Robotic Technologies in ADHD Care: Literature Review

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ABSTRACT Robotics has made it possible to change and improve many support processes for vulnerable people in different settings. In recent years, its use has been oriented toward supporting therapeutic interventions of neurodevelopmental disorders (NDD), including attention deficit hyperactivity disorder (ADHD). This review of the literature highlights how advances in robotics have evolved in different scenarios of ADHD treatment, its collaboration with other emerging technologies, its results, its limitations, and the research challenges for the future development of robotics in the field of supporting children with ADHD. The authors conducted a literature review based on the location of keywords 'robotics' and several NNDs such as 'ADHD', 'Autism Spectrum Disorder (ASD)', 'cerebral palsy', and 'dementia' in titles, abstracts, and introduction of scientific articles in the Scopus and Web of Science (WoS) database. The reviewed literature was classified according to the type of therapy supported by the robots, the type of robot and the associated technologies. From this analysis, we can solve the research question: Which types of robots have the potential for specific applications in ADHD treatment? Furthermore, this article shows that despite favorable technical results, robotic technologies that support ADHD therapies require significant improvements in terms of scalability, human-machine interaction, and treatment and processing of acquired information to be applied effectively in real-world therapies. The most significant research challenges are proposed to drive research efforts to develop new approaches to enable robotic assistants to participate in ADHD therapies.

I. INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder (ADHD) that affects a large number of children and whose timely treatment is the only way to prevent its prevalence in adulthood [1]. In recent years, non-pharmacological treatments, such as cognitive training, neurofeedback, and behavioral interventions, have gained prominence as they have been accepted by therapists as useful alternatives to avoid the use of medications in

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children, which in many cases can cause dependence [2], [3]. Several non-pharmacological treatments to treat these NND have implemented technological developments such as the Internet of Things (IoT) [4]–[6], Artificial Intelligence (AI) [7]–[10], Virtual Reality (VR) [11]–[14], Augmented Reality (AR) [15]–[17], and Robotics [18]–[23].

Several NDD treatments have significantly harnessed the potential of robotics. The use of robots in the treatment of autism spectrum disorder (ASD) [24]–[28], cerebral palsy [29]–[32] and dementia [33]–[37] has produced good results and established the basis for applying their developments in the treatment of ADHD. However, its application

in the field of ADHD has been much less, representing 1.1% – 1.8% compared to other NND.

The remainder of this paper is organized as follows. Section II explains the methodology applied to this review of the literature. Section III defines ADHD and its treatments. Section IV explains the evolution of robotic application in ADHD treatment and makes a comparison with its application in other NDDs. Section V presents the robotic developments with their principal characteristics and features. Section VI contextualizes all robotic interventions in the treatment of ADHD and their results. Section VII shows the technical and functional limitations of the analyzed studies. Section VIII discusses the lessons learned and proposes research challenges for robotics developments to support ADHD interventions, and finally, Section IX presents the conclusions of this review of the literature and the answer to the research question: Which types of robot have the potential for specific applications in ADHD treatment?

II. METHODOLOGY

A. SEARCH METHODOLOGY

Based on the research question, the authors conducted a search based on the location of keywords 'robotics' and 'ADHD' in titles, abstracts, and introduction of scientific articles in the Scopus and Web of Science (WoS) database. To establish a comparison with other NDDs, this search also includes the keywords 'ASD', 'cerebral palsy', and 'dementia.' The search range is from the publication of the first article in the year 2000 to mid-2021. Preliminary and unfinished work were excluded.

B. ANALYSIS OF RESULTS

The studies obtained in the search are analyzed according to the methodology and experiments applied, the results obtained, and the conclusions reached by the authors. Through this analysis, a classification is made based on the type of robot used, the therapy applied, and the associated technologies (other than robotics).

C. DISCUSSION

The analysis and classification of results allow us to establish a discussion in which the benefits and limitations of the investigations found become evident, and from them establish new challenges for future developments and studies. This discussion is approached from a technological, psychological, and pedagogical point of view. Through this discussion, it is possible to answer the research question of this manuscript.

According to Figure 1, this work contributes: (i) to clarify concepts, characteristics, and gaps about the application of robotics in ADHD treatments and interventions, (ii) to present a classification of these robotic applications, treatments, and their results, (iii) to present the limitations of these contributions; in particular, we identify gaps and challenges related to robotic development to support the therapeutic process of children with ADHD, (iv) to present research challenges for
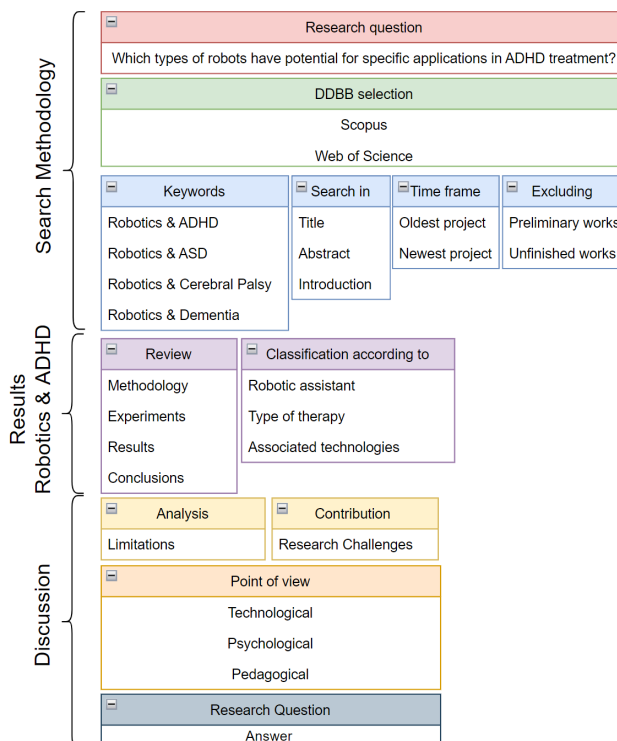

FIGURE 1. Applied methodology for the review of the literature.

future robotic developments to face all previous limitations and finally (vi) solve the research question about which types of robots have potential for specific applications in ADHD treatment?

III. ADHD

Attention is the ability to select and process information from the environment. The lack of development of this function is associated with a disorder, especially ADHD [38]–[40]. ADHD is considered an NND that is usually manifested by inattention and, in some cases, combined with hyperactivity [41]. This disorder represents a serious problem for children, parents, and teachers, as children have difficulties in performing daily activities at home and school. In addition, parents have pay more attention to their child, which can even lead them to stop working [42], and at school, a child with ADHD demands more attention from his teachers, significantly affecting their workload [43].

ADHD is considered one of the most commonly diagnosed NDDs in childhood and has become controversial due to the lack of sufficient expertise to distinguish it from similar disorders (e.g., anxiety, conduct disorders, speech or language delay, other NNDs) [44]–[50].

Its prevalence from childhood to adulthood was 2.58% in 2020, representing 139.84 million affected adults [51]. An epidemiological study of 20 countries from the World Health Organization, World Mental Health Surveys, found that prevalence rates of ADHD in children and adolescents

TABLE 1. Associated disorders with ADHD and its comorbidity.

