Differences in nonlinear correlations between brain regions for patients with multiple sclerosis

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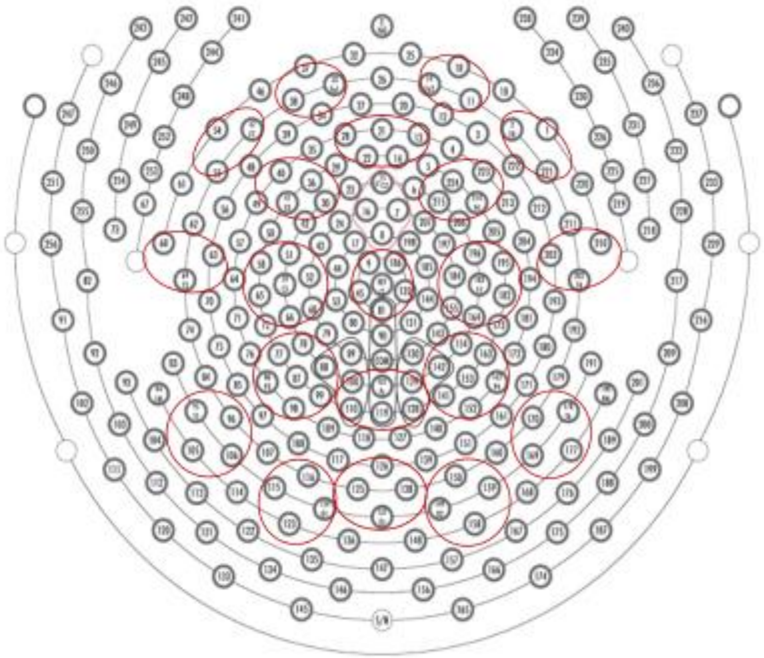
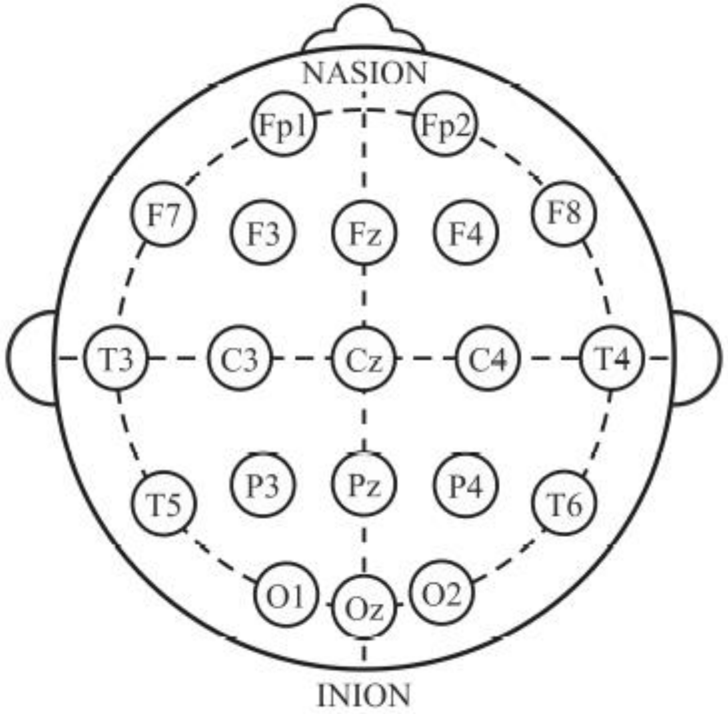
Aim of the research – study EEG time series properties for differences between patients with multipoles sclerosis and healthy people

- 38 multiple sclerosis patients (mean age: 34.3 ± 2.97, 19 females) from Jagiellonian University's Multiple Sclerosis Clinic and 27 healthy controls (mean age: 35.6 ± 2.79, 16 females)
- Prior to participating in the study, all the patients were diagnosed with early onset relapsing-remitting multiple sclerosis (RRMS) with EDSS scores ranging from 0 to 3.5 points (mean: 1.2 ± 0.84).
- The complexity of the EEG time series, quantified by scaling exponents and cross-correlations between signal has been compared between the control group and patients
- Diseases duration, EDSS - Expanded Disability Status Scale

EEG recording and preprocessing

- Continuous dense-array EEG data (HydroCel Geodesic Sensor Net, EGI System 300; Electrical Geodesic Inc., OR, USA) was collected using 256-channel EEG
- Sampling rate of 1000 Hz, band-pass filtered at 0.01–100 Hz
- The impedance for all electrodes was kept below 50 kΩ.
- Data was digitally filtered to remove frequencies below 0.5 Hz and notch filter was applied to remove 50 Hz frequency





