

Cortico-subthalamic neural interactions: relation to cognitive task performance and evidence for a novel interaction mode across multiple time scales in patients with Parkinson's disease

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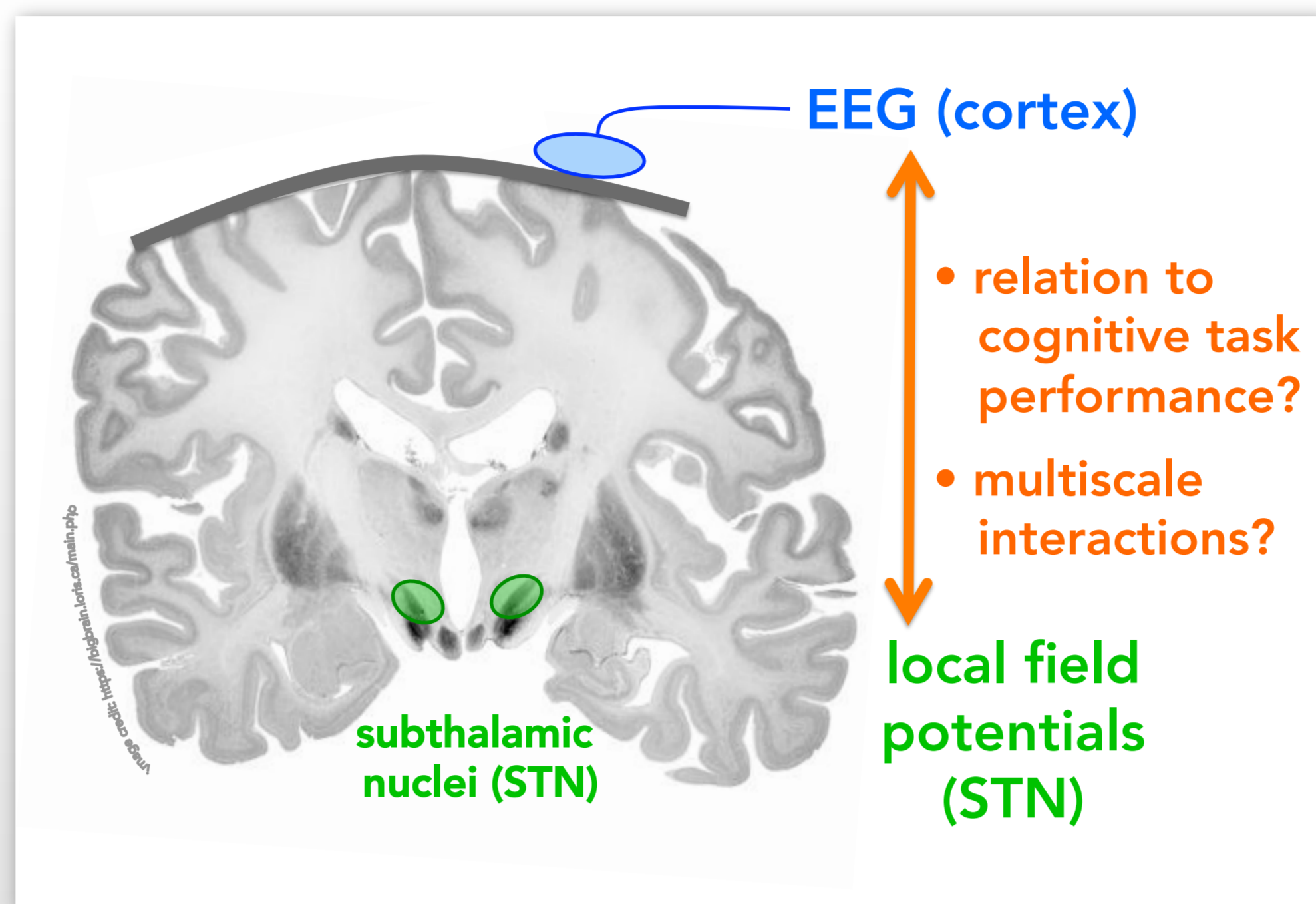


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Background and research questions

- neural interactions between cortex and subthalamic nucleus (STN) in Parkinson's disease (PD) is frequently studied for determining neural markers of disease and task performance [1]
- Question (1): Does cortico-subthalamic synchronization relate to cognitive aspects of task performance, e.g., language-related, and how to efficiently deal with multi-channel recordings?
- Question (2): Is there a link between the major cortical rhythm (alpha) and subthalamic rhythms (beta), suggesting additional communication modes across different temporal-spatial scales?