Associated Disorder	Comorbidity
Oppositional Defiant Disorder (ODD)	40% - 50%
Conduct Disorder	40% - 50%
Anxiety, phobia, generalized anxiety, and separation anxiety	25% - 35%
Learning disorder	8% - 39% [a] 12% -30% [b]
Autism Spectrum Disorder (ASD)	26% - 33%
TIC disorder (Tourette syndrome)	10%

[a]Reading Disorder. [b]Calculation disorder

were highest in the United States (8.1%) and lowest in Iraq (0.1%). This prevalence depends mainly on age, socio-cultural level, sex, and types of ADHD [52]–[54].

Depending on the types of ADHD, it is possible to classify the three most significant types, and even these can vary with age in terms of severity [54].

1) ADHD with attention deficit and hyperactivity.
2) ADHD with the predominance of attention deficit.
3) ADHD with a predominance of hyperactive-impulsive behavior.

Treatments for ADHD seek to avoid academic failure and social disorders. It is possible to identify four types of treatment [2], [49], [55]–[65].

TABLE 2. Treatments for ADHD.

Treatments	Characteristics
Pharmacological	Application of medicaments to reduce symptoms
Psychological	Cognitive-behavioural therapy in daily activities
Psychoeducational	Addresses the educational and learning needs of the child.
Occupational therapy	Metacognitive Strategies, Sensory Integration, and Environmental Adaptations

In recent years, as a complement to nonpharmacological therapies (such as psychological, psychoeducational, and occupational therapies), technical assistance has been introduced through the application of emerging technologies such as IoT, AI, VR, AR, and especially the use of robotics, which is the core of this review.

IV. EVOLUTION OF ROBOTIC APPLICATION IN ADHD TREATMENT

The advent and advancement of robotics have enabled the development of tasks that humans cannot perform, or at least not with such precision [66]–[68]. In the field of eHealth, robotics has played a fundamental role in helping and treating people with various neurological conditions such as trauma [69], dementia [33]–[37], ASD [24]–[28], cerebral palsy [29]–[32] and ADHD [18]–[23]. Although in recent years the application of robotics in the treatment and
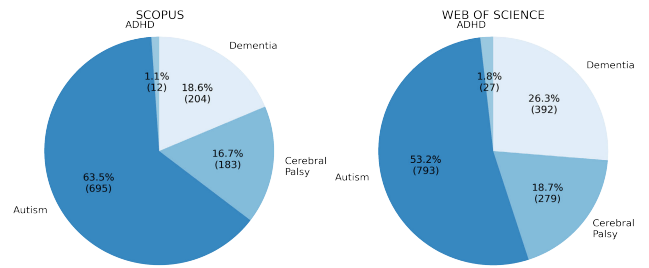

FIGURE 2. Studies that involve robotics for the assistance of neurological disorders according to the Scopus and WoS databases.

support of ADHD has received considerable research attention, however, it is far inferior compared to dementia, autism, and cerebral palsy. Figure 2 shows how studies using robotics to help ADHD reach 1.1% and 1.8% in the Scopus and WoS databases, respectively.

The application of robotics in the treatment and support of ADHD started in the 2000s, but its peak has occurred in the last five years, showing that the implementation of this technology became attractive to therapists as an alternative treatment (according to the Scopus and WoS databases).
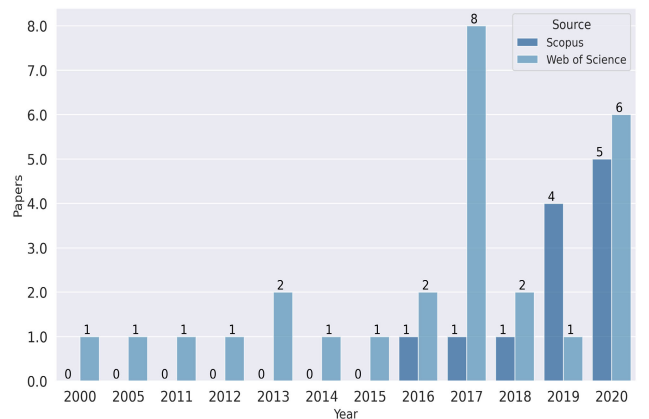

FIGURE 3. Evolution of robotic studies for the aid and treatment of ADHD according to the Scopus and WoS databases.

V. ROBOTS USED IN THE TREATMENT AND SUPPORT OF CHILDREN WITH ADHD

Several types of robots have been used to help with the treatment of ADHD. Some have been adapted to accomplish this purpose; others are developed by the authors under certain parameters according to the objective of their studies.

A. HUMANOID MULTIPURPOSE ROBOTS

The field of humanoid robotics focuses on the creation of robots that are directly inspired by human capabilities and/or selectively imitate aspects of human form and behaviour [70]. Humanoids come in a variety of shapes and sizes, from complete human-sized legged robots to isolated robotic heads with human-like sensing and expression [71].

TABLE 3. Comparison of humanoid robots.

Humanoid Robot	Height	Released	Manufacturer	Equipment/characteristics	Programming	Purposes	Languages
NAO	58 cm	2004	SoftBank Group	2 cameras, 4 microphones, 9 touch sensors, 2 ultrasound sensors, 8 pressure sensors, 1 accelerometer, 1 gyroscope, 1 speech synthesizer, and 2 speakers	Python C++	Education, Personal use at home	Several
PEPPER	120 cm	2015	SoftBank Group	17 joints, 12-hour battery, voice, touch screen, tactile head and hands, LEDs and humanoid expressions	Python Java C++	Business-to-Business (B2B) Learning	Several
SILBOT	115 cm	2014	Robocare	6-hour battery, 11 degrees of freedom, Gyro sensor, Camera, 9.7 in display, Human emotion recognition	ROS Kinetics	Elderly People Healthcare and Dementia Treatments	Korean English
Sanbot Elf	92 cm	2014	Qihan Technology	4-hour battery, 10.1-inch touchscreen, 2 cameras, 3D imaging, 60 sensors, speech, gesture control, and posture recognition.	By a mobile application	Retail, Education, Healthcare, Hospitality, Events	Several
Bioloid	45 cm	2007	ROBOTIS	Various sensors, remote controller,	C	Education	No one

FIGURE 4. Humanoid Robots applied in ADHD treatments. From left: NAO, Pepper, Silbot, Sanbot Elf, and Bioloid.

FIGURE 5. Small commercial robots are used in various treatments and support processes for ADHD in children. From left: Asus Zenbo, CommU, and LEGO® robot.

Many companies have dedicated their efforts to the study and development of multipurpose humanoid robots [72]–[74].

This study shows that most of the robots used in ADHD care and support are humanoid, such as the NAO robot [75], Pepper [76], Silbot [77], [78], Sanbot Elf [79], Bioloid humanoid robot [82].

B. SMALL MULTIPURPOSE ROBOTS

Small robots have served in various settings to treat and support children with ADHD, such as the Asus Zenbo Robot [80], [81], the CommU robot [82], [83] and LEGO® robots [84].

These robots have been adapted to address their functionalities in the treatment of children with ADHD and other NND. The technical and functional specifications are detailed in Table 4.

C. CUSTOM ROBOTS

There are several original developments that the authors have carried out to test their theories and hypotheses on the application of robotics in the support and treatment of children with ADHD.

