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Robotics in Special Education: Children with Autism Spectrum Disorder

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Abstract

The integration of robotics in special education, particularly for children with autism spectrum disorder (ASD), has demonstrated promising outcomes in fostering social, communication, and academic skills. This article examines how robotics addresses the unique challenges faced by children with ASD, emphasizing socially assistive robotics (SARs) as tools to improve social interactions and reduce the difficulties these children face in traditional educational settings. While skepticism exists regarding the replacement of human educators with robots, studies show that robots can complement teaching by providing consistent, non-judgmental, and engaging environments for skill development. Research highlights the potential of SARs to model social behaviors, promote interactive learning, and assist in therapy sessions. Child-friendly designs, such as humanoid or animal-like robots, have proven effective in engaging children with ASD. However, limitations persist, including small sample sizes and a lack of robust clinical trials. Most research in this field focuses on technological advancements rather than evaluating the efficacy of robots in real-world educational contexts.

Despite these challenges, robotics offers significant potential for creating inclusive learning environments and enhancing the quality of education for children with unique learning needs. The article calls for further research to optimize the integration of robotics into educational and therapeutic frameworks, ensuring equal opportunities and societal inclusion for individuals with ASD.

Keywords: robotics, special, education, ASD

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Робототехника в специальном образовании: дети с расстройством аутистического спектра

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Резюме

Интеграция робототехники в специальное образование, особенно для детей с расстройством аутистического спектра (РАС), продемонстрировала многообещающие результаты в развитии социальных, коммуникативных и академических навыков. В этой статье рассматривается, как робототехника решает уникальные проблемы, с которыми сталкиваются дети с РАС, уделяя особое внимание социально-вспомогательной робототехнике (SAR) как инструменту улучшения социальных взаимодействий и уменьшения трудностей, с которыми эти дети сталкиваются в традиционных образовательных учреждениях. Хотя существует скептицизм относительно замены преподавателей роботами, исследования показывают, что роботы могут дополнять обучение, обеспечивая последовательную, непредвзятую и увлекательную среду для развития навыков.

Исследования подчеркивают потенциал SAR для моделирования социального поведения, содействия интерактивному обучению и помощи в терапевтических сеансах. Удобные для детей конструкции, такие как роботы-гуманоиды или животные, доказали свою эффективность в привлечении детей с РАС. Однако сохраняются ограничения, в том числе небольшие размеры выборки и отсутствие надежных клинических исследований. Большинство исследований в этой области сосредоточено на технологических достижениях, а не на оценке эффективности роботов в реальных образовательных контекстах.

Несмотря на эти проблемы, робототехника предлагает значительный потенциал для создания инклюзивной среды обучения и повышения качества образования для детей с уникальными потребностями в обучении. Статья призывает к дальнейшим исследованиям для оптимизации интеграции робототехники в образовательные и терапевтические рамки, обеспечения равных возможностей и социальной интеграции для людей с РАС.

Ключевые слова: робототехника, специальное образование, РАС

INTRODUCTION

Many specialists are needed in today's high-tech world because of the importance of providing high-quality instruction in special education. Teachers in the field of special education are prepared to help children with autism through early intervention. Unfortunately, many students with special needs do not receive the optimal enrichment they need because of high expectations and insufficient classroom resources. Special education programs may fail if individuals are forced to use antiquated tools. However, owing to robotic technologies, teachers can utilize cutting-edge innovations to facilitate students' learning while exposing them to fascinating, thought-provoking, and socially enriching situations [1].

Children who have been diagnosed with autism spectrum disorder (ASD) may face significant challenges when attending regular school. These kids require an unstructured, tolerant, and enriching setting to practice social skills such as making friends, working with others, and finding solutions to issues. This might be a challenging situation for children with autism spectrum disorder. However, there is a helpful resource that may be used in the classroom [2]. Children on the autism spectrum will benefit from engaging in constructive, enjoyable practice of these skills with robotic technology. When the next generation of children with special needs arrives, many obstacles will be eliminated thanks to using robots in special needs education. Robotic advancements will play a vital role in the future of education, with far-reaching consequences for all three of these spheres of human endeavor [3].