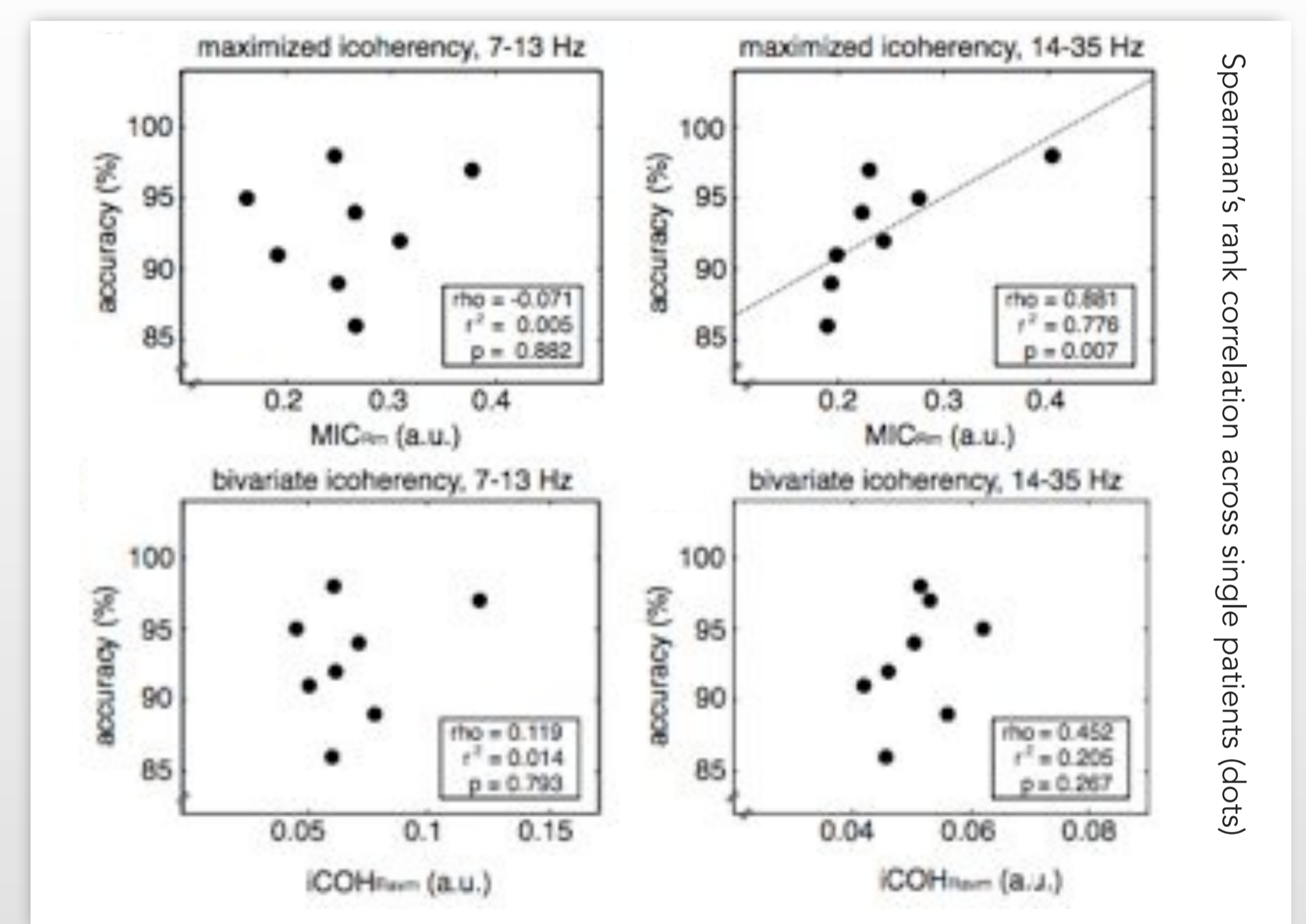