One of these developments is IfBot, a small android that can communicate with humans through joyful conversation and emotional facial expressions [85]. This robot has a limited number of expressions and does not move its arm or body.

Another original development is KASPAR (Kinesics and Synchronization in Personal Assistant Robotics). This robot is a humanoid robot for human-robot interaction research [86]. Its shape is similar to that of a child and its functionalities allow it to show expressions related to mood states.

IROMEC is a robotic platform consisting of a mobile platform, an application module, and a set of additional components that modify the appearance and behavior of the robot [87]. It is capable of autonomous movements to engage and retain children's attention. IROMEC is able to detect obstacles and people in its environment through ultrasonic

TABLE 4. Comparison of small multipurpose robots.

Robot	Height	Manufacturer	Equipment/characteristics	Purposes	Languages
ASUS ZENBO	31.5 cm	Asus	6-inch LCD, camera, microphone, and 5-6 hours battery	Assistant in education, healthcare, and even customer communication	Several
COMMU	30.4 cm	-	facial expressions, eye movements and eye expressions, several movements.	Autism Treatments	No one
LEGO® ROBOTS	20 - 45 cm	LEGO®	Different possibilities to assemble.	Education	No one

and infrared sensors located on the mobile platform. Both the body and the head have an integrated digital screen [88].

Atent@ is another original development. Its design is more compact and has a user interface with a touch screen and speakers. This robotic assistant can move around the workspace as it is equipped with wheels [19]. It helps the child with homework processes at home.

CARBO (CAretakerRoBOt) is an autonomous socially assistive robot (SAR). Its shape is spherical and its surface is covered with a collection of 67 tactile sensors and LEDs. In addition, it has a camera and a drive module to move the robot on a flat surface. It is used to play and train children's attention through hands-on interaction.

Finally, KIP3 is a small social robot companion that can be triggered to present a small set of pre-made gestures. The trigger for the gestures were the performance errors of the participants in the CPT test (i.e., errors associated with inattention and impulsivity) [89].

FIGURE 6. Original developments for the treatment of ADHD in children. From the left in the first line: IfBot, KASPAR, and IROMEC. In the second line from left: Atent@, CARBO, and KIP-3.

VI. TYPES OF THERAPIES DEVELOPED WITH ROBOTS
A. SPEECH THERAPY DEVELOPMENT
Language is important to communicate and socialize, especially in children. Delay in the development of language and communication skills can carry phonological and pragmatic problems [90], [91].

Following the use of robotic assistance in speech therapy for children with ADHD, [20] investigated the potential of using a social robot in speech therapy interventions. This study involved children participating in individual sessions with the NAO robot. The treatment was focused on attention and writing, where NAO triggered an increase in children's motivation and engagement.

The results show an improvement in the construction, structure, and vocalization of sentences by children, increasing their confidence. However, the children's perspective of therapy was associated with a game instead of a therapy session. On the other hand, technical errors, such as delays and errors in the robot's responses, made it difficult to interact in the session. The robot's responses had to be modified by the programmer all the time. The authors concluded that more research is needed to make NAO the best assistant in speech therapy.

B. MOTORSKILLS THERAPY
Handwriting is a complex perceptual-motor skill that involves the use of attention, perception, language, and fine motor skills [92]. When handwriting skills become challenging, it can lead to dysgraphia, which is defined as an impairment in quality or speed to achieve sufficiently smooth and automated handwriting [44]. Several robotic developments focus on providing better treatments to improve fine motor skills in people with motor disorders [93], [94].

Following common and impaired writing disorders, [21] developed a co-writer scenario in which a child is asked to teach the NAO robot how to write by demonstrating on a tablet (Wacom tablet). This scenario combines a series of games to train the control of pressure, tilt, speed, and letter connection [21]. This set-up was proposed to a 10-year-old boy with a phonological disorder, ADHD, dyslexia, and developmental coordination disorder (DCD) with severe dysgraphia. The Wacom tablet allows for the extraction of the position of the pen (2D), the pen tilts in two directions, and the pressure of the pen on the surface of the tablet [95]. NAO remains next to the child to engage the child in the learning games computed on the tablet [96].

The therapist controls the rhythm of the therapy session and decides whether or not to give NAO feedback (e.g., "Come, try again"), but can also participate in the play session if the child appears bored playing with NAO. The results show that the treatment of dysgraphia using a child-robot interaction is feasible and that both the quality of the child's handwriting and posture improved dramatically. However, the authors

consider that extensive clinical studies are needed to confirm that children with dysgraphia could benefit from this scenario setup.

In the same field, to improve handwriting in children with impaired motor skills, [97] investigated the effectiveness of robotic handwriting assistance in 18 participants with cerebral palsy (CP), ASD, ADD, and ADHD. The intervention consisted of repetitive three-dimensional robotic movements in 15-20 daily sessions of 25-30 minutes each over 4-8 weeks with a developed matric robot. The software generated a three-dimensional haptic path when the user entered one or more letters, numbers, or punctuation marks to analyze the haptic path according to speed, glyph size, amount of pen lifts from paper, attempts, strength, and stroke patterns of left- or right-handed users.

A typical session included a 10-minute review of the letters and numbers covered in previous sessions, 10 minutes of robot-assisted spelling under the supervision of the tutors (who adjusted speed or letter size and provided verbal feedback during the session), and 10 minutes for the workbook lesson. All children with ASD or ADHD were able to increase speed while maintaining legibility. Robotic training improved handwriting fluency in children with mild to moderate fine motor deficits associated with ASD or ADHD within 10 hours of training.

Following motor memory [98] a robotic arm covered by the horizontal screen was developed in which children with ASD and ADHD held the handle and played a game of catching animals that had escaped from a zoo. If the child could reach the target in time (0.5-0.05 s), the animal is caught and the child receives points. The robot generated a velocity-dependent curvature force field. The results show that the ASD sample had a greater generalization of motor memory in proprioceptive coordinates compared to children with ADHD. Furthermore, children with ASD showed slower adaptation rates compared to the ADHD group.

Motor control deficits in children with ADHD are known to come from the upper limb, specifically the dominant limb [99]. The study [22] used two robotic behavioral tasks to investigate motor control in the dominant and nondominant limbs of children with DCD. Twenty-six children with ADHD, learning disorder (LD), or generalized anxiety disorder (GAD) were evaluated by a registered healthcare provider in 155 controls. Motor performance was assessed using the Kinarm exoskeleton robot [100] at the Alberta Children's Hospital, Calgary, Alberta, Canada. Participants were driven to an augmented reality workstation. The targets were 6 cm apart and displayed as red dots on the screen. Participants completed a total of five blocks, each consisting of four randomly generated peripheral target positions. Participants processed the task first with the dominant hand and then with the nondominant hand [101], [102].

Motor performance was quantified across several parameters: reaction time (seconds), the initial motion direction error (degrees), the difference between the minimum and maximum speed (m/s), the hand path length ratio, the hits

with the dominant and non-dominant hand, the area of movement (m^2), the movement speed (m/s), the hand bias of hits, and hand transition (meters). The results provided new information on motor impairments in children with DCD and ADHD and support the presence of underlying deficits in motor control. This study demonstrated the potential of robotics to help understand and identify motor impairments in children with DCD and ADHD and to suggest appropriate treatment that fits the characteristics of individual children.

