Dopaminergic modulation of cortical motor network lateralization

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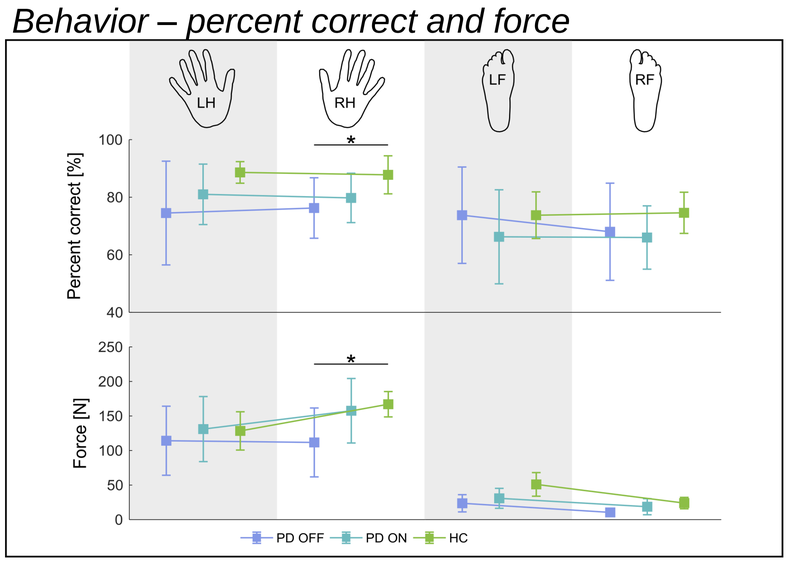
Introduction

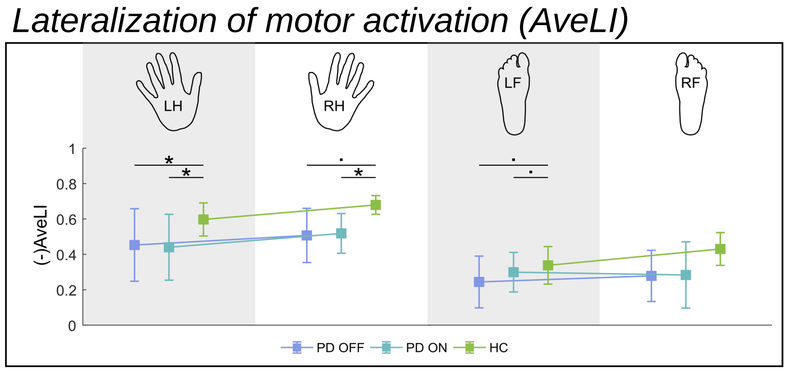
While unilateral movements typically result in highly asymmetric activations in fMRI, an increase in symmetry of motor activation has been reported in drug-naïve Parkinson's disease (PD)[1]. The finding of reduced lateralization is in line with the *reduced inhibition – increased facilitation* hypothesis of basal ganglia-thalamo-cortical compensation[2]. We used fMRI to study motor activations and cortical motor network connectivity in long-term PD patients – 'ON' and 'OFF' of their usual dopamine medication, as well as in healthy controls (HC). Our hypotheses were as follows: (1) Decreased lateralization of motor activation persists in long-term PD, particularly during movements of the body side dominantly affected by the disease. (2) Administration of levodopa restores laterality measures, bringing them closer to levels observed in HC. (3) Altered network interactions – as observed through DCM – in PD patients mirror lateralization changes, with dopamine administration partially reinstating 'normal' connectivity, both in terms of connectivity strengths and connectivity lateralization.

