Sensory Responses of Autism via Electroencephalography for Sensory Profile

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Abstract—The aim of this study is to investigate the brain signals of autism children through electroencephalography (EEG) associated to physical tasks. The physical task was meant to stimulate the sensitivity correlation of sensory response of a child. A group of autism children was chosen for this study and were given by five sensory stimulations which are audio, taste, touch, visual and vestibular. The acquisition of brain signals was acquainted using EEG Neurofax 9200 and the electrode positions were using 10-20 International System placements. The preprocessing signals were analyzed using independent component analysis (ICA) using EEGLAB Software and Discrete Wavelet Transform (DWT). The alpha wave was selected by level 6 decomposition and the extracted features represents the characteristic of the sensory task. The means, standard deviations and approximation entropy were extracted on the clean signals and forms into Sensory Profile (Sensory Profiling). From the overall results, the behavior of each autism children has been observed unstable emotion while running the sensory stimulation. The observation also helps to improve their learning strategy for the future work in assessment.

Keywords—Electroencephalography (EEG); autism; independent component analysis (ICA); discrete wavelet transform (DWT); sensory profile (SP)

I. INTRODUCTION

The abnormalities of a person can be evaluated through physician and psychiatric observation. Hence this assessment sometime can leads to human error because the human physical regulation occurs not same at a certain time to be detected. However the difficulties of a child who impairs with autism spectrum disorder may occur. The early identification, screening and intervention have been highlighted by ministry. One of diagnostic tools such as questionnaire also brings difficulties to detect the syndrome. Sensory systems in human provide a pathways for the brain to receive information through synaptic activation, how its interprets the stimulation and implement the response as the output [1]. The EEG machine can be most powerful tool to measure the abnormalities of the autism child.

The purpose of EEG has well known of using to record brain’s electrical activity over a long time period [2] and non-invasive testing method. Electroencephalogram is a recorded EEG and one of the best methods for monitoring the brain dynamics due to its high temporal resolution and portability [3]. Sensory organ, which consists of tactile sensation, auditory sensation, olfactory sensation, visual sensation, oral or gestation sensation and vestibular sensation, has a close relationship with the brain to send the message to the sensory organ. Different parts of the brain will reacts to every part of the sensory organs respectively. Hence, this study is to investigate the response of the sensory organ using EEG is conducted.

The greatest sensorimotor organization occurs during an adaptive response to sensation [4]. This is a response in which the person deals with his body in and the environment in a creative or useful way. The spinal cord, brain stem, cerebellum and cerebral hemispheres use sensory input from the receptors to produce the awareness, perception and knowledge, and to produce body postures, movements and the planning and coordination of movements, emotions, thoughts, memories and learning. There are two types if sensations in human body systems that effected from the outside and inspace.

The sensation that gives the information from the outside called as extraceptors which include sight (visual sense), sound (auditory sense), taste (gustatory sense), smell (olfactory sense), and touch (tactile sense). While the proprioceptors that is tell the body system when it is inspace or dynamical moving includes position and movement (propiroceptive sense) and also the gravity changes, head movement and balancing were categorized as vestibular sense. Sensory modulation difficulties comprise one category of sensory processing disorders, and occur when a child is unable to respond to sensory information with behavior that is regulated relative to the intensity of the input [5].

Difficulty to pay attention, getting lost easily, oblivious in an active environment or leaving clothing twisted is a major of multisensory characteristic behavior of autistic child. In multiple regression analyses of sensory modulation and
autistic traits of children with ASD, multisensory processing, derived as a sensory profile (SP) subscore significantly prediction of the degree about autistic pathology in the children and also a measurement by the child autism rating scale [6, 7, 8].

II. ELECTROENCEPHALOGRAPHY (EEG)

A. Electrode Placement

10-20 International System electrode placement technique was used to record the brain signals [9]. The head is divided into four standards points: the nasion (nose), the inion (external occipital protuberance or projection), and the left and right preauricular points (ears). Electrodes are placed by measuring the nasion - inion distance and marking points on the head 10%, 20%, 20%, 20%, and 10% of this length. Electrode placements are labelled according to adjacent brain areas which are F (frontal), P (Parietal), O (Occipital), T (Temporal) and C (Central) as shown in Fig. 2. A channel in EEG represents the difference in potential from two inputs. An electrode scalp with maximum impedance of 10kΩ were placed on the subject’s head by using conductive gel containing salts is applied, so that, ions can carries current between the electrode and skin. In this study, EEG is used to read the pattern of brain activity in normal and autistic children through 5 sensory stimulations to the ASD children.

EEG signal is classified into its frequency [10]. Table I shows the classification of EEG signal based on their frequency.

