A scoping review of artificial intelligence-based robot therapy for children with disabilities

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ABSTRACT

The integration of artificial intelligence (AI)-based robot therapy (AIBRT) has become prominent in addressing the needs of children with disabilities, including autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), learning disabilities, and speech delays. However, questions arise regarding the effectiveness of different AI techniques in enhancing therapy for children with specific needs. This review explores current literature on AIBRT for children with disabilities, aiming to understand the efficacy and potential of various AI techniques in improving their therapy. This paper presents a comprehensive search of research articles published from 2019 to September 2023. 39 articles focusing on AI-based robot platforms, the employed treatment or therapy methods, assessment procedures during therapy, and the variables or parameters used to measure intervention effectiveness have been discussed in detail. These AI-based robot platforms have been utilized to engage individuals diagnosed with ASD, offering therapeutic interventions and assessments. In conclusion, the integration of AI and robotics in therapy shows promise for enhancing the development and quality of life for children with disabilities. The findings of this review have implications for therapists, practitioners, and researchers interested in incorporating AI applications into therapy practices. This integration can lead to improved therapy outcomes, optimized children's development, and enhanced quality of life.

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1. INTRODUCTION

Children with a range of impairments, including physical, cognitive, emotional, and developmental disabilities or disorders, fall under the category of those with special needs. This encompasses conditions such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), intellectual disability (ID), learning disability (LD), speech and language disorders, physical disabilities, sensory processing disorders, as well as emotional and behavioral disorders, among others [1]. It is essential to recognize that each child with special needs possesses distinct characteristics and should be regarded as an individual with their strengths, viewpoints, challenges, and requirements [2]. Therapy plays a pivotal role in enabling children with special needs like ADHD, ASD, learning disabilities, speech delays, and developmental delays to realize their full potential. In recent years, there has been a growing focus on incorporating artificial intelligence (AI) into the realm of therapy [3], [4]. As depicted in Figure 1, AI-driven therapeutic applications hold significant promise for enhancing therapy outcomes and facilitating optimal development among children with special needs.

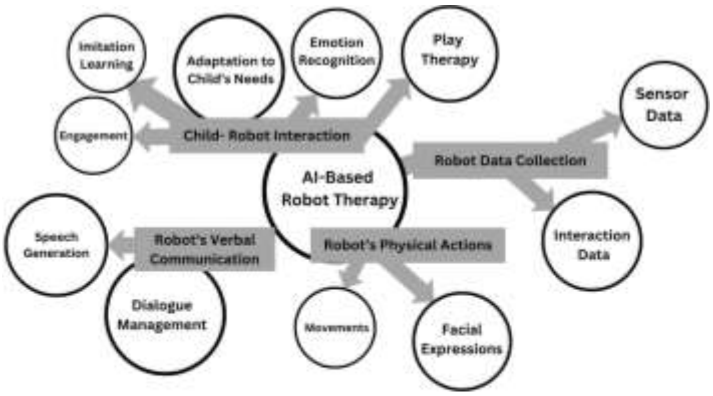

Figure 1. Key components of AIBRT for children with special needs

Cutting-edge AI methodologies, including machine learning, natural language processing, computer vision, and virtual reality are pioneering novel and impactful therapeutic tools. These tools can be customized to cater to the distinctive requirements and capabilities of each child, rendering them genuinely exceptional. In the contemporary digital landscape, AI applications have demonstrated profound potential in bolstering therapeutic support for children with special needs [5]. AI has emerged as a potent instrument to elevate therapy for these children, with the rapid progress of AI presenting fresh avenues to surmount the challenges they face. Within the clinical domain, AI resources possess the capacity to enhance diagnostic accuracy, personalize intervention approaches, and provide an impartial assessment of children's developmental progress.

