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Evaluating the Integration of a Diagnostic App for Autism Spectrum Disorder: Case Study

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Abstract:
This study evaluates the effectiveness of a diagnostic application for Autism Spectrum Disorder (ASD) implemented at the Al-Bayda Autism Center. The app was integrated into the diagnostic process and compared against traditional expert assessments. Results highlighted a higher prevalence of ASD in males than females, consistent with a 4:1 ratio reported in prior research, though influenced by diagnostic criteria and potential underdiagnosis in females. A dataset of 15 cases provided detailed comparisons between app-based diagnoses and those of specialists, revealing notable discrepancies in certain cases.The app demonstrated advantages in efficiency and accuracy, particularly when discrepancies arose due to reliance on parental assessments, which can be subject to bias. Furthermore, the app's classification of some children as "normal" following therapeutic interventions underscores its utility in reflecting behavioral improvements. However, limitations of the CARS (Childhood Autism Rating Scale), such as its inability to detect subtle behavioral progress, were identified, emphasizing the need for complementary qualitative assessments.
The findings suggest that integrating digital tools like the diagnostic app into clinical workflows can enhance the accuracy and efficiency of ASD assessments while reducing testing time. However, these tools should be used alongside expert evaluations to ensure comprehensive and reliable diagnoses. Future work should focus on refining app-based assessments to capture nuanced behavioral changes and on validating these tools to enhance their reliability and acceptance in clinical practice.
Keywords: *Autism, Spectrum, Disorder, Mobile, Applications, diagnose.*

I. Introduction

Autism spectrum disorder (ASD) is one of the most common and complex neurodevelopmental disorders in children that generally manifests in the first few years of life and tends to persist into adolescence and adulthood [1]. The core characteristics of autism spectrum disorder (ASD), which were initially identified as repetitive and atypical sensory-motor behaviors and social communication deficits, the spectrum nature of the disorder signifies those individuals with ASD can present with varying degrees of impairment, with some exhibiting significant challenges in daily functioning while others may display milder symptoms that allow for high levels of independence [2]. Diagnostic criteria for ASD include deficits in social-emotional reciprocity, nonverbal communicative behaviors, and the development of peer relationships. However nowadays, autism is recognized as a spectrum that varies from extremely mild to severe [3]. As awareness and understanding of ASD grow, there is an increasing emphasis on early intervention and tailored therapeutic approaches to support individuals on the spectrum in achieving their full potential and enhancing their quality of life.

Early screening for autism spectrum disorder (ASD) has shown to be an effective approach to treating many of these children's challenges. Consequently, it is now more important than ever to accurately diagnose children with this range of disorders. The diagnosis of autism spectrum disorders will continue to emerge at later developmental stages if children are not screened early, missing essential opportunities to support optimal development. Furthermore, early intervention services can significantly help young children with autism spectrum disorders overcome obstacles to learning and adjusting to school. Developing efficient methods to recognize and diagnose children with ASD at an early age is crucial [4][5]. Early identification facilitates timely access to therapeutic interventions—such as Applied Behavior Analysis (ABA) and speech therapy—and fosters better educational and social outcomes [6]. Increased awareness and accessibility of screening programs can significantly mitigate the challenges associated with delayed diagnoses, thus promoting an inclusive environment for individuals with ASD. Therefore, enhancing early screening practices is imperative for advancing public health initiatives and supporting families navigating the complexities of autism.

Nowadays technology has an important role in our lives in various fields such as health, education, especially mobile devices. The advent of technological advancements has significantly transformed various domains of healthcare, specifically in the diagnosis and management of autism spectrum disorder (ASD). Among these advancements, the proliferation of smart technologies, particularly smartphones, has emerged as a

promising tool in identifying and assessing ASD, leveraging their ubiquitous presence in contemporary society. Numerous studies have highlighted the potential of mobile applications designed to screen for symptoms characteristic of ASD, facilitating early detection and intervention, which are crucial for improving developmental outcomes [7]. Moreover, devices equipped with advanced sensors and cameras enable the capture of real-time data on an individual's behaviors and interactions within their natural environments, thereby enhancing the diagnostic process by ensuring a more comprehensive understanding of the individual's unique challenges and strengths [8]. As the field of digital health continues to expand, the integration of smartphone technology into ASD diagnosis not only promises to streamline the assessment process but also fosters a paradigm shift towards more personalized and accessible healthcare solutions, ultimately benefitting individuals and families affected by this complex disorder. Integrating mobile technology in autism diagnostics not only improves health outcomes through timely interventions but also fosters a greater understanding of the spectrum, paving the way for a more inclusive society.

In Libya, the diagnosis of autism spectrum disorder (ASD) primarily relies on traditional methods, which are often time-consuming. These conventional approaches require significant time to complete test questionnaires, making it challenging to repeat assessments as needed. To address these limitations, we have developed an application that streamlines the diagnostic process. This application utilizes the Childhood Autism Rating Scale (CARS) to assess ASD, significantly reducing the time required for completion to approximately 10 to 15 minutes. The app automatically calculates scores, determines the severity of the condition, and securely stores the results in a database for easy access and retrieval. This innovation aims to enhance the efficiency of ASD diagnosis in Libya, facilitating timely and accurate assessments.

