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RESEARCH ARTICLE

Autism Assistant: A Platform for Autism Home-Based Therapeutic Intervention

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ABSTRACT According to the U.S. Department of Health and Human Services, Applied Behavior Analysis (ABA) is regarded as the gold standard for treating autism. However, it requires a significant time commitment of 20 to 40 hours per week, which can be expensive for families who may not be able to afford the treatment. ABA therapists emphasize the importance of practicing therapeutic techniques in the child's natural environment to maintain their effectiveness. Therefore, there is a need to supplement therapy in the home environment where the children spend most of their time. If a parent or caregiver assumes the role of co-therapist and practices with the child, it can result in faster skills improvement. However, many parents lack knowledge about therapeutic protocols. To address this gap, we conducted research and developed educational software for therapeutic interventions for Romanian children diagnosed with Autism Spectrum Disorder (ASD) in a home-based setting. We followed the Double Diamond Model, emphasizing the core principle of Human-Centered Design (HCD) methodology, to design the software with a focus on the special needs of end-users. This involved developing proto-personas, wireframes, and interactive prototypes, exploring the latest technologies, and incorporating feedback from experienced ABA therapists. Based on these inputs, we developed the Autism Assistant platform, which includes a mobile application built with Unity and a web application developed with React and Ruby on Rails. The platform underwent evaluation using the Quantitative Evaluation Framework (QEF) based on ISO 9126, and it was considered suitable as educational software for special education.

INDEX TERMS Autism, autism spectrum disorder (ASD), human-centered design (HCD), human-centered computing, assistive technologies, applied behavior analysis (ABA), mobile application, web sites, educational technology.

I. INTRODUCTION

Autism Spectrum Disorder (ASD) refers to a broad range of conditions characterized by persistent impairment in reciprocal communication and social interactions as well as restricted repetitive patterns of behaviors, interests, or activities [2]. ASD is believed to have a genetic basis, with several genes and genetic mutations being linked to its development. Other factors, such as environmental influences and prenatal complications, may also contribute to the development of ASD [3]. Individuals with ASD often experience co-occurring conditions, such as intellectual disability, attention deficit hyperactivity disorder (ADHD), anxiety disorders, and depression [4]. Currently, there is no medication for ASD treatment, and pharmacological interventions focus mainly on treating co-occurring symptoms. Therefore, the primary treatment options for ASD core symptoms are limited to psychosocial therapy.

According to the U.S. Department of Health and Human Services [1] Applied Behavior Analysis (ABA) is considered

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the gold standard for treating ASD [1]. ABA is an evidence-based, structured approach to learning that involves breaking down complex tasks into smaller, more manageable steps. It is based on the principles of behaviorism and discrete-trial teaching (DTT) [5] and involves teaching new behaviors and skills through positive reinforcement and repetition. Therapy is typically provided through one-on-one sessions, with the therapist working closely with the individual with ASD to teach new skills and behaviors. ABA therapy is efficacious in improving communication, socialization, and adaptive behavior in individuals with ASD [6]. The duration and intensity of ABA therapy differ depending on the individual's needs and the severity of the symptoms. On average, 20 to 40 hours of therapy per week are recommended [7]. ASD is a lifelong condition, and patients require ongoing support and interventions.

The World Health Organization estimates that the prevalence of ASD among children is now 1 in 100 [8], which represents an increase from the 2012 global prevalence report that identified 62 autistic children per 10,000 children [9]. The rise in the number of children affected by ASD comes at a time when health and social care budgets are severely curtailed in many countries and access to trained personnel must be rationed [10].

Autism not only affects individuals diagnosed with ASD, but also their families, who face challenges in adapting to the new life context and making decisions about necessary treatments and therapies. The lack of information and dedicated government programs for autism often leads families to discontinue school attendance or therapy practices. Economic and social factors, such as the high cost of therapies and transportation to therapy centers located far from home, pose financial burdens for families. Recent studies [11], [12], [13] have explored innovative approaches, such as augmenting center-based programs with home-based interventions, which have been described as transformative. Involving trained parents and caregivers to participate in interventions within the home environment seems to be an effective strategy for enhancing the learning potential of children diagnosed with ASD [14]. Home-based therapeutic interventions offer several advantages over conventional therapies. Individuals with autism often interpret the environment differently than neurotypical individuals. Environmental factors, such as sounds, temperature, or light, can trigger critical behavior, which is minimized in home-based therapy as the patient is in a familiar environment. Another significant advantage is the active involvement of the family, which promotes the development of interpersonal relationships and the patient's integration into the community. Families and caregivers learn that autism therapy is not just occasional, but rather a special way of life that everyone must adopt to achieve positive results. Interactive technologies have emerged as valuable tools to support the distinctive lifestyles of individuals with autism. These technologies include a broad range of applications, such as mobile and desktop applications, augmented and virtual reality applications, web-based applications, devices, and robots. Patients are often motivated and engaged by interactive technologies, leading to improved focus, fine motor skill development, and better self-regulatory behavior. Many research studies [15], [16] have demonstrated the efficacy of these technologies in the context of autism therapy, encouraging further exploration of their potential in this field.

Dr. Ole Ivar Lovaas, a respected clinical psychologist and professor at the University of California, Los Angeles [17], once emphasized the importance of teaching individuals with ASD in a way that suits their unique learning style, stating, "*If they can't learn the way we teach, we teach the way they learn.*". Inspired by this philosophy, our team initiated the "Autism Assistant" project to transform the research of this venerable psychologist in applied behavior analysis, into an innovative software platform for therapeutic interventions, for Romanian children diagnosed with ASD, in home-based settings. The project spanned a period of six months, during which the platform was designed using a human-centered approach to ensure that it effectively met the unique needs of its end users. The platform comprises two main components: an admin web application built with React and Ruby on Rails, designed for therapists to input information regarding therapeutic protocols, and a mobile application developed with the Unity game engine, dedicated to parents, caregivers, and children with ASD, which facilitates the therapy sessions.

This research brings an innovative contribution by integrating ABA therapy protocols into educational software that is adaptable for use in various nomadic settings. The study introduces a novel approach by involving parents as co-therapists for their children and providing them with high-quality therapeutic information. This empowers parents to create personalized educational scenarios tailored to their child's specific needs and effectively manage daily therapeutic activities at home. This enhances the potential for positive outcomes, as relying solely on therapeutic interventions in specialized centers may prove insufficient.

The structure of this paper is organized to provide a comprehensive understanding of the entire platform design process, from the initial idea to end-user feedback. Section II presents the related work. Section III provides an overview of the context in which the research was conducted. Section IV describes the methodology used to conduct the research and gather insights from experts in ASD therapy. Section V provides an in-depth analysis of the results obtained and a comprehensive discussion of the advantages and limitations of the platform. In the final section, we present our conclusions and outline future work.

II. RELATED WORK

Traditionally, the medical management of various conditions has primarily relied on pharmaceutical interventions. A study conducted by Aishworiya et al. [18] highlights that despite extensive research in the field of ASD, the existing evidence only supports the effectiveness of non-pharmacological behavioral treatments as the primary approach for addressing the core symptoms of ASD. Over time, behavioral therapies

have continuously evolved, with researchers incorporating modern technologies to mitigate the challenges associated with repeated attempts that can diminish patient motivation. The use of digital health technologies in autism treatment was previously considered optional, but the COVID-19 pandemic has made these technologies an essential reality [19].

The rapid advancement of computer and robotic technologies in the past decade offers hope for earlier and more accurate ASD diagnoses, as well as more effective, consistent, and cost-conscious treatment approaches [20]. Technologies are highly regarded by researchers in studies [21], [22], [23], [24] as valuable tools that can enhance the functional abilities, social interactions, and communication skills of individuals with ASD. In particular, a study conducted by Xanthopoulou et al. [25] highlighted the benefits of mobile applications owing to their user-friendly touch screen, portability, affordability, and accessibility. However, the researchers emphasize the lack of a standardized framework to assist in the selection of applications that align with the specific needs and socio-cultural background of individuals diagnosed with ASD.

The Autism Assistant is a platform designed for children between the ages of 0 and 8 who have been diagnosed with ASD, as well as their parents, caregivers, and therapists. Since the platform will be used in Romania, we deemed it necessary to conduct a market analysis of existing applications, developed for use in a similar context, before initiating the platform's development process. Thus, we analyzed mobile applications intended for use in the ASD context available on Google Play. Google Play was chosen because it is a virtual store that provides Android-based applications. According to a study [26] conducted by the International Data Corporation (IDC), a leading American digital technology research firm, the Android operating system was the most popular among smartphone users, with a market share of 82.2%. The study also revealed that iOS was the second most popular operating system with 13.9% of users, followed by Windows Phone with 2.6%. In 2018, the IDC conducted new research that revealed that the Android system maintained its market-leader position with 85.1% of users, followed by iOS with 14.9%. Thus, the analysis of apps on Google Play was justified in this research. The analysis was composed of three steps: identifying applications for children with ASD, mapping the results, and analyzing the functionalities of the applications of interest in the project's context.

The applications were identified by conducting a search for the word ''autism'' in the Google Play Store, which returned 96 results. The results were categorized according to inclusion and exclusion criteria. The inclusion criteria were as follows: the application must be for children with autism under 8 years of age, the type of application must be educational, and its content and interface must be in the Romanian language or offer the possibility of setting the Romanian language. The exclusion criteria consisted of eliminating applications without associated relevant research. This search yielded only three applications that met the inclusion and exclusion criteria. The results obtained in the second stage are summarized in Table 1.

TABLE 1. An overview of ASD applications available in the romanian language on the google play store.

Application	Objective	Language	Rating	Downloads
Romanian language learning game	Educational, it aims to teach everyday words.	Romanian	4.6 ☆	10 K+
Leeloo AAC - Autism Speech App	Educational and aims to learn words using the flashcard technique.	Support for 35 languages, including Romanian.	3.8 ☆	100 K+
Tell a Story - Speech & Logic	Educational and aims to develop speech.	Support for 37 languages, including Romanian.	4.1 ☆	1 million+

In the final stage, an analysis was conducted to examine the features of the ''Romanian language learning game'', ''Leeloo AAC - Autism Speech App'' and ''Tell a Story - Speech & Logic'' applications.

