# IHI :– A Mobile Application for ADHD Analysis and Detection

Chandrasena A.S
Faculty of Computing
Sri Lankan Institute of Information
Technology
Malabe, Sri Lanka
it19075136@my.sliit.lk

Weerasinghe G. G. D. D
Faculty of Computing
Sri Lanka Institute of Information
Technology
Malabe, Sri Lanka
it19075204@my.sliit.lk

Dilshan K. G. T
Faculty of Computing
Sri Lanka Institute of Information
Technology
Malabe, Sri Lanka
it19020822@my.sliit.lk

Sadun G. W. P
Faculty of Computing
Sri Lankan Institue if Information
Technology
Malabe, Sri Lanka
it19390260@my.sliit.lk

Uthpala Samarakoon
Faculty of Computing
Sri Lanka Institute of Inforamtion
Technology
Malabe, Sri Lanka
uthpala.s@sliit.lk

Pasangi Ratnayake
Faculty of Computing
Sri Lanka Institute of Information
Technology
Malabe, Sri Lanka
pasangi.r@sliit.lk

*Abstract*— **Attention Deficit Hyperactivity Disorder (ADHD) is a common disorder, which can be identified mostly among children which often lasts till their adulthood. A person with ADHD would not be able to pay attention, would not think about consequences of their actions(impulsivity) and sometimes could be hyperactive (overly active). According to the statistical reports of ADHD Institute, worldwide prevalence of ADHD is ~2.2% overall (range, 0.1-8.1%) which has been estimated only within the children and adolescents (aged < 18 years) [1]. A person with ADHD could have troubles with socializing, making friends and may struggle with studies as well. It is stated that people with ADHD could often choose smaller rewards over bigger rewards considering only the time they have to spend on. A physical examination, series of interviews, reports from associates of the patient are some of the existing methodologies used to diagnose ADHD. Adult ADHD Self-Report Scale Symptom Checklist (ASRS), Barkley Adult ADHD Rating Scale - V, Brown ADD Scales (Adult), Conners' Adult ADHD Rating Scales (CARRS) and Copeland Symptom Checklist for Attention Deficit Disorders - Adult Version are some of the screening tools and checklist methods used currently. Above mentioned tools and methods mainly focus on adults. It is complicated to test children as they have certain behaviors at several ages that make symptoms of this disorder undistinguishable. The current methods of diagnosing have issues such as lack of concentration to the patient, difficulty to monitor child/adult under different environments, maintaining patient's records etc. We have developed a localized mobile application which includes questionnaire and gaming activities to identify and diagnose symptoms such as Hyperactivity, Impulsivity, Inattention and organizing disorders. This application is not restricted for adults as above-mentioned tools and methods that are currently being used. If we can identify these disorders as early as possible this would deliver many benefits to the children's growth and future.**

**Keywords—ADHD children and adults diagnose, mobile application, DSM-5**

## I. INTRODUCTION

Attention deficit–hyperactivity disorder (ADHD) is characterized by the inability to marshal and sustain attention, modulate activity level, and moderate impulsive actions.[1] mainparts of ADHD are Inattention, Hyperactivity and Impulsiveness.

These symptoms can be identified in children and adolescents. ADHD was once known as a childhood disorder is now acknowledged to persist into adulthood with a probability ~50–65% of individuals [13,14,15]. ADHD is recognized as a severe mental disorder and its symptoms may become severe over time specially in adulthood if proper medications are not taken. Undiagnosed ADHD in adulthood can cause serious consequences in life. A mean value of ~2.8% overall (range, 0.6–7.3%) has been estimated as widespread presence of ADHD among adults (aged 18-44 years) from Asia, Europe and the Middle East[13].

Most of the existing methods which are available to identify ADHD patients' symptoms are commonly based on the guardians' and third parties such as teachers, parents, and doctors. These measurements are identified using a scaling or rating system and need to be performed manually (SNAP -IV, CONNER-3 etc.).