II. Background of diagnoses the ASD

Traditional methods:

The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) was produced over the course of a 12-year project that employed hundreds of individuals to achieve a common objective. Examining the diagnostic criteria, taking into account how the manual is organized in every way, and developing additional elements that are regarded to be most helpful to physicians required careful consideration. The aim of all these efforts was to improve the clinical utility of the DSM-5 as a reference for mental disorder diagnosis [9].

In order to plan mental health services, identify patient groups for clinical and basic research, guide treatment recommendations, and record crucial public health data, accurate diagnoses are necessary. Medical, scientific, and clinical professionals have concentrated on the traits of particular disorders and their implications for treatment and research as our understanding of mental disorders and their treatments has evolved [9].

According to the DSM-5, ASD is diagnosed based on specific criteria that include persistent deficits in social communication and social interaction across multiple contexts, as evidenced by challenges in social-emotional reciprocity, nonverbal communicative behaviors, and the capacity to develop, maintain, and understand relationships. Furthermore, the DSM-5 necessitates the presence of at least two of four specified symptoms related to restricted and repetitive patterns of behavior, interests, or activities, which may include stereotyped movements, insistence on sameness, highly restricted interests, and sensory sensitivities. In contrast, the International Classification of Diseases, 10th Revision (ICD-10) classifies autism under the broader category of "Pervasive Developmental Disorders," emphasizing similar characteristics but with a somewhat different framework for diagnosis that primarily focuses on the severity and impact of symptoms on daily functioning. Both classification systems underscore the importance of a comprehensive assessment that includes clinical evaluation and consideration of developmental history to ensure accurate diagnosis and appropriate intervention strategies. The ongoing evolution of these diagnostic criteria reflects an increasing recognition of the complex nature of ASD, encouraging further research and understanding within the clinical and academic communities [9].

In order to help with the diagnosis of autism spectrum disorders, the Autism Diagnostic Observation Schedule (ADOS) is a standardized, semi-structured observational assessment that measures communication, reciprocal social interaction, imagination/creativity, stereotyped behaviors, and restricted interests. [10]. ADOS is designed to give a uniform set of situations for the observation of social and communicative behavior in individuals with autism and related disorders. The schedule aims to differentiate between autism and other disabilities as well as normal functioning. Eight tasks are given by the examiner in the ADOS, and they usually take 20 to 30 minutes to complete. For the most part, each task has two sets of materials, allowing the content and cognitive demands to be adjusted based on the subject's developmental stage and age. The tasks can be completed in any order; the sequence is decided by the way the interaction proceeds [11].

Transitioning from the Autism Diagnostic Observation Schedule (ADOS) to the Autism Diagnostic Interview-Revised (ADI-R). The ADI-R is a semi-structured, standardized interview designed by investigators for caregivers of people with autism. It offers a diagnostic algorithm based on the ICD-10 definition of autism. Five sections make up the ADI-R: opening questions, questions about play and social development (both early and current), questions about communication (both early and current), questions about restricted and repetitive behaviors (all scored for both current and ever judgments), and fewer questions about general behavior problems. After extensive practice, it is now feasible to complete the interview with the parent of a child who is suspected of having autism in less than an hour and thirty minutes; for older children, this may take a little longer [12]. While the main focus of ADOS is on direct observation of behaviors through structured interactions, the ADI-R necessitates a thorough parent or caregiver interview in order to collect behavioral concerns and developmental history.

The childhood autism rating scale (CARS) is one commonly used rating scale for the identification and diagnosis of autism. The CARS has 15 domains that rate a person's overall impression of autism, and its 14 domains evaluate behaviors linked to autism. Higher scores are linked to a higher degree of impairment for each domain on a scale that runs from one to four. The total score can vary from 15 to 60; a score of less than 30 indicates that the person is not autistic, a score of 30 to 36.5 indicates mild to moderate autism, and a score of 37 to 60 indicates severe autism [13].

Limitations of Traditional Methods

Medical practitioners must perform a clinical assessment of the patient's developmental age as part of the ASD diagnostic process, taking into account a number of different categories (such as behavior excesses, communication, self-care, and social skills). This generally recognized method is known as clinical judgment. Common diagnostic tools for ASD include the Autism Diagnostic Observation Schedule (ADOS) and the Autism Diagnostic Interview-Revised (ADI-R), which allow diagnosticians to assess a variety of activities and questions. Additionally, since neuroplasticity is greater in younger children, early diagnosis is also crucial. Clinical diagnosis techniques have been criticized for a number of reasons, including taking a long time to complete, having a large number of questions, requiring specialized clinicians to administer the process, and using a static basic scoring function to generate the autism score, even though their validity and accuracy are acceptable [14].

