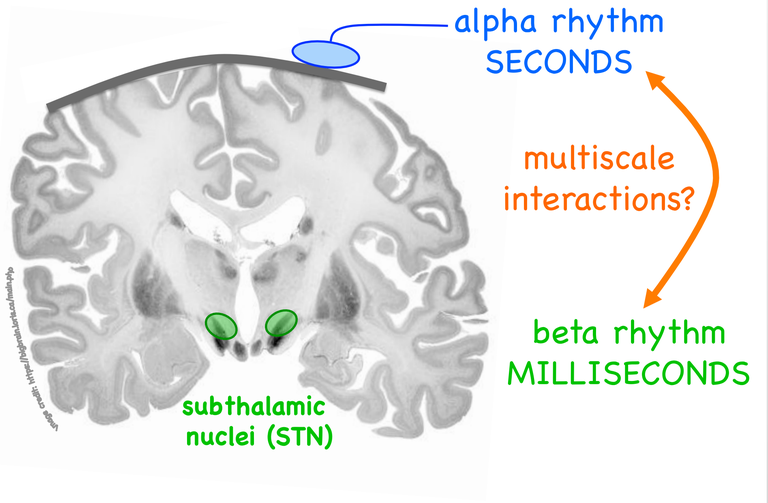
Multiscale interactions – a novel relation between cortical and subthalamic neural dynamics in patients with Parkinson's disease

FU Hohlefeld[1], F Ehlen[2], HO Tiedt[2], LK Krugel[2], A Horn[3], AA Kühn[3], G Curio[1,4], F Klostermann[2], VV Nikulin[1,4]

1) Neurophysics Group, Department of Neurology, Charité University Medicine Berlin; Germany
2) Motor and Cognition Group, Department of Neurology, Charité University Medicine Berlin, Germany
3) Motor Neuroscience Group, Department of Neurology, Charité University Medicine Berlin, Germany
4) Bernstein Center for Computational Neuroscience, Berlin, Germany

Background and research question

- neural interactions between cortex and basal ganglia (subthalamic nucleus, STN) in Parkinson's disease (PD) were frequently studied for understanding brain mechanisms underlying the disease[1]
- so far, cortical-subcortical interactions were only investigated in the same frequency bands and on same temporal scales[1,2]
- research question[3]: link between major cortical rhythm (alpha) and subthalamic rhythms (beta)?
- multiscale interactions: neural communication across different temporal-spatial scales



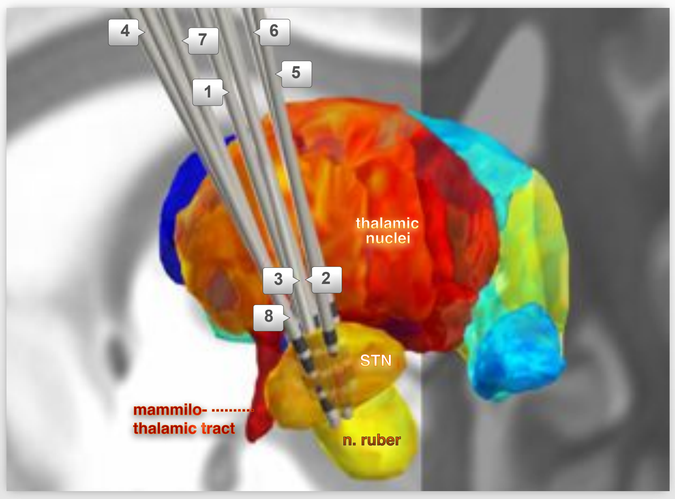
Patients and recordings

- patients with severe idiopathic PD (n=8; 5 males)
- eligible for deep brain stimulation
- mean age 54 yrs
- simultaneous EEG-LFP recordings (EEG: 12 channels, linked-mastoids; bilateral LFP: channels 01, 12, 23)
- OFF stimulation, ON levodopa
- lexical decision task[4] (6 min): button press if genuine word

