Dynamic analysis of critical features in EEG for motor imitation among Autistic children

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Abstract: - Research study among children with autism had shown impairment in motor imitation in addition to social disability. Currently, imitation becomes an important issue which can be seen as new procedure to detect early childhood autism. Hence, this paper proposed the used of motor imitation action by analyzing the brain waves frequency. Experimental results revealed that control and autistic children both perform the motor imitation well but the brain activation for both group are different. Autistic children demonstrate a very high intensity brain activation indicating they are struggling to do the action. This illustrates some potential methods that can be extended in detecting autism for early childhood.

Key-Words: - Autism, electroencephalogram (EEG), motor imitation, brain waves, Mu waves, fMRI.

1. Introduction

Autism had started to be known in 1911 by Eugen Bleuler; psychiatrist from Switzerland. He started using this term to describe one symptom in Schizophrenia. Then in 1940, an American researcher adopts this term in order to describe children with emotional and social problem. As for current description regarding autism was extended in its own definition. According to one resource of autism in Malaysia, autism was defined as a form of neurological disorder and it was categorized under Pervasive Developmental Disorder (PDD). Besides, in PDD it also includes some other types which are Asperger's Syndrome and Rett's syndrome. The characteristics of autism problems can be in one or more major areas of development including impairment in social interaction, impairment in communication and restricted/repetitive behaviors, activities and interest. In fact autism is a spectrum disorder and each child disorder may vary from one to the other. Some of them can be mild autism while other might be worse. Autism affects the brain development and it has been proven in few research studies [1, 2 & 3]. In neurological side, few types of neuroimaging techniques had been used such as functional magnetic resonance (fMRI), pet scan and also EEG. Currently, electroencephalogram (EEG) had been used widely in neuroimaging and biofeedback areas. Results from the study did show great potentials and improvement for this disorder. Researchers at Kennedy Institute had discovered some important insight into the neurological aspect of autism. They did a fine motor test by tapping their fingers in sequence for both autistic and normal children using fMRI machine. The result showed that the activation of the brain for autistic children has less connectivity between different regions of the brain includes coordinating and executing movement compared to normal children. Autistic children also relied more on the region that responsible for conscious and effortful movement.

2. Motor imitation in autistic children

The deficit in autism group related to imitation had been discussed widely in many research studies many years ago [4, 5]. Imitation becomes critical in the group of autistic children. It does play an important role to help for improvement in their development of social interaction and communication. Imitative scheme can guide them to learn or practice and mastery of new skills [15]. According to Mataric J.M (1994), imitation is an ability to observe and repeat the behavior or actions of others and it allows us to learn how and when to perform the behavior. In the psychological perspectives, researchers always try to correlate the relations between one characteristic in autism to another. For example, in Stone and Yoder (2001) [11] study, they looked into the correlation between imitation and social communicative behavior among autistic children. They found the significant result of prediction language outcome after the tests. In other positive outcome from the imitation test, it helps autistic children to increase their joint attention [12]. Thus, it can be seen that imitation did play a big role correspond to other criteria in human nature.

2.1 Mu waves/rhythm

EEG work was conducted in the 1950s is the first neurophysiological evidence of an execution/ observation matching system in humans which focused on the mu rhythm band oscillations. Mu band is between 8 to 13 Hz, which recorded on the human scalp near sensorimotor cortex. According to Oberman and colleagues [6] reported attenuation of the mu rhythm in the 8-13 Hz band during the execution and observation conditions for the typical group, whereas, the autism group showed attenuation only during the execution condition.

However, in other study [7] found that mu rhythm included alpha band and also low beta band which is between 12-20Hz. Besides, Bernier et al. [8] also found that there is correlation between the degree of mu power desynchronization during the observation of a movement and performance on the behavioral imitation task. Specifically, in the ASD group, lower mu power desynchronization during observation was correlated with poorer imitation skills.

Table 1 is explaining the location of the brain which related to specific brain wave. As far as frequency concern, the electrode placement can be at the C3 and C4. Electrode placement was measure before it can be placed on the human scalp. The measurement of the position must be precise in order to captured good signals [10]. This paper was decided to use the entire 2 channels in EEG to publish result of analysis in relation to motor imitation.

Bands	Role in body	Pathologically
Alpha bands (8-13Hz)	Associated with physical calmness and lack of activity	Back - Occipito-parietal & parietal-central region
Beta bands (13-35Hz)	Seen when the mind is alert or actively dreaming	Fronto-central region
Mu bands (8-13Hz)	Movement and intended movement (Niedermeyer, 1987)	Central/centro-parietal region

Figure 1. The brain waves correlate with recording location in brain [9].