The integration of technology in screening ASD through the use of artificial intelligence algorithms, machine learning capabilities, and mobile applications offers the promise of enhanced objectivity, scalability, and efficiency. Technological tools can analyze vast datasets to recognize patterns and correlations that might elude human practitioners, thereby enabling earlier and more accurate diagnoses. Additionally, these systems can facilitate continuous monitoring and data collection in naturalistic settings, capturing a comprehensive range of behaviors and interactions that reflect the individual’s daily life, inevitably leading to a more nuanced understanding of the disorder. Therefore, while traditional methods have laid the groundwork for the identification of ASD, the incorporation of advanced technological solutions represents a pivotal advancement in the pursuit of more effective, timely, and accurate screening processes for individuals on the spectrum.

Types of Diagnostic Apps

Children are frequently evaluated only through pediatric screening before starting preschool or even kindergarten. Pediatricians must therefore be cognizant of developmental issues. Therefore, a screening tool that notifies doctors of potential cases of ASD and related disorders at 18 months would be priceless. An instrument of this type needs to be objective, brief, and simple to use, considering the demands of a typical pediatrician's office. A potentially serious communication and social delay may be confused with shyness in a child who is typically developing, and behavior in the doctor's office may not represent the child's typical behavior. Furthermore, doctors are not always able to reliably identify a developmental delay based on a child's behavior during a single session in the doctor's office, especially for very young children.

Parent report is therefore crucial to any screening tool. These specifications for a screening tool have been met by the Modified Checklist for Autism in Toddlers (M-CHAT) [15].

The M-CHAT is a 23-item yes/no parent report checklist. Physician observation of the child is not necessary for the M-CHAT, but regardless of checklist responses, physicians may "flag" an M-CHAT when they suspect a possible ASD. There is no need for parent or physician training, the format is straightforward, and the reading level is roughly equivalent to sixth grade. (Eaves et al. 2006) evaluated the MCHAT's performance with 84 children (mean age 37 months) who were sent to a specialized clinic for a suspected autism diagnosis; 64% of these children went on to receive an ASD diagnosis [16]. The M-CHAT is an essential tool in the early detection of autism spectrum disorder. Its user-friendly design and effectiveness in identifying at-risk children underscore its significance in pediatric health care. By facilitating early intervention, the M-CHAT contributes

to better developmental trajectories for children with autism, highlighting the necessity of such screening tools in contemporary practice.

The Autism-Spectrum Quotient (AQ), another screening tool, was developed to be brief, simple to use, and straightforward to grade. The Appendix has a picture of it. It has fifty questions total, ten of which evaluate each of the following five areas: social skills, communication, attention to detail, attention switching, and imagination. If the respondent reports any of the above-mentioned aberrant or autistic-like behaviors, either slightly or severely, each item receives one point [17]. The utility of the AQ extends beyond mere classification; it serves as a valuable tool for researchers and clinicians alike. In research settings, the AQ's empirical basis supports studies exploring the prevalence and nature of autism across different demographics, enhancing our understanding of the condition. Clinically, the AQ enables practitioners to screen individuals efficiently, thereby determining the necessity for more comprehensive diagnostic evaluations. The AQ is a significant screening tool in the landscape of autism spectrum research and clinical practice. Its structured approach allows for a nuanced understanding of autistic traits, promoting early identification and intervention while emphasizing the need for thorough diagnostic processes.

The ASDTests app, which is based on two shorter versions of the AQ and M-CHAT screening procedures, is an example of using both the AQ and the M-CHAT and is intended for users of all age groups. There are four primary screening questionnaires in all, with ten questions dependent on the age group of the user in each. To be more precise, there is a questionnaire for children (4–11 years old), adolescent (12–16 years old), adults (17 years and above), and newborns (less than or equal to 36 months). In order to save doctors time during screening, the authors condensed the M-CHAT to only ten questions and examined the many iterations of CHAT and AQ.

The authors' approach involves only keeping the most important items during the screening process after calculating a discrimination index. Based on an analysis of primary data acquired from cases and controls, it was determined that the sensitivity and specificity rates of the shortened version of M-CHAT were acceptable. The Autism Spectrum Quotient (AQ) is one of the early autism screening instruments that was devised by behavioral scientists at the University of Cambridge to enable persons with an average IQ to discover autistic symptoms in a self-administered questionnaire. Subsequently, the AQ test was developed in somewhat different variants; the first is known as AQ-10-Adult. certainly agree, slightly agree, slightly disagree, and certainly disagree are the four options for each question on the AQ-10-Adult test that the user must choose from during the screening phase. The score is then calculated using an elaborately designed diagnostic rule. A comprehensive ASD diagnostic exam is therefore recommended for any person who receives a score higher than 6. Additional condensed versions were created for the complete adolescent and pediatric AQ assessments. The adolescent and child short versions' score computations differ from those of the AQ adult short version. The ASDTests app's primary purpose is to make it possible for various user types to gauge ASD traits [18].

