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Application and Trends of Artificial Intelligence in Special Education: A Case Study of Autistic Children

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Abstract: With the rapid development of artificial intelligence (AI) technology, its application in special education has demonstrated great potential for enhancing educational effectiveness and promoting inclusivity. This article explores the current applications and future trends of AI in special education settings from a human-computer interaction perspective, with particular focus on children with autism. The paper first outlines the transition from universal computer-assisted education toward AI-driven specialized interventions that meet the personalized needs of special education students. Through research cases applying affective computing systems, speech recognition technology, and large language model tools for children, it illustrates how AI enables personalized learning and real-time feedback. Finally, the article prospects future directions for AI in special education, emphasizing human-centered approaches to support the comprehensive development of learners with special needs.

Keywords: Artificial intelligence; Human-computer interaction; Children with special needs

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1. Introduction

Computer-assisted education is an educational model that uses computer technology to enhance learning efficiency and effectiveness. In primary and secondary education for general children, computer technology is mainly used to optimize the presentation of teaching content, automatically evaluate teaching effectiveness and student performance, and promote students' understanding of the content and teacher-student interaction [1]. In contrast, special education primarily serves students, teachers, and parents who struggle to receive adequate support within the educational system, including but not limited to groups with neurological disorders such as autism, intellectual disabilities, and other learning disorders.

As different special education populations exhibit varying degrees of cognitive, emotional, and behavioral challenges, their educational models often rely on methods such as multi-sensory stimulation, continuous feedback, structured teaching, and intensive behavior management, emphasizing individualized and personalized instruction. Therefore, compared to general education, special education focuses on designing personalized teaching plans for students with diverse learning needs, often going beyond the traditional framework of academic knowledge teaching to address students' comprehensive development in social life, interaction, emotions, cognition, and other aspects [2]. Consequently, computer-assisted technology in special education pays more attention to meeting the personalized needs of disabled or vulnerable groups [3,4]. Furthermore, the implementation settings for special education are more diverse and complex, ranging from inclusive schools integrated with general education, special education schools, child rehabilitation and development centers, to homes and even communities. In inclusive education settings, general education students and special education students share a learning environment, and teachers meet the needs of different students through differentiated instruction. In special education schools or institutions, students receive more specialized teaching interventions, with educational resources and intervention measures being more concentrated. Homes and communities provide additional learning opportunities for special education students in daily life, supplementing school education.

2. Current application status of artificial intelligence technology in special education

Firstly, artificial intelligence (AI) technology plays an important role in various stages of special education, from diagnosis and teaching intervention to assessment. For instance, intelligent technologies such as multimodal data analysis, deep learning, and pattern recognition can help doctors, behavior analysts, or special education professionals assess the learning abilities of children with special educational needs. For students with language disorders or hearing/visual impairments, AI-driven technologies like speech recognition, text-to-speech, and sign language translation can provide effective language, text, learning, and communication tools. Secondly, during the teaching phase in special education, AI can design personalized teaching content and strategies to help students gradually improve cognitive and social skills. For example, augmented reality (AR) or virtual reality (VR) technologies can create immersive learning environments for students with special needs, helping them better understand abstract concepts or practice specific skills [5]. Additionally, intelligent chatbots can assist students with cognitive disabilities or delayed language development in learning and improvement through interaction and feedback [6], or help improve students' mental health status through emotion recognition and behavior analysis [7]. Beyond vertical technology applications targeting specific disability types, intelligent technologies can also horizontally serve multiple groups related to special education. For example, for parents, AI can provide home intervention strategies and daily behavior management suggestions, helping parents better understand and support their children's development; for teachers, intelligent technology can provide teaching resources and personalized teaching suggestions, enhancing their teaching efficiency and outcomes.

Children with different disabilities have vastly different educational needs and learning abilities during the special education process, making the flexibility and personalization of intelligent technology particularly important in special education. For instance, AI applications for hearing-impaired children might focus on optimizing hearing assistance devices, while applications for children with intellectual disabilities might focus more on personalized cognitive training and behavioral intervention. Through multi-dimensional, multi-level technical support, intelligent technology can meet the diverse needs of special education populations, enhancing educational outcomes and quality of life. Next, this article focuses on autism as an example to explain from different perspectives how existing research in the field of human-computer interaction applies intelligent technology to special education scenarios.

