

Computational Classification of ADHD using the Vanderbilt Rating Scale

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Abstract—

Aim / Objective: Assessing whether symptoms of attention-deficit hyperactivity disorder (ADHD) in children are correlated and are appropriate to diagnose a child as ADHD subtypes as Predominantly Inattentive, Predominantly Hyperactive or Impulsive and Combined ADHD. The main aim of this study is to ascertain the association between the various symptoms connected to the ADHD Combined Subtype, Predominantly Inattentive and Predominantly Hyperactive or Impulsive subtype ADHD. **Method:** The various rating scales are there to diagnose ADHD and its subtypes. The data from 77 children collected using NICHQ's Vanderbilt Rating Scale and analyzed as per the rating scale's Diagnostic criteria diagnosed 6 children with Combined ADHD, 12 were diagnosed as Predominantly Inattentive and 39 were of Predominantly Hyperactive or Impulsive subtype. This data when analyzed using a computational technique called Multivariate Regression concludes that when a child's inattention rises and hyperactivity or impulsivity lessens he or she is diagnosed as Predominantly Inattentive.

Results: When Inattention declines and Hyperactivity or Impulsivity rises, the likelihood of classifying a child with the Predominantly Hyperactive or Impulsive subtype rises. And when a child has both inattention and hyperactivity or impulsivity, the odds of him or her being diagnosed with ADHD increase.

IndexTerms—ADHD, Vanderbilt Rating Scale, Predominantly Inattentive, Predominantly Hyperactive or Impulsive, Combined ADHD, Multivariate Regression

I. INTRODUCTION (HEADING 1)

One of the most common neuro-developmental disorders is ADHD (Attention Deficit Hyperactivity). It is most often diagnosed in childhood and can last into adulthood. Children with ADHD may struggle to pay attention, manage impulsive behaviors or be overly active [1]. Medical problems, below-average intelligence, specific learning disabilities, attention deficit hyperactivity disorder, emotional problems, a poor socio-cultural home environment, psychiatric disorders, or even environmental causes can all cause children to underperform in school. ADHD is a psychiatric disorder that can affect children [2]. ADHD can make it difficult for a student to focus, pay attention, listen, or exert effort in school. According to the DSM, ADHD can also cause a student to be fidgety, restless, and always on the go, to talk excessively or disturb the classroom, to blurt out answers before the question has been completed, to frequently lose his things, to be easily distracted, and to be forgetful in daily activities [3, 4].

ADHD symptoms can cause problems in the workplace for adults just as they can for children. Some adults with ADHD have a high rate of success in their careers. Others may experience difficulties such as poor communication, distractibility, procrastination, and difficulty managing large projects. Each person with ADHD faces unique challenges [5].

ADHD medications aid in the regulation and strengthening of neurotransmitters, thereby alleviating symptoms. Approximately 70-80% of patients benefit from stimulant medications. They work for both mild and severe ADHD symptoms[6]. Some stimulants are permitted to be used by children over the age of three or six [7]. These medications assist children, teenagers, and adults who are having difficulty at work, at home, or in school. ADHD medications include the following:

1. **Stimulants:** This drug aids in improving focus and avoiding distractions. Amphetamine, dextroamphetamine, Dexmethylphenidate, Lisdexamfetamine, Methylphenidate.
2. **Non-stimulants:** If the stimulant's side effects are severe, this medication can help to alleviate them. Non-stimulants include Atomoxetine or Bupropion, Clonidine hydrochloride, and Guanfacine [8].

ADHD in children is a cognitive disorder that affects approximately 4% to 12% of children worldwide [9]. The prevalence of ADHD in India, on the other hand, is much higher than the global average. In India, children with ADHD face long-term consequences such as reduced educational and employment attainment. It can affect a person's everyday functioning even until adulthood. Parents are also dealing with issues of their own.

In terms of social impact, a child with ADHD can cause significant anxiety in those around him, straining parent/sibling-child relationships. ADHD prevalence in Indian children was found to be higher than the global estimate, at 11.32 % (study conducted in Coimbatore). The highest prevalence is found in children aged 9 (26.4 %) and 10. (at 25 %) [10]. Another study conducted in different parts of India also suggested a prevalence between 2% to as high as 17% [11]. In numbers, an article published in India Today mentioned that it is estimated that 10 million Indian children have been diagnosed with ADHD annually [12].