Though it is confined to in-clinic observation in practice, behavior observation in the natural environment is important in obtaining an accurate and thorough assessment of a child's conduct. The two components of the Naturalistic Observation Diagnostic Assessment (NODA) are NODA Connect and NODA smartCapture. With the help of the smartphone app NODA smartCapture, parents may quickly capture clinically significant, recommended video evidence of their child's behavior. Four, up to ten-minute-long naturalistic observation diagnostic assessment (NODA) scenarios can be recorded and uploaded. These scenarios were selected based on pilot studies on video-based autism diagnosis. These include the following scenarios: (1) children playing by themselves; (2) a child playing with a sibling or peer; (3) a family lunch; and (4) any behavior that raises a parent's concern. While play-based activities and standard social communication are encouraged in the first three scenarios, parents can provide evidence of a behavior that particularly concerns them in the last scenario. Through the NODA Connect Web interface, diagnosticians can oversee the gathering of in-home films, get the child's developmental history, and carry out a remote diagnostic evaluation by connecting behavioral evidence from the videos to DSM criteria. The diagnostician makes a determination regarding the child's diagnostic outcome based on clinical judgment. Additionally, NODA provides the user with a report that can be used by medical professionals at a later time to aid in diagnosis [19].

A Framework called the Smart Autism is used to diagnose and screen for autism. An internet-connected smart device (smartphone or tablet) is required to operate the system. Many actors, including parents, physicians, and social workers, can use the framework.
The procedures for autism confirmation and screening are used in Smart Autism in order to automate the conventional methods. The framework incorporates three levels of assessment. They are the following: actual assessment, virtual assessment, and screening. Both the virtual and actual assessments are part of the confirmation procedure. It is determined that the child has autism when all of these processes point to a vulnerability to the condition. These procedures for autism diagnosis and intervention programs are handled automatically by the suggested framework.

In the phases of autism screening, assessment, and confirmation, Smart Autism operates. It can also recommend preliminary intervention plans in addition to these aspects. The cloud platform, which can coordinate three layers of assessment, combines the screening and confirmation processes. First, the user can check their autism susceptibility using the Smart Autism program if they observe developmental delays. Following the child's registration, the application requests the child's birthdate. For children aged 0-17, the framework automatically chooses the best screening method among those currently included in Smart Autism based on the child's birthdate (M-CHAT, etc.). The application then displays a series of interactive screening questions with pertinent visual aids (images, animations, and videos) so the screener can quickly understand the content. After the user responds to each question, the program instantaneously generates a decision by analyzing the data using the appropriate method's built-in algorithm. Positive screening results advance to the virtual assessment stage. Here, the framework uses the smart device's camera to record the child's interaction and expression while displaying a video that includes evaluation activities. After the specialists watch the recorded video, if they notice any signs of autism, the framework links the child to the closest Autism Resource Center (ARC) for further evaluation. Here, the actual assessment process begins, during which the child is watched by specialists in person. Confirmation decisions are generated by the framework based on the expert opinion. The decisions and all user reactions are kept in a cloud database. All of these processes are coordinated and automated thanks to the cloud-based framework [20].

Benefits of Mobile Applications in Autism Diagnosis:

1. Enhanced Accessibility

Regardless of location, many users can easily access healthcare apps. By removing geographic restrictions, this accessibility democratizes healthcare. Through their smartphones, patients in underserved or remote areas can access telehealth services, resources, and information, enhancing their access to healthcare [21]. The field of autism diagnosis stands as one of the areas where these applications can facilitate heightened accessibility.

2. Cost-Effectiveness:

When compared to traditional healthcare delivery methods, mobile apps can be more affordable. They optimize resource allocation, expedite administrative tasks, and lessen the need for in-person visits. Both people and healthcare systems gain from this cost-effectiveness, which may reduce medical costs and enhance resource use [21]. Furthermore, access to specialists is not equal for all families, especially in underserved or rural areas where there may be a shortage of skilled practitioners. Travel expenses and lost productivity may increase if frequent trips to medical institutions are required.

3. Data Collection and Monitoring:

Numerous pieces of information about a user's health and behavior, such as vital signs, physical activity, and symptom progression, can be gathered by mobile apps. Healthcare professionals can securely receive this data, empowering them to make better decisions and treatments. Remote monitoring and real-time data collection are essential for managing chronic diseases and identifying health problems early. Remote patient health condition monitoring is made possible by mobile apps. Early intervention in critical health events, postoperative care, and the management of chronic diseases are particularly benefited by this. When health metrics diverge from typical ranges, remote monitoring enables prompt interventions and lessens the strain on medical facilities [21]. Furthermore, artificial intelligence can be used in a variety of applications to evaluate this data and identify patterns or problem areas. In addition to improving the precision of initial evaluations, this real-time analysis gives medical practitioners access to more comprehensive datasets that can guide their diagnosis.