The intervention system encompasses a range of services, including early intervention, special education, inclusive education, assistive technology, therapy, and support services. Its core objective is to equip children with the requisite resources and assistance to unlock their full potential and actively engage within their communities [6]. Robotic intervention systems can emerge as highly advantageous and efficient tools in supporting children with special needs. These systems can serve as aids for socialization, motivation, repetition, and customization. A significant advantage of robotic involvement lies in their ability to convey an extensive array of facial expressions, gestures, and body language. This capability is especially valuable in aiding children in practicing and comprehending the nuances of social situations [7]. Robots can be skillfully programmed to offer positive reinforcement and encouragement, particularly benefiting children who grapple with self-esteem or motivation issues [8]. Additionally, robots can be tailored to provide repetitive practice of skills and tasks. The adaptability of robotic intervention systems is a notable strength, allowing customization to address the unique requirements of each child. For instance, a robot can be personalized to deliver speech therapy exercises for a child with a speech disorder or physical therapy exercises for a child with a physical disability. Leveraging various sensors such as microphones or cameras, the robot can closely monitor the children's progress and performance throughout the program [9] While numerous intervention systems have been developed, creating interventions that cater to the distinct needs of each child with special needs remains a challenge.

2. ARTICLES SELECTION PROCESS

2.1. Identification process

The scoping review process consists of three basic phases that were used to choose many relevant papers for this study. The first phase entails the identification of keywords and the search for associated, related terms using thesaurus, dictionaries, encyclopaedias, and prior research. Following the selection of all pertinent terms, search criteria involved a combination of keywords, including "AIBRT for children with special needs," "autism," "ASD," "ADHD," "disabilities in children," "learning difficulties," "speech delay," and "sensory issues". The current research endeavour was effective in successfully retrieving 1,464 papers from Google Scholar, Scopus, and Semantic Scholar databases throughout the first stage of the systematic review process.

2.2. Screening process

There are 1,464 papers in the initial screening phase. During this first step, 774 articles were excluded. The second phase involved the screening of 690 articles using a set of inclusion and exclusion criteria established by the researchers. The primary criterion for inclusion was peer-reviewed journal articles, as they provide the most practical information. Other publication types, such as meeting abstracts, book chapters, conference proceedings, and dissertations were excluded from the study. Additionally, the review focused exclusively on papers written in English. It is worth noting that the study covered a five-year timeframe from 2019 to 2023. Furthermore, only studies conducted within the eligibility boundaries of children were chosen to align with the research objective. In total, 563 publications were excluded based on these specific criteria see in Table 1. For the third step, known as eligibility, a total of 127 articles have been prepared. All articles' titles and key content were thoroughly reviewed at this stage to ensure that the inclusion requirements were fulfilled and fit into the present study with the current research aims. Therefore, 88 reports were omitted because they were not due to the out-of-field, title not significantly and abstract not related to the objective of the study. Finally, 39 articles are available for review.

Table 1. The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2019–2023	<2019
Literature type	Journal (Article)	meeting, abstracts, book chapters, conference proceedings, and dissertations
Publication stage	Final	In press

3. ARTIFICIAL INTELLIGENCE ROBOTS-BASED PLATFORM

A technological system that integrates artificial intelligence algorithms with robotics to create a platform capable of providing therapeutic interactions and interventions. This platform could involve a robot equipped with AI capabilities to engage individuals, particularly those with special needs in therapeutic activities [10]. Notably, certain researchers employed a compact robotic toy as the foundation for their AI-based robot platform [11]. The low-cost assistive robotic platform developed [12] incorporates state-of-the-art advanced online action recognition and navigation functionalities, demonstrating the integration of cutting-edge capabilities. AI-powered robotic systems are intended to aid people with neurodevelopmental disorders in acquiring and strengthening their skills related to daily tasks [13]. The platform incorporates artificial intelligence to support activities of daily living (ADLs), robot operating system (ROS)-based navigation system capabilities, a user interface for both healthcare professionals and users, and an online action detection module for monitoring activities [14]. The softbank robotics NAO robot was utilized as a robust platform for artificial intelligence research by [15]–[25]. A screening system called Q-CHAT-NAO adapts six questions from the quantitative checklist for autism in toddlers to work in a robotic context, obtaining information directly from the toddler instead of relying on caregivers' responses [26]. Pepper is a humanoid robot equipped with a touchscreen that allows interaction with patients through the application developed with a system connected to a remote server, and the patient receives customized exercises in the form of therapeutic games. The ability to recognize emotions through artificial intelligence algorithms helps the therapist build the right therapeutic path and behavioural measures to take. The webcam data collected during therapy sessions are analysed to monitor the progress of the patients suffering from behavioural disorders [27].