Results

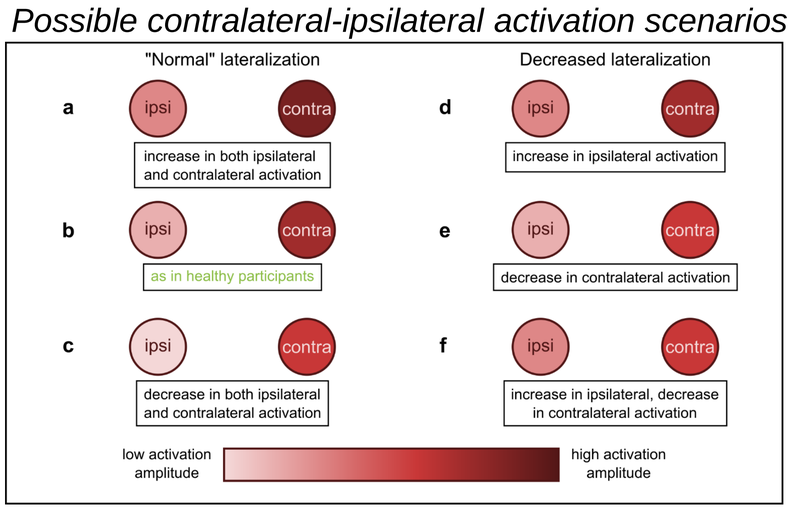
Behavior – percent correct and force



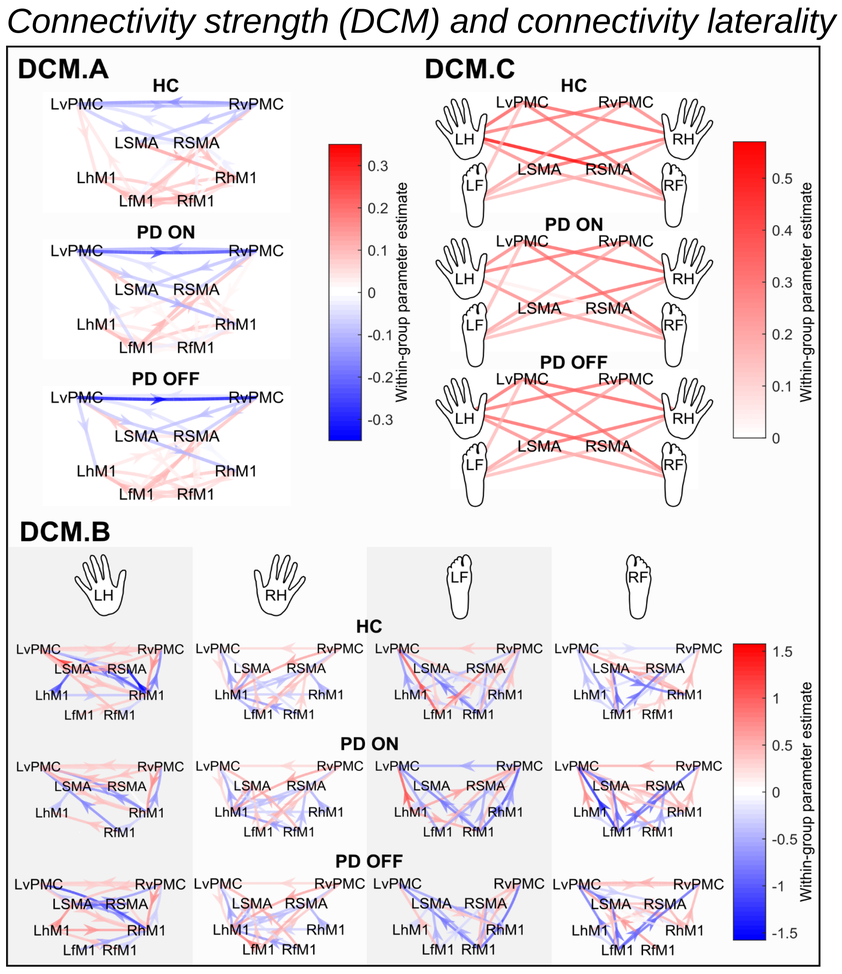
Lateralization of motor activation (AveLI)

