Periodic and aperiodic mechanisms of electroconvulsive therapy for Major Depressive Disorder

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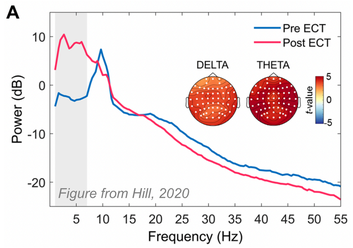
Abstract & Background

- Patients with Major Depressive Disorder (MDD) are typically treated with therapy and medication.
- For otherwise treatment-resistant MDD, electroconvulsive therapy (ECT) can be highly efficacious, but its precise neural mechanisms are still unknown.
- ECT has serious cognitive side-effects including loss of autobiographical memory and short-term reduction in new learning. (Porter, 2020)
- Power in the delta (1-4 Hz) and theta (4-7 Hz) ranges, also known as "EEG slowing", has long been associated with cognitive side effects of ECT. (Adams, 1986)
- Prior research has not distinguished between band power and oscillatory power, and has not considered the role of aperiodic activity.
- Changes in 1/f-like aperiodic activity can be mistaken for changes in band power.
- Aperiodic activity has demonstrated clinical relevance for psychiatric disorders, including MDD. (Veerakumar et. al 2019)
- We computed the following EEG features from 22 patients pre- and post-ECT:
  - Band power (delta and theta)
  - Oscillatory power (delta and theta)
  - Aperiodic exponent



Dataset

Pre- and post-ECT treatment data collection

Resting-state EEG data was collected from 22 MDD patients before and after administration of a course of ECT treatment. (Hill et al. 2020)

Variable	Descriptive Statistics
N	22
Age (mean ± SD)	47.29 ± 16.75
Gender (M/F)	9/14
No. ECT Treatments (mean ± SD)	13.87 ± 5.32
HDRS-17 pre (mean ± SD)	24.61 ± 3.80
HDRS-17 post (mean ± SD)	12.57 ± 6.66

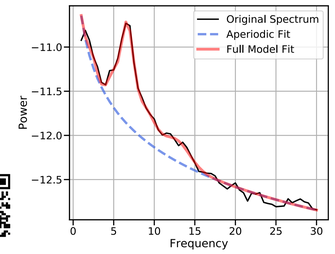
PSDs computed per 2-second epoch, per 60 channels for each patient.

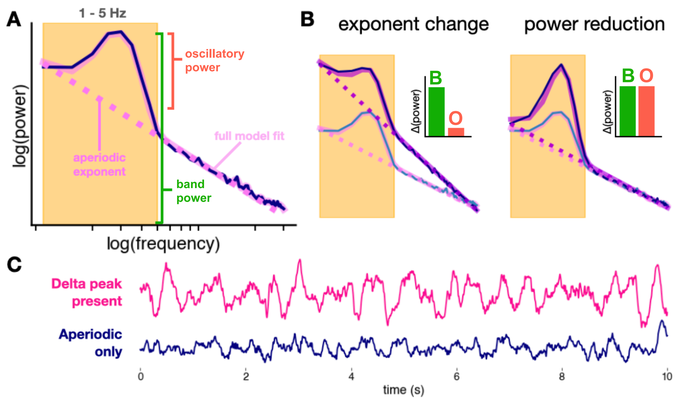
Parameterized Power Spectra

The spectral parameterization method conceptualizes the power spectrum as a combination of two functional processes:

1. Aperiodic 1/f-like component, exponential fit and offset
2. Periodic components (oscillations), gaussian fit

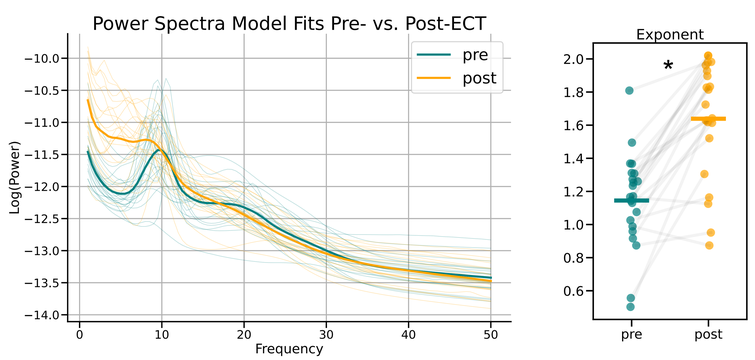
Donoghue et al. (2020) *Nat Neuro.*



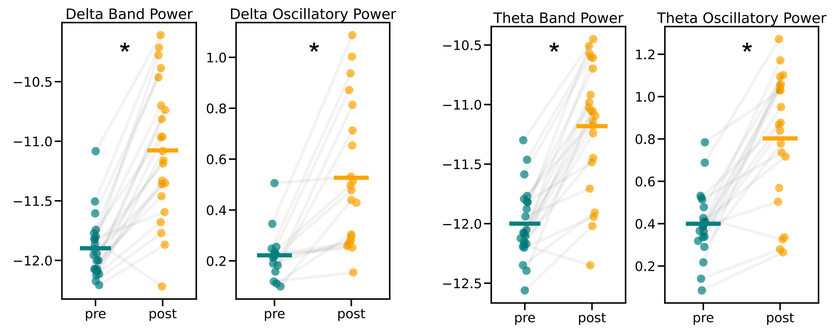


Power Spectra Steepen Post-ECT

In MDD patients receiving ECT treatment (n = 22), the aperiodic exponent of EEG recorded from frontal electrodes increases immediately following treatment, reflected in a visible "steepening" of the power spectrum.



Delta & Theta Oscillatory Power Increase Post-ECT



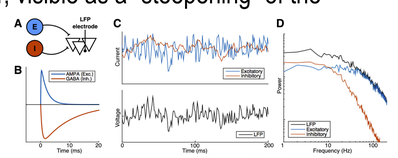
Statistics

Feature	T-Statistic	p-value	cohen-d	Parametric?	Permutation Test*: p-value
Exponent	-7.35	3.10E-07	1.54	No	3.90E-03
Delta Oscillatory Power	-4.33	6.93E-04	1.39	No	9.20E-02
Delta Band Power	-8.41	3.64E-08	1.84	No	<1.00E-03
Theta Oscillatory Power	-7.34	8.13E-07	1.83	Yes	1.19E-02
Theta Band Power	-9.27	7.24E-09	1.88	Yes	<1.00E-03

**10,000 permutations of shuffled, paired data*

Summary & Discussion

- Both aperiodic and oscillatory activity contribute to "EEG slowing".
- Aperiodic exponent increases post-ECT, visible as a "steepening" of the power spectrum.
  - Aperiodic changes can potentially capture relative contributions from excitatory/inhibitory neural activity. (Gao, 2017)
  - MDD patients are theorized to have insufficient inhibitory activity. (Sackeim, 1983)
  - ECT might restore healthy levels of inhibition as indexed by the aperiodic exponent



- Power increases for both delta and theta oscillatory peaks post-ECT.
  - Further investigation is needed to elucidate the neural mechanisms underlying delta and theta oscillations
- The current findings cannot be extrapolated to long-term changes in EEG post-treatment due to lack of longitudinal data.

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