A robot platform was created for android applications to receive real-time commands via transmission control protocol/internet protocol (TCP/IP) from the processing unit and act on them. This platform was used along with a fully wearable augmented reality (AR)/brain-computer interface (BCI) system to remotely control the robot in ADHD rehabilitation paediatric therapies [28]. The architecture of the first view robot, which is based on AI, is comprised of four layers. These layers include the collection of data from ASD children and their environment, communication with other intelligent terminal devices, cloud analysis, and interaction layers utilizing wearable robotics to provide interactive care for children with ASD from a first-person perspective to enhance autism perception and improve the quality of care for children with ASD [29].

The robot development kit (RDK), powered by the HARIX brain operating system, is the innovative cloud-based platform used by [30]. With its game blueprint editor, scene map editor, motion dance editor, robot operator, and emulator, the RDK streamlines application development. The study utilizes the cloud ginger XR-1 robot, equipped with a three-tier control setup consisting of a robot control unit, central control unit, and electronic control unit, as well as sensors like cameras, radar, navigation, speakers, and microphone arrays. To achieve intelligent brain cloud collaboration, the RDK works alongside the robot develop platform (RDP), which includes skills, roles, map management, and visual recognition model training, and is connected to both physical robots and simulation systems. Additionally, the smart voice intelligent voice platform helps refine voice dialogues, allowing the robot to accurately understand commands and perform relevant actions based on real intentions. Robot-assisted therapy can be an effective intervention to teach children with ASD about visual perspective talking skills and theory of mind to understand others' thoughts, beliefs, and intentions [31].

The compliant soft robotics (CASTOR) project studied spectrum disorder using the open-source social robot CASTOR. It has been previously implemented in physical interaction studies. Some adaptations were made to identify the usability of the CASTOR robot in different scenarios of ASD therapies by evaluating the same variables in the same activities [32]. The development of a therapy bot integrated with a high-resolution camera for image acquisition and a Raspberry-pi microcontroller. The bot's design is based on computer-aided design (CAD) modelling and aims to monitor and provide therapy to children with ASD [33]. The use of a socially assistive robot (SAR) is designed to interact with and assist humans in a social and therapeutic context. This SAR adjusts its behaviour based on a child's interactions and responses, allowing for greater flexibility in treatment location [34], [35]. SAR with an expressive humanoid design. The QTrobot offers 12 degrees of freedom, upper-body motions, and animated faces on a screen [35], [36]. The use of humanoid robots to enhance the development of emotion recognition and facial expression imitation skills in children with ASD [37], [38].

The type of robot used by [39] is called Hookie. Hookie is a social robot that has been specifically developed to engage individuals diagnosed with ASD to enhance social skills and learning abilities [25]. Hookie contains nine dynamixel motors for movement and a humanoid appearance. Its facial expressions are displayed through the HookieFace App on a smartphone attached to its head. The robot is controlled through a mobile application called Hookie Talk. Tinku, a cost-effective robot, has been developed for autism therapy. It incorporates offline speech processing, computer vision for obstacle avoidance, and the ability to express emotions in an anthropomorphic way. This promising tool highlights the importance of social robotics in improving the quality of life for individuals with special needs [40].

Cozmo is a compact robot, measuring approximately 7.2 inches in length, 5.6 inches in width, and 6.5 inches in height [10]. It features a small head with an light emitting diode (LED) display, a video graphics array (VGA) camera capable of capturing 30 frames per second, four motors, and over 50 gears. Its mobility includes head and fork movement (up/down) as well as track movement (forward/backward and left/right). The robot can express emotions, interact with its cubes, and identify people and their basic facial expressions using facial recognition [41]. The RE4BES protocol is a treatment protocol designed to improve cognitive, neuropsychological, behavioural, and social skills in children and adolescents with special needs. The protocol incorporates robotics construction kits as a tool for intervention, allowing personalized activities for cognitive empowerment and rehabilitation [42]. AI-integrated robotics for therapy demonstrates significant promise, with platforms ranging from simple toys to sophisticated humanoid robots, each uniquely addressing the needs of children with disabilities. A critical comparison of these systems reveals a diversity in application yet a gap in standardized effectiveness metrics. The field's evolution underscores the necessity for rigorous long-term efficacy studies and accessibility enhancements. Future work must focus on harmonizing assessment protocols and democratizing technology access, ensuring that advancements in AI-robotic therapy translate into tangible benefits for the everyday lives of children with special needs.