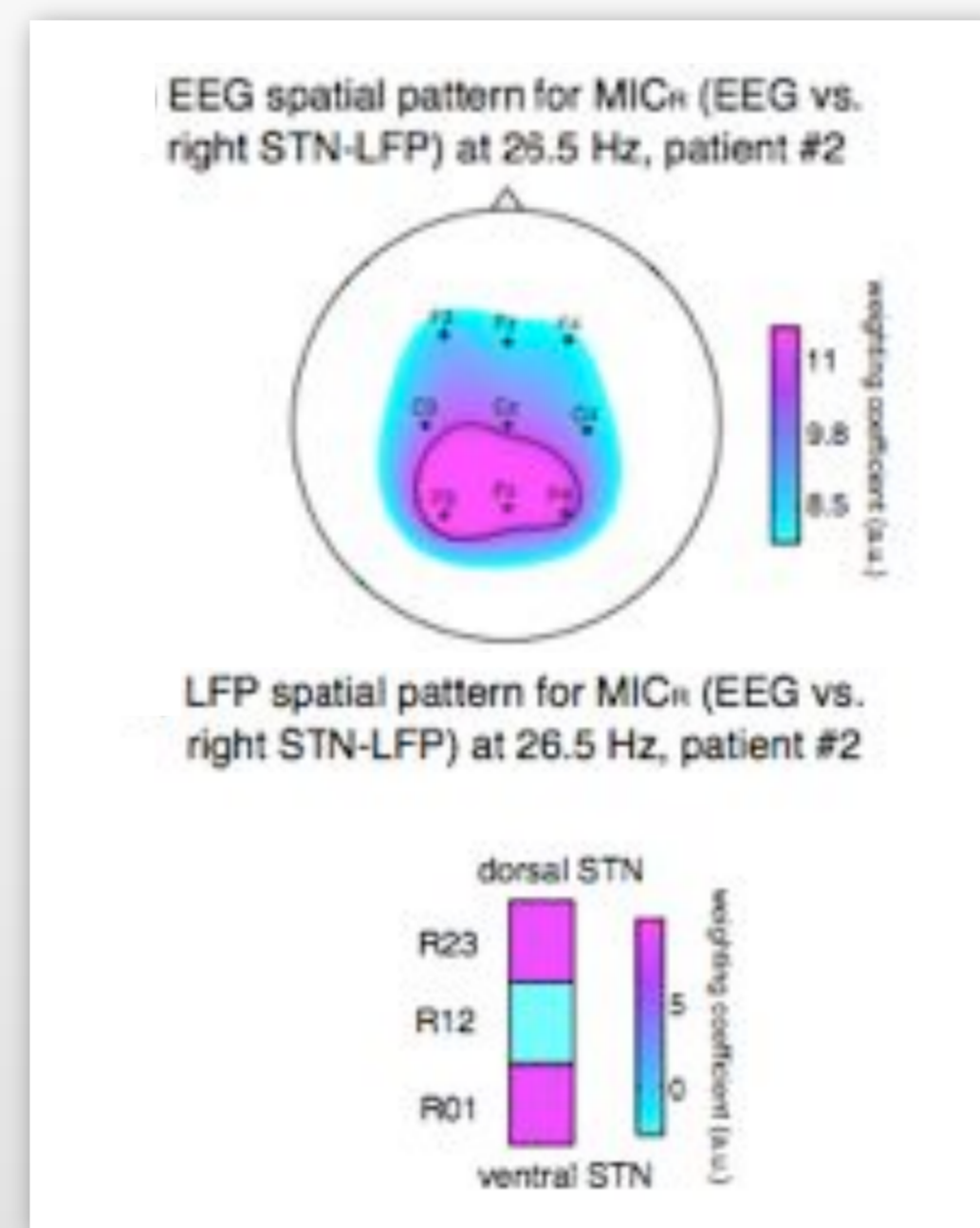
