Spectral analysis of the EEG for the differentiation of normal children and children with mild epilepsy

***Abstract*— One of the major roles of the electroencephalogram (EEG) is an aid to diagnose epilepsy. Although various computational methods have been developed for the analysis of the EEG signal over the past three decades, little of them have been applied to groups of children with mild epilepsy. The present study was carried out to evaluate the Peak Frequency (PF), mean voltage and mean power of different frequency bands of the EEG signal, in order to try to differentiate between groups of normal children and children with mild epilepsy. The analysis showed that the spectra of the normal and mild epileptic children overlap quite heavily. For this reason a reliable classification of a patient in one of the groups could not be achieved using the mean power distributions, mean voltage variation and peak frequency distribution using direct comparison for the commonly used EEG frequency bands.**

I. Introduction

ONE of the major roles of the electroencephalogram (EEG) is an aid to diagnose epilepsy. The analysis of the EEG signal for epileptic patients can be done both in the time domain, where abnormal patterns such as spikes, sharp waves and/or spike and wave complexes can be visually observed, and in the frequency domain where visually almost undistinguishable events can be observed. These types of analysis can assist the physician in diagnosing a patient and in prescribing the correct medication.

Although over the past three decades various computational methods have been developed for EEG signal analysis, most of the analyses in the frequency domain have been based on power spectrum analysis and they reported absolute and relative power values of different bands or frequencies of the background EEG activity [1]-[4]. The alpha rhythm is one of the most important graphoelements in electroencephalography and it has been known ever since the first human electroencephalograms. The alpha frequency, typically between 8 Hz and 13 Hz in healthy adults, was shown to be reduced in children and in the elderly, and in patients with some neurological and psychiatric diseases, including dementia, schizophrenia, stroke and epilepsy [1]-[3]. The peak alpha frequency (PAF) commonly used in studies of cognitive and memory performance, was recently proved to have a compromised variability in patients with epilepsy [4]-[5].

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Based on the recent PAF findings, the present study was carried out to evaluate the average power distributions, peak frequency, and the mean voltage variations in different frequency bands, in order to try to differentiate between groups of normal children and children with mild epilepsy.

II. Patients and Methods

In this study, we used epochs of 10 seconds recorded from 20 control subjects and 20 subjects with mild epilepsy, without clinical or laboratory signs of dysfunction and with normal neurophysiologic findings. The data were recorded during 11 cognitive tests that involved speech and mathematical thinking. All the recordings have been sampled at 400 Hz and all 30 channels available were included in the study.

For each epoch we calculated three indicators: the average power, the peak frequency, and the mean voltage in each of the commonly used frequency bands of the EEG signal:

- delta frequency band (0.5 – 4.0 Hz);
- theta frequency band (4.0 – 7.0 Hz);
- alpha frequency band (8.0 – 12.5 Hz);
- beta1 frequency band (13.0 – 16.0 Hz);
- beta2 frequency band (16.0 – 26.0 Hz);
- gamma frequency band (26.0 – 48.0 Hz).

The indicators were calculated separately for three different representative tests:

- test 1: child observes a star;
- test 2: child subtracts numbers n=16: right or wrong in turns: dx or sin. Two digits numbers subtractions or two digits minus one digit;
- test 3: fractals.

For each of the six frequency bands Fast Fourier Transforms (FFT) were applied to the epochs. All computations were done in Matlab® 7.2 The MathWorks Inc. for Windows. The peak frequency was calculated as the highest peak within the frequency range and the mean voltage was calculated as the absolute mean of the FFT peaks within the frequency range.

The mean power distribution for each group of patients was calculated as the mean of the Power Spectra Densities estimates calculated for each epoch (Signal Processing Toolbox 6.5 The MathWorks Inc.).

III. Results and Conclusion

Six representative channels have been selected to graphically present the results: two frontal (F3, F4), two central (C4, C3), and two occipital (O2, O1).

As Fig. 1 shows, the Mean Power Distributions for the normal and mild epileptic children overlap quite heavily. For this reason a reliable classification of a patient in one of the groups could not be achieved using the distributions of the mean powers, considered for the commonly used EEG frequency bands. Although the *beta1* frequency band seems to have slightly different distributions for the two groups, our attempt to classify a patient in one of the groups using a thresholding method resulted in many false classifications. Using only the channels that show clear visual differences between the mean power distribution of the group of normal children and the group of mild epileptic children, the results improved but a reliable classification was still not achieved (see Table I).

Fig. 2 shows the distributions of the Peak Frequencies calculated for each frequency band. Once again it can be seen that the distribution overlap and the difference between the two groups is not clear.

In Fig. 3 the distributions of the mean voltages show the same behavior. A reliable classification was not achieved.