3. Application of AI in special education settings: The case of children with autism

From the perspective of the medical model of disability, autism spectrum disorder is a group of highly heterogeneous neurodevelopmental disorders originating in early childhood, characterized primarily by social interaction and communication deficits, restricted interests, and repetitive stereotyped behaviors [8]. In recent years, researchers have redefined autism spectrum disorder from the perspective of the social model of disability and inclusivity-viewing "disability" as "difference" [9]. This definition also aligns with the self-perception of some individuals within the autism community who view autism as an expression of neurodiversity [10]. Currently, the World Health Organization ranks autism as the leading childhood mental disorder, meaning autism has become a global public health issue severely affecting children's health. With the development of computer technology, especially AI technology, attempts have been made both domestically and internationally to use computer-assisted methods to support the special education and intervention training for children with autism. The following sections will analyze the application of technologies such as computer vision, speech recognition, large language models, and generative AI in educational settings for children with autism.

3.1. Research on affective computing technology applied to social-emotional intervention for children with autism

Children's emotional perception and social skills play a key role in their social development. However, children with autism face challenges in understanding the social context of emotions [11], recognizing and expressing facial emotions [12], among other areas [13]. Affective computing is an interdisciplinary field within AI that studies emotion and related phenomena [14], aiming to enable intelligent systems to recognize, experience, infer, understand, and mimic human emotions [15]. For example, many computer-assisted designs based on affective computing require children with autism to imitate characteristic facial expressions displayed in pictures [16,17] or videos and provide real-time feedback. However, these tasks often lack integration with social contexts, thus hindering children's generalized understanding and application of emotional and social knowledge.

EmoLand is an online educational product for social norm and emotional cognitive development targeting children with autism aged 3–9. It utilizes AI affective computing, interactive animation, and gamified learning to help children with autism understand the recognition and expression of emotions within social contexts. The research team used an AI convolutional neural network and trained an emotion recognition algorithm model for children with autism in social scenarios (neutral, happy, sad, angry, excited, surprised, disgusted) based on available small-sample datasets of children's facial expressions. Based on this, they designed the web-based interactive application EmoLand. This application includes two main units: EmoStory and EmoGame. EmoStory contains 21 social animation stories across three major scenarios, co-designed with frontline intervention experts, along with six structured games for each story, assisting children with autism in completing the learning experience from emotional cognition to emotion recognition, and then to emotional analysis and application, integrated with social scenarios. In the emotion imitation and application stage, the affective computing model provides children with different levels of incentives based on the match between the child's presented emotion and the target emotion. EmoGame is similar to EmoStory, but it breaks down the previous linear structured tasks and presents them in a modular format, facilitating intensive training by parents and teachers for children with autism; simultaneously, educators can define personalized training frequency and content based on the child's abilities.

This product underwent three rounds of user testing, with nearly 60 children with autism and over 10 intervention teachers participating in the trial experiments. The results indicated that EmoLand, as a feasible teaching tool in special schools, through the use of multimedia audiovisual content, structured tasks, gamified interaction, and AI emotion recognition and feedback, can enhance the focus and participation of children with autism, effectively supporting their learning and application of emotion-related knowledge.

3.2. Research on speech recognition technology applied to social language intervention for children with autism

Besides difficulties in emotional cognition, children with autism also face challenges in verbal communication, eye contact, and joint attention. To ensure intervention effectiveness, therapists must provide one-on-one, continuous, and intensive intervention tailored to the individual child's situation. With the increasing maturity of intelligent speech technology and digital human technology, some interactive applications have attempted to use virtual tutors, i.e., 2D or 3D digital avatars, to guide or accompany children with autism in learning social knowledge. However, most applications do not fully consider the cognitive characteristics and emotional states of children with autism when designing virtual tutors, and work specifically dedicated to their social language intervention is relatively lacking.