4. THE THERAPEUTIC INTERVENTION FOR CHILDREN WITH DISABILITIES

The treatment method involves using a robot platform to help kids with neurodevelopmental disorders do daily activities. There is a need for new and effective tools and strategies to support individuals with ASD. Anecdotal evidence suggests that robots can offer unique opportunities for individuals with ASD. Robots create a structured learning environment, helping individuals with ASD focus on important things and engage in standardized social situations. Robots also provide consistent performance, which is beneficial for long-term interventions that require patience [43]. This platform supports them in being more independent and engaged with their environment. The focus is on learning tasks with the help of technology, like practising social skills [13], communication, and behaviour through things like robots, virtual reality, and games. These tools aim to improve skills and engagement in areas like talking and interacting with others [23]. The therapy or treatment approach involved the use of the robot platform as a companion and facilitator in performing ADLs, promoting independence, and improving functionality and autonomy for assisting children with neurodevelopmental disorders [12].

Applied behaviour analysis (ABA) is a method of therapy that uses principles of learning and motivation to improve social, communication, and learning skills for children while focusing on teaching children to communicate actively and effectively, improve their social development, minimize inappropriate behaviours, develop academic abilities, and enhance their independence [10], [15], [30], [44]. The social motivation theory of ASD suggests that individuals with ASD may be more motivated to interact with robots because robots are likeable, have repetitive behaviours, have a simple appearance, and do not judge socially [45], [46]. Cognitive behavioural therapy (CBT) is a method used to help children with ASD develop critical emotional skills. The therapeutic method focuses on strengthening the knowledge of emotions [47], proper contextual recognition, and the acquisition of a basic emotional language. These sessions, contributed by the QTrobot, are divided into three phases: fostering the association between emotions and contexts; clarifying the relationship between thoughts and emotions; and providing participants with tools to learn and use positive thoughts connected to primary emotions. Wearable wireless technologies are used to gather behavioural and physiological data to support therapy by utilising cutting-edge technology along with evidence-based therapeutic concepts to improve emotional awareness and regulation in kids with ASD [36].

The approach of employing SAR with AI is utilized to enhance therapy sessions for children with behavioural disorders, especially those diagnosed with ADHD, more appealingly and interactively [27], [46]. The use of a highly wearable, single-channel BCI based on AR and steady-state visually evoked potentials (SSVEP) for children in the therapy wore AR smart glasses that displayed flickering icons and able to control a social robot in real-time. During one month, therapy sessions were held for children with different tasks assigned based on their level of involvement to improve symptoms of ADHD such as inattention, hyperactivity, and impulsiveness [28]. The system focuses on enhancing the cognitive and social interaction skills of children with ASD through the utilization of wearable robots, offering immersive and personalized therapy [29]. This is achieved through three main methods: i) dynamic dataset supplement, which gathers real-time data from various wearable devices, including audio, video, and physiological signals, to ensure system reliability and validity. ii) Individualized modelling in the cloud, where cloud-based computation and storage enable personalized modelling of each child with ASD, using terminal data analysis to identify user states and enhancing model learning through shared terminal data. iii) Immersive interaction with the robot, functioning as a first-person view robot that complements the child’s cognitive abilities and guides their behaviours in the surroundings. It offers diverse interactions like voices, stroking, and music based on the child’s mental and physical cues, providing tailored and effective ASD therapy. This approach addresses the existing limitations of AI-based treatment systems and offers a comprehensive solution [25]. Educational robotics has the potential to be a valuable resource for promoting cognitive stimulation and facilitating rehabilitation in children with special needs [42].