Some people doubt the effectiveness of robotics as an aid for those with autism, and this has historically given robotics a lousy name. Some parents are wary of introducing their kids to robotics because of the negative connotations associated with the technology and the concern that their kids may be replaced by "nonhuman" machines. However, this prejudice quickly fades as more people learn about the numerous advantages and prospects robots present. Because children with ASD exhibit a wide range of symptoms, from communication difficulties to inappropriate responses to specific social cues, it is crucial to provide them with an environment where they can feel comfortable making mistakes and trying new things without fear of being penalized. However, robots are increasingly taught to assist with these and other difficulties [4].

While it is true that machines will never be able to replace human educators, there's no denying the great strides that have been made in education thanks to the advent of the digital era. Thanks to the usage of robotics in education, teaching professionals can benefit from increased opportunities for assessment, observation, and analysis of a student's performance. Education is given high priority because the future needs in the realm of education are difficult to forecast. This makes it especially difficult to teach pupils with special needs; thus, it is helpful to have a variety of aids at one's disposal [5].

For the benefit of students with special needs, roboticists and software developers are working on creating robot-assisted instructions. Children with learning impairments will benefit from these robots because they can naturally learn the fundamentals that most people acquire. Furthermore, parents are in a promising new era of interactive education ahead of them thanks to robot-assisted instruction. Interactive robots are the wave of the future when it comes to helping children with autism spectrum disorders. Therapists and educators are currently using the newest robotics technology as a tool in their work with patients [6].

These robotic systems allow far more robust contact than is occasionally obtained with only conventional instruction in special education, and they are still being developed and improved. When children's activities become more disruptive through their learning, robots that encourage open communication could be the solution. When technology is improved, parents will have more options for their children's education and upbringing. Participating in this program could alter A child's life, which would better prepare them for elementary school and teach them essential life skills. Roboticists are developing systems that can assist therapists in helping patients develop social and communication skills [7]. Taking such a novel approach will allow the robot to mimic the stimuli that people with autism experience in other settings. The child's attention can then be directed toward the encounter rather than the lack of response, providing a more nuanced understanding of the social context [8].

This technological innovation is a giant step forward in science. The use of robots to teach students with autism spectrum disorder is a revolutionary step forward in the field of special education. Parents, caregivers, and educators who want their students to learn, grow, and have the greatest possible developmental experience should be aware of the benefits of robotics in special education.

Educators may convey the joy and creativity children need to study by utilizing various technologies, such as robot-assisted instruction, to improve the learning and socialization experience. Robotics can help students with unique needs in multiple ways. Technology can make a significant difference in the effectiveness of science and math instruction for students with autism who are failing. Educators can encourage students to explore technology and accept its benefits by creating an engaging, hands-on classroom setting [9]. Engaging children with autism or other learning impairments in meaningful activities would be one of the most significant contributions robotic assistive technology could ever make to society, helping them overcome the difficulties they experience daily. These obstacles frequently prevent kids from obtaining the education they need to thrive later.

■ THEORETICAL REVIEW

A study by Kumazaki et al. suggested that autistic children's performance improved when a robot was present with a human partner [10]. Participants' ages ranged from five to six years, and their results showed that they had improved their social communication skills. As a result, educators in both the general and special education sectors are compelled to experiment with new teaching approaches to stem the tide. Even outside the regular school day, instructors put in extra work to reassure parents that they are doing well. To ensure that no child with ASD falls behind, educators and researchers are exploring the possibilities of technology-driven therapies by testing evidence-based strategies in rapid succession.

Several professionals have recognized the potential power of the widespread introduction of technology into special and inclusive education. Sensory aids, adaptive software, and other forms of augmentative and alternative communication have all been proven to help students with special needs perform better than they do now. Robotics and other cutting-edge technologies help students on the autism spectrum respond to feedback from their surroundings in social and interactive settings. The fields of education and medicine are increasingly focusing their attention on robotics. Positive results have

been found in trials investigating its usage to aid young people with autism spectrum disorder [11].

However, like any new method or technology, robotics has been criticized for not helping students with autism spectrum disorder (ASD) learn and progress in the classroom enough. Arguments were presented citing the work of Alcorn et al. [12], with a focus on three main points: (1) that robots are seen as uninspiring but still allow for free participation in responses; (2) that robots serve a similar purpose to existing tools and are thus seen as indifferent to what teachers are currently using; and (3) that robots must be customized depending on the curricular goals to target before their adoption. This study's reasoning counters the widespread conclusions drawn by other studies about the best ways to put certain technologies to use in the classroom. The same authors note that while robots may increase children's readiness to process information, they may also discourage them from interacting with their teachers and peers, leaving a void for educators and practitioners to decide whether robotics could realistically result in statistically significant outcomes in the learning process of children with ASD.