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency (Hz)</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>0.5 to 4</td>
<td>Deep sleep</td>
</tr>
<tr>
<td>Theta</td>
<td>4 to 8</td>
<td>Consciousness toward drowsiness</td>
</tr>
<tr>
<td>Alpha</td>
<td>8 to 13</td>
<td>Relaxing without focus and attention</td>
</tr>
<tr>
<td>Beta</td>
<td>13 to 30</td>
<td>Active thinking, full attention</td>
</tr>
<tr>
<td>Gamma</td>
<td>31 to 100</td>
<td>Finger movement</td>
</tr>
</tbody>
</table>

EEG signal is known as highly non-Gaussian, non-stationary non-linear characteristics of nature [11]. Because of the undeterministics manner and the spectral content changed over time, the short time Fourier Transform is performed to determine the technical content of EEG signal. The analysis includes statistical and parametric analysis method are used such as time-frequency analysis, self-relation, crosswise relation and wavelet transform [12]. This study also is to verify the right band for the extraction feature for sensory response. Short time Fourier transform (STFT) is an important analysis to describe the spectral or frequency content of non-stationary signal at each point at time [13]. The segmented signal with N samples is applied a sliding window or a fast Fourier transform (FFT) on it. The frequency content is usually represented in spectrogram in time-frequency output.

Then, the wavelet was introduced by Morlett, and commonly use in EEG signal processing. The translational of window function on a sinusoidal Fourier Transform was called as ‘wavelet’. There are two types of wavelet transform: discrete wavelet transform (DWT) and continuous wavelet transform (CWT). The information of analysis and synthesis signals with a significant of computation time was provided by DWT. The raw EEG signals were passed through to the high pass and low pass filters and widely use to noise reduction. The cutoff frequencies that were used by the filters can extract to alpha, beta, gamma and theta brain wave [14]. The scale of analysis window, the window was shifted in time, and the signal was multiplied with the window, it is called as CWT analysis. It will form the wavelet coefficient in functions of scales and position.

Therefore, the wavelet analysis is the best trade-off between time and frequency resolutions to get the extraction signals at a certain frequency bands [10]. More descriptions about wavelet transform will be discussed in the next section

III. METHODS

A. EEG Acquisition Setup and Data

The task involves five sensory such as vestibular, audio, tactile or touch, visual and taste. Each task was designed with uniqueness activity that is suitable for the autism children with age of 3 to 7 years old. For taste stimulation consists of the three tastes such that are sweet, sour, and salt.

The EEG was recorded using 10-20 International System electrode placement of electrode. The data were recorded through 20 subjects. The data was sampled in 500 Hz for each subject. Most recording time elapse on 1 to 2 minutes. On each session, the subject was asked to close the eyes to avoid the artefact except for the visual stimulation. The EEG was recorded using Neurofax 9200 that is standard machine in medical premises. Fig. 1 shows how an autism child was running a session with EEG machine.

![Fig. 1: One of the subjects is doing the experiment](image-url)

B. Data Analysis

In this study, pre-processing signal starts with artefact removal and analysis of noise reduction using ICA. The artefact usually occurred when the subject was moving and eye blinking. Then feature extraction was executed by using DWT for the selected points of electrode. Fig. 2 shows the flowchart of sensory response via EEG data analysis.
The artefact removal of the signal must be done by selecting the large value of distortion and the most unwanted of the signal. From the user interface in Matlab, the artefact can be rejected and the noises were cleaned by using ICA method through EEGLAB.

After the artefact of the signal was removed by ICA, the clean signal again will get through another filter system of DWT. Hence now, the DWT will level down the signal into range of frequency bands of alpha, beta, gamma and theta. The signal also formed into the clean signals where the next step is to extract the features in signals content. Fig. 3 shows the raw and clean filtered EEG signal of vestibular of an autistic child.

**C. Wavelet Transform**

Wavelet transform forms a mathematical tool for signal processing with many applications in EEG data analysis[14]. This method is a suitable analytical tool for the non-stationary signals analysis such as EEG. It was proposed in 1982 by a French geophysicist, Jean Morlett [15]. The basic usage of the wavelet transform includes time-scale analysis, signal decomposition and signal compression. This set of wavelet consists of mother wavelet and its decompositions. They are formed by scaling and translating the mother function on time axis [16].

In discrete wavelet transform analysis, a multi-resolution description is used to decompose a given signal f(t) into increasingly finer details based on the two sets of basic functions.

The equations, expressed by [15] is,

$$DWT(a,k) = \frac{1}{\sqrt{a}} \sum s(t) \cdot \varphi (a,t-k)$$  (1)

Frequency band that is decomposed is 0-500Hz. Due to the physiological aspect, frequency greater than 60 Hz are considered as noise and can be neglected. For the extraction of DWT, there are eight decomposed signals that needed in this method, which shown in Table II.