Therapy for children with ASD or ASD combined with ADHD involves using robot-assisted therapy. The robot’s behaviours were customized for each child’s unique reactions, offering a range of activities that were suitable for different types of autism. The therapy sessions were personalized and adapted based on the therapist’s expertise and assessment [16]. Robot-assisted imitation training with a preliminary evaluation of incorporating robot-assisted therapy for children with ASD and intellectual disability (ID). The experiment involved using a robot to assist in imitation training for six hospitalized children with different levels of ID. The children’s progress was evaluated using a quantitative psycho-diagnostic tool, showing success in the training, and suggesting the potential benefits of using robotic assistants in the care of children with ASD and ID [21]. The robot is equipped with a high-resolution camera for image acquisition and a Raspberry-pi microcontroller and integrates with a deep learning model such as VGG16, MobileNet, and ResNet 50 is trained to recognize facial expressions and emotions to monitor and provide therapy to children with ASD. The system engages children with interactive games and recognizes facial expressions and touch patterns to evaluate their responsiveness and involves the movements of the robot to engage the children [33], [37].

The creative strategy encouraged children to imitate the robot’s facial expressions [43], [47]. Based on the emotional classification of the child’s facial reactions, the robot’s level of participation was constantly adjusted. Moreover, the automaton proficiently performed a sequence of intricate bodily movements and articulated vocal prompts to enhance the therapeutic engagement. The therapy included an organised breathing exercise that was separated into three distinct phases to complement the main method: an inhale phase lasting four counts with raised arms, a breath retention phase lasting seven counts with extended arms, and an expiration phase lasting eight counts with arms down. The session included three repetitions of this breathing exercise [17]. The utilisation of a convolutional neural network by the humanoid robot Nao enables the assessment of autism in children and the provision of therapy recommendations. The autonomous robot functions under the guidance of a human therapist, operating autonomously to accomplish a designated therapeutic goal. The therapeutic intervention consists of a predetermined sequence of exercises. The robot’s controller carries out a sequential execution of its senses, systematically assessing their accuracy regarding the patient. If any inconsistencies arise, the controller takes steps to resolve them prior to the termination of the therapeutic session. The robot utilises a machine learning technique to ascertain whether the youngster displays indications of ASD. The algorithm for therapy selection takes into consideration the kid class, the age range of the patient, and the correspondence matrix as input parameters. Subsequently, the system generates a comprehensive compilation of therapeutic interventions that are deemed appropriate for a prescription to the patient, serving as the resultant output [19]. Machine learning methods aim to provide tailored and effective treatment recommendations for individuals with ABA therapy needs [44]. A convolutional neural network (CNN) model was trained to recognise and analyse patterns indicative of eye contact. This model uses input from a webcam to perform real-time analysis. The use of CNNs for facial feature extraction is widely recognised as a powerful tool in the field of computer vision. This is mainly due to the inherent ability of CNNs to autonomously capture hierarchical features from images [34].

The mathematical model for improving therapy for children with ASD using a multi-robot system to improve joint attention and imitation skills [48]. Joint attention training and imitation therapy are both essential components of the IOGIOCO protocol created to improve gesture-related skills in children with ASD. Joint attention training improves the ability of children with ASD to engage in joint attention activities [24], where attention is between persons and things or people in the surroundings through gestures like eye-gazing and pointing. This method aims to develop cooperative attention skills through interactive turn-taking games facilitated by the humanoid robot, the children, and the therapist. In addition, the imitation therapy approach attempted to strengthen the imitation abilities that are frequently weakened in children with ASD. The tasks in the therapy sessions required the child to imitate the therapist's and the robot's gestures. These interventions were carried out in an environment that allowed for natural mobility and were recorded using a single camera for later analysis [20]. In the context of the study, Cozmo, a robot, utilizes its display screen, sound, and movements to express various emotional expressions to the participant. Additionally, Cozmo engages in activities such as simulating a fire alarm using sound, movement, and display screens, building a pyramid with cubes, and participating in a game of keep-away where the participant tries to prevent Cozmo from reaching a cube [41]. The RE4BES protocol, with its integration of robotics construction kits, offers a comprehensive and innovative approach to cognitive empowerment and rehabilitation for children and adolescents with special needs. It combines theoretical frameworks, hands-on learning, and motivational elements to create a personalized and effective intervention tool [42]. Robot-assisted therapy provides innovative support for children with neurodevelopmental disorders, yet it varies widely in implementation-from aiding daily tasks to enhancing communication and social skills. However, the lack of a unified effectiveness measure is a critical gap. Future work should focus on standardizing evaluation metrics, ensuring that these diverse approaches yield consistently positive outcomes across the spectrum of neurodevelopmental challenges, thereby optimizing therapeutic strategies for individual needs.