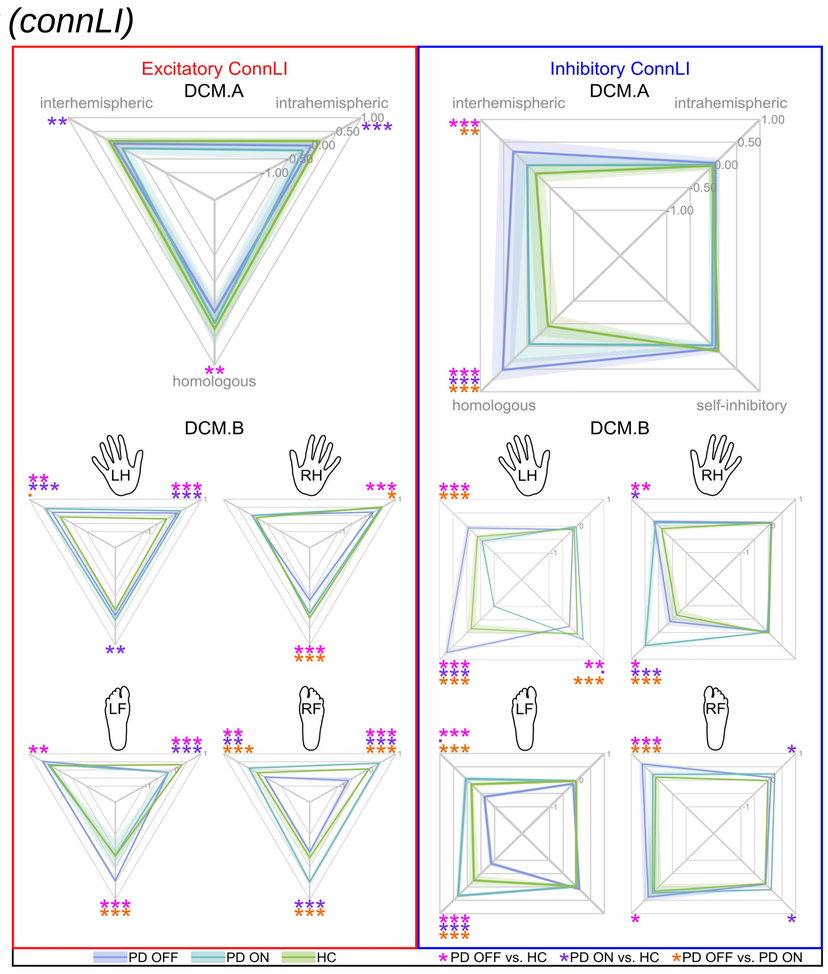


Possible contralateral-ipsilateral activation scenarios

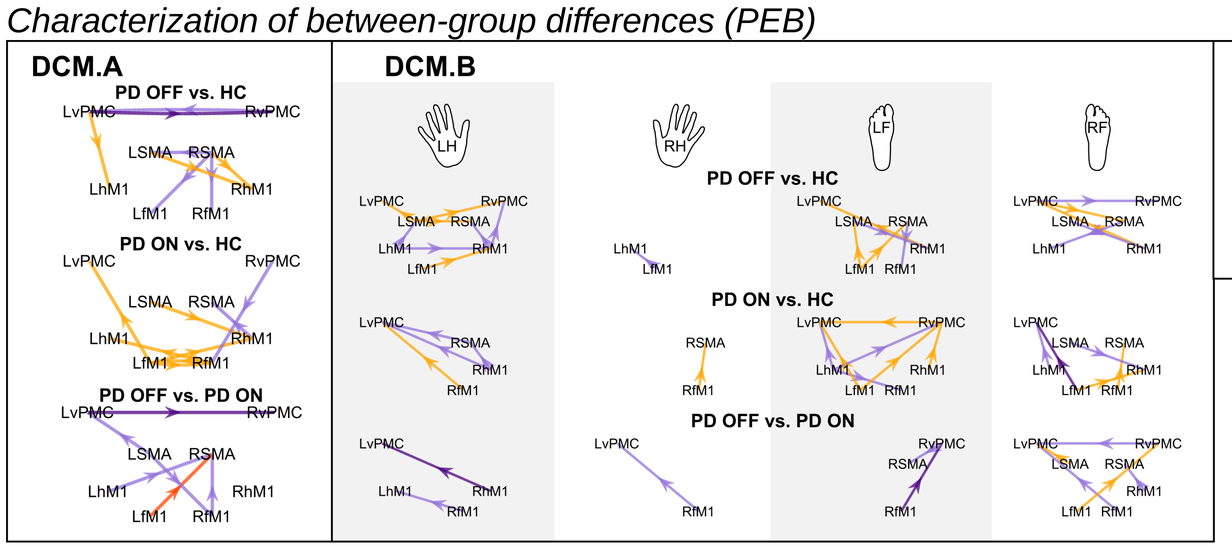


Connectivity strength (DCM) and connectivity laterality (connLI)





Characterization of between-group differences (PEB)



Error bars represent 95% CI; '.' p<0.1, '*' p<0.05, '**' p<0.01, '***' p<0.001, Bonferroni corrected

