Multimodal Brain Imaging Technique: A review of the applications in ADHD diagnosis

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Abstract: *Attention Deficit Hyperactive Disorder (ADHD) is neuro-biological disorder. It affects the behavior of a person. It makes difficulty even in doing his own routine work. In this proposed paper, the facts related to ADHD and the multimodal Brain Imaging techniques used to find out the abnormalities that lead to this chronic condition are discussed. The powerful techniques like Degree-Based Statistic, Neuroimaging of the Children's Attention Project (NICAP),Rich-Club organization, mCCA + jICA – multiway fusion method, Machine Learning (ML) approach with the support of Multiple Support Vector Machine Recursive Feature Elimination (SVM-RFE) and Radial Basis Function Kernel SVM (RBF-SVM), Graph Cut Techniques, Multi-kernel learning (MKL) are analyzed here. The results of this study points out that ADHD is neurological disorder. It should be diagnosed earlier through the apt method and treated effectively for better and improved performances.*

Keywords: Attention Deficit Hyperactivity Disorder , Multimodal Brain Imaging Techniques, Brain Disorders, Brain Structure

1.INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is a childhood disorder. It may persist from childhood to even adolescence. It is a chronic condition which affects the behavior of a person. It can be of inattentive, overactive and impulsive behavior. It may be any one of above said behavior or combination of them. It affects the development and functions of a person. ADHD persons find significant difficulties during the school years as well as post school years. During the school years they may face difficulties such as educational underachievement, mingling difficulty with peers, distraction, social isolation, lack of concentration, antisocial behavior, etc.

According to DSM-IV, the Attention Deficit Hyperactivity Disorder (ADHD) is featured as pervasive, inattentive, overactive or hyperactive, and impulsive nature. The World Health Organization (WHO) uses another name – hyperkinetic disorder (HD) to explain ADHD. ADHD/HD is one of the most important disorder in medicine under going various researches. [10]

2. SYMPTOMS OF ADHD

A. INATTENTIVE

- Unable to keep attention during carrying out of tasks or in play.
- No proper eye to eye contact . Seeing somewhere when spoken directly to them.
- Find difficulty in following instructions and often fails to complete the work in a particular time.
- No proper organizing skill.
- Usually they avoids or dislikes assignments, projects, etc that need lot of sustained mental effort.
- Habit of losing materials such as pencils, books or tools that are inevitable to carry out the task.
- Find difficulty in attaining concentration and very often get distracted and get diverted.
- Even unable to do routine work properly one after another and often forgetful.

B. HYPERACTIVE

- Find difficulty in sitting in the same position for particular time. Starts to fidgets with hands or feet or shakes body.
- Starts to wander in the class when remaining seated is necessary.
- Unnecessarily starts to run, hop, jump or climb when they are not expected to do so.
- Often makes unwanted noises and are unable to play or work silently.
- They are of "on the go," attitude and behaves as "driven by a motor"
- Excessive talks and unable to control their speech.

C. IMPULSIVE

- Habit of blurting out the answers prior to the completion of questions.
- Lack of patience and unable to wait for their turn.

Boys and Girls have very different ADHD symptoms. The following points mention the difference in ADHD symptoms in them.

Boys

- More Obvious and external
- Impulsivity i.e., out acting
- Hyperactivity or over activity such as running, kicking and hitting
- Unable to focus and inattentiveness
- More Physical aggressive nature

Girls

- Attitude of being often withdrawn
- Expression of low self-esteem and anxiety
- Find difficulty in academic achievement due to intellectual impairment
- Inattentiveness or often day- dreaming
- Expression of Verbal aggression by teasing, name calling, etc.
- Less Obvious and more internal

3. BRAIN DISORDERS

Attention Deficit Hyperactivity Disorder (ADHD) a brain disorder. It is influenced by Genes. The following are the important reasons for brain disorders.

A.BRAIN INJURIES

Brain injuries are Traumatic injuries. They are caused by the consumption of toxins, alcohols, etc during the maternity. Genetic facts plays a very important role here.

B. BRAIN DAMAGE

Brain damages are often caused by accidents, violence activities , blows to head, etc.These brain damages lead to ADHD.

