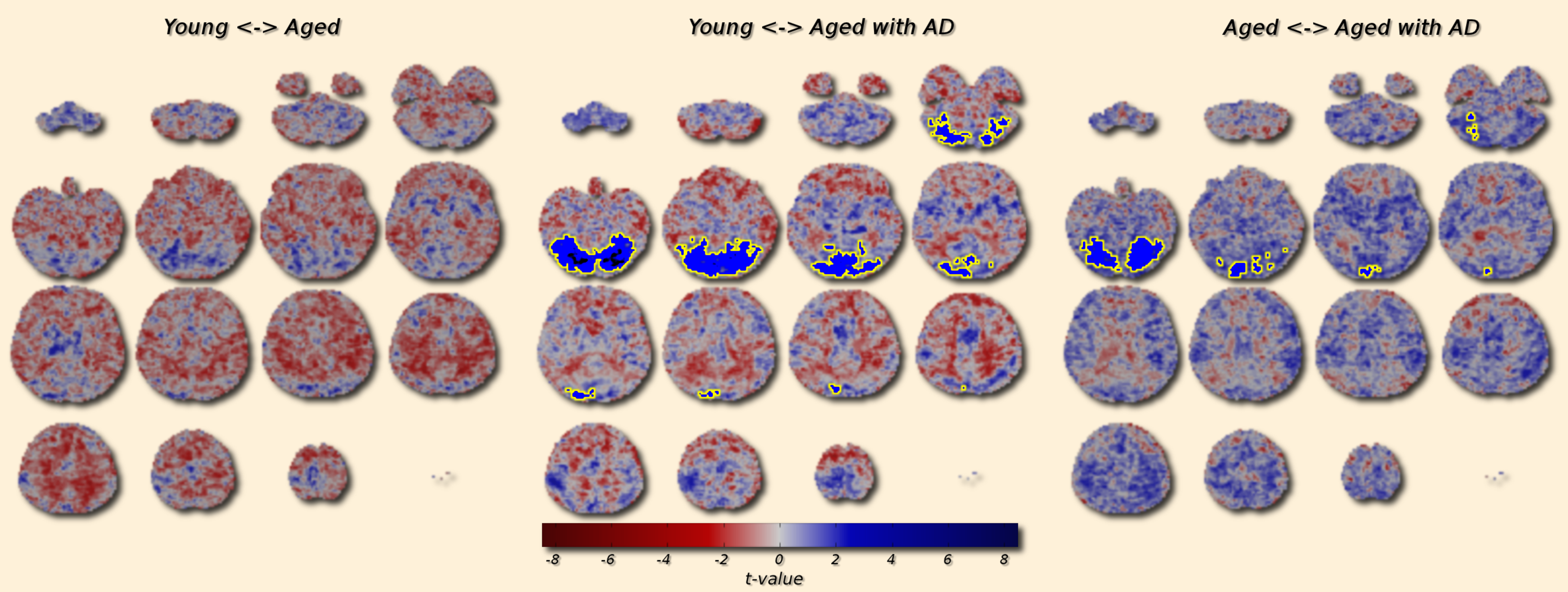
We used a data set from Buckner et. al. (2000) to discover how functional connectivity in the brain changes with aging and Alzheimer's disease. fMRI scans were taken from 40 subjects: 14 classed as *Young*, 14 as *Aged*, and 12 as *Aged with AD*. The experiment consisted of a visual stimulus triggering right hand motion. We applied slice timing and motion correction, high pass temporal filtering, and alignment to the ICBM452 standard template before applying graph theoretical analysis.

Voxelwise analysis

Shown below is the mean number of connections at each voxel in each of the three groups. Across the groups, high levels of connectivity are present in the occipital lobe, and sensorimotor region of the left hemisphere. It is likely that this is task-related, given the nature of the experiment.



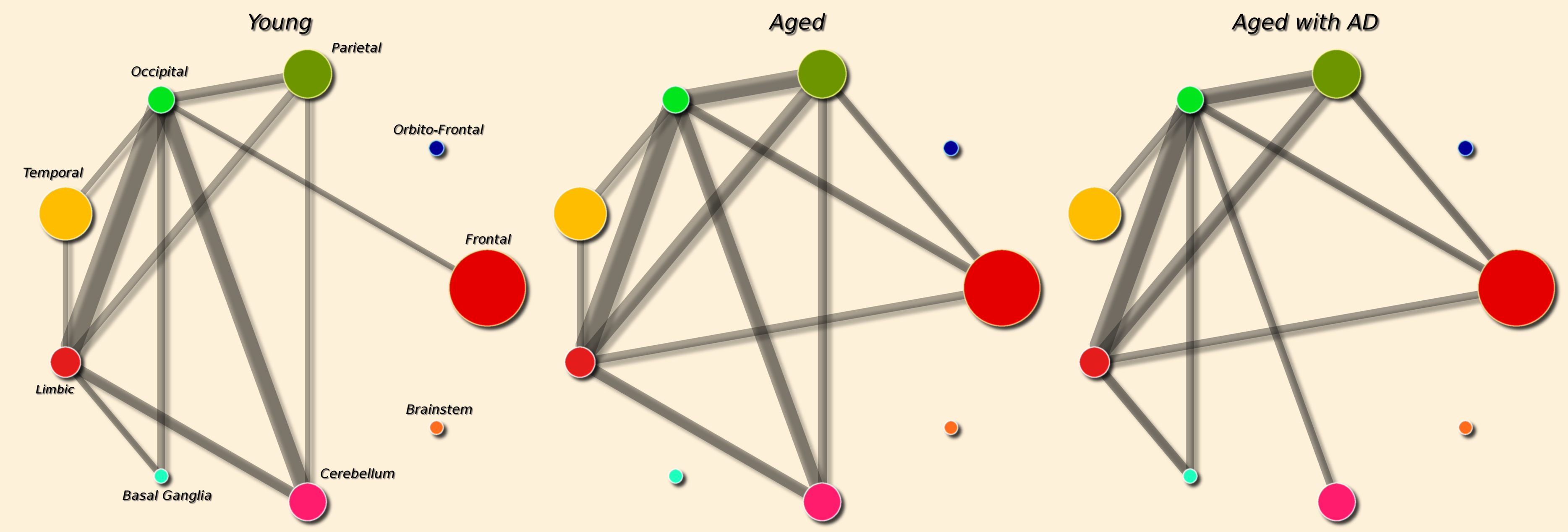
A two-sample t-test between each pair of groups shows a decline in occipital lobe connectivity in the Aged with AD group when compared with both the Young and Aged groups. The regions highlighted with a yellow border were found to be significantly different ($\alpha \leq 0.05$) after applying non-parametric TFCE multiple comparisons correction.



