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Personalized virtual reality therapy for children with autism spectrum disorder

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ABSTRACT

The treatment of autism spectrum disorders (ASD) has often relied on broad therapeutic approaches that may not meet each individual's specific needs. This research highlights the importance of personalized therapy to address the unique sensory and emotional requirements of autistic children. We explore recent advances in therapeutic technologies, focusing on serious games and virtual reality (VR) as promising tools in this field. Our proposed solution is a VR application designed to provide a personalized, relaxing experience for children with autism. The application is tailored to accommodate individual preferences and sensory sensitivities, adjusting visual and auditory stimuli to reduce sensory overload and promote emotional regulation. This personalized approach aims to help children manage anxiety and stress more effectively.

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1. INTRODUCTION

Augmented reality (AR), virtual reality (VR), and serious games are innovative technologies that have recently been used to support learning, communication, social skills, and everyday activities for children with autism spectrum disorder (ASD). Serious games are particularly designed to improve communication, learning, social behavior, and motor skills [1], and they have shown success in ASD therapies, especially in improving social interactions. As AR solution, "educational game for multisensory stimulation (JeStiMulE)" [2] is a novel platform to teach social cognition and emotion recognition to individuals with developmental disorders. Another example of AR solution, "ShopAut 2.0" [3] which is a 3D personalized serious game adapted to help children with autism to improve essential life skills, particularly through simulated shopping activities. In addition to serious games, AR integrates virtual and physical elements by adding digital content to the user's perception of the real world. It helps autistic people, especially children, in improving their attention, speech, and interaction skills. As an interactive learning environment, Khowaja *et al.* [4] proposed a mobile augmented reality App for ASD to learn vocabulary (MARVoc) to help teaching staff in Doha ASD centers improve vocabulary acquisition.

Moreover, Fuster *et al.* [5] found that pictogram room, as AR intervention, significantly improved the responding to joint attention skills. Thus, AR technology can assist autistic individuals by improving communication, social relationships, and learning. It combines visual and audio signals into real-world environments, providing crucial support. AR coaching systems [6], for example, aim to ameliorate specific skills like toothbrushing in children with ASD, providing real-time feedback and assistance during the simulation. Wedyan *et al.* [7] has demonstrated that AR can effectively enhance social interactions for children with ASD by helping them recognize and associate facial expressions with emotions. The

effectiveness of AR is highlighted in [8] as demonstrated by AutistAR, in improving communication and social skills in individuals with autism.

In addition, VR technology creates immersive digital environments where users can engage and navigate as if they were experiencing a real-world setting. This technology has gained popularity in the field of therapy for panic [9] and autism disorders due to its ability to provide controlled and adjustable environments for social skills training, sensory integration, and exposure therapy. Autism researchers are exploring the use of VR for personalized social skills support, aiming to enhance the development of social cognition in individuals with ASD [10]. Numerous studies have explored the therapeutic potential of VR for addressing diverse challenges faced by individuals with developmental disorders. Noteworthy among these are VR simulations like the supermarket environment [11], which aim to facilitate the acquisition of shopping skills in individuals with ASD. Also used by Almazaydeh *et al.* [12] as a VR-based system designed to teach street crossing and social attention skills. Furthermore, virtual reality-based collaborative activities simulator (ViRCAS) simulation [13] fosters collaboration between autistic and neurotypical individuals in a shared virtual space, promoting teamwork and social skills development. Moreover, self-guided VR therapies, such as "Auticare" [14], show promise in enhancing socio-cognitive and self-care skills in individuals with developmental disorders. As well, a study aimed at meeting the growing demand for effective services for autistic adolescents and young adults utilized a virtual airport environment to teach air travel skills and treat fear of flying [15]. Maskey *et al.* [16] explored the effectiveness of combining VR with cognitive-behavioral therapy (CBT) to help young people with autism reduce specific fears or phobias. In Table 1, we tried to summarize some examples of the use cases where the AR, VR, and serious games were used for helping and support children with autism.