Multifractal cross-correlations analysis MFCCA/MFDFA

1. Detrending: $X_\nu(s,i) = \sum_{j=1}^{i} x(\nu s + j) - P^{(m)}_{X,s,\nu}(j)$

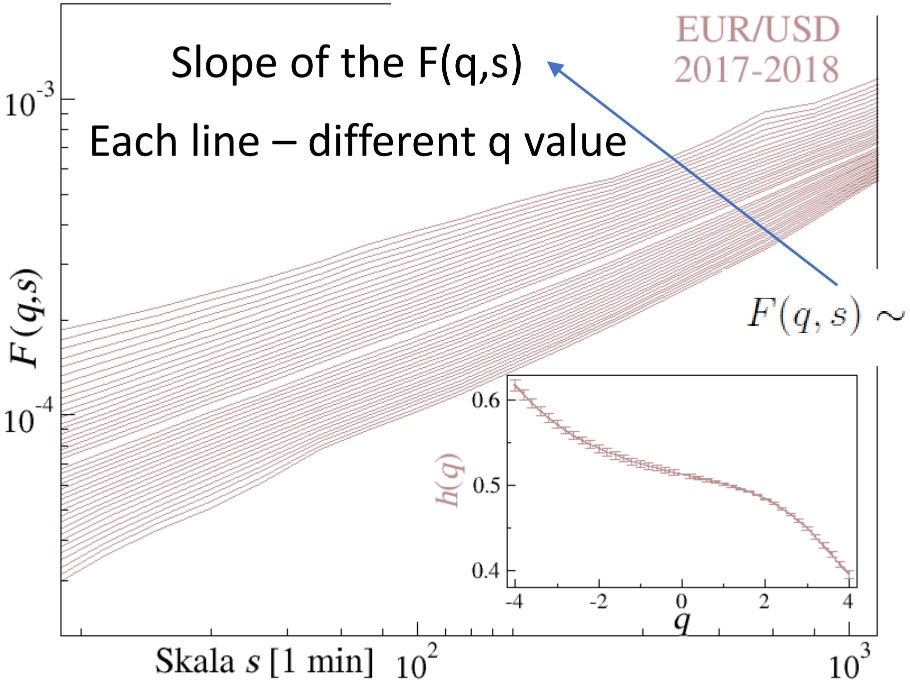
2. Covariance: $f^2_{XY}(s,\nu) = \frac{1}{s}\sum_{i=1}^{s} X_\nu(s,i) Y_\nu(s,i)$

3. Fluctuation function:

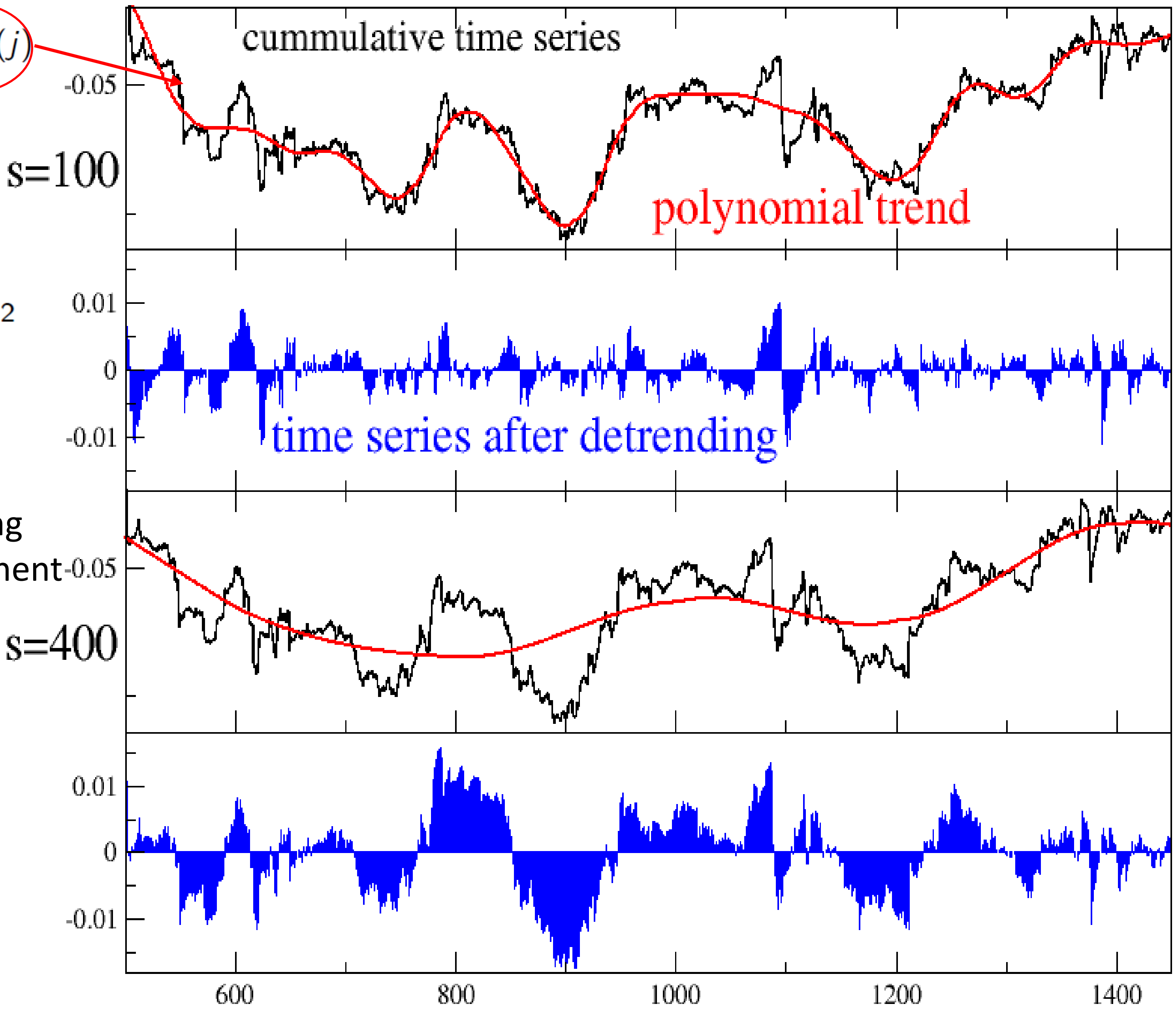
$$F^q_{XY}(s) = \frac{1}{2M_s}\sum_{\nu=0}^{2M_s-1} \mathrm{sign}\left[f^2_{XY}(s,\nu)\right] \left|f^2_{XY}(s,\nu)\right|^{q/2}$$

