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EEG Interpretation through Short Time Fourier Transform for Sensory Response Among Children

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ABSTRACT

This study is prepared to interpret the electroencephalography (EEG) signal through Short Time Fourier Transform (STFT). The STFT form was about the representative of the non-stationary signal from EEG through 5 sensory responses where it involves 17 normal children and 1 autism child. It is important to differentiate the brain activity pattern when the normal and autism children were given 5 different types of stimulations, which are task of taste, touch, vestibular, hear (sound) and visual. The acquired EEG signal is analysed based on the windowing technique through Hamming windows. The narrowband and wideband windowing also been selected to get the segmented data, which is later considered as segmented window. Then the fast Fourier transform is applied to the segmented window. This process is also known as filtering operation where the window operates based on impulse response. At the end of results, the brain activity pattern of normal and autism children will be viewed via spectrogram plotting for each acquisition signal. The spectrogram consists of multiple EEG band but only alpha band signal and it's characteristic will be chosen as the Sensory Profile of the subjects.

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INTRODUCTION

The awareness of disabilities children becomes a task of ministry to educate the public about special need of this disorder; that autism can be treated through medical and psychology treatment. The stages of diagnosis and assessment process involve the children, parents, teachers and expertise in special training and treatment as shown in Fig 1.

The sensory of a newborn starts with the visual, taste, smell and heard develop and further with sensory motor such as gross motor and fine motor action; that is show an infant starts to know and adapts his new world. Then the next phase of 7 month's baby now about the permanence objects which is relate to memory. Sensory integration is the organization of sensation for use. The greatest sensorimotor organization occurs during an adaptive response to sensation (Ayres and Robbins, 2004). 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.

According to Ermer& Dunn (1998), sensory profile was an instrument of sensory assessment for children with and without disabilities. It is a degree of scoring on sensory ability scale for a child in health occupational discipline. It involves the observation and the score will indicates the attention that need to be given to the subjects. Nowadays it is companion to schools and being standardized widely used to improve the children's ability (Dunn, 2006).

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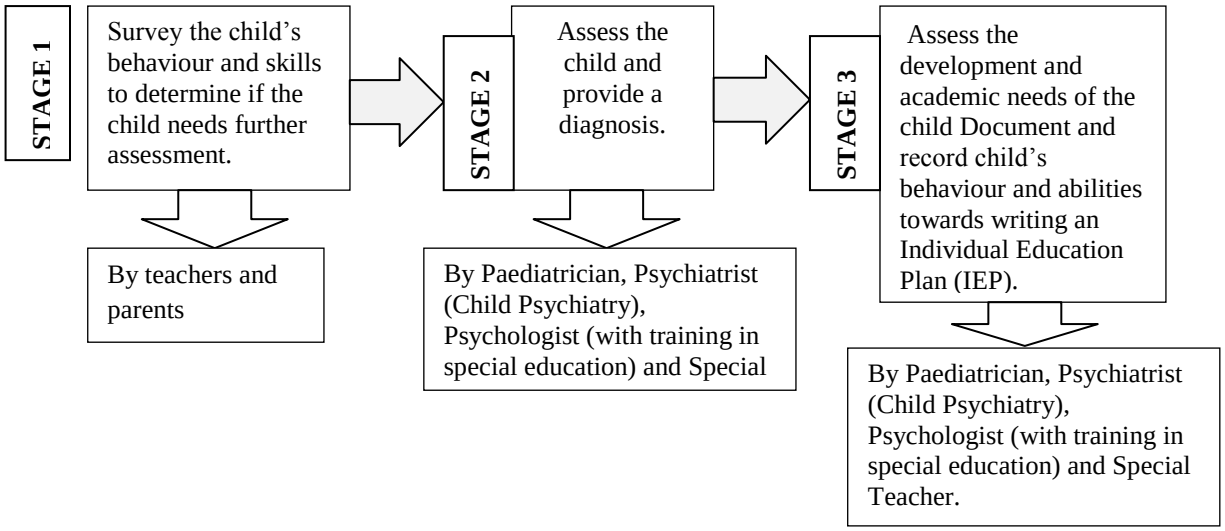

Fig. 1 : Stage of diagnosis and assessment for special children in Malaysia.

