Technology-Mediated Interventions for Autism Spectrum Disorder

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***Abstract*—According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), Autism Spectrum Disorder (ASD) is a complex neurological and developmental condition characterized by impairments in social interaction and communication. Despite significant advancements in the research field, no pharmaceutical medication has been designed for ASD treatment. Therefore, ASD treatment relies mainly on therapeutic intervention. Interactive technologies have emerged as valuable therapy augmentation tools. This research focuses on interactive technologies developed for ASD therapeutic intervention. The study introduces a conceptual framework for understanding the full spectrum of technologies involved in the ASD context. The employed methodology encompasses expert opinions and entails a cross-sectional study that included 59 participants with significant experience in interacting with individuals diagnosed with ASD in various real-life settings, including therapists, teachers, and parents of children with ASD. The research findings revealed a broad spectrum of technologies involved in ASD interventions, including applications, devices, and robots. The results bring a new perspective on the interactive technologies used in the therapy and diagnosis of ASD and highlight their important characteristics that can serve as a standard in the development of future technological solutions.**

***Keywords*—Autism spectrum disorder; technology-mediated interventions; assistive technologies; therapy; cross-sectional study**

I. Introduction

The technological prowess of human beings has been a defining characteristic since the dawn of our existence. Even in ancient times, our ancestors created innovative tools from stone to help them survive and work more efficiently. As time has passed, our desire to augment our lives through technology has only increased, and it is now a ubiquitous presence in all aspects of modern society. We rely on technology to communicate, enhance our physical capabilities, perform complex computations, and even cure medical conditions. From the earliest inventions to the latest cutting-edge breakthroughs, technology has been the driving force behind human progress and the key to unlocking new levels of knowledge and achievement. Technology is playing a critical role in shaping our world and advancing civilizations to new heights. But sometimes, some peaks are difficult to conquer. Similar to climbing Mount Everest, the development of medical technologies is a challenge because it is difficult to create applications and devices that efficiently diagnose and treat a disease. In the last century, Leo Kanner published a groundbreaking paper about early infantile autism [1] initiating a quest among therapists, doctors, and researchers to devise effective practices and interventions for treating autism spectrum disorder (ASD). However, it is a difficult task as this human condition ASD is a neurodevelopmental disorder characterized by deficits in social communication and the presence of restricted interests and repetitive behaviors [2]. Autism is frequently accompanied by other conditions such as epilepsy, depression, anxiety, attention deficit and hyperactivity disorder, as well as difficult behaviors like self-injury and sleep disturbances [3]. As a result, some individuals with autism can function independently, while others require lifelong assistance due to the severity of their disabilities.

Despite the fact that contemporary research shows people with autism are highly interested in using technology, they often require support from an intermediary person such as a caregiver, to use it effectively. This research enlisted the help of parents, teachers, and therapists who had children with ASD under their care. Their insights into the technologies used, goals pursued, desirable features, and drawbacks, as well as the digital solutions' adaptability to the social-cultural context, were instrumental in identifying the interactive technology aimed at ASD therapy.

According to the European Parliament's Research Service technologies for ASDs are less mature [4] and effects of technology-mediated interventions (TMIs) in ASD should be better understood. Thus, we adopted a new methodological strategy to understand the usability of technology-mediated therapeutic interventions in ASD. This approach involved the collection of expert opinions, real-world experiences of caregivers, and academic research. This innovative framework added depth and clarity to the results obtained. The structure of this paper is designed to provide a comprehensive understanding of the benefits and limitations of using interactive technologies in autism therapy. Section II of this paper presents the methodology. Section III offers a detailed analysis of the results and findings. In Section IV, we delve into a discussion about limitations of this study. Finally, we conclude the paper in Section V by summarizing the key takeaways and implications of our findings.

II. Materials and Methods

The main objective of this research is to explore the most efficient ASD therapies and cutting-edge technologies that can be integrated into therapy to facilitate the treatment of children diagnosed with autism. To address each topic of interest, we formulated three research questions presented in Table I.

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TABLE I. RESEARCH QUESTIONS

ID	Research Question (RQ)
RQ_1	What therapies are used in the ASD treatment?
RQ_2	What technologies are employed in ASD therapeutic intervention?
RQ_3	What characteristics should technologies employed in ASD therapeutic interventions possess in order to effectively meet the needs of individuals with autism and promote positive outcomes?

In this study, we employed two research methods: expert opinion and cross-sectional study. Expert opinion was used to collect and analyze the opinions of professionals who have extensive experience working with individuals with autism, including medical practitioners and therapists. Through in-depth interviews, we were able to gain a deep understanding of the most effective therapeutic strategies. Cross-sectional study was conducted to explore and collect data directly from the end-users of the ASD technologies, including parents, therapists and teachers. This allowed us to obtain feedback on the usability and effectiveness of the interactive technologies in real-world settings. The research methodology was approved by the Research Ethics Board of Ștefan cel Mare University of Suceava, Romania, approval number 128.

A. Participants

1) Expert opinion participants: Expert opinion participants were selected based on rigorous criteria to ensure their qualifications. These criteria included: having accredited studies, approved by the College of Psychologists in Romania, possess extensive professional experience, showcase the ability to develop effective therapeutic intervention plans, and actively engage in academic activities such as participation in conferences, workshops, and research studies. As a result of selection process, two experts were invited to collaborate. The first expert brings more than a decade of experience in the field of psychology. He holds a certificate of practice in clinical psychology and specializes in Ericksonian Psychotherapy and Hypnosis. Additionally, he is internationally accredited as a Board Certified Behavior Analyst (BCBA). The second expert has over nine years of experience in Applied Behavior Analysis (ABA) therapy and is internationally accredited as a BCBA in behavioral analysis.

2) Cross-sectional study participants: Cross-sectional study involved individuals who have regular interactions with children diagnosed with ASD including: therapists, teachers, and parents. Over 100 individuals affiliated with the Association for Autism Intervention Suceava (AIAS), located in Romania, were invited to participate in the study and share their experiences by completing the survey using the web-based version of Google Forms. A total of 60 participants responded to the survey.

Fig. 1 illustrates the distribution of participants based on their roles, indicating that the majority of the participants 74.6% were parents of children with autism, while therapists accounted 23.7%. Unfortunately, only one teacher expressed interest in participating in the study, highlighting the educational system's reluctance towards individuals diagnosed with autism in Romania.