Due to the impairments in tactile sensitivity and social interaction observed in children with ADHD, a CARBO was presented in [103] to perform tactile and interactive games such as 'ColorMe'. This game is part of CARBO and it consists of the child must follow the desired colour and direction of movement on CARBO's shell. The child must rub CARBO's surface at a constant speed in the desired direction to paint the bowl the desired colour and the robot provided auditory and motion feedback when the expected colour criterion was met or not.

In a small feasibility study with children with ADHD, the authors found that the interaction with CARBO was engaging and the recorded data were sensitive to various impairments. Furthermore, the authors concluded that CARBO has potential as a diagnostic tool for children with developmental disabilities and could be very useful in the future as an automated form of sensory integration therapy (SIT), but a larger study is needed with matched children with typically developed children. With the development of future games and analysis, CARBO could become a robotic assistant (RA) that focuses on the tactile impairments observed in these developmental disorders.

C. IMPROVEMENT OF TRADITIONAL THERAPEUTIC SESSIONS

To develop effective intervention strategies in the therapeutic process with children with ADHD, careful observation of the patient's behavior is necessary to fully understand its causes and identify the most appropriate resources. In conjunction with their social and communication skills deficits, children with ADHD often have difficulty managing their emotions. It is common for therapists to have difficulty communicating with these children due to the highly expressive nature of the individual and the tone of voice, which is never consistent, affecting the child's perception of feeling comfortable.

The study [18] used Pepper [76] as a robotic toy / game approach to improve social skills by creating personalized therapeutic pathways based on the profile of children with ADHD. This prototype focuses on the recognition of facial expression, the attention of the patient and the evoked emotion (thanks to the identical cameras of Pepper), Pepper's tablet is used for interaction through some exercises in the form of games. The exercises performed by the children are analyzed and combined with the data collected by the cameras. The combination of these data serves to propose appropriate levels of therapeutic activity. The work was developed in collaboration with a diagnostic and therapeutic center,

where it is currently being tested. The results show that a system is a useful tool when a therapist is trying to help, teach, communicate, or interact with children with ADHD. The results showed that a humanoid robot in a therapeutic context has proven to be very attractive, both for the therapist and for the children, who are better motivated by the results.

The associated consequences of ADHD are behavioral and emotional problems that affect learning and social integration. The study *[23]* has found that emotions can be detected through processing of physiological and image data. However, some children with critical ADHD are often accompanied by the inability to control their facial expressions, making it difficult to recognize the emotion. This study aims to predict the emotions of children with ADHD and properly address their emotional problems with IoT robotic devices (ASUS Zenbo robot).

Zenbo contains a video camera and a platform that functions as an IoT robotic device (Raspberry Pi installed in the gap behind the robot's head) that collects infrared images to recreate the sample and training the image-based cognitive learning (Deep Reinforcement Learning) on Microsoft Azure platform to be embedded in the application through its API to periodically stream information.

Tests with 25 students with ADHD showed that the introduction of robotic aids can effectively reduce the number of emotional incidents, demonstrating that a leadership strategy using robotics has some impact. In the future, different detection methods can be integrated or emotion recognition methods can be adapted for students to improve overall recognition performance and address appropriate therapy according to the results.

For the rehabilitation of children with ADHD, a system that evolves augmented reality glasses with a noninvasive single channel brain-computer interface (BCI) based on steady-state visual evoked potentials (SSVEP) has been proposed in [104]. An untrained user can move a robot (SanBot Elf) by focusing on flickering stimuli and eye blinks through the BCI channel, enabling effective treatment of inattention, hyperactivity, and impulsivity. The goal of the AR application is a rehabilitation robot that provides feedback to the child via remote control while the robot provides feedback in the form of movement (according to the user's wishes) and speech (about what it is going to do). This ensures a high level of patient participation, which has a positive impact on the effectiveness of rehabilitation. The robot was connected by WiFi to the Raspberry Pi server, which retrieved the information in JSON format. The feature extraction algorithm does not need to be trained. Optical see-through AR technology allows the user to see the robot's movements while simultaneously viewing the visual stimuli. Preliminary further testing in four children with ADHD aged 6 to 8 years gave very positive feedback on device acceptance and attention performance.

A patient-centered interaction design for robot-assisted therapy (RAT) or robotic-assisted play (RAP) applications is presented in [105]. Its design was evaluated in multiple iterations with therapists, clinicians, and parents.

The authors continuously refined the behaviours of the humanoid robot NAO. Any interaction design (ID) involves activities such as identifying needs and establishing requirements to adapt the behaviour of NAO to other populations with special needs. The ID makes it possible to improve it from cycle to cycle based on the experiences and recommendations of other stakeholders (physicians). The authors evaluated robot behavior through observations of child-robot interactions and semi-structured interviews with therapists and parents. During this experience, the ideal setup included two NAO robots (the second as a backup), two laptops, a Wi-Fi router, and printed images for the games. Consequently, the presence of researchers (to adapt the characteristics of NAO) and parents (to increase child confidence) in the room was unavoidable.

The results showed that RAP had positive results for most children. Some children had striking results, such as P5, who began to look her mother in the eye after about five sessions. P9 never uttered words with meaning before, but she said "Again" a few times and asked the robot to dance more. She also sang along during the "Spider" song. Another participant said his first word to the robot, "Bye." And finally, a child who normally avoids people gave all researchers a high-five gesture after one of the sessions. However, the delays made some children very unhappy and often led them to become aggressive toward the robot.

An observational study conducted in the Children's Rehabilitation Center premises to investigate the effects of RAT on nonverbal children with severe forms of ASD and ADHD is presented in [106]. Similarly to [105], based on an iterative observational evaluation process of three children (one girl, two boys) and interviews with their parents, the behaviors of a humanoid robot NAO were refined to be used for RAT research. The experiment was conducted at a branch of the Republican Enterprise Fund "University Medical Center" Children's Rehabilitation Center in Astana, Kazakhstan. Each child and his parents stayed in the center for 21 days for therapy. Each session lasted approximately 15-20 minutes every other day.

Similarly to [105], each child was accompanied by the therapist and parents in the robot room. There are no interactions records, just observational data collected through notes and reports from the therapist and parents. To measure the effect of RAT on children with ADHD and ASD, a series of interviews with the parents of the children was conducted.

Furthermore, three games were used. In the "Follow me" game, the child was asked to help NAO learn to walk, while the robot is slow in walking, and it teaches the child patience.

In the game 'Touch me' to develop tactile contact skills, the child was asked to touch the robot's body parts to learn their names. The robot uses alternative verbs, e.g., "scratch my head," "stroke my head," "tap my blue toes on my right foot," "stroke a bruise on my right hand". If executed correctly, NAO congratulates the child.

Finally, the game "Dance with me" animated the child to listen to songs, dance, and repeat the movements of the robot.

Already, a few sessions showed significant results, indicating that robotic interaction improves social traits and concentration. However, implementation in therapies for ASD and ADHD showed some complications, such as RAT behavior and games, that must be adapted to meet all types of diverse needs of children, while extending the variety of games, as well as holding their attention for longer periods. This work is limited by the number of subjects in the session; however, future work can refer to the need demonstrated in this thesis to further develop and continue in this specific field of research and study.