C.BRAIN ABNORMALITIES

Problems in utero, physical injuries, swelling of blood vessels in brain , cerebral palsy, etc are some of the abnormalities which are happen before birth. These type of abnormalities affects brain and leads to ADHD.

4. ADHD BRAIN STRUCTURE

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neuro disorder, which affects the normal development. It approximately affects 6% of children in the world. The ADHD brain is 3% to 4% smaller than normal brain.

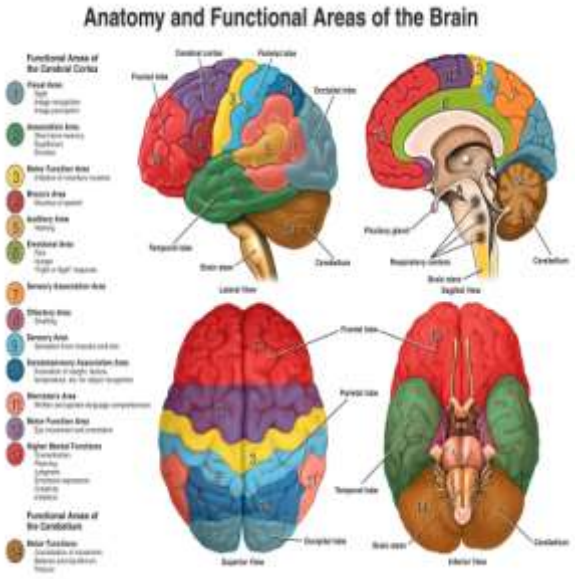

Fig.1: Anatomy and Functional areas of Human Brain[13].

The above figure clearly tells about the structure and the functional parts of a human brain[13]. Fig[1]. Frontal lobes, caudate nucleus, cerebellum and temporal gray matter are the most important brain areas that are connected with focus, concentration, controlling power of impulsation, attentiveness, inhibition, and carrying out of motor activities. The brain development in normal persons as well as the ADHD persons are similar.

a. Cerebral Cortex

Cerebral Cortex is the surface of the cerebrum, also known as "gray matter". This is divided into two parts namely the Right and Left cerebral hemispheres. These two parts are connected by a thick band of nerve fibers, known as corpus callous. This band allows them to communicate and share information each other. Further, the each hemisphere is divided into four lobes. They are called as frontal, temporal, parietal, and occipital lobes. The variations in these lobes makes some abnormalities in neural function. ADHD persons have some variations in these lobes. The persons having typical neural structure also have ADHD. Smaller volume of the PFC and basal ganglia and reduced cortical thickness across prefrontal, parietal, and temporal cortex are such type of typical neural structure.

b. Frontal Lobe

This area is concerned with focus, concentrating power, the sound decision making power, attentiveness, learning process and rememberance of the facts. Normal frontal lobes play the most important role in the situational behavior, proper behavior, emotional control and impulse control. If the Frontal Lobe does not function properly, the person lacks the above said abilities and termed as learning disabled. This happens in ADHD persons.

c. Cortexes

The cortex is the body's impulse control center. If the inhibitory mechanisms of cortex did not function properly the control ability becomes less. In the ADHD, the cortex do not perform properly, so that there is little or no impulse control in particular situations.

d. Limbic System

This is located deep in the center, and at the base of the brain. This is our "watchman," and gives alert to dangerous situations. It is concerned with the emotional changes, sleep patterns, supervision of stress and energy levels. ADHD persons have faulty limbic systems that makes emotional outbursts and oversensitive.

e. Reticular Activating System (RAS)

RAS is situated at the back of the head in the brain stem. It is responsible for walking control, sleeping patterns, concentration, focus, and attentiveness. The abnormal functioning of RAS happens in ADHD. There is a decrease in cerebral volume as well as cortical volume above 5 and 8 % in ADHD persons. The thickness of the cortex is achieved with the three years gap in ADHD brain when compared to normal brain.

5. MULTIMODAL BRAIN IMAGING TECHNIQUE

Brain Imaging is not a new term. Everyday innovations are carrying out with sophisticated tools in the field of technology. Now a days there are several ways to know about the brain. The important methods to study about the brain are Structural and Functional Imaging.