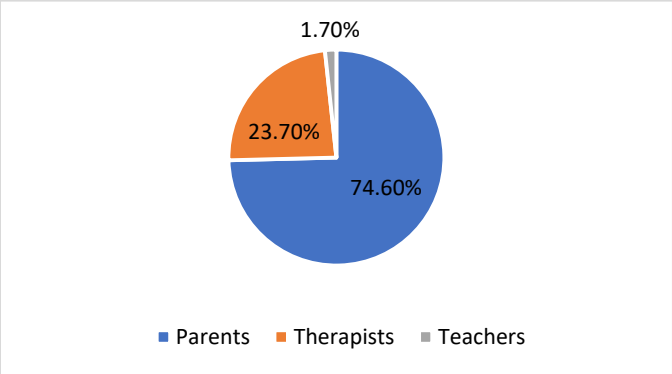


Fig. 1. Distribution of participants in the cross-sectional study based on their role in the lives of patients with autism.

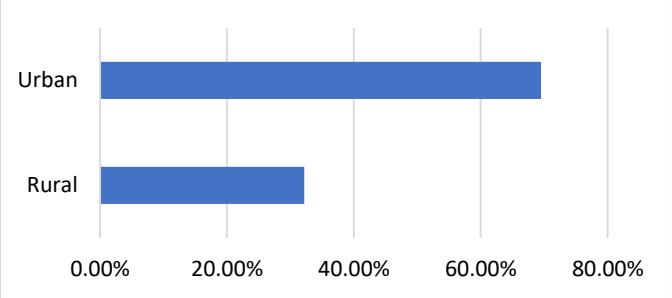


Fig. 2. Administrative organization in which the study participants reside.

In order to capture the diversity of personal experiences and socioeconomic backgrounds, the study included individuals from urban and rural administrative organizations. Fig. 2 presents the distribution of study participants based on their residence. The data reveals that the proportion of participants living in rural areas was 32.2%, which is lower than the proportion from urban areas 67.8%.

The importance of the participants' experience in interacting with people affected by ASD was the central aspect. Thus, we included both individuals with extensive experience of over 18 years, as well as beginners with only 1 year of experience in order to ensure diversity in the study. This method allowed to highlight both traditional and innovative approaches. Fig. 3 illustrates the distribution of participants' experience in years.

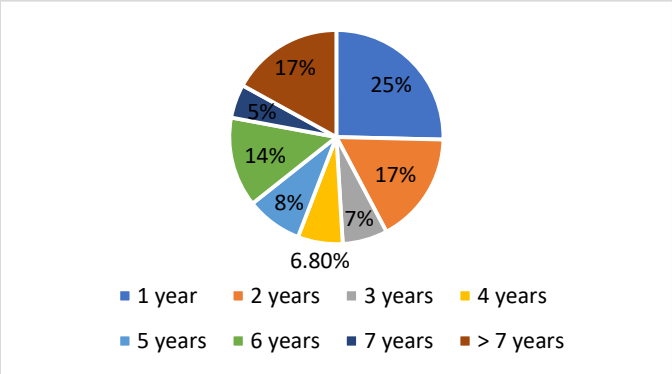


Fig. 3. Participants' experience expressed in years of interaction with ASD patients.

More than 22.1% of the participants are highly experienced individuals who possess a deep understanding of the behavior of patients with ASD. Meanwhile, 25.4% of the participants are novices with just 1 year of experience, which makes them well-suited for analyzing diagnostic methods, as their experiences are fresh. Additionally, 52.5% of participants possess notable experience ranging from two to six years.

B. Data Collection

1) Expert opinion data collection: Collaboration with therapists began in November 2022 and lasted six months. This partnership involved a mix of physical and online meetings, using the Microsoft Teams platform, version 1.0. The team interacted with therapists to discuss diverse aspects of therapeutic methods, the use of technology, and the specific abilities and disabilities of children with ASD.

The collaboration with therapists went beyond interviews, as we had the opportunity to observe therapy sessions in a real environment at the AIAS therapy center (see Fig. 4). During our observation, we paid attention to the educational materials used in therapy, including their content and visual representation. Furthermore, we became aware of the importance of the input type available in technologies for ASD, as we noticed that many children had challenges such as fine motor disabilities or speech impairments.

2) Cross-sectional study data collection: Conducting a cross-sectional study is a common method for collecting data from a specific population at a particular time. Our study focused on children diagnosed with ASD and their caregivers, with Romania serving as our research location. To reach our target population, 100 individuals, affiliated with AIAS therapy center, were invited via emails and social media to participate in the research, of which 59 expressed their willingness to participate, indicating a response rate of 59%. Ethical standards where followed during the study, the researchers informed participants about the study's scope and purpose, and participants were required to sign an agreement before their involvement.

To collect data, we used a survey questionnaire designed to explore the utilization of technologies in autism context. The questionnaire was created using Google Forms. Google Forms is a web-based app developed by Google which is used to create forms for data collection purposes [5]. The questionnaire was made available on February 1, 2023, and the participants' responses were collected over a period of three weeks.

The survey contained open-ended questions, multiple-choice questions, and Likert scales to evaluate the importance of certain factors related to technology use for ASD diagnosis, therapy, and entertainment. The survey consisted of four distinct categories. The first category focused on the experience of parents and therapists, posing questions about their background and experience in caring for children with autism. The second category inquired about the child's diagnosis and abilities, asking about the age of diagnosis and the child's functional level. The third category was centered around technologies and personal experiences in using them, with participants answering questions about their use of different technologies in the autism context.

Fig. 4. The collaboration with the ASD experts from the AIAS therapy center located in Suceava, Romania.

The fourth category was directed at identifying the best characteristics and features of technologies suitable for children with autism.

After concluding the data collection phase, we proceeded to perform statistical analysis on the gathered responses in order to detect patterns and trends within the data. The survey questionnaire results offered valuable insights into the use of technologies and therapeutic interventions for children with autism in Romania. These findings provided an overview of the real needs of parents, caregivers and children with ASD, highlighting the challenges they face, especially when access to formal therapy services is limited due to financial constraints.

III. Results

The results of this study are structured into three subsections, each addressing a specific research question:

Subsection A "Therapies for ASD Treatment" focuses on research question RQ_1 and reviews therapies that have demonstrated efficacy in ameliorating ASD symptoms.

