Brainwaves Analysis Using Spectral Entropy in Children with Autism Spectrum Disorders (ASD)

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Abstract. In the beginning of this recent years, the number of children with Autism Spectrum Disorders (ASD) in Indonesia has increased. Previous studies showed that brain activity of children with ASD was found to be prominently different in frontal and temporal lobes. One of the known methods to measure brain activity in both normal and disorder brain condition is the measurement of brainwaves using electroencephalography (EEG). Therefore, this study aimed to analyze the brainwaves of frontal and temporal lobes of children with ASD, using a calculation of spectral entropy. The subjects group on this research were the children with ASD and the normal children as a control group. EEG recordings were conducted while the children from both of the group was resting and eyes closed. As a preprocessing method, data filtering and algorithm normalization were done to get EEG data. Periodogram Welch method, based on Fast Fourier Transform (FFT), was then used to calculate the power spectral entropy (PSE) of alpha and beta frequency bands. The results were show that at 14 second of children with ASD had the PSE peak. The peak that was observed in the frontal lobe (F8) located in the right hemisphere was higher than the peak shown in the temporal lobe (T8). However, the peak of left hemisphere T7 was higher than F7. On the control object, T8 had a peak with values that was greater than the peak of F8 located in the right hemisphere. Meanwhile, for the left hemisphere, the peak of F7 was greater than T7. Based on these results, it could be concluded that the ASD object and the control object had different frontal and temporal lobe PSE conditions.

1. Introduction
Autism and Developmental Disabilities Monitoring (ADDM) DDM reported that the number of children with Autism Spectrum Disorders (ASD) continues going to increase every each year [1]. ASD are classified into four conditions based on the ability to communicate, socialize, sensory or cognitive behavior. This condition can be influenced by several factors, including genetic, cerebral and digestive factors. The genetics associated with autism varies from case to case. It is therefore difficult for research to find mutation factors for certain that was responsible for ASD [2]. In addition, people with ASD usually have a digestive problem, such as an excess of microflora [3]. However, children's behavior patterns that provide different responses to the state of the environment must be taken into account when assessing the effectiveness of different interventions.
account from the beginning. Several studies have been conducted to detect cerebral signals in children with ASD. The instrument used for this detection is electroencephalography (EEG).

One of the techniques used to study the relationship between brain performance and autistic behavior is Quantitative Electroencephalography (QEEG). This method is used to determine the electrical activity of the brain in people with autism. The electrical activity of the brain can be analyzed using several methods. An intra-hemispheric and inter-hemispheric coherence analysis indicates that there is no difference in consistency between ASD and the normal children [4]. However, the various features of the brain in children with autism need further study.

This study analyzed the spectral entropy data comparing children with ASD to children without ASD. EEG signal analysis with spectral entropy should be useful as complementary data in autism diagnosis.

2. Methods

This study used the data that featured the characteristics of Autism Spectrum Disorders (ASD) on 8-12 years old children at YPAC Cipaganti, Bandung. The objects consisted of 6 children with ASD and 5 children as control objects. The recording process used Emotiv epoc with 14 channels (AF3, F7, F3, FC5, T7, P7, O1,) 2, P8, T7, FC6, F4, F8, AF4). Electrode position used the 10-20 system as shown in Figure 1. The recording run for 15 minutes, in a relaxed atmosphere and eyes closed. Data generated in edf format was processed using the eeglab toolbox contained in MATLAB.

2.1. Pre-Processing of EEG signal

The centering and filtering steps were given to eliminate the noise in the EEG signal. During the filtering phase, the data was used by selecting the alpha (7.5-12.5 Hz) and beta (12.5-25 Hz) frequencies. Signals that had passed the centering and filtering steps were analyzed using the following methods:

2.1.1. Fast Fourier Transform (FFT) method. The aim of the FFT to calculate the spectral power of the cerebral signals at each frequency. At this point, the time domain signal is converted into the frequency domain.

\[
F(k) = \sum_{n=1}^{N} f(n) \cos \left( \frac{2\pi k T}{N} \right) - j \sum_{n=1}^{N} f(n) \sin \left( \frac{2\pi k T}{N} \right) \tag{1}
\]
2.1.2. The Welch Periodogram. The power spectrum was analyzed using the Welch periodogram by grouping the data into \( p \) portions of a certain length (D) which overlap with an offset of \( S \) less than or equal to the value D formulated [5]:

\[
P_{xx}^{(p)} = \frac{1}{UDT} \left| \sum_{n=1}^{D-1} x^{(p)}(k) \exp(-j2\pi nk) \right|^2
\]

\( P_{xx}^{(p)} \) is a power spectrum, with \( x^{(p)}(k) \) as a signal function as data, \( U \) as a factor of normalization and \( T \) as the enumeration period.