Autism spectrum disorder (ASD) is characterized by apparent deficits in socialization, especially in children's capacity for social and emotional reciprocity, interaction, and nonverbal communication. This is supported by the diagnostic criteria in DSM 5, which highlight "persistent deficits in social communication and social interaction across multiple contexts" [13] in children with ASD. This is followed by symptoms that are diagnostic of the illness, such as a failure to make eye contact, a lack of ability to imitate, a failure to follow directions, a failure to participate, a lack of empathy, and inadequate facial expressions.

Remarkably, several of the studies included in this meta-analysis specifically addressed these manifestations within the context of social skills. Despite their limitations, this approach made it possible for the study participants to develop social skills typical of their age group.

There is a wide range of options available for children with ASD who have the goal of improving their most troublesome skills.

Wittke et al. reported that children with ASD may also exhibit language impairments or issues, especially in the area of pragmatics, which is crucial for effective communication [14]. Furthermore, students on the spectrum often have linguistic delays [15] due to language code processing and social context analysis difficulties. The inability to comprehend data or grasp ideas is not included among the cognitive deficits that constitute a diagnosis of ASD. However, it should be noted that some children with ASD have difficulty reaching their full potential in areas of executive functioning, such as planning, problem-solving, and reasoning [16]. These justifications confirm that people with ASD have language and cognitive difficulties; thus, using these factors as variables in some of the amassed robotics-based studies can help this disabled population reach its full potential; this is especially true when the results of these studies generally show positive effects after the introduction of robots to children with ASD.

Educators and practitioners have been scrambling to find a solution to the rising number of children identified with ASD so they can help these kids develop better adaptive and functioning skills. Robotics is a potentially helpful tool in the treatment and education of children with autism spectrum disorder. To better understand the potential of robotics for assisting children with ASD and its prospective implications for children's learning performance, the present research involved a meta-analysis.

■ THE CHALLENGES FACED BY CHILDREN WITH AUTISM SPECTRUM DISORDER

Young children on the autistic spectrum tend to respond positively to small child-sized robots with simplified human-like characteristics and monotonous voices because these robots provide predictable, consistent behavior and minimal sensory input [17]. However, some therapists and teachers have been skeptical of the employment of robots in educational and clinical contexts [18]. One contributing factor is that most existing studies have not followed accepted research protocols. For instance, many studies do not include a control group, and their sample sizes are petite (often five people or fewer) [19]. Although the tendencies shown by these small sample sizes are helpful, extrapolating the results (typically from a single encounter to the robot) to draw sweeping conclusions about the impact of robots on the educational or therapeutic outcomes of children and adolescents on the autism spectrum is not compelling [20]. Educators have raised concerns concerning their understanding of autism and their ability to instruct pupils on the spectrum [21]. Teachers' self-assurance and students' grasp of the material benefit when they can access materials designed to help them [22]. There is a lack of data on how teachers of students on the autism spectrum feel about the introduction and use of robots in the classroom, and there are few professional development programs designed to prepare teachers for using robots in the school [23].

Educators and policymakers are becoming increasingly interested in studies investigating the hopes and fears of adults on the autism spectrum and the instructors and therapists of adolescents on the autism spectrum regarding using robots to enhance learning and teaching. Educators and therapists for autistic children and young people have expressed optimism that this technology may prove helpful in the classroom [24]. However, there is a lack of participation in the research process and a paucity of data about the perspectives and experiences of people on the autistic spectrum.

