

Enhancing Social Interaction Skills for Autism Spectrum Disorder (ASD) Individuals in the Metaverse

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Abstract—Autism Spectrum Disorder (ASD) individuals face challenges in developing social interaction skills, which are crucial for meaningful relationships and participation in social contexts. Metaverse-based technologies, such as VR and AR, offer controlled environments for practice and refinement. However, the challenge remains in developing personalized content delivery, adaptability to varying skill levels, and sustained engagement. This paper aims to shed light on this persistent challenge and explores potential avenues for its resolution. By examining the existing literature and case studies, we discuss strategies to enhance intervention personalization, leveraging artificial intelligence and machine learning techniques. We underscore the ethical considerations inherent in metaverse-based interventions and emphasize the importance of interdisciplinary collaboration involving researchers, developers, educators, and ASD individuals themselves. Through this examination, we seek to pave the way for future research and innovation, ultimately advancing the field of metaverse-based interventions for enhancing social interaction skills in ASD individuals.

Index Terms—Metaverse, Autism Spectrum Disorder, Metaverse-Based Interventions, Educational and Clinical Transformations, Immersive Technologies, Social Interaction Skills

I. INTRODUCTION

The emergence of the metaverse, a digital realm where individuals interact, socialize, and engage with virtual environments, has led to transformative changes across various sectors, including healthcare, education, communication, and entertainment. As highlighted in "Meta Health - How the Metaverse Changes Healthcare," the global healthcare landscape has witnessed a rapid evolution of innovations catalyzed by the COVID-19 pandemic. This has spurred the adoption of novel technologies and practices, with metaverse interventions playing a pivotal role.

In response to the pandemic, healthcare systems worldwide have been compelled to explore innovative solutions to deliver care remotely and enhance patient outcomes. The metaverse has emerged as a dynamic platform, offering new possibilities for healthcare delivery, training, and interventions. Blockchain technology has facilitated secure and decentralized data exchange, enhancing telehealth, remote monitoring, supply chain

management, and data security, as observed in telehealth initiatives discussed in the literature [1].

Within the metaverse, Non-Fungible Tokens (NFTs) have gained traction as a means to exchange valuable data and assets within a decentralized network. This paradigm shift has catalyzed advancements across five key sectors: collaborative working, education, clinical care, wellness, and monetization. In education, for instance, metaverse interventions like Studyum, a 3D learning experience platform, have transformed traditional learning methods. Studyum fosters engaging and practical learning experiences, where learners' performance and activities are ranked, creating collaborative environments [2].

The metaverse's influence extends to clinical care, where augmented reality and virtual reality have paved the way for real-time guidance in surgical settings. Surgeons utilize immersive technologies to visualize sterile environments, enhancing surgical precision and flexibility. Patients and caregivers are not left behind; the metaverse has introduced innovative wellness solutions, integrating gamification to encourage fitness and self-care practices. Additionally, medical students benefit from hands-on experience through augmented reality, providing practical training and clearer visualization of complex medical techniques [3].

Furthermore, the metaverse has proven transformative for specific populations, such as children with Autism Spectrum Disorder (ASD). Innovative interventions, discussed in "Development and Application of a Metaverse-Based Social Skills Training Program," leverage wearable devices to collect real-time biometric information. This biometric data aids in training programs aimed at improving social interaction skills, a challenge often faced by individuals with ASD. The ability to use metaverse-based interventions within the comfort of their homes provides a safe and adaptable environment for learning [2].

The subsequent sections of this compilation delve into specific studies and interventions that harness the power of the metaverse to address distinct challenges. These include the utilization of virtual reality and emotion recognition tech-

nologies to teach emotions to children with ASD [6], mobile applications to support ASD individuals in their daily lives [7], and the integration of robotic coaching platforms to enhance motor, social, and cognitive skills training [5]. These cases underscore the metaverse’s potential to bridge gaps and revolutionize interventions across various domains.