In the longitudinal study [107] with a cohort of 15 children (all male) aged 3 to 12 years; 10 children were diagnosed with ASD and ADHD. Through several sessions (at least seven per child on different days) of 15-20 minutes, a large number of robot behaviours, targeting joint attention, imitation, turn-taking skills, and participants' emotional well-being, were implemented and fine-tuned using a new robot (NAO) behaviour that aimed to improve children's social skills through imitation. By demonstrating a series of simple social nonverbal communicative actions such as high-five, peace sign, handshake, kiss, hug, or yawn, the robot asked the child to repeat the action with their parents and a therapist. If done correctly, the robot praised the child.

Through a final questionnaire for parents and caregivers, the authors concluded that robot-assisted sessions were able to improve children's social skills, particularly their eye contact and concentration. For example, some nonverbal children began to say simple words, such as "bye," "tick-tock," and "nao", others became interested in the sounds of transportation and animals, leaving parents with the wish to apply this type of therapy regularly.

Focusing on various forms of ASD, ADHD, or delayed speech development (DSD) with autistic traits, [108] presents a large clinical study that was conducted with 21 children (4-8 years old) in 4-6 sessions of robotic assisted therapy (RPT) lasting 15 minutes.

During the session, the child was animated to interact with a robot (NAO) through the games mentioned above in [106]. To find behavioral patterns, engagement, and valence scores, sessions were video-coded and data was processed to analyze the effects of child contact with the robot.

Through, for example, improved eye contact, the valence score demonstrated that the child developed his skills through positive interaction with the robot during the sessions.

D. INTERVENTION OF EDUCATIONAL THERAPY

The educational context is the application most explored according to the implementation of robotics as a support tool, even with children with ADHD. For example, a communication training system using a teleoperated robot (CommU) is proposed in the study [26] to improve the communication skills of children with ADHD during classes. Participants were randomly assigned to two groups: the group taking a class by teachers alone (TCT) and the robot-mediated communication exercise (RMC) group. Participants in RMC were

grouped in pairs and communicated with each other through CommU once a week for 4 weeks. During the intervention, participants input words into the PC, which were read aloud by CommU. Participants could also replicate non-verbal expressions, such as nodding and lifting their hands, with CommU. The results showed that as hypothesized, people with ADHD improved listening to the thoughts or feelings of others by using teleoperated robots. Furthermore, they demonstrated higher self-confidence that they are good at describing their thoughts to others.

To introduce AI perception technology to help teachers solve the behavioral problems of children with ADHD, the study [109] introduced emotion recognition through robotic aids to recognize student emotional performance. This allows a personalized emotional guidance strategy to improve or reduce the emotional occurrence of students and reduce the need for teachers during the session. The effectiveness of the strategies is recorded using the ASUS Zenbo robot to identify the best assistant processing strategies and construct the best-personalized activities to help teachers improve students' behavior problems and emotional control in the classroom. The results showed that the introduction of robotic aids can effectively reduce the emotional appearances of students, which means that a counseling strategy with robotic aids has an effect. The authors explained that different recognition methods can be integrated or adapted for students with severe emotional expressions to improve the overall recognition performance of this system.

In the study [110], learning from a demonstration framework (LfD) is presented that uses a deep recurrent Q-network (DRQN) to learn how to execute a behavioural intervention (BI) based on demonstrations by a human. BIs are highly structured procedures in which children with ADHD learn new behaviors and life skills. The trained DRQN enables the NAO robot to execute a similar BI autonomously. The model predicts appropriate actions with more than 80% accuracy. This offers an alternative to the challenges of perception, as it can identify significant features in large image datasets and can generate a policy from a small number of examples. As a result, deep Q-learning appears to be a suitable tool to solve many LfD problems to generalize the features that are important for a robot as an assistant in the learning of new behaviors and life skills of children with ADHD.

An investigation of the effects of collaborative learning between robots and children with ADHD ()[111] presented a collaborative learning methodology in which the child and robot IfBot take turns reading a page of educational material aloud. IfBot has been designed to use the Wizard of Oz method [112] and interact with children in real-time. In this process, the robot was designed to read sentences slowly to ensure that the children could understand and follow the words.

The results of this study indicate that the robot stimulated the children to improve their concentration while learning together. Furthermore, learning time increased during the session in the presence of the robot than without it. In addition,

they tend to remain calm and learn much more efficiently during collaborative learning sessions with the robot. The authors claim that a long-term experiment will be conducted to investigate the psychological and learning effects of collaborative learning between a robot and children.

The project [89] presents the design and evaluation of a social robotic device for students with ADHD that provides immediate feedback for inattention or impulsivity events. The tablet-based Continuous Performance Test (CPT) assesses inattention and impulsivity with a socially expressive robotic device (Kip3) to provide feedback. The evaluation was carried out with ten students with ADHD, and nine of them felt that Kip3 helped them regain focus. However, there are questions about whether the device is effective for a longer period and how it detects inattention in more complex situations outside the lab.

This work showed that providing students with ADHD with a robotic social device that serves as immediate feedback for events of inattention or impulsivity is promising. Even if most of the study participants indicated that immediate feedback from the social robot helped them focus on the laboratory-based CPT test, many were sceptical about whether the device would help outside of the lab. The authors established that further work should focus on understanding the relationship between the design of the gesture, the emotion it evokes, and the effect on the user's performance.

The study [86] provides a comprehensive introduction to the design of the minimally expressive robot KASPAR, which is particularly suitable for human-robot interaction studies. KASPAR offers multiple applications for studies of human-robot interaction in the laboratory or schools by providing a high degree of expressiveness and the ability to play interactive games with children with ADHD. Mobility is suitable for a wide range of interaction scenarios and applications, but must be set up and operated by well-trained personnel. The evaluation criteria proposed can also be applied to other robotic platforms, allowing a reconciliation of requirements from application contexts and robot capabilities.

KASPAR not only has fulfilled its original purpose, but has also exceeded expectations through a large number of peer-reviewed publications that have resulted from the work with the robot.

Another study [121] describes the use of KASPAR [85] and a mobile robotic platform IROMEC [87], in a six-month longitudinal study with children with different levels of cognitive and social disabilities. IROMEC was designed for children with special needs to encourage them to participate in playful activities. KASPAR was designed to facilitate social interaction, including applications to help children with autism. Similar play scenarios were conducted with both robots, and their effects on the children's behaviour were observed. The cause-effect game 'Make it move' was evaluated, showing very encouraging results [88]. In general, the interaction with the robots seemed to have a positive impact on the development of children's social skills. The degree of success

in achieving the various goals varied from child to child, depending on the degree and type of disability.

The game "Make it move with IROMEC" consists of clapping hands to make IROMEC move around the room. The child can choose the direction in which the robot moves, such as going straight, turning left, and turning right. This game scenario is played in the Wizard of Oz modality [113]. However, for the child, IROMEC's movements seem to be directly related to his actions. The setting for this game scenario was a large room to allow the robot to move. The game is played as long as the child is interested.