Subsection B "Technologies in ASD" addresses research question RQ_2 and presents the technologies used to improve outcomes and provide support for people with ASD.

Subsection C "Characteristics of Technologies in ASD Therapeutic Interventions" answers RQ_3 and presents the key features of therapeutic technologies.

The results from the expert opinion and cross-sectional study are presented in a cohesive manner. By coupling theoretical frameworks and empirical evidence we aim to provide new insights and implications in the field of technology-mediated ASD interventions.

A. Therapies for ASD Treatment

The World Health Organization (WHO) estimates that worldwide about 1 in 100 children has autism [3]. The statistics surrounding this condition have raised concerns and encouraged researchers to investigate its etymology and potential treatments. Advances in autism research have gone hand in hand with significant progress in international policy. In May 2014, the Sixty-seventh World Health Assembly adopted a resolution entitled "Comprehensive and coordinated efforts for the management of autism spectrum disorders", which was supported by more than 60 countries. The resolution urges WHO to collaborate with Member States and partner agencies to strengthen national capacities to address ASD and other developmental disabilities ("Autism," n.d.). These legislative, social, medical and research efforts have led to the development of intervention and support strategies for people with ASD. In many countries, children can benefit from therapy and special education starting with kindergarten. The education learning plan is developed by a team of professionals and the child's parent. It is very important that parents are involved in the decisions that affect the education of their child. During the learning process, many types of therapies are applied. The most effective therapies according to the experts opinion are presented below.

1) Behavioral therapy: ABA is the most well supported intervention for ASD. ABA is the use of scientifically based behavioral principles in everyday situations. ABA Therapy works toward goals that help to increase or decrease different behaviors. All ABA programs share similar components, including specialized instructional strategies and parental involvement. ABA helps teaching skills that can be used at home, school, and in other settings [6]. Most commonly used ABA programs include: early intensive behavioral intervention (EIBI), positive behavioral and support (PBS), pivotal response training (PRT), discrete trial teaching (DTT) and relationship development interventions (RDI) [7].

2) Communication, speech and language therapy: Individuals diagnosed with ASD can experience communication difficulties regardless of their condition. Some individuals may not have acquired verbal communication skills at all, while others may have strong verbal abilities but struggle with social communication and interaction.

Speech and language therapy can help people with autism to improve their abilities to communicate and interact with others [8]. The therapy is designed to improve communication skills for both verbal and non-verbal individuals. It focuses on developing verbal communication skills, including pronunciation, syntax, and grammar, to help the person make themselves understood more easily and on developing non-verbal communication skills such as eye contact, gestures and body language, as well as on learning to interpret and respond to social cues.

3) Occupational therapy: Occupational therapy (OT) helps people ASD do everyday tasks by finding ways to work within and make the most of their needs, abilities, and interests [9]. Occupational therapists contribute to the care of children and adults with intellectual and developmental disabilities by focusing on activities and goals that are meaningful to the individuals and their families. Relevant performance areas include cognitive, sensory, perceptual, motor and psychosocial [10]. Occupational therapy methods include play-based activities as a way to help patients develop social and communication skills, and learning through movement activities to help patients improve motor and coordination aptitudes. Assistive technologies (ATs) are another important tool used in occupational therapy. Communication through tablets or other devices can help individuals with ASD to develop their communication skills and express their thoughts and emotions. .

4) Physical therapy: The way a person can use their motor skills impacts the ability to perform tasks. Sometimes individuals with autism have less developed motor skills and completing simple activities such as walking, climbing, or dressing is a challenge for them. Physical therapy can help in treating these disabilities. Physical therapy methods for individuals with autism may include adapted physical training activities and games that involve movement. In physical therapy the therapist works on physical limitations to help a person to develop muscles, balance and coordination needed for day-to-day activities [6]. The effectiveness of therapy in treating individuals with autism can vary depending on the severity of the condition.

5) Cognitive behavior therapy: Cognitive Behavioral Therapy (CBT) refers to a group of well-researched techniques that are effective in treating difficulties experienced by children and adults. CBT works well for treating anxiety and mood disorders, teaching stress and anger management, and improving interpersonal skills [6]. CBT generally consists of 12 to 18 1-h sessions and focuses on identifying and changing problematic thinking and behavioral patterns that maintain the youth's presenting symptomatology [11]. CBT combines two different approaches: cognitive therapy and behavioral therapy, to help change maladaptive thoughts and behaviors. Cognitive therapy focuses on changing the negative or distorted thoughts and perceptions of people with autism by learning techniques for self-observation and reflection on thoughts and feelings, identifying and replacing negative thoughts with more positive and realistic thoughts. Behavioral therapy focuses on changing maladaptive behaviors by learning new and healthier behaviors, such as developing social skills or developing a stress management program. CBT techniques have proven their effectiveness in studies conducted on adults and adolescents, clinical

experience shows that individual therapy with children of preschool/school age must involve a certain level of play therapy.

Svetha Venkatesh from Curtin University, Australia et al. presented the "Playpad" multimedia-based system for delivering early intervention therapy for autism [12]. The system is based on cognitive therapy and allows individuals with autism to learn by performing natural interactions such as pointing and touching. Parents or non-experts can use the system to deliver home-based therapy, while therapists can construct lessons by specifying stimulus concepts and variations. Trials of the system have shown its effectiveness in training both adults and autistic children.

6) Art therapy: ASD is a condition that can affect sensorial functions, communication, and interpersonal relationships, leading to challenges in areas such as emotional, social, and behavioral interactions. Art therapy has the potential to address these complex issues due to its multisensory nature and relational approach [13]. Art therapy allows people with ASD to use their already visually-minded brains to communicate through artistic media. They can record images and visual data, express ideas and process memories that they are unable to do verbally [14]. Engaging in art therapy on a regular basis can benefit ASD individuals by promoting better family interactions, enhancing self-esteem, and improving emotional regulation both at school and home. Exposure to a variety of art materials can also contribute to the development of fine and gross motor dexterities, while providing children with the ability to adapt easily to new or unfamiliar situations. Most art therapy sessions are one-on-one, they can occur in a group setting, too. Working collaboratively on a single piece of art also fosters peer relationships. In this type of setting, one child draws something and the picture is passed to the next person, who adds to the work until everyone has contributed their part. This activity allows the children to acknowledge those around them and be more aware of others and their involvement in the project.