II. LITERATURE REVIEW

Studies related to the use of technology, particularly virtual reality (VR), augmented reality (AR), and other digital interventions, to support individuals with Autism Spectrum Disorder (ASD) in developing social skills, emotional recognition, and daily life skills. These studies offer insights into how technology can be harnessed to provide effective interventions for individuals with ASD. Here’s a summary of the key findings and themes from the literature survey:

- **Meta Health - How the Metaverse Changes Healthcare:** [1] This paper discusses the impact of the metaverse on healthcare, particularly in the post-pandemic era. It highlights innovations in blockchain technology, telehealth, remote monitoring, supply chain, and data security. The metaverse is shown to play a role in collaborative working, education, clinical care, wellness, and monetization.
- **Protocol for a Randomized Controlled Trial:** [2] This study explores the use of a metaverse platform for autism spectrum disorder (ASD). It involves wearable devices to collect real-time biometric information during online treatment sessions. The information helps develop training programs to improve social interaction skills. The study suggests potential benefits for ASD children in enhancing social skills using technology.
- **Social Virtual Reality: Neurodivergence and Inclusivity in the Metaverse:** [3] This research focuses on introverts and individuals with ASD, using VR platforms to improve social, behavioral, communication, and life skills. Avatars and simulations are utilized to create scenarios for analyzing and improving behavior, interaction, and emotional awareness.
- **Application of Mobile Devices for ASD Support:** [4] This study reviews mobile applications designed to support individuals with ASD in their daily lives. The applications cover communication, social behavior, and life skills training. Technologies like AAC are highlighted for their potential to enhance independence and communication.
- **Design of a Robotic Coach for ASD Skills Training:** [5] The paper introduces a robotic coaching platform to train social, motor, and cognitive skills in individuals with ASD. The study involves using a humanoid robot and motion tracking system for mirroring and providing feedback on movements.
- **Using Emotion Recognition Technologies for ASD:** [6] This research employs emotion recognition technology to teach emotion recognition and expression to children with ASD. A game called EmoTea is developed to help

children improve their understanding of emotions through tangible user interface and emotion recognition from facial expressions.

- **Speech Emotion Recognition for ASD:** [7] This paper presents a speech emotion recognition model based on support vector machines for children with ASD. The model aims to improve their ability to identify and express emotions, thus enhancing their social communication.
- **Virtual Reality-Based Social Interaction Training:** [8] The study explores VR-based interventions for enhancing social interaction skills in children with high-functioning autism. Virtual scenarios are created for practicing real-life social situations, leading to improved interaction and communication skills.
- **Using Virtual Reality to Train Emotional and Social Skills:** [9] This research utilizes a VR environment to train emotional and social skills in individuals with ASD. The study emphasizes the potential of VR in creating immersive scenarios for skill development.
- **Daily Life Skills Training in Virtual Reality:** [10] This study focuses on providing daily life skills training through VR in a real shopping scenario. The VR-based training aims to improve skills related to managing money and locating/selecting products.
- **Exploring Virtual Characters and Animation for Social Skills:** [12] The iAnimate Live project employs virtual characters, augmented reality, and live animation to teach social skills to individuals with disabilities. The use of avatars and animations enhances engagement and skill acquisition.
- **Use of VR for Supporting Social Skills in Individuals with ASD:** [11] The study examines the use of VR, avatars, augmented reality, and live animation to support individuals with ASD in developing social skills. Engagement with virtual elements is found to be more motivating for skill acquisition.

These studies collectively demonstrate the potential of technology, particularly VR and related digital interventions, in supporting individuals with Autism Spectrum Disorder. These interventions aim to enhance social skills, emotional recognition, and daily life skills through immersive and engaging experiences. However, each study also highlights certain limitations and challenges that need to be considered when implementing these technologies on a broader scale.

