



Innovative Approaches for the Mental Development and Education of Children with Autism Through Mixed Reality

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Abstract. This study explores an innovative approach for enhancing the mental development and education of children with autism spectrum disorder (ASD) through the use of mixed reality (MR) technologies. Integrating augmented reality (AR) and virtual reality (VR) creates a blended environment that offers unique opportunities for personalized learning experiences tailored to the needs of children with ASD. Our research examines the effectiveness of MR in improving cognitive, social, and emotional skills by providing immersive and interactive educational interventions. We conducted a series of case studies and controlled experiments involving children with varying levels of autism, utilizing MR applications designed to engage and stimulate learning processes. The findings indicate significant improvements in attention, communication, and adaptive behaviors, suggesting that MR technologies can be a powerful tool in the special education toolkit. Furthermore, this study highlights the potential of MR to bridge gaps in traditional educational methods, offering a supportive and engaging learning environment for children with autism. Future research directions and practical implications for educators and therapists are also discussed.

Keywords: virtual reality · augmented reality · Special Educational Needs · education · autism spectrum disorder

1 Introduction

Autism is associated with developmental issues based on the impaired function of the brain, leading to problems in human behavior and socialization. People with autism often live in their own world, where they frequently do not understand the language of others, feel helpless, and are unable to defend themselves. The term “autism” was first associated with Austrian-American psychiatrist Leo Kanner, who, in 1943, described the peculiar behavior of 11 children – 3 girls and 8 boys – who exhibited autistic disturbances in his publication. He termed their condition early infantile autism [1]. Their

symptoms were distinctly different from schizophrenic manifestations. Kanner's main views were that society neglects intellectual deficits and disabilities because they suggest easy manipulability and a lack of reactions to hostility, rejection, and disapproval.

Almost simultaneously, in 1944, Austrian physician and pediatrician Hans Asperger described symptoms resembling autism, although he was unaware of Leo Kanner's work in 1943. His initial discoveries were based on observing the behavior of 4 children with disturbances in vision, speech, and motor skills. They could not make friends but showed a noticeable interest in a chosen field. Asperger referred to them as "little professors." Thus, the understanding of an autism spectrum disorder named after him, Asperger Syndrome, emerged [2]. A key characteristic of children and individuals with this disorder, unlike autism, is their desire for communication and understanding of the world without intellectual problems, albeit in their unique way. They exhibit strong individuality and cognitive abilities [3]. Regarding their health, they are often prone to depressive states that could impact their immune system and defense. A strong interest in a specific area and atypical language proficiency combined with weak motor skills are almost an integral part of diagnosing Asperger Syndrome.

Theories about the manifestation of autism in a child have been seeking answers to what triggers or causes this condition and its characteristics for over 70 years since Leo Kanner's initial discoveries. Ideas and theories even suggest unlikely claims that the "culprits" are parental attitudes, excessive use of electronic devices, or vaccination. Despite all allegations and variations of the truth, it is believed that the primary cause of autistic symptoms is genetic [4]. The exact genetic damage remains unclear, but it is thought to be linked to oxygen deprivation immediately after the child's birth. Alongside the genetic basis, a therapeutic approach for those suffering from this disorder emphasizes the need for closeness, care, and protection, especially from parents, particularly the mother.

The diagnosis of the condition is often established around the third year of a child's development. This age is associated with the establishment of the child's "self" at this stage of personal awareness. Understanding and perception of the world, as well as self-assertion and self-awareness, are typical for children of this age group. A stereotypical pattern of behavior is typical for autistic manifestations. The main areas of direction can be grouped into three domains:

- lack or impairment of social relationships, such as unnoticeable emotions, feelings, facial expressions, and contact;
- impairment of language and speech abilities: fragmented, missing, or incomprehensible speech;
- repetitive actions: spinning objects, rocking, jumping, often accompanied by restlessness and tantrums when given conditions or reprimands by an elder [5].