Although ADHD is extremely common in India, parents are still afraid to treat their children with ADHD medications. 83.3% of people who are prescribed ADHD drugs stop taking them within the first month. According to one study, the reasons given by parents for discontinuing the medicine include, among other things, adverse effects, lack of effectiveness, hospital difficulties, and fear that the kid may become addicted [13].

To diagnose such disorders the healthcare providers use standard guidelines from the American Academy of Pediatrics or the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM), also can have interaction with parents, teachers, and the relatives of children along with this the Food and Drug Administration (FDA) has approved Neuropsychiatric EEG-Based Assessment Aid (NEBA) which is based on the concept that theta/beta ratio of ADHD children is higher as compared to the normal children [14-16].

In India, alternative solutions being advised are:

1. Psychosocial interventions: entail behavioral intervention, parent training, peer and social skills training, and School/classroom intervention/training.
2. Body-oriented activities: such as yoga, physical exercise, sleep, and mindfulness-based interventions such as using Breathing exercises with music therapy or attention training.
3. Cognitive-behavioral treatment: such as play therapy.
4. Neurocognitive training - computer-based attention and EEG biofeedback training, such as the CogoLand game developed by Singapore-based Neuro Pvt. Ltd. in collaboration with researchers from the Institute of Mental Health (IMH), Duke-NUS Medical School, and Singapore's Agency for Science, Technology, and Research (A*STAR)

The researchers' worked for over a decade and suggested that EEG-based attention training is a promising solution. Brain scans performed on children with ADHD in their most recent clinical trial revealed reorganized brain network activity, indicating less inattentive symptoms [17].

It takes several steps to determine whether a child has ADHD. There is no single test for ADHD, as it has many other issues, such as sleep disorders, anxiety, depression, and certain forms of learning challenges that might exhibit symptoms in ADHD children. While diagnosing ADHD, the first step is to contact with psychologist or psychiatrist, or pediatrician, to see if the symptoms match the diagnosis. Scales and checklists help clinicians collect data about symptoms and functioning. To meet DSM-5 criteria, symptoms must arise in more than one scenario.

The purpose of this investigation is to ascertain the association between the various symptoms connected to the ADHD Combined Subtype, Predominantly Inattentive and Predominantly Hyperactive or Impulsive subtype ADHD. It is estimated using computer algorithms, which are discussed further in the Computational Analysis section.

II. METHODS

Diagnosing ADHD in Children

Pediatricians, psychiatrists, and child psychologists can use standard guidelines from the American Academy of Pediatrics or the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders to diagnose ADHD (DSM). A health care provider will assess how a child's behavior compares to that of other children his or her age, and use standardized rating scales to document these behaviors. Interviews with parents, teachers, and any other adults who play a significant role in the child's life may also be included as part of the evaluation. The evaluator recommends filling out standardized forms known as "behavior rating scales" to score various areas of performance [18]. Various rating scales for ADHD used by the healthcare providers are represented in Table 1

Table 1 rating scales for ADHD

Rating Scale	Age (in yr)	Scoring Criteria
Children		
Child Behavior Checklist (CBCL) [19]	6 to 18	113 questions, scored on a three-point scale (absent, occurs sometimes, occurs often). <ul style="list-style-type: none"> · emotional, behavioral, and social problems. · It covers many conditions from autism to depression · six or more symptoms of inattention or hyperactivity and impulsivity,
Swanson, Nolan, and Pelham-IV Questionnaire (SNAP-IV) [20]	6 to 18	26 questions <ul style="list-style-type: none"> · rated on a 4-point scale (not at all, just a little, quite a bit, very much).
National Institute for Children's Health Quality (NICHQ) Vanderbilt Assessment Scale [21]	6 to 12	54 questions <ul style="list-style-type: none"> · six behaviors with a score of 2 or 3 out of the 9 questions for inattention or hyperactivity to meet DSM-5's criteria for ADHD · performance questions, there must be a score of 4 or higher on two questions, or a score of 5 on one question, for the results to indicate ADHD.
Conners Comprehensive Behavior Rating Scale (CBRS)[22]	6 to 18	18-90 questions <ul style="list-style-type: none"> · T-scores above 60 indicates there may be an issue, ADHD. · T-scores from 61 to 70 indicate issues are moderately severe. · T-scores above 70 indicate issues are more severe.
Adults		
Adult ADHD Self-Report Scale (ASRS v1.1 TH) [23]	Adults	two forms: 6 questions form and 18 questions form.
Brown Attention-Deficit Disorder Symptom Assessment Scale	Adults	40 questions in 5 areas <ul style="list-style-type: none"> · organizing and prioritizing work and activation for work, focusing, sustaining, and shifting attention to tasks, regulating alertness and sustaining effort,