4. Scaling: $F^q_{XY}(s)^{1/q} = F_{XY}(q,s) \sim s^{\lambda(q)}$

Scaling exponent



$F(q,s) \sim s^{h(q)}$



Multifractal detrended fluctuation analysis MFDFA

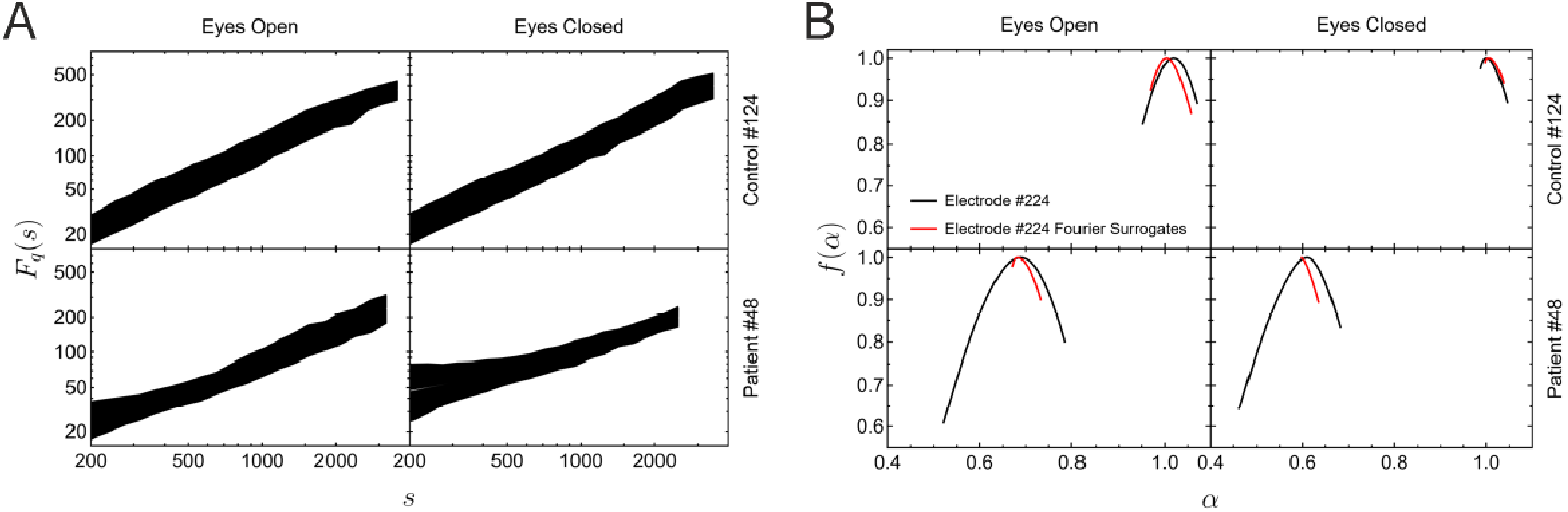
Generalized Hurst exponent

$$F(q,s) \sim s^{h(q)}$$

Multifractal spectrum

$$\alpha = h(q) + qh'(q) \qquad f(\alpha) = q[\alpha - h(q)] + 1$$