The scenario of the game with KASPAR was conducted in a room with a table and two chairs. The goal of the game scenario was to raise KASPAR's arms by clapping hands. The KASPAR movements were controlled by remote control. The experimenter controlled KASPAR's movements in the Wizard of Oz modality. In some cases, the experimenter gave the remote control to the child to control KASPAR's movements. The game was played several times until the child lost interest.

The use of IROMEC in children with ADHD and some autism traits appears to be beneficial due to its mobile properties, which allow the needs of children with this specific disorder to be more explicit.

The study [114] presented a Kindergarten Assistive Robot (KAR) platform. It provides kindergarten teams with a novel tool to achieve educational goals through social interaction through NAO. The kindergarten teams have full control over the robot: defining the daily task, stop/run behaviour, etc. Children with ADHD / ADD benefited from KAR to train their cognitive skills, such as constructive learning, selective attention, etc. KAR has the ability to provide feedback to children on their performance and monitor their progress over time. KAR showed how soon assistive robot platforms will be used in kindergartens, hospitals, and homes in training and therapy programs that monitor, encourage, and support children with ADHD.

The most recent project [115] presents an assessment of Atent@ as a support tool for homework activities for children with ADHD. The results showed that Atent@ with the smart objects not only makes observations with a high degree of precision as a therapist does, but also generates positive influences on the homework performance of children with and without ADHD. Atent@ and the smart objects are connected to the Internet and the information about the behavior of the child is available to parents and therapists remotely.

E. ATTENTION AND MEMORY THERAPY

Engaging the training mode by transforming a traditional neurofeedback training session into a competition consisting of commanding a Lego®robot using brain waves is presented in [116]. The brain is trained to produce brain waves in specific amplitudes and in specific positions. The proposed system consists of a BrainWave Mobile Kit headset kit [121], a Lego®robot [86] in the shape of a rover, and an ad-hoc system installed on a PC. The goal of the game is to direct

the player's attention and concentration: if the player pays enough attention to the coloured disk, the robot's speed will increase, allowing the robot to win the race against the other players' robots. The software uses the attention parameter provided by the e-Sense algorithm to accelerate a Bluetooth-connected Lego®robot.

The authors indicated that it is possible to create engaging interactions even for children with ADHD using these robots. However, channelling and improving children's attention would be one of the most interesting challenges of the future.

The current study [117] proposes a novel cognitive architecture for a computational model of the limbic system inspired by human brain activity that improves interactions between a humanoid robot (Bioloid) and preschoolers. Using human-robot interaction (HRI), this framework may be useful to ameliorate problems related to the acquisition and maintenance of attention in children suffering from ADHD. This mechanism was designed to increase attention-based interaction activity in preschool-age children.

In the current proposed limbic model system, the authors applied adaptation processes based on reinforcement and unsupervised learning to a dynamic neural field model (DNF), resulting in a system capable of monitoring (by a Kinect camera) [118] and controlling the physical and cognitive processes of a Bioloid. Several interaction scenarios were tested to evaluate the performance of the DNF model, which provided an efficient computational mechanism to represent the cognitive activity of the humanoid robot.

The results were compared with a neural mass model that used artificial neurons population dynamics instead of neural system field dynamics as a comparison method showing its superiority over the neural mass model.

Studies [119], [120] are related to the previous study [117] to show the interaction between humans and robots and their applications in rehabilitation in social settings as a suitable solution to problems related to optimizing focus and maintenance of attention states in children with ADHD and ASD.

Human-robot communication experiments aimed at modeling attention levels are predicted to be an efficient method in rehabilitation areas with ADHD and ASD [11]. The Bioloid's cognitive architecture performs tasks using the motion selection module, evaluates children's attention levels during these tasks, and records them in the robot's memory.

The interaction scenario tasks guided by the Bioloid's short-term memory allowed the scenario to be implemented with the contribution of the robot's long-term memory. The first experiment included normal children, and the second included children with ADHD.

The results showed a relationship between the response delays of the tasks performed in the scenario and the focus of attention. In addition, the difference in success levels between the two groups decreased. The authors concluded that this treatment could help solve other rehabilitation problems and may allow a more accurate examination of the levels of preschool children.

Research [121] developed a spherical robot that engages children using its motion capabilities. This robot has two kinds of outer spheres with a diameter of 170 mm, which are made of different materials. One is a softball made of paper, and the other is a hardball made of plastic. As a result, the jump height of the inner mechanism reaches 110 mm, while that of the softball reaches 65 mm. On the contrary, the softball robot exhibits an unstable rolling motion and a seemingly prancing pace that is difficult to control. Overall, the proposed spherical bouncing and rolling robot may be a suitable tool for children with developmental disabilities such as ADHD. The authors concluded that there are many possibilities for future work based on this study.

For a trial of attention training programs for children with ADHD, [122] have developed a combination of a BCI analysis involving the NAO humanoid robot.

The BCI Emotive EPOC [123] is used by the child, while the robot explains the rules of the game to the child by voice. The robot voice is synthesized by the ALTextToSpeech module of the NAOqi framework. The robot then demonstrates a sequence of four activities (e.g., forward, backward, left, right) to the child. The robot then asks the child to repeat the sequence. The commands are formed by the BCI and the robot executes these commands one by one. If the command is correct, the robot waits for the next command; if not, it asks to try again. In the end, the robot congratulates the child and offers to play again.

The cycle of the game is successfully completed when the robot completes the initial sequence of activities.

The main problem was the long delay between commands. The results established that [7], this scenario can be used in more experiments with people suffering from ADHD investigating the therapeutic effectiveness of the prototype.

F. DIAGNOSTIC PROCESS
A novel approach to the screening of children with ADHD is presented in [124]. This study demonstrates the design of a robotic assistant that involves machine learning technology and a game-like test that directly reflects children's behaviour when measuring ADHD symptoms. Using sensors in the robot Silbot, the children's behaviour is measured automatically. This test consists of children performing activities guided by Silbot. These activities are designed to reveal the possible assessment of ADHD measuring three factors for the diagnosis of ADHD: Inattention, Hyperactivity-Impulsivity, and Executive Function Working Memory Deficits. The child should complete all levels on one test and its difficulty level increases along with the tests [124].

Robot-assisted with the collected data from 326 children in 3rd-4th grade would help parents and teachers agree to make more efficient decisions based on reliable and objective data than the Likert scale test by screening report.

The results of the data analysis show a very reliable ADHD classification of up to 97%. It could be a practical tool for clinicians and special educators to use to diagnose childhood ADHD. Unlike traditional questionnaire-based tests, the

robot-based test increases the accuracy of ADHD diagnosis by directly reflecting the quality of children's behaviour during activity play with the robot involved in the action.

The authors established that setting it up in a school setting that is more familiar to children than a hospital could alleviate their stress to improve educational evaluation. It could be a practical tool for clinicians and special educators in diagnosing childhood ADHD, which would indeed help ensure that children in need receive the right educational services promptly.

Most of the projects are aimed at correcting the effects, the long-term consequences of ADHD, and even try to mitigate the negative effects that cause, such as lack of confidence in expressing their feelings and emotions (social interaction), frequent loss of concentration (hyperactivity). On the other hand, some studies seek to help children with ADHD improve their behavior, improve their reading ability, and, in the best cases, educate them to be more independent at school.