5. EFFICACY OF THE INTERVENTION MEASURABLE VARIABLES OR PARAMETERS

Effectiveness could be measured by tracking the children's progress in mastering various daily living activities over time. Observations and data collected from the online action detection module could provide insight into the children's learning curves and performance trends. An AI-based robot platform is to aid children with neurodevelopmental disorders in their daily activities. This implied the success of the intervention by observing whether the children's capability to perform these activities improved when using the robot platform's assistance [12]. The focus is more on technically validating and evaluating the performance metric of the robotic platform could be considered as intervention effectiveness measured variables or parameters [14]. The feasibility of utilizing an artificial neural network to classify aggressive behaviours of children towards robotic toys is doable, and the system can accurately understand different ways they interact with robots being friendly could help calm down kids and make therapy better, and it talks about using technology to help kids with autism [11]. The evaluation of engagement in therapy sessions with autistic children was conducted through a comprehensive process by using a script implemented in Python code to analyse videos frame by frame and count the engaged moments. Furthermore, therapists also contributed to rate engagement on a scale [10], [15], [27]. During the therapy session, the therapist may monitor different factors such as the patient's behaviour, attention, and working memory to analyse their progress [27], the Italian battery for ADHD (BIA) tests have effectively evaluated the therapy's effectiveness, revealing significant improvements in all participants, even with a limited number of therapy sessions [28].

The success of the treatment was conclusively determined through various effective behavioural measures such as engagement, valence, and eye gaze duration. Furthermore, to improve the therapy process actively sought and received invaluable feedback from both parents and therapists [16]. Throughout the therapy session, the therapist meticulously assessed the patient's progress using a comprehensive set of seven variables, including focused attention, ability to follow instructions, working and procedural memory, physical and verbal imitation, emotion identification, emotional response, and overall performance. In addition to this, the therapist also gathered valuable data from recordings, which included two-time variables, namely robot attention time and therapist attention time, and three physical interaction variables. The CASTOR robot's actions were controlled using the Wizard of Oz method, and the operator deftly manipulated the robot's movements through a video camera [32].

The use of transfer learning models, such as VGG16, MobileNet, and ResNet 50 for facial expression recognition, shows promising results in accurately identifying emotions in real-time images and demonstrates the effectiveness of leveraging pre-trained models for facial emotion recognition tasks [33]. The assessment of effectiveness was conducted through a comparative analysis with the latest advancements in emotion classification research, to gauge the accuracy of the ConvNeXt model in categorising facial expressions into seven distinct emotion classes. Furthermore, the methods were subjected to rigorous testing to evaluate the proportion of instances pertaining to each level of engagement observed throughout the duration of the activity [17]. A deep learning classification system based on convolutional neural networks to identify children with ASD is one way used to assess the efficacy of therapy interventions for kids with ASD. To find the best therapy strategies for each patient, screening tests are carried out to assess their unique difficulties and diseases. A correspondence matrix contains the suggested interventions for each disorder and engagement. Fuzzy logic is used to select therapies for each patient based on their needs and the relative importance of each therapy. The ultimate choice of which therapies to use is left up to the therapists, allowing for a personalised and individualised treatment strategy [19].

The effectiveness of the therapy was evaluated by examining the average amount of time children with ASD were able to maintain eye contact in various settings and contrasting the children’s performance in maintaining eye contact in an environment with interactive robots with that in a typical classroom. The duration and frequency of eye contact were used as quantitative measurements to evaluate the efficacy of the therapy [34]. Through a comparative analysis of the pre-and post-intervention test outcomes, as well as an examination of the behavioural and physiological data, it was observed that the CBT protocol exhibited a tendency towards enhanced emotional skills in children diagnosed with ASD. Specifically, there was a notable improvement in emotional comprehension and a statistically significant enhancement in emotional language abilities [36]. The effectiveness of the therapy is assessed based on changes in the child’s ability to engage in joint attention and improvements in communication and social skills, which are often targeted outcomes of joint attention training [20]. Children exposed to the robot decrease their distress and positively change their attitude toward the technological device using the content of the tales (knowledge or emotional) and the different social behaviour of the narrators: static human, static robot, expressive human, and expressive robot [21]. The effectiveness of the adaptive emotion-aware robot system was measured through various metrics such as recognizing emotions, eliciting intended emotions, and enhancing trust, engagement, and empathy in social interactions [38]. In assessing the effectiveness of AI-based robotic therapy, measures like task mastery, engagement, and eye contact duration are pivotal. Future work should not only refine these assessment tools for greater reliability but also explore how robotic therapy can be standardized and integrated into traditional therapeutic practices, potentially transforming the landscape of interventions for neurodevelopmental disorders.