J.W. Kantelhardt, S.A. Zschiegner, E. Koscielny-Bunde, S. Havlin, A. Bunde, H.E. Stanley, Multifractal detrended fluctuation analysis of nonstationary time series, Physica A 316 (1) (2002) 87–114, http://dx.doi.org/10.1016/S0378-4371(02)01383-3.

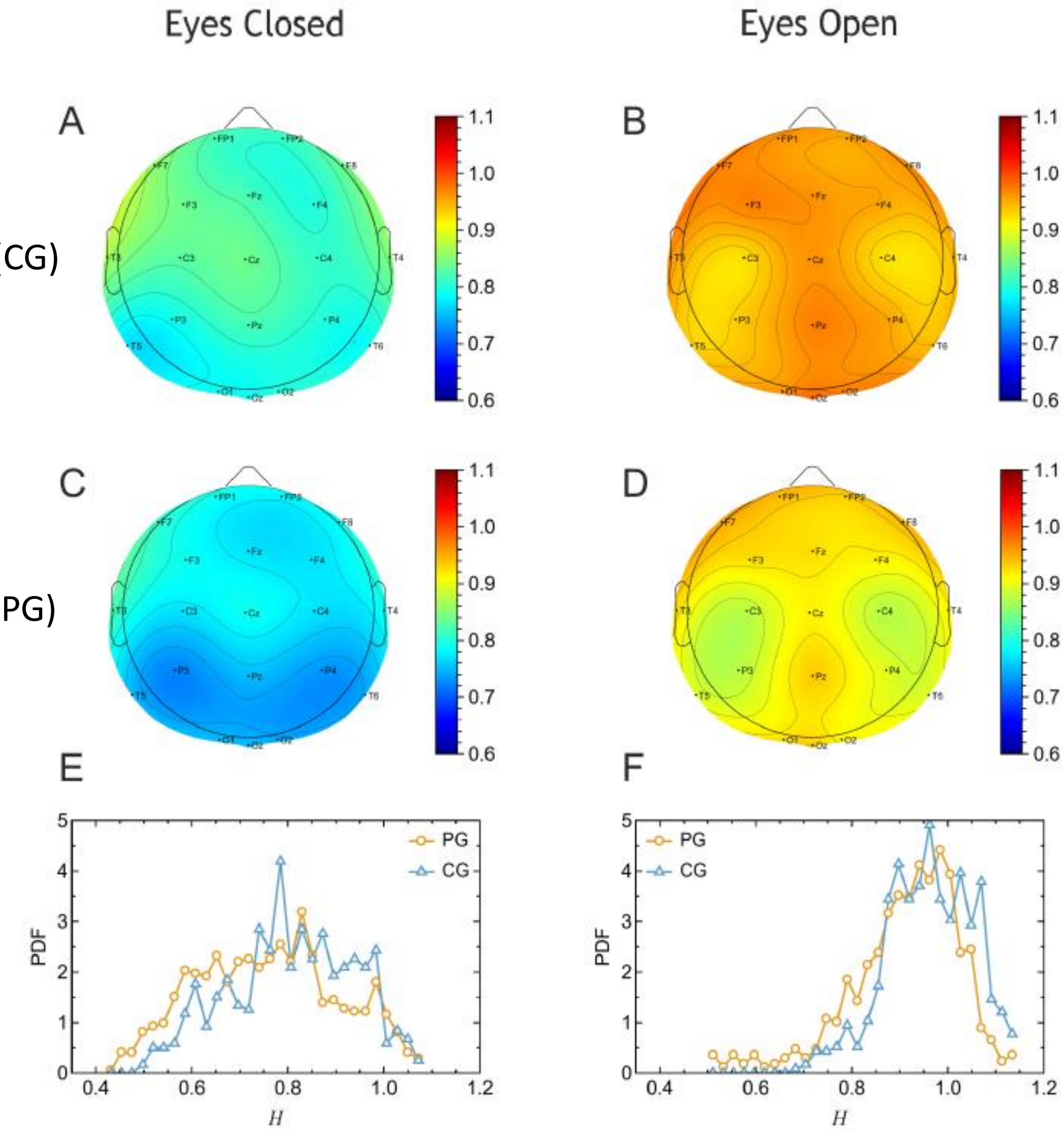


Hurst exponent (h(q=2))