The ''Romanian language learning game'' created by 22MEDIA digital agency is an educational application for preschool children. The application includes six different games that help children learn the basic words of everyday life and develop their fine motor skills. In total, more than 200 different words were introduced into the game, grouped into the following categories: animals, vegetables, and fruits, shapes and colors, household items and furniture, clothing and seasons. The games are built on levels of knowledge, so it is easy to follow and discover the beauty of the Romanian language. The ''Romanian language learning game'' application is free and is suitable for children from the age of two [27].

''Leeloo AAC - Autism Speech App'' is an application designed to improve children's communication abilities. The app is based on the principles of Augmentative and Alternative Communication (AAC) and the Picture Exchange System (PECS), which are proven techniques in autism treatment and communication therapy. Each word that a non-verbal child might need for daily interaction is presented on a card. These cards feature an accurate vector image of the corresponding phrase or word that the child is attempting to communicate. Leeloo provides voice functionality, and each card press reveals a range of phrase options that are read out via text-to-speech once chosen by the user. Users can select from over ten voices available in the AAC Leeloo speech app. The app was designed for children with mental, cognitive, or behavioral disorders [28].

''Tell a Story - Speech & Logic'' is an application created by LADistribution that is designed to develop the cognitive skills of children between the ages of 4 and 7, particularly in the development of speech and logical thinking. The game is structured into three levels of difficulty: each level contains sequences of images that tell a story. Children have to arrange pictures in the correct order to tell the story and say it aloud. This activity helps children develop the ability to formulate coherent sentences and draw logical conclusions based on a story's events. The game is very useful for preschoolers because it challenges them to tell a story or explain in their own words why the pictures have to be in that order, or what happens in each picture. Consequently, this application encourages children to think creatively and improves their speech and logic skills [29].

After reviewing and analyzing the available Romanian language applications for children with ASD, we identified several limitations. The applications did not provide educational content that could be adjusted to suit the needs of a specific child. Although the game difficulty increased progressively, it could not be personalized for individual children, which can be a challenge when the app is used in a therapy center with several children or at home for families with multiple children diagnosed with ASD. Another limitation noticed was the lack of learning session timing settings. The developers may have assumed that a parent or therapist would supervise the session and observe the duration of the session. However, in this case, no information was provided regarding the therapeutic protocol that should be followed during the child's activity. Moreover, the applications did not offer any help or guidance to parents on how to assist their children during educational activities. Frequently, applications reached a stage where user input was required. However, unclear instructions and missing information about the therapeutic protocol made it difficult for users to understand what they needed to do. Essentially, each user had to play the game without knowing whether they were using the application correctly or whether it would have a positive or negative impact on their child's learning.

The research of commercial applications was particularly useful in analyzing what the market for ASD mobile applications offers and in identifying which of the real problems of children diagnosed with ASD and their parents have not been addressed by any other existing application. Thus, the Autism Assistant platform brings a new perspective by providing high-quality therapeutic information to parents and caregivers and enabling personalized educational scenarios for each child.

In addition to the commercial sector, there are also research-driven technologies developed by academic sector. A review focused on computer-assisted learning for people with autism by Sue Fletcher-Watson [30] reveals that these technologies rarely make the transition from theoretical research to commercial development. However, research in the ASD field offers important insights into the experiments carried out in recent decades. Assistive technologies developed as a result of research studies vary considerably, from simple communication devices to software solutions involving Virtual Reality (VR), Augmented Reality (AR) and Machine Learning (ML). The classification proposed by Philipp Michel [31] divides them into three categories: ''low'', ''mid'' and ''high'' technology. ''Low'' technologies represent rudimentary solutions that do not require electricity, such as sensory objects, color-coded schedules or cards used in PECS [32]. Low technologies are highly valued and frequently used in schools and therapy centers. ''Mid'' technology includes independent and inexpensive electronic devices that can be used in the treatment of autism symptoms. Within the ''mid'' category the most representative are Voice Output Communication Aids (VOCAs) devices [31]. These devices produce synthetic or digitized speech when the user selects a symbol on the device screen [33]. ''High'' technologies have experienced remarkable development in recent years, as a result of innovative research that has included experiments with advanced software applications and robots [31]. A relevant example is the research carried out at the Autism Research Center at the University of Cambridge that presents the ''Mind Reading'' application [34]. This application allows autistic children to interpret social signals from everyday life and learn to recognize emotions. The educational process is facilitated through three modes of interaction: Emotion Library, Learning Center and Games Zone. The Emotion Library includes 412 emotions grouped into 24 categories, accompanied by short videos of actors expressing those emotions. The Learning Center contains collections of emotions similar to those in the library, but is organized to facilitate learning and exploration. The Games Zone contains games that allow users to practice their emotion-related skills, including hand-eye coordination games and games with real faces. The integration of learning and entertainment elements is a key aspect of this technology, which has the potential to produce significant impact on the learning process. However, a more detailed description of the design and implementation process would contribute to a better understanding of the architectural decisions and to the argumentation of the sustainability of the therapeutic act.

Comparative studies on interactive technologies reveal that people with autism prefer high technologies [35].

Communication and social interaction deficiencies represent some of the most common manifestations of autism, and for this reason most researchers [36], [37], [38] have focused on the development of technologies that facilitate the development of verbal and non-verbal communication skills.

In the study [39], an online platform was proposed to encourage social interaction in children with autism. The platform development methodology involved the use of the ASP.NET, a framework for building web applications and services with.NET and C# programming language, and Unified Modeling Language (UML), a visualization method for designing software systems, especially those built in the

object-oriented style. The evaluation of the platform was carried out by testing it with 20 students from the College of Applied Studies and Community Service, within Imam Abdurrahman Bin Faisal University (IAU), Saudi Arabia. Test results indicated that users were satisfied with the functionality and usefulness of the system. Given the sensitive mental context of autistic patients, an additional evaluation using internationally recognized standards and involving users with autism and experts in autism therapy, would have been essential to validate aspects related to the performance of the didactic act and the effects produced.

However, a small number of studies have explored the development of technologies that encourage the acquisition of skills needed in ''everyday life''. These skills relate to essential self-care and coping functions that contribute significantly to the individual's autonomy. Our research contribution brings significant value in bridging this gap through the Autism Assistant platform, specifically developed to facilitate the improvement of functional and cognitive skills of children with autism.

Most research studies have focused on the use of interactive technologies in schools or research laboratories, which can be explained in part by the fact that, until recently, computer equipment was more readily available in educational and treatment institutions than in the homes of research participants [30]. Through the Autism Assistant software platform, we propose a more accessible and convenient approach, bringing therapy directly into the familiar environment of children with autism spectrum disorders. The active integration of family members, especially parents, in the process of therapeutic intervention significantly facilitates educational progress [40]. However, we recognize that engaging parents as therapists requires learning specific skills to achieve beneficial outcomes for the child. Therefore, our platform takes an innovative approach, assigning the role of co-therapist to the parent, who is trained in educational activities according to a well-defined protocol. The protocol is entered by medical experts in the web administration page and provides parents with access to high-quality autism education content via the mobile application. Many parents were already actively involved in managing their children's problems and looking for appropriate solutions [41]. By providing a platform specifically designed for them and their children's needs, developed in collaboration with experts in the field of autism spectrum disorders treatment, we give parents the confidence that their actions are in line with best practice and that the technology used is safe for the child.

III. CONTEXT

To create a context-aware application, it was crucial to gain a comprehensive understanding of the relevant context. To achieve this, we researched the meaning of the term ''context'' and consulted the work of Anind K. Dey. Professor Dey defines context as ''*any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application.*'' [42].

Our research is supported by the European Regional Development Fund, which aims to facilitate the development of a specialized therapeutic software for use in Romania. In a prior European project [43] that assessed the prevalence of ASD in Romania, it was found that 14.3% of children were diagnosed with this condition. However, the prevalence rate of children diagnosed with ASD is rising annually. Unfortunately, in our country, parents of children with ASD face a lack of information resources available in Romanian and a reduced number of certified centers and therapists. Furthermore, there are few applications for children with autism, their parents, and therapists that are available in Romanian or with a language option for Romanian. Therefore, our project aims to develop a Romanian-language therapeutic software platform that enhances the skills of Romanian children diagnosed with ASD. The platform will address the market gap resulting from the absence of software specifically designed for non-English speakers.

IV. METHODOLOGY

The study was conducted following the guidelines of the Code of Ethics and Professional University Deontology and received approval from the Research Ethics Committee at Stefan cel Mare University, Suceava, Romania (approval number: 128).

A. RESEARCH QUESTION

The aim of this study is to investigate the most effective theoretical principles of ABA therapy to create a platform tailored for home-based therapeutic intervention in the context of ASD. The research question driving this study is: *''How can educational software be designed to provide home-based therapeutic interventions for Romanian children under 8 diagnosed with ASD?''*. To accomplish this goal, the researchers utilized cutting-edge technologies to design and implement a set of intelligent modules for the platform named ''Autism Assistant''. The primary objective of this platform is to promote greater self-reliance and independence among children with ASD.

B. RESEARCH TEAM AND END-USERS

This article presents some of the research results obtained within a collaborative research project between Stefan cel Mare University and Assist Software Company, both located in Suceava, Romania. The project was carried out over a period of six months, from November 2022 to May 2023, using an interactive agile approach. The project involved rigorous collaboration between 22 specialists employed within the university and the company, with experience in various relevant fields, such as: computer scientists, education researchers and professors, a psychologist, an ABA therapist, software engineers, 2D artists, a user experience (UX) designer, a user interface (UI) designer, and a quality assurance (QA) engineer. In addition to this multidisciplinary

team, there was a target group of 60 future users of the platform, including therapists, teachers, and parents of children diagnosed with autism spectrum disorders.

C. RESEARCH METHOD

Our research aimed to develop a platform that meets the special requirements of individuals diagnosed with ASD. To achieve this objective, we conducted a cross-sectional study by surveying a target group of 60 parents, teachers, and therapists from both urban and rural areas of Romania.

The data collected from the survey is highly valuable and have provided us with a clear understanding of the actual needs of children diagnosed with ASD in their daily lives, their experiences with technology, and their concerns related to technological features. The results of this cross-sectional study are presented in the article titled ''Interactive Technologies for Autism Spectrum Disorder Therapeutic Intervention'', which is under review for publication.