■ SOCIALLY ASSISTIVE ROBOTICS

A social assistance robot (SAR) is a robot that helps its human companions in a social context [25]. This means that robots have the potential to perform a variety of interactions that can fulfill a clinical role without the need for a trained professional or with minimal contribution from the professional's time and that the SAR educates and feeds back to the user while playing the role of coach and monitoring the treatment's progress. Assistive robotics (AR) are similar to SARs in concept but are typically employed in rehabilitating patients with physical impairments or disabilities through direct physical interaction and the execution of suitable activities designed to aid the user's physical movement. Wheelchair robots, mobility aids, companion robots, manipulator arms, and instructional robots are good examples of augmented reality. Socially interactive robotics (SIR) is a subfield that shares some conceptual similarities with SIR. The capacity to engage is central to these robots; this interaction can advise the user by imitating social interaction, but the robots are not intended to provide actual aid to humans [26]. Robotic toys are one such example since they can mimic the user's expressions and movements and even mimic what the user does with their face and body. Individuals' language, body language, and other fundamentals of social interaction with robots and humans are compared and contrasted using these robots. To aid human users, SARs have the unique quality of including social interaction features [27].

Socially assistive robots (SARs) are similar to assistive IRs in that they both help humans, but SARs aid in social interaction rather than physical movement. While SIRs are designed to match their movements to the user's interactions with the robot, SARs aim to use familiar and effective interactions to help the user make measurable progress in areas such as rehabilitation, recovery, and academic studies [28].

A robot must meet significant requirements to be used as a SAR; it must be able to see its surroundings, interact with humans, exhibit proper social signs, and communicate with humans. Because of these unique characteristics, a SAR can be used to educate or model socially desirable behaviors, helping children with ASD who have problems communicating due to a lack of developed language and social skills.

An integral part of SARs is designing a robot with a child-friendly aesthetic so that it may be used effectively in the treatment of children with ASD. Humanoid robots, animal-like robots, and machine-like robots (nonbiomimetic) with the ability to mimic human facial expressions and gestures have been produced. Humanoid robots can help children with autism spectrum disorder (ASD) learn social skills by providing social cues that are highly realistic simulations of those offered by real people. The robots can also be programmed with applications that give the kids experience with the necessary interpersonal skills [29]. Robots designed to look like simple animals or cartoon characters are also being created to help children with autism spectrum disorder (ASD) learn social skills, in addition to the more traditional applications already available [30]. Examining the practicality of SARs, we find that many of them include things such as lights or a song to provide positive reinforcement to children with ASD and that SARs may be programmed with various movements and gestures to maintain the children's attention. Sharp features should be avoided in robots, and the danger of them being knocked over or falling should be considered, as some children with ASD also exhibit hyperactivity and impulsive behavior. SARs should be configured to be more active than passive, and they should be able to communicate with the patient even when the therapist is not present [31]. A robot can never fully replace a human therapist. Human therapists are still an integral element of the therapy system for the time being because robots are not yet as adept as humans at determining how the child's activity should be represented [32].

■ LIMITATIONS AND REMAINING ISSUES

Over the past decade, there has been much pressure on the clinical use of interactive robots for people who have autism spectrum disorder (ASD). However, research on this topic is still in its infancy regarding utility and effectiveness. However, much of the related research has been published in robotics-specific journals (e.g., Autonomous Robots, Robotica) rather than in well-known ASD journals or clinically focused publications. Since most of the prior studies relied on anecdotal data or were composed of undocumented educational activities, this is one reason why additional research is needed [33]. Furthermore, the amount of data available for analysis in SAR studies is low because most related studies have been undertaken to advance the state of robotic system development rather than to assess these robots' clinical efficacy and utility. Only three of the fifteen scholarly publications published on this topic involved studies including six or more children with ASD, and most were studies involving only three or four individuals, as stated by Diehl et al. [34]. Only two related studies were published in clinical journals, and only four used gold-standard diagnostic techniques for ASD (such as the ADOS or ADI-R).

■ CONCLUSION

Individuals with unique learning requirements, such as those with high-functioning autism or exceptionally bright kids, should have the same unfettered access to education, information, society, and knowledge as everyone else. Therefore, in their integration into society as a whole, to achieve smooth and equal coexistence with the other members, robotics could prove to be an invaluable tool in the education of these people, as it positively contributes to the development of their skills, the strengthening of their sociability, the construction of the necessary knowledge, and the provision of equal opportunities in social life. This study is a literature review that focuses on the benefits and applications of robotics in the education of children and adults with high-functioning autism and other forms of giftedness. Children with high-functioning autism and brilliant children were targeted since their participation in all aspects of society was a research priority; therefore, this was the topic of choice.

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