

Broadband Spectral Slope of EEG in Patients with Parkinson's Disease

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Background

- Excessive synchronization in Parkinson's disease (PD) manifests as elevated oscillatory beta band (13-30Hz) activity in basal ganglia and can be reduced by therapies^[1].
- At cortical level, findings about beta oscillations are rather controversial^[2,3]. Phase amplitude coupling (PAC) between beta phase and broadband gamma amplitude has been shown to be more promising in serving as a reliable biomarker^[3].
- Except for periodic components, aperiodic property of broadband spectra has been shown altered due to physiological and pathological states^[4,5].
- More recently, simulation work and experimental data have demonstrated evidence of linking the slope of the background spectra to excitation/inhibition (E/I) ratio of the recording site^[6].
- Previous transcranial magnetic stimulation (TMS) studies have demonstrated a reduced intracortical inhibition in PD^[7].

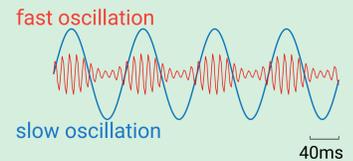
Our questions:

- Is Parkinson's disease associated with the changes in the spectral slope of EEG?
- What is the effect of dopaminergic medication on spectral slope?
- How does spectral slope relate to PAC?
- How does the broadband spectral slope impact the periodic power estimation, especially in beta band?

Methods

Data: a previously published EEG dataset^[8], 3 minutes of resting state, 15 PD patients On and Off medications, 16 healthy controls

PAC: modulation index (MI)



Spectral slope: three-step of robust regression to find the slope for the line of best fit over power spectrum density (PSD) in frequency range of 2-40Hz in the log-log space.

$$P(f) \propto 1/f^\beta$$

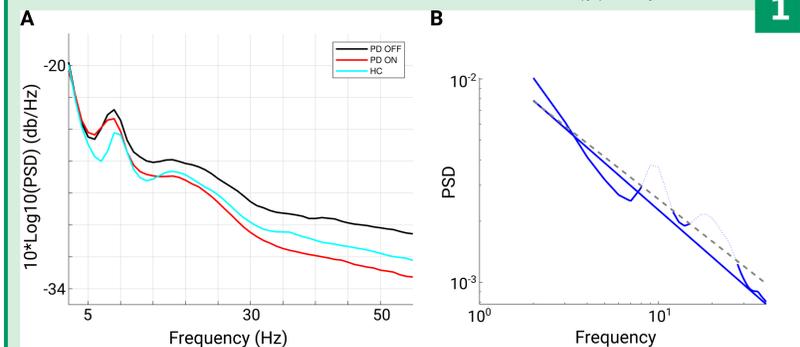


Figure 1. A) grand average of PSD for each group: healthy control in blue, PD off medication in black and PD on medication in red. B) an illustration example of estimation of PSD slope.