Structural imaging is a technique which gives a two-dimensional or three-dimensional image of the brain according to our requirement. Structural images can be obtained by Magnetic Resonance Imaging (MRI) or Diffusion Tenser Imaging (DTI). It tells us only about the structure of the brain and nothing regarding the functions and abnormalities.

Functional imaging provides information about the functions of specific regions. It tells us about the activities of the person's brain while he is doing particular actions. Functional Magnetic Resonance Imaging (fMRI), Electroencephalography (EEG) and Magneto Encephalography (MEG) are the techniques we used to get functional images.

The above said techniques enable us to the know and analyse the brain function and structure in detail. But at a time we can get only functional data or

structural data. This is not enough to diagnose well. So there came usage of combination of techniques. So that we can study the nervous system both under normal and pathological conditions.

Multimodal neuro imaging is a technique of brain imaging that was developed to solve the problems with the individual modalities. It is capable of providing a more comprehensive picture of the brain. Under this technique, we can combine and jointly analyze the structure and function data. EEG combined with functional MRI (fMRI), PET/CT and PET/MRI can be done under this multimodal technique. By this combination technique, we can improve the spatiotemporal when compared with the single modality alone.

Multimodal neuroimaging advances Neuroscience research is concerned with neurology, psychiatry, neurophysiology, neurosurgery,etc. For these neuroscience researches the multimodal neuroimaging techniques are widely used. This technique can be used in cross-validate findings from different sources and the identification of associations and patterns. It can provide access for the determination of activities of various brain parts from multiple perspective view by making an experimental set up.

Multimodal neuro imaging plays an important role in clinical as well as non-clinical findings. We can build a Brain Machine Interface (BMI) under this technique. The mapping of mind and the connections between behavior to brain areas, finding and following up of neural activities and information pathways, evaluation of the effects of pharmacological treatments,etc. can be carried out effectively by using this multimodal technique.

Under this multimodal technique, the MRI-dMRI-fMRI data has been combined and ubiquitously used for the diagnosis of ADHD. It has high clinical availability. This technique is capable of linking the functions of the brain, connectivity and its structure. This technique is widely used in ADHD researches nowadays. (as shown in figure 2)

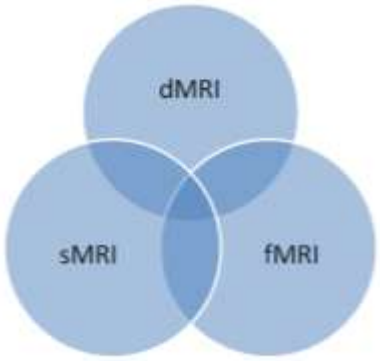

Fig: 2 Multimodal method for ADHD

6. EXISTING TECHNIQUES

KwangsunYoo (2016) et.al, proposed "Degree-Based Statistic and Center Persistency for Brain Connectivity Analysis" – under this a new method is used, called as degree – based statistic (DBS). It performs cluster – wise inference to control the FWER (family-wise error rate) in the analysis of connectivity. This DBS method solves the problem of lack of spatial specificity and the threshold problem in initial cluster-forming. Here, a few brain areas are considered as important in the integration of network.

The demerits of this system are the DBS should be considered as a complementary method and not replacement for other clustering techniques. Further it does not consider about the smoothness of fMRI data[1].

Timothy J. Silk (2016) et.al, proposed "Developmental brain trajectories in children with ADHD and controls: a longitudinal neuroimaging study" – here they describes a multimodal neuroimaging method to study about the children with and without ADHD. Under this study, assessments are done through a structured diagnostic interview, parent and teacher questionnaires, direct child cognitive or executive functioning and Magnetic Resonance Imaging (MRI). They used the advanced neuroimaging procedure such as e Mock scanner training, Multi-band, Multi-Shell Diffusion MRI, Multi-band Resting State functional MRI, etc.

By modifying according to our requirements we can use these techniques and can get better results[2].

Siddharth Ray (2014) et. al, proposed "Structural and functional connectivity of the human brain in autism spectrum disorders and attention-deficit/hyperactivity disorder : A rich club organization study" – here they used the graph theory for combining the structural and functional connectivity. They examined among three groups of children: a group with ADHD , a group with ASD and typically developing controls (TD). They applied the rich – club organization technique. Under this ,the brain is considered as two different network domains viz., inside and outside a rich-club network phenomena.