ADHD is diagnosed using questionnaires related to DSM V criteria [12]. Questionnaires consists of several questions related to patients' behaviour, attention, and memory. Diagnosing children using this questionnaire has been complicated since parents must answer on behalf of the behaviour of their children. Parents or guardians' answers may not be accurate because children spend their time in both school and home. So, the guardians cannot observe children's behaviour all the time.

Until 1976, ADHD in adults was not considered nor treated for. Adults' symptoms are seen in the office environments mostly [9]. But symptoms must be present in the home environment too because in an office or work environment ADHD like symptoms can occur due to the work stress and many other factors. An adult tends to have the symptoms from the childhood although there is a decrease in hyperactivity in the adulthood. Also, there can be cases where ADHD symptoms have appeared only in the adulthood instead of childhood symptoms continuing into adulthood gradually.

Diagnosing a patient [10] according to the DSM criteria is subjective. An adult patient answers a questionnaire and answers can be subjective to him and his environment. Since child patients cannot answer for themselves, their guardians and parents must answer for them. Also, the answers can be

highly subjective to themselves. In school environment, the teachers are busy with many children and might not have time to pay close attention to each child and they observe a fraction of child's time spent on school hence making teachers opinion subjective too. [d2] Measuring hyperactivity, impulsivity, inattention can be complex for guardians and teachers unless it's done by an experienced consultant by always observing the child. DSM V criteria questionnaires in their very nature are subjective.

## II. LITERATURE REVIEW

### A. Attention and Organizing skills

Most often attention and organizing skills difficulties are identified among the ADHD patients. These symptoms can be identified as lack of attention to the details, difficulties of listening, does not follow instructions, trouble organizing tasks, and forgetfulness in daily activities (loosing memory power). Among these symptoms most common and major issue is that losing their memory power or having troubles in recalling the daily activities. They often fail to recall the memory compared to the normal people [1].

Further, most of the attention disorder symptoms were commonly identified among the adult patients. Identifying this attention and organizing difficulties in the early stages is more important to start with counseling and treatments.

Inattention is a main characteristic of ADHD patients. Most of the patients have trouble holding attention on a task or playing activities. ADHD patients cannot complete an activity that they have started and abandon the task without finishing the task [8]. So, mainly we must focus on this kind of characteristic in patients. So, it should follow the DSM-5 criteria standards to identify the patients and ADHD must be identified at the early stages so the treatment can be started immediately.

Considering the Organizing skills, this mainly consider under two main concepts based on the DSM-5 criteria standards in this research paper; they are organizing skills difficulty and memory impairment. Psychiatrists identify that ADHD patients have short term memory power as short terms memory imbalance. They usually face problems when remembering the day today activities and recalling them, most of them have impairments on their virtual working memory [1]. Therefore, it needs to be identified and the treatment should be started immediately.

### B. Impulsivity and Hyperactivity

Impulsivity and Hyperactivity relates to more behavioral aspects of the ADHD patients. Patients with these disorders take unnecessary risks in daily life and have trouble getting along with others. With the rise of covid-19 pandemic, there's a high probability of undiagnosed ADHD patients because of the lack of medical attention and restricted medical services for diseases like ADHD in this period.

Impulsivity can be defined as act without thinking of the consequences of the actions. Most studies suggest that impulsivity is not a unitary construct, and it consists of many aspects [2]. Some of these are categorized as impulsive choice and behavioral impulsivity.

Stop signal reaction time (SSRT), The five-choice reaction time are some of the methods used to assess impulsive action [2]. Furthermore, Barratt Impulsive Scale (BIS) which consists of a four-scale score is used in questionnaire which are manually processed to identify impulsivity level of the patients [3]. The four scales are Rarely/Never = 1, Occasionally = 2, Often = 3 and Almost Always/Always = 4.

It is stated that SSRT result score for children are usually lower when compared to adults [2]. So, it is not convenient to implement a system to assess impulsivity of the children with SSRT method as it would create limitations on scoring or require many tests to be performed to determine a convenient scale to be used for children.

