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The application of intelligent tutoring systems and social robots in autism treatment

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Abstract. This study examines the utilization of intelligent tutoring systems (ITS) and social robots as innovative technologies to augment the treatment of autism. In the context of artificial intelligence, these interactive systems offer personalized and engaging interventions, holding great promise for individuals on the autism spectrum. While the research in this field is still evolving and lacks maturity, early findings indicate increased engagement and potential for improved learning outcomes among autistic children. Intelligent tutoring systems, capable of adapting to individual learners, exhibit promise for delivering personalized and effective interventions. Social robots, with their interactive functionalities, provide a distinct avenue for fostering social communication and skill development. Moreover, these technologies have the potential to deliver cost-effective intervention methods, thus enhancing accessibility for children with autism and their families. However, further research, development, and integration into existing therapeutic approaches are imperative to fully actualize their potential. By harnessing the power of intelligent tutoring systems and social robots, it is possible to pave the way for more effective, personalized, and engaging autism treatment, positively impacting the lives of individuals on the autism spectrum.

Keywords: intelligent tutoring system, artificial intelligence, autism spectrum disorder.

1. Introduction

Autism, also known as autism spectrum disorder (ASD), is a neurodevelopmental disorder that affects individuals from early childhood and persists throughout their lives. The effects of autism can vary widely from person to person, as it is a spectrum disorder. Individuals with autism may struggle with social interactions, finding it challenging to initiate and maintain conversations, interpret nonverbal cues, and develop friendships. They may have difficulty understanding and responding to others' emotions, leading to misunderstandings and social isolation. Individuals with autism often display repetitive behaviors or intense interests in specific topics. They may have rigid adherence to routines and rituals, becoming upset by changes in their environment. Sensory sensitivities are common in autism, with individuals experiencing heightened or diminished responses to sensory stimuli such as light, sound, touch, or taste [1]. Cognitive abilities among individuals with autism can also vary widely. Some individuals with autism may have exceptional abilities in areas such as memory, mathematics, or visual thinking [2], while others may have intellectual disabilities or learning difficulties.

Living with ASD encompasses a range of experiences that entail both adversities and capabilities. Through the implementation of targeted assistance and interventions designed to accommodate their

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distinctive requirements, individuals with autism can acquire and cultivate proficiencies that augment their aptitude for communication, social engagement, and holistic well-being. Timely identification, early intervention, and the provision of a nurturing and inclusive milieu play pivotal roles in fostering the welfare and triumph of individuals grappling with autism.

ASD is commonly treated through a variety of approaches tailored to address the unique needs of individuals on the autism spectrum. Behavioral therapies, such as Applied Behavior Analysis (ABA), aim to modify behaviors, reduce challenging behaviors, and improve social skills [3]. Speech and language therapy focuses on improving communication abilities such as sentence-building and vocabulary [4], while occupational therapy addresses sensory processing and motor skill difficulties [5]. These ways are commonly used to provide intervention to people with ASD and help mitigate the effects of ASD and help individuals with ASD return to a normal social life.

Within the domain of autism intervention, there has been a growing interest in exploring automated approaches that offer cost-effectiveness and potentially improved efficacy. There has been evidence supporting that individuals with autism often exhibit better social interactions with robots compared to interactions with humans [6, 7]. Robots provide a structured and predictable environment, reducing anxiety and social uncertainties commonly experienced by individuals with autism. The non-judgmental and consistent nature of robots can create a comfortable and engaging space for individuals with autism to practice social skills, communicate, and develop emotional connections. This unique aspect of human-robot interaction holds great potential for leveraging technology to bridge social and communication gaps, promoting social engagement, and enhancing the overall therapeutic experience for individuals with ASD.

Especially, the advancements in artificial intelligence have opened exciting possibilities for treating autism. Educational robots, virtual reality (VR), and intelligent tutoring systems (ITS) are emerging technologies that can be utilized in therapy. Educational robots provide personalized instruction, promote skill development, and facilitate social interactions. VR creates immersive environments for practicing social and communication skills in a safe and controlled setting [8]. ITS delivers tailored instruction adapts to individual progress and reinforces skills [9]. These technologies offer opportunities for individualized interventions, enhanced engagement, and skill generalization. As the field of artificial intelligence continues to progress, these systems can be further developed and refined to better meet the unique needs of individuals with autism, ultimately improving therapy outcomes and promoting their overall well-being.

