Complexity of Fronto-Temporal Electrocortical Activity in Untreated Parkinson's Disease. Evidences of a Topographical Neuronal Organization

Giovanni Mostile *, MD, PhD, Alessandra Nicoletti *, MD, MSc, Loretta Giuliano, MD, Valeria Dibilio, MD, Antonina Luca, MD, PhD, Loredana Raciti, MD, PhD, Giorgia Sciacca, MD, Calogero Edoardo Cicero, MD, Rosario Vasta, MD, Vito Sofia, MD and Mario Zappia, MD.

Dipartimento di Scienze Mediche, Chirurgiche e Tecnologie Avanzate "G.F. Ingrassia", Università degli Studi di Catania, Catania, Italy.

** These authors equally contributed to this work.*

BACKGROUND

Complexity has been associated to the temporal structure of different biological signals, which usually sit in an intermediate state between two extreme situations: absolute absence of variability (constant signal) and pure unstructured randomness ("white noise"). Complexity is a characteristic of fractal phenomena. Fractals are self-similar structures, where the whole has the same shape of its parts. Self-similarity of biological signals can be evaluated by analyzing the presence of a power law relationship between frequency and size of process variation: this means that power (variance or amplitude) of the process is inversely proportional to its frequency (Hausdorff et al, J Appl Physiol 1996; Stadnitski, Front Physiol 2012). It can be hypothesized that the presence of a power law functional relationship in electrocortical activity of specific sites may indicate an increased level of local neuronal organization (Pereda et al, Neurosci Lett 1998; Li et al, J Neural Eng 2005). The aim of the current analysis was to study self-similarity of electrocortical activity as expression of brain signal complexity in L-dopa untreated Parkinson's disease (PD) subjects.

METHODS

Study population.

We analyzed data of N = 34 L-dopa naïve PD subjects according to Gelb et al. (age: 65.8 ± 7.7 years; sex: 16 women; age at onset: 64.1 ± 8.2 years; 33 were right handed, 1 bi-manual) who had undergone standardized electroencephalography. We also selected N = 18 subjects group-matched by age (62.7 ± 11.2 years), sex (5 women) and manual dominance (16 right) with normal electroencephalography and no parkinsonism and/or cognitive decline as controls (CTRL).

Signal Processing and Scaling β Index Computation.

Details have been provided elsewhere (Mostile et al, Parkinsonism Relat Disord 2015). A Welch's periodogram (50% overlap between 1-s Hamming windowed segments) was applied to 5-seconds artefacts-free (not-detrended) electroencephalographic signal epochs (voltage unit: mV) recorded from specific homologous pairs of electrodes over each hemisphere (F3/4, F7/8, T3/4, P3/4, O1/2) during the eyes-closed task, to compute the Power Spectral Density [PSD (mV^2/Hz)].

The power law exponent β was then obtained for each coordinate as minus the slope of the power spectrum versus frequency in a Log-Log scale to evaluate the relationship between frequency and size of process variation (see **Fig.1**). For β = 1, process variance is inversely proportional to its frequency (1/f process), implying self-similarity. For β = 2, process resembles a Brown noise (random process) (Stadnitski, Front Physiol 2012).

RESULTS

Clinical assessment scores for the PD subjects performed at the time of the EEG study were: HY 2 ± 0.4, UPDRS-ME at baseline 27.8 ± 9.8, MMSE 27.6 ± 1.8.