As per the studies Matching Familiar Figures Test (MFFT-20) has proved to be more reliable when assessing reflection-impulsivity of the children. So, it is more convenient to use MFFT-20 rather than using SSRT method to assess impulsivity of children [6].

Delay discounting paradigms are used to assess impulsive choice of the patients. This method compares patients' choices on reward over time. The choice could be the smaller reward within a less time (sooner) over the larger reward with a more time (delayed reward) for an ADHD patient with impulsivity [2].

It is identified that five traits may associated with impulsive behavior such as negative urgency, positive urgency, lack of premeditation, lack of perseverance and sensation seeking [4]. According to DSM IV and DSM-5 criteria six or more symptoms for children below age of 17 and five or more symptoms for patients of age 17 and above 17 could be considered to have impulsivity and hyperactivity disorder. If the patient is in a above category and the criteria is met for 6 months, it could be identified as a positive case of Impulsive and hyperactive ADHD patient.

Hyperactivity is one of the main characteristics of ADHD, it is commonly known as "driven by motor" like behavior. It is also stated that being unable to sit still in a calm, quiet environment and being unable to concentrate on tasks are both characteristics of hyperactivity. These symptoms can cause severe problems in a child's life such as underachievement in school, getting punished constantly for disturbing the classroom, not having good relationships with fellow students. These symptoms can grow into adulthood and significant problems could arise in social life such as being distant from the community and underachieving in professional life.

Patients who are suffering from hyperactivity are identified through questionnaires related to DSM V criteria. They have been diagnosed by doctors based on the questionnaire and information regarding their behaviours form parents and guardians.

## III. METHODOLOGY

There are several existing applications that monitors ADHD symptoms, but most of them consider one or two symptoms only. However, the proposed application can identify all the possible symptoms in ADHD patients such as lack of attention, lack of recall memory power, poor organizing skills, lack of patience while working and hyperactivity etc. These are the key points covered in the proposed IHI application. Therefore, this application is more than a screening tool which guides the users to decide whether they need treatments for ADHD or not.

Figure 1 represents the high-level architecture of the proposed solution. The system consists of 4 main components: Attention Detection, Organizing skills, Memory impairment, Impulsivity Detection and Hyperactivity Detection.
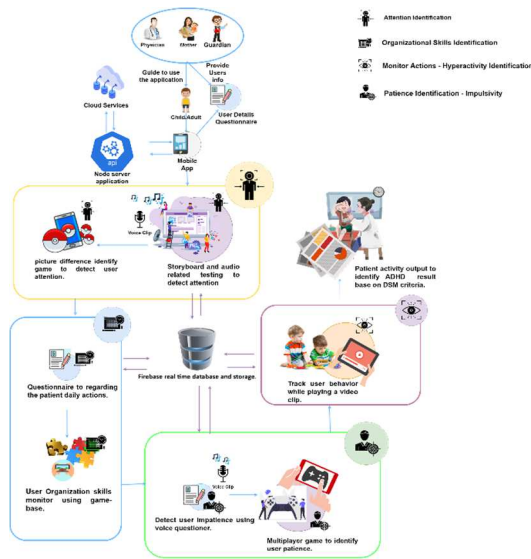


Fig. 1. Overall System Architecture

In practical scenario, doctors need to monitor patients during a period of 6-months via the application to identify ADHD available probability based on the DSM-5 standards. but this system is providing an alternative for that, it determines the patient's behavior and results and generates reports according to the probability of patients having ADHD, this is more helpful for doctors to start their treatments in early stages [5].

DSM-5 criteria describe all possible symptoms that can be seen from an ADHD patient. This indicates 2 areas of ADHD considering 2 age groups. Age groups are below 17 and above 16 years old. 2 areas of ADHD are Attention ADHD and Hyperactivity ADHD. A patient above the age of 16 should have 6 or more symptoms and a patient below 17 years should have 5 or more symptoms to be positive in any of the 2 areas of ADHD. So, this symptom count and the age groups described in the DSM-5 criteria are used as the core of this solution that is implemented to identify ADHD.