4. Early Detection and Intervention:

At 18 and 24 months of age, children should be exposed to an ASD screening; however, not all demographic groups or underprivileged communities have access to these services. In situations like the COVID-19 pandemic or other situations that require people to stay at home, screenings may be particularly limited. Therefore, it's critical to increase the availability of evaluation services that can accurately identify ASD in young children by utilizing technology like mobile application platforms and videos [22]. These tools may detect potential symptoms of autism by giving immediate feedback based on professional-designed standardized questionnaires.

III. Research Methodology

1. Application development:

The application has been developed using Flutter, an open-source cross-platform framework that enables the efficient creation of mobile applications for both Android and iOS operating systems. This application is specifically designed to assist in the preliminary diagnosis of autism spectrum disorder (ASD) by implementing the Childhood Autism Rating Scale (CARS), a widely recognized tool used to identify autism in children, particularly those aged 2 years and older. It helps determine the severity of autism spectrum disorder (ASD) in children. By leveraging the CARS, the application serves as a vital resource for healthcare professionals, enhancing the diagnostic process through the systematic evaluation of key behavioral indicators

associated with autism. The CARS methodology is grounded in empirical research and clinical practice, making it a trusted instrument for assessing the presence and severity of autism traits in children. The application is characterized by a user-friendly interface that facilitates interaction among clinicians, parents, and caregivers. This design allows users to navigate through a structured framework that aligns with the diagnostic criteria outlined in the CARS methodology. The user experience is optimized to ensure that both healthcare providers and concerned parents can efficiently input data and interpret results, thereby fostering an environment conducive to accurate and timely diagnosis. In addition, the application incorporates features such as auto-calculating the score from the CARS answer to give the appropriate diagnosis and storing the result in the database.

2. Application Flow:

The comprehensive nature of the application not only enhances diagnostic accuracy but also empowers parents and caregivers by providing them with a greater understanding of their child's behavioral patterns. Figure 1 illustrates the navigation diagram of the app, detailing the user interface components and the flow of interaction designed to support users in the assessment and monitoring of autism characteristics effectively. Such an approach underscores the potential of technology to improve the diagnostic process and support ongoing development in the field of pediatric mental health.