6. ASSESSMENT UTILIZED IN THE THERAPY PROCESS

The assessment involves evaluating the effectiveness of the robotic platform and its associated applications. Quantitative assessments measure improvements in the children's ability to perform specific daily living tasks. Qualitative assessments might involve observations and interviews to gather insights into the children’s engagement, comfort level, and satisfaction with using the technology. The system generates comprehensive reports encompassing various facets of user performance, notably tracking metrics like task completion time, action precision, and the accuracy of task execution. The focus is more on technically validating and evaluating the performance of the robotic platform [10], [12], [14]. The evaluation of children’s engagement during therapy sessions involved the utilization of a therapist assessment scale formulated in collaboration with ABA specialists and therapists, ensuring alignment with the expertise of professionals in the field. Converting these scores into a percentage format enabled a quantifiable measurement of engagement, contributing to a comprehensive understanding of the children’s involvement dynamics throughout the therapy sessions [15], [38], [47]. The assessment involves monitoring the patient’s progress by observing their therapy sessions in real-time and analysing the recorded sessions, including capturing their emotions [27]. The BIA consists of various tests designed to evaluate different aspects of ADHD, including semantic fluency, phonological fluency, visual-sequential tasks, span-4 tasks, reading tasks, the “Ranette” test, and tau tasks. These assessments were administered to the children participating in the therapy to measure their progress and improvements over time [28], [42]. In the field of autism, two assessment tools are heavily relied upon by experts: the childhood autism rating scale (CARS) and the autism behaviour checklist (ABC). These tools have gained popularity due to their effectiveness in accurately gauging the severity of autism symptoms and behaviours, making them indispensable for researchers and therapists alike [30]. The use of the sensory profile checklist revised (SPCR) to assess unusual sensory experiences in individuals with ASD using correlation between the children’s sensory abnormalities and their prosocial behaviors [45].

The robot-assisted therapy incorporated various robotic applications, such as dances, songs, emotional displays, social actions, body parts identification, storytelling, and imitation games. These activities targeted joint attention, imitation, turn-taking skills, and the emotional well-being of the participants [16]. Each participant underwent four 30-minute sessions that focused on improving their social skills. The sessions included activities that aimed to enhance their abilities in areas such as focused attention, following instructions, working and procedural memory, physical and verbal imitation, and recognizing basic emotions. A tailored approach to meet individual needs and limitations combined provided extra tablets with pictograms for hearing sensitivity and simplified instructions for non-verbal participants [32].

The assessment is based on the accuracy of the deep learning models in recognizing facial expressions and emotions. The models are trained using datasets from an open-source platform known as Kaggle, which includes general facial expressions and images of autistic and non-autistic children. The performance of the models is evaluated by comparing the predicted emotions with the actual emotions in the test dataset. The accuracy of the models is then calculated. The VGG16, MobileNet, and ResNet 50 models are evaluated, with the VGG16 model achieving the highest accuracy of 97.66% on real-time images [33]. The assessment used by [17] is a combination of emotion classification and engagement level classification. Using CNN model, specifically ConvNeXt, to classify facial expressions into seven emotion classes were then used to infer four levels of engagement: strong engagement, high engagement, medium engagement, and low engagement. Two methods were used for engagement classification. Method-1 uses emotion classification to infer the levels of engagement based on an effective model. Method-2 employs the same classification network to directly classify the four levels of engagement. A deep learning neural network architecture to estimate the child's focusing visual attention during a therapy session that indicates engagement [21], [32]. The neuropsychological assessment is one sort of assessment for therapy. The social, behavioural, communicational, and imaginative domains of children are all covered in this assessment of their cognitive and socioemotional development [37]. This technique provides the identification of the strengths and weaknesses inherent in everyone, thereby facilitating the provision of suitable therapeutic interventions tailored to their specific needs [18].