Another characteristic expression of autism-like symptoms is the complete absence or lack of expression of emotions, fear, or pain. Between the ages of 3–6 years, different types of emotional experiences begin to be expressed and interpreted, as before this, especially in infancy, physiology, and primary needs prevail over emotional expression [6].

Therapeutic means to improve the condition of people with autistic manifestations include the use of biofeedback training as a catalyst for more effective brain function

and controlling mental endurance and autonomic body reactions. The classical view of biofeedback is associated with interpreting and solving the “mind-body” problem [7]. Behavioral analysis, which works on creating motivation through stimuli, influences voluntary behavior [7, 8]. The development and formation of social skills by improving speech abilities and overcoming sensory dysfunctions are achieved through various new and enhancing physical and psychological therapies for people on the autism spectrum, such as swimming, proximity to animals (especially horses, as horseback riding sets a calming rhythm), dolphin therapy, and sound stimulation [9].

Another way for the implementation of technology in the therapy of children with ASD and the development of emotional intelligence is application of educational/serious computer games [10]. The studies show that in Bulgaria language therapists and teachers have a positive attitude to use of educational computer games in their practice, but unfortunately there exist some barriers in using of educational/serious computer games. The main barriers refer to lack of games with a serious training or therapeutic effects, lack of necessity information about available and useful technologies, etc. [11, 12].

2 Methodology

This study delves into the complex developmental issues faced by individuals with autism spectrum disorder (ASD) and explores the innovative use of mixed reality (MR) technologies to address these challenges. Autism is characterized by difficulties in social interaction, communication, and repetitive behaviors, often linked to impaired brain function. Understanding these characteristics and their underlying causes is crucial for developing effective therapeutic interventions.

The genetic basis of autism, as suggested by various studies, underscores the complexity of the condition. While early theories proposed factors like parental behavior or vaccination as potential causes, contemporary research emphasizes genetic predispositions, potentially exacerbated by environmental factors such as oxygen deprivation at birth. This multifaceted etiology necessitates a comprehensive and nuanced approach to both diagnosis and treatment.

The integration of MR technologies, which encompass both augmented reality (AR) and virtual reality (VR), offers promising avenues for personalized and engaging therapeutic interventions. VR and AR applications support complex UI, and classical software modeling approaches based on UML diagrams cannot effectively reflect all the details of multimedia applications [13]. Our study demonstrates that MR can significantly enhance cognitive, social, and emotional skills in children with autism. By providing immersive and interactive experiences, MR helps bridge gaps left by traditional educational methods, offering a supportive and stimulating environment.

The success of MR applications in improving attention, communication, and adaptive behaviors among children with autism highlights the potential of technology to transform special education. These technologies enable therapists to create tailored interventions that cater to the unique needs of each child, fostering a more effective learning process. For instance, virtual environments can simulate social scenarios, allowing children to practice social interactions in a controlled and safe setting. This practice can be particularly beneficial for children with Asperger Syndrome, who desire communication and understanding but struggle with conventional social cues.

Our findings suggest that MR technologies could become an integral part of therapeutic strategies for ASD. However, further research is needed to refine these tools and expand their applications. Longitudinal studies could provide deeper insights into the long-term effects of MR interventions and their impact on various aspects of development. Additionally, exploring the combination of MR with other therapeutic approaches, such as biofeedback training and behavioral analysis, could enhance overall outcomes.

The importance of early diagnosis and intervention cannot be overstated. Identifying ASD around the age of three, when children begin to assert their own identities, allows for timely and targeted interventions. As our understanding of the genetic and environmental factors influencing autism deepens, the development of more precise diagnostic tools and personalized therapies will become increasingly feasible.

Children with autism often exhibit a range of emotional and behavioral challenges, such as repetitive behaviors and a lack of expressive emotions. MR technologies can play a crucial role in addressing these issues by offering repetitive yet engaging tasks that reinforce positive behaviors and emotional expression. For example, interactive games that reward social interaction can motivate children to engage more with their peers and caregivers.