7) Autism therapies in practice: There is no prescription medication designed to treat ASD [6]. For this reason, therapies become extremely important in the treatment process of this condition. Choosing the appropriate therapy to treat the individual with ASD is a complex process that involves a multitude of factors, including patient symptoms, comorbidities, family, and physician expertise. In addition to these obvious factors, the choice of therapeutic method is also influenced by social norms, cultural values, and legal regulations. In countries that have progressive health insurance legislation, there is a significant evolution in the diversity of medical interventions for ASD treatment. However, in countries with a less developed medical system such as Romania, the diversity of therapies can be limited. In Romania the education for children with special needs began with segregation during the communist period [15]. In this context, our study aimed to identify the therapies practiced in real-life settings for the treatment of ASD symptoms in Romania. To achieve this, we conducted a cross-sectional study that involved 59 participants including parents and therapists who have experience in working with children with autism. Given the small data size we performed the statistical analysis of the answers received and identified that 84.7% of the study participants currently use therapeutic methods to improve children's abilities. A worrying fact is that more than 6% of the participants did not use any therapy at all, despite the ASD diagnosis (see Fig. 5). Experts in the field suggest that the abandonment of therapy practice can be attributed to insufficient financial resources.

Families often depend solely on the income from the patient's personal caregiver role. Furthermore, the limited availability of specialized facilities and services in Romania results in difficulties in accessing therapeutic support. The geographical distance between family residences and therapeutic centers presents another challenge, making it harder for individuals with ASD to access treatments.

Fig. 6 presents the therapies practiced in real life in Romania. We identified that the most commonly used therapies in the treatment of ASD patients are classic therapies, such as ABA Therapy, communication, speech and language therapy, sensory integration, and physical therapy. Many of these therapies are performed in an integrative way, combined with other complementary therapies, such as art therapy and 3C therapy.

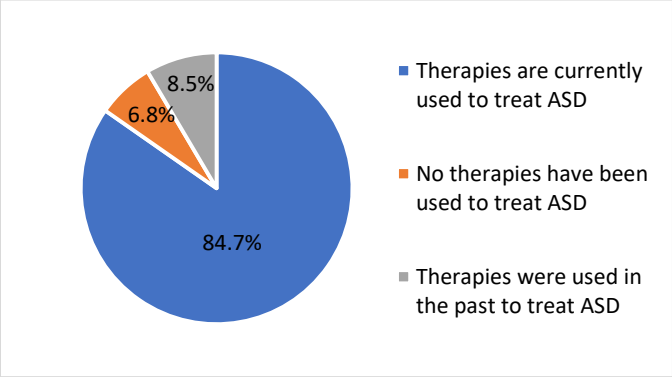


Fig. 5. Statistics on the use of ASD therapies.

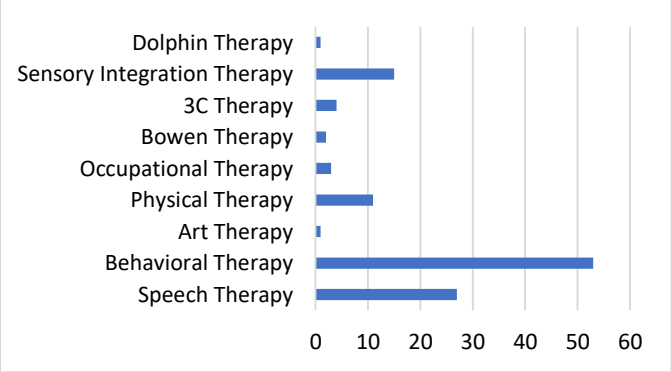


Fig. 6. ASD therapies practiced in real-life by the study participants.

B. Technologies in ASD

The medical field has evolved significantly in the 21st century due to the strong involvement of new technologies in diagnosis and treatment methods. In contemporary society, concepts such as telehealth and telemedicine have become common. Technologies are used for providing different medical services such as medical consultations through video calls, real-time diagnosis, or remote monitoring despite the fact that patients and medical professionals are in different locations. ASD therapy has also been impacted by technological evolution. Therapeutic strategies have integrated various types of interactive technologies to improve patients' abilities.

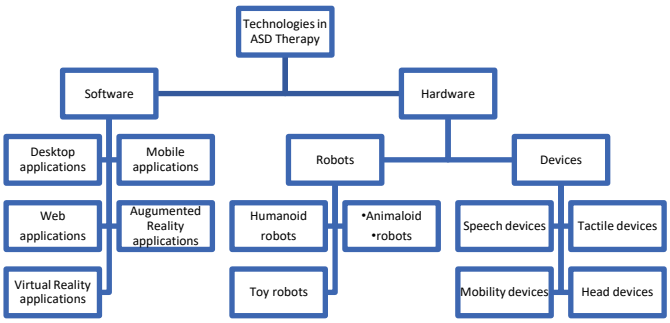


Fig. 7. Classification of technologies used in ASD therapy.

Studies [16], [17], [18] highlighted the idea that technologies used in teaching and therapy are well accepted by individuals with autism.

Technology can be defined as any electronic item, equipment, application, or virtual network that is used intentionally to increase, maintain, or improve daily living, work, productivity, recreation, and leisure capabilities of individuals with ASD [19]. Following our research results, we have proposed a classification of the technologies used in ASD therapy based on their features and characteristics. It is presented in Fig. 7.

Hardware technologies include robots and electronic devices that have computerized physical components such as sensors and actuators. These devices can be programmed to provide real-time feedback, detect and respond to gestures and movements, or provide support based on individual patient needs. On the other hand, software technologies represent packages of software modules containing instructions, documents, and procedures that perform various tasks, these being desktop applications, mobile applications, web applications or augmented reality (AR), or virtual reality (VR) applications. Software technologies are typically used to support therapists and patients in the treatment process, allowing therapy to be customized according to patients' specific needs.

1) Desktop applications: Desktop applications used in autism therapy are software programs that run on personal computers or laptops, most commonly having Microsoft Windows, Apple Mac OS and Ubuntu Linux operating systems. Desktop applications are used to improve the communication, learning and development skills of individuals with autism. These applications include interactive games, educational applications and communication applications. Desktop applications are characterized by high performance, because they have enough memory to support complex user interfaces with numerous graphic elements and resource-consuming animations. The applications are easily adaptable to the individual needs of the users and the learning experience can be customized according to the skill level and preferences. The accessibility of technology is an important aspect in their frequent choice for ASD therapy, as there is no need to purchase expensive equipment.