2.2 Participants

12 children (6 control children, 6 autistic children) were included in this study. The autistic children were recruited from National Autism Society of Malaysia (NASOM) at Setapak while the control children are mix of the staff and relatives' children. All participants will go through IQ test using Standford Binet IV. It was done by the psychologists from NASOM itself. Results of the IQ test must be same level for both groups.

2.3 Procedure

Before proceed with the experiment, participants were briefed about the experimental procedure. Parents, guardian or teacher from NASOM required filling up a consent form. To reduce the feeling of nervous or anxiety among the participants, they were introduced with the equipments. They are allowed to take a look at the unused electrodes.

Once the participants were familiarize with the equipment and were finish with the explanation, participants were asked to sit properly at the chair provided. Since EEG signal is very sensitive to the surrounding, thus a quite, lighted room and temperature controlled were chose. This criterion is reducing the noise captured during the experiment. Once they had seated, electrodes will be place on the scalp using EEG paste. A common procedure before continue with the real stimuli, participants need to do eyes open and close for one minute each. This basic procedure is to neutralize their brain signals. After this procedure, the participants will look at the computer screen for the real video stimuli. A video stimulus for the clinching hand was adopted from Brainmakers. The participants required to follow video stimuli in 1 minute time. Figure 3 are some example of situation that happened during experimental session.

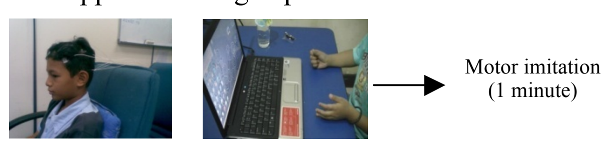

Figure 1. Example of an experiment conducted showing a child with electrodes on their scalp and having the child to follow video stimulus.

3. Methodology

Before analysis can be carried out the raw EEG signals data need to first be preprocessed through filtering and transformed from Time to frequency domain as indicated by Figure 2 below. Since only certain frequencies will be required for the analysis features extracted or a particular band will be used for analysis.

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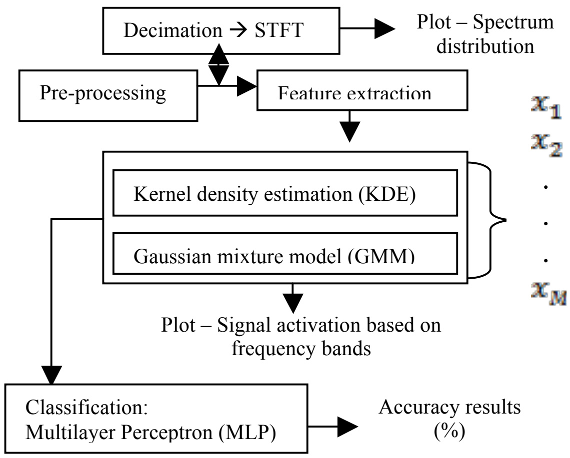


Figure 2. Proposed methodologies towards this research study for analyzing signals of control and autistic children.

3.1 Pre-processing and feature extraction

In the beginning of our analysis, there are 2 steps required in other to achieve the end results. The 2 steps include the pre-processing and feature extraction analysis. During pre-processing stage, signals of the data were decimated by 3 and then the data were change from time domain to frequency domain by applying short time fourier transform (STFT). In our analysis, all data were analyzed in term of frequency domain. In the second step, features extracted using Kernel Density estimation (KDE) and Gaussian mixture model (GMM). KDE have been tested in our previous studies which related to emotions and problem solving [13&14]. Results showed the potential of using this method in analyzing the EEG signals. Features were calculated based on the specific mathematical equations.

The total number of data which were extracting by KDE is presenting as M. During STFT analysis, signals were cut off into specific window size which 64 with overlapping as 50. Features per-sampling window is given by:

$$X_w = x_1, x_2, x_m, \cdots, x_M \tag{1}$$

Which w is the window, m is features vector while M is the total numbers of features. As noted earlier, this research study is interested to look into the distribution of signals in term of specific frequency bands. Thus, features were extracted based on Mu and beta bands. Firstly the maximum and minimum frequencies for the mu and beta band number of features in the mu and beta band need to be derived. In order to plot the data for both the Mu and beta bands, the features extracted must first be subdivided into its own bands. Thus, equation (2) below describes the feature number for the Mu and beta band respectively.

$$\mu_{\min} = \frac{f_{\mu_{\min}}}{\frac{f_s}{2}} M, \quad \mu_{\max} = \frac{f_{\mu_{\max}}}{\frac{f_s}{2}} M$$
$$\beta_{\min} = \frac{f_{\beta_{\min}}}{\frac{f_s}{2}} M, \quad \beta_{\max} = \frac{f_{\beta_{\max}}}{\frac{f_s}{2}} M \tag{2}$$

