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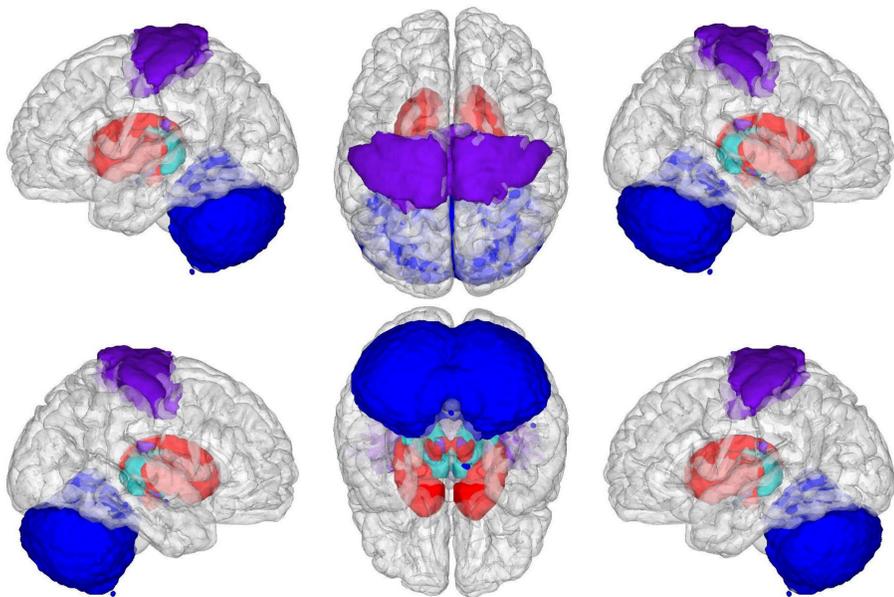


## INTRODUCTION

Functional magnetic resonance imaging (fMRI) studies have shown altered functional connectivity (FC) between nodes of the motor network in patients with Parkinson's disease (PD) [1].

### Goal of this study:

- Measure the density of connectivity with the degree of centrality (DC) at each node of the motor network (Fig. 1).
- Find group differences between PD patients and healthy control subjects.



**Fig. 1. The motor network.** The template of the motor network is composed by atlases of the sensorimotor cortex [5], thalamus [6], basal ganglia [7] and cerebellum [8]. This template is used to measure the density of connectivity with the DC.

## PROPOSED METHODOLOGY

DC is a measure of density of connectivity at the voxel-level. It measures the number of connections that a voxel has with the whole brain or within a specific template (such as the motor network) [2,3]. DC might be used to find the most densely connected regions within large brain structures.

We used the following framework:

- Define the template of the motor network (Fig. 1), and apply DC to find the most densely connected regions.
- Locate the main nodes per brain structure (sensorimotor cortex, thalamus, basal ganglia and cerebellum), and divided each structure by their maximum peak of DC. This helps to distinguish more densely connected areas (Fig. 2).
- Find differences of DC among PD and Control subjects (Fig. 3).

### Experimental Setup

**Data:** 40 PD patients "on" medication (25 males, age 66.5(8.6) years, mean disease duration 5.2(3.5) years, H&Y scale 1.5(0.6)) and 42 healthy controls (23 males, age 65.1(8.3) years) matched for age, gender and level of education. Resting-state BOLD fMRI data were acquired using a short TR on a 3T MRI scanner (voxel size 3.4x3.4x5 mm; matrix size 64x64x20, TR = 1.3 s; 350 scans).

**Preprocessing:** Standard fMRI data preprocessing steps were applied with SPM12 and included: head motion correction, coregistration into structural MRI, spatial normalization with DARTEL and smoothing with FWHM 6mm. Data was linearly detrended, bandpass filtered (0.01 – 0.1Hz); and time series of white matter, cerebrospinal fluid, six affine motion parameters and outliers (from ART) were regressed out with CONN15.

**Motor Network Template:** The template was created by merging the map of the cortical sensorimotor network (from the group of 17 networks) [5] with the atlases of the thalamus [6], basal ganglia [7] and cerebellum [8], as shown in Fig. 1. This template was DARTEL-normalized, so that it would be adjusted to the MRI images of our population.

**Degree of Centrality:** We computed the DC per subject within this template. DC maps were created using the 3dDegreeCentrality function in AFNI with sparsity = 1% [3].

**Group Differences:** Group results were averaged and non-parametric statistical tests were performed using the toolbox SnPM13 of SPM12 with 1000 permutation tests. We considered the results that surpassed the threshold of  $p < 0.001$ .