Regarding motor skills, several projects have presented their developments to mitigate problems or improve fine and gross motor skills with vision coordination, the development of handwriting, proprioceptive ability, and motor control in general.

The development of speech therapy is presented by one project that addresses this deficit.

For the specific treatment of attention and memory development, several solutions have been presented, such as playing games that require a lot of concentration, and through human-machine interaction sessions.

Several projects have been included in the general therapeutic process of ADHD, either through interaction with games, human-machine interaction to improve social skills or in rehabilitations in different aspects within a specialized center.

Finally, due to the complexity that the diagnosis of a child with ADHD represents even for a therapist, there is only one project that has established the diagnosis of this pathology in children as an objective [124].
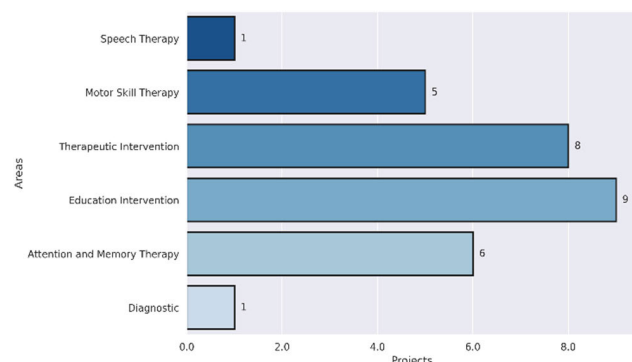

FIGURE 7. Projects oriented toward a specific treatment.

The study shows that in addition to robotics, other technologies have been implemented to complement the

intervention processes of children with ADHD. The addition of artificial intelligence algorithms began in 2016 and has been present in ten projects. Of these developments, four have also been implemented with BCI and two with IoT. Similarly, one project has involved only BCI and another only AR, but a third has incorporated both technologies.

VII. LIMITATIONS
A. MOBILITY AND SCALABILITY
Those projects that have used premade humanoids such as NAO, Pepper, Sanbot Elf, Bioloid humanoid and Silbot [18], [20], [21], [104]–[108], [110], [117], [119], [120], [122], [124], which represent nearly half of all projects developed for ADHD, have the limitation that they cannot operate within a therapy session without the supervision of the developer or programmer who will adapt the behaviour of the robot according to the therapy development. This prevents therapy from being moved to a location other than the experimental center. This limitation also imposes a significant time burden on the parents and the child, which could affect the child's acceptance of the therapy as the parents do not have time to take the child to a medical center. In terms of scalability, the cost of these robots prevents replication of the experiment proposed by these projects in further scenarios or trial sites.

On the other hand, projects that use small prefabricated robots, such as LEGO robots, Asus Zenbo, and Commu [23], [26], [109], [116], could allow changing the place of therapy. However, it has been shown that the supervision of the programmer is also required. This limits the opportunities for locational changes. According to the scalability, as with humanoids, their replicability represents a significant investment for other research groups.

Most of these projects have shown good feasibility results; however, for low/low middle-income countries that show a high prevalence of ADHD [52], the application of this alternative treatment of ADHD would be impossible just taking into account that most of the robots presented in Section IV cost on average more than a full year of a therapist's salary. Without closing the topic, the cost issue of incorporating these technologies limits their expansion, and therefore the concept of learning improvement is limited to institutions and users who participated in trials or experimental phases; this is mainly in developing countries, where it is even worse in rural contexts, where even Internet penetration and communication inputs are still insipient [126].

B. HUMAN-MACHINE INTERACTION
Projects were presented that do not use an artificial intelligence algorithm. This limitation means that therapy or intervention always requires a programmer or engineer to adjust the robot's responses and movements according to the child's behaviour or the type of therapy. Not to mention that several studies have reported that delays in responses cause the

TABLE 5. Summary of the classification of therapies and robotic assistants used.

Intervention	Study	Year	Robot	AI	BCI	AR	IoT	Games	Other hardware
Speech therapy	[20]	2021	NAO						PCs
Motor Skill Therapy	[21]	2021	NAO					Learning Games	Wacom
	[97]	2012	Matricial robot						
	[98]	2012	Robotic Arm					Catching animals	
	[22]	2021	Kinarm exoskeleton			✓			
	[103]	2018	CARBO					ColorMe	
Therapeutic intervention	[18]	2021	Pepper	Recognition of facial expression, patient attention, and emotion evoked					
	[23]	2021	Asus Zenbo	Image-based cognitive learning (Deep Reinforcement Learning)			Azure to stream information		Raspberry Pi
	[104]	2020	Sanbot Elf		✓	✓			Raspberry Pi
	[105-108]	2019 - 2020	NAO					FollowMe, TouchMe, DanceWithMe, Transport, Animals, Emotions, Storytelling	
Education Intervention	[26]	2021	CommU						PCs
	[109]	2019	Asus Zenbo	AI emotion recognition algorithm					
	[110]	2017	NAO	Deep recurrent Q-network					
	[111]	2016	IfBot						
	[89]	2016	KIP-3						Tablet
	[86]	2009	KASPAR						PCs
	[125]	2011	KASPAR & IROMEC					Make it move	
	[114]	2011	KAR						
	[19, 115]	2020 - 2021	Atent@	Rule-Based Inference Engine			A smart-home environment with smart things		Smart Objects
Attention and Memory Therapy	[116]	2019	Lego Mindstorm® Kit	e-Sense algorithm	✓				
	[117, 119, 120]	2016 - 2017	Bioloid	Reinforcement- and unsupervised learning-based adaptation processes to a DNF	✓				Kinect camera
	[122]	2016	NAO		✓				
Diagnostic	[124]	2019	Silbot	Machine Learning Algorithm					PCs

child to become distracted or drop out of the session. Therefore, due to the constant intervention of a third agent, the programmer/engineer, these projects cannot be considered a more "natural" human-machine interaction.

As we have illustrated, most of these projects do not directly "learn" the child's profile, preferences, and needs during the therapy process. Moreover, these projects are unable to adapt their functionalities and interaction commands according to the type of ADHD.

C. EMERGING TECHNOLOGIES THAT COULD REPLACE THE APPLICATION OF ROBOTICS

This paper has shown how robotics has been of great help in various areas of NDD support. However, in recent years its rise has been evident, as has that of other emerging technologies; however, as with applications in ASD, robotics will tend to be displaced by other emerging technologies such as AR or VR. A clear example can be found in speech therapy processes, where a virtual assistant in an AR environment could

do the same job (even better) than NAO [20], but in this case it is not necessary to take the child away from home, as shown by certain jobs [127]. The same occurs in educational therapies; the real therapeutic scenario with a robotic assistant can be replaced by virtual assistants in an augmented or virtual scenario [128].

However, there are still interventions where robotics will be necessary due to their measurement accuracy and especially because motor interventions require a physical element of interaction. However, care should be taken to incorporate technologies such as RA or VR that make these therapeutic interventions more attractive to children. As well as the possibility of performing these interventions at home with more ergonomic robotic developments that allow remote monitoring and control of motor development therapies through IoT.