The SAR system used to collect data on children's eye contact behaviour, with a particular emphasis on measuring the duration and frequency of eye contact [34]. This method made it possible to collect a large amount of data that shows how children interact with their surroundings, especially in reaction to SAR. This approach helps us understand human-robot interaction better by measuring different aspects of eye contact behaviour. It can be useful for developing and using socially assistive technologies in areas like child development, communication disorders, and therapy. The test of emotional comprehension (TEC) is used to measure emotional comprehension in kids with ASD. It consists of nine components that evaluate several facets of emotional understanding, such as recognition, external causes, belief, desire, reminder, hiding, regulation, mixed, morality, and the emotional lexicon test (ELT), which evaluates emotional language abilities. It evaluates the youngsters' comprehension and use of a fundamental emotional lexicon. The ELT assesses how well the kids did at recognising and describing emotions. To assess the efficacy of the group-based CBT procedure, these tests are given both before and after the therapy intervention [36], [48].

A robot, a child, and a therapist are the main elements of the triadic robotic setup used for the assessment. Utilizing a combination of manual and automatic methods to analyse gaze patterns to indirectly measure joint attention. To estimate the 3D joint coordinates needed to control the robot's movements, depth camera technology, specifically the Kinect tracks eye movements. The YOLO and Gaze360 algorithms are used to determine gaze orientation by comparing with areas of interest (AOI) of the robot and the therapist or patient. Inter-rater reliability analysis and sensitivity assessments for the evaluation process, culminate in a comprehensive and quantifiable measurement of joint attention dynamics throughout therapy sessions [48]. This multifaceted approach, which includes manual analysis, automatic classification, tracking, and reliability analysis, enables an in-depth understanding of the impact of therapy techniques on joint attention in children with ASD [20]. Deep learning models such as Yolo v3-tiny and single shot detector (SSD) are utilized for object detection [40]. The use of observational study as a new insight into acceptance, expectations, and consensus regarding social robots in therapy through qualitative and quantitative questions [41]. Robotic therapy's efficacy is gauged through quantitative and qualitative assessments, tracking task mastery and engagement. However, the variability in therapeutic impact and the need for standardized evaluation criteria are clear. Future research must focus on unifying these approaches, ensuring consistent and measurable benefits for neurodevelopmental therapy, and expanding the accessibility of such advanced interventions.

7. CONCLUSION

In recent years, the integration of artificial intelligence and robotics has facilitated the development of novel therapeutic platforms designed to address the needs of individuals, particularly those diagnosed with neurodevelopmental disorders such as autism, ADHD, speech delay, and learning difficulties. These various platforms, each implementing unique methodologies, provide valuable insights into the potential of technology to augment the effectiveness of therapeutic interventions. Robotic platforms such as Softbank Robotics NAO and Pepper effectively utilize AI-based emotion recognition techniques to facilitate customized interventions, thereby assisting in the improvement of communication and behaviour. The integration of Android applications with wearable AR and BCI systems is significantly transforming the landscape of ADHD rehabilitation. This innovative approach allows for the remote control of robots and facilitates real-time engagement in therapeutic tasks.

Furthermore, the incorporation of cloud-based platforms, such as the RDK, serves as a compelling demonstration of the capabilities of AI in streamlining the process of application development and fostering synergistic interactions between robots and simulations. SARs, including but not limited to QTrobot and Hookie, have been observed to exhibit expressive features. These robots have shown promising advancements in the realm of promoting engagement and augmenting social skills among individuals diagnosed with neurodevelopmental conditions. The integration of cutting-edge assessment methods, such as facial expression recognition and eye gaze measurement, ensures a full assessment of the success of the intervention. Recent innovations serve as proof of the capacity of technology in addressing developmental challenges. Moreover, they emphasize the significance of customized strategies in promoting social interaction, emotional comprehension, and overall well-being. As the ongoing progress in these advancements persists, there arises a renewed sense of optimism regarding a forthcoming era wherein interventions propelled by technology can yield substantial enhancements in the quality of life for individuals afflicted with neurodevelopmental disorders.

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