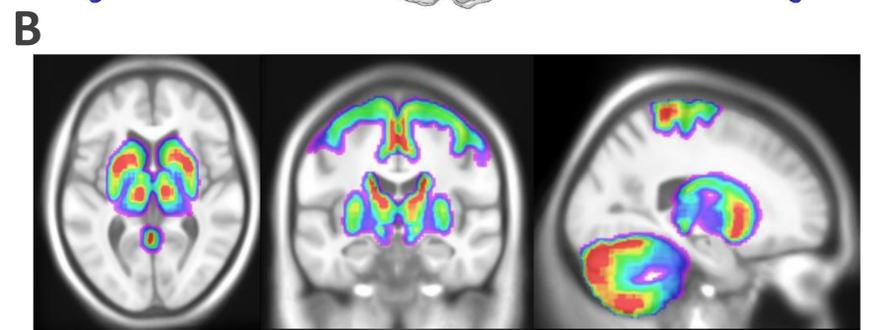
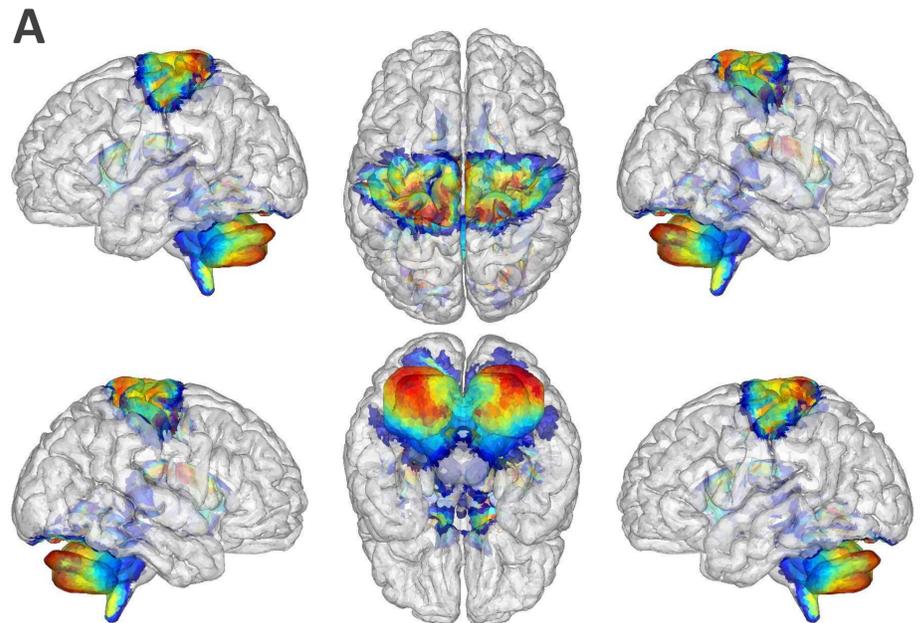
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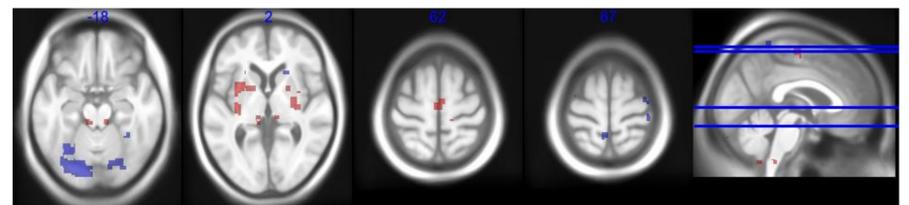
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## PRELIMINARY RESULTS



**Fig 2.** Mean of DC for the whole population (PD and control subjects).  
A. Shows the distribution mainly in the cortex and cerebellum.  
B. Shows the distribution in the putamen, thalamus, SMA and part of the cerebellum.

Max DC per node:  
SM cortex: 3843  
Thalamus: 1226  
Basal Ganglia: 1277  
Cerebellum: 1810



**Fig 3.** Results of the non-parametric statistical maps with 1000 permutation tests of DC within the motor network ( $p < 0.01$  uncorrected for illustration purposes). Red indicates Control > PD, and blue PD > Control.

- Main regions with largest DC per node (Fig. 2): M1 and SMA for the sensorimotor cortex, anterior putamen, ventral and medial part of the thalamus and motor cerebellum.

- Statistical differences in DC (Fig. 3): R and L posterior putamen, R anterior putamen and SMA, for Control > PD  
R and L motor cerebellum, for PD > Control.

## DISCUSSION & CONCLUSION

- DC permits to locate the most densely connected regions without the need of a priori information or ROIs definition in a desired network.
- We could discriminate the brain regions that are known to be important for PD.
- With this framework, we found consistent differences between PD and healthy subjects.