Moreover, MR can support motor skills development, often a challenge for children with Asperger Syndrome, through activities that combine physical movement with cognitive tasks. This holistic approach can help children develop a more balanced set of skills, enhancing their overall quality of life.

Within our study, we utilize Unreal Engine 5 (UE5), which offers powerful tools for game development and interactive experiences. By using UE5 and its visual scripting system known as Blueprint, we create games that can be played both in mixed reality and on tablets. This allows us to offer flexible and adaptive solutions that can be used in various contexts and environments.

Unreal Engine 5 provides a platform with high graphical performance and flexibility, which is particularly useful for creating engaging and interactive educational games. With the help of Blueprint, the visual scripting system of UE5, developers can quickly and efficiently create complex interactive scenarios without the need for coding. This accelerates the development process and facilitates the customization of games according to the needs of individual children with autism.

Through the integration of mixed reality, our games provide immersive and interactive experiences that can improve the cognitive, social, and emotional skills of children with autism. These games create virtual environments that simulate real social situations, allowing children to practice social interactions in a controlled and safe setting. This can be especially beneficial for children with Asperger Syndrome, who seek communication and understanding but struggle with conventional social cues.

In addition to mixed reality, our games are designed to be played on tablets, which provides additional flexibility and accessibility. Tablets allow children to engage in therapeutic games in various environments, such as at home, school, or therapy centers. This multi-platform compatibility ensures that therapeutic interventions can be easily integrated into the children's daily lives, providing them with constant support and stimulation.

3 Result and Discussion

The application of mixed reality in the education and mental development of children exhibiting autistic spectrum disorders proves to be promising and important in modern pedagogy and psychology. Special attention is given to augmented reality (AR), which is a part of the broader spectrum of mixed reality. Augmented reality can be an effective means of entertaining and educating such children. AR technology facilitates interaction between the real world and digital content, allowing users to see computer-generated objects in the real world. This can include the use of special AR glasses or mobile applications. AR products support various techniques for adding and overlaying computer graphics and sound onto the user's vision and hearing, which can help develop mental abilities, imaginative thinking, social skills, overcoming fears, expressing emotions, and other aspects of the development of children with disabilities and special educational needs.

On the other hand, transitioning to a digital learning environment for children with special educational needs, including children with autism, presents its own challenges and advantages. For example, special education teacher Violeta Georgieva shares that one of the main advantages is the possibility of continuing the educational process for these children in conditions of remote learning, which allows parents to be more actively involved in the process. Among the challenges is the lack of appropriate online educational resources and technical difficulties in adapting educational materials to the needs of children with special educational needs.

The use of Unreal Engine 5 (UE5) in the context of education and psychological development of children with manifestations and characteristics of the autistic spectrum can offer several innovative approaches:

Using UE5, we can create interactive games aimed at developing social skills, communication, and emotional understanding. These games can include scenarios for social interaction, emotional recognition, and stress management exercises. Designing multimedia applications requires special approaches. Classical Model-Driven Development methodology does not satisfy the requirements of the component-oriented architectural style used in Unity and Unreal Engine Game Engines [14].

VR experiences created with UE5 can help children understand and practice social situations in a controlled environment. Avatars can be used to model behavior and communication, allowing specific elements of the existing real environment to influence and elicit reactions from the child [15].

- **Educational Simulations** - Developing simulations to help children acquire practical skills and understand complex concepts, such as virtual field trips, scientific experiments, and interactive lessons.
- **Personalized Learning** - Creating personalized educational platforms that meet the individual needs of each child, including adaptive learning plans and feedback based on the child's specific strengths and challenges.
- **Interactive Stories and Storytelling** – Developing visually rich and interactive stories that help children develop their imagination and language skills. These stories can include elements of choice and consequences to help children learn about cause and effect.

- **Stress Management and Relaxation Exercises** Creating applications with relaxation environments using calming visualizations and sounds to help children manage stress and practice calming techniques.

All these approaches can be created using the visually impressive and highly customizable capabilities of UE5, thus creating an engaging and stimulating educational environment.