EEG is a short term for electroencephalography that is tested on human body especially brain activity. In medicine, it is an imaging technique and record the brain activity which different person has their own pattern of brain activity.EEG signal is known as highly non-Gaussian, non-stationary non-linear characteristics of nature (Subha, *et al*, 2010).Then the brain activity is categorized refer to it's frequency range as shown as in Table 1.

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 channelin 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.

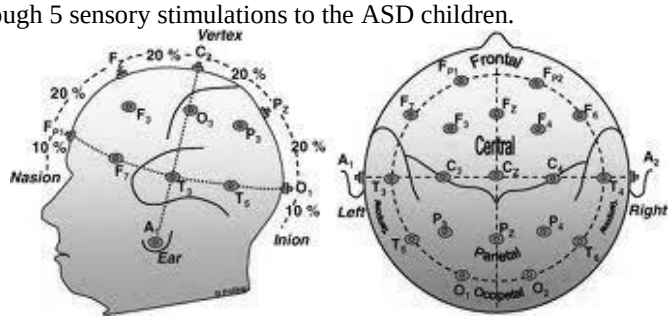

Fig. 2: International Electrodes Placement 10-20 system(Sanei, 2007).

Table 1: Brain Activity and their Frequency.

Rhythm	Freq (Hz)	Mental Activities
Delta	0.1 – 3	Deep sleep, lucid dreaming, increased immune functions, hypnosis
Theta	3 – 8	Deep relaxation, meditation, increased memory, focus, creativity, lucid dreaming, hypnagogic state
Alpha	8 – 12	Light relaxation, "super learning", positive thinking
Low Beta	12 – 15	Relaxed focus, improved attentive abilities
Midrange Beta	15 – 18	Increase mental ability, focus, alertness, IQ
High Beta	18 – 30	Fully awake, normal state of alertness, stress and anxiety
Gamma	30 – 60	Associated with information rich task processing and high level information processing

Because of the undeterministics and the spectral content changed over time, the short time Fouriertrans form 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.(Kiymik *et al*, 2005).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 (Fadzal *et al*, 2012). 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.

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MATERIALS AND METHOD

EEG Data Acquisition Setup:

The task involves five sensory such as vestibular, audio, tactile or touch, visual and taste. Every task was designed with uniqueness activity that is suitable for the children with age of 7 to 8 years old. For taste stimulation consists of the three taste such that are sweet, sour, and salt.

The EEG was recorded using 10-20 International position of electrode. The data were recorded through 18 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 artefactexcept for the visual stimulation. The EEG was recorded using Nihon Koden 9100 that is standard machine use in hospitals.

Table 2: Suggested Electrode Position(Hussin and Sudirman, 2013).

Sensory	Electrodes Location	Electrode Channel
Touch	Parietal lobe	C3,C4,Cz
Taste	Parietal lobe	C3,C4,Cz
Vision	Occipitical lobe	O1,O2
Vestibular	Parietal lobe	C3,C4,Cz
Audio	Parietal lobe	C3,C4,Cz

Data Analysis:

In this study, the EEG data analysis involves the process of data acquisition, filtering system to reduce noise, and short time Fourier transform as shown as Fig. 3.

The EEG signal that was recorded by the machine is called as raw data. This raw data should be remove the DC offset and filtered. The low pass filter with cutting frequency of 45 Hz (Fc = 45Hz) and high pass filter with cutting frequency (Fc=0.5Hz) were designed to reduce the noise that was existed in the signal using Matlab Software. While the bandpass filter is designed to filter up signal from 8Hz and 30Hz as the brain activity range as shown in Table 1.

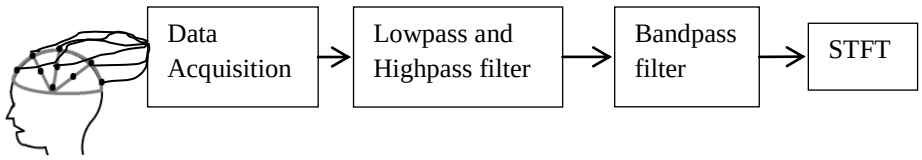

Fig. 3: Experimentation Setup.