The Autism Assistant platform was developed based on the well-known product design principle: ''*To design a great experience, you need to understand the user's perspective*.'' [44]. As a result, individuals with the autism spectrum and their caregivers were placed at the heart of the development process. Instead of the technology-driven approach commonly used in software development, we embraced the Human-Centered Design (HCD) approach, where the needs of people took precedence over technology. Human-centered design involves understanding human needs and how design can address them [45]. The term ''design'' encompasses three crucial elements: empathy, creativity, and business. Empathy is essential as we strive to truly understand and care for the people we are designing for. Creativity plays a pivotal role in developing software that is visually appealing and user-friendly while effectively solving challenges. Considering business needs is also vital, as the solution provided must be viable and sustainable for long-term user benefits.

The United Nations Children's Fund (UNICEF), originally known as the United Nations International Children's Emergency Fund, recognized the high effectiveness of the HCD process in developing human-centered services, particularly for children [46]. As the end users of the platform are also children, the decision to use HCD-based research and development methods ensured a better understanding of the challenges they face and how to effectively address them.

In this research, we followed the well-established steps of the HCD process, known as the Double Diamond Model (see Figure 1), developed by the British Design Council in 2005 [47], which includes four stages: discovery, definition, development, and delivery [48]. The Double Diamond Model emphasizes the core principle of HCD, which involves two essential phases: identifying the correct problem to solve (''designing the right thing'') and then creating designs that effectively meet human needs (''designing things right'') [49]. This approach ensures that the focus remains on understanding the actual problems faced by users and addressing those needs through a thoughtful and effective design.

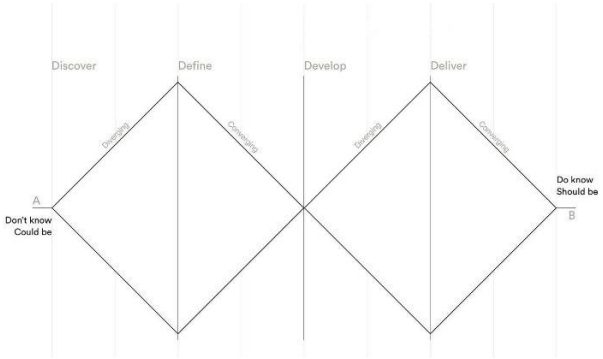

FIGURE 1. Visualization of the human-centered design process using the double diamond model [48].

1) DISCOVER – RESEARCH PHASE

The research phase involved three research methods: Systematic Literature Review, Cross-Sectional Study, and Expert Opinion.

Systematic Review was conducted during the project period to analyze the current state of the field of autism therapy, identify trends, and identify state-of-the-art results.

Cross-Sectional Study was conducted to collect direct feedback from the end-users of the application, including parents, therapists, and teachers. This allowed us to gain insights into the usability and effectiveness of interactive technologies in real-world settings.

As part of our research phase, we applied the *Expert Opinion* method to extract valuable information about autism therapy. We interviewed experts in the ASD domain to gain insights into the current challenges and opportunities in autism treatment. This approach allowed us to include experts' perspectives in our design process and to ensure that our solution was aligned with the latest research and best practices in the ASD field. The results from the systematic literature review, cross-sectional study, and expert opinion are presented in detail in the article ''Interactive Technologies for Autism Spectrum Disorder Therapeutic Intervention''.

2) DEFINE – SYNTHESIS PHASE

The synthesis of information from the systematic literature review, cross-sectional study, and expert opinion was conducted to identify relevant and useful information for the development of a platform for the treatment of autism in both home and therapy center environments. This synthesis involved extracting and grouping information into relevant categories, such as users, available therapies, and their effectiveness, as well as the needs and experiences of parents, caregivers, and therapists.

a: PROTO-PERSONA

The term ''persona'' has its roots in the Latin language and was initially used to refer to a mask worn by actors to

represent a specific character in a theatrical performance. The term is believed to have originated from the Latin word ''personage'', which means ''to sound through'' [50].

In today's user experience practice, personas represent the voice of the user. Personas are artifacts that have been applied to support software teams in both activities, elicitation, and the use of UX requirements. The technique to create the personas follows a process that analyzes end-user data [51].

Gothelf proposed a new approach to elaborating personas called proto-persona [51]. Proto-persona is different from a standard persona, it is created based on the assumptions of stakeholders and checked against actual data [50].

In this study, we used this powerful tool to identify the end users, as we are dealing with children with special health needs who may experience delays in physical and mental development, parents who face financial difficulties and social discrimination, and therapists who have specific expectations. Therefore, the proto-personas were created using Figma. Figma is a design tool that is specifically geared toward creating user interfaces and designing user experiences [52]. Proto-personas are fictional representations of the end users of the Autism Assistant platform: the child diagnosed with ASD, the parent, and the therapist. Each proto-persona was developed with specific details that can be seen in Figure 2. We analyzed different aspects of the end users, including their personal characteristics such as age and occupation, level of digital culture, proficiency in using technology, as well as their specific goals and expectations. Furthermore, the study also identified potential pain points that users might encounter in real life. Based on this comprehensive analysis, proto-personas were developed to serve as archetypical representations of the user groups for the project.

Figure 2 (a) illustrates the proto-persona of a child between the ages of 0 and 8, diagnosed with autism spectrum disorder, who may experience difficulties in communication, social interaction, and may exhibit repetitive or unusual behaviors. This child may also have difficulty managing emotions and be hypersensitive to stimuli, such as loud sounds or bright lights. Additionally, they may have an intense and specific interest in certain subjects or activities, needing predictability and a routine to feel secure.

Figure 2 (b) shows the proto-persona of a parent who has well-defined goals and expectations regarding their child's therapy. The parent is looking for a product or service that will help him identify if their child has autism and support them in the therapeutic process. However, the parent may experience financial constraints and may have limited knowledge regarding the implementation of therapeutic procedures.

Figure 2 (c) illustrates the proto-persona of an ASD therapist, aged between 25 and 60 years, who aims to create educational content and follow the protocol in the therapeutic intervention. The therapist has strong skills in the use of digital tools and the internet. However, the therapist faces challenges related to the lack of Romanian educational materials and the limited involvement of parents in caring for children at home. Thus, they seek ways to optimize therapeutic intervention by identifying and providing appropriate educational materials and promoting effective communication with parents.

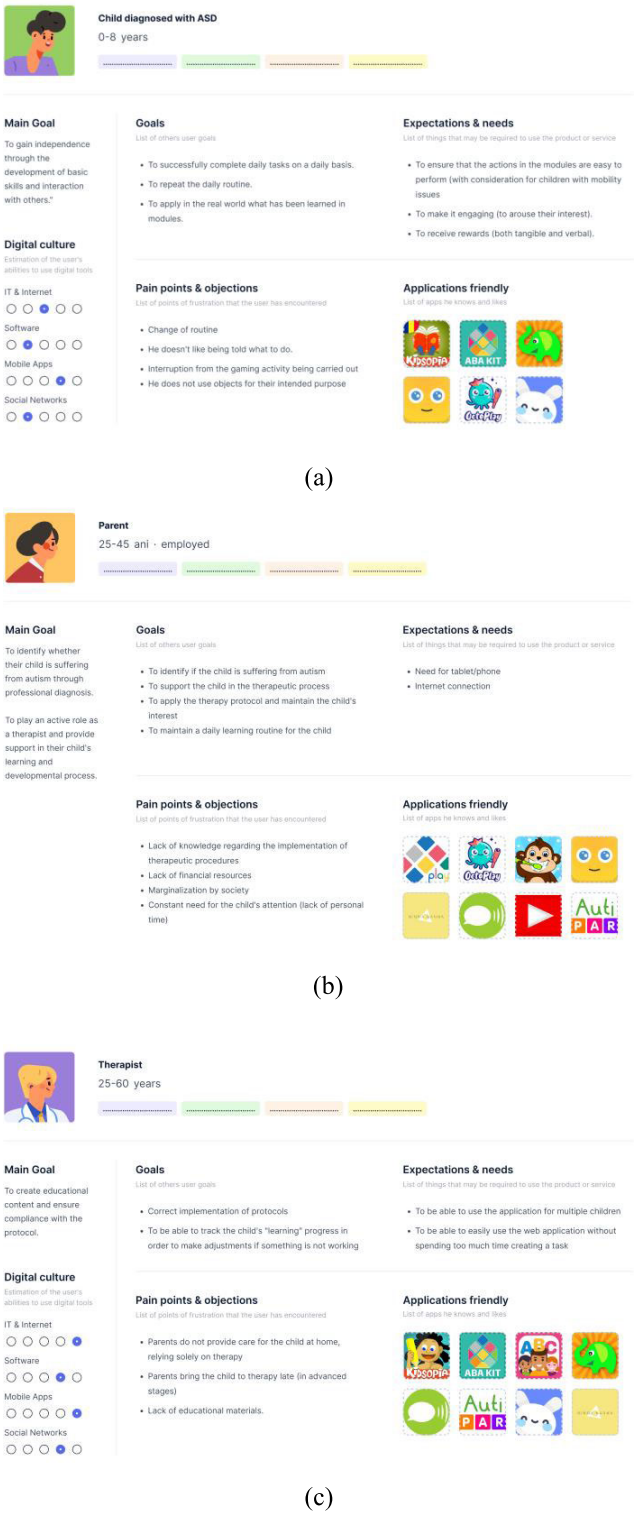

FIGURE 2. Proto-personas created using Figma, representing the end users of the platform a) Child diagnosed with ASD b) Parent c)Therapist.

b: PLATFORM CHARACTERISTICS

The findings from the research phase have yielded invaluable insights into the key characteristics that are essential for an effective therapeutic application for ASD. Through feedback obtained from parents, teachers, and therapists via a comprehensive questionnaire, we gained a valuable understanding of their needs, preferences, and priorities in terms of functionalities. The most highly regarded features of such an application include the following:

Intuitive and user-friendly interface for children and adults: An autism therapy application should be designed with an easy-to-use interface that is visually appealing and can be easily navigated by both children and adults. This ensures that children with autism can effectively interact with the application without encountering difficulties.