The team through prior participatory observation in classroom teaching for children with autism, discussions with intervention teachers and parents, and inviting children with autism to co-create through drawing, summarized general principles for designing virtual tutors for children with autism. Based on this, the team designed and developed the "Virtual Tutor" feature as a web-based interactive application, primarily using an intelligent virtual tutor to assist children with autism aged 3–6 in learning daily social language and need expression. This product has three main features: First, it integrates a cartoon-style virtual tutor with AI speech recognition technology. The virtual tutor's emotionally expressive and affinity slow speech, cartoon appearance, and relatively exaggerated body movements help shorten the social distance with children with autism, increasing their sense of participation and learning motivation. Second, it allows parents and teachers to upload and customize the incentives that children receive after learning, based on the child's preferences, thereby transforming the child's stereotyped behaviors into learning motivation. Third, it allows parents and teachers to upload their own photos as teaching scenarios for the virtual tutor, allowing the child to learn in familiar and comfortable environments, alleviating psychological stress and anxiety. Research showed that children with autism exhibited great interest in conversations with the cartoon-style virtual tutor: with the help of special education teachers, 12 children with autism aged 6–8, after three months of training, showed significant improvement in their social language expression abilities. This research indicates that endowing intelligent technology with a cartoon anthropomorphic form, while selecting language content and expression styles suitable for children with autism, can shorten the social distance with children and enhance their learning outcomes.

3.3. Application of large language models and affective computing technology to stakeholders of children with autism

Beyond focusing on the student population, our research has also further explored using existing large language models and affective computing to help caregivers and related practitioners of children with autism. Research shows that early behavioral intervention is crucial for improving the overall health and behavioral problems of children with autism. Caregiver involvement in the intervention education of children with autism not only promotes the child's overall ability development but can also further reduce the stress burden on caregivers. Therefore, training and attention for novice practitioners and caregivers are particularly necessary. Although behavioral interventions, such as applied behavior analysis (ABA), are common professional intervention methods, caregivers and practitioners still face many challenges in accepting, adopting, and integrating these intervention frameworks and specific methods into daily practice. Most existing research primarily focuses on developing digital intervention tools for children with autism themselves, often overlooking the roles of practitioners and caregivers; while some other studies explore how to apply computer technology to help practitioners and caregivers learn and execute behavioral interventions at home or in institutions, most are limited to the form of online learning websites.

With the development of large language models and the proven potential of LLMs in improving personal health behaviors, we explored the opportunities and challenges of using LLM-based virtual digital humans to support caregivers and practitioners in ABA behavioral intervention for children with autism. We first conducted three rounds of iterative design research with caregivers and practitioners of children with autism to understand their current situation, problems, and expectations for technology. Based on the research findings, they further developed a prototype system named Glitter. This system provides a self-directed learning module and an LLM-based virtual human module to help practitioners and caregivers learn and execute behavioral interventions. Additionally, Glitter can collect and extract emotional information from the user's facial expressions, voice, and language, and drive the virtual human's expressions and actions based on the user's emotions. In a one-week field study and evaluation, 10 practitioners provided positive feedback on Glitter's overall trustworthiness and usefulness. Their main usage scenarios and motivations included "Asking and Resolving," "Comparing and Improving," and "Preparing and Summarizing." Practitioners also shared opportunities and concerns regarding Glitter's practical application. This research also showed that practitioners valued the virtual human's language functions the most, considering the intervention content crucial for information acquisition. Although the virtual human's avatar appearance provided a sense of realism, visual or emotional feedback features did not affect their experience of acquiring behavioral intervention information.

4. Trends in the application of AI in special education

Whether in the field of AI or human-computer interaction, human-centric values are universally acknowledged. In special education settings, we not only need to recognize the complexity of children with special needs but also reflect on the shift in design values under the contemporary concept of inclusive design.

Firstly, the population of children in special education settings and their needs are relatively complex, requiring AI technology to be supplemented by more precise group matching and more detailed needs research. Children with varying degrees of physical and cognitive disabilities have significantly different physical, mental characteristics, and core needs compared to general children. Even among these groups, there can be considerable differences, such as the large variations in cognitive abilities among children at different points on the autism spectrum.

