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Comparison of EEG Quantitative Parameters for Students with ASD Based on EIBI Duration Program

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Abstract

In this paper, an analysis is carried out to review the comparison of the mean EEG power between groups of ASD students in terms of duration <3 years, 3 to 9 years and ≥9 years, so a significant difference can be seen. In this study, 33 ASD students were observed using EEG, which had a sampling frequency of 500 Hz with eight electrodes at points F3, F4, C3, C4, P3, P4, O1, and O2. The results show that the longer the child gets EIBI, the absolute power of the delta and slow theta waves will decrease. Relative power results also show that the longer the duration of the student obtaining EIBI, the higher the percentage of the emergence of alpha waves. So, the comparison of power EEGs based on group division for the duration of the intervention program shows that EIBI has the potential to improve student quality.

Keywords: ASD, Comparison, Duration, QEEG, Students.

Introduction

Social interaction, communication, language and behaviour, emotional disorders, sensory perceptions, and even individual motor aspects can be referred to as autism disorders (Parr et al., 2011). It is also indicated as a developmental condition with a varied presentation, where each individual has its uniqueness (L.Matson & S.Nebel-Schwalm, 2007). Therefore it is appropriate to be given interventions or training that can help improve the quality of independence of students with autism spectrum disorders (ASD). One appropriate intervention is Early Intensive Behavioral Intervention or abbreviated as EIBI. This intervention follows the principles and procedures of the Applied Behavior Analysis (ABA) to teach adaptive behaviour to ASD students (Klintwall & Eikeseth, 2014). The EIBI intervention contains three levels of the curriculum that are used to differentiate the portion of the intervention for ASD students, namely beginner, intermediate and advanced (Maurice, Green, & Luce., 1996; Dawson et al., 2012). EIBI adopts six important skill intervention indicators, all implemented in three different curricula, namely covering attending, imitation, receptive language, expressive language, pre-academic, and self-help skills. One of the supporting assessments can assess the evidence of the results of giving EIBI intervention to each group of students in 3 different curricula, namely brain wave examination or Electroencephalography (EEG).

The EEG is a tool for studying images of recorded electrical activity in the brain, including EEG recording technology and its interpretation. The EEG test is a test that uses electrodes to be attached to the scalp to detect electrical activity in the brain, including ASD (Wang et al., 2013). Brain cells communicate via electrical impulses and are always active even when a person is sleeping. Several studies show that in ASD children, delta (0.1-4 Hz) and theta (4-8 Hz), which are slow-wave rhythms, are more dominant. This condition can indicate an atypical developmental status of the child (Bosl, Tager-Flusberg, & Nelson, 2018). The high percentage of delta and theta slow wave rhythms can suggest that the motor level, calmness and concentration are relatively unstable or low in the person (Gabard-Durnam et al., 2019). In ASD children, there is an atypical development of excessive neural connectivity and a deficit in connectivity between functional areas of the brain (Hernandez, Rudie, Green, Bookheimer, & Dapretto, 2015) (Kana, Libero, & Moore, 2011) (Emerson et al., 2017).

However, based on previous research that the team conducted, the classification of the three groups of ASD students who underwent different levels of the EIBI curriculum showed that delta and theta activity tended to be high among students in the intermediate curriculum (O'Reilly, Lewis, & Elsabbagh, 2017). This result is also because many students have not been able to move to a higher curriculum even

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though they have been undergoing intervention for a long time. Therefore, in this paper, an analysis is carried out to compare the mean EEG power between groups based on the classification of students according to the duration (years) of undergoing EIBI intervention. This assessment based on the power EEG parameter is very important for evaluating three groups of ASD students in terms of duration under three years, 3 to 9 years and nine years and above so that a significant difference can be seen.