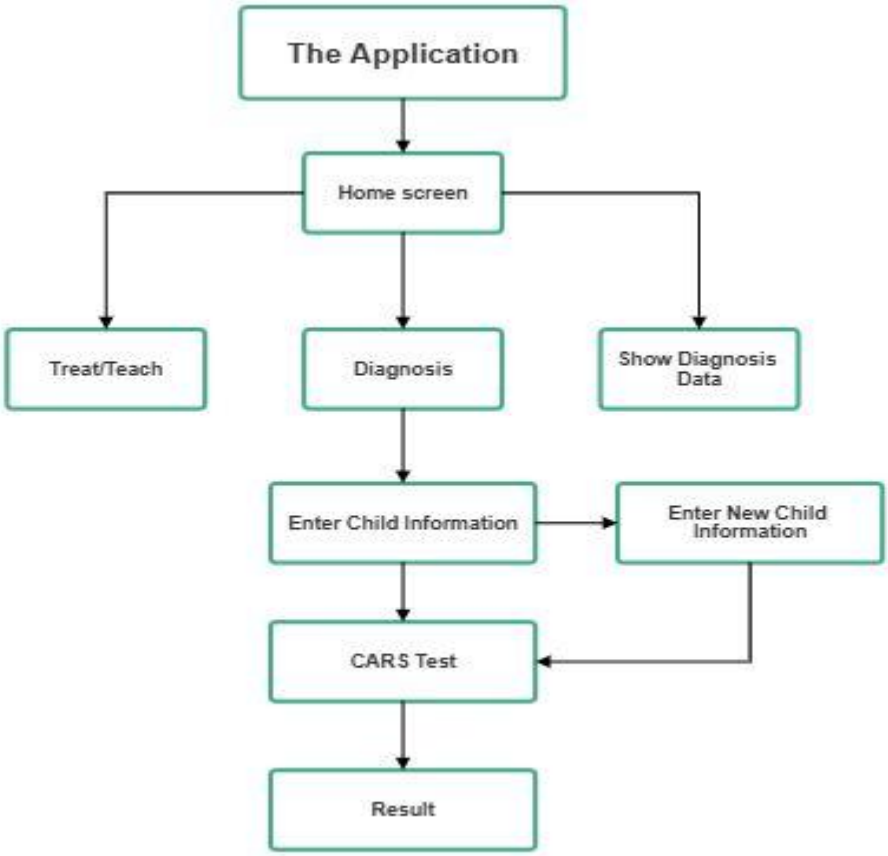


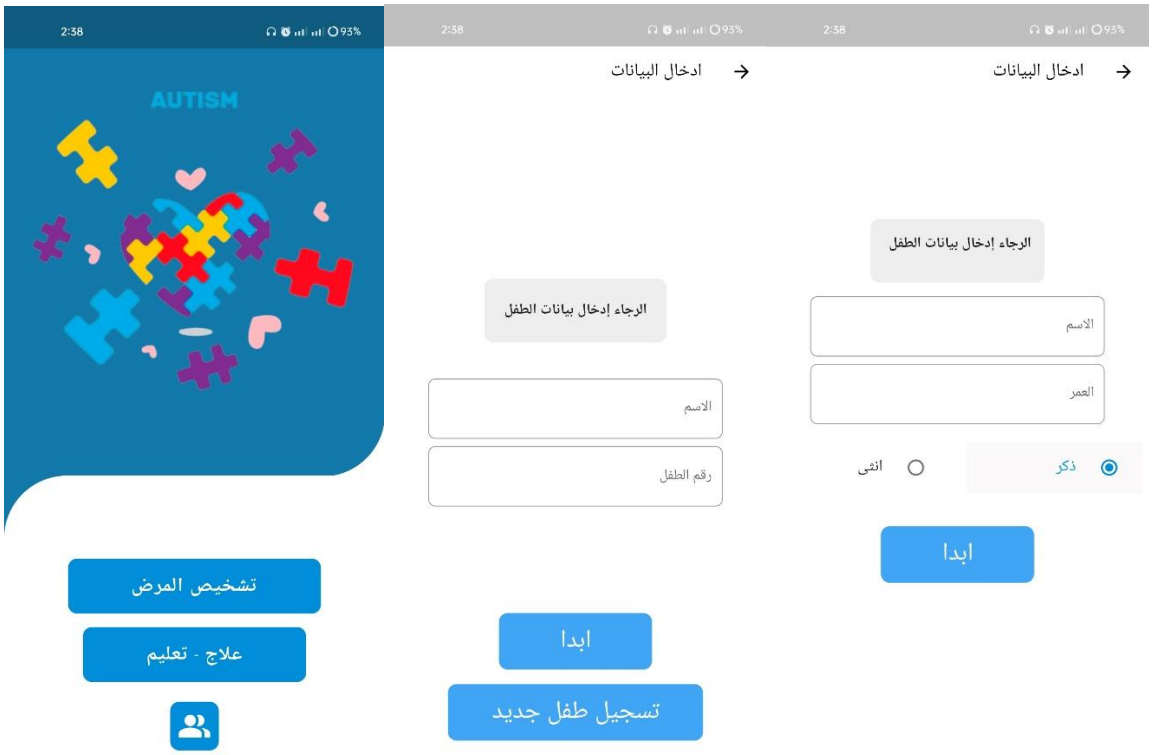
Figure 1. The app navigation diagram.

3. Functionality of the application:

A fundamental function of the application is to facilitate the assessment of autism spectrum disorder (ASD)-related traits through the use of the Childhood Autism Rating Scale (CARS) by various types of users, including healthcare professionals, clinicians, and parents. Upon accessing the application, users begin their journey from the home screen (as illustrated in Figure 2(a)), navigating towards the diagnosis page. Here, users can input the name and identifying number of a child who is already registered within the system (shown in Figure 2(b)). In instances where the child has not been previously registered, the application provides the option to initiate a new registration process (demonstrated in Figure 2(c)). This feature is essential for maintaining an organized database of child profiles, allowing for personalized assessments. Once a child is registered, the CARS assessment process commences, comprising 15 sequential questions designed to evaluate various behaviors associated with ASD. Each question offers four discrete response options that represent a spectrum of

behavioral observations, ranging from typical to severely atypical behaviors. This structured approach allows for a nuanced understanding of the child's behavior while ensuring clarity and ease of use. The user interface is optimized for touch-screen navigation, affording compatibility with both smartphones and tablets, which enhances accessibility for users in diverse settings. Figure 2(d) displays a sample question from the toddler assessment, showcasing the clear presentation of behavioral indicators. Upon completion of the assessment, users are directed to a results screen that presents feedback based on their inputs (illustrated in Figure 2(e)). This feedback is critical as it informs users of the child's behavior as interpreted through the CARS framework.

The backend of the application is equipped with sophisticated functionalities that compute individual scores, correlating them with corresponding diagnostic interpretations per the established CARS scoring system. For instance, if a parent administers the CARS test for toddlers and the resulting score is 35, this indicates a diagnosis of mild autism. According to the CARS scoring criteria, a score below 30 suggests that the child is not on the autism spectrum; scores ranging from 30 to 36.5 signify mild to moderate autism; and scores from 37 to 60 indicate severe autism. The application is designed to prioritize user privacy and data security; all collected data are securely stored in an SQLite database, which facilitates thorough future data analysis. This robust data storage solution allows for the exploration of key behavioral characteristics that may influence ASD diagnoses, offering valuable insights within the broader context of behavioral science and enhancing the understanding of autism spectrum disorder through data-driven analysis. Such functionalities not only support the immediate diagnostic process but also contribute to ongoing research and development efforts aimed at improving assessment methodologies and interventions for children with ASD.