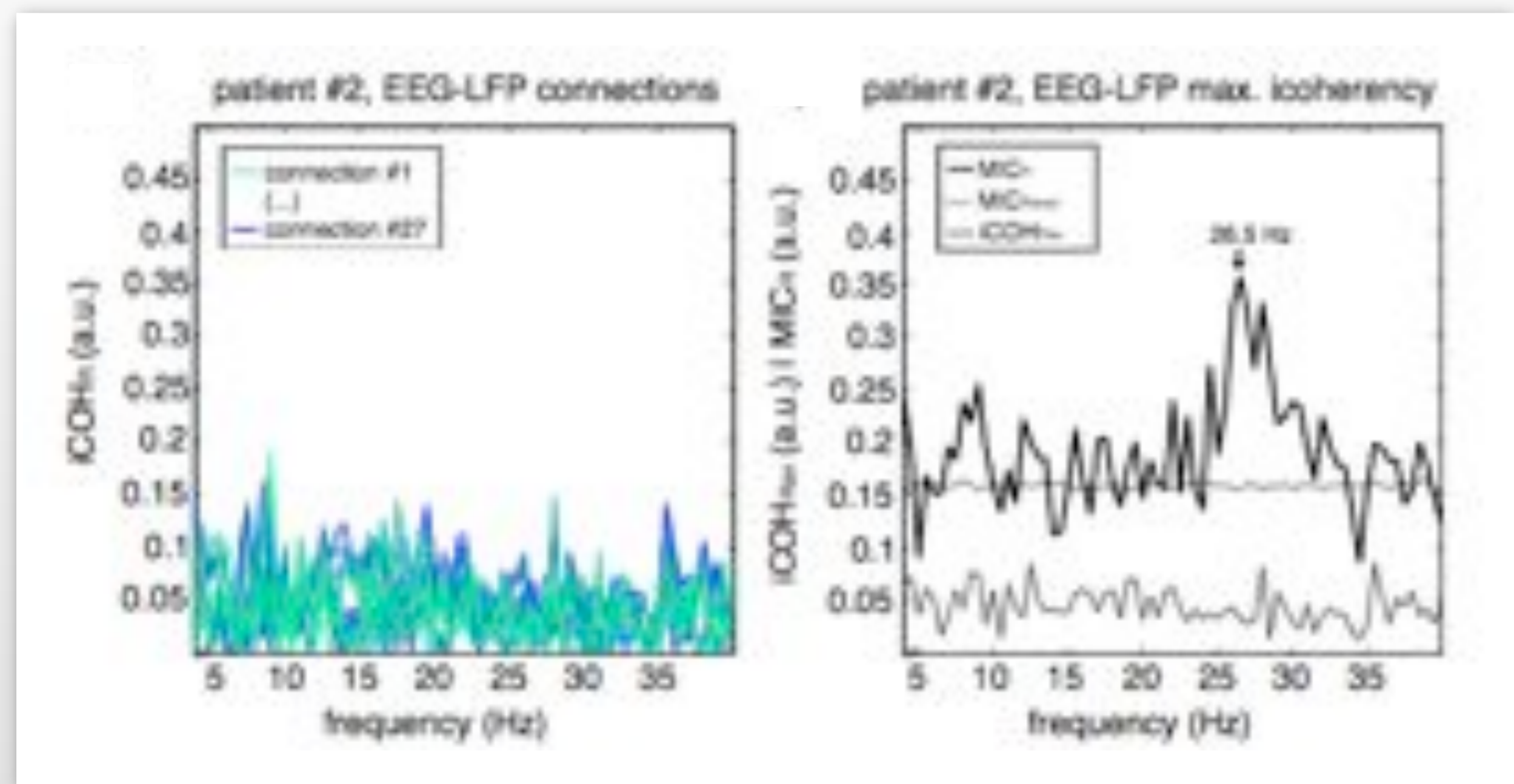