Measure of time series persistance

Control group (CG)

Patient group (PG)

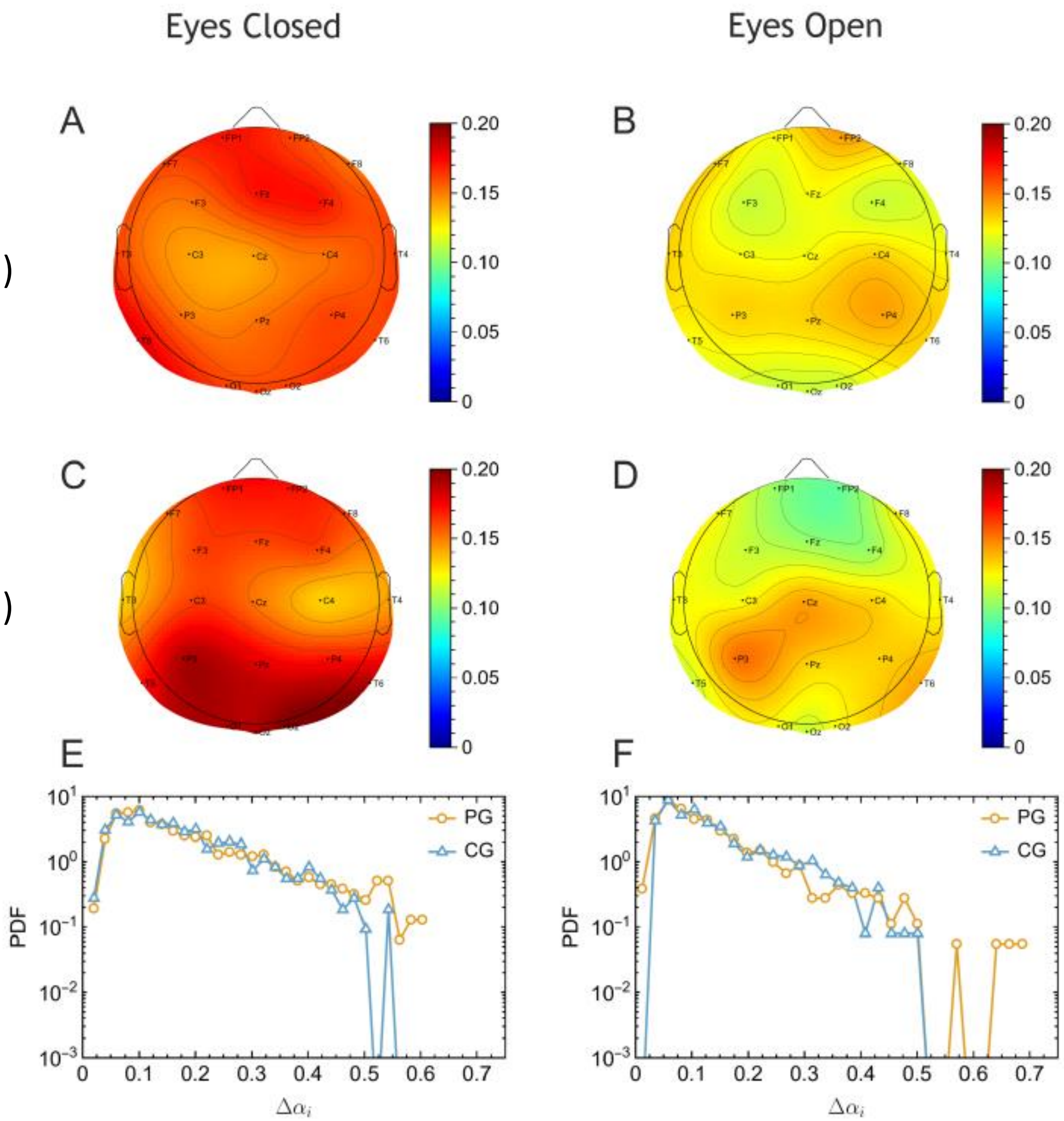


Multifractal spectrum width (Δα)