2) Mobile applications: Mobile applications are an important part of autism therapy, giving users access to a variety of learning, communication and development tools. These applications are developed to be compatible with the most popular mobile operating systems, such as iOS or Android, and can be downloaded and installed on users' mobile devices: phones or tablets. The technological features of mobile applications for autism therapy include advanced tactile interaction such as multi-touch that allows the application to be used by several patients simultaneously, this versatility enables the use in both individual and group therapies.

In the Google Play and App Store, there is a large number of commercial applications dedicated to individuals with ASD. Most of them are educational games [17], visual schedule software [20], and tools for progress tracking [21]. Many academic researchers have also created functional prototypes targeting mobile devices. Common goals include support for development of language-communication skills, daily life skills, vocational-related skills, and social and emotional interaction [22]. A study conducted by Khaled Jedoui et al. from Stanford University School of Medicine [23] presents the mobile application "Guess What?". "Guess What?" is a mobile game available for Android and iOS platforms, designed to be a shared experience between the child, who tries to act out the request shown on the screen through gestures and facial expressions, and the parent, who has the task of guessing the word associated with the prompt within a game session time of 90 seconds. The study focuses on extracting emotion-tagged frames from video footage to train emotion classifiers that can adapt game difficulty and provide real-time feedback to the child. The study results show that the proposed tagging technique surpassed existing commercial emotion recognition APIs. The approach achieved an accuracy of 83.4% in labeling frames, a significant improvement over the best API's accuracy of 62.6%. The research presents a promising approach for using mobile games and automatic emotion labeling algorithms to provide social instruction to children with ASD.

3) Web applications: A web application is a software program that communicates via the World Wide Web and delivers web-based information to the user in HTML format [24]. The intrinsic features of web applications make them a complete solution for online and offline use. One of the main advantages of web technologies is their accessibility and for this reason, they are widely used in ASD therapy. They can be

accessed from anywhere with an internet connection, making them particularly useful for individuals who live in rural or remote areas or who have limited access to logistic facilities. Therapists and educators prefer web applications for the educational content customization often provided by the platforms [25]. Educational content is tailored to the individual's learning abilities and progress. Visual aids such as images and videos are used in creating websites to engage and help people with ASD better understand concepts.

4) Augmented reality applications: Augmented reality technology uses a virtual environment that is overlaid on the real environment. This is done using video cameras These applications include interactive games, educational applications and communication applications. Desktop applications are characterized by high performance, because they have enough memory to support complex user interfaces with numerous graphic elements and resource-consuming animations. that are built into the devices. These cameras film the real environment and the AR software processes the image and adds virtual elements to it. Therefore, the user can see the real environment enhanced with virtual elements. The hardware used in AR technology includes video cameras, motion sensors, and specialized devices such as AR glasses, for instance Microsoft's HoloLens and Magic Leap One allow users to see virtual elements while moving through the real environment. AR technology is used in autism therapy to help autistic individuals develop social and communication skills. A common use case is to create scenarios for social interaction, such as engaging with virtual characters or participating in role-playing games. AR helps individual to understand and remember information, and it is not limited to one age group or level of education [26].

5) Virtual reality applications: Virtual reality is attracting increasing attention in the medical and healthcare industry, as it provides fully interactive three-dimensional simulations of real-world settings and social situations, which are particularly suitable for cognitive and performance training, including social and interaction skills [27]. Almost two decades ago, VR has been introduced as an effective tool in neurocognitive rehabilitation of patients with ASD [28]. VR applications include equipment such as a head-mounted display (HMD), haptic devices , hand controllers, foot controllers, non-body controllers, wireless trackers, and wrap-around displays. VR equipment allows the user to interact with the computer-generated environment in a seemingly real or physical way. Therapeutic applications of VR are based on the theory that the brain can process information more effectively when it is presented through a combination of sight, sound, and touch [29]. Owing to these distinctive features, therapists use VR to create scenarios that allow individuals affected by ASD to interact with virtual characters and learn to communicate. A study showed that the use of virtual reality technology in autism therapy can improve social and communication skills [30]. Academic researchers have shown interest in the impact VR technology can have on life and motor skills. In a study conducted by Tzanavari et al. [31], VR was employed to instruct six children with ASD on the safe method of crossing the street. The researchers observed that the children successfully acquired the necessary skills through the simulation and were able to apply them in real-world situations. VR technologies are a powerful tool for autism therapy. These technologies allow the creation of a safe and controllable environment for individuals with autism, where they can learn and develop their social and communication abilities.

6) Robots: Robot-assisted autism therapy (RAAT) is a method of therapy that uses specially designed robots to help individuals with autism spectrum disorders develop their social, communication, and cognitive skills. In RAAT, several types of robots are used: humanoid robots, animaloid robots, toy robots, and machine robots.

7) Humanoid robots: Humanoid robots are robots that resemble human beings, having hands, legs, and head with well-defined facial characteristics, including mouths and large eyes. These robots can be programmed to mimic human behavior and gestures, as well as to simulate human emotions. A research study conducted by Feng Wu et al. [32], aimed to replicate emotions by developing a humanoid robot equipped with thermoplastic elastomer (TPE) skin, which closely resembles human skin. The lifelike appearance of this robot had significant implications for clinical rehabilitation in the context of ASD. It provided a valuable platform for training individuals with autism to identify and mimic facial expressions, thus enhancing their emotional and social skills. Studies [33], [34] have also addressed this area of research and showed that individuals with ASD interpreted robots as a new intelligible species that present anthropomorphic thinking, that can have emotions and feel physical pain and treated them equitably as human beings. Humanoid robot can engage autistic people in ways that demonstrate essential aspects of human interaction, guiding them in therapeutic sessions to practice more complex forms of interaction found in social human-to-human interactions [35].