(a) (b) (c)

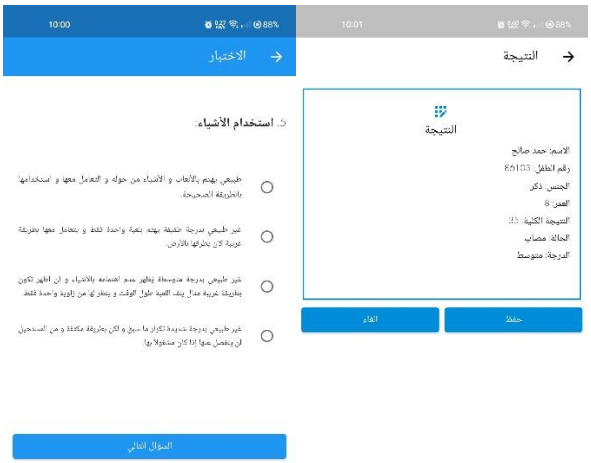


Figure 2. (a) Home screen, (b) child information, (c) register new child, (d) CARS test and (e) Result page.

4. Case Study

The case study examines the implementation and efficacy of a diagnostic application designed for use among 15 children, comprising both male and female participants, aged between 6 to 16 years, at the Al-Bayda Autism Center. The children who participated in this study had a range of developmental difficulties, mostly related to different levels of autism spectrum disorder (ASD). The diagnostic app used in this study was developed to expedite the evaluation procedure and make it easier to spot behavioral patterns associated with autism. In order to determine how much technology could improve conventional diagnostic techniques, the study also aimed to evaluate the app's effectiveness and accuracy in diagnosing children with autism. Table 1 shows the sample.

Table1.Shows the sample size

Gender	Age	Number
Male	6-16	13
Female	13-15	2

IV. Results and discussion

This section analyzes the results of utilizing a diagnostic application for autism spectrum disorder (ASD) within the Al-Bayda Autism Center. By integrating the app into the diagnostic process, we notice that autism spectrum disorder exhibits a significantly higher prevalence in males compared to females. as shown in the research methodology section. The study [23] has proven that a male-to-female ratio of approximately 4:1. However, the authors note that this ratio can vary across different studies, suggesting that factors such as diagnostic criteria, methodological variations, and potential underdiagnosis in females may influence the reported gender disparities in ASD prevalence.

After utilizing the app by specialists for the diagnosis of children, the results produced by the app were systematically compared with the initial diagnoses made by specialized experts or the parents of the child, following thorough clinical examinations. This comparison aimed to evaluate the app's accuracy and reliability in assessing autism spectrum disorders. Table 2 presents a detailed dataset comprising 15 sample instances collected during this diagnostic process. Each row corresponds to a unique child, with the first column indicating the child's identification number for reference and tracking purposes. The second column specifies the child's gender, categorized as either Male or Female, which can be important for understanding gender-related differences in diagnoses. The third column lists the child's age in years, providing context for the developmental stage at the time of evaluation.

Moreover, the fourth column illustrates the CARS (Childhood Autism Rating Scale) result produced by the app, while the fifth column displays the corresponding CARS result determined by the diagnostic center's experts. This dual representation enables a direct comparison of the two diagnostic modalities. The sixth column records the date of the first CARS assessment, which is essential for understanding the timeline of the diagnostic process. In columns seven and eight, the diagnoses are elucidated: the seventh column presents the diagnosis

derived from the app's result, including specific categorizations such as 'severe autism' for a CARS score of 45 (as seen in the first row), demonstrating the app's capability to classify severity levels. The last column conveys the diagnosis obtained from the center's assessment, with examples including 'normal' for a score of 18 in the same row. This comprehensive dataset not only highlights discrepancies or agreements between the app and expert assessments but also serves as a foundation for analyzing the effectiveness and potential advantages of using such technological tools in pediatric diagnostics.

Table 2.presents a detailed dataset that collected during the diagnostic process.

No.	Sex	Age	App CARS degree	Center CARS degree	First CARS date	App diagnoses	Center diagnoses
1	M	10	45	18	9/10/2017	Severe autism	Normal
2	M	13	27	34	8/26/2014	Normal	Mild autism
3	M	11	24	37	3/11/2020	Normal	Mild autism
4	F	15	20	19	10/22/2016	Normal	Normal
5	M	9	34	27	7/26/2018	Mild autism	Normal
6	M	10	30	26	1/21/2018	Mild autism	Normal
7	M	11	26	30	5/26/2015	Normal	Mild autism
8	M	11	20	18	11/1/2017	Normal	Normal
9	M	14	31	27	1/21/2014	Mild autism	Normal
10	M	6	18	27	8/8/2021	Normal	Normal
11	M	15	20	24	3/13/2014	Normal	Normal
12	M	13	33	39	8/17/2013	Mild autism	Severe autism
13	M	15	35	38	5/9/2016	Mild autism	Mild autism
14	F	13	39	43	9/7/2014	Severe autism	Severe autism
15	M	16	30	41	10/3/2013	Mild autism	Severe autism