Table 1. Overview of technology-based solutions in autism therapy and skill development

Treatment/therapy type	Paper	Objective	Personalization
Serious games	[2]	"JeStiMulE" is a game aimed at teaching social cognition and emotion recognition to individuals with developmental disorders.	Not applicable
	[3]	"ShopAut 2.0" 3D personalized serious game to assist children's patients with autism in practicing shopping activities	Setting game parameters by external users/therapists (content, scenario, difficulty, user interface)
Augmented reality	[4]	Interactive mobile AR app (MARVoc) to aid vocabulary learning for children with ASD.	Not applicable
	[5]	AR intervention as a pictogram room to target and improve responding to joint attention skills in children with autism.	adapted based on visual and musical preferences
	[6]	Interactive AR coaching system aimed at improving the toothbrushing skills of children with ASD	Not applicable
	[7]	To help children with ASD recognize and understand facial expressions, improving social interactions	Not applicable
	[8]	Develop and evaluate the AutistAR: AR application to enhance communication and social skills in children with autism through an interactive and immersive learning experience	Not applicable
Virtual reality	[9]	A self-guided VR therapy for treating panic disorder symptoms	Not applicable
	[11]	VR supermarket simulation to train participants with ASD in shopping skills	Not applicable
	[12]	A fully immersive VR environment to teach daily living skills in a safe and controlled setting	Not applicable
	[13]	ViRCAS simulation enables autistic and neurotypical adults to work together in a shared virtual area, promoting teamwork and progress assessment.	Not applicable
	[14]	"Auticare" offers VR therapy platform used to develop socio-cognitive and self-care skills	Not applicable
	[17]	Adaptive immersive VR training system, a personalized learning environment tailored to enhance social interaction and communication skills in children with ASD	The VR object adjusts his behavior based on the emotions and actions of the participant.
	[15]	The goal is to enhance air travel skills in autistic young adults while improving their attentiveness, language abilities, and understanding of activities.	Not applicable
	[16]	To reduce specific fears and phobias in young people with ASD through VR-graded exposure and CBT, aiming for functional improvement.	Not applicable

So, from this table, the first thing to note is that most of these studies do not include personalization aspect. The complexity of ASD, characterized by sensory sensitivities and communication difficulties, exacerbates anxiety levels, necessitating adapted and individualized intervention strategies [18]. Recent studies have highlighted the effectiveness of personalized anxiety interventions, with a UK National Health Service (NHS) study demonstrating strong retention rates and positive changes in anxiety levels among participants, indicating the potential of tailored treatments to improve outcomes for individuals with autism [19]. A systematic review [20] examined mindfulness-based interventions, revealing promising evidence of their effectiveness in alleviating anxiety, enhancing social skills, and reducing aggressive behaviors in children with autism. Additionally, Ketcheson *et al.* [21] demonstrated the potential of the "mindfulness yoga program (MYtime)", which positively influenced perceived stress, anxiety, and depression among caregivers of autistic children. These findings emphasize the need for personalized approaches to address the unique challenges faced by individuals with ASD in managing anxiety and related emotional difficulties.

In this regard, our suggested VR therapy solution takes into consideration the preferences and sensory needs of autistic children. Regardless the potential therapeutic benefits of AR, VR, and serious games, these technologies frequently ignore customization, leading into a "one-size-fits-all" strategy. Building on our previous work [22] that introduced profiling as a way to tailor VR scenarios for developing effective personalized virtual reality therapy (PVRT). This study fills a major gap in the current treatments for autistic children, which makes it valuable. The development of PVRT solution aims to create an engaging and effective experience tailored to each child's unique needs, such as learning preferences and sensory sensitivity. This approach goes beyond traditional VR applications, ensuring a comfortable, motivating and safe experience. The objective is to enhance critical abilities like communication, social interactions, daily living skills, and providing a support to children with ASD. This innovative approach represents a novel contribution to autism therapy, helping children with ASD develop more effectively and integrate successfully into everyday life.

2. METHOD

The development of the VR application was intended for children with autism and involved a comprehensive and thoughtful methodology to address their unique sensory needs and preferences.

2.1. Literature review

The first step in the development process was to elaborate a literature review to gather and analyze the specific sensory needs and preferences of children with autism. This involved an extensive review of existing literature on autism therapy, particularly focusing on anxiety and stress management techniques. Key insights were identified from research on sensory sensitivities, emphasizing the importance of individualized approaches to therapy. In this phase, defining the goals and target demographic for the designed application was an important step [23]. Additionally, we reviewed studies related to applied behavior analysis (ABA), a widely accepted intervention for autism that utilizes scientifically based principles and strategies, often involving parental participation [24].

2.2. System design

The whole system focused on personalizing a 3D environment tailored to individual preferences. It was developed using a modular architecture consisting of 3 main modules: environment, audio, and interaction. Knowing that children with autism often experience sensory overload, the