The reason for the great number of false classifications might be the presence of significant outliers in the data that greatly influence the calculated indicators. As future work we will try to eliminate the outliers and to define narrower frequency ranges (divide the commonly used EEG frequency ranges in smaller bands) and consider only those which show significant differences for each distribution.

TABLE I
Mean Power Distributions differences between the two groups of patients

	delta	theta	alpha	beta1	beta2	gamma
Ch 01						
Ch 02		D				
Ch 03		D				
Ch 04		D				
Ch 05			D			
Ch 06			D			
Ch 07		D		D		
Ch 08				D		
Ch 09		D				
Ch 10		D				
Ch 11		D	D			
Ch 12						
Ch 13		D		D	D	
Ch 14				D		
Ch 15		D				
Ch 16		D				
Ch 17		D			D	
Ch 18						
Ch 19						
Ch 20		D				
Ch 21		D	D			
Ch 22		D				
Ch 23		D				
Ch 24		D		D		
Ch 25		D		D		
Ch 26		D				
Ch 27		D				
Ch 28		D				
Ch 29		D				
Ch 30			D			

A "D" in the cell means that a visual difference was observed for the corresponding frequency band and channel, between the distribution of the normal group and the group of mild epileptic children. An empty cell means that no clear visual difference was noticed.

Acknowledgment

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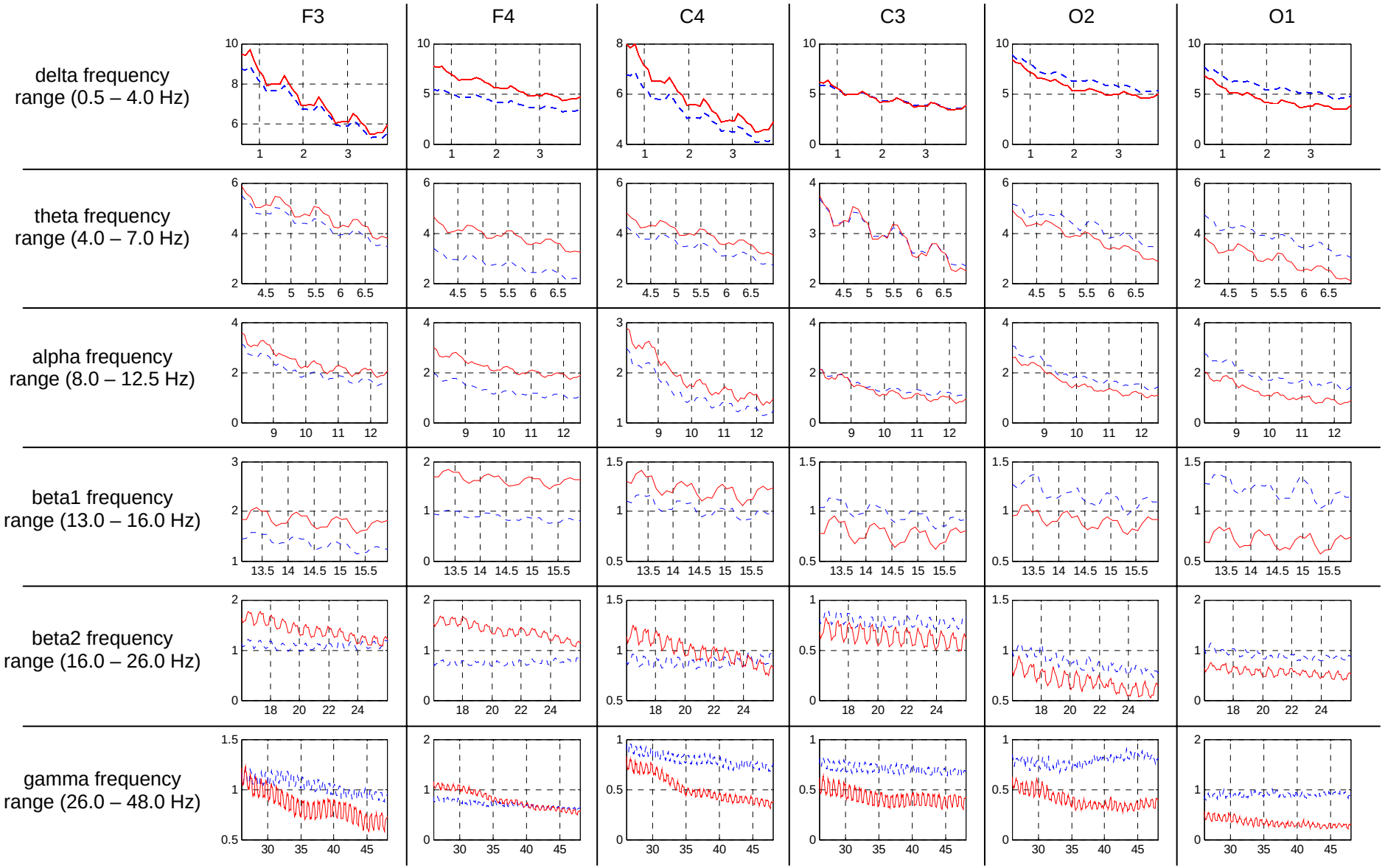