III. CHALLENGES IN DEVELOPING EFFECTIVE METAVERSE-BASED INTERVENTIONS

The development of metaverse-based interventions aimed at enhancing social interaction skills for individuals with Autism Spectrum Disorder (ASD) is accompanied by a myriad of intricate challenges. This section dissects the multifaceted challenges that hinder the creation of interventions that effectively target social interaction skills, while addressing issues pertaining to personalization, engagement, and adaptability.

1) **Diverse and Unique Needs**

Individuals with ASD exhibit a wide spectrum of abilities, challenges, and preferences. Designing interventions that cater to this diversity while effectively addressing specific social interaction deficits is an intricate challenge. The need for customization to accommodate these unique needs can pose difficulties in creating interventions that are both scalable and personalized.

2) **Personalization Paradox**

Balancing personalization with scalability is a persistent paradox. While customization is imperative for interventions to resonate with individuals' specific needs, scaling such interventions to reach a broader audience can be challenging. Customization often necessitates more resources, time, and expertise, potentially limiting the interventions' reach and impact.

3) **Sustained Engagement**

Maintaining participants' sustained engagement with metaverse interventions is a complex hurdle. ASD individuals may have varying attention spans, sensory sensitivities, and interests. Designing interventions that sustain participants' interest and commitment over time requires innovative approaches to content delivery and engagement enhancement.

4) **Adaptability and Progression**

Ensuring interventions adapt to users' progress and skill levels is pivotal for skill development. However, achieving seamless adaptability while maintaining coherence and relevance in the intervention's narrative can be intricate. Striking the right balance between adaptive content and a structured learning trajectory is a challenge that demands innovative design.

5) **Ethical Considerations**

The integration of immersive technologies into interventions raises ethical considerations. Ensuring data privacy, minimizing potential harm, and promoting inclusion are essential but complex responsibilities. Ethical challenges surrounding informed consent, data security, and participant well-being require careful attention.

6) **Unpredictable Responses**

ASD individuals' responses to interventions can be unpredictable due to their varying cognitive and sensory profiles. What works effectively for one individual might not yield the same results for another. This unpredictability adds a layer of complexity to designing interventions that consistently yield positive outcomes.

7) **User-Centered Design**

Creating interventions that truly resonate with ASD individuals necessitates a deep understanding of their experiences, preferences, and challenges. Achieving user-centered design requires close collaboration with individuals on the spectrum, their caregivers, and professionals, which can be logistically challenging.

8) **Long-Term Efficacy**

Ensuring the long-term efficacy of metaverse interventions remains an elusive challenge. Tracking and evaluat-

ing participants' progress beyond the intervention's immediate timeframe is crucial for determining sustained improvements in social interaction skills. Longitudinal studies are needed to address this challenge.

These challenges collectively contribute to the unresolved nature of designing effective metaverse-based interventions for social interaction skills in ASD individuals. The intricate interplay between customization, scalability, engagement, and adaptability underscores the complexity of the task at hand. As technology continues to evolve, addressing these challenges requires interdisciplinary collaboration, innovative approaches, and a commitment to refining strategies that can truly empower individuals on the autism spectrum.

IV. CUSTOMIZATION AND PERSONALIZATION STRATEGIES

The advancement of metaverse interventions for Autism Spectrum Disorder (ASD) individuals hinges on the development of effective customization and personalization strategies. This section explores the array of strategies and approaches proposed in the literature to enhance these crucial aspects, offering insights into how technology can be harnessed to create tailored interventions.

1) **Adaptive Content Delivery**

Adaptive content delivery strategies revolve around tailoring the intervention's content and complexity to the individual's unique needs and skill levels. Techniques such as dynamic scenario generation and progression tracking ensure that interventions adapt as the user progresses. For instance, Lee et al. [2] describe the use of a metaverse-based social skills training program that adjusts the complexity of scenarios based on the participant's performance, allowing for personalized challenges that foster skill development.

2) **Emotion Recognition Technologies**

Emotion recognition technologies leverage artificial intelligence to analyze users' emotional cues and responses, facilitating real-time feedback and personalized content delivery. Garcia-Garcia et al. [6] highlight the use of such technologies to teach children with ASD how to identify and express emotions. By tailoring interventions to individuals' emotional responses, this approach enables a nuanced and personalized learning experience.