Patients and recordings

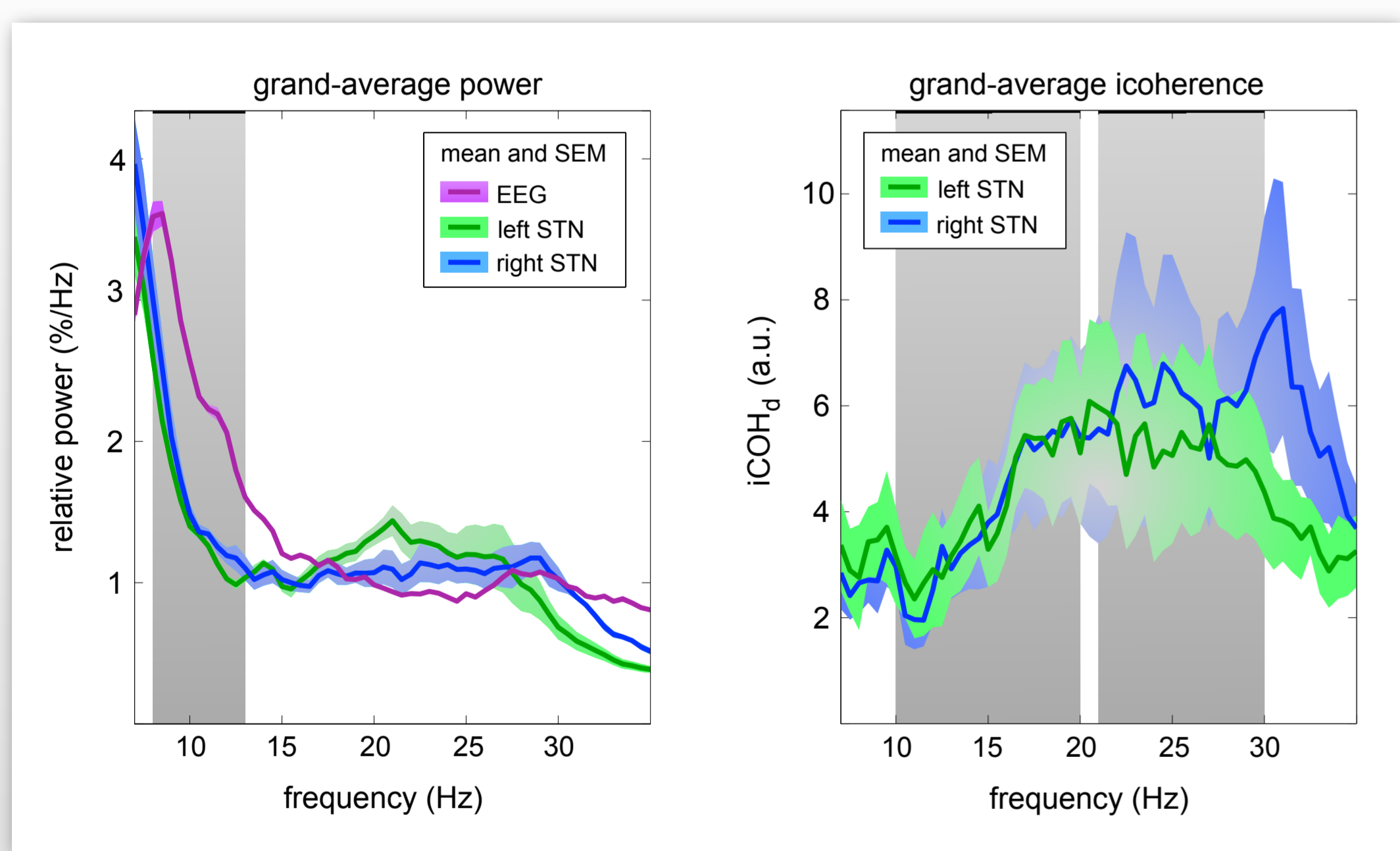
- patients with severe idiopathic PD (n=8; 5 males)
- surgery for deep brain stimulation
- mean age 54 years
- simultaneous EEG-LFP recordings (EEG: 12 channels, linked-mastoids; bilateral LFP: channels 01, 12, 23)
- OFF stimulation, ON levodopa
- lexical decision task [2] (6 min): button press if genuine word (noun vs. pseudo noun)

Results (1) accuracy in lexical decisions correlates with maximized cortico-subthalamic synchronization [3]