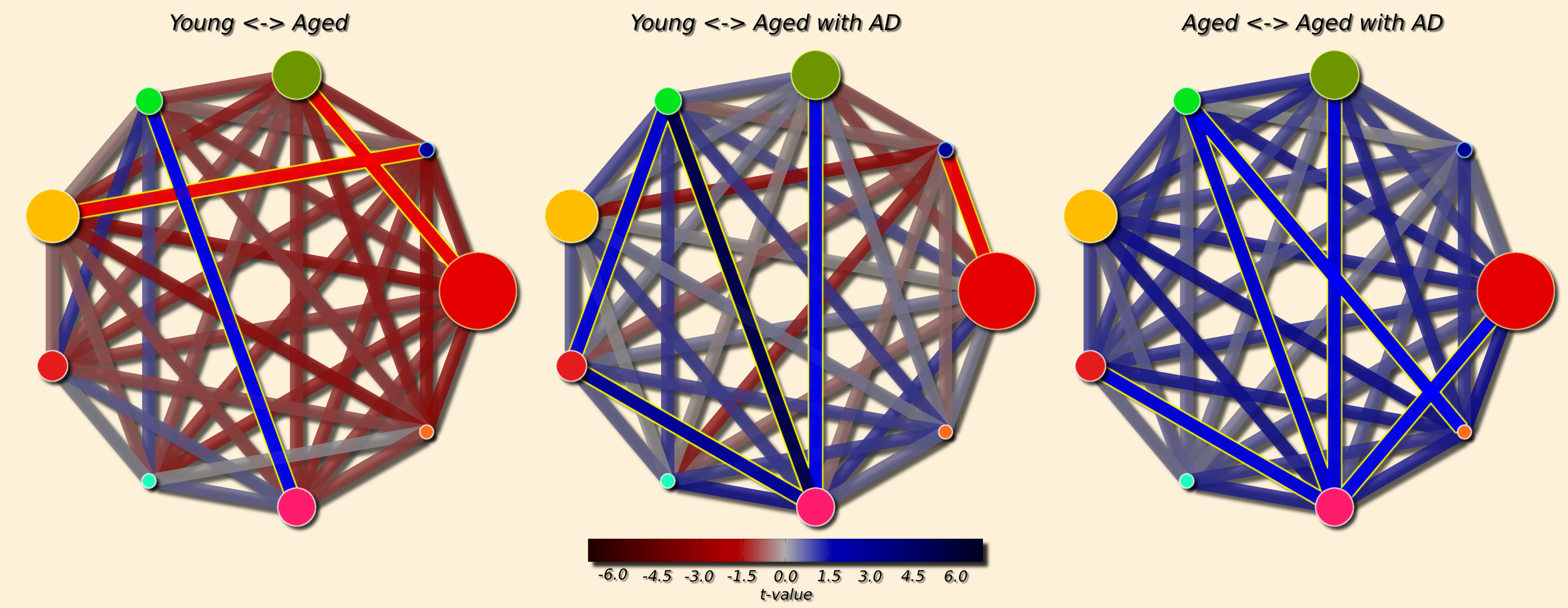
Other interesting trends are apparent: the Young group exhibits increased connectivity in the task related regions, but reduced connectivity elsewhere, when compared with the other groups. The Aged group exhibits increased connectivity throughout most of the brain when compared with the other groups.

Regional analysis

By counting the number of connections between different regions, we can reduce the networks down for regional analysis. In the networks below, the radius of each node is proportional to the number of voxels in that region. Similarly, the width of each edge is proportional to the number of connections between corresponding regions (only the strongest edges are shown). Strong connectivity is present in each of the groups between the occipital, limbic, and parietal regions. The cerebellar region is also strongly connected in the Young and Aged groups; cerebellar connectivity is weaker in the Aged with AD group.



In the networks shown below, the edges highlighted in yellow were found to be significantly different in connectivity ($\alpha \leq 0.05$) when each pair of groups was compared with a two sample t-test. The Young group exhibits reduced connectivity between the parietal and frontal, and the temporal and orbito-frontal regions, but increased connectivity between the occipital and cerebellar regions, when compared with the Aged group. Increased connectivity between the occipital, limbic, and cerebellar regions are also present in the Young group when compared with the Aged with AD group. Finally, widespred declines are present in the Aged with AD group when compared with the Aged group, most notably around the cerebellar and occipital regions.



More generally, the trends found in the voxelwise analysis are also present in the regional analysis: a widespread increase in connectivity is present when the Aged group is compared with both other groups. The difference in connectivity between the Young and Aged with AD groups is more complex, involving both reductions and increases between different regions.

http://miracle.otago.ac.nz/postgrads/pmccarthy/
https://github.com/pauldmccarthy/
pauldmccarthy@gmail.com