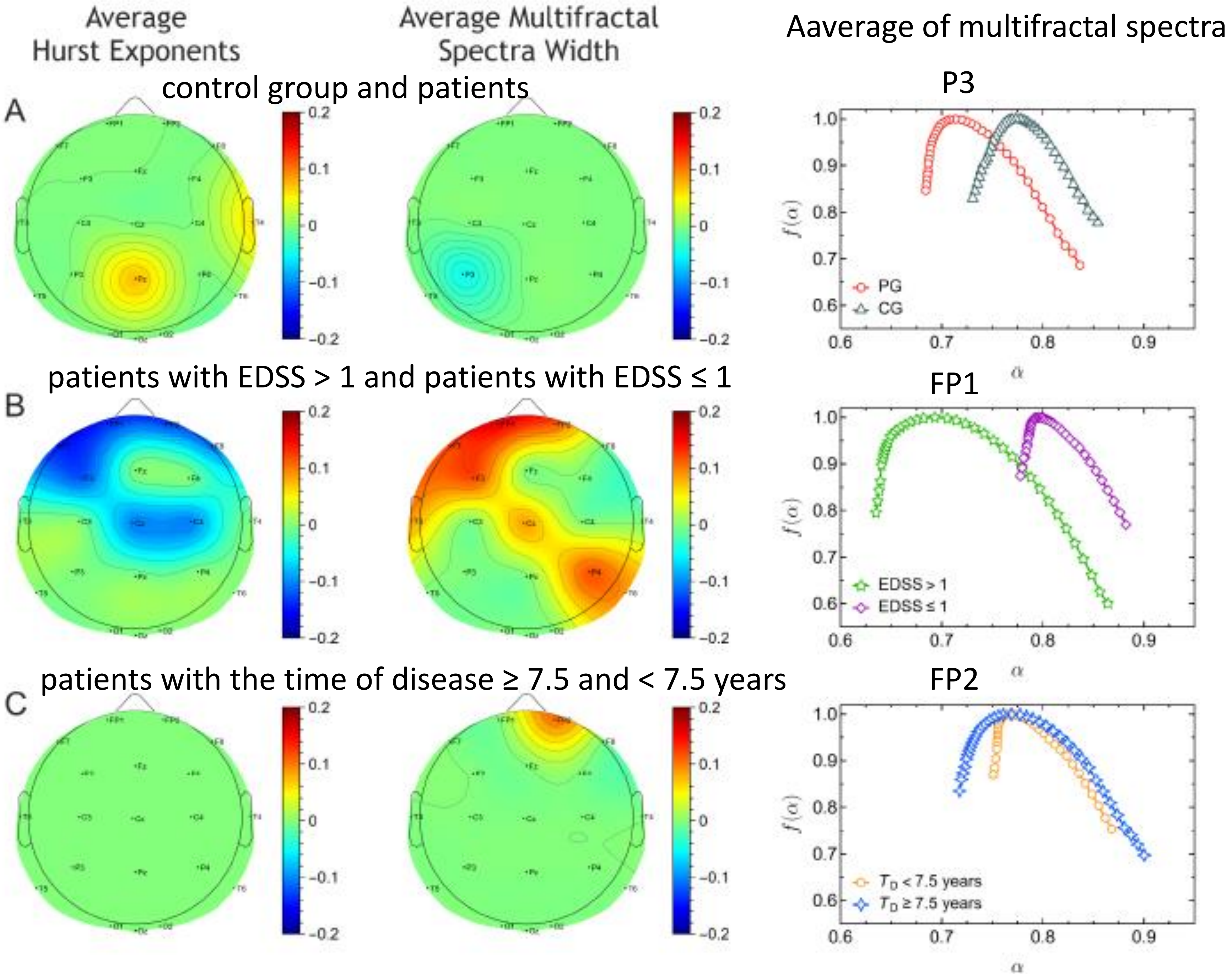
Measure of time series complexity

Control group (CG)

Patient group (PG)