The application collects ADHD patients' user data at the initial registration in the IHI application. Then, the user is directed to the attention identification module and then to the Organizing skills identification module. Then, the user is presented with games and activities of impulsivity detection and then is directed to the hyperactivity module. The user details, and particular data per user on each module is stored in the firebase Realtime database. This data is used to summarize the results and generate more accurate probability scores in the IHI application later.

*A. Attention detection*

This module was implemented to identify the attention probability of a patient. In this component, there are four methods to assess attention probability. The four methods are based on a questionnaire and a game-based type activity. There are two age groups: child and adult. According to the age, questionnaires and games are generated. All the results of the games are stored in the firebase real-time database.

In the first activity, there are questions to identify the symptoms of ADHD patients. The questionnaire content was created according to the DSM-5 criteria. So, based on the answers there is a rating, and the rating scale is according to the BIS scale [2]. Four symptoms can be identified using the questionnaire and a total of 16 points are given at the end. As per the BIS scale number of 4 points will calculate for one question and the attention probability are identified based-on the sum of all answers. If the result is more than 75% then the patient has the probability of having all 4 symptoms and if it is 50% or more could have 3 symptoms. More than 25% could have 2 symptoms. Percentages below 25% could have only one symptom or none. Final probability is stored in database to track users' history to make a conclusion. Also, there is a picture difference game as the second activity to identify one of the symptoms of ADHD according to DSM-5 criteria. User must identify the different picture and there are 4 rounds for this activity.

As the third activity, there is an audio-based storyboard game to identify one symptom of ADHD. There is an audio clip played and the user needs to memorize it and recreate the story using scene cards according to the story revealed in the audio clip.

In fourth activity, there is a bunch of color names with the text and the text also colored with that color as below figure presents. So, the patient needs to read the color of the text and the time taken to read all the texts are measured and calculated.



Fig. 2: Stroop test & Stroop test (color-text mismatched)

Then again, the text of the color will change as above right image. Text of the color needs to be read by patients then the time to read is calculated again.

Further, patient's voice input is sent to google speech-to-text API to get the text and compare it to the actual color emphasized from the text. The above calculated time difference must be 5 seconds to 10 seconds for a normal person.

*B. Organizing skills and memory impairement*

This component mainly considers the patient's organizing skills and memory impairment. Most commonly patients who are having ADHD can have short-term memory power impairments and forget daily activities. Memory impairment is measured in this system in two major sections. First, we gather patient's information and daily activity information via third party person such as a parent, teacher, doctor etc. Here, most of the questions are related to the patient's daily routine such as "what did the patient have for his/her breakfast?". These types of questions will gather all the information regarding the patients' daily activities based on the answers input by the guardian or the third-party person. Based on those answers patients need to recall their memory and need to provide the correct answers to a generated set of questions. The score scale is decided on the count of wrong answer points and is contributed to the result when generating the memory impairment score.

Further, as the second task of memory impairment, it considers the age ranges up to 5-16 as children and ages more

than 17(17<=age) as adults when preparing the monitoring environment for the task. According to the age considerations, the patients are directed to the memory board, which contain 12 words for adults and 12 images for children, patient needs to remember all the objects from the memory board within 1 minute, and afterward, they must recall those objects to identify the correct objects which were shown earlier. Based on the incorrect objects, score is generated for the 2nd activity. This activity is currently performed in the clinical environments manually and used to identify the memory impairment of the patient accurately. Based on these activities, the probability and the summarized reports are generated for memory impairment, those probabilities will weigh the results according to the DSM-5 criteria standards. Below figure 3 represents the child's image memory board with a time counter.