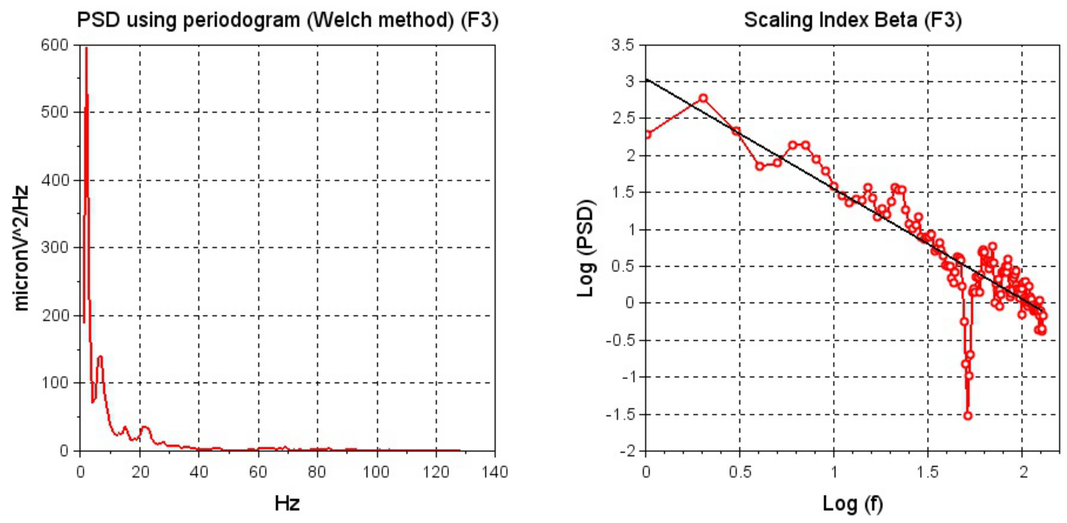
In both PD subjects and controls, β values detected at each electrode coordinate increases with an antero-posterior gradient, changing from values around one in the fronto-temporal sites to values around two among parieto-occipital sites due to posterior predominance of low frequency components. PD subjects present overall lower β values among different sites compared to control, with significant differences for the left fronto-temporal sites (F7: 1.31 ± 0.47 vs 1.6 ± 0.36, p = 0.025; T3: 1.3 ± 0.51 vs 1.63 ± 0.54, p = 0.038) (see **Tab.1** and **Fig.2**).

Tab.1. Scaling Index β values per Electrode Coordinates in PD and CTRL.

Electrode Coordinates	Group	Mean	Std. Deviation	S.E. Mean	p values
F3	PD	1,42	0,51	0,09	
	CTRL	1,52	0,34	0,08	0,408
F4	PD	1,35	0,51	0,09	
	CTRL	1,53	0,41	0,1	0,201
F7	PD	1,31	0,47	0,08	
	CTRL	1,6	0,36	0,09	**0,025**
F8	PD	1,34	0,45	0,08	
	CTRL	1,54	0,49	0,11	0,141
T3	PD	1,3	0,51	0,09	
	CTRL	1,63	0,54	0,13	**0,038**
T4	PD	1,35	0,4	0,07	
	CTRL	1,54	0,52	0,12	0,176
P3	PD	1,99	0,5	0,09	
	CTRL	2,14	0,4	0,09	0,284
P4	PD	1,94	0,45	0,08	
	CTRL	2,1	0,36	0,08	0,199
O1	PD	1,96	0,42	0,07	
	CTRL	2,17	0,4	0,09	0,095
O2	PD	1,94	0,4	0,07	
	CTRL	2,15	0,41	0,1	0,072

