A REVIEW OF AUTISM DIAGNOSIS IN CHILDREN USING EEG SIGNALS

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Abstract

Autism Spectrum disorder (ASD) is one of the fastest growing developmental disorder worldwide. Recently, the number of people diagnosed with ASD has increased tremendously. ASD should be diagnosed as early as possible to provide effective intervention or atleast a way to live with. Even though many neuro-imaging and diagnostic techniques are available, no such technique is accurate or practically implemented by medical practitioners. Thus, there is urgency for the development of an accurate and practically implementable autism diagnosis system. Unique EEG patterns are widely used to differentiate autistic and normal children. This study focuses on various aspects of EEG data processing which will assist the development of an automated autism diagnosis system.

Keywords: Autism Spectrum Disorder (ASD), Electroencephalography (EEG)

I. Introduction

Autism, also referred as Autism Spectrum Disorder (ASD) was first described by Kanner and Asperger in 1945 as an intriguing disorder characterized by the child's inability to relate himself in an ordinary way to people and situations from the beginning of his life. Autism is a neurodevelopment disorder with an onset in early childhood characterized by impairment in language and social skills. Autistic behaviour also includes rigidity of interests and repetitive, stereotypical behaviours [1]. ASD is generally considered a life-long disability of yet undetermined etiology, without an established confirmatory laboratory test, and as yet without universally established, curative pharmacological or behavioural therapy [2-4]. In 2011, Manning et al. [5] reported the incidence of autism around 1% globally and yet the attention given for this disorder is less as compared to other disorders of same prevalence. The diagnosis of ASDs is based on the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders) criteria which include the following three conditions namely impairment in social interaction, impairments in communication and restricted repetitive and stereotyped patterns [6]. Accordingly, Autism can be broadly classified as Autistic Disorder, Asperger's Disorder, Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS), Rett's Disorder and Childhood Disintegrative Disorder (CDD).

II. Autism In India

Autism was first mentioned in Indian Journal of Paediatrics in the year 1944 by Dr. A. Ronald, a Viennese paediatrician. In his work, an overview of the detection, causes, types and treatment of the 'abnormal children' were given. This was a year

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before Leo Kanner's described Autism. The term 'Autism' was first used in an Indian literature was in 1959. Later many papers were published through the 1960's. Erna Hoch's 1967 Psychiatrist on an Indian Playground provided a careful and comprehensive portrait of sixteen children diagnosed by Hoch with autism and treated through parental counselling and child psychotherapy. Through the 1970s, not much study was noticed. However, by the late eighties a lot of initiatives had started to take place with regard to autism awareness. And a few autism specific organisations had also begun in different parts of the country, as well as a few schools. Till date, lots of research articles, studies and books related to autism are available in India. [37]

According to prevalence study done by various websites and journals in 2012, India has an autism rate of 1 in 250 [38]. About 15 million people in India have autism. Still autism is considered as a 'Western syndrome' not prevalent in India. Very few professionals are able to diagnose and categorize children with Autism. Awareness of autism is limited to the rich and educated people. As a result, it is mandatory to provide an easily accessible, economic and accurate diagnostic tool for autism in India.

III. Electroencephalography

EEG is a neuro imaging system which studies the brain signal and its functional behaviour by reading the scalp electrical activity generated by brain structures which are recorded from the scalp surface after being picked up by metal electrodes and conductive media [7]. Electrical voltages generated inside brain due to action potentials and post synaptic potentials of neurons are responsible for generation of EEG at human scalp. Action potentials are composed of a rapid series of electrochemical changes that run from the beginning of the axon at the cell body to the axon terminals where the neurotransmitters are released. Postsynaptic potentials occur when the neurotransmitters bind to the receptors on the membrane of the postsynaptic cell which causes the ion channels to open and close and lead to graded change in the electrical potential across the cell membrane [8].

Moreover, EEG is a non-invasive and inexpensive method which can be used to quantify the psychological health of patient [9]. Currently, Autism is being diagnosed using DSM-IV criteria. But it is a difficult job for the psychiatrist to quantify the degree of disorder manually. As a result, currently lots of emphasis is given on autism diagnosis using EEG.