Below are some specific examples and scenarios using Unreal Engine 5 to support children with manifestations and characteristics of the autistic spectrum:

Interactive Educational Game: “Social Skills in Action”.

Scenario: The player controls an avatar in a school environment. The game presents various social situations, such as talking with a classmate, working in a group, and sharing toys on the playground.

Goal: Learning basic social skills like sharing, taking turns, listening, and responding in conversations.

Interaction: The game offers multiple choices for reactions and actions, each decision leading to different consequences that demonstrate the effects of social interactions.

Virtual Reality Simulator: “Experience Emotions”.

Scenario: Creating a virtual reality where children can observe and interpret the emotions of different characters.

Goal: Learning to recognize various emotional expressions and understanding the emotions of others.

Interaction: Characters in the VR scenario express different emotions, and children must choose how to react to them, receiving feedback on their decisions.

Interactive Story: “Mia’s Adventure”.

Scenario: The story follows Mia, a girl with autism, who faces various challenges and adventures in her world.

Goal: Helping children understand and identify with characters who have similar experiences.

Interaction: Children make decisions on behalf of Mia, which influence the course of the story, helping them learn about cause and effect and different ways of coping with emotional and social situations.

Educational Simulation: “Virtual Botanical Garden”.

Scenario: A simulation of a virtual botanical garden where children can learn about different plants and their ecosystems.

Goal: Educational aim focused on science and nature.

Interaction: Children explore the virtual environment, discover information about plants, and participate in interactive activities like planting and caring for virtual plants.

Relaxing Environment: “Magic Ocean”.

Scenario: A virtual relaxing environment where children can explore a peaceful underwater world.

Goal: Provide a calming and soothing experience for children who may feel overwhelmed by sensory stimuli.

Interaction: Children swim among various marine creatures, listen to calming underwater sounds, and interact with different objects in this peaceful environment, learning self-regulation and relaxation techniques.

Educational Adventure Quest: “Secret of the Ancient Temple”.

Scenario: An archaeological adventure game where children solve puzzles and uncover secrets in an ancient temple.

Goal: Stimulating logical thinking, spatial orientation, and problem-solving skills.

Interaction: Children explore the temple, solve puzzles, and interact with various objects and mechanisms, learning to organize their thoughts and plan their actions.

Social Simulation: “My Virtual Classroom”.

Scenario: A virtual classroom where children participate in educational activities and social interactions with virtual classmates.

Goal: Helping develop social skills and adapting to an educational environment.

Interaction: Children engage in educational activities, communicate with classmates and teachers in a safe virtual environment, develop communication skills, and learn how to handle different social situations.

Interactive Art Lesson: “Create Your Virtual Museum”.

Scenario: Children create and manage their own virtual art museum.

Goal: Developing creative and aesthetic skills.

Interaction: Children select artworks, organize exhibitions, and create their unique museum, enhancing their sense of design and creative thinking.

Each of these scenarios can be adapted and developed using the visually impressive and dynamic capabilities of Unreal Engine 5 to provide enriching, interactive, and educational experiences for children with autistic spectrum disorders. These scenarios can be tailored to children’s different needs and abilities, offering educational and therapeutic benefits.

In summary, Unreal Engine 5 offers opportunities for creating various educational and therapeutic applications that can benefit children with autistic spectrum manifestations. These applications include:

- **Interactive Educational Games:** Creating games that stimulate social skills and emotional understanding, such as “Social Skills in Action.”.