Autism is a complex developmental disorder involving communication, social interactions, cognitive and imaginative activities. Autism symptoms begin to appear before the child is three years old. In infants, it is indicated that the symptoms of autism appear from birth. EIBI intervention based on applied behavioural analysis (ABA) is an intervention that provides psychological education and has been researched in-depth as beneficial for preschoolers with ASD (Eikeseth & Klintwall, 2014) (Rahmahtrisilvia, 2015). EIBI effectively treats mental health problems in children with ASD (Studer, 2017). This result is based on ten years of psychiatric observation and evaluation. Then, in another case study meta-analysis, 20 preschool children with ASD were given EIBI intervention for 2.9 to 7.8 hours per month. The results showed that the number of children after the intervention had increased compared to before. In addition, the mean IQ score obtained increased from the previous mean score between 85-100 and a standard deviation of 15 in a published paper reviewing meta-analysis methods from five studies published from 2009 to 2010 on ASD children undergoing EIBI as an intervention. Four of the five studies show that interventions using EIBI are effective for growing children with ASD. The meta-analysis results with IQ score and adaptive behavior were g = 0.38-1.19 and g = 0.30-1.09, respectively (Reichow, 2012).

Then, the results of another analysis of the EIBI intervention also showed that the hearing symptoms in children with ASD were reduced (Smith, Hayward, Gale, Eikeseth, & Klintwall, 16 October 2019). EIBI will affect the cognitive improvement and adaptive standard score of ASD children by undergoing EIBI for two years (or even ten years after the intervention). This evidence comes from an analysis of 16 autistic adolescents who received an average EIBI intervention for two years and 11 months during childhood. Frequency domain analysis is divided into several EEG frequency bands, namely coherence, asymmetry, absolute power, relative power and ratio power. This analysis predicts the subject's cognitive and perceptual abilities, which are recorded in the form of a continuous signal and then transformed into a particular frequency domain (Wise, McFarlane, Clark, & Battersby, 2011). The total energy at the electrodes located in the cortical area in the frequency specification is called absolute power (Cunha, 2004). At the same time, relative power represents the percentage of absolute power in the frequency band relative to the total power in the EEG. EEG has been used in many studies to observe brain wave patterns or responses, including ASD assessment.

In one other study, a multi-level model was used to evaluate the EEG power spectrum in infants aged 6, 9, 12, 18, and 24 months to assess the δ, θ, α, β, and γ bands. The results showed that babies at risk of autism had lower strength in all frequency bands compared to babies at six months with a low risk of autism. Then, infants at high risk of autism showed different changes in spectral strength patterns, but the differences between the two groups fluctuated over two years (Tierney, Gabard-Durnam, Vogel-Farley, Tager-Flusberg, & Nelson, 2012). Then, in another study, 20 ASD and 20 normal children were subjected to EEG recording with their eyes closed for analysis. The EEG quantitative evaluation is based on the analysis of absolute, relative, and total power in the interhemispheric and intrahemispheric coherent. The results showed that the right posterior θ wave was dominant in the autistic group compared with the healthy subject group. Then, in the frontal lobe, you can see lower delta and theta waves, but higher beta waves appear (Coben, Clarke, Hudspeth, & Barry, 2008). Another study also analyzed alpha waves and coherence from 15 autistic patients and 16 healthy people with closed and open eyes. The results showed that when the subjects closed their eyes, there was no difference in ability or alpha coherence between the two groups. However, when the eyes are open, in the hindbrain area, the mean capacity and appearance of alpha waves in autistic patients are lower than in healthy patients (Mathewson et al., 2012).

Then, in another finding after comparing infants at high risk of ASD and groups of infants with lower risk (healthy), the group of infants with high autism spectrum disorders had lower EEG power in several bands for the frontal lobe brain area. The significant reduction in alpha-wave ability in the frontal brain area at three months of age was associated with the presence of abnormal brain function and poor language skills at 12 months of age (Levin, Varcin, O'Leary, Tager-Flusberg & Nelson, 2017). These results were obtained from the EEG recording data of 29 high-risk ASD infants at ± three months of age and 19 other low-risk infants (controls). Researchers evaluated the relationship between EEG power activity in the frontal brain at three months of age and the risk of autism, language development and other developments.