Methods

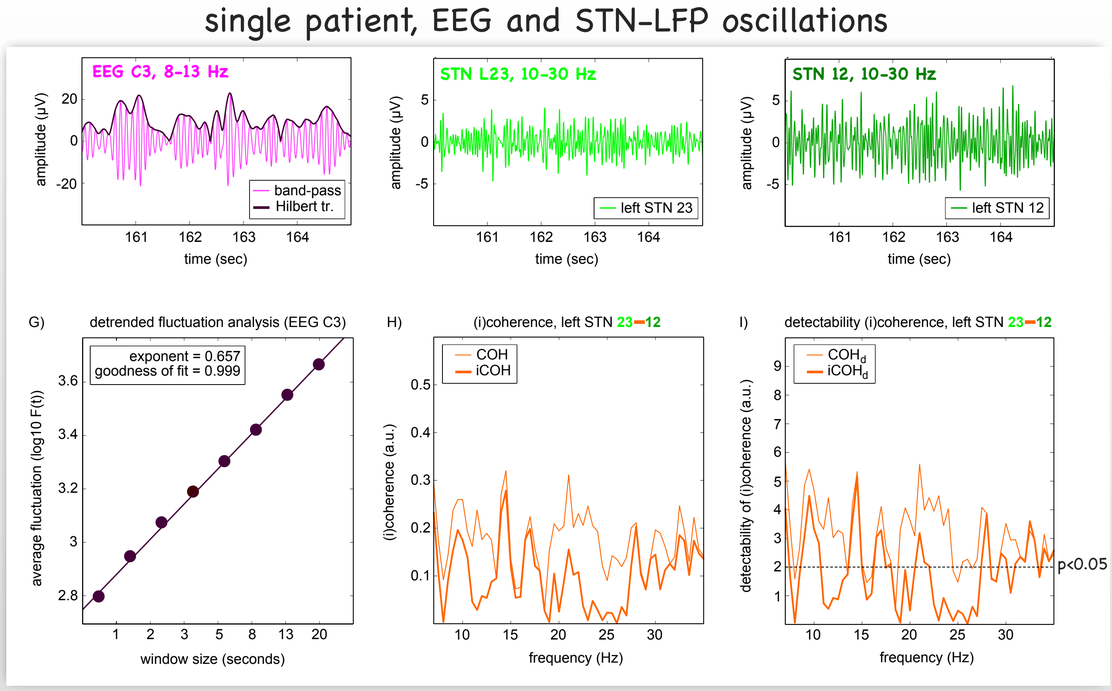
- EEG: long-range temporal correlations (up to 20 sec)
  → detrended fluctuation analysis[5]
- LFP: connectivity (milliseconds range)
  → imaginary part of coherency[6] (time-lagged phase synchr.)
- electrode localization[7]
- spatial average[8,9] across available channels (EEG) and connections (separately in left and right STN)
  → robustness to data heterogeneity

electrode localization[7]



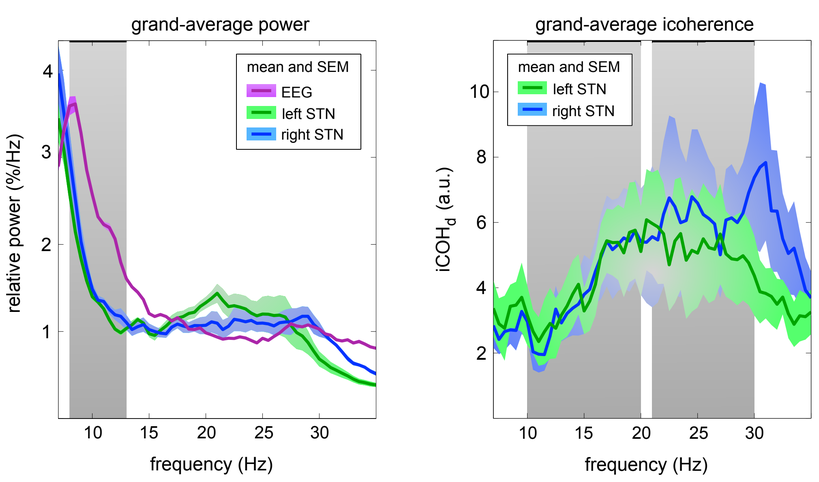
toolbox available: http://www.lead-dbs.org