DCM/PEB: posterior probability > 0.95

Methods

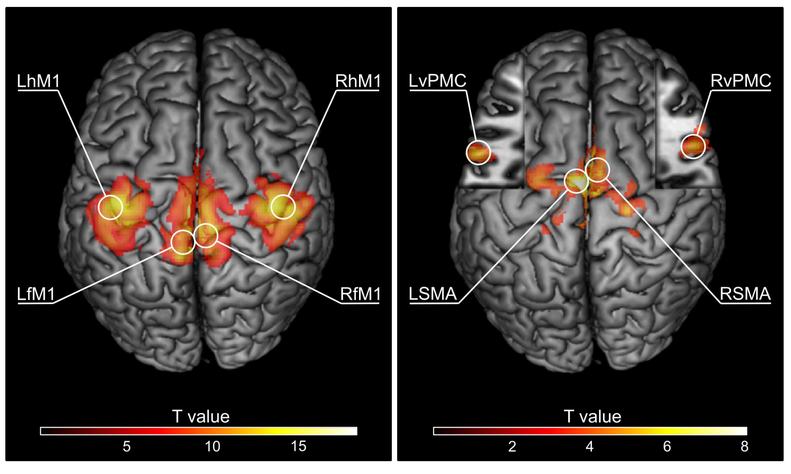
Participants: 10 PD (5F), 18 age-matched HC (9F). All participants right-handed, PD patients left-dominant symptom side, tested 'OFF' and 'ON' dopaminergic medication

Data acquisition: Siemens Prisma 3T MRI 1.5 mm MPMs[3], 2 mm fMRI (TR = 3.328 s)

Experimental design: Externally paced (visually cued) 0.5 Hz frequency movements of right hand, left hand, right foot, left foot. Block design with 5 blocks per limb, 8 mvts per block.

Data analysis

- Activation laterality quantification (AveLI[4])
- Estimation of effective connectivity through dynamic causal modeling (DCM[5]), quantification of connectivity laterality (connLI)
- Parametric empirical Bayes (PEB[6,7,8]) used to compare parameter estimates between each of the group pairs
- Characterization of between-group differences – increased/decreased excitation/inhibition)



Topography of clusters containing group activation maxima within DCM motor ROIs

Conclusions

- Increase in symmetry of motor activation persists in long-term PD, regardless of medication status
- Decrease in laterality corresponds to decrease in contralateral activation and/or increased ipsilateral activation
- Connectivity laterality, as estimated through DCM analysis, is significantly different across groups, with particularly pronounced differences in inhibitory interhemispheric and homologous connectivity
- PEB analysis revealed qualitatively more between-group differences in input-specific modulation on the more affected PD side and included many interhemispheric connections
- Connectivity changes can mainly be characterized as *reduced inhibition – reduced facilitation*

References

[1] Wu T, Hou Y, Hallett M, Zhang J, Chan P. Lateralization of brain activity pattern during unilateral movement in Parkinson's disease. Human Brain Mapping 2015; 36: 1878–1891. [2] Rothwell JC, Edwards MJ. Parkinson's disease. In: Lozano AM, Hallett M, editors. Handbook of Clinical Neurology Vol. 116 (Brain Stimulation). Amsterdam: Elsevier B.V.; 2013. p. 535–542. [3] Helms G, Dathe H, Kallenberg K, Dechent P. High-resolution maps of magnetization transfer with inherent correction for RF inhomogeneity and T1 relaxation obtained from 3D FLASH MRI. Magnetic Resonance in Medicine 2008; 60: 1396-1407. [4] Matsuo K, Chen SHA, Tseng WYI. AveLI: A robust lateralization index in functional magnetic resonance imaging using unbiased threshold-free computation. Journal of Neuroscience Methods 2012; 205: 119–129. [5] Friston KJ, Harrison L, Penny W. Dynamic causal modelling. NeuroImage 2003; 19: 1273–1302. [6] Litvak V, Garrido M, Zeidman P, Friston, K. Empirical Bayes for Group (DCM) Studies: A Reproducibility Study. Frontiers in Human Neuroscience 2015; 9: 1–12. [7] Friston KJ, Litvak V, Oswal A, Razi A, Stephan KE, van Wijk BCM, et al. Bayesian model reduction and empirical Bayes for group (DCM) studies. NeuroImage 2015a; 128: 413–431. [8] Friston KJ, Zeidman P, Litvak V. Empirical Bayes for DCM: A Group Inversion Scheme. Frontiers in Systems Neuroscience 2015; 9: 164.