Secondly, a child-centered approach is also reflected in a fundamental shift in design values. First, from "Cure" to "Empowerment," i.e., shifting the design focus from compensating for the deficiencies of children with special needs to creating a more supportive environment, encouraging children to develop their own learning skills and confidence. Second, from “Segregation” to “Inclusion,” including integrating the characteristic pathways of practicing inclusive education in China, promoting the integrated application of intelligent technology and products in diverse local scenarios in China, and preparing children with special needs for integration into society. Third, from “Disability” to “Advantage,” i.e., guided by a “strength-based perspective,” combining intelligent technology with interaction methods (e.g., multimodal interaction) and learning paths (e.g., structured learning) that are more aligned with the cognitive logic of children with special needs, utilizing and amplifying their unique strengths. Fourth, from “User Research” to “Co-creation,” involving children with special needs in the design context through role-playing, drawing activities, embodied interactive games, etc., to fully express their design needs. Traditional special education interventions often overemphasize the “special” characteristics of the children themselves, such as the social deficits, repetitive stereotyped behaviors, or language expression difficulties of children with autism. Recent research and practice have gradually shifted towards educational models oriented towards adapting to natural contexts and the laws of children’s cognitive development. By enhancing the metacognitive abilities of children with special needs—i.e., enabling them to learn how to live and learn—their cognitive abilities, self-regulation, and independent learning skills are improved, helping them better adapt to social and living environments. Technologies such as AI and big data analysis can help educators better assess students’ specific skills, understand their life and learning needs, thereby formulating personalized teaching plans and providing precise support. Only by respecting the individuality and abilities of students with special needs can we help them achieve greater independence and a sense of accomplishment in daily life.

In the practice of special education, besides the students themselves, the combined role of multiple participating groups such as parents, teachers, doctors, and therapists is also key to success. Therefore, the application of AI technology in special education should not be limited to supporting individual students but should also form a multi-party collaborative ecosystem by providing technological empowerment to related groups such as parents, teachers, doctors, and therapists. Parents are not only the primary supporters of their children in the home environment but also important implementers and feedback providers for intervention plans. Research shows that active parental involvement in the intervention plans for children with autism can not only effectively improve the child’s learning and behavior but also reduce the parents’ own stress. Through technological means, parents can receive more personalized support. For example, intelligent technology can provide parents with suggestions for their child’s daily learning content and behavior management, helping them cope with the child’s specific needs in the home environment. Simultaneously, intelligent technology can provide parents with real-time progress reports through applications or smart devices, helping them better understand their child’s growth trajectory and adjust intervention strategies promptly. Teachers play a crucial role in the school environment, especially in inclusive education, where teachers need to cater to the different needs of both general education students and students with special needs simultaneously. For teachers, implementing differentiated instruction to meet the personalized needs of each student is a major challenge. Intelligent technology can analyze student learning data to provide teachers with personalized teaching suggestions, helping them design learning activities more suitable for students. Furthermore, intelligent technology can reduce teachers’ workload through automated assessment tools, allowing them more time to focus on interaction with students and personalized guidance. Therapists or special education teachers play important roles in intervention and assessment; they are not only responsible for developing detailed intervention plans for students but also need to track students’ long-term progress. The introduction of AI technology provides them with more precise tracking and data analysis tools. Integrating intelligent technology with this ecosystem can enhance education and intervention outcomes, reduce the workload for all parties, enhance communication and cooperation among them, thereby providing more comprehensive support for special education students.

5. Conclusion

Looking ahead, the application of AI technology in special education will continue to develop in depth. This article, from a human-computer interaction perspective, has deeply explored the application and future development trends of AI in the field of special education, particularly in the education of children with autism spectrum disorder. The introduction of AI technology has provided children with autism with personalized intervention strategies, real-time feedback, and emotional-cognitive training, significantly improving teaching effectiveness and engagement. Simultaneously, intelligent technology has also empowered parents and teachers, enhancing their roles in intervention and education. Furthermore, this article has also discussed some basic design principles for the practical application of intelligent technology: AI must balance the multi-dimensional relationships between technology, users, and context, and focus on being child-centered for special needs, consider human-AI interaction and educational effectiveness, combine the requirements and challenges of real application scenarios, and empower diverse user groups such as students, parents, teachers, and therapists in special education settings.

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Disclosure statement

The authors declare no conflict of interest.

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