Research methods

This study aims to evaluate children with ASD who have undergone Early Intensive Behavioral Intervention (EIBI. The subjects of this study were ASD children or students from 3 autism special schools, namely autism special schools under the auspices of a foundation, namely SLB Autisma YPPA Solok, SLB Autisma YPPA Bukit Tinggi and SLB Autisma YPPA Padang. The recording of the subject data was carried out for 12 days, from 6th to 18th July. The subjects recorded were given the same treatment, namely sitting quietly in a chair and facing a teacher of their intervention. Each student recording has taken ± 10 minutes.

The number of subjects recorded for EEG data recording was 42 people, but 9 data subjects were excluded due to noise factors and data similarities. Hence, the data in this study involved 33 ASD student data. Therefore, the number of subjects analyzed exceeded 15, which is consistent with the minimum acceptable sample size based on experimental research methods of at least 15 samples (Darmadi, 2011). Then, the data on these subjects were classified into three groups, namely in terms of the duration of obtaining EIBI under three years, 3 to 9 years and finally nine years and over. This grouping aims to see the comparison between students who have recently received EIBI with those who have long undergone EIBI by disregarding the level of the subject curriculum. Each group consisted of 11 ASD subjects, whose recorded data were then analyzed. Table 1 shows the subject descriptions. StarStim Neuroelectric EEG wireless (Bluetooth) was used as a recorder in this study. The EEG has a sampling frequency of 500 Hz with eight electrodes. The EEG electrodes are placed at points F3, F4, C3, C4, P3, P4, O1 and O2 as well as Ref using the 10-20 localization principal rules shown in Figure 1.

The first segmentation signal is taken for 10 minutes from the original record. Then, it was filtered by Band Pass Filter (BPF), only taking a frequency range of 0.5-40 Hz. Next, the filtered digital signal data are pre-segmented for 60 seconds to choose, with minimum noise. Thus, it can be written in a mathematical equation as given below in equation (1):

$$v(c, s, t_s); s \in [1 \ldots q], t_s \in [0 \ldots 60] \qquad (1)$$

Table 1: Subject description of students with ASD

	≤ 3 Years	*3-9 Years*	*≥ 9 Years*
The average duration of the intervention (years)	1.4 ± 0.5	5.7 ± 2.1	13.3 ± 2.8
Average Age (Years)	10.4 ± 3.2	12.3 ± 2.8	17.1 ± 3.4
Male	7	9	10
Female	4	2	1

where v is the EEG signal after segmentation, s is the number of segmentation, and t_S is the time of segmentation. If u (c, t) represents the EEG signal in time function t with the number of channels c = [1 ... p], the signal that has 50 seconds of segmentation is divided into 5 seconds per segment. The segmentation for each channel is plotted graphically using Matlab 2016b software. Next, the windowed signal is separated based on the frequency band. This separation used the Finite Impulse Response (FIR) filtering method at predetermined frequencies. Determination frequencies band of EEG signal are delta (0.5-4Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz) and gamma (30-40 Hz). The next step converted the signal in the time domain to be frequency domain. This change used the calculation of power spectral density (PSD), which is done using the Welch method with windowing 2 seconds and overlapping 50% (Setiawan, Valentine, & Zakaria, 2019). The results will be obtained in the power spectrum for each segment per channel and frequency band, as given in equation (2).

$$P_k(c, s, f)\ c \in [1 \ldots q], s \in [0 \ldots 5], k \in K, K = \{\alpha, \beta, \theta, \delta\}, f \in \left[f_{x_{\min}}, f_{x\max}\right] \qquad (2)$$

This section explains the results of the research and, at the same time, gives a comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily. The discussion can be made in several sub-chapters, where P_x is power in frequency band per segment, k is a member of a set of EEG signal frequency bands, and f is the upper and lower limits of each calculated brain wave. Through the selected power, peak power is detected and determined by the local maximum function. The selection obtained peak power for each frequency band and an index that stated frequency at peak power.

Discussions

In this study, the results are shown in Tables 2, 3, 4 and 5. The mean absolute power is obtained if the appearance of delta waves for a group of students with a duration of undergoing

Fig. 1: EEG placement and Subject Recorded based on 10-20 localization rule.