Fig. 1. Mean Power distributions for channels: F3, F4, C4, C3, O2, and O1. The data was recorded during Test 6 (mathematical thinking): "Child subtracts numbers n=16: right or wrong by turns: dx or sin; two digits numbers subtractions or two digits minus one digit". For each graphic, the horizontal axis represents the frequency (Hz) and the vertical axis represents the power. The red plots (continuous line) represent the distributions of the mild epileptic children and the blue plots (dotted line) represent the distributions of the normal children.

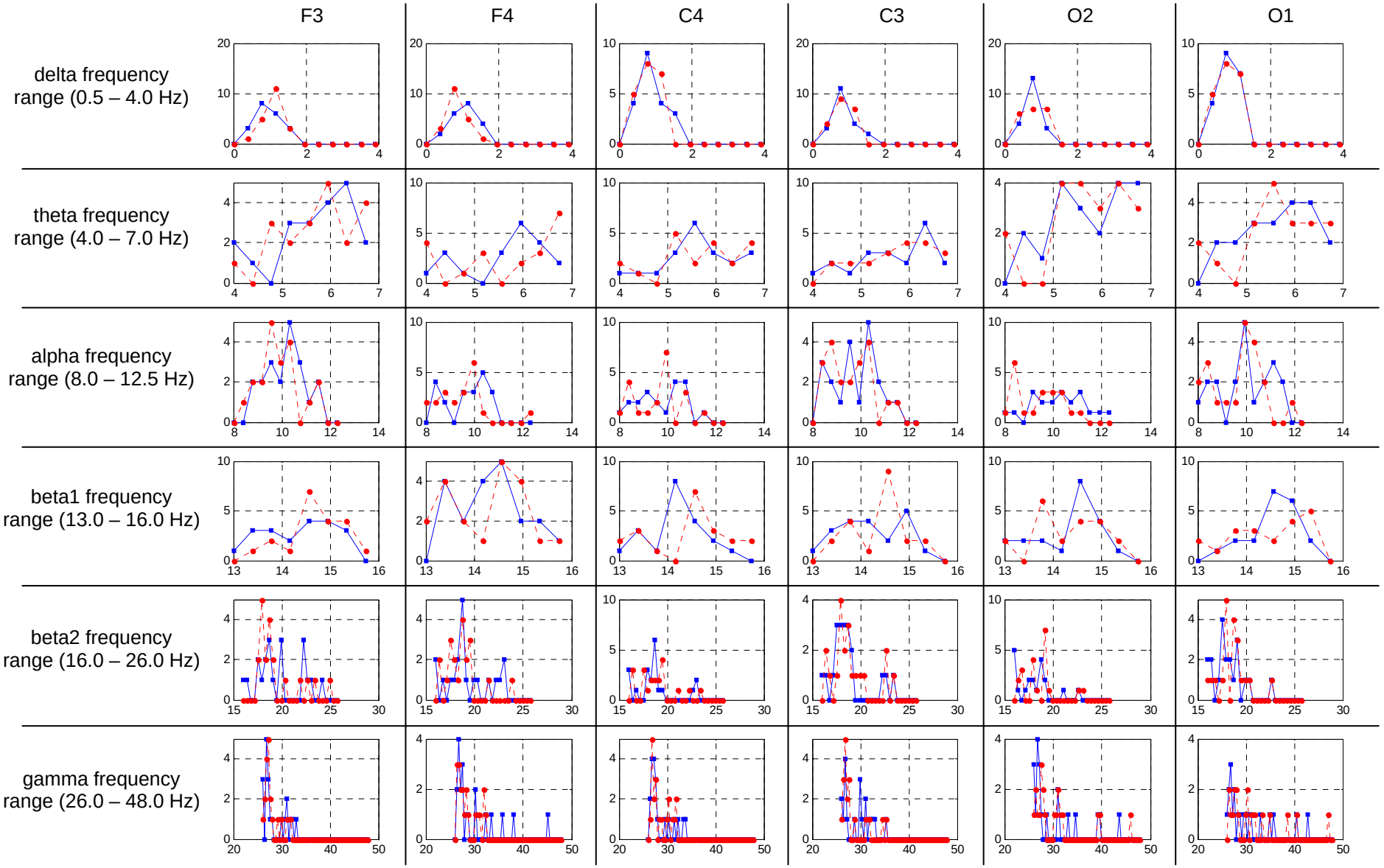

Fig. 2. Peak frequency distributions for channels: F3, F4, C4, C3, O2, and O1. The data was recorded during Test 6 (mathematical thinking): "Child subtracts numbers n=16: right or wrong by turns: dx or sin; two digits numbers subtractions or two digits minus one digit". For each graphic, the horizontal axis represents the frequency (Hz) and the vertical axis represents the number patients. The red plots (circle dotted line) represent the distributions of the mild epileptic children and the blue plots (square continuous line) represent the distributions of the normal children.