Personalization and adaptability: The content of the application must be personalized and adaptable to the individual needs of children with autism. As each child has unique needs and interests, the therapeutic application should offer flexibility in adjusting the level of difficulty, type of activities, and exercises based on the child's developmental stage and interests.

Progress monitoring and skill assessment: The therapeutic application should provide functionality to monitor the progress and assess the skills of children with autism. This allows therapists and parents to track the child's progress in skill development, identify areas where further intervention is needed, and adjust therapy plans accordingly.

By incorporating these key characteristics into the design and functionality of the Autism Assistant platform, our aim was to create an effective and user-friendly tool that can support children with autism in their therapeutic journey while providing valuable tools for therapists and parents to monitor progress and customize the therapy approach.

3) DEVELOP - IDEATION PHASE

During the development phase of the HDC process, the research team members collaborated closely to generate ideas that contributed to the conceptualization of the platform. All ideas were thoroughly discussed in daily meetings and refined to shape the structure of a platform for home-based therapeutic interventions that will be truly beneficial for individuals diagnosed with autism.

a: PLATFORM'S MODULES

The platform is designed to have five modules, as illustrated in Figure 3.

The Core Module implements the fundamental logic of the application, where the connection and initialization of the components occur. It also retrieves data from the database based on user input during authentication, and provides the option to create a new account and manage profiles for authenticated users.

Module I focuses on providing information to the parents. It serves as a personal guide to assist them in detecting potential developmental delays in their children and outlining a treatment plan. Familiarizing parents with the typical stages of development that their child should reach, helps them understand how to interact with their children. Given the challenges parents may face in including children under the age of two in a specific therapy center, this module emphasizes early identification of signs of autism and appropriate parental intervention. Diverse materials and resources will be available to parents for this purpose. Activity recommendations for each developmental stage (0-2 months, 3-4 months, 5-6 months, 7-9 months, 10-12 months, 13-15 months, 16-18 months, and 19-24 months) will be provided alongside each module.

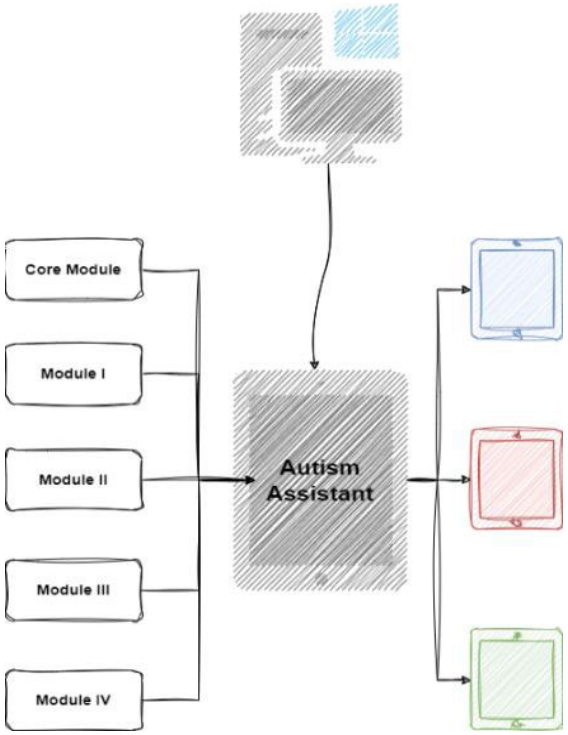

FIGURE 3. Visual representations of the autism assistant platform's modules created with Draw.io.

Module II addresses the lack of resources necessary for purchasing therapeutic materials that parents can use at home with their child. It also considers the lack of knowledge and guidance parents may have received from therapists regarding appropriate activities for their child. To address these issues, each activity will be accompanied by age-appropriate working protocols. The activities will be directed by the adult, who will have the option to choose what the child works on. Tracking progress is also an important element, and this module will include a functionality similar to an agenda where parents can take notes regarding the performance of a certain activity. Accessing the notes will be possible later through a history. This module not only supports parents but also therapists, as it aims to integrate the learning programs from therapy sessions into functional scenarios.

Module III considers the tendency of children with autism to isolate themselves from others and their preference for interaction with technology over other children of similar ages due to underdeveloped interaction skills. Instead of competitive games that focus on a single winner, this module emphasizes collaborative games adapted for an interactive whiteboard. Collaborative games typically require two players, where one can be the child and the other the therapist, parent, or another play partner with similar capabilities. Players work together to achieve the goal of completing the game.

Module IV focuses on the video modeling of behaviors, which involves providing the child with examples of certain actions through videos that they can imitate. Video modeling is used to help children with autism acquire new skills needed in everyday life, such as social and communication skills, and can also be useful for behavior change. This module provides access to a video library that can be used by parents and caregivers for scenario creation.

b: PLATFORM'S WIREFRAMES

Wireframes are essential for arranging elements to achieve a specific purpose. They display the layout and arrangement of the application's content, including interface elements and navigational systems, and how they work together [53].

During this stage, the UX/UI designers created the wireframes for the platform modules. A wireframe is a powerful tool that accurately translates ideas into a visual representation that deliberately excludes color, graphics, and stylized fonts. Wireframes also facilitate thinking about the optimal path selected by a user, allowing consideration of the visual hierarchy of each element. Visual hierarchy determines the visual order and priority of different design elements on a page or screen by utilizing principles such as contrast, balance, and scale to emphasize specific elements. This simplifies the page layout, preventing users from being overwhelmed by visual information [54].

The wireframes for the platform were created using Figma. Figure 4 (a) and (b) illustrate some of the most significant wireframes of the platform modules. During the ideation process, the wireframes were presented to the therapists and to the research team in regular meetings in order to receive prompt and efficient feedback.

Therapists' suggestions were incorporated into the interactive representation of the interface, as illustrated in Figure 5. A clickable prototype is different from design wireframes because it is not static. A person using a clickable prototype can perform all interactive operations, such as navigating the interface [55].

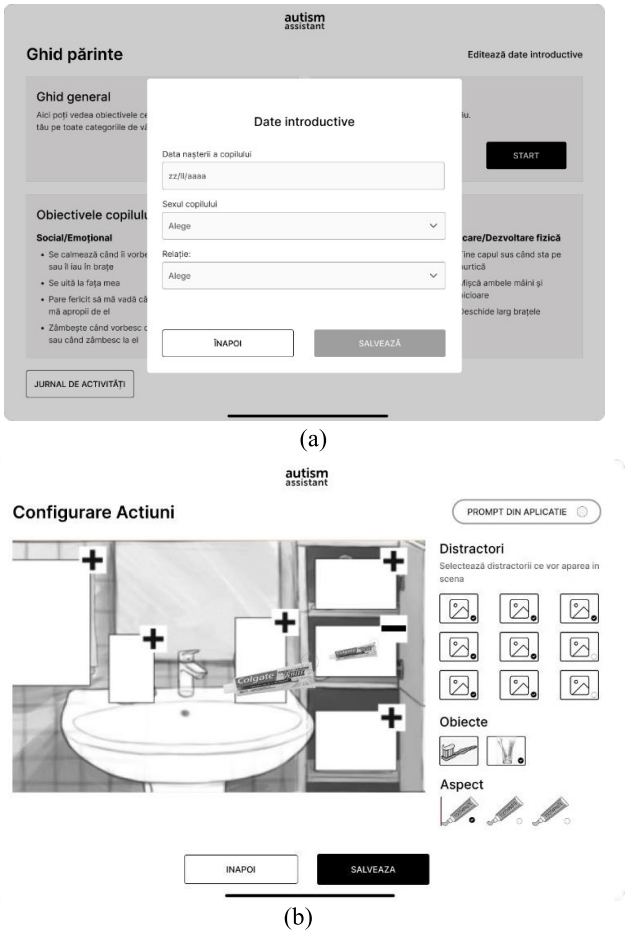

FIGURE 4. Wireframes of the platform, including: a) Parent guide and b) Scenario editor. These wireframes were created using Figma.

4) DELIVER - IMPLEMENTATION PHASE

The delivery or implementation phase in the Double Diamond model is a pivotal stage in which the chosen concept, identified through meticulous research and definition processes, is transformed into a tangible product. During this crucial phase, the development team made important decisions regarding the technologies to be used, development instruments and tools, platform architecture, and design elements. These decisions are carefully weighed to ensure that the final product aligns with the intended vision and objectives.

a: ARCHITECTURE

Figure 6 illustrates the architecture of the Autism Assistant platform, which was created using the Drow.io desktop application. This diagram provides a high-level overview of the main components and how they connect and interact with each other. In addition to its technical components, the architecture also features the involvement of end-users, who serve as a means to demonstrate how the platform operates.

The platform comprises several key components, including the mobile application, web application, database, and third-party plugins. The system is divided into two main parts: the client side and the server side. The client side is represented by the mobile application, which was developed using the Unity3D game engine. This application is designed to run on mobile devices, such as phones or tablets. On the other hand, the server side is composed of a web application that

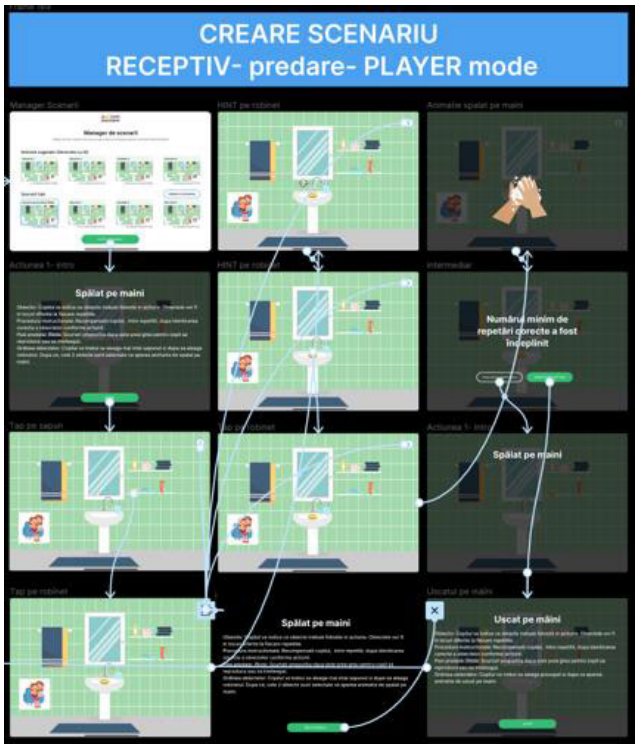

FIGURE 5. Interactive prototype of the platform created using Figma.