8) Animaloid robots: Animaloid robots are a category of robots that mimic the appearance of animals, such as dogs or cats, by using zoomorphic features such as fluffy fur, whiskers, a tail, or a beak. These robots are frequently used in therapy for children with autism spectrum disorders to improve their social and interaction skills. Because animal like robots have a playful appearance and often resemble pets, they are more attractive to children with autism, making them more receptive to their use in therapy [36]. Therapists use the animaloid robots to calm the child's emotional state and teach them how to interact with non-speaking beings, both from the perspective of empathy and to prevent exposure to danger. Through these robots, autistic children can learn how to behave with animals and learn how to develop their social skills [37], such as verbal and non-verbal communication, but also understand their emotions and needs [25].

9) Toy robots: Toy robots are a more affordable category of robots than other robots used in autism therapy, making them a popular choice for home use. The robotic toys come in a variety of sizes and shapes [35], often representing fantastic or imaginary characters, which makes them even more attractive to children. Toy robots help children to learn and perform tasks, thereby improving their cognitive skills [38]. These robots can also help develop motor skills and hand-eye coordination, as well as improve problem-solving skills. In addition, toy robots can be used for entertainment purposes [39], providing children and adults with a variety of fun activities.

10)Devices: In the context of autism therapy, devices are employed to provide assistance and help to improve the physical or mental capabilities of individuals with ASD, whether they are children or adults. They are classified into four main categories: tactile devices, speech devices, mobility devices, and head devices.

11)Tactile devices: Touch plays a crucial role in social communication and interactions and may be severely affected by the challenges in tactile perception, which are commonly observed in children with ASD. This results in either hyper- or hypo-sensitivity in these children [40]. Most tactile devices use vibrotactile sensors, pneumatic, and heat pump actuation [40]. Hardware capabilities of tactile devices enable complex simulations of different actions such as touching and hugging, and also provide the ability to capture fine finger touches. Tactile devices include toys with various textures and clothing with pressure sensors. The devices are frequently used in the therapy of people who have self-harming tendencies. They also help individuals with ASD with sensory stimulation and behavioral regulation. An example of smart clothing is "TellMe" created by Helen Koo from the University of California [41]. This clothing is specifically designed to address ASD and encourage boys who suffer from it to express themselves and enhance their communication skills. It incorporates therapeutic features such as sensors and actuators. The clothing includes a pressure sensor, a light sensor, and a motion sensor, along with actuators such as light-emitting diodes (LEDs), a direct current (DC) motor, and a vibration motor. Through interaction with interactive robot characters on the clothing, children can engage in activities like speaking into a microphone or triggering sensors and actuators. This interactive experience enables children to learn and practice expressing their feelings, emotions, and opinions. The clothing aims to provide a joyful and fascinating experience for children with ASD, stimulating self-confidence and self-expression .

12)Speech devices: Speech devices are technologies that help individuals with autism to communicate more effectively. These include speech synthesizers, tablets with specialized software [42], and hand-held pictographic devices for augmentative and alternative communication (AAC). Speech devices use advanced technology such as text to speech (TTS) and speech to text (STT) for natural language processing. These innovative devices prove to be invaluable resources for people who face language-related challenges, as they enable seamless communication with others, express emotions and interact with environment in a more meaningful way.

13)Mobility devices: Mobility devices are designed to assist individuals with ASD who have difficulty with mobility and motion. These devices range from simple walkers to advanced robotic exoskeletons. The hardware capabilities of mobility devices vary depending on the specific device. Some mobility devices are equipped with sensors and advanced software to help individuals with ASD improve their balance and coordination. These devices can also help individuals with ASD to become more independent and improve their overall quality of life.

14)Head devices: Head devices are used to address sensory and motor challenges faced by individuals with ASD. These devices include head-mounted displays and virtual reality headsets, which use advanced software and hardware to simulate real-world environments and activities. The hardware features of head devices include a variety of sensors that can monitor brain activity, stress levels and other aspects of psychological health. These devices also come with headphones that can play sounds. Head devices are specially designed to help autistic people focus, calm down and interact more easily with the environment through various techniques such as meditation and relaxing music.

Researchers' interest in the use of head-mounted devices increased in the past years due to the availability of affordable, consumer-grade HMD-based VR systems [43]. Dennis P. Wall et al. from Stanford University explored the power of head devices and developed a system named "SuperpowerGlass" [44]. This wearable aid is designed to assist children with ASD. The system uses Google Glass and an Android phone to provide children with real-time social cues. It includes various activities such as "Capture the Smile" and "Guess the Emotion" to engage children and promote emotional recognition and social interaction skills. The system underwent a 3-month study involving 14 families, and the results showed that children with ASD responded well to wearing the system at home and preferred the most expressive feedback option. The study also highlights an increased involvement of children in the wearable therapy sessions.

15)Interactive technologies in practice: In this study, we applied the unified theory of acceptance and use of technology (UTAUT) principles to understand why certain technologies are preferred over others and how they are used in practice. UTAUT is a model for user acceptance of information technology toward a unified view that explains user intentions pertaining to technology and subsequent usage behavior [12]. The theory states that there are four key constructs: (a) performance expectancy, (b) effort expectancy, (c) social influence, and (d) facilitating conditions, where the first three are direct determinants of usage intention and behavior, and the fourth is a direct determinant of user behavior [17].

The survey results, from cross-sectional study revealed that 55.9% of parents, therapist and teachers use technologies in ASD context. The remaining 44.1% of participants do not use technology, and one of the main reasons mentioned is the high price of devices, robots and applications.

The statistical analysis of participants' purchasing behavior revealed that 25% chose to purchase technology through direct payments, while the majority preferred to explore and use free technology. Further examination of the data indicates that participants' preferences for technology acquisition varied based on price ranges:

- 7% of participants preferred technology priced between €1 and €10;
- 10% of participants selected technology priced between €20 and €50;
- 3% of participants chosen technology priced between €50 and €100;
- 3% of participants purchased technology priced between €100 and €200;
- 2% of participants invested in technology priced above €400.

These findings are supported by Fig. 8, which visually represents the distribution of participants' preferences for technology acquisition.

A significant proportion of study participants, comprising over 40%, expressed a preference for mobile applications as their favored technology. This preference is primarily attributed to the ease of installation on personal smartphones or tablets, coupled with the convenience of accessing these applications from any location. In addition to mobile applications, speech devices, and desktop applications are commonly used by parents, caregivers and therapists in the context of therapy Fig. 9. These technologies are perceived to be effective in facilitating the development of communication skills and promoting social interaction of children with ASD.

