International Journal of Bioelectromagnetism
Vol. 14, No. 2, pp. 80 - 83, 2012

www.ijbem.org

Analysis of awake and sleep EEG in autistic children

Monica Cusenza[a], Agostino Accardo[a], Sergio Zanini[b], Paolo Brambilla[b]

[a]*Department of Engineering and Architecture, University of Trieste, Trieste, Italy*
[b]*IRCCS Eugenio Medea Scientific Institute, Udine, Italy*

Correspondence: M Cusenza, Department of Engineering and Architecture, University of Trieste, Via A. Valerio, 10 – 34127 Trieste, Italy E-mail: monica.cusenza@phd.units.it, phone +39 040 5587817, fax +39 040 5583460

Abstract. In this study the characteristics of autistic EEG are explored by means of linear and fractal analysis on traces recorded in the awake state and during both light and deep sleep. Results are compared with those obtained from EEG assessment of children with mental retardation. Significant differences were found between the two groups, suggesting that EEG parameterization could be a powerful tool for early diagnosis of autism and effective intervention.

Keywords: Autism; Mental Retardation; Diagnosis; EEG; Awake; Sleep; Fractal Dimension

1. Introduction

Autism is a behavioural, cognitive and brain developmental disorder characterized by impairments in social interaction and communication, as well as by the presence of restricted and repetitive behaviours, interests and activities [Rapin, 1993]. Gross brain structure, neuronal growth patterns and abnormal connectivity in autism have been extensively studied by means of EEG, MEG, MRI and fMRI techniques [Belmonte et al., 2004; Penn, 2006; Mengotti et al., 2011; Philip et al., 2012; Wilson et al., 2007]. However, objective measures that could help physicians in screening for autistic children are not yet available. The EEG, as a non-invasive and cheap methodology characterized by high temporal resolution, could represent a promising diagnosis tool. Although most EEG investigations concern the co-occurrence of autism and epilepsy, some studies have been carried out in order to distinguish autistic EEG from normal EEG on the basis of linear [Grice et al., 2001; Chan et al., 2009; Pop-Jordanova et al., 2010] and nonlinear measures [Ahmadlou et al., 2010; Catarino et al., 2011]. However, more important is the possibility to reliably discriminate autism from similar behavioural and developmental disorders. Early diagnosis of autism allows early intervention, increasing treatment effectiveness and improving patient's long-term quality of life. This paper explores EEG linear and fractal features of autistic children in comparison with those of children with mental retardation. The investigations is carried out in the awake state as well as during light and deep sleep.

2. Material and Methods

2.1. Patients

A total of 19 autistic children and 19 children with mental retardation were included in the study. Subjects were recruited at the Developmental Psychopathology Unit at the IRCCS Eugenio Medea of Udine (Italy). The two groups were matched for age (5-13 yrs), gender (17 boys and 2 girls) and IQ. The study was approved by the local Ethics Committee and written informed consent was obtained from the parents of all children.

2.2. EEG recording

A total of three EEG recordings were collected from each subject. About 5 min of resting EEG were recorded in the awake state (AW). Two further recordings were collected during afternoon sleep after being sleep-deprived the night before the test. EEGs of about 10 min were acquired during light sleep (LS, stages 1 and 2) and deep sleep (DS, stages 3 and 4). Unfortunately, not all registrations were used for the analysis. Some AW recordings had to be excluded because of the poor quality of registration either due to lack of cooperation or extensive movement artefact. Moreover, sleep EEG could not be acquired for those children who did not achieve natural sleep (lack of both LS and DS recordings) or awoke before deep sleep was reached (lack of DS recording). The number of EEG analyzed for each group in each electrical state are summarized in Table 1. Nineteen unipolar and sixteen bipolar derivations were used for the analysis. Signals were acquired at 256 or 512 Hz with Ag-AgCl electrodes positioned according to the 10-20 system.