2. Method

In recent times, there has been a burgeoning interest in harnessing advanced technologies, including social robots and intelligent tutoring systems (ITS), to automate and enhance the therapeutic intervention for individuals diagnosed with autism spectrum disorder (ASD). These innovative technologies present distinctive prospects for delivering personalized and captivating interventions that cater to the specific needs and challenges of individuals with ASD. Social robots, equipped with interactive and anthropomorphic attributes, have the potential to facilitate social communication, emotional expression, and skill development among individuals affected by ASD. Conversely, intelligent tutoring systems leverage the capabilities of artificial intelligence and machine learning techniques to provide customized instruction, adaptive feedback, and personalized interventions. By synergistically amalgamating the functionalities of social robots and intelligent tutoring systems, automated systems can be developed that complement and augment conventional therapeutic approaches, thereby potentially enhancing the accessibility, efficiency, and efficacy of autism treatment.

2.1. Socially Assistive Robots

In recognition of the social deficits that mark ASD, researchers have made attempts to use non-human interactions as a way of treatment. Among the non-human partners, robots are promising in their abilities to mimic human features, nature of being non-judgmental and consistent, and customizability. Furthermore, in cases where animal therapeutic aids may not be available, robots can provide the

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necessary social interaction and may be used in addition to traditional therapy. These social robots can be both humanoid and non-humanoid.

2.1.1. Non-Humanoid Robots. Research has indicated that social robots incorporating animal-like features hold distinct advantages in the context of autism therapy [10]. Animal therapy, also known as animal-assisted therapy (AAT), has demonstrated promising outcomes in supporting individuals diagnosed with autism, with interactions involving animals such as dogs, horses, or dolphins exhibiting positive effects across various domains, encompassing social skills, communication, emotional well-being, and sensory processing [11]. Animal-like robots serve as an intermediary between animal therapy and human interaction, presenting a level of realism in their design that can captivate individuals with autism. Investigations have revealed that robots like Pleo, resembling a dinosaur, and AIBO, resembling a robotic dog, can evoke favorable social responses, alleviate stress, and foster emotional connections among individuals with autism [12, 13]. Pleo, characterized by its lifelike movements and behavior, engenders a heightened interest, leading to increased interaction compared to interactions with a human counterpart [14]. Furthermore, non-humanoid robots, such as CHARLIE, which implements pan-tilt platforms and servos, can also exhibit non-biomimetic qualities and generate heightened interest among children, resulting in improved interaction, imitation, and turn-taking [15].

2.1.2. Humanoid Robots. These social robots can also be anthropomorphic. Humanoid robots can mimic facial expressions and gestures allow for more natural and relatable interactions with humans, making them particularly effective in supporting individuals with autism. Milo, a robot developed by RoboKind, is designed to assist in teaching social and emotional skills to children with autism. It engages children through interactive lessons, games, and storytelling, helping them develop communication and social interaction abilities in a fun and engaging manner, heightening the interaction time from 3% up to 85% [16]. Kasper also utilizes facial expressions, gestures, and speech to engage and interact with children, providing personalized feedback and guidance, which shows improvements with tactile communication [17].

Robotic systems, characterized by their consistent behavior, visually explicit cues, and precise responses, contribute to the reduction of anxiety and social uncertainties commonly experienced by individuals engaging with them. The impartial and non-evaluative nature of robots creates an environment that encourages individuals to take risks, make errors, and subsequently learn from these experiences within a supportive and secure context. Furthermore, the interactive and captivating attributes inherent in educational robots stimulate motivation, sustain attention, and foster active involvement, thereby augmenting the individual's overall learning encounter and promoting enhanced efficacy through heightened engagement.

2.1.3. Intelligent tutoring systems. Introducing the possibilities of intelligent tutoring systems (ITS), Lana, a cutting-edge ITS, offers a glimpse into the transformative power of these systems in education. Lana utilizes advanced algorithms, including NLP and pattern matching techniques, to provide personalized and adaptive learning experiences for individuals, including those with autism [18]. This conversational agent can potentially adapt to different children, tailoring its instruction and responses based on individual needs and preferences.