In the survey, we conducted an inquiry into the specific purposes for which participants use interactive technologies, aiming to gain insights into the objectives associated with their usage. The findings indicate the following distribution of purposes among the participants:

- Educational purposes were reported by the majority, constituting 30% of the participants;
- Entertainment purposes accounted for 26% of the participants' responses;
- Communication purposes were reported by 17% of the participants;
- Therapeutic purposes were indicated by a relatively lower percentage, with only 15% of participants mentioning them;
- Diagnostic purposes were reported by merely 2% of the participants.
- Assistance purposes had the lowest percentage, with only 1% of participants indicating their usage for this objective.

Fig. 10 highlights the prominent utilization of technologies for educational and entertainment purposes.

Technologies used for educational purposes include learning platforms, video tutorials and applications that help children acquire new knowledge and skills. On the other hand, technologies used for entertainment purposes include video games, social media and music apps.

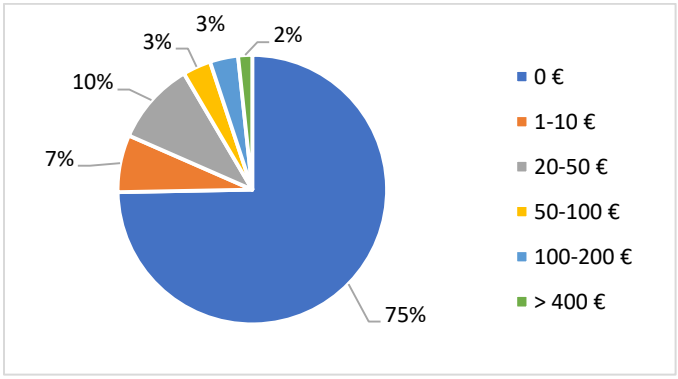


Fig. 8. The cost of technologies purchased by study participants.

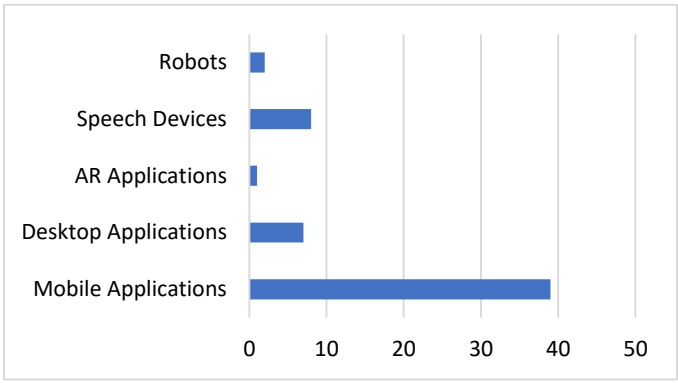


Fig. 9. Technologies practiced in real-life by parents, therapists and teachers.

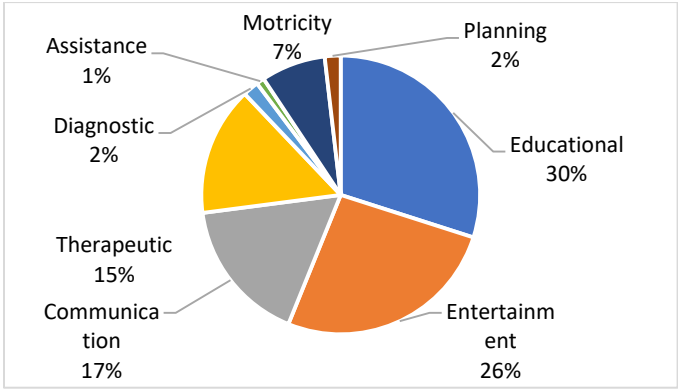


Fig. 10. The purposes for which the technologies were used by study participants.

Fig. 11. Interactive technologies used by study participants (Logos depicted in the graphic were sourced from official websites).

Fig. 11 presents some of the most frequently used interactive technologies by parents, therapists, and teachers to support the development of children with special needs. These technologies include apps like Leeloo AAC, AutiSpark, LetMeTalk, ABA Kit, and Autism ABC, which are specifically designed to help children with ASD communicate and improve their social and learning skills.

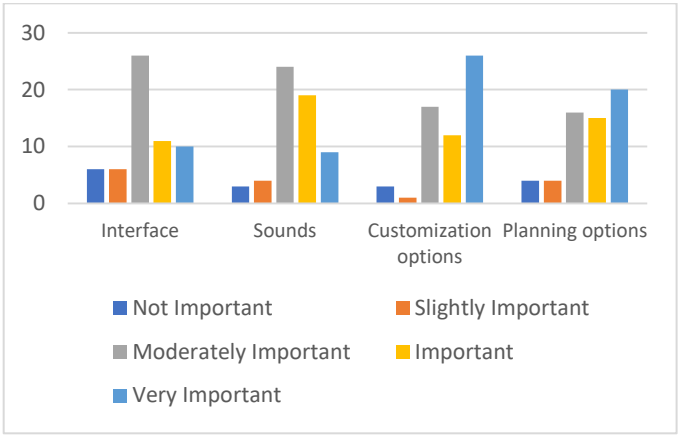
According to experts, interactive technologies are most frequently used in ABA therapy and in communication, speech and language therapy.

C. Characteristics of Technologies in ASD Therapeutic Interventions

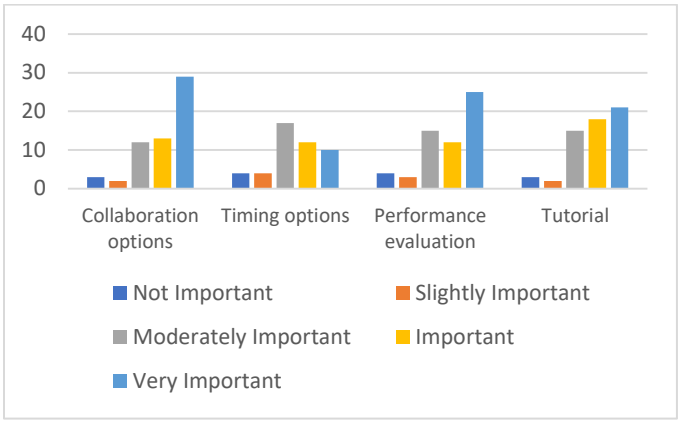
Improving skills of individuals with autism is a complex task that requires a personalized approach, taking into account the specific needs and characteristics of each individual.