EIBI ≤ 3 Years is 37.6 ± 24.6 μV^2 / Hz, 3-9 Years group amounted to 23.3 ± 18.8 μV^2 / Hz and the ≥ 9 Years group of 19.1 ± 16.0 μV^2 / Hz. This result showed that the longer the child gets EIBI, the absolute power of the slow-wave delta will decrease. This condition is the case with the theta wave indicator, which shows the same descending pattern as the delta. However, in the absolute power alpha parameter, there was a pattern that tended to be lower in the group whereas it should have been higher, namely the ≥ 9 Years group, which only produced a mean of 7.0 ± 4.1 μV^2 / Hz. This value was even lower than the EIBI ≤ 3 Years group, which obtained a mean value of 7.8 ± 5.0 μV^2 / Hz. Meanwhile, for the 3-9 years group, the results were 9.5 ± 9.4 μV^2 / Hz, which was much higher. However, these results differ from the mean relative power, which shows better results and follows the hypothesis. In the relative power alpha, the mean value obtained for the ≤ 3 Years group was 8.4 ± 1.5%, while for the 3-9 Years group, it was 11.7 ± 2.7%, and the ≥ 9 Years group was 12.5 ± 3.6%. It can be seen from the results that the longer the duration (years) of students receiving EIBI intervention, the higher the percentage of the emergence of alpha waves. Meanwhile, beta and gamma waves showed fluctuating results between groups. This phenomenon can indicate that a specific subject has absolute power in the five-wave band, which is much higher than others in the group.

Then, observing the power ratio in each group of students, the results obtained for the ≤ 3 years duration group showed that EEG power was more dominant in the right hemisphere. This result is because after comparing the absolute power of the EEG, the ratio of the frontal, central, parietal and occipital areas is more dominant in the right hemisphere than in the left. Furthermore, the 3-9 years group of subjects showed more dominant left hemisphere results for the frontal, central and occipital areas. Meanwhile, the parietal area shows more dominant EEG power for the right hemisphere. Then, for the group with the most prolonged time duration, which is ≥ nine years, the power ratio data is more dominant in the left hemisphere in the central, parietal and occipital areas. Power EEG for the right hemisphere is more prevalent in the frontal

Table 2: The Average absolute power of subjects in 5 frequency bands

Duration of Undergoing EIBI	*Average of Power Absolute (μV^2/Hz)*				
	Delta	*Theta*	*Alfa*	*Beta*	*Gamma*
≤ 3 Years	37.6 ± 24.6	32.0 ± 17.5	7.8 ± 5.0	8.0 ± 11.4	5.7 ± 11.3
3-9 Years	23.3 ± 18.8	23.6 ± 18.1	9.5 ± 9.4	5.0 ± 3.9	3.8 ± 3.2
≥ 9 Years	19.1 ± 16.0	20.8 ± 12.7	7.0 ± 4.1	4.2 ± 2.2	2.5 ± 1.4

Table 3. The Average relative power of subjects in 5 frequency bands

Duration of Undergoing EIBI	*Average of Relative Power (%)*				
	Delta	*Theta*	*Alfa*	*Beta*	*Gamma*
≤ 3 years	43.6 ± 11.6	35.2 ± 10.4	8.4 ± 1.5	7.8 ± 6.2	5.0 ± 5.3
3-9 years	43.4 ± 9.0	30.8 ± 8.6	11.7 ± 2.7	7.6 ± 3.5	6.5 ± 4.6
≥ 9 years	37.3 ± 9.2	33.4 ± 7.6	12.5 ± 3.6	10.8 ± 8.1	6.0 ± 3.5

Table 4. The Average Interhemispheric Power Ratio

Duration of Undergoing EIBI	*Average of Interhemispheric Ratio Power*			
	Frontal	*Central*	*Parietal*	*Occipital*
	F3/F4	*C3/C4*	*P3/P4*	*O1/O2*
≤ 3 years	0.8 ± 0.5	0.8 ± 0.2	0.8 ± 0.4	0.7 ± 0.3
3-9 years	1.1 ± 0.7	1.1 ± 0.7	0.7 ± .5	1.3 ± 0.9
≥ 9 years	0.6 ± 0.3	1.6 ± 1.1	1.6 ± 1.3	1.0 ± 0.7