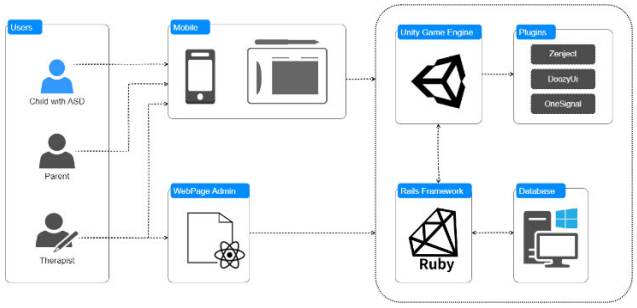

FIGURE 6. High-level architecture of the autism assistant platform created with Draw.io.

was developed using the React and Ruby on Rails framework. The primary role of the web application is to manage the data and transmit it to the client side.

b: DATABASE

The project database (presented in Figure 7) was implemented in MySQL. We chose MySQL because of its open-source nature, ease of use, and ability to efficiently handle large amounts of data. MySQL is compatible with various programming languages and frameworks, including Ruby on Rails (ROR).

In RoR, Active Record is used to manage the database. Active Record is an Object-Relational Mapping (ORM) library that allows programmers to integrate databases using objects [56]. Active Record in Rails provides a binding interface between the relational database tables and Ruby code that manipulates database records.

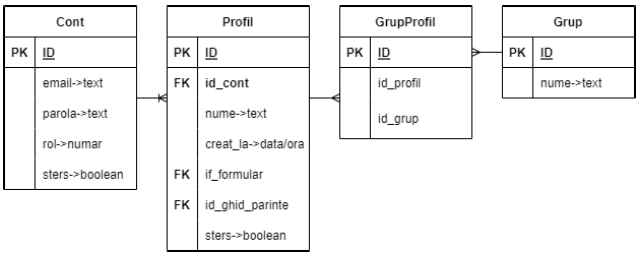

FIGURE 7. Entity-Relationship (ER) schema for the core module.

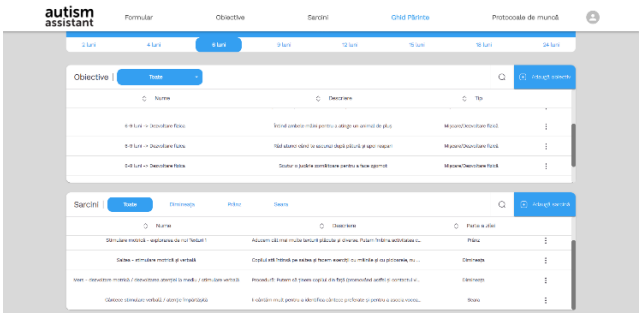

FIGURE 8. Web admin application from autism assistant platform.

Communication with the database was achieved through Unity Web Requests. The client application is responsible for making requests to the API that manages the database.

c: WEB APPLICATION

The Autism Assistant' web application was created using React, also known as React.js, an open-source JavaScript library for developing web interfaces [57]. The application was specifically designed for psychotherapists who specialize in treating individuals with ASD and possess the necessary knowledge to conduct treatment sessions. To access the web page, users must provide their login credentials. Figure 8 displays the interface of the web page, which includes a main menu with the following options: objective configuration, daily task configuration, parent guide configuration, and work protocols.

The objective configuration interface enables therapists to create goals in four categories: social-emotional, language-communication, cognitive, and movement-physical development.

Through the daily task configuration interface, therapists can define specific tasks that patients or groups of patients must perform regularly to improve their skills. When creating a new task, therapists must specify the task name, time of day it should be completed, and description of the task.

Identifying and addressing ASD in children at an early stage can have a significant impact on their ability to become more integrated members of society. With this goal in mind, we have introduced the parent guide feature as an innovative concept that has the potential to enhance parents'

understanding and perspective on ASD treatment. The parent guide configuration interface enables specialists to create parent guides based on previously defined goals and daily tasks. These guides are designed to train parents on how to conduct therapeutic interactions with their children, particularly those under the age of 2. The guide is structured by age categories: 2 months, 4 months, 6 months, 9 months, 12 months, 15 months, 18 months, and 24 months.

The web application is a powerful tool for applying therapeutic content and methodology in accordance with the ABA protocols. One of its most significant advantages is its accessibility through a web browser from anywhere and at any time, which facilitates the consumption of educational content.

FIGURE 9. Visualization of the login flow graph with doozyui nody.

d: MOBILE APPLICATION

The development of the Autism Assistant' mobile application involved the utilization of the Unity game engine and the C# programming language. Unity is a cross-platform game engine [58] developed by Unity Technologies [59]. This engine can generate realistic scenarios based on physical laws, including the simulation of gravity, collisions, and friction. Since the platform was designed for mobile devices such as smartphones and tablets, the Unity game engine proved to be the most suitable option owing to its development capability for mobile platforms such as iOS and Android. Additionally, it offers a wide range of integrations with services and tools such as data analysis, graphic creation, and automated testing.

Unity Analytics was used to enhance the platform's functionality. This package, delivered as part of Unity Gaming Services (UGS), provides a comprehensive solution for analyzing data at distinct stages of the application. The package was used to capture specific events related to user profiles, groups organization, daily tasks, scenarios, and gameplay. The insights obtained through Unity Analytics were employed to enhance educational content, ensuring that it aligned with the user's personalized progress.

The user interface was implemented using Doozy UI, a set of systems provided by Doozy Entertainment for creating, managing, and animating interfaces. This technology allowed the creation of user interface panels using views and handling them using Flow Controllers, as shown in Figure 9.

Doozy UI facilitated the creation of an intuitive and visually appealing interface that enhanced the overall user experience.

Spine is a program designed specifically for the creation of 2D animations [60], and was used for development of project's animations. Animations made in Spine are efficient in terms of loading and rendering even on mobile devices. The animations developed for the platform are not just aesthetically pleasing, but also serve a functional purpose. Through carefully crafted movements and fluid transitions, the artists have directed the users' attention towards critical elements of the application. In addition, they employed a range of techniques, such as netting, attachments, and procedural animation, to add a layer of interactivity that engages and captivates users.

FIGURE 10. Main menu screen of autism assistant platform.

The platform notification system utilizes the OneSignal push notification service. Our development team implemented a specialized service to handle the REST API provided by OneSignal, ensuring that notifications are sent with the correct data. The service uses OneSignal credentials provided via the interface, which are securely stored as environment variables in the code to make the external API call.

The Autism Assistant platform was developed to provide personalized support to parents and therapists who work with children who suffer from autism and have special needs. Users, including parents, therapists, and caregivers, can create personalized profiles for each child and group them according to well-established therapeutic criteria. The application modules can be accessed from the main menu, as shown in Figure 10, or from the settings bar, which includes options for configuring the application settings, selecting modules, or logging out. The application settings allow users to configure notifications, adjust sound volume, log out of their account, delete their account, or review the application's terms and conditions.

Module I focuses on children diagnosed with ASD up to 2 years old. Modules II, III, and IV cater to children aged 2 to 8, considering their increased technology interaction

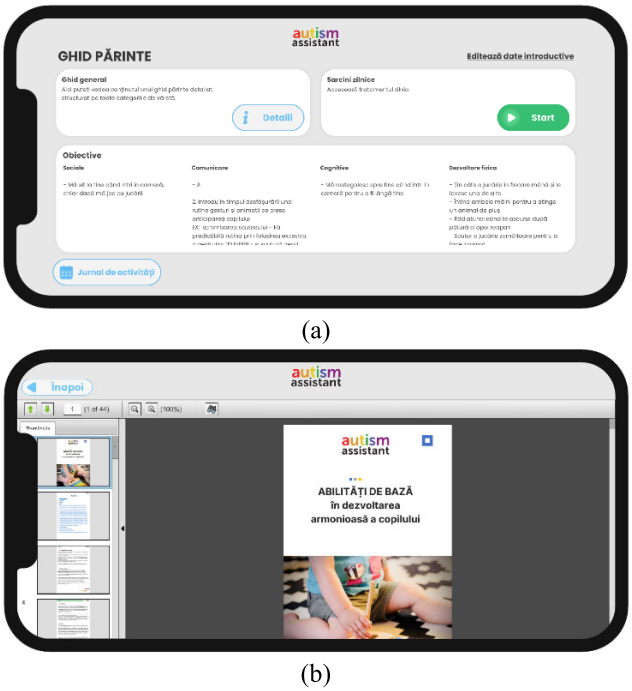

FIGURE 11. Parent guide that includes the following components: a) Objectives and daily activities tailored to the child's age and b) A comprehensive guide for parents.

FIGURE 12. Scenario configurator of module II including: a) Scenario manager and b) Actions configurator.

abilities. All modules provide parents with detailed information on the therapeutic protocol and guidance for implementation.

Module I is designed for the child's parent or caregiver and includes an introductory data form that collects the necessary information to personalize the educational content based on the child's age. Parents can access the guide and begin treatment with daily tasks that are divided into three parts of the day. Figure 11 depicts the parent's guide, which features separate sections for the child's goals and daily tasks. At the bottom of the page, users can find the "Activities Journal" button, where they can view the treatment history, completed tasks, and observations.

Module II of the platform focuses on enhancing children's ability to recognize objects and perform actions through a variety of game scenarios. These scenarios can be created by adult users using the scenario configurator. The parent/caregiver or therapist can configure the scenario to meet the specific needs of each child, considering their age and ability level.

The scenario configurator, as illustrated in Figure 12, comprises three key components: the scenario manager, the scenario editor, and the action configurator.

The scenario manager is responsible for overseeing all scenarios.

The scenario editor enables users to create new scenarios or modify existing ones to fit child's needs. The scenario editor allows the parent or therapist to customize the scenario by adjusting various settings. For instance, they can modify the scenario's name, scenario's mode, and action list based on the chosen environment bathroom, park and so on.

FIGURE 13. Illustration of the therapy game module in the Autism Assistant platform.

The action configurator facilitates the selection of object aspect, their positioning in the scene, and the inclusion of distractors to enhance the game's level of difficulty. Furthermore, the action configurator provides options for configuring the number of times an action is repeated, as well as time-related settings such as the duration of the action and the interval between repetitions.