Then, the signal was performed by short time Fourier analysis to determine the alpha wave is one of spectral contents in the acquainted EEG signal. As the Fourier analysis is to decompose a signal into its frequency components(Behnam *et al*, 2007).

The Fourier transform is

$F(w) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$, for stationary input signal

$$= \frac{1}{2\pi}\int_{-\infty}^{\infty} F(w)e^{j\omega t}\,dw \quad (1)$$

However, due to the content of EEG signal which is non-stationary signal and changes over time. The Fourier transform is no longer suitable to analyse the EEG signal. The STFT is used when the input signal with N samples is divided into segmented data.

$$\text{STFT, } \{f|n|\} = F(m,w) = \sum_{n=-\infty}^{\infty} f[n]w[n-m]e^{-j\omega n} \quad (2)$$

w(n) represents the sliding window that emphasize the local frequency parameter. When the non-stationary signal is applied a sliding window, it looks like that a pieces ofFFT by using a window at a stationary signal. There are also several type of window, however the Hamming window is chosen as the sliding window.

The STFT positions a window function $\psi(t)$ when it is called as Gaussian function and a Gabor Transform (Behnam *et al*., 2007). Windowing technique plays important role due to the size of window band where w and τ are modulation and translation parameters respectively. It will cause the high resolution of the graphical display for frequency content in a signal The limitation of $\psi(t)$ is at fixed-time frequency and the explanation of uncertainty principle such as Heisenberg Inequality when one can only trade time resolution for frequency resolutions.

From the formula expression (1), hence that $F(w) \leftrightarrow f(t)$, with the formula window function

$$F(w,\tau) = \int_{-\infty}^{\infty} f(t)\psi(t-\tau)e^{-j\omega t}dt \quad (4)$$

$$\psi(t) \leftrightarrow \Psi(w),\ \Delta t \Delta w \geq \frac{1}{2} \tag{5}$$

Where $\Delta w$and Δt denote to bandwidth and time spread of$\psi(t)$. When t increases, the window function translate in time while w translate in frequency with a constant bandwidth (Behnam *et al*, 2007). By choosing short window may cause poor frequency resolution as it good for sinusoidal components, and long window may improve frequency resolution for fast time-varying components when the signal is assumed as stationary within the window (Quatieri, 2002; Reddy, 2005).

The output of STFT as followed,

$$\text{Output of N} = \begin{cases} \text{FFT} \quad \frac{\text{Length}}{2}+1 & , \text{ if input signal is real} \\ \text{FFT} \quad \text{Length} & , \text{ if input signal is not real} \end{cases} \tag{3}$$

The steps to apply the STFT onto the EEG signals are :

1. The EEG signal was recorded and sample into N data.
2. A window of chosen type is used to multiply the extracted data through point by point
3. The zeros padded are applied on both sides of the window. The window size should be less the size of FFT section.
4. The FFT is computed on the FFT section.

Results:

This study involves 17 normal children and an autistic child where all subjects have to get through 5 stimulation activity via their sensory response such as vestibular, audio, touch, visual and taste. The spectrogram of a normal child and an autistic child were generated and will be discussed in this paper. Each stimulation was recorded into 1 to 2 minutes and been saved in .m files.

One sample of five activities, audio sensory stimulation was selected to show the different and also to verify the frequency range between 2 children. The audio sensory usually took about 1-2 minutes.

Fig.4 shows the output signal after the band pass filter and the spectrogram for normal children while Fig. 5 shows the output signal for the autistics children. The spectrogram is generated to show that the frequency of the activity were at range alpha band. From the Fig. 5 displays that the wave propagation on audio sensory through normal subject shows strong signal compare to the autistic child.

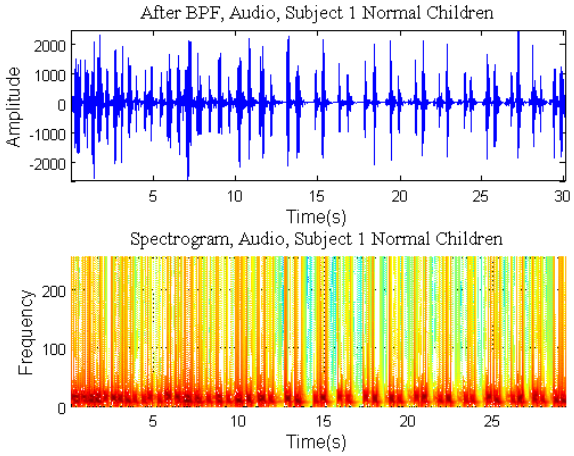

Fig. 4: Data Analysis of Normal Children through Audio Sensory.