(BADDs) for Adults [24]	processing speed, managing frustration and modulating emotions, and using working memory and accessing recall.
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Corpus Collection

The Vanderbilt Assessment Scale (NICHQ) is a semi-structured interview/history-focused scale that assesses inattention, impulsivity, and hyperactivity. It includes 8 more items for assessment of classroom functioning such as reading, writing skills, peer relations, following directions, interrupting class, assignment completion, and organizational skills. These symptoms are evaluated at school and at home, following the DSM IV criteria for ADHD. When diagnosing ADHD, this is the most feasible approach for a pediatric neurologist to follow. While questionnaires are an efficient and important tool in the diagnosis process, they cannot be utilized to achieve an ADHD diagnosis on their own. The correlation between direct observation and rating scale diagnoses supports not entirely, the validity of the latter for reaching the diagnosis [25].

Hence, by distributing leaflets to nearby schools, a community sample of youngsters was collected. The study's recruitment leaflets said to look for children with and without attention issues. Children had to be between the ages of 11 and 15 and had never received psychiatric medication for ADHD or other mental health disorders to be eligible for the study. Using the Vanderbilt Teacher's Rating Scale, we collected data from 77 children (54 male and 23 female) with an average age of 11.5 years old. Teachers are educated on the signs and symptoms of ADHD, and it is recommended that they observe the students for a month throughout their academic careers.

Data Analysis

The statistical demographics of the subjects following Vanderbilt's Teacher's Rating Scale diagnostic criteria are shown in Table 2. To be classified as Predominantly Inattentive, the child must score 2 or 3 on 6 of the 1-9 questions and 4 or 5 on any of the Performance questions 36-43, according to the NICHQ Vanderbilt Teacher's Rating Scale scoring criteria. Table 2 shows 77 children, 54 of whom were male and 23 of whom were female. According to the scoring criteria, 11 males (20.37 % of the total male sample) and 01 females (04.34 % of the total female sample) were classified as Predominantly Inattentive subtype.

To be classified as Predominantly Hyperactive / Impulsive, a child must score a 2 or 3 on 6 of the questions 10-18 and a 4 or 5 on either of the Performance questions 36-43. Table 2 shows out of 77 samples, 28 males (51.85% of total male samples) and 11 females (47.82% of total female samples) were identified as Predominantly Hyperactive / Impulsive subtype.

To be classified as ADHD Combined Inattention / Hyperactivity requires the above criteria on both inattention and hyperactivity/impulsivity. Statistical demographics in Table 2 show, that out of 77 samples, 05 males and 01 female were identified as ADHD Combined Inattention / Hyperactivity subtype, indicating that 09.25% of the male sample and 04.34% of the female sample were diagnosed as ADHD Combined Inattention / Hyperactivity subtype.

Whereas lesser scores in all the above subtypes indicate that the child is normal. Table 2 depicts that out of all samples 19 (35.18% of all male samples) male and 13 (56.52% of all female samples) female were diagnosed as normal.

Computational Analysis

To diagnose ADHD, a variety of symptoms must be evaluated, some of which can be easily recorded and others that are unreliable and hence require careful examination. Inattention, hyperactivity, and impulsivity are related factors. As a result, data must be collected and processed thoroughly to prevent typical mistakes. As a result, data analysis is roughly classified into three categories based on the sorts of variables in question:

- **Univariate analysis:** It is the simplest of all data analysis methods because it only considers one variable in the calculation. As a result, despite its ease of use, it is limited in its application to massive data analysis.
- **Bivariate analysis:** It considers two variables for analysis. It offers a little broader range of applications, although it is still limited when dealing with massive data sets.
- **Multivariate analysis:** A plethora of variables are considered in multivariate analysis. As a result, it is a complicated and necessary instrument. The major advantage of such a model is to take into account as many aspects as feasible. This leads to a significant reduction in bias and a more accurate outcome.