- **Virtual Reality and Avatars:** Using VR to simulate social scenarios and teach emotional recognition.
- **Educational Simulations:** Developing virtual environments for learning practical skills, like through the “Virtual Botanical Garden”.
- **Personalized Learning:** Creating adaptive learning platforms that meet the individual needs of children.
- **Interactive Stories and Storytelling:** Using visual stories to stimulate imagination and develop language skills.
- **Stress Management and Relaxation Exercises:** Creating relaxation environments like “Magic Ocean” to help with self-regulation and relaxation.
- **Educational Adventure Quests:** Developing adventure games to stimulate logical thinking and problem-solving.
- **Social Simulation:** Simulating a classroom environment to improve social skills.
- **Language Exercises:** Using games to develop speech and language skills.
- **Simulation of Daily Skills:** Creating virtual environments for learning life skills.
- **Interactive Textbook:** Integrating educational elements into adventure games to stimulate interest in learning.
- **Sensory Room:** Developing environments for sensory stimulation and exploration.

These applications use the advanced capabilities of UE5 to create realistic and engaging virtual environments that can enhance the learning process and offer innovative therapeutic approaches for children with autism.

Unreal Engine 5 (UE5) is a powerful tool that provides advanced capabilities for developing multiplayer games that can be used to support children with autistic spectrum disorders.

The process of developing multiplayer games with UE5 involves using the engine’s visual scripting system, Blueprint, and its robust networking framework. Blueprint allows developers to create game logic without the need for coding, significantly speeding up the development process and facilitating the customization of games according to the specific needs of children with autism. UE5’s networking framework supports the creation of complex multiplayer environments, enabling simultaneous interactions among multiple users (Fig. 1). The Model-Driven Development methodology recommends using UML diagrams (or other types of software models) to model data flow for requirement analysis activities and software testing [16].

Multiplayer games developed with UE5 have the potential to enhance the social and communication skills of children with autism. By simulating real-life social situations in a controlled virtual environment, these games provide a safe space for practicing social interactions. Children can interact with virtual characters and other players, aiding in the development of key social skills such as sharing, taking turns, and emotional recognition.

Moreover, the ability to adapt these games for different platforms, including tablets and AR/VR devices, allows therapeutic games to be integrated into the daily lives of children. This ensures continuous support and stimulation, regardless of the context—whether at home, at school, or during therapy sessions.

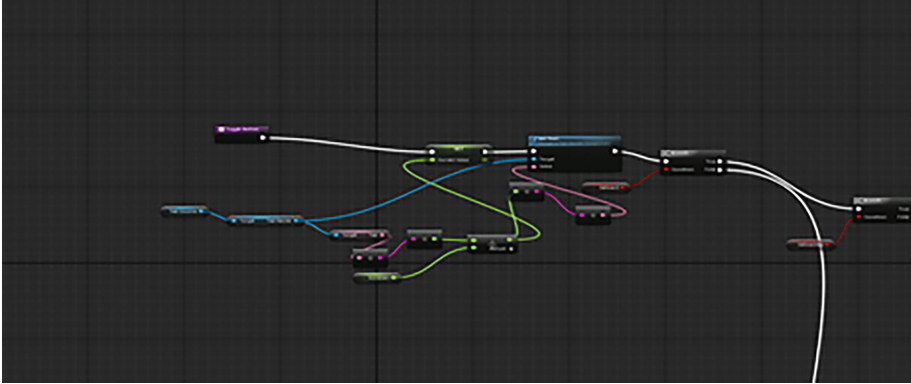


Fig. 1. Creating a blueprint script

Unreal Engine 5 offers flexible and powerful tools for creating multiplayer games that can significantly improve the educational process and social integration of children with autism. These technologies provide new opportunities for personalized learning and social adaptation, tailored to the individual needs and characteristics of each child.

Unreal Engine 5 (UE5) offers an advanced platform for developing interactive and immersive educational experiences. For children with autism spectrum disorders (ASD), the integration of auditory and visual stimuli within UE5 can significantly enhance learning outcomes. This essay examines the scientific basis for using these sensory modalities in UE5 and presents specific examples of their application to improve cognitive and social development in children with autism.

UE5’s capabilities for rendering high-fidelity graphics create detailed and vibrant environments that can significantly enhance the learning experience for children with autism. Studies have shown that visually engaging content can improve attention and retention in children with ASD [17]. The realistic and dynamic scenes that UE5 can generate stimulate visual processing and maintain engagement – Fig. 2.