Where $\mu_{\min}$ and $\mu_{\max}$ is the minimum and maximum feature number for Mu band respectively

$\beta_{\min}$ and $\beta_{\max}$ is the minimum and maximum feature number for beta band respectively

$f_{\mu_{\min}}$ =8hz and $f_{\mu_{\max}}$ =13hz is the minimum and maximum frequency for Mu band respectively

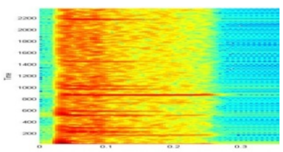
$f_{\beta_{\min}}$ =13hz and $f_{\beta_{\max}}$ =35hz is the minimum and maximum frequency for beta band respectively and

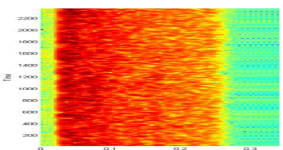
f_s is the sampling frequency which has been decimated from the original raw EEG signals by 3.

After extracting the data according to the bands, then we plot the results. However, in Gaussian mixture model, data were extracted based on 3 modes. By using GMM, mean of the features were decided to be analyzed. Based on the 3 modes, each mode represents the specific frequency bands. First mode is the Mu, second mode is beta and the third mode consider as gamma band. But, only Mu and beta bands were plotted to be analyzed. Results will be explained in the next chapter.

4. Results and findings

In our study, we did some preliminary analysis. At the preliminary stage we looked in to the spectrum distribution and present the accuracy results which discriminate between both groups. Gaussian mixture model was adopted during this preliminary stage. Based on figure 4, there are clear distinctions of distribution between both groups. Red color represents the high intensity activation while performing the action. As shown below, control children had high activation compared to autistic children during the experiment. These results proved some problem occurred during the communication in their brain while doing required action.





(a) (b)

Figure 4. Both figures represent the spectrum distribution for both Groups. a) Autistic children b) Control children

Then, features from the signals were extracted using GMM and were fed into classifier. Multilayer perceptron (MLP) was adopted in order to perform the classification. According to the analysis findings, percentage of discrimination between both groups in term of mean is high up to 87% (figure 5).

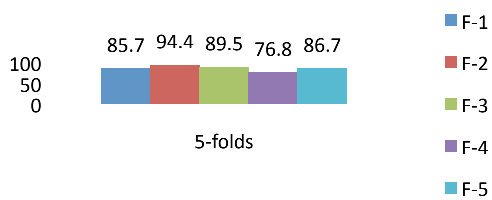
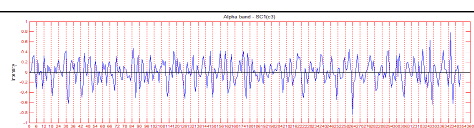
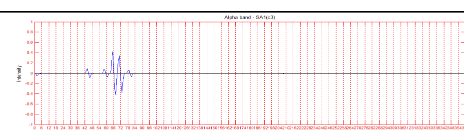
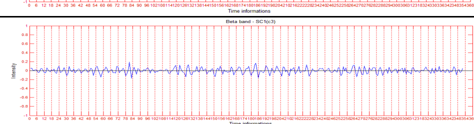
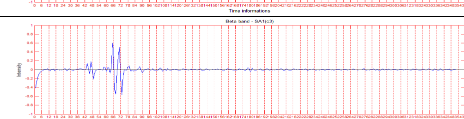


Figure 5. Experimental results on percentage discrimination between ASD and Control subjects using k-fold analysis.

Thus, the accuracy results showed that both groups can be discriminate using the proposed methods. Even though GMM can produced accurate result for discriminating both groups, but it is not good enough to present the signals activation in term of specific frequency bands. It can be seen clearly in figure 2 and 3. We can see clearly that GMM produced unpredictable results compared to KDE.
Results were based on 2 different channels which is C3 and C4. It also represents the data based on Mu and beta bands. As prior to GMM results, they are difficult to be group either for control or autistic children which have no consistency of the distribution between the subjects in the same groups. Thus, method of GMM was considered inappropriate for this study. Prior to the finding, Kernel density estimation (KDE) was used as other feature extraction method.
The activation of fine motor imitation signals are varies in autism and control children. Based on the observation during data collections, the control children did follow the video stimuli for 1 minute. Same action happened to the autistic group. They also execute the motor imitation from start till end of the session. However, the activation signals of their brain do not correlate well. This can be seen for the figures below which proved the signal activation for both group according to specific channels.
In table 4 and 5, it reveals that the activation signals for autistic children are high according to intensity. It also showed the awkwardness of action imitation during the experiment.

Table 2. Present the signals activation for both groups according to channel C3 based on Gaussian mixture model (GMM). The figures below were group according to the specific frequency bands.