Fig. 3. Child image memory board with time counter

The final activity monitors patient's organizing skills and time management. This task is designed using a Jigsaw puzzle game and this identifies the patient's organizing and logical thinking patterns. For the given time, user needs to complete the jigsaw puzzle to collect rewards. This game/activity is set to generate based on the age groups as mentioned in the above sections. Research was done by the Tsinghua University, Beijing, China monitoring patients' minds using EEG biofeedback and with the electrical waves, identified that the puzzle games can identify the patient's ideas about the interaction patterns and their logical thinking. This is more helpful to identify ADHD patient's thinking pattern and at the meantime, this is a therapy activity for the mind of the patients to improve their organizing and thinking patterns [7].

All the data is stored based on the rewards in the firebase real-time database and those data is summarized at the end of the day and generates the reports based on those statistical data.

*C. Impulsivty detection*

As discussed above in the literature review, impulsivity can be assessed using the methods such as Delayed reward activity, MFFT and questionnaire activities based on DSM-5 criteria. These methods are used presently to identify impulsivity of patients with manual processes such as filling forms with BIS scale scorings etc. But there are a few screening tools and applications available which are only focused on impulsivity detection of the users.

This individual module was designed to assess the impulsivity probability of a patient and contribute to the final determination of the ADHD probability. Whole manual process of forms was automated, and more focused activities were designed to determine the impulsivity probability in this solution.

First activity is an age-based questionnaire designed according to the DSM-5 criteria which captures the symptoms specified in the criteria. This activity is used to determine the impulsive probability based on the BIS scale. Four symptoms are captured in this questionnaire and the total of 16 points can be scored on given the highest BIS scale score (4) for each answer. Based on the answers, the designed algorithm generates the impulsive probability percentage and positive symptom count according to this first questionnaire activity. The activity's content was designed in a dynamic approach which will change according to the age group of the user. A user with more than 75% result from this activity has the probability of having all 4 symptoms while more than 50% result could have 3 symptoms. More than 25% could have 2 symptoms and below 25% could have only one symptom or none. This activity assesses 4 symptoms of hyperactivity and impulsivity ADHD out of 6 symptoms that are needed to decide according to the DSM-5 criteria.



Fig. 4. Questionnaire & Auditory Questionnaire

Second activity was designed to assess the symptom of "blurting out answer before a question is asked". This activity is presented only for age group over 17(17 <= age) as the users below the age of 17 could have trouble and the result will not be accurate due to practical reasons. The activity presents two auditory questions where user is provided with answer buttons to tap on even while the audio clip of the question is playing. This evaluates if the user taps on the answer button before the question/audio clip completes. Based on the results, the impulsive percentage is calculated using an algorithm. There is no correct or wrong answer to these questions, but the response time is evaluated in this. The probability is calculated considering the response to both questions. If the user responses to both questions before the audio clip finishes, the impulsive probability is considered 100% while one response before question completion is considered 50% impulsive probability. If the user does not response to any question before the completion, it is considered 0% of impulsive probability for the symptom. So, this activity focuses on only one symptom probability which contributes to the final impulsive probability percentage.

Third activity consists of Matching familiar figures test which mainly focuses on child group. This test is used to assess user's reflective impulsivity. Activity was designed using unity engine with more user-friendly features to keep the user more focused on the activity. This test basically contains figures according to the age group. User needs to identify and choose the odd figure from a given list of figures. An impulsive user would take a choice with lack of premeditation. Figure 5 is an example of a MFFT.
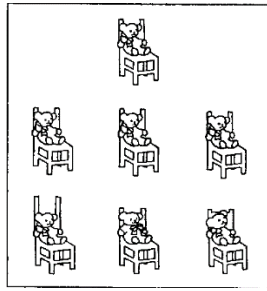
Fig. 5. Matching Familiar Figures Test

So, above three activities were designed to determine impulsive probability and symptom count. First and third activities are used for the child age group (<17) while first and second activities are used for the adult age group (>=17) to generate the impulsive probability of the patient.

Furthermore, the system consists of a media library which allows the administrators of the system to upload media to be used in the activities.