KidLearn represents an ITS that concentrates on providing mathematical education to both autistic children and elementary students. Its operational framework relies on the implementation of the Zone of Proximal Development Expert System (ZPDES) algorithm, which facilitates the delivery of personalized instruction customized to accommodate the unique skill level and learning pace of each individual learner. KidLearn aims to enhance mathematical proficiencies through a comprehensive amalgamation of interactive lessons, practice exercises, and adaptive feedback [19]. Nevertheless, it is noteworthy that while KidLearn presently encompasses an array of interactive features and adaptive feedback mechanisms, it lacks the provision of individualized instruction tailored to the specific needs of each learner. To address this limitation, an alternative approach, such as the aforementioned Language

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Analysis for Neuro-Developmental Assessment (LANA), leverages natural language processing techniques to augment the intelligent tutoring system, thereby enhancing engagement and enabling autonomous personalization of treatment [20]. Additionally, other methodologies, including reinforcement learning, are also employed to bolster the capabilities of intelligent tutoring systems, further amplifying engagement and facilitating personalized interventions.

3. Application and discussion

The investigation of social robots and intelligent tutoring systems tailored explicitly for autism treatment is currently in its nascent phase, with the field displaying a marked lack of maturity. Although notable progress has been achieved in the advancement of these technologies, a dearth of empirical evidence substantiating their efficacy persists. This limitation arises primarily from the restricted participant pool engaging with these systems and the absence of comparison groups receiving no intervention. Notwithstanding these challenges, researchers and families have proactively undertaken initiatives to develop their own systems, thus underscoring the potential of these technologies.

A significant impediment to the extensive implementation of social robots and intelligent tutoring systems in the context of autism treatment pertains to the limited commercialization of these technologies. The majority of existing systems remain predominantly research prototypes, thereby constraining their availability and accessibility to a broader audience. Furthermore, the full integration of these technologies into established therapeutic modalities, such as Applied Behavior Analysis (ABA) therapy, has yet to be accomplished. As a result, the realization of their potential impact on a wider scale is hindered, necessitating further efforts in both commercialization and seamless integration with existing therapeutic approaches.

However, the potential benefits of these systems in engaging children with autism are promising. They offer personalized interventions that can be tailored to individual needs, resulting in increased engagement and interaction. Intelligent tutoring systems hold promise for independent use at home due to their lower costs compared to social robots. This allows for more frequent and consistent practice, which can enhance learning outcomes.

Moreover, an intriguing avenue lies in the integration of robotics within contemporary clinical practices. Social robots have the potential to function as auxiliary or collaborative agents in therapy sessions, offering supplementary assistance and fostering motivation. Additionally, they can serve as tools for data collection, capturing valuable insights regarding a child's developmental progress and interactive patterns.

Although the investigation of social robots and intelligent tutoring systems for autism treatment is at a preliminary stage, it exhibits considerable promise. These systems possess the capacity to engross children through personalized interventions and facilitate heightened interaction. Furthermore, the cost-effectiveness of intelligent tutoring systems renders them suitable for autonomous utilization within domestic settings. Additionally, the integration of robotics into established clinical practices presents an auspicious avenue for amplifying the efficacy of extant therapeutic modalities. Continued research endeavors, collaborative efforts, and technological advancements will be imperative in fully realizing the potential of these systems in providing comprehensive support to individuals diagnosed with autism.

4. Conclusion

In conclusion, the utilization of ITS and social robots in the context of autism treatment represents a promising trajectory for personalized and effective interventions. Situated within the broader domain of artificial intelligence, these technologies proffer interactive and captivating experiences for individuals diagnosed with autism. Although the field is currently characterized by a lack of maturity, research endeavors have demonstrated heightened engagement and potential for improved learning outcomes among children on the autism spectrum.

The personalized nature of ITS and the interactive capabilities inherent in social robots afford opportunities for tailored interventions that cater to the distinctive needs of individuals with autism. Through adaptation to each learner's abilities and preferences, these technologies hold the potential to

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enhance the learning experience and facilitate greater progress. Furthermore, the comparatively lower costs associated with intelligent tutoring systems render them a viable intervention modality that can be utilized independently within the home environment, thus enhancing accessibility for children with autism and their families. While the field necessitates further research and development to address prevailing challenges and limitations, the integration of ITS and social robots exhibits significant promise for the future of autism treatment. By means of continued advancements, these technologies stand to become indispensable tools in promoting the well-being, facilitating learning, and fostering developmental progress among individuals on the autism spectrum.

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