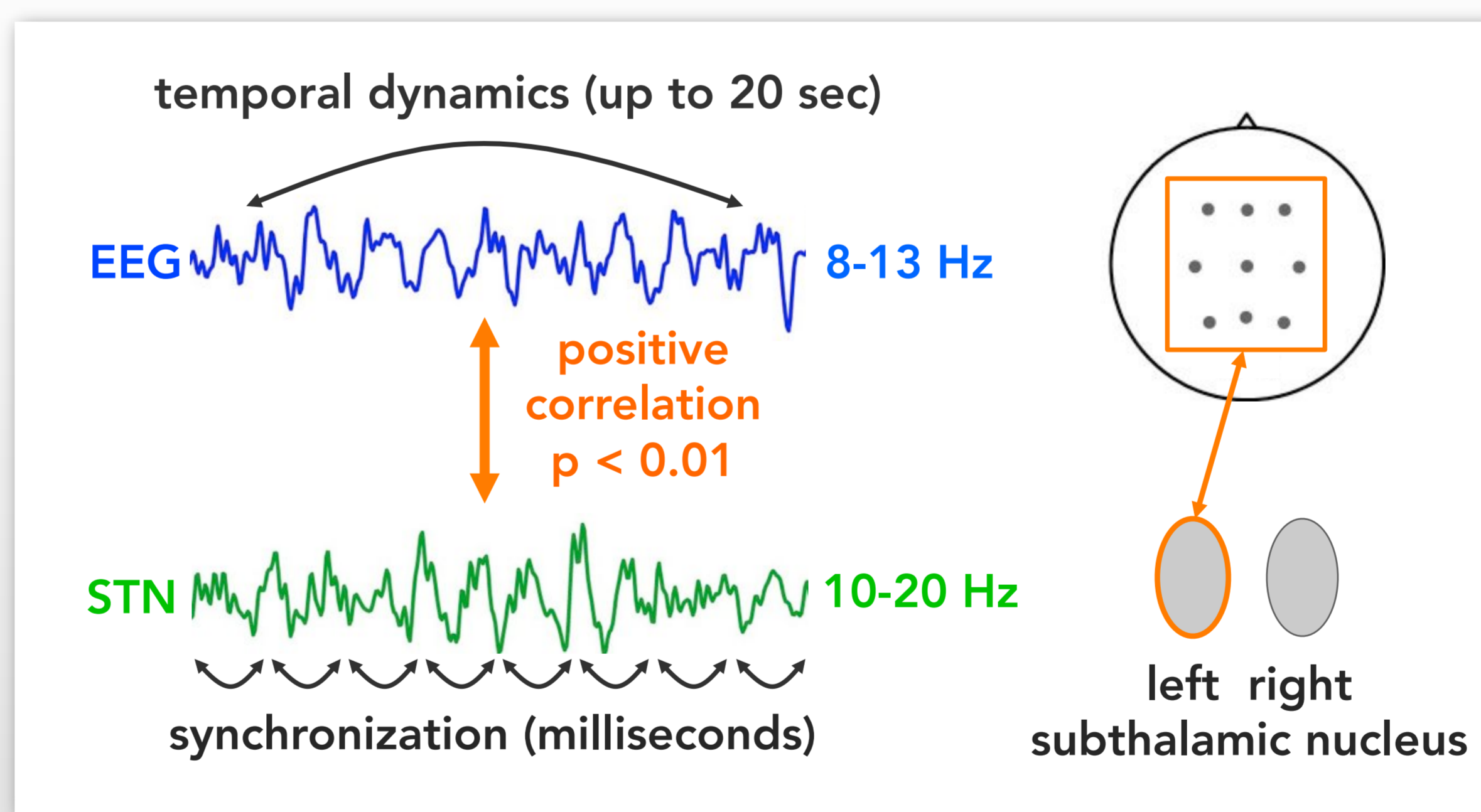
- analysis of continuous recording (~6 min)
- long-range temporal correlations (up to 20 sec): detrended fluctuation analysis [4,5]
- neural synchronization (time-lagged, no volume conduction artifacts):
 - imaginary part of coherency [6,7] (icoherency; bivariate, single sensors)
 - maximized icoherency [8,9] (MIC; multivariate, all sensors)