2.1.3. Spectral Entropy. Spectral entropy is the value of the irregularity of a dynamic system. The value of spectral entropy can be obtained from the power spectral value normalized according to the equation [6]:

\[
C_{xy}(f) = \frac{|w_{xy}|^2 f}{W_x(f)W_y(f)}
\]

where \( W_{xy} \) is the cross-spectral density of the signals \( x \) and \( y \), \( f \) as the frequency dan \( W_x \) ana \( W_y \) respectively as the Power Spectral density (PSD) \( x \) and \( y \) value.

3. Results and Discussion

The parameters that used in this study were spectral entropy and power spectral density. Analysis of time-domain transformed EEG values in the frequency domain using the Welch periodogram. This transformation provides information from the signal in the form of harmonics. The purpose of the brain map analysis is to provide information on brain electrical activity and interconnectivity in the cortical region as measured by spectral entropy.

![Figure 2. Spectral power changes in the ASD object with a relaxed eye condition](image-url)

Before the quantitative analysis was complete, it was necessary to start from pre-processing signal. First, the signal was mapped to the same length. In addition, the filters with low and high frequencies below 0.5 Hz associated with motion artifacts and the filters with frequencies above 60 Hz related to muscle movements. Then, the power spectral analysis step was performed using the Welch Periodogram. Figure 2 shows an example of a power spectral analysis chart using the Welch Periodogram. The figure showed that, when the eyes were relaxed and closed, the EEG power spectrum of objects with ASD at the alpha frequency decreased relative to the power spectrum of the control objects, as shown in Figure 3.
Then, a spectral entropy analysis was performed to determine the functional connectivity of the brain. The spectral entropy in the right hemisphere had the highest value in the frontal lobe (F8) compared to the temporal (T8). However, in the left hemisphere, the largest spectral entropy value is in the temporal lobe (T7) over the frontal lobe (F7), as shown in Figure 4. The highest spectral entropy in the right hemisphere of the control object was in the temporal lobe (T8), while in the left hemisphere the spectral entropy was highest in the frontal lobe (F7), as shown in Figure 5. The entropy value in the control object increased within 8 to 10 seconds and decreased within 14 seconds. It was different for objects with ASD that the entropy value increased by 14 seconds. High spectral entropy values indicated a high level of complexity.

**Figure 3.** Spectral power changes in the control object with a relaxed eye condition

**Figure 4.** Spectral entropy for the left (a) and right (b) hemispheres of the ASD object
4. Conclusions
Based on the results of the study above, we obtained the information of the difference of spectral entropy between ASD objects and control objects. The difference of value between the right hemisphere and the left hemisphere showed the changes on functional connectivity of ASD. The complete EEG signals in ASD can be achieved by adding more physical parameter analyzes.

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References
[1] Autism and Developmental Disabilities Monitoring Network Surveillance Year 2010 Principal Investigators 2010 Prevalence of autism spectrum disorder among children aged eight years—Autism and Developmental Disabilities Monitoring Network, 11 sites, United States. MMWR Surveill Summ 2014 63(No. SS-2)
[2] Morrow EM, et al 2008 Identifying Autism Loci and Genes by Tracing Recent Shared Ancestry US. Science 321(5886):218-23
[3] Parracho HM, Bingham MO, Gibson GR and McCartney AL 2005 Differences between the Gut Microflora of Children with Autistic Spectrum Disorders and that of Healthy Children US. J.Med.Microbia 54(Pt 10):987-91
[4] Mathewson KJ, Jetha MK, Drmic IE, Bryson SE, Goldberg JO and Schmidt LA 2012 Regional EEG Alpha Power, Coherence, and Behavioral Symptomatology in Autism Spectrum Disorder Clin. Neurophysiol, 123: 1798–1809
[5] Emmanuel CI and Barrie WJ 2005 Digital Signal Processing A practical Approach Second Edition. Person Education: USA.
[6] Nunez PL and Srinivasan R 2006 Electric Fields of The Brain: The Neurophysics of EEG Second Edition. Oxford University Press: New York