Statistically significant differences between



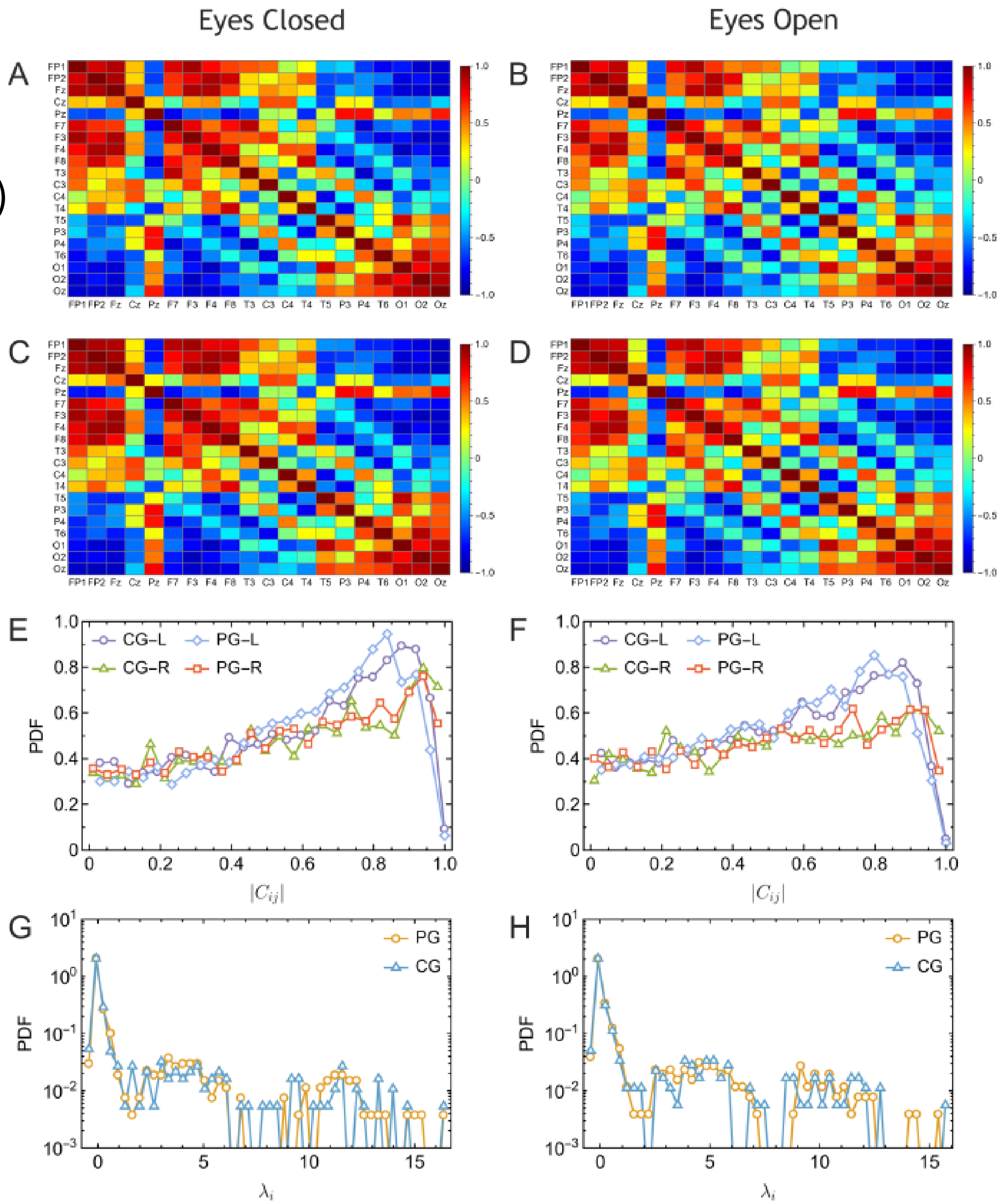
Correlation matrix analysis

Pearson correlation coefficient

$$C_{ij}=\frac{cov(X_i,Y_j)}{\sqrt{var(X_i)var(Y_i)}}$$

Control group (CG)

Patient group (PG)



Time scale dependence

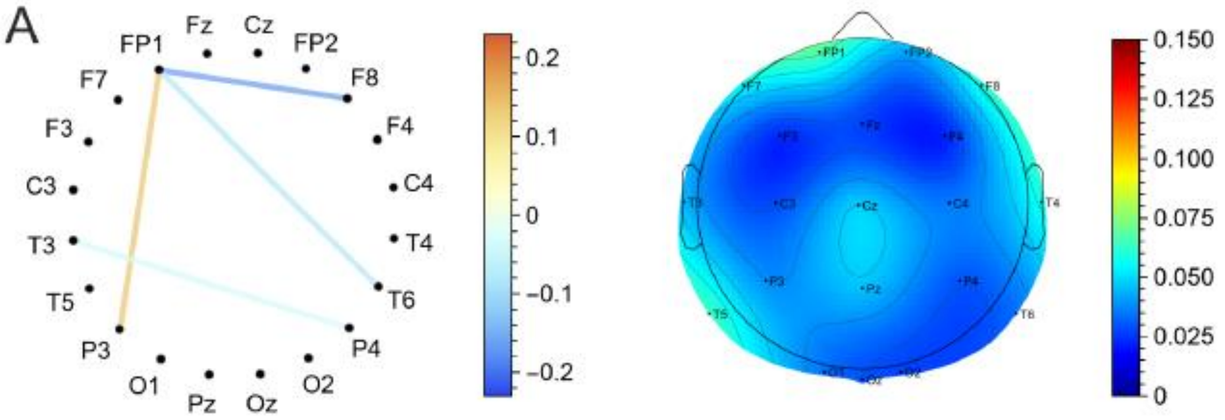
$$\rho(q,s)=\frac{F^q_{xy}(s)}{\sqrt{F^q_{xx}(s)F^q_{yy}(s)}}$$