The module responsible for running therapeutic scenarios, as shown in Figure 13, is a vital component of the autism-specific therapeutic application. This module simulates a therapy session based on well-defined therapeutic techniques and strategies, such as ABA therapy procedures.

The Receptive Mode involves child input, requiring children to perform a set of actions to learn how to associate different concepts and develop the necessary skills. In the

FIGURE 14. Illustration of the "Brushing Teeth" animation.

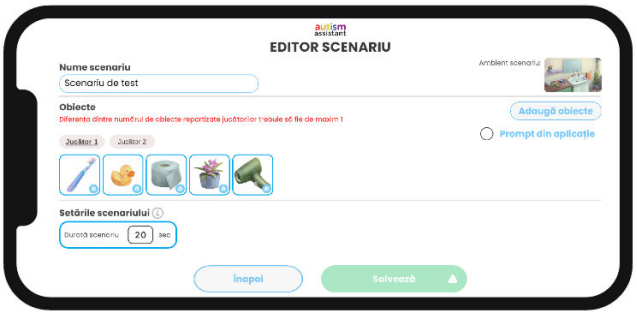

FIGURE 16. Scenario configurator of module III.

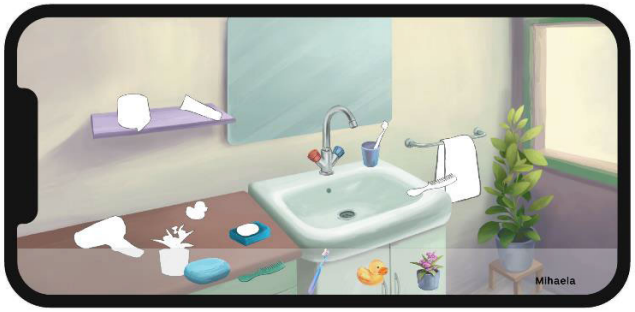

FIGURE 15. Module III of the autism assistant platform.

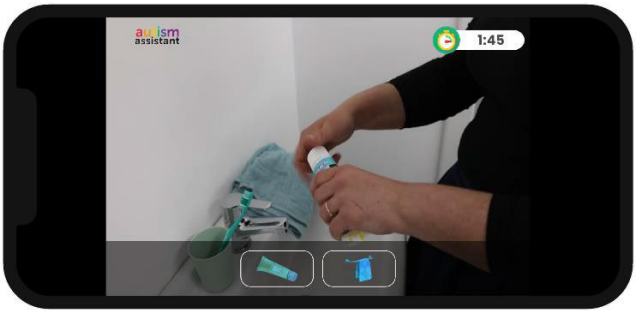

FIGURE 17. Module IV of autism assistant platform.

Receptive-Teaching mode, users are presented with action steps one by one. In the Receptive-Verification mode, users are assessed to determine if they understood how to perform the action correctly and if they have made progress in developing the necessary skills.

The Expressive Mode is also based on ABA therapy strategies, and aims to develop the behavioral skills of individuals diagnosed with ASD. The scenario helps children learn to perform various actions and identify elements within the scenario, with parents and therapists serving as evaluators and supporters. In the Expressive-Teaching mode, the app runs the action steps automatically, and the child must identify each element in the action. Parents and therapists evaluate whether each item was correctly detected by the child or not. In the Expressive-Verification mode, actions are executed to evaluate whether the child has mastered them.

An example of an action is ''Brushing Teeth'' whose purpose is to teach the child how to brush their teeth correctly. To do this, the child must perform the steps of selecting the toothbrush and toothpaste in the correct order without being distracted by other elements present in the bathroom environment. If the child performs the steps correctly, they will see an animation of a child with an open mouth and a hand holding the toothbrush, brushing their teeth, as illustrated in Figure 14.

Module III is designed to enhance cooperation skills by focusing on the ability of two participants to associate contextual elements within the given scenario (presented in Figure 15). This module contains a scenario configurator that sets the objects for each player and determines the duration of the scenario, as illustrated in Figure 16.

Module IV aims to improve a child's ability to perform actions independently through video modeling. The videos will feature real people demonstrating different activities and their corresponding tasks. The training method consists of three modes: the ''Library'' mode, which allows users to pause or fast-forward videos, the ''Decisional'' mode, where videos pause for child decision-making, as illustrated in Figure 17, and the ''Mini-session'' mode, which starts a small game scenario from Module II after playing the video.

This training method has proven effective, focusing on repeating actions as closely as possible to those presented, interpreting emotional states based on video data, and analyzing the gestures of people filmed.

e: QUALITY ASSURANCE

To ensure high-quality performance of the modules developed for the Autism Assistant platform, a comprehensive quality assurance process was employed. This involved both manual and automated testing of each feature. Automated testing was conducted using the state-of-the-art AltTester framework, which was specifically designed and developed by the reputable Altom company for this purpose.

V. RESULTS

This section provides a detailed description of the evaluation carried out by two ABA therapists who assessed the platform's modules for compliance with the requirements of educational software for special education. The evaluation

TABLE 2. Autism assistant evaluation using QEF.

Dimension	Factor	Requirement examples
Functionality	***Easy of use***	Can the user operate the educational software with minimal instruction?
The platform is designed to be simple and not distracting for children, while still allowing caregivers to grade responses and access additional information. It can be used on devices with or without a touch screen, and only minimal keyboard skills are required. The interface is uncluttered, and the button arrangement prevents accidental exits.		
		Is there an online system available to assist the user in overcoming difficulties?
There is an online system available to assist users in overcoming difficulties. Designed with simplicity in mind, the system includes button controls for accessing additional information during use.		
This platform is especially useful for parents, as it allows them to access teaching techniques and strategies for their child. Communication between the user and the multidisciplinary team is streamlined, and progress is closely monitored with changes proposed to the intervention plan as necessary. Users can also add comments on interventions and the child's response, providing real-time feedback to further improve the intervention plan.		
	Content's quality	The information is well-structured and effectively differentiates between the objectives, context, results, and multimedia resources.
The information is well-structured and covers general and individual needs, including access to the parent's guide and setting work objectives based on the child's needs.		
		Has the content been validated? Does the text contain any spelling errors?
Information comes from reliable and scientifically validated sources, including applied behavior analysis studies and specialized books. The parent guide is organized according to developmental stages and provides clear information, while daily tasks are structured with specific objectives, activity suggestions, and work protocols. There are no typographical errors in the content of the platform.		
		Is the content relevant to the user's current situations and areas of interest?
The platform has been specifically designed for parents and therapists caring for children with ASD, other developmental disorders, or suspected developmental delays, with a focus on addressing each child's individual needs. To achieve this, the instructor creates a personalized profile at the beginning of use, enabling customized programs.		
Adaptability	***Versatility***	Is the educational software easy to integrate into other educational environments?
The platform aims to facilitate the teaching process and enhance knowledge retention and generalization. Furthermore, Module III (Cooperative Games) and Module IV (Video Modeling) can be applied not only in informal settings (such as home) but also in formal educational environments (e.g., school activities involving peer collaboration, or video modeling of routine activities like getting ready for classes).		
		Does the software allow for configuration changes, such as difficulty level, number of users, language, and so on?
Users can personalize the platform for their child by entering their child's information and selecting age-specific teaching objectives. Each module can also be customized to fit the child's individual needs and teaching objectives, such as choosing the scenario, object color, distractors, number of players, and game type.		
A current limitation of the platform is that information is only presented in the Romanian language.		
		Does the software include an evaluation system?
The platform records the child's answers and whether they were helped by the parent or therapist. Progress reports can be accessed by those involved in the child's therapy process.		
		Does it facilitate the development of new techniques and improved learning?
Module I allows the user to review information from the Parent's Guide, set goals, tasks, and record progress. Module II focuses on teaching expressive and receptive concepts in various scenarios, utilizing simple instructions and error-free teaching. The child receives ample practice opportunities to master the taught concepts, which are then applied to new activities to ensure retention and generalization.		
	Pedagogical aspects	Does it provide activities that maintain the child's curiosity and interest in the content while avoiding causing anxiety?
The platform uses attractive design and realistic scenarios. Instructors can customize teaching items by changing their color, or position based on the child's needs. The tasks are presented in a simple way and designed to capture the child's attention for response fluency. Errorless teaching techniques ensure correct responses and increase the child's success, while avoiding anxiety-inducing situations. Module II focuses on maintaining the child's attention, while Module III promotes curiosity and collaboration with a playing teammate. In Module IV, personal autonomy is emphasized to access animation through actions.		
		Does the software provide various types of activities that facilitate knowledge acquisition, allowing for its use in multiple ways?
The platform offers a variety of teaching modes based on ABA therapy, including receptive and expressive teaching modes. In addition, the platform utilizes video modeling and collaborative games to provide a well-rounded learning experience for the child. The software is designed to be adaptable and allow the user to choose from a variety of activities while still maintaining focus on the personalized intervention plan.		
	Stimulates initiative and self-learning	Does it enable the user to make decisions regarding the task performed and the teaching objectives?
A parent or caregiver can select the module based on their teaching objectives and customize the scenario according to specific details, including the teaching type, skills, time, and number of repetitions required to master the item.		
	Cognitive effort of the activities	Does the software enable easy memorization, interpretation, generalization, and experimentation?
The module structure is designed to gradually increase difficulty from easier levels to more complex ones, ensuring generalization and experimentation of concepts learned in different activities. Module I provides information and helps create an action plan. Modules II through IV progress from learning items in simple scenarios to demonstrating understanding in complex scenarios, promoting the child's efforts and comprehension. The strategy ensures an effective learning experience.		
Efficiency	***Audiovisual quality***	Does it have a well-designed UI that includes a title, menu, videos, sounds, pictures, and attractive colors?
The platform has a well-designed and pleasant user interface.		
	Navigation and interaction	Does the software have a well-organized program structure that allows for easy and quick access to content and activities?
The platform structure enables easy and quick access to content and activities, making navigation and interaction effortless.		
	Originality and use of advanced technology	Was the software developed with creativity and innovation?
The platform was developed collaboratively with the needs of children with ASD and instructors (parents and therapists) in mind, in order to provide a software that benefits both the child (learning new skills) and instructors (learning ABA techniques and strategies).		

process was conducted using the Quantitative Evaluation Framework (QEF). The QEF framework evaluates the quality of educational software, developed with XTEC based on the standard of reference ISO 9126 [61]. ISO 9126 is an internationally recognized standard that outlines procedures for assessing the quality of software. This comprehensive evaluation allowed for a complete analysis of the platform's strengths and weaknesses in fulfilling the criteria of educational software for use in an autism context. The results of the evaluation of the Autism Assistant platform using QEF are presented in Table 2. The software was evaluated across various dimensions, including functionality, adaptability, and efficiency.