### D. Hyperactivity detection

A pictorial questionnaire is used to assess patients' thinking ability of how they should behave in each situation. This questionnaire is for children who are under the age of 12. Children under the age of 12 are most likely to behave in a certain way due to imitating others or that they are encouraged by someone they admire. This is commonly known as "monkey see monkey do" behavior [11]. Two pictures are shown to the child which are chaotic and peaceful scenarios of the same situation. If the child chose a picture with chaotic behavior, it's because either the child is encouraged to behave in such a way or the child doesn't know how to behave in a situation like that. Messages are shown to the guardians to let the child learn the correct way to behave in such situations. This will increase the accuracy of the environmental monitoring system.



Fig.6. Pictorial Questionnaire

The manual process of diagnosing hyperactivity is to use a questionnaire based on DSM-5 criteria. By automating this process, the application gives patients eight questions to assess their behavior [12]. For children under the age of 12 their guardians are required to answer the questionnaire. Four answers are given for each question and marks are given to calculate the score according to the Self-Report Scale (ASRS-v1.1). A total of four marks can be obtained for each question. This questionnaire is based on the same method doctors and consultants use when diagnosing hyperactivity.

The third and final part of assessing hyperactivity is the use of environmental monitoring system (EMS). The EMS analyzes the patient's behavior commonly known as "driven by a motor". To assess this, patients are instructed to calmly watch a small video clip staying in one place. Patients can do this on their mobile phone wearing headphones.

Mobile phone camera (front facing) is used to record patients face and the surrounding environment and mic is used to record the audio. Additionally, patients' emotions shown on their face is assessed using our application to get an accurate idea about user's current emotional state. And this will also be used to make sure that the patient is paying attention to the video by tracking the patient's eyes. Mic in the mobile device will record the audio of the environment to assess if the patient is talking too much. This is calculated using words per minute (WPM) method. To assess users' ability to stay in one place, GPS is used (when user taps play on the video GPS coordinates of that location are compared with his movements to get a clear idea).

## IV. RESULTS AND DISCUSSION

System is designed in the purpose of automating the whole process of analysis and detection of ADHD patients. Basically, it allows a user to perform activities and maintain a profile which is assessed by a doctor or any medical officer to decide on treatments immediately. However, the outcome of the proposed IHI application is based on both third-party scaling and the activity results of patients. Activities used in this application were made self-testable as much as possible. Hence, the outcome is more accurate and efficient than existing methods when considering other screening applications which exist in the market.

The system is tested with users throughout the process of implementation at all milestones. For example, when an activity is designed, it is released to some identified users to be tested for accuracy considering both identified positive and negative cases. This process was followed throughout the project to ensure the accuracy and stability of the system. Further, the tests are performed per each module to assess the performance of module in generating the expected outcomes.

The system is tested with randomly selected 23 children above the age of 5 and below 17. Overall results from the system indicated 4 of children with higher probability of having ADHD symptoms while 3 children were diagnosed with ADHD and attends medical treatments. Furthermore, 37 adults have been tested using the system and results indicated that 10% of them showed higher probability towards ADHD symptoms. Among them two adults which falls under the 10% were undergoing medical consultations due to their memory impairments and shorter attention span thus proving the accuracy of the system.

Questionnaires in hyperactivity and impulsivity components have been tested with adults and children after the implementation stage and accuracy of the results proved to be above 90%. 18 adults out of 20 were accurately identified. Although there were two false positives due to the patients' similar symptoms which are not directly related to ADHD.

Finally, all the modules were integrated in the designed flow and each module contribution was added to the result of the ADHD probability detection. Integration tests were

performed to ensure the system stability and identify any defects.

All modules have considered symptoms elaborated in DSM-5 criteria for ADHD analysis and each module is optimized with multiple activities to improve the accuracy of the result.

The system's accuracy can further be improved with adding machine learning algorithms to dynamically change content presented to the user by analyzing user behavior. Also push notifications and automated emails can be configured to further enhance the user experience by sending out important information to the patient or guardians of the patient. Moreover, with further usage and by analyzing the reports stored in database, the system can be configured on recommending visiting a doctor based on user's reports in future.

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