Table 1. *Number of subjects analysed in the different electrical states.*

State	*Autism*	*Mental retardation*
AW	17	17
LS	14	15
DS	12	12

2.3. EEG analysis

EEG traces acquired at 512 Hz were resampled at 256 Hz for the linear analysis and were then resampled at 128 Hz for the fractal analysis. Both groups of 256 and 128 Hz EEGs were processed with a Butterworth band-pass filter between 0.5 and 60 Hz and with a 50 Hz notch filter. After de-trending each 256Hz-trace was divided into 50% overlapping segments of 10s. After Hamming windowing, each segment was fast Fourier transformed to estimate the power spectral density by periodogram method. The percentage power in the EEG sub-bands (delta 0.5-4 Hz, theta 4-8 Hz, alpha 8-13 Hz, beta 13-30 Hz and gamma 30-60 Hz) was calculated from the power spectral density. The fractal dimension was estimated in the same segments on the 128Hz-traces by means of Higuchi's algorithm [Higuchi, 1988]. For each unipolar and bipolar derivation a mean value of each parameter was calculated as the average among all 10s segments. The unipolar and the bipolar derivations were then clustered into 9 unipolar and bipolar groups, respectively, according to the brain regions, as shown in Table 2 and Table 3. Mean values within the 18 groups were calculated for each parameter. Mann-Whitney U test was finally performed to assess statistical differences between the two groups ($p<0.05$).

Table 2. *Groups of unipolar derivations and corresponding brain regions.*

Brain region	*Left*	*Right*	*Midline*
Frontal	Fp1 F3 F7	Fp2 F4 F8	
Temporal	T3 T5	T4 T6	
Central-parietal	C3 P3	C4 P4	
Occipital	O1	O2	
Midline			Fz Cz Pz

Table 3. *Groups of bipolar derivations and corresponding brain regions.*

Brain region	*Left*	*Right*	*Midline*
Frontal	Fp1-F3 F3-C3	Fp2-F4 F4-C4	
Temporal	F7-T3 T3-T5	F8-T4 T4-T6	
Central-parietal	C3-P3	C4-P4	
Occipital	P3-O1 T5-O1	P4-O2 T6-O2	
Midline			Fz-Cz Cz-Pz

3. Results and discussion

In the AW, an increase of EEG relative delta activity in the right posterior bipolar region was observed in autistic children with respect to mentally retarded controls (p=0.021). Moreover, Higuchi's fractal dimension was higher in Fp1 channel (p=0.046) as well as in the midline unipolar region (p=0.032). With respect to the comparison group, LS EEG of autistic children showed higher percentage delta power in the left temporal bipolar derivation (p=0.017) with a contextual increase of the relative beta activity in the left occipital unipolar region (p=0.014) and in the left temporal bipolar derivation (p=0.017). Moreover, higher percentage of gamma power was revealed in the Fp1-F3 bipolar derivation (p=0.008). Similar results were obtained for DS EEG, showing higher percentage of delta power in the T3-T5 bipolar derivation (p=0.019) and a concomitant reduction of relative beta activity in T3-T5 (p=0.012) and P3-O1 (p=0.023) bipolar derivations. Increased percentage power of the gamma band was observed in the Fp1-F3 bipolar derivation of autistic children (p=0.001). The higher irregularity of autistic awake EEG, quantified by Higuchi's fractal dimension, suggests that, for the same IQ, the neuronal activity is more organized in autistic subjects than in mentally retarded controls. The shift in the prevalence of slow activity from right to left hemisphere, observed in the wake-to-sleep transition for the autistic children, may be related to deficits in information processing and memory consolidation, as well as to abnormal transcallosal transfer of information. Such cognitive functions occur during sleep [Hobson and Pace-Schott, 2002] and sleep disorders are well-known correlates of autism [Malow, 2004; Buckley et al., 2010]. The differences in the percentage gamma power may be explained by autistic impairment in perceptual and cognitive processes.