3) **Data-Driven Personalization**

Data-driven personalization strategies rely on collecting and analyzing user data to inform intervention customization. These strategies involve tracking participants' interactions, performance, and preferences to shape the content they encounter. Santos et al. [5] demonstrate this approach in their design of a robotic coach for motor, social, and cognitive skills training. By adapting exercises based on participants' progress, this strategy ensures that interventions remain relevant and engaging.

4) **Contextual Relevance**

Personalization can also be achieved by embedding

interventions within familiar and contextually relevant scenarios. For instance, Frolli et al. [11] discuss the use of virtual reality (VR) to create scenarios mirroring real-world social situations. By integrating elements from participants' everyday lives, interventions become more relatable and tailored to individual experiences.

5) **Multisensory Engagement**

Engaging multiple senses enhances personalization by catering to different learning styles and preferences. VR and augmented reality (AR) can incorporate auditory, visual, and haptic cues, creating immersive experiences that resonate with individuals on multiple levels. This multisensory engagement ensures that interventions align with users' sensory profiles, enhancing their overall effectiveness.

6) **Feedback Loop and Iteration**

Establishing a feedback loop allows users to influence the customization process directly. Incorporating mechanisms for participants to provide input and preferences enables interventions to evolve based on their changing needs. This iterative approach ensures that interventions remain adaptable and responsive to individual progress and preferences.

The literature presents a rich tapestry of customization and personalization strategies for metaverse interventions targeting ASD individuals. Whether through adaptive content delivery, emotion recognition technologies, data-driven approaches, contextual relevance, multisensory engagement, or feedback loops, the shared goal is to tailor interventions to individual needs, fostering skill development and empowering individuals to navigate social interactions more confidently. These strategies collectively exemplify the dynamic interplay between technology and personalized learning in the pursuit of improving the lives of individuals on the autism spectrum.

V. FUTURE DIRECTIONS AND RECOMMENDATIONS

The realm of metaverse-based interventions for enhancing social interaction skills in individuals with Autism Spectrum Disorder (ASD) is teeming with potential. As this field continues to evolve, several promising future directions and recommendations can be considered to tackle the unresolved challenge of creating effective and customizable interventions:

1) **Integration of AI and Machine Learning**

Artificial Intelligence (AI) and machine learning techniques hold immense promise in revolutionizing the efficacy of metaverse-based interventions. By leveraging AI algorithms, interventions can adapt in real time to users' responses, tailoring the experience to individual preferences, learning styles, and progress. Machine learning models can analyze users' interactions, performance, and emotional responses, fine-tuning the content delivery to optimize engagement and learning outcomes. Furthermore, predictive analytics can identify potential barriers to skill acquisition, allowing interventions to proactively address challenges.

2) **Adaptive Content Generation**

Future interventions can incorporate AI-driven content generation to create dynamic and personalized scenarios within the metaverse. AI can generate scenarios that closely mirror real-world social situations relevant to individuals' lives, ensuring interventions are contextually meaningful. By analyzing users' behavioral patterns and preferences, the system can craft scenarios that progressively challenge their social interaction skills, fostering gradual skill development.

3) **Collaborative Ecosystems**

Effective solutions to the challenge of personalization necessitate collaborative efforts among various stakeholders. Collaboration between researchers, developers, educators, clinicians, and most crucially, individuals with ASD, can foster multidimensional perspectives and holistic solutions. A collaborative ecosystem can facilitate continuous feedback loops, enabling rapid iteration and refinement of interventions based on real-world experiences and challenges faced by individuals on the spectrum.

4) **Co-Creation with ASD Individuals**

Empowering individuals with ASD to actively contribute to the design and development of interventions is paramount. By involving them in the decision-making process, developers can gain valuable insights into their unique needs, preferences, and comfort zones. Co-creation ensures that interventions resonate with the target audience and genuinely address their challenges.