The evaluation highlighted the platform's strengths in terms of ease-of-use functionality, high-quality informational content, adaptability, and well-implemented pedagogical strategies. It is praised for its ability to maintain the child's curiosity and interest in the content, while avoiding anxiety-inducing situations. The platform is also noted for its well-designed user interface and easy navigation, making it efficient. The evaluation provided a comprehensive assessment of the software's capabilities, highlighting its suitability for children with special needs and the potential for personalized learning experiences.

The conclusions regarding the suitability of the platform for educational purposes in ASD therapeutic intervention were drawn by only two specialists in ABA therapy, which is insufficient to make generalized conclusions. This limitation may affect the accuracy of the evaluation of the implemented modules. Therefore, it is necessary to assess the usability and acceptance of the platform by other users in order to determine their level of satisfaction.

To address these limitations, we propose conducting an experimental test of the application with parents and children diagnosed with ASD in the near future. The study will be carried out over a significant period of time to obtain accurate results. After practical experiments, we intend to use the Mann-Whitney [62] test to evaluate the satisfaction levels of parents, teachers, and children who have used the Autism Assistant application during the therapy process.

VI. CONCLUSION

This study aimed to investigate the theoretical and practical principles necessary to address the research question: "*How can educational software be designed to provide home-based therapeutic interventions for Romanian children under 8 diagnosed with ASD?*". To answer this question, we designed the Autism Assistant platform utilizing the Human-Centered Design methodology to ensure that the needs of the end-users - therapists, children with special needs, and their caregivers, were the primary focus of the design.

During the platform's development, we created various design elements such as proto-personas, wireframes, and interactive prototypes. We also collaborated with ABA therapists specializing in autism treatment to validate our ideas. The iterative development process allowed us to identify the best design and functionality requirements for an educational application catering to children with special needs. Thus, the platform incorporates the principles of ABA therapy, such as receptive and expressive learning methods, as well as educational techniques such as video modeling, which is an effective learning method by example.

We employed the latest technologies, such as the Unity game engine, Ruby on Rails, React, MySQL, Doozy UI, OneSignal, and Spine, to build well-structured and efficient modules, providing improved performance on mobile devices while conserving resources.

The Autism Assistant platform is suitable for use not only in home-based therapy, but also in educational centers that offer therapy sessions. It allows personalized educational content for individual or group-based learning and includes a module that encourages collaborative gaming.

Our evaluation of the platform's suitability as educational software utilized a quantitative evaluation framework based on ISO 9126, demonstrating that the software met the established criteria. The platform was described as an easy-to-use tool that provides quality therapeutic information for parents and caregivers. Moreover, its pleasing design helps maintain focus on the educational process. However, the validation requires further strengthening through practical experiments conducted over a significant period. Thus, future research will focus on evaluating the platform's impact on educational performance and user satisfaction using the Mann-Whitney test.

Moving forward, we propose the development of new modules for adolescents and young people with autism. These modules aim to enhance communication skills and interpersonal relationships by simulating real-life scenarios in a virtual environment using virtual reality technologies.

REFERENCES

[1] M. Gitimoghaddam, N. Chichkine, L. McArthur, S. S. Sangha, and V. Symington, "Applied behavior analysis in children and youth with autism spectrum disorders: A scoping review," *Perspect. Behav. Sci.*, vol. 45, no. 3, pp. 521–557, Sep. 2022, doi: 10.1007/s40614-022-00338-x.

[2] *Diagnostic and Statistical Manual of Mental Disorders: DSM-5*, American Psychiatric Association and American Psychiatric Association, Washington, DC, USA, 2013.

[3] L. Rylaarsdam and A. Guemez-Gamboa, "Genetic causes and modifiers of autism spectrum disorder," *Frontiers Cellular Neurosci.*, vol. 13, p. 385, Aug. 2019, doi: 10.3389/fncel.2019.00385.

[4] Y. Leitner, "The co-occurrence of autism and attention deficit hyperactivity disorder in children—What do we know?" *Frontiers Hum. Neurosci.*, vol. 8, p. 268, Apr. 2014, doi: 10.3389/fnhum.2014.00268.

[5] S. S. Chahin, R. W. Apple, K. H. Kuo, and C. A. Dickson, "Autism spectrum disorder: Psychological and functional assessment, and behavioral treatment approaches," *Transl. Pediatrics*, vol. 9, no. S1, pp. S66–S75, Feb. 2020, doi: 10.21037/tp.2019.11.06.

[6] Q. Yu, E. Li, L. Li, and W. Liang, "Efficacy of interventions based on applied behavior analysis for autism spectrum disorder: A meta-analysis," *Psychiatry Invest.*, vol. 17, no. 5, pp. 432–443, May 2020, doi: 10.30773/pi.2019.0229.

[7] B. Reichow, K. Hume, E. E. Barton, and B. A. Boyd, "Early intensive behavioral intervention (EIBI) for young children with autism spectrum disorders (ASD)," *Cochrane Database Systematic Rev.*, vol. 2018, no. 10, May 2018, Art. no. CD009260, doi: 10.1002/14651858.CD009260.pub3.

[8] World Health Organization. (Mar. 29, 2023). *Autism*. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders

[9] M. Elsabbagh, G. Divan, Y.-J. Koh, Y. S. Kim, S. Kauchali, C. Marcín, C. Montiel-Nava, V. Patel, C. S. Paula, C. Wang, M. T. Yasamy, and E. Fombonne, "Global prevalence of autism and other pervasive developmental disorders: Global epidemiology of autism," *Autism Res.*, vol. 5, no. 3, pp. 160–179, Jun. 2012, doi: 10.1002/aur.239.

[10] R. Hood, A. Goldacre, S. Gorin, and P. Bywaters, "Screen, ration and churn: Demand management and the crisis in children's social care," *Brit. J. Social Work*, vol. 50, no. 3, pp. 868–889, Apr. 2020, doi: 10.1093/bjsw/bcz035.

[11] A. Mullan, K. Boyd, and R. McConkey, "The impact of a brief home-based intervention on families with a child with autism spectrum disorder," *J. Develop. Phys. Disabilities*, vol. 33, no. 4, pp. 693–708, Aug. 2021, doi: 10.1007/s10882-020-09768-4.

[12] A. L. Rickards, J. E. Walstab, R. A. Wright-Rossi, J. Simpson, and D. S. Reddihough, "A randomized, controlled trial of a home-based intervention program for children with autism and developmental delay," *J. Develop. Behav. Pediatrics*, vol. 28, no. 4, pp. 308–316, Aug. 2007, doi: 10.1097/DBP.0b013e318032792e.

[13] K. Nohelty, C. B. Bradford, L. Hirschfeld, C. Miyake, and M. N. Novack, "Effectiveness of telehealth direct therapy for individuals with autism spectrum disorder," *Behav. Anal. Pract.*, vol. 15, no. 3, pp. 643–658, Sep. 2022, doi: 10.1007/s40617-021-00603-6.

[14] V. Bono, A. Narzisi, A.-L. Jouen, E. Tilmont, S. Hommel, W. Jamal, J. Xavier, L. Billeci, K. Maharatna, M. Wald, M. Chetouani, D. Cohen, and F. Muratori, "GOLIAH: A gaming platform for home-based intervention in autism—Principles and design," *Frontiers Psychiatry*, vol. 7, pp. 1–10, Apr. 2016, doi: 10.3389/fpsyt.2016.00070.

[15] K. Valencia, C. Rusu, D. Quiñones, and E. Jamet, "The impact of technology on people with autism spectrum disorder: A systematic literature review," *Sensors*, vol. 19, no. 20, p. 4485, Oct. 2019, doi: 10.3390/s19204485.

[16] P. W. S. Leung, S. X. Li, C. S. O. Tsang, B. L. C. Chow, and W. C. W. Wong, "Effectiveness of using mobile technology to improve cognitive and social skills among individuals with autism spectrum disorder: Systematic literature review," *JMIR Mental Health*, vol. 8, no. 9, Sep. 2021, Art. no. e20892, doi: 10.2196/20892.

[17] E. V. Larsson and S. Wright, "In memoriam: O. Ivar lovaas (1927–2010)," *Behav. Analyst*, vol. 34, no. 1, pp. 111–114, Apr. 2011, doi: 10.1007/BF03392239.

[18] R. Aishworiya, T. Valica, R. Hagerman, and B. Restrepo, "An update on psychopharmacological treatment of autism spectrum disorder," *Neurotherapeutics*, vol. 19, no. 1, pp. 248–262, Jan. 2022, doi: 10.1007/s13311-022-01183-1.

[19] H. J. Nuske and D. S. Mandell, "Digital health should augment (not replace) autism treatment providers," *Autism*, vol. 25, no. 7, pp. 1825–1827, Oct. 2021, doi: 10.1177/13623613211043368.

[20] X. Liu, Q. Wu, W. Zhao, and X. Luo, "Technology-facilitated diagnosis and treatment of individuals with autism spectrum disorder: An engineering perspective," *Appl. Sci.*, vol. 7, no. 10, p. 1051, Oct. 2017, doi: 10.3390/app7101051.

[21] J. W. Kim, T.-Q. Nguyen, S. Y.-M.-T. Gipson, A. L. Shin, and J. Torous, "Smartphone apps for autism spectrum disorder—Understanding the evidence," *J. Technol. Behav. Sci.*, vol. 3, no. 1, pp. 1–4, Mar. 2018, doi: 10.1007/s41347-017-0040-4.

[22] R. Munoz, C. Morales, R. Villarroel, Á. Quezada, and V. H. C. De Albuquerque, "Developing a software that supports the improvement of the theory of mind in children with autism spectrum disorder," *IEEE Access*, vol. 7, pp. 7948–7956, 2019, doi: 10.1109/ACCESS.2018.2890220.