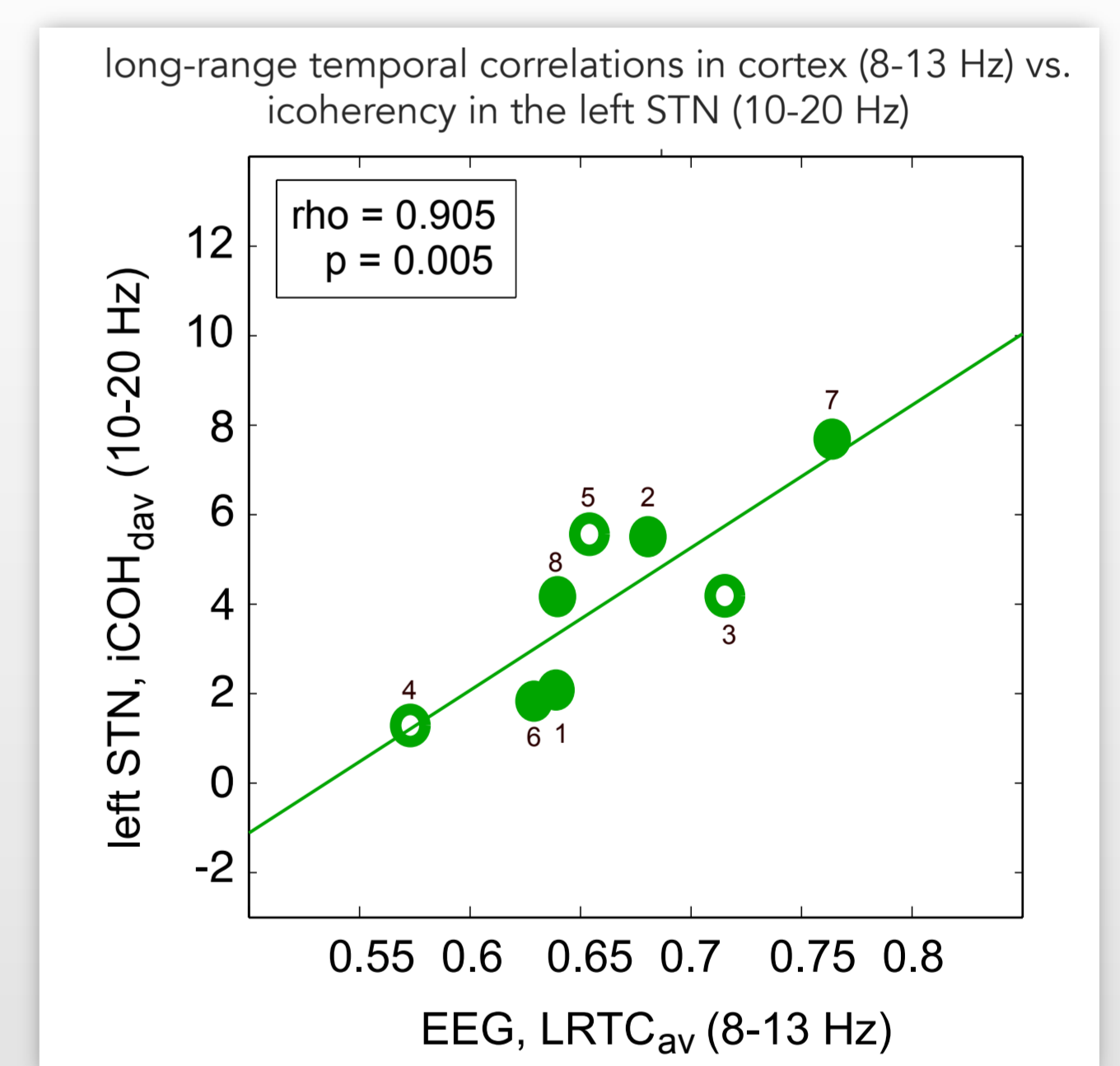
Results (2) novel cortical-subcortical communication mode: relation of neural dynamics across multiple time scales [9]



grand-average (n=8), ON medication



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



Spearman's rank correlation, ON med., across patients

Summary of results [3,9]

- increased cortico-subthalamic time-lagged neural synchronization (14-35 Hz) relates to increased accuracy in lexical decisions
- extracted by the multivariate icoherency method [8] considering all sensors simultaneously; not significant with the "standard" bivariate icoherency
- results not affected by volume conduction artifacts
- increased cortical long-range temporal correlations (up to 20 sec) in 8-13 Hz oscillations relate to increased subthalamic phase synchronization (millisec) in 10-20 H oscillations → so-called "multiscale interactions"
- no correlation between cortico-subthalamic neural markers (temporal correlations, coherency) and movement-induced modulations of neural oscillations or clinical scores

Conclusions [3,9]

- novel finding: cortico-subthalamic synchronization relates to cognitive aspects of task performance (lexical processing) beyond the motor domain
- possible involvement of basal ganglia in lexical processing
- multivariate methods useful for extracting neural markers from multi-channel recordings with increased signal-to-noise ratio [8,9]
- novel interaction mode: relation between neural dynamics in the major rhythms in cortex (alpha oscillations) and basal ganglia (beta oscillations)
- link between different time scales: cortical long-range temporal correlations (many seconds) and subthalamic synchronization (milliseconds)
- novel multiscale interactions: possibly realized by excitation-inhibition balance [10] and might enhance information coding and memory

References

- [1] Hirschmann et al. (NeuroImage, 2013)
 [2] Ehlen et al. (PloS One, 2013)
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 [9] Hohlefeld et al. (submitted)
 [10] Poil et al. (J Neurosci, 2012)

Acknowledgements

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