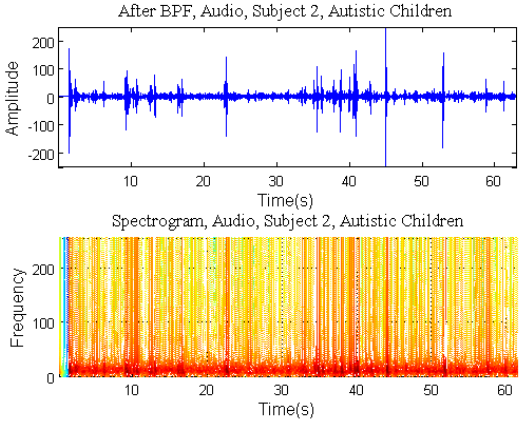

Fig. 5: Data Analysis of Autism Children through Audio Sensory.

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Discussion:

Based on Fig. 6 and Fig. 7 show the spectrogram of EEG output signals for normal child and autistic child. The zoom in view of spectrogram for both figure shows about the frequency content of EEG signal through audio stimulation. From this experiment, the frequency of brain activity range had been obtained. For the normal child, the frequency range of the signal is 5-12 Hz, while the frequency range for the autistics children is at 6 – 26 Hz. Therefore in this experiment the frequency range for both subjects lied on the Alpha band which is 8-12 Hz.

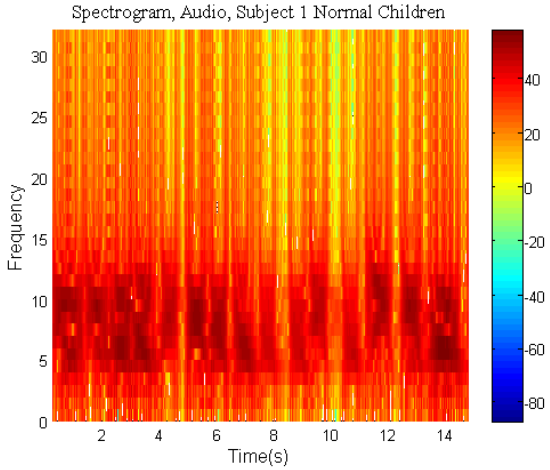

Fig. 6: Spectrogram of EEG Signal of Normal Child.

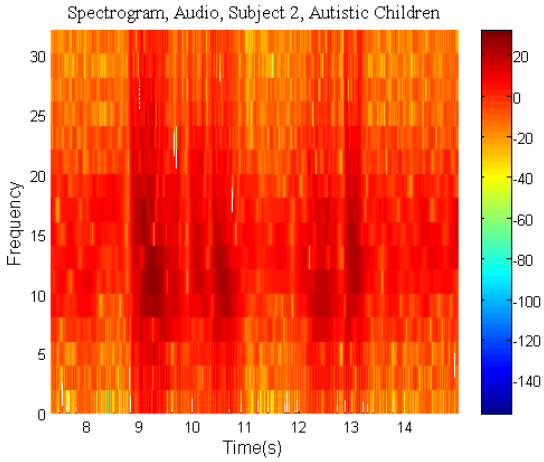

Fig. 7: Spectrogram of EEG Signal of Autistic Child.

Conclusion:

This experiment is to determine the pattern of sensory response using EEG through normal child and autistic child. The graphical using spectrogram view had been obtained for both subjects via audio sensory. From the result show that the range of EEG signals occupied the Alpha wave band for brain activity which is laid on 8-12 Hz. It is based on theoretical information about another Fourier transform series which this paper had discussed about short time Fourier transforms (STFT). STFT is a statistical analysis for non-stationary signal whereas the EEG signal is a time-varying signal. In the experiment, the acquisition EEG signal was get through the filtering systems and the computation using STFT algorithm had been used to obtain the spectrogram of the signals.

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