single patient, EEG and STN-LFP oscillations

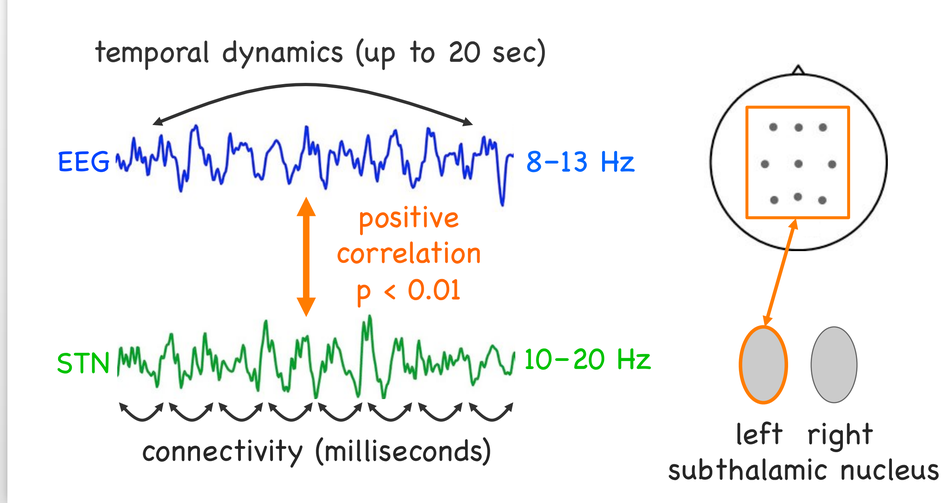


Results

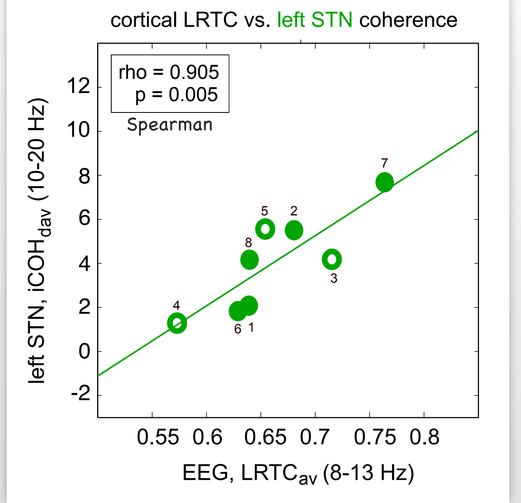
grand-average (n=8), ON medication



cortical long-range temporal correlations (up to 20 sec) relate to subcortical phase synchronization (ms)



cortical 8–13 Hz vs. subthalamic 10–20 Hz, ON med., across subjects



Results – summary

- significant correlation between long-range temporal dynamics in cortex (8–13 Hz LRTC) and short-range phase synchronization in STN (10–20 Hz imaginary part of coherency)
  → so-called "multiscale interactions"
- hemispheric asymmetry (specifically for left STN)
- topographically specific: relation was most significant for centro-parietal regions of interest
- frequency specific: for beta oscillations in STN (not alpha or gamma)
- no significant relation of long-range temporal dynamics and connectivity with movement-induced modulations of neural oscillations (event-related desynchronization)

Conclusions

- novel relation between neural dynamics in the major rhythms in cortex (alpha oscillations) and STN (beta oscillations) in PD
- link between two phenomena on different time scales: cortical long-range temporal correlations (20 sec) and subthalamic i-coherence (milliseconds)
- multiscale interactions might be realized by excitation-inhibition balance[10] in cortical-subcortical neural networks
- multiscale interactions might enhance information coding and memory
- left-hemispheric expression of multiscale interactions might depend rather on task context (here lexical decisions) than on movement-induced modulations of neural dynamics

References

[1] Hirschmann et al. (NeuroImage 2013)
[2] Litvak et al. (J Neurosci 2012)
[3] Hohlefeld et al. (under review)
[4] Ehlen et al. (PloS One 2013)
[5] Linkenkaer-Hansen et al. (J Neurosci 2001)
[6] Nolte et al. (Clin Neurophysiol, 2004)
[7] Horn and Kühn (NeuroImage 2015)
[8] Litvak et al. (Brain 2011)
[9] Hohlefeld et al. (E J Neurosci 2012)
[10] Poil et al. (J Neurosci 2012)

Contact

friederike.hohlefeld@gmx.de
Neurophysics Group, Department of Neurology,
Hindenburgdamm 30, 12200 Berlin
Charité – Universitätsmedizin Berlin, Germany

Acknowledgements

Supported by the German Research Foundation (DFG) grant # KFO 247.