IV. Protocols for Data Acquisition

Uvais Qidwai et al. has acquired EEG data from normal and autistic children in eye-open and eye-closed conditions [10]. W. Bosl et al. collected data from 79 different infants among whom 46 were at high risk of ASD and 33 controls. Data were collected when infants were seated on their mother's lap and research assistant were blowing bubbles to get the child's attention [11]. Elizabeth Milne et al. acquired data while the children watched computer screen which contained Gabor patches. Gabor patches were created using Matlab and the psychophysics toolbox.

An additional stimulus, a gray-scaled image of a zebra was presented. Participants were instructed to respond by pressing a response button with the index finger of their dominant hand as quickly as possible whenever they saw the zebra [12]. Mohammed J. Alhaddad et al. [13] and Mahmoud I. Kamel et al. [14] collected data while children were in relaxed state. EEG data acquisition was taken by Ana Catarino et al. while the children performed face and chair detection task [7]. M. Ahmadlou acquired data while children were in close-eye active condition [15]. Sheikhani A. et al. acquired EEG from 10 autistic children and 7 age matched controls while they were seeing the picture of their mother [16]. Ali Sheikhani et al. acquired data from 15 autistic and 11 normal age matched children while the children performed tasks such as eye-closed, relaxed eye-opened, looking at 3 samples of puzzle shapes, looking at mother's picture upright and inverted, looking at a stranger's picture upright and inverted [17].

V. EEG Acquisition Using Evoked Potentials

Evoked potentials is a neurophysiologic examination that assess the role of the sensory system, visual, and somatosensory pathways through evoked responses to a stimulus known and standardized. Some such evoked potentials include Related Evoked Potentials (ERP) and Visual Evoked Potential (VEP), Evoked Potential Acoustic (PEA), Motor Evoked Potentials (MRP), Steady State Visual Evoked Responses (SSVEP) [18]. EEGs of autistic individuals have shown definite variations when evoke potentials are given to stimuli while acquiring data.

The P300 (P3) wave is an Event Related Potential (ERP) elicited by infrequent, task-relevant stimuli. It is considered to be an endogenous potential as its occurrence links not to the physical attributes of a stimulus but to a person's reaction to the stimulus. More specifically, decrease of P300 components in autistic individuals indicate that this population presents abnormalities on central aspects of auditory processing [19].

Results focusing on bottom-up and top-down attention in High functioning - Autism Spectrum Disorder (HF-ASD) using P300 suggested that bottom-up involuntary attention is unaffected in high functioning autism spectrum disorder (HF-ASD), while lower level and top-down visual information processing are impaired [20]. This explained why the individuals with HF-ASD often show superior performance in simple visual tasks, despite difficulties in the perception of socially important information such as facial expression. The neural basis of visual perception abnormalities associated with HF-ASD is currently unclear.

Ragan et al. stated that SSVEP is a direct response in the primary visual cortex [21] while Silberstein et al. [22] observed that indirect cortical responses via cortical-loops, from the peripheral retina, while a cognitive task is performed causes SSVEP. SSVEP is caused when the retina is excited by a visual stimulus ranging from 3.5 Hz to 75 Hz and correspondingly, the brain generates electrical activity at the same (or multiples of) frequency of the visual stimulus. SSVEP-based BCI is essentially EEG based vision-tracking system which can be useful to measure the autistic ability to control eye movements. Abnormal attention in autism is shown by SSVEP which implied that lack of hemispherically independent modulation in autism may reflect the operation of a non-specific mechanism of sensory gating [23].

VI. EEG Feature Extraction and Classification Techiques

Uvais Qidwai et al. presented a study where Time Difference of Arrival (TDOA) was used to quantify EEG signal to relative source-temporal features. Data was acquired from 6 Autistic children and 6 typical subjects around 6-9 years. Multi-layer perception (MLP) with back propagation was used for classification. The results showed a high discrimination between eyes-open and eyes-closed for both groups of 90% classification accuracy [10].

Multiscale entropy of EEG signals is a vital measure of signal complexity associated with health and disease. W. Bosl et al [11] investigated about finding biomarker for autism in infants, by computing multi-scale entropy (mMSE) of EEG signals in resting state as a feature vector and using multiclass Support Vector Machine (SVM) algorithm for classification of each age group from 6 to 24 months. Classification accuracy for boys was close to 100% at age 9 months and between 70% to 90% at ages 12 and 18 months. For girls, classification accuracy was the highest at age 6 months, but declines thereafter. Overall the accuracy was 80% for both control and ASD children in 9 months.