Fig. 2. Creating an interactive environment

Example 1: Virtual Classroom Environment. A virtual classroom designed in UE5 can include interactive elements such as animated characters, colorful backgrounds, and visually rich instructional materials. This immersive environment can help children with autism engage more effectively with educational content. For instance, a study by Zhang et al., [18] found that children with ASD showed improved social skills and increased engagement when using virtual environments for learning.

Customizable Visual Feedback. Immediate and clear visual feedback is crucial for reinforcing learning in children with autism, who often require concrete and consistent feedback to understand and retain new concepts [19]. UE5 allows for the customization of visual feedback, which can be tailored to each child's specific needs.

Example 2: Language Learning Application. In a language learning application, UE5 can be used to provide instant visual rewards, such as celebratory animations and color changes, when a child correctly identifies a word or phrase. This type of feedback reinforces positive behavior and helps solidify learning. Research by Htet Aung [17] supports the use of visual aids and feedback in improving language and social communication skills in children with autism.

Auditory Perceptions. UE5's advanced audio capabilities enable the creation of immersive soundscapes that complement visual stimuli, enhancing the overall sensory experience. Auditory stimuli have been shown to aid in the processing and retention of information [20]. Creating rich auditory environments can help maintain attention and support learning in children with autism.

Example 3: Virtual Nature Reserve. In a virtual nature reserve created with UE5, children can hear ambient sounds like bird calls, flowing water, and rustling leaves. These soundscapes create a realistic and engaging learning environment that can enhance the educational experience. Studies have indicated that natural sounds can have a calming effect and improve focus in children with ASD [21].

Providing consistent auditory feedback and instructions is essential for guiding the learning process. UE5 can deliver clear and realistic voice recordings, which are crucial for children with autism who benefit from precise and predictable feedback.

Example 4: Mathematics Game. A mathematics game developed with UE5 can include a virtual instructor who provides step-by-step verbal instructions and immediate feedback on the child's performance. This method helps children understand tasks more clearly and reinforces correct answers. Research by Möller et al., [22] highlights the effectiveness of auditory feedback in improving academic skills in children with autism. Many other authors, such as [20, 21,23], also denoted this.

Integrative Sensory Experiences. Combining visual and auditory stimuli in UE5 creates a multisensory learning experience that caters to the unique needs of children with autism. Integrated sensory approaches have been shown to enhance cognitive processing and support sensory integration, leading to improved learning outcomes [18, 23].

Example 5: Virtual Art Class. A virtual art class in UE5 can combine colorful visual elements with soothing background music and encouraging voice prompts. This multisensory approach creates a calming and engaging environment that supports creative

expression and skill development. Studies by Zhang L. et al., [18] have demonstrated that multisensory environments can significantly improve engagement and learning outcomes for children with ASD.

Unreal Engine 5 provides extensive capabilities for integrating auditory and visual stimuli to create engaging and effective educational tools for children with autism. By leveraging high-quality graphics, tailored visual feedback, immersive soundscapes, and integrative sensory experiences, UE5 can significantly improve cognitive and social skills in children with ASD. These advanced features offer new opportunities for personalized and adaptive learning, ensuring that educational applications meet the unique needs of each child. The scientific evidence supports the use of these technologies to enhance learning outcomes and provide a supportive educational environment for children with autism – Fig. 3.



Fig. 3. Game environment in UE5

4 Conclusion

Mixed reality (MR) includes a combination of virtual reality (VR) and augmented reality (AR), allowing users to interact with virtual and real objects in the real world. The use of mixed reality technologies is advancing to support children with autistic spectrum disorders, as they can easily be adapted to individual needs and offer new ways for learning and social integration, as well as improving motor skills and coordination. Potential positive impacts can be seen in social and communication skills, with careful attention to the individual needs and characteristics of each child. Collaboration between specialists in education and healthcare, combined with family care, is essential for enhancing psychological development, enriching educational abilities, and overall well-being.

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