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# DETRENDED FLUCTUATION ANALYSIS APPLIED TO CORTICAL SPREADING DEPRESSION: THE MALNUTRITION EFFECT

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**Abstract**: Detrended Fluctuation Analysis (DFA) has been applied to the Cortical Spreading Depression (CSD) in well-nourished rats (1). Here we applied the DFA to study the fluctuations dynamics induced by spreading depression in the electrocorticogram (ECoG) in malnourished rats. The scaling exponents (α) from the DFA were calculated for ECoG record in the followings time intervals: before CSD or control, immediately before CSD, characterized by burst, during and post-CSD. Our results show that the malnourished animal presents persistent long-term correlations for all intervals. The DFA scaling exponent (α) values showed only significant difference in the burst period in relation to the others periods. The malnourished animals present a lower correlation than observed for well-nourished.

**Keywords**: DFA, Cortical Spreading Depression, scaling exponent, malnourished.

## 1. INTRODUCTION

Detrended Fluctuations Analysis (DFA) is a method introduced by Peng and collaborators [2] for determining the statistical self-affinity of a signal and it is useful for analyzing time series that presents long-term memory. The scaling exponent α of the DFA, parameters that disclose memory in time series is similar to the Hurst exponent, except that DFA may also be applied to signals whose measurement statistics are non-stationary.

The CSD is a self-propagating electrical wave characterized by a reversible suppression of neural activity for a period of minutes. The CSD can be induced by mechanical, chemical or electrical stimulus and propagates from stimulated local to adjacent regions of the brain with speed of 2-3 mm/min and 15-20 min after the stimulus the neural activity is recovered [3]. There are some evidences that the CSD is related to following clinical disorders: migraine, epilepsy, cerebral ischemia and others diseases. Recently, we applied DFA to analysis of signal fluctuations of CSD phenomenon in nourished rats and we showed long-range correlation in this time series [1].

Animals submitted to malnutrition during early periods of life have revealed changes in excitability of central nervous system and peripheral [4]. Therefore, the investigation about the phenomenon of CSD in early malnourished animals may provide information about brain electrical activity and diseases in nutritional stress.

In this work, our main objective was to apply Detrended Fluctuations Analysis in the ECoG signal recordings aiming characterize scaling exponent patterns before, in the burst and after the CSD, for malnourished adult rats.

## 2. MATERIAL AND METHODS

Wistar male 90-120 days old albino rats malnourished as previously described [5], from the colony of the Department of Nutrition of the UFPE, were submitted to stimulus and recorded of the electrical activity before, during and after the CSD. A metallic bipolar concentric stimulating electrode was positioned in the left cortex (1 mm deep) and used to stimulate electrically the cortex. A glass recording micropipette (10 µm tip diameter; Borosilicate, World Precision Instruments) filled with 2M NaCl was impaled in the homologous region of the right cortex, in which the field potential responses, evoked by the contralateral electrical stimulation, were recorded as control of activity of the recording electrode. We selected time series of the ECoG of the cortex of three malnourished rats. The time series ranged around a million points, which were pre-processed in the program QUB (www.QuB.Bufalo.edu), which allowed the collection of smaller files or segments, characterized by samples in this work which are then analyzed to remove the trends of the signal and provide information about your memory, as assessed by software available on Physionet (www.physionet.org). The quantity of α exponents obtained was: in the control equal to 239, in the burst equal to 3, in the CSD equal to 308 and post-CSD equal to 241.

## 2.1. DETRENDED FLUCTUATION ANALYSIS

The DFA can be synthesized as follow. The first step is to integrate the original time series X(i), i=1,2,,…,N

$$y(k) = \sum_{i=1}^{k} [x(i) - \bar{x}] \qquad (1)$$

Where $\bar{x} = \sum_{i=1}^{N} x(i) / N$ is the data mean value, k is an integer between 1 and N. The next step is to divide the integrated series Y (k) into boxes of equal length n, and in each box a linear regression is implemented (capturing the trend in the observed box) , where the ordinate of thus obtained straight line segments is denoted by Yn (k). The integrated series Y (k) is then detrended by subtracting the local trend Yn(k) from the data, within each box, and the root-mean-square fluctuation is calculated as follow

$$f(n) = \sqrt{\frac{1}{N} \sum_{k=1}^{N} [\ y(k) - y_n(k)]^2} \quad (2)$$

Repeating this calculation for various box sizes provides the relationship between F(n) and box size n, where F(n) increases with n as a power law F(n) ~ $n^{\alpha}$ . The scaling exponent α is obtained by the slope of the least squares line fitting of log F(n) versus log n. The value of α = 0.5 indicates the absence of correlation, α > 0.5 indicates persistent long-term correlation, meaning that large (small) values are more likely to be followed by large (small) values, α < 0.5 indicates a antipersistent long range correlations, meaning that large values are more likely to be followed by small values and vice –versa.

## 3. RESULTS AND DISCUSSION

Table 1 shows that malnourished rats present long term correlation in the intervals before CSD, in the CSD and post-CSD. The exception is only the burst, period in which α = 0.58 ± 0.08, indicating that in this phase the ECoG is a series poorly correlationed. The mean value of α, observed in other intervals show that the series present a persistent correlation. Except the burst the α values did not present any significantly difference in the various ECoG time intervals, different of the well-nourished rats previously studied that showed very significant differences in the same time intervals analyzed here (1). Another aspect important is that malnourished animals presented a lower correlation than observed for well-nourished, indicating a lost of complexity in the ECoG records.

| Scaling exponent (α) from DFA | | | | |
|---|---|---|---|---|
| **Animals** | **Before** | **Burst** | **CSD** | **Post-CSD** |
| **D1** | **0.83 (0.03)** | **0.64** | **0.74(0.05)** | **0.81(0.05)** |
| **D2** | **0.68(0.03)** | **0.59** | **0.79(0.05)** | **0.69(0.03)** |
| **D3** | **0.54(0.04)** | **0.49** | **0.57(0.08)** | **0.61(0.02)** |
| **N** | **239** | **3** | **308** | **241** |

**Table 1 – Scaling exponent for malnourished rats. Alfa is represented as mean (SD). N is equal to number of segments analyzed.**

## 4. CONCLUSIONS

The results show that: 1. malnourished rats presented long-term correlation, except during the burst phase; 2. the α value is significantly lower in burst than in other periods, indicating loss of memory in the ECoG signal in this phase; 3. The malnourished animals present a lower correlation than observed in previously studied well-nourished rats, indicating loss of complexity in the electrical neural activity.

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