The analysis of data from the cross-sectional study has highlighted the importance of different characteristics of interactive technologies used in ASD therapy.

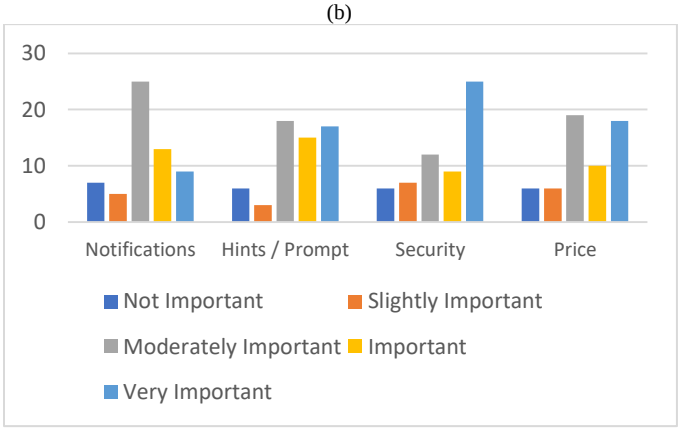
The participants assessed the importance of these technological characteristics, as depicted in Fig. 12. The data analysis unveiled that six characteristics were rated as "very important": collaboration options between parents and therapists; customization options for educational content; evaluation options for assessing the performance and progress of ASD patients; planning options; data security; and tutorial.



(a)



(b)



(c)

Fig. 12. Assessment of significance of technological characteristics. ASD experts' perspectives on (a) visual and audio design, customization of educational content and planning (b) collaboration and timing options, progress monitoring and evaluation, tutorial (c) notifications, hints, security, and price.

The characteristics that received evaluations of "moderately important" included: interface customization options; diagnostic options; timing options; notification; avatar; colorful UI interface; background music/sounds; price. The results did not indicate any prevailing evaluations for the characteristics evaluated as "slightly important" and "not important".

By combining the findings of the cross-sectional study and expert opinion, the most important characteristics of technologies used in ASD context were identified:

- *Visual and audio design*: Visual and audio design play a vital role in helping individuals with autism comprehend presented information. Interactive technologies with engaging design stimulate the senses and facilitate learning.
- *Planning and scheduling options*: Planning and scheduling options are important because individuals with autism may struggle with organizing and planning tasks. Interactive technologies provide planning options to assist ASD patients in managing their time efficiently and performing tasks more effectively.

- *Personalization of educational content*: Personalization of educational content is crucial because each individual with autism has specific educational needs and learns best through different methods. Interactive technologies can be customized for each individual, providing tailored educational content that meets their specific needs and abilities.
- *Progress monitoring and evaluation*: Progress monitoring and evaluation are essential to track the progress of individuals with autism in therapy. Interactive technologies provide monitoring and assessment tools that enable therapists and parents to follow the progress of individuals with autism.
- *Collaboration options*: Collaboration options with therapists, doctors, and parents are important because they must work together to provide appropriate therapy for individuals with autism. Interactive technologies can be designed to facilitate collaboration and communication between these stakeholders, thereby improving the quality of therapy provided to individuals with autism.

IV. LIMITATIONS

Our study focuses on interactive technologies that are designed for ASD therapy. Technologies can be a valuable tool in developing the aptitudes of patients with ASD, but their impact is not sufficiently investigated worldwide. Although we had a good representation of study participants, they were limited to parents, therapists, and teachers from a single county in Romania. The small number of subjects participating in the cross-sectional study, may affect the conclusions and their general applicability. To address this, future research will aim to include a larger and more diverse sample of participants to cover a wide spectrum of sociocultural experiences.

V. CONCLUSIONS

This research began by analyzing the ASD diagnosis and understanding that "spectrum" is a key term that characterizes the variety of forms and disabilities that individuals with ASD exhibit. Thus, we understood that the patient is the central element of our research, and technology is just a way to help the patient improve certain skills. Regardless of the degree of novelty and innovation of the technological solution, it must move from paper to practice and prove its effectiveness through well-documented results.

Individuals diagnosed with ASD show an increased interest in using technology for various purposes such as entertainment, communication, planning, or education. The positive attitude towards technology makes their use feasible in therapies by augmenting the information presented, simulating the visual, tactile and auditory senses, or monitoring the patient's physiological parameters. Experts in the field have highlighted that applied behavior analysis, communication, speech and language therapy, occupational therapy, and physical therapy are the therapies that most often involve technology in therapeutic procedures. The technology designed for use in the ASD context has various hardware specifications and software characteristics, depending on which they have been grouped into applications, robots, and devices. Current body of evidence supports the effectiveness of interactive technologies in improving ASD impairments such as communication deficits, social interaction deficits, motor disabilities, and mental retardation. Despite the obvious benefits, the participants in the study expressed concerns about the negative effects of technology use, such as agitation, aggression, and difficulty in use, associated with non-respect of the ISO standards in terms of appropriate visual or auditory design for persons with disabilities.

The multidisciplinary team that participated in this research consisted of therapists, teachers, software engineers, and parents of children diagnosed with ASD. Each participant brought their vast expertise to identify the important characteristics for ASD-specific technology. Thus, the adaptability of the technology to the patient's progress is by far the greatest need and challenge.

In response to cross-sectional study survey's question, which invited the participants to provide feedback and additional information not covered in the survey, a parent expressed a hopeful desire: "*I hope an application will be developed in Romania to assist parents, who don't have enough financial resources, to work with their children at home*.". This desire aligns perfectly with the goal of our future research, which is to leverage the valuable insights gained from the current study to create an accessible application that can support children with ASD and their families.

In conclusion, we encourage researchers to explore and develop innovative technological interventions for the ASD treatment, especially considering the growing prevalence of this neuropsychiatric condition.

ACKNOWLEDGMENT

This work was supported by European Regional Development Fund, Competitiveness Operational Programme 2014-2020, project "119722/ Centru pentru transferul de cunoștințe către întreprinderi din domeniul ICT—CENTRIC, Contract subsidiar 22080/05.10.2022, Autism ASSISTant—Asistent virtual pentru dezvoltarea abilităților cognitive ale copiilor cu patologie de spectru autist", contract No. 5/AXA 1/1.2.3/G/13.06.2018, code SMIS 2014+ 119722 (ID P_40_305).

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