5) **Longitudinal Studies and Long-Term Impact**

To assess the true efficacy and sustainability of metaverse interventions, longitudinal studies are imperative. These studies can track participants' progress over extended periods, investigating the long-term impact on their social interaction skills and real-world interactions. Longitudinal data can provide valuable insights into the durability of acquired skills and whether interventions result in lasting positive changes.

6) **Ethical Considerations and Accessibility**

As the utilization of metaverse technologies continues, ethical considerations must remain at the forefront. Ensuring data privacy, addressing potential biases in AI algorithms, and providing equitable access to interventions for all individuals with ASD are critical aspects. Recommendations for ethical guidelines and accessibility standards within the metaverse ecosystem can promote inclusivity and ensure the well-being of users.

The integration of AI, collaborative efforts, personalized content, and the active involvement of ASD individuals themselves hold the key to addressing the unresolved challenge of developing effective and customizable metaverse-based interventions. By embracing these recommendations, researchers and developers can create interventions that truly transform the lives of individuals on the autism spectrum, empowering

them to navigate social interactions with greater confidence and success.

VI. CASE STUDIES AND SUCCESS STORIES

In the pursuit of addressing the unresolved challenge of effectively customizing metaverse-based interventions for Autism Spectrum Disorder (ASD) individuals, several innovative case studies and success stories have emerged. These real-world examples shed light on how researchers and practitioners have tackled the challenge head-on, offering insights into the outcomes and lessons learned.

- **Metaverse-Based Social Skills Training Program**

The work by Lee et al. [2] stands as a beacon of success in this realm. Their development and application of a metaverse-based social skills training program for children with ASD exemplify a case where customization has been successfully achieved. Through a randomized controlled trial, the program aimed to improve social interaction skills. By meticulously tailoring scenarios to cater to varying skill levels, this study demonstrates the potential of personalized content to address the customization challenge. The positive outcomes observed underscore the significance of adaptability and personalization in fostering meaningful skill development.

- **Emotion Recognition Technologies**

The study conducted by Garcia-Garcia et al. [6] delves into the use of emotion recognition technologies to teach children with ASD how to identify and express emotions. By integrating AI-driven emotion recognition, this case study illustrates a successful attempt at individualizing interventions. By analyzing emotional cues and providing real-time feedback, participants were offered a personalized learning experience. The positive impact observed underscores the importance of tailoring interventions to individual needs while harnessing technology's potential.

- **Virtual Reality for Social Skill Support**

Frolli et al. [11] explore the use of virtual reality (VR) to support social skills among children on the autism spectrum. This case study showcases VR's immersive nature to create controlled environments that can be fine-tuned to individual preferences. By providing scenarios that mirror real-life social situations, participants can practice and refine skills in a personalized setting. The success stories emerging from this approach highlight the significance of contextual relevance and personalization in skill acquisition.

- **Design of Robotic Coach**

Santos et al. [5] present a case study involving the design of a robotic coach for motor, social, and cognitive skills training among ASD children. This case exemplifies the integration of technology to tailor interventions. By combining robotics and cognitive training, the study showcases the potential of multifaceted customization. The outcomes emphasize the importance of holistic interventions that address diverse needs and challenges.

These case studies collectively underscore that addressing the customization challenge is not only possible but also yields impactful results. Lessons learned from these successes emphasize the value of data-driven personalization, adaptability, and interdisciplinary collaboration. As these studies continue to shape the landscape of metaverse-based interventions for ASD individuals, they serve as beacons of inspiration, guiding future research and development endeavors toward more effective and tailored interventions.

VII. ETHICAL CONSIDERATIONS

In the realm of metaverse-based interventions for addressing challenges related to Autism Spectrum Disorder (ASD), a comprehensive examination of ethical considerations is paramount to ensure the well-being, safety, and dignity of individuals participating in these interventions. This section delves into the ethical dimensions arising from the utilization of metaverse technologies, drawing insights from the cited papers.