Table 5: The Relative Power Average Based on Area (%)

Duration of Undergoing EIBI	*Relative Power Average Based on Area (%)*			
	Frontal	*Central*	*Parietal*	*Occipital*
≤ 3 years	20.5 ± 7.1	26.0 ± 4.4	25.5 ± 3.4	28.0 ± .3.0
3-9 years	23.7 ± 7.9	24.8 ± 6.9	22.0 ± 7.9	29.5 ± 10.0
≥ 9 years	21.9 ± 6.4	25.1 ± 4.1	26.4 ± 4.9	26.5 ± 6.1

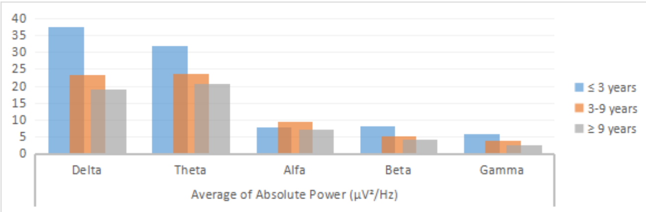

Fig. 2: Average Absolute Power of Subjects in 5 Frequency Bands Based on Duration Group of EIBI

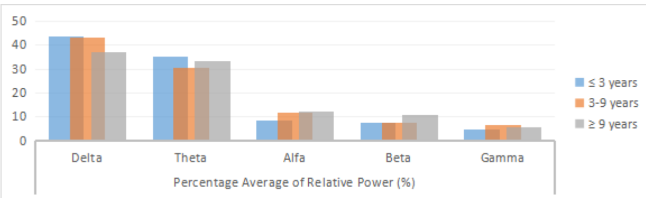

Fig. 3: Average relative power of subjects in 5 frequency bands based on duration group undergoing EIBI

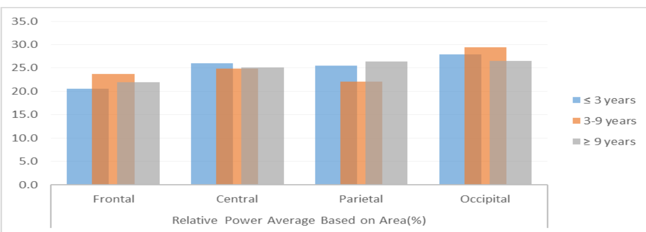

Fig. 4: Relative Power Average Based on Area (%) in the duration group undergoing EIBI

region. These three results tend to show varied results; this could be due to the different subjects for each group for which data was taken.

In subsequent analyzes for total relative power by brain area. The results for all groups of students, ≤ 3 years, 3-9 years and ≥ nine years, showed that the EEG power was more significant than the mean on occipital. The ≤ 3 Years group shows a 28.0 ± .3.0% percentage, the 3-9 Years group is 29.5 ± 10.0%, and the ≥ 9 Years group is 26.5 ± 6.1%. All areas show a percentage of about 20%, so there is no dominance too far between frontal, central, parietal and occipital. At the same time, the total relative power tends to be lower in percentage compared to other areas, namely the frontal area with 20.5 ± 7.1% for group 1, then 23.7 ± 7.9% for the second and last group of 21.9 ± 6.4% for group 3 which is the group of subjects with the most extended duration.

Conclusion

In this study, several results were found that indicate the potential that Early Intensive Behavioral Intervention (EIBI) can improve the quality of ASD children. This result is viewed from the classification based on three duration groups to obtain the EIBI intervention program by analyzing power EEG. So, the longer the child gets EIBI, the absolute power of delta and slow theta waves will decrease. Relative power also shows that the longer the duration of students obtaining EIBI, the higher the percentage of the emergence of alpha waves. All brain areas show a rate of about 20-30% of the total relative power, so there is no dominance too far between frontal, central, parietal and occipital. However, occipital showed a slightly higher mean than the other regions for the three groups, namely ≤ 3 Years, 3-9 Years and ≥ 9 Years. So, the comparison of EEG power based on group division seen from the duration of the intervention program shows that EIBI can increase students' quality.

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