D. NO INFORMATION FOR SUBSEQUENT ANALYSIS

In this study, it has been evident that most of the analyzed projects do not automatically provide relevant information for the subsequent analysis of the therapists on the evolution of the therapies. The information that the robots could obtain could be very useful when it comes to improving therapy processes or proposing new procedures. Moreover, favorable technical results do not guarantee that they are also favorable at the therapeutic level.

E. SCHOLAR ENVIRONMENTS

Other limitations are inherent in educational environments, as it is known that maintaining the same learning strategies for prolonged periods and with the same school groups leads to limited results and even higher levels of school disinterest. An important strategy to consider is the incorporation of resources from the theory of multiple intelligences [129]. Therefore, the combination of didactic resources, methodologies, alternation of sequences in subjects and disciplines, reorientation of objectives based on findings, achievements, and deficiencies is suggestive. Therefore, learning assistance focused on ADHD through robotics or technologies should always and in parallel be combined with those commonly described in the curriculum for regular people and educational environments, in favour of integrative education.

F. TECHNOLOGICAL CULTURE IN EDUCATIONAL CENTERS

Similarly, and in the educational field itself, a common limitation is that teachers do not maintain didactic planning over time at the classroom level that includes technological strategies and resources, due to factors associated in some cases with their limitations in terms of technology management capacity or because in others, the inclusion of this type of inputs, tools, software, and robots requires more time for school planning at the classroom level [130].

VIII. RESEARCH CHALLENGES

After analyzing the limitations of all projects, in this section, we explore the main research challenges emerging from the reviewed literature, related to the improvement of the robotic assistant to support therapeutic processes in children with ADHD.

A. TECHNICAL IMPROVEMENTS

The limitations section showed how several robots have mobility problems or otherwise need a conditioned space to function properly. Future research or development should take into account the robot's navigation system. Nowadays humanoids are gaining their place in the development of autonomous robots because their navigation system is close to that of a human being and does not need a conditioned space, but the robot adapts itself to the established space.

An additional parameter that future research could establish is the use of voice recognition, natural speaking, body movements, facial expressions, and perception of physical contact for the more natural development of a human-machine interaction during therapy with a child.

B. CREATING A FRAMEWORK FOR INTELLIGENT THERAPY ENVIRONMENTS

To maximise the therapeutic benefits of a robotic assistant, it must be accompanied by other devices that enhance interaction with children. Establishing a framework for creating intelligent environments would establish development guidelines that would facilitate interoperability between robotic assistants and the environment in which they encounter the child. In this way, a solution can be provided where robotic assistants, smart objects, tablets, etc. Work together to provide the necessary support from the child and the therapist in any location such as home, school, etc.

C. REPORTING SYSTEM FOR THERAPISTS

Interpretable information for therapists and standardisation of data would make it easier to make high-level classifications of the child's information. All information should be presented in an appropriate form so that a therapist without low-level data interpretation skills can suggest new and innovative therapies or modify traditional therapies. In addition to making charts showing the variables, it is important to relate the data properly to make the information of interest to the therapist.

D. SCALABILITY

We believe that the biggest challenge for future developments is the replicability of robotic therapies in low/low middle-income countries. This challenge forces developers to continue to look for ergonomic robots that do not represent a high investment for the therapy center. The same limitation was presented in [131]. In this project, the authors present an alternative way to generate low-cost technology using a collaborative network of institutions, educational centers, research groups, and volunteers. This replicability must also include consideration of linguistic and cultural diversity for the development of human-machine interaction and user experience.

E. ADAPTABILITY

To allow for a more natural intervention, robotic development must be able to learn from children to adapt its characteristics to the type of ADHD, age, gender, behavior, preferences, and needs.

Finally, the improvement in children after starting therapy can be significant in the short and medium-term. Therefore, it is necessary to prepare the robotic assistant so that it can adapt to the child's behaviour and needs at any time. The architecture of the robot must be flexible enough at the hardware and software level to be up-gradable to increase the lifespan of the robotic assistant and the range of therapies for which it can be used.

F. DIAGNOSIS BY THESE ROBOTIC DEVELOPMENTS

Another challenge would be the use of these technologies in the diagnosis process of children with ADHD. As Table 5 showed, only one of the solutions analyzed (Silbot) presented a robot-assisted, game-like test that directly reflects the behaviour of children in measuring symptoms of ADHD. The authors consider the early detection of children with ADHD key, therefore helping with the technology of interest to the population under study is a milestone that we hope will be successfully achieved in the next few years.

G. EVIDENCE OF THEIR USEFULNESS IN A REAL THERAPEUTIC PROCESS

Studies that demonstrate the actual benefit of these robotic assistants in real therapeutic processes must be documented. Although there is already evidence of the enhancements offered as therapeutic elements in themselves, no further evidence was found of their usefulness as supportive elements in real therapeutic processes.

In addition, some robotic assistants use artificial intelligence methods such as machine learning. These types of study could provide a good database of data collected in the real world and allow developers to access it so that new designs in this line of research already have a data set to train their models using the necessary security and privacy criteria.

IX. CONCLUSION

ADHD is considered a very common NDD in children, which is unfortunately diagnosed in most cases when academic difficulties become apparent and when this is accompanied by another NDD such as ASD. However, several studies have also considered it to be an overdiagnosed NDD due to the difficulty in determining accurate parameters for diagnosis. The reviewed bibliography shows different types of treatments, divided into pharmacological and non-pharmacological. The latter show an increase in the tendency to implement some kind of technology in their methodology.

In this article, all studies focused on the specific use of some kind of robot in therapies and accompanying information was presented. It became clear that compared to ASD, CP and dementia, the use of robotics in the treatment

and accompaniment of ADHD is far inferior; however, their contributions were significant, and their results showed that they are a useful tool to support children with ADHD. Several projects have shown that robotics can provide good results, and even some of them can work in conjunction with other technologies such as IoT, AR, VR, and BCI. Almost all projects have demonstrated possible outcomes by experimenting with children in specialised centres, obtaining promising feasibility results.

Along with this review of the literature from 2000 to mid-2021, several technical limitations were addressed, discussed, and grouped, such as replicability, interaction methods, emerging technologies that can replace robotics applications due to previous limitations, and the lack of information for subsequent analysis.

All these limitations allowed the authors to define that besides its limitations, the NAO robot has the best potential in all kinds of treatments (Therapeutic intervention, education intervention, speech, motor skills, attention and Memory Therapy) of ADHD. The functionality of NAO as a humanoid provides the best user experience to children during session therapies. However, some research challenges were proposed to avoid the limitations of NAO and other humanoid robots.

In the educational intervention, Atent@ presented a good potential because its functionality is independent of the therapists and works within the home. This opens several possibilities for new lines of research that address innovative solutions from the presented projects.

Finally, the concept of a defined product or project does not fit when it comes to contributing to educational programs focused on ADHD care issues, because, like educational theory and practice, they are considerations of permanent construction and reconstruction, especially regarding the diffuse nature of technological constructs, as they are effective insofar as they are at the service of the user, in this case, a person with such specific difficulties that it is unfair to say that this artefact fits as a guarantee solution for all cases of study [132].

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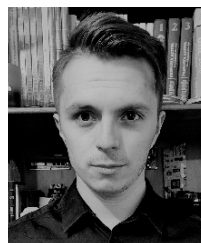
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