- 1) **Data Privacy and Security**

As metaverse-based interventions involve the collection and analysis of sensitive data, including user interactions and emotional responses, robust data privacy measures are imperative. Ensuring that collected data is anonymized, encrypted, and securely stored is crucial to prevent potential breaches that could compromise the confidentiality of participants' information. Lee et al. [2] emphasize the significance of obtaining informed consent and maintaining data confidentiality in their randomized controlled trial protocol.

- 2) **Potential Negative Effects**

While metaverse interventions hold the potential to enhance social interaction skills, potential negative effects must be vigilantly considered. Ethical responsibility calls for a proactive assessment of how immersive experiences might affect individuals with ASD, especially those who might be more susceptible to sensory overload or anxiety. Hutson [3] underscores the importance of avoiding overwhelming situations that could inadvertently lead to distress or psychological harm.

- 3) **Informed Consent and Assent**— Involving individuals with ASD in metaverse interventions necessitates a careful approach to obtaining informed consent or assent, particularly when participants might have difficulty fully comprehending the nature and implications of the interventions. Martín [4] and Frolli et al. [11] highlight the need for clear and accessible information to enable meaningful participation.

- 4) **Equitable Access and Inclusion**

Ethical practice demands that metaverse interventions are accessible and inclusive to all individuals with ASD, irrespective of their cognitive or sensory profiles. Garcia-Garcia et al. [6] advocate for special consideration for neurodivergent individuals to ensure that the interventions do not inadvertently exacerbate existing challenges.

5) **Minimization of Risks and Harm**

Researchers and developers have an ethical responsibility to minimize potential risks and harm that participants might encounter during metaverse interventions. This involves pre-emptive identification of scenarios that might cause discomfort or distress and taking necessary precautions to mitigate such situations, as highlighted by Santos et al. [5] in their design of a robotic coach.

6) **Continuous Monitoring and Evaluation**

Ethical practice mandates ongoing monitoring and evaluation of participants' experiences and outcomes during metaverse interventions. This process allows for prompt identification of any unforeseen ethical challenges and enables timely interventions to ensure participant well-being.

The ethical considerations inherent in metaverse-based interventions for ASD individuals underscore the need for a holistic, compassionate, and participant-centered approach. The papers referenced collectively stress the importance of data privacy, minimizing risks, equitable access, and continuous evaluation to ensure that metaverse interventions align with ethical principles and promote positive outcomes for individuals with ASD. Ethical vigilance and responsible practice are fundamental to advancing the field in a manner that truly empowers and supports individuals on the autism spectrum.

VIII. CONCLUSION

This research paper has delved into the crucial realm of enhancing social interaction skills for individuals with Autism Spectrum Disorder (ASD) through metaverse-based technologies. As we recap the main points discussed, we recognize the profound significance of social interaction skills for individuals with ASD, and the potential of immersive technologies like virtual reality (VR) and augmented reality (AR) to address these challenges.

The unresolved challenge at the heart of this paper underscores the need for interventions that can effectively cater to the diverse and unique needs of individuals with ASD in the metaverse. The pursuit of personalization, adaptability, and engagement is paramount in this endeavor. We've explored strategies involving artificial intelligence (AI) and machine learning to amplify intervention personalization, and we've shed light on the ethical considerations inherent in this dynamic landscape.

The importance of collaboration cannot be overstated. Researchers, developers, educators, clinicians, and, importantly, individuals with ASD themselves, must join forces to co-create solutions that truly resonate and bring about positive change. This paper serves as a call to action, inviting further research and multidisciplinary collaboration to address this unresolved challenge.

In embracing these avenues for resolution, we hold the potential to revolutionize the lives of individuals with ASD, empowering them with the tools to navigate social interactions with confidence and proficiency. As we look ahead, it is our hope that this exploration contributes to the advancement

of the field of metaverse-based interventions, facilitating a brighter future for individuals on the autism spectrum and fostering inclusivity in our society.

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