Gaussian Mixture Model (GMM)		
Channel C3	Control children	Autistic children
Mu waves		
Beta waves		

Furthermore, it was found, during observations experiment, they illustrate the smoothness of the action execution. Autistic children show some difficulties in open and close hand. Some of them need a help from the experimenter or psychologist during the experiment. As shown in tables 4 and

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5, we can see a much lower intensity for both the Mu and beta wave for the control subjects as compared to the autistic children indicating the process of high brain activation for the autistic children. The degree of EEG Mu wave's attenuation can be seen to be significant in term of motor imitation for the control subjects. Most literature refers to the motor imitation problem based with respect to Mu bands. However, our finding showed that beta bands also demonstrate significant results. It can be seen in table 4 and 5, beta band for control children is low as compare to autistic children. In addition it is also interesting to note that the beta wave also indicate intensity variation showing movement from left to right clinching of the palm. Thus, beta band can be a better option in viewing the change of motor movements.

Table 3. Present the signals activation for both groups according to channel C4 based on Gaussian mixture model (GMM). The figures were group according to the specific frequency band.

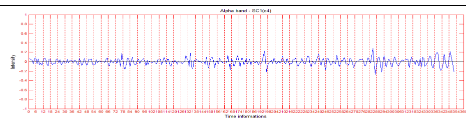
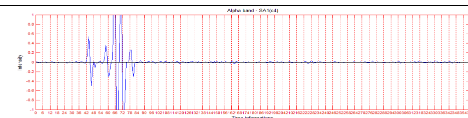
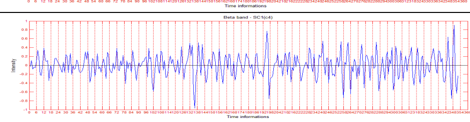
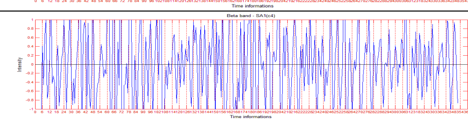
Gaussian mixture model (GMM)		
Channel C4	Control children	Autistic children
Mu waves		
Beta waves		

Table 4. Present the signals activation for both groups according to channel C3 based on Kernel density estimation (KDE). The figures below were group according to the specific frequency band.

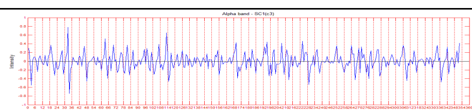
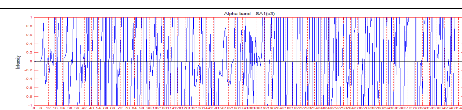
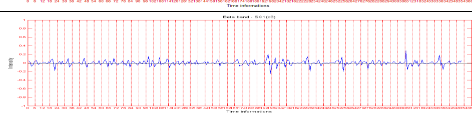
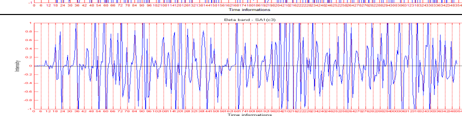
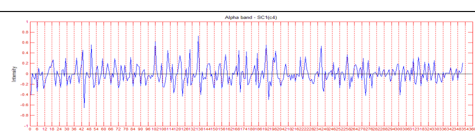
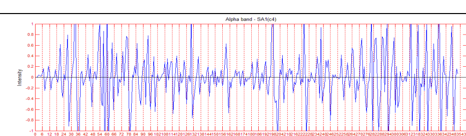
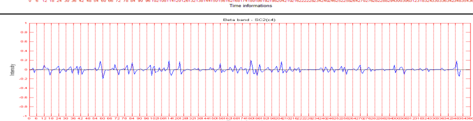
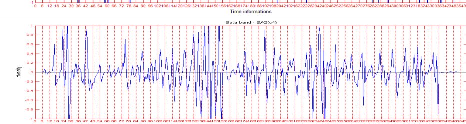
Kernel Density Estimation (KDE)		
Channel C3	Control children	Autistic children
Mu waves		
Beta waves		

Table 5. Present the signals activation for both groups according to channel C4 based on Kernel density estimation (KDE). The figures were group according to the specific frequency band.

Kernel density estimation (KDE)		
Channel C4	Control children	Autistic children
Mu waves		
Beta waves		

5. Conclusion and future works

Result from our experiments show that, there are possibility and potential to discriminate autistic children from control (normal) children by looking at the specific bands. Although Mu wave has been well known in detecting autistic children but beta waves is found to be more useful. Both the KDE and GMM can be used for feature extraction in detecting autistic children through motor imitation but using the beta wave and KDE will be the best for analysis. Although at present there were only 6 autistic and 6 control subject we are right now in the process of collecting more data from the control subjects based on preschoolers in the KL areas.

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