Fluctuation size dependence

Jarosław Kwapień, Paweł Oświęcimka, and Stanisław Drożdż
Phys. Rev. E **92**, 052815 – Published 30 November 2015

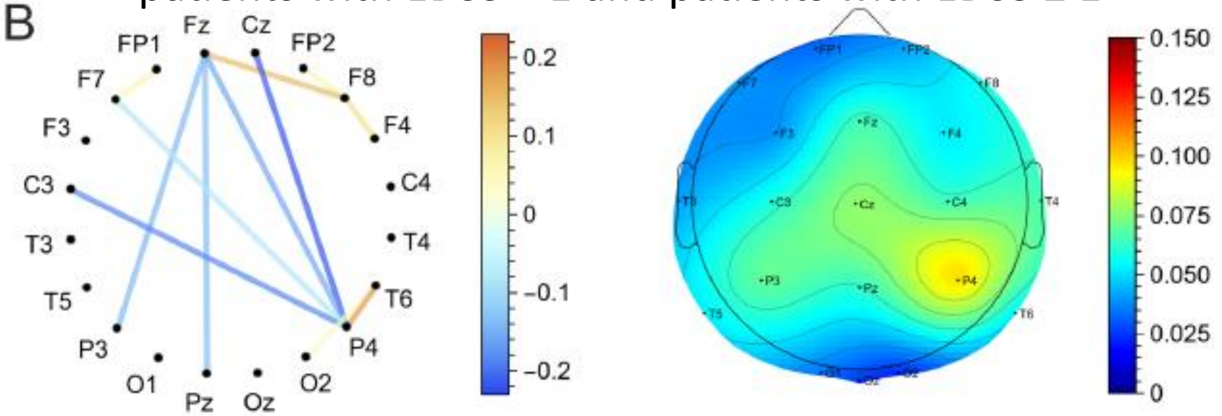
control group and patients

Connections between electrodes represent statistically significant differences between average correlation matrices

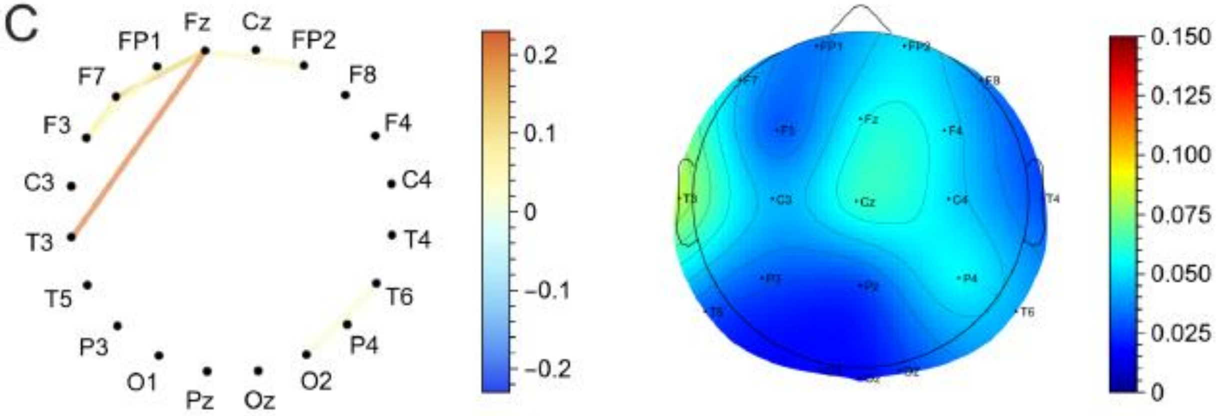


the average of absolute values of differences estimated for each electrode

patients with EDSS > 1 and patients with EDSS ≤ 1 → level of disability



patients with the time of disease ≥ 7.5 and < 7.5 years → disease duration



Main conclusions

- Significant relation between the complexity of the time series and multiple sclerosis development
- The well-developed multifractality and less persistence of the time series have been identified for patients with a higher level of disability, quantified by the Expanded Disability Status Scale (EDSS), compared to the control group and patients with low-level EDSS, for which the EEG signals are characterized by persistence and monofractality
- The most significant difference in the brain areas cross-correlations has been identified for the cohort of patients with EDSS > 1 and the group of patients with EDSS ≤ 1

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- https://cna2023.ift.uj.edu.pl/

- 20 student scholarships which include fee waiver and should be enough to cover travel and lodging during the school