The main drawback of this system is the small size of ASD and ADHD subjects in [3].

Jing Sui (2013) et. al, proposed "Combination of Resting State fMRI, DTI, and sMRI Data to Discriminate Schizophrenia by N-way mCCA + jICA " – developed an approach called "mCCA + jICA" here they used a multi-way fusion method. Under this the risk factors that are shared or across multiple modalities can be investigated . This multi-way fusion model combines resting state fMRI, gray matter density, and DTI data in order to find out the abnormalities.

The main disadvantage of this method is that the subject number is not very high and mCCA – jICA operates on extracted features than the original data[4].

John B. Colby (2012) et. al, proposed "Insights into multimodal imaging classification of ADHD " – here they provided a multi set collaborative approach. Under this method, the structural magnetic resonance image is combined with the functional magnetic resonance imaging data. This combination is done on the basis of the demographic information. This is done mainly to predict diagnostic status of individuals with ADHD from Typically Developing (TD) children.

They used Pearson correlation functional connectivity method to define the connectivity. Further, they used the nodal and global graph and power spectra, voxel wise global connectivity and regional homogeneity also for definition.They used the Multiple Support Vector Machine Recursive Feature Elimination (SVM-RFE) algorithm for feature extraction and also applied Radial Basis Function Kernel SVM (RBF-SVM). This approach is done for the evaluation of structural and functional features which define the abnormal brain circuitry in ADHD person[5].

Jason W. Bohland (2012), et. al, proposed "Network, Anatomical, and Non-Imaging Measures for the prediction of ADHD Diagnosis in Individual Subjects". – here they introduced three methods for computation of graphs which represents interdependencies between activations in various brain regions, They fitted a L1-norm regularization penalty and under that they performed the inverse of the time series covariance matrix. They used the anatomical and network feature sets and non-imaging phenotypic features. Machine learning algorithms and cross-validation methods are used for accurate diagnosis. This paper is also pointed out some future research in related areas [6].

Dai Dai (2012) et. al, proposed "Classification of ADHD children through multimodal Magnetic Resonance Imaging" – here they introduces an automatic classification framework. This is done on the basis of the brain imaging features of ADHD persons. The cause and effects of using various features are compared with each other. Using the multi-kernel learning (ML) the integration of the multimodal features are done. This is the best efficient method in terms of sensitivity and J-statistic.

They used F-score as another measure. If the J-statistic and F-score is high, it indicates the efficient and better performance of the classifier.

The disadvantages of this method is that non taking of the phenotypic information and the performance on the imbalanced datasets[7].

Arati Kothari and Dr. B. Indira (2016) proposed "An Overview on Automated Brain Tumor Segmentation Techniques". Here they analysed and pointed out the different techniques for brain segmentation. They did this analysis to be applied in the detection of the tumor. But we can apply these techniques with modification according to our requirement in the brain segmentation for diagnosing the ADHD[11].

Pratibha proposed "Performance Evaluation of Skull Stripping Methods and Tools"(2013) – she proposed a method called Skull Stripping which aims on segmenting the brain tissue; that is the cortex and cerebellum from the skull and non brain tissues in Brain MRI images. Here she presented the methods BET (Brain Extraction Tool) and BSE (Brain Surface Extraction) for segmenting the brain images. She also did the comparison and evaluation of the methods integrating with the updated versions of FSL and BrainSuite[12].

7.CONCLUSION

This paper gives information related to ADHD (Attention Deficit Hyper Activity Disorder) which is a neurological disorder. Brain imaging techniques are playing an important role in the diagnosis of ADHD. Now a days with the advancement of the technology multimodal brain imaging techniques are emerged in the studies related to Attention Deficit Hyper-Activity Disorder. (ADHD). Multimodal neuroimaging focuses on computational analysis of multimodal neuroimaging data. It contains several steps like pre-processing, feature extraction, image fusion, machine learning, visualization, and post processing. This is done to know about the differences in spatiotemporal resolution and merging of the biophysical or biochemical information in pictures or images. Multimodal neuroimaging assists in diagnosing this well with the advancement in the technology. So by using this super multi modal technology we must diagnose the ADHD earlier under the supervision of a clinical psychologist and undergo treatment for better results. Then we can make ADHD child a gifted child.

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