Multivariate analyses are employed primarily for four reasons: to discover data patterns, to make obvious comparisons, to reject undesired information, and to analyze numerous aspects at the same time. To study relationships in vast volumes of data, multivariate analysis approaches might be applied. A variety of strategies have been used to build multivariate models, including multiple linear regression and partial least squares regression [26]. One of the most successful methods for determining the relationship between groups of datasets is multivariate analysis. When a structured study design is adopted, it is very effective at reducing bias. The rating scale data contains categorical information, and each category is interrelated in some way. In this work,

Table 2 Demographics of Sample

	Age	No. of Subjects	Diagnoses			
			Predominantly Inattentive subtype	Predominantly Hyperactive / Impulsive subtype	ADHD Combined Inattention / Hyperactivity	Normal
Male	11 ± 6.041	54	11 (20.37%)	28 (51.85%)	05 (09.25%)	19 (35.18%)
Female		23	01 (04.34 %)	11 (47.82 %)	01 (04.34%)	13 (56.52 %)
Total		77	12 (15.58%)	39 (50.64 %)	06 (07.79 %)	32 (41.55%)

we used multivariate regression analysis to diagnose ADHD subtypes, which have several symptoms, such as inattention, hyperactivity, and impulsivity in data i.e. various categories in data. We have two independent factors in the Vanderbilt's Rating Scale data, Inattentive and Hyperactive + Impulsive, and three dependent variables; Predominantly Inattentive, Predominantly Hyperactive or Impulsive, and ADHD Combined. To diagnose children with these subtypes, Multivariable Regression analysis is done on Vanderbilt Rating Scale data.

III. RESULTS

Mean Absolute Error (MAE)

MAE is a method for assessing the properties of a model metric in regression models. The mean absolute error of a model about a test set is the average of all individual prediction errors on all instances in the test set [27].

When the data is subjected to multivariate regression analysis, the MAE for Predominantly Inattentive, Predominantly Hyperactive or Impulsive, and ADHD Combined is 0.38, 0.71, and 0.14 respectively. A standard MAE value is 0.0, which means that all predictions matched the predicted values exactly. The model is considered to perform well concerning the data because the values indicated are significantly closer to the standard value.

Mean Square Error (MSE)

MSE is the average of the squares of the errors; it indicates that the greater MSE value suggests a greater error in predictions. The MSE estimated using the data is 0.20, 0.73, and 0.04 for the predicted subtypes of ADHD, as these values are significantly lesser indicating that there is no significant error in the predictions. Hence, both MAE and MSE show that the designed prediction model is less prone to errors and is considered to be more accurate.

R2 Score

It indicates how much of the variance in the independent variable can be explained by changes in the dependent variables. The R2 score of 0.594 means that our model accounts for 59.4% of the variation in our dependent variable, 'Predominantly Inattentive'. Also, the same 68.8% for Predominantly Hyperactive or Impulsive and -0.283 is a negative R2 means the regression is worse than the mean value for predicting the Combined ADHD subtype.

Coefficient

The coefficients describe the mathematical relationship between each independent variable and the dependent variable. The sign of a regression coefficient indicates whether there is a positive or negative correlation between each independent variable and the dependent variable.

- Positive coefficient: indicates that as the value of the independent variable increases, the mean of the dependent variable also tends to increase.
- Negative coefficient: indicates that as the independent variable increases, the dependent variable tends to decrease.

The regression coefficient for Predominantly Inattentive children of Inattentive symptoms is 0.119 indicates when the Inattention of a child increases by 0.119 the chances of a child being diagnosed as Predominantly Inattentive increases by 1 unit. At the same time the -0.032 regression coefficient of Hyperactive + Impulsive suggests when Hyperactivity or Impulsivity decreases by 0.032; the chances of diagnosing a child as Predominantly Inattentive increases by 1 unit. Hence, it is clear that when Inattention increases and Hyperactivity or Impulsivity decreases; a child is diagnosed as predominantly inattentive.

The same interpretation applies to Predominantly Hyperactive or Impulsive and ADHD Combined. When Inattention decreases by 0.012 and Hyperactivity or Impulsivity increases by 0.175 a child's chances of diagnosing a Predominantly Hyperactive or Impulsive Subtype increases by 1 unit. In the same instance, when Inattention increases by 0.018 and Hyperactivity or Impulsivity increases by 0.008 a child's chances of diagnosing Combined ADHD Subtype increases by 1 unit

Table 3: Results of Regression

Parameters ADHD Subtype	MAE	MSE	R2 Score	Coefficient	
				Inattentive	Hyperactive + Impulsive
Predominantly Inattentive	0.38	0.20	0.594	0.119	-0.032
Predominantly Hyperactive or Impulsive	0.71	0.73	0.688	-0.012	0.175
ADHD Combined	0.14	0.04	-0.238	0.018	0.008