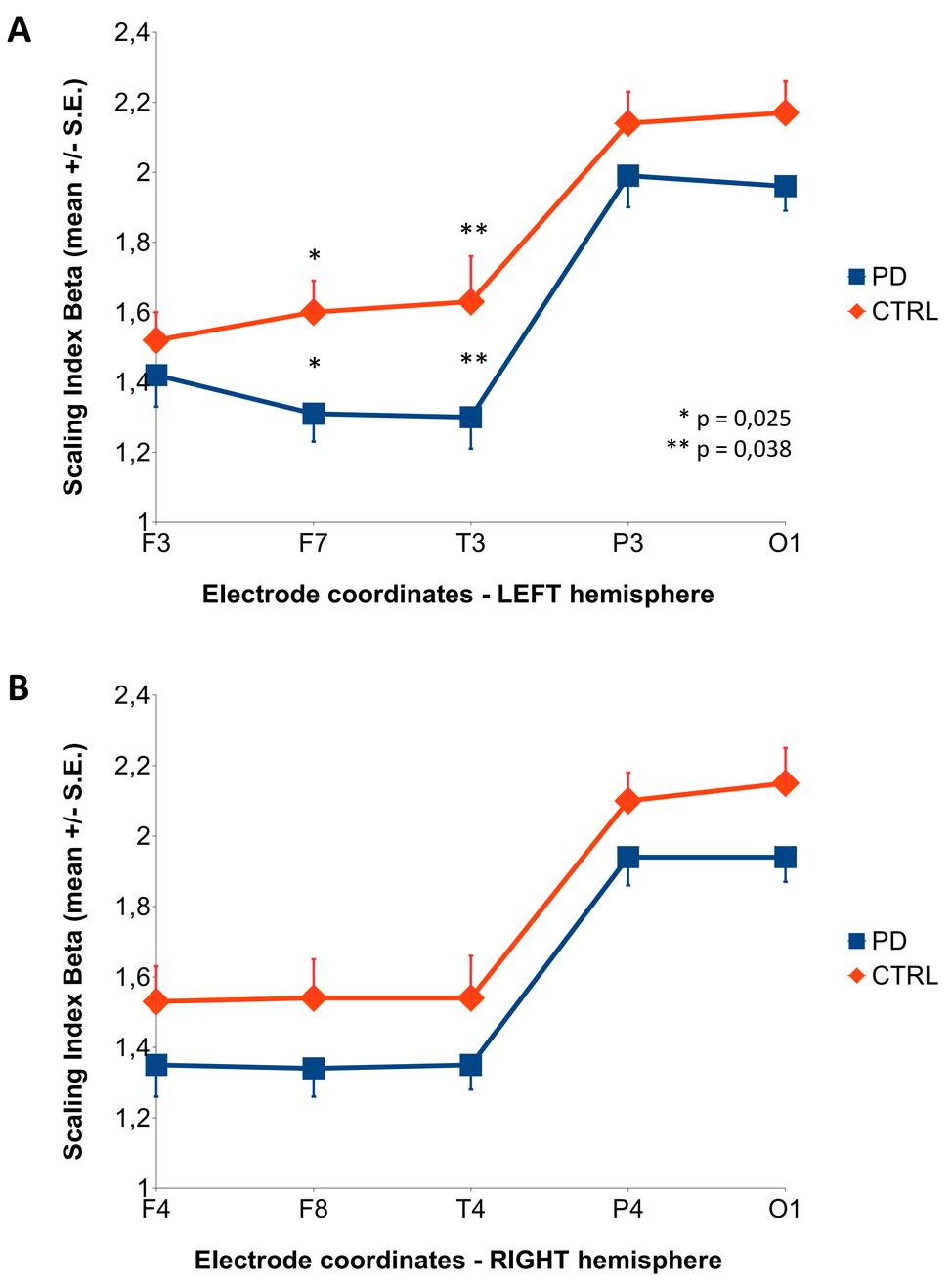
Notes: independent samples t-test using Levene's test first for equality of variances. Significant p values are in bold.

Fig.1. Scaling Index β Computation.



Notes: Left: power spectrum of a signal epoch recorded from F3; Right: scaling index β computation for the same signal as minus the slope of the line relating Log(PSD) to Log(f).

Fig.2. Hemispheric Antero-Posterior β Gradient in PD and CTRL.



Notes: Left (A) and Right (B) hemispheric β gradient from frontal to occipital electrode coordinates in PD and CTRL. Note the "S-Shaped" curve describing changes in signal complexity from sites with predominant high-frequency components to sites with predominant low-frequency components. In PD, β values were sig. lower compared to CTRL in the left fronto-temporal regions (see Tab.1).

CONCLUSIONS

Our findings suggest that in untreated PD, complexity of unilateral electrocortical activity in fronto-temporal sites may underlay an increased neuronal organization in such topographical regions, probably due to cortico-subcortical networks. This notion is supported by the presence of a power law functional relationship in local electrocortical activity.