Results

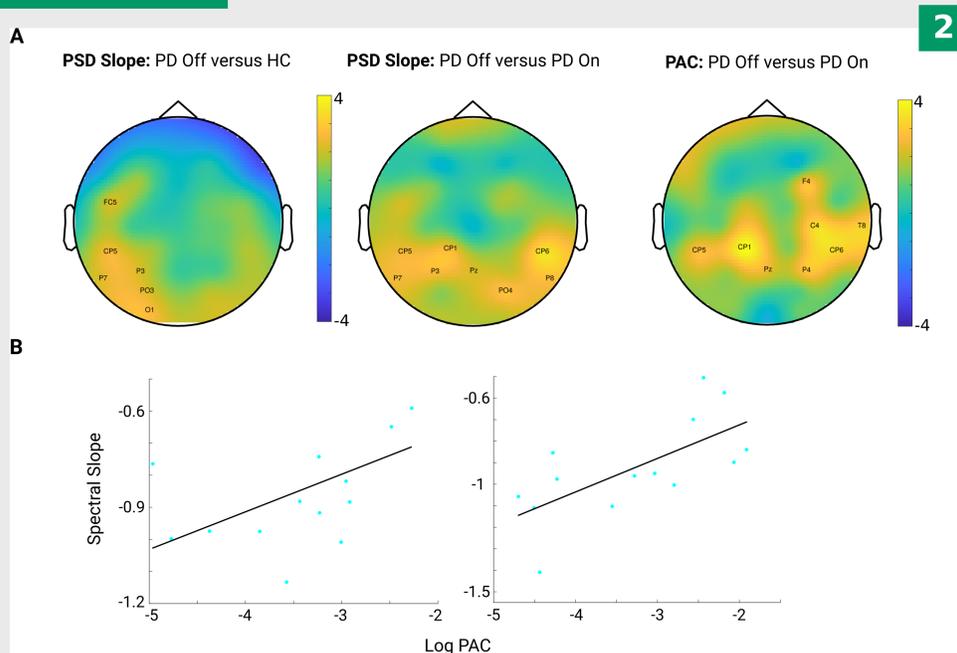


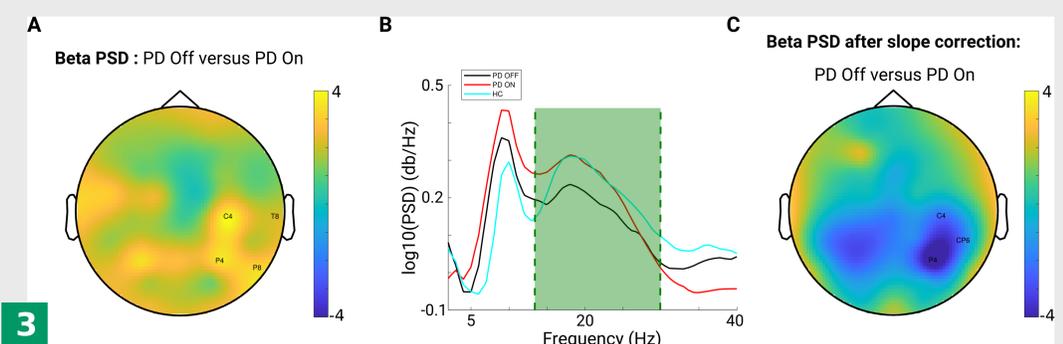
Figure 3. The impact of background spectral slope on estimating the oscillatory band power. A) Topography for comparison of beta band power between PD off versus PD on medication conditions. A positive cluster indicates that medication reduced beta band power in PD. B). Mean of residuals of PSD after subtracting the spectral slopes. The shaded area indicates the beta frequency range for estimating the power. C). Topography for the comparison of oscillatory beta band power between medication states in PD after accounting for the PSD slope. A negative cluster demonstrates that beta band power increased with medication.

Figure 2. A). Topography of difference in PSD slope in comparisons between PD off medication and healthy controls (left panel), and between medication states (middle panel). Positive clusters demonstrated in PD, the spectral slope is flattened and dopaminergic medication restore this abnormality. The right panel shows PAC is elevated in PD off compared to on medication state (consistent with previous studies). B). Relationship between PAC and slope. Left panel shows a positive association between them at centro-parietal regions, while the right panel shows that from sensorimotor areas. Both are from healthy control group. In PD groups, the relations are not significant.

Effect size of different metrics:

- Estimated from Cohen's d (1 indicates the mean of two groups differ by a standard deviation)
- Spectral slope from centro-parietal regions can differentiate the groups with a "medium" effect size, which is larger than that of PAC
- However, PAC from sensorimotor areas has a larger effect size than spectral slope

Effect Size	PD Off vs. HC		PD Off vs. On	
	PAC	PSD slope	PAC	PSD Slope
centro-parietal	0.6101	1.0585	0.2103	1.1104
sensorimotor	0.4421	0.4225	0.6285	0.2963



Discussion & Conclusion

- PD is characterized by a flattened spectral slope compared to the healthy controls
- Dopaminergic medication could effectively restore or normalize the flatteness
- Effects are most pronounced in the centro-parietal regions, which might suggest the detected slope changes are more related to the sensory component of motor processing
- The findings might indicate an imbalanced E/I state at cortex in PD and we hypothesize that a shift from balance towards more excitation tune might reflect complex consequences of different pathways in the basal ganglia-thalamo-cortical loop due to the dopamine loss

References

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