[23] C. D. P. Gallardo-Montes, M. J. C. Cara, and A. R. Fuentes, "Technologies in the education of children and teenagers with autism: Evaluation and classification of apps by work areas," *Educ. Inf. Technol.*, vol. 27, no. 3, pp. 4087–4115, Apr. 2022, doi: 10.1007/s10639-021-10773-z.

[24] R. Munoz, R. Villarroel, T. S. Barcelos, F. Riquelme, Á. Quezada, and P. Bustos-Valenzuela, "Developing computational thinking skills in adolescents with autism spectrum disorder through digital game programming," *IEEE Access*, vol. 6, pp. 63880–63889, 2018, doi: 10.1109/ACCESS.2018.2877417.

[25] M. Xanthopoulou, G. Kokalia, and A. Drigas, "Applications for children with autism in preschool and primary education," *Int. J. Recent Contrib. Eng., Sci. IT*, vol. 7, no. 2, p. 4, Jun. 2019, doi: 10.3991/ijes.v7i2.10335.

[26] F. M. D. A. Dias, D. F. Rodrigues, and C. H. M. D. Souza, "Mobile applications for autisticchildren: An analysis of the Google play store platform," *Int. J. Adv. Eng. Res. Sci.*, vol. 7, no. 9, pp. 476–486, 2020, doi: 10.22161/ijaers.79.55.

[27] 22 MEDIA. (May 7, 2021). *Romanian Language Learning Game*. [Online]. Available: https://play.google.com/store/apps/details?id=com.media22.invatajucandromaneste&pli=1

[28] Dream Oriented. (Nov. 22, 2017). *Leeloo AAC—Autism Speech App*. [Online]. Available: https://play.google.com/store/apps/details?id=org.dreamoriented.leeloo&hl=en_US

[29] LADistribution. (Apr. 1, 2014). *Tell a Story—Speech & Logic*. [Online]. Available: https://play.google.com/store/apps/details?id=com.hedgehogacademy.sequencesfree&hl=en_US

[30] S. Fletcher-Watson, "A targeted review of computer-assisted learning for people with autism spectrum disorder: Towards a consistent methodology," *Rev. J. Autism Develop. Disorders*, vol. 1, no. 2, pp. 87–100, Jun. 2014, doi: 10.1007/s40489-013-0003-4.

[31] P. Michel, "The use of technology in the study, diagnosis and treatment of autism," in *Final Term Paper for CSC350: Autism and Associated Developmental Disorders*. New Haven, CT, USA: Yale Univ. Press, 2004, pp. 1–26.

[32] Z. Zohoorian, M. Zeraatpishe, and N. M. Sadr, "Effectiveness of the picture exchange communication system in teaching English vocabulary in children with autism spectrum disorders: A single-subject study," *Cogent Educ.*, vol. 8, no. 1, Jan. 2021, Art. no. 1892995, doi: 10.1080/2331186X.2021.1892995.

[33] V. T. Mueller, "Voice output communication aids," in *Encyclopedia of Autism Spectrum Disorders*, F. R. Volkmar, Ed. New York, NY, USA: Springer, 2013, pp. 3338–3341, doi: 10.1007/978-1-4419-1698-3_1713.

[34] S. Baron-Cohen and T. Tead, "Mind reading: The interactive guide to emotion," *J. Can. Acad. Child Adolescent Psychiatry*, vol. 16, no. 4, p. 182. Jan. 2002.

[35] E. C. Bouck, M. Savage, N. K. Meyer, T. Taber-Doughty, and M. Hunley, "High-tech or low-tech? Comparing self-monitoring systems to increase task independence for students with autism," *Focus Autism Other Develop. Disabilities*, vol. 29, no. 3, pp. 156–167, Sep. 2014, doi: 10.1177/1088357614528797.

[36] F. D. DiGennaro Reed, S. R. Hyman, and J. M. Hirst, "Applications of technology to teach social skills to children with autism," *Res. Autism Spectr. Disorders*, vol. 5, no. 3, pp. 1003–1010, Jul. 2011, doi: 10.1016/j.rasd.2011.01.022.

[37] G. De Leo, C. H. Gonzales, P. Battagiri, and G. Leroy, "A smart-phone application and a companion website for the improvement of the communication skills of children with autism: Clinical rationale, technical development and preliminary results," *J. Med. Syst.*, vol. 35, no. 4, pp. 703–711, Aug. 2011, doi: 10.1007/s10916-009-9407-1.

[38] M. Heimann, K. E. Nelson, T. Tjus, and C. Gillberg, "Increasing reading and communication skills in children with autism through an interactive multimedia computer program," *J. Autism Develop. Disorders*, vol. 25, no. 5, pp. 459–480, Oct. 1995, doi: 10.1007/BF02178294.

[39] A. F. A. Dawodi, S. F. Alzahrani, R. A. Almumtin, S. S. Alshyban, M. Alshabanah, D. Alrajhi, M. K. Alsmadi, and I. Almarashdeh, "Developing and implementing an online learning platform for children with autism," *Int. J. Sci. Res. Sci. Technol.*, pp. 176–188, Mar. 2020, doi: 10.32628/IJSRST207162.

[40] L. P. Rojas-Torres, Y. Alonso-Esteban, and F. Alcantud-Marín, "Early intervention with parents of children with autism spectrum disorders: A review of programs," *Children*, vol. 7, no. 12, p. 294, Dec. 2020, doi: 10.3390/children7120294.

[41] D. Papadopoulos, "Mothers' experiences and challenges raising a child with autism spectrum disorder: A qualitative study," *Brain Sci.*, vol. 11, no. 3, p. 309, Mar. 2021, doi: 10.3390/brainsci11030309.

[42] A. K. Dey, "Understanding and using context," *Pers. Ubiquitous Comput.*, vol. 5, no. 1, pp. 4–7, Feb. 2001, doi: 10.1007/s007790170019.

[43] M. Budisteanu, F. Rad, V. Tudosie, R. Zgura, B. Budisteanu, S. M. Papuc, A. Tutulan-Cunita, A. Arghir, and I. Dobrescu, "Prevalence study of autism spectrum disorder in Romania," *Eur. J. Paediatric Neurol.*, vol. 21, p. e143, Jun. 2017, doi: 10.1016/j.ejpn.2017.04.1291.

[44] N. Babich. (Jul. 9, 2020). *Human-Centered Design: An Introduction, Practices, and Principles*. [Online]. Available: https://www.shopify.com/partners/blog/human-centered-design

[45] M. Melles, A. Albayrak, and R. Goossens, "Innovating health care: Key characteristics of human-centered design," *Int. J. Quality Health Care*, vol. 33, no. 1, pp. 37–44, Jan. 2021, doi: 10.1093/intqhc/mzaa127.

[46] UNICEF. (2016). *Human Centred Design (HCD*. [Online]. Available: https://www.unicef.org/innovation/hcd
[47] *Eleven Lessons: Managing Design in Eleven Global Brands A Study of the Design Process*, Design Council, London, U.K., 2022.
[48] D. Nessler. (Feb. 6, 2018). *How to Apply a Design Thinking, HCD, UX or Any Creative Process From Scratch—Revised & New Version*. [Online]. Available: https://uxdesign.cc/how-to-solve-problems-applying-a-uxdesign-designthinking-hcd-or-any-design-process-from-scratch-v2-aa16e2dd550b
[49] D. A. Norman, *The Design of Everyday Things*. New York, NY, USA: Basic Books, 2013.
[50] A. J. Jacobs. (Sep. 12, 2016). *UX: Creating Proto-Personas*. [Online]. Available: https://uxdesign.cc/ux-creating-proto-personas-76a1738401a2
[51] E. G. Pinheiro, L. A. Lopes, T. U. Conte, and L. A. M. Zaina, "On the contributions of non-technical stakeholders to describing UX requirements by applying proto-persona," *J. Softw. Eng. Res. Develop.*, vol. 7, p. 8, Dec. 2019, doi: 10.5753/jserd.2019.155.
[52] R. Gonzalez. (Oct. 20, 2020). *Figma Wants Designers to Collaborate Google-Docs Style*. [Online]. Available: https://www.wired.com/story/figma-updates/
[53] J. J. Garrett, *The Elements of User Experience: User-Centered Design for the Web and Beyond*, 2nd ed. Berkeley, CA, USA: New Riders, 2011.
[54] (Jan. 10, 2023). *Why Wireframes are Important in the Design Process*. [Online]. Available: https://blog.proto.io/wireframes-design-process/
[55] Z. Zehra. *What is a Clickable Prototype and How to Create it?* Accessed: May 1, 2023. [Online]. Available: https://www.educative.io/answers/what-is-a-clickable-prototype-and-how-to-create-it
[56] *Active Record Basics*. Accessed: May 1, 2023. [Online]. Available: https://guides.rubyonrails.org/active_record_basics.html
[57] M. de Sousa and A. Gonçalves, "Humanportal—A React.Js case study," in *Proc. 15th Iberian Conf. Inf. Syst. Technol. (CISTI)*, Jun. 2020, pp. 1–6, doi: 10.23919/CISTI49556.2020.9141070.
[58] S. Singh and A. Kaur, "Game development using unity game engine," in *Proc. 3rd Int. Conf. Comput., Anal. Netw. (ICAN)*, Nov. 2022, pp. 1–6, doi: 10.1109/ICAN56228.2022.10007155.
[59] D. Marie. (Jan. 16, 2023). *What is the Best Game Engine: Is Unity Right for You?* [Online]. Available: https://www.gamesindustry.biz/what-is-the-best-game-engine-is-unity-the-right-game-engine-for-you
[60] *Spine. 2D Animation for Games*. Accessed: May 1, 2023. [Online]. Available: https://esotericsoftware.com/
[61] P. Escudeiro, J. Bidarra, and N. Escudeiro, "Evaluating educational software," *J. Systemics, Cybern. Inform.*, vol. 1, pp. 177–182, Jan. 2009.
[62] A. Hart, "Mann-whitney test is not just a test of medians: Differences in spread can be important," *BMJ*, vol. 323, no. 7309, pp. 391–393, Aug. 2001, doi: 10.1136/bmj.323.7309.391.

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