To analyze the data that has been collected efficiently, an interview was conducted with Professor Fathi Al-Dayikh, the head of the autism center. During the discussion, several critical aspects of the CARS (Childhood Autism Rating Scale) testing process utilized at the center were highlighted by him. He explained that the parents of the child complete all CARS assessments and after the parents answer the CARS questions, the specialists put the child under observation to determine whether the CARS result is correct or not. However, this reliance on parental input can sometimes lead to inaccuracies, as parents may inadvertently provide misleading answers or exhibit denial regarding their child's condition. This phenomenon is evident in certain cases, specifically in rows 1, 4, 5, 6, 8, 9, 10, and 11 of Table 2. According to the specialists, the app's diagnoses reveal a more accurate portrayal of the children's conditions compared to the parental assessments. Interestingly, the app identified several children as normal in rows 2, 3, 4, 7, 8, 10, and 11. This observation suggests that these children had likely spent a significant amount of time receiving therapy at the center, indicating that their conditions may have improved over the course of their treatment. It is important to note that the CARS is primarily a behavior-rating scale designed to assess a child's behaviors and characteristics that may indicate autism traits.

However, one limitation of the CARS is its inability to capture subtle improvements in behavior over time. For example, if a child initially spins in circles for five minutes and, after undergoing therapy at the autism center, reduces this behavior to three minutes, the CARS may not reflect this positive change. The CARS focuses on specific behaviors and does not account for the duration or frequency of those behaviors over time, which can be a significant oversight in assessing a child's progress. As a result, while the CARS serves as a valuable tool for initial diagnosis, it may not fully encapsulate the nuances of behavioral improvement that occur with ongoing therapy. This limitation underscores the importance of combining quantitative assessments like the CARS with qualitative observations and parental insights to gain a more holistic understanding of a child's developmental trajectory.

The results imply that, in comparison to parental assessment, the app's diagnostic features might provide a more accurate picture of the children's conditions. The difference highlights the importance of incorporating technology into the diagnostic process since the app enables the specialists to perform the CARS after the child has been observed, ensuring the child's actual condition. because the app is effective at decreasing the CARS test's time and displaying the results as soon as the test is over.

The app's ability to classify certain children as "normal" following treatment suggests that received intervention can result in notable behavioral improvements. Studies indicates that while the diagnosis of ASD stays constant with age (generally), adaptive functioning improves and co-morbid behavioral symptoms lessen, while social functioning, cognitive ability, and language skills show more fluctuating results [24]. However, the CARS has limitations in its ability to record subtle behavioral changes over time, despite its effectiveness for initial diagnoses. One crucial weakness in the CARS is demonstrated by the example of a child cutting the amount of time spent spinning from five minutes to three minutes. This scale may miss significant gains from

therapeutic interventions because it concentrates on particular behaviors without taking into consideration how frequently or how long those behaviors occur.

V. Conclusion and Future Work

In conclusion, a promising development in the fields of developmental disorders and mental health is the use of mobile apps for the diagnosis of autism spectrum disorder (ASD). In addition to offering parents and clinicians useful resources for early detection and intervention, these digital tools can improve accessibility and lessen the stigma attached to traditional diagnostic methods. But it's important to understand the drawbacks of app-based assessments, such as issues with accuracy, the risk of becoming overly dependent on technology, and the requirement for appropriate validation and standardization of these instruments. A more dependable and efficient method of diagnosing ASD is ensured by working with medical experts to create and deploy these applications. Mobile apps will probably become more crucial in the early detection and support of people with ASD as this field of study develops, which will ultimately improve outcomes for those impacted and their families. This app has proven its flexibility, ease of use, ability to save time and effort, and effectiveness in storing diagnostic data. The app's drawback is that it only offers a preliminary diagnosis; experts are crucial in diagnosing these conditions, so they cannot be left out of the diagnostic process. Professionals and people on the autism spectrum still need to interact face-to-face.

Future work in the realm of using mobile apps for diagnosing autism spectrum disorder (ASD) holds exciting potential, especially with advancements in artificial intelligence (AI) and the opportunity to engage larger, more diverse samples. Here are some key directions for future research and development:

- AI Algorithm Integration: Adding AI and machine learning algorithms can greatly improve mobile apps' capacity for more efficient data analysis. Compared to conventional diagnostic techniques, these algorithms can provide more nuanced insights and increase accuracy in identifying behavioral markers of ASD by utilizing large datasets.

- Integration with Healthcare Systems: It will be crucial to investigate how mobile applications can communicate with current healthcare systems to share data and coordinate care. Families going through the ASD diagnosis process may benefit from this integration by having quicker interventions and a better overall healthcare experience.

- Cooperation with Clinical Experts: When developing an app, psychologists, pediatricians, and autism specialists will work together to make sure that the diagnostic standards and algorithms employed are in line with accepted clinical standards and practices.

Future research on these topics will help make mobile apps for diagnosing ASD more precise, useful, and accessible for identifying and assisting people on the spectrum, which will ultimately improve outcomes for both individuals and their families.

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