Heatmap for Correlation Factor

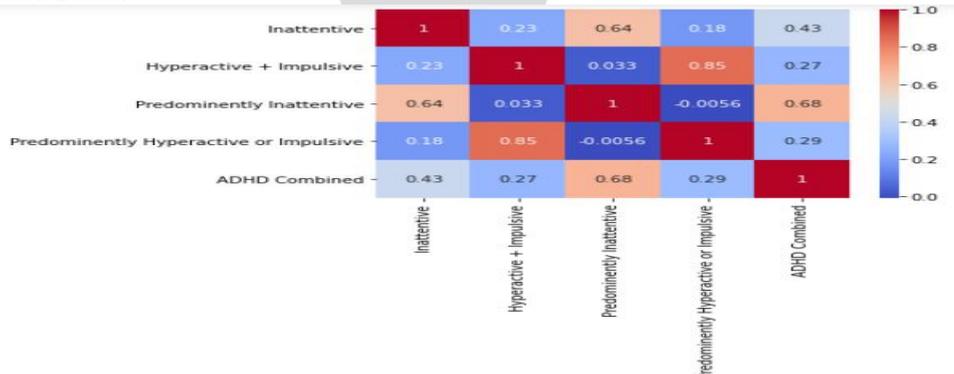


Fig. 1 Heatmap for correlation of symptoms

Figure 1 shows the heatmap for the correlation of symptoms of ADHD where Dark red indicates positive correlation, Blue indicates negative correlation. The stronger color indicates a larger correlation magnitude.

Correlation is a statistical measure that expresses the degree of similarity between two variables. There are two forms of correlation: positive and negative. When two variables move in opposite directions, they form a negative correlation; as one increases, the other declines. In Fig. 1, the variables Predominantly Inattentive and Predominantly Hyperactive or Impulsive have a negative correlation, whereas the other variables have a positive association. The negative association between Predominantly Inattentive and Predominantly Hyperactive or Impulsive shows that as the Hyperactivity or Impulsivity decreases, the chances of predicting a child with Predominantly Inattentive increase. When two variables move in the same direction, they have a positive correlation; as one increases, so does the other. According to Figure 1, there is a positive correlation between variables Predominantly Inattentive and ADHD Combined, which means that the likelihood of predicting a child as Predominantly Inattentive increases as the likelihood of having ADHD Combined increases. Correlation is frequently used to examine whether two variables have a cause-and-effect relation. The values 0.64 and 0.033 in Fig. 1 show that when Inattention and Hyperactivity or Impulsivity increases, the chances of identifying the child as Predominantly Inattentive increase. Furthermore, the numbers 0.43 and 0.27 indicate that when Inattention and Hyperactivity or Impulsivity increase, the child is more likely to be diagnosed with ADHD Combined. However, the chances of being identified as Predominantly Inattentive are higher than those of being labeled as ADHD Combined subtype.

Our study concludes that, when a child's attention and hyper-activeness or impulsiveness decreases the child will be diagnosed as Predominantly Inattentive type of ADHD. Whereas when attention increases and hyper-activeness or impulsiveness increases, the child will be diagnosed as Predominantly Hyperactive or Impulsive type of ADHD.

IV. CONCLUSION

ADHD is a psychiatric disorder that can affect children as well as adults. Approximately 70-80% of patients benefit from stimulant medications for ADHD. These medications aid in the regulation and strengthening of neurotransmitters, thereby alleviating symptoms. ADHD prevalence in Indian children is higher than the global estimate. To diagnose ADHD, a variety of symptoms must be evaluated, some of which can be easily recorded and others that require careful examination. The data from 77 children (54 male and 23 female) with an average age of 11.5 years using the Vanderbilt Teacher's Rating Scale when examined by the Vanderbilt Diagnostic criteria diagnosed 6 children with Combined ADHD. A child is diagnosed as Predominantly Inattentive when his or her inattention rises while his or her hyperactivity or impulsivity lessens. Also, as Inattention declines and Hyperactivity or Impulsivity rises, the likelihood of classifying a child with the Predominantly Hyperactive or Impulsive subtype rises. And when a child has both inattention and hyperactivity or impulsivity, the odds of him or her being diagnosed with ADHD increase.

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