The wavelet coefficients were computed using fourth order daubechies (db4) discrete wavelet transform as the mother wavelet and D6 as the decompose wavelet. Daubechies 4 is used as it is the most suitable mother wavelet for biomedical signal processing while level 6 is chosen because it refers to the alpha frequency range. All of the signals are decompose by using Wavelet Toolbox Main Menu in the Matlab program. Fig. 4 is wavelet tree for decomposition of the signal. Wavelet tree is a flow diagram of the decomposition of the signal after the signal has been filtered. The alphabet ‘a’ in the Fig. 4 refers to approximations.

The approximation of the signal is a decomposition details of wavelet through low pass filter while’d’ is decomposition of high pass filter. Fig. 5 shows the result of decomposition signal from level 1 to level 6. The mean and standard deviation, standard deviation of the signal of the

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**Fig. 2 Flowchart of Sensory Response procedure via EEG**

**Fig. 3 a)The raw signal of EEG of Autism child. b) The clean filtered signal of EEG of Autism child**

**Fig. 4 a)The raw signal of EEG of Autism child. b) The clean filtered signal of EEG of Autism child**
wavelet coefficients were calculated through mathematical algorithm.

TABLE II. CLASSIFICATION OF EEG SIGNAL

<table>
<thead>
<tr>
<th>Frequency Range (Hz)</th>
<th>Decomposition Level</th>
<th>Frequency Band</th>
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<tbody>
<tr>
<td>250-500</td>
<td>1</td>
<td>Noise</td>
</tr>
<tr>
<td>125-250</td>
<td>2</td>
<td>Noise</td>
</tr>
<tr>
<td>63-125</td>
<td>3</td>
<td>Noise</td>
</tr>
<tr>
<td>31-63</td>
<td>4</td>
<td>Gamma</td>
</tr>
<tr>
<td>16-31</td>
<td>5</td>
<td>Beta</td>
</tr>
<tr>
<td>8-16</td>
<td>6</td>
<td>Alpha</td>
</tr>
<tr>
<td>4-8</td>
<td>7</td>
<td>Theta</td>
</tr>
<tr>
<td>0-4</td>
<td>8</td>
<td>Delta</td>
</tr>
</tbody>
</table>

The entropy is a statistical and predictability measure of randomness. Approximate entropy (ApEn) quantified the complexity of stochastic process. In signal processing the approximate entropy in the non-stationary signals to distinguish normal and abnormal data situations where the statistics failed to detail about the significant of differences [17]. The purpose of ApEn is used to compare the pattern within the time series in order to estimate the regularity of data.

The procedure of ApEn computation was determined by this algorithm [17]:

1) Subtracts the mean value of original data series
2) Calculate the standard deviation; find the maximum and minimum values (it is known as bounds of r). r is the tolerance for accepting matches.
3) Select the parameter of m, length of sequence to be compared and by N is the length of time series. Where the formula of ApEn is obtained :

$$ApEn(m, r, N) = \phi^m(r) - \phi^{m-1}(r)$$

IV. RESULTS AND DISCUSSION

The frequency range of alpha lay on 8 to 16 Hz where the decomposition is at level 6 and daubechies 4. From the 19 subjects, the calculation of mean of the signals is presented in Fig. 6. From the overall experiment, the highest sensory of autism children felt was taste of salt. From the observation, mostly the autism children did not comfortable with the taste, and it indicates the autistic child does have food preference of salty food at value of 27.13 μV. However, the touch sensory tends to be the second highest sensory at 17.08 μV but moderately because the children feel excited and curious to touch the object given. In addition the visual sensory tends to be low at 7.72 μV because of the less of focus span in autism children.

The standard deviation of each sensory was also calculated to know more about how far the EEG data spread from the...
standard value. Fig. 7 represents the highest standard deviation is at 336.83 μV on taste-salty sensory. The lowest standard deviation on visual sensory is 172.84 μV. This indicates that the value of data points for autism children are spread far from a large range of values. Although an autism child has a lower mean value at visual sensory, it means the autism child mood can easily change. This situation was seen during experiments session when they can calm only for a while before being aggressive and uncomfortable in the new environment.

Because of the EEG signals were known as non-stationary signals, the approximate entropy is used to measure the complexity of irregularity of a time series. When the value of approximate entropy is large, the signal becomes more complex and irregular. Entropy is also a statistical measure of randomness. The function is created by length of the sample signal, tolerance of accepting matches and the delay of down-sampling time. The large approximate entropy was at tasting-signal, tolerance of accepting matches and the delay of down-sampling time.

EEG is a non-invasive medical instrument which is safe and low risk for children. In this study, we had use 19 channel EEG to compare the acceptance of sensory response among autism children. DWT is using to decompose the signal using daubechies 4 and level 6. The extraction features involve in were mean, standard deviation and approximate entropy. For overall results, the experiments show that the autism child has mood easily change due the unstable focus span.

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