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Immediate network effects of focal neurostimulation by a novel implantable device

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Purpose: Reduction of seizures achieved by open-loop neurostimulation beyond the stimulation intervals is attributed to adaptations in brain network dynamics. This study investigates global network effects based on high-density electroencephalography (HD-EEG) after focal direct current (DC)-like stimulation by an implantable device at the day of first activation of the stimulator.

Method:

- 8 patients implanted with an epicranial stimulation device.
- Direct current (DC)-like components applied via electrode arrays placed epicranially above the epileptic focus region.
- High-density EEG recordings were performed immediately before the initiation of neurostimulation and after 20 minutes od DC-like neurostimulation.
- From 10 minutes of resting-state EEG, 10 artefact-free segments of equal length were selected for the analysis.
- Connectivity matrix based on the concept of the mean phase coherence was estimated from these segments.
- Global graph metrics, including average path length, average cluster coefficient, synchronizability, assortativity, a measure, which reflects the tendency of edges to connect vertices with similar properties, and average degree, were derived from the connectivity matrix.

Results: Due to the small sample size, no statistical tests were applied between the groups or across the two time points.

	Average Path Length	Average Clustering Coefficient	Assortativity	Syncronizibility	Average Degree
Baseline	2,69	0,71	0,59	101,85	52,36
After Stimulation	1,78	0,76	0,47	148,14	95,27

The comparison between the graph metrics before and after the DC-like stimulation showed:

- Substantial decrease of the average shortest path length after DC-like stimulation
- Higher synchronizibility and average degree after DC-like stimulation.

Conclusion: DC-like focal neurostimulation showed consistent immediate effects in three network measures indicating a facilitated co-operation on global network levels. These results may contribute to an increased understanding of the mechanism behind focal neurostimulation.

References:

Schulze-Bonhage A, et al.. Focal Cortex Stimulation With a Novel Implantable Device and Antiseizure Outcomes in 2 Prospective Multicenter Single-Arm Trials. JAMA Neurol. 2023

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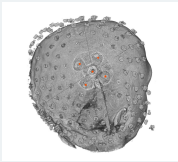
Setup:

Epicranial stimulation array:

3 D MRI rendering with HD-EEG contacts:



Preprocessing:

HD-EEG → Filter: 0.5 – 70 HZ → ICA → 10 x 5 sec. resting state EEG

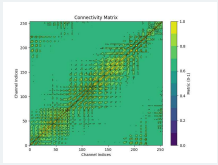
Mean phase coherence:

- Application of Hilbert transformation on the single EEG channels
- Extraction of phase values for each sample and channel
- Setup of phase synchronization matrix:

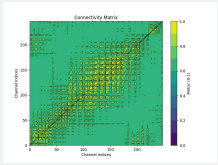
$$\rho_{ij} = \left| \frac{1}{N} \sum_{t=0}^{N-1} \exp(\Phi_i(t) - \Phi_j(t)) \right| .$$

Connectivity Matrix (example):

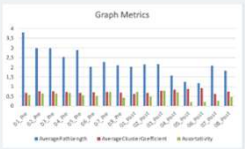
Baseline:



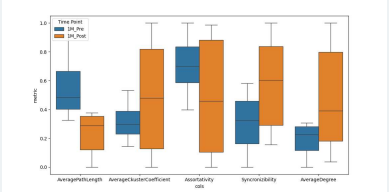
After DC-like Stimulation:



Graph Metrics per Patient:



Normalized box plots over patients



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