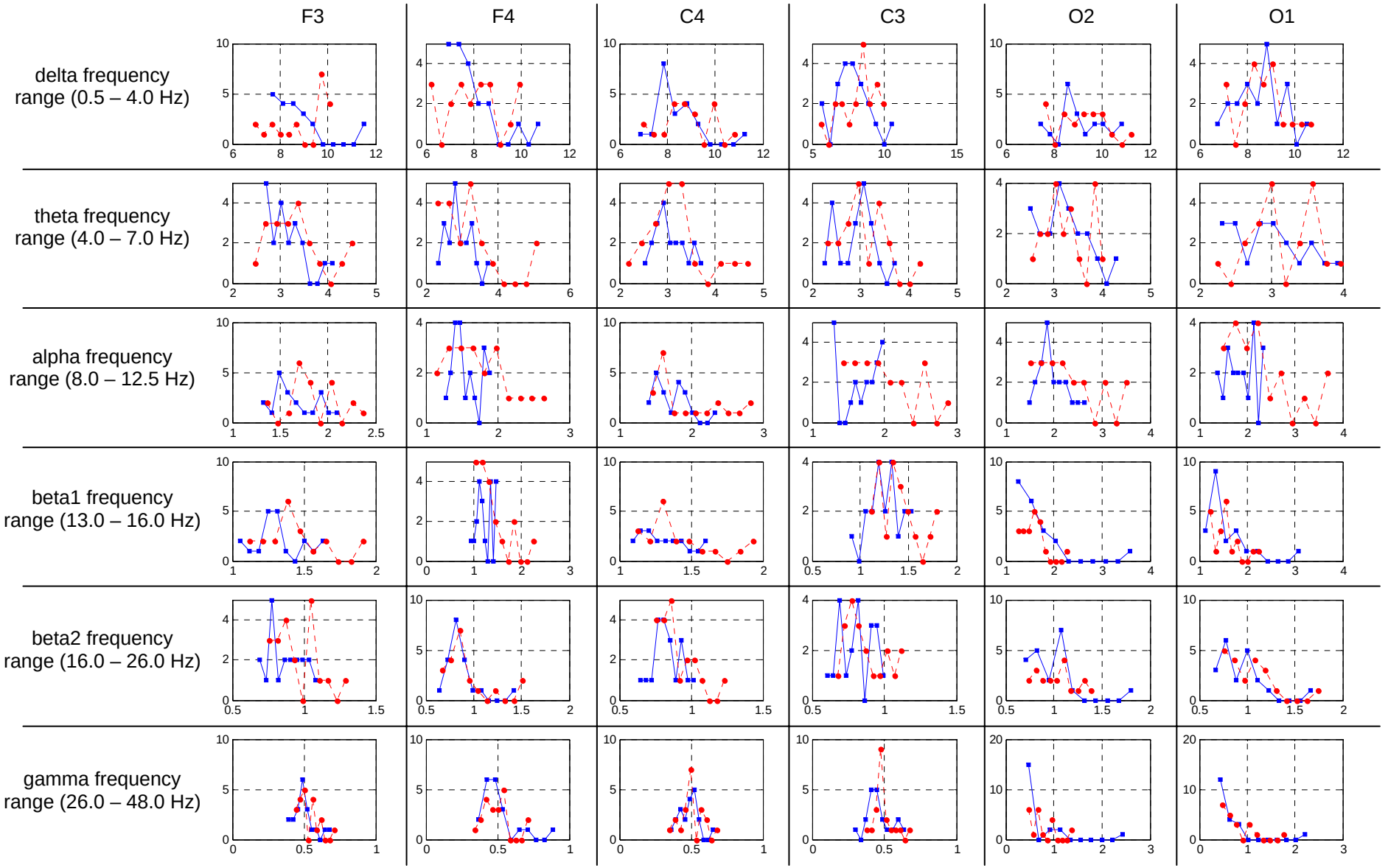

Fig. 3. Mean voltage distributions for channels: F3, F4, C4, C3, O2, and O1. The data was recorded during Test 6 (mathematical thinking): "Child subtracts numbers n=16: right or wrong by turns: dx or sin; two digits numbers subtractions or two digits minus one digit". For each graphic, the horizontal axis represents the voltage and the vertical axis represents the number of patients. The red plots (circle dotted line) represent the distributions of the mild epileptic children and the blue plots (square continuous line) represent the distributions of the normal children.