Elizabeth Milne provided the first empirical demonstration of increased neural noise in people with ASD. ASD and neuro-typical group comparison showed intra-participant variability of P1 latency and P1 amplitude was greater in the participants with ASD. Also in inter-trial á-band, phase coherence was lower in the participants with ASD. Thus the theory that individuals with ASD were less able to synchronize the activity of stimulus-related cell assemblies than neuro-typical individuals was supported [12]. Mohammed J. Alhaddad et al. used EEG diagnose Autism using various combinations of preprocessing techniques such as raw, referenced, filtered, windsorized and normalized. Features were extracted in both temporal and frequency domains i.e. as raw data and Fast FFT using FLD classification. The average accuracy rate was 90%. Windsor Filtered Data gave the best mean and the lower standard deviation of both raw and FFT features. Over all, FFT features had a better correct rate of 88.14% and lower standard deviation 0.0404 than raw features [13]. In a similar study, Mahmoud I. Kamel et al. have used Regularized Fisher Linear Discriminant (RFLD) with FFT for feature extraction. RFLD remedies the error caused in FLD classifiers when data is high-dimensional with only few points given. As a result, with similar pre-processing combination of raw, referenced, filtered, windsorized and normalized techniques; an average accuracy of 92% was achieved with best mean and lower standard deviation for winsorised filtered data [14]. Another study proposed by Sudirman et al. captured EEG signals from normal and special children based on their visual response using Visual Evoked Potential (VEP) method [24]. Fast Fourier Transform (FFT) was used to analyse data, where normal and special children were distinguished based on alpha (á) value. Result showed that alpha value for normal children at 10 Hz was higher than autism and Down syndrome children.

Ali Sheikani et al. used Lempel-Ziv classification and STFT to diagnose Autism [25] using EEG signals. The mean and variance values were computed within all bands and within limited bands (STFT-BW) and using ANOVA with K-Nearest Neighbour classification. The approach gave a result of 81% accuracy suggesting that it is difficult to discriminate a significant marker for ASD in STFT while there is discriminate in STFT-BW. As a result, abnormal connection between Parietal- temporal and central lobe was found. Sheikhani A. et al analysed the EEG background activity in Autism [16]. Short time Fourier transform was used to extract EEG features and classification was done using k-nearest neighbors (k-NN). This work was applied at beta band to find differentiation accuracy of 82.4%. Coherence values showed abnormal connectivity and were present in parietal lobe and temporal lobe and connectivity between these lobes and central lobe. ASD and control children of same age group were compared in this Quantitative EEG based approach. Classification was performed using Coherence and feature extraction was performed using Short time Fourier transform (STFT). A distinction of 96.4% was found in relaxed condition using spectrogram. Two significant points inferred were that in ASD individuals, decreased activity was found in left brain hemisphere, in alpha band detected by spectrogram criteria and that increased connectivity of temporal lobes was found with other lobes, in gamma band, using coherence values [26].

Wavelet Transform Coherence (WTC) performs a time-frequency analysis of the signals by transforming the original signal using a wavelet function with a characteristic time t and frequency f [27]. Ana Catarino et al [7] used WTC to show reduced interhemispheric coherence in people with ASD. An experiment was performed using 15 ASD and 15 control subjects. WTC analysis and Power analysis were performed to find the interaction between frequency bands. Reduction in interhemispheric coherence was observed and found to be widely dispersed across the brain in people with ASD.

Further, M. Ahmadlou et al investigated about children with ASD, by using wavelet chaos theory and Katz Fractal Dimension to extract EEG signal features. The study focused on the difference between autistic child and normal in close-eye active condition, reporting an accuracy of 90% in delta and gamma EEG sub-bands [15].

VII. Conclusion

Medical diagnosis of ASD based on behaviour of children can be confusing and tedious. Many neuro-imaging tools such are MRI, MEG, FMRI etc. are available, but they are not as effective and accurate as EEG for Autism diagnosis. Distinct EEG patterns have predicted autism risk for children as young as 6 to 24 months. As a result, various studies are performed to develop EEG based autism diagnosis system which can be both efficient, economic and user friendly.

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