4. Conclusions

The study presented in this paper aimed at the characterization of brain electrical activity of autistic children. Linear and fractal measures of the EEG were explored in the awake state and during light and deep sleep, and were compared with those obtained for children with mental retardation. Results revealed that significant differences exist between autistic EEG and mentally retarded EEG. Higher complexity was found in autistic children in the awake state while significant higher delta and gamma activity was observed mostly during sleep. Since quantitative EEG could represent a powerful tool for the early diagnosis of autism, future studies should attempt to clarify and hopefully confirm these preliminary findings.

References

Ahmadlou M, Adeli H, Adeli A. Fractality and wavelet chaos-neural network for EEG-based diagnosis of autistic spectrum disorder. *Journal of Clinical Neurophysiology*, 27(5): 328-333, 2010.

Belmonte MK, Allen G, Beckel-Mitchener A, Boulanger LM, Carper RA, Webb SJ. Autism and abnormal development of brain connectivity. *The Journal of Neuroscience*, 24(42): 9228-923, 2004.

Buckley AW, Rodriguez AJ, Jennison K, Buckley J, Thurm A, Sato S, Swedo S. Rapid eye movement sleep percentage in children with autism compared with children with developmental delay and typical development. *Archives of Pediatrics & Adolescent Medicine*, 164(11): 1032-1037, 2010.

Catarino A, Churches O, Baron-Cohen S, Andrade A, Ring H. Atypical EEG complexity in autism spectrum conditions: a multiscale entropy analysis. *Clinical Neurophysiology*, 122(12): 2375-2383, 2011.

Chan AS, Cheung MC, Han YM, Sze SL, Leung WW, Man HS, To CY. Executive function deficits and neural discordance in children with Autism Spectrum Disorders. *Clinical Neurophysilogy*, 120(6): 1107-1115, 2009.

Grice SJ, Spratling MW, Karmiloff-Smith A, Halit H, Csibra G, de Haan M, Johnson MH. Disordered visual processing and oscillatory brain activity in autism and Williams syndrome. *Neuroreport*, 12(12): 2697-2700, 2001.

Higuchi T. Approach to an irregular time series on the basis of the fractal theory. *Physica D: Nonlinear Phenomena*, 31(2): 277-283, 1988.

Hobson JA, Pace-Schott EF. The cognitive neuroscience of sleep: neuronal systems, consciousness and learning. *Nature Reviews Neuroscience*, 3(9): 679-693, 2002.

Malow BA. Sleep disorders, epilepsy, and autism. *Mental Retardation and Developmental Disabilities Research Reviews*, 10(2): 122-125, 2004.

Mengotti P, D'Agostini S, Terlevic R, De Colle C, Biasizzo E, Londero D, Ferro A, Rambaldelli G, Balestrieri M, Zanini S, Fabbro F, Molteni M, Brambilla P. Altered white matter integrity and development in children with autism: a combined voxel-based morphometry and diffusion imaging study. *Brain Research Bulletin*, 84(2): 189-195, 2011.

Penn HE. Neurobiological correlates of autism: a review of recent research. *Child Neuropsychology*, 12(1): 57-59, 2006.

Philip RC, Dauvermann MR, Whalley HC, Baynham K, Lawrie SM, Stanfield AC. A systematic review and meta-analysis of the fMRI investigation of autism spectrum disorders. *Neuroscience and Biobehavioral Reviews*, 36(2): 901-942, 2012.

Pop-Jordanova N, Zorcec T, Demerdzieva A, Gucev Z. QEEG characteristics and spectrum weighted frequency for children diagnosed as autistic spectrum disorder. *Nonlinear Biomedical Physics*, 4(1): 2010.

Rapin I. Autism. *The New England Journal of Medicine*, 337: 97-104, 1993.

Wilson TW, Rojas DC, Reite ML, Teale PD, Rogers SJ. Children and adolescents with autism exhibit reduced MEG steady-state gamma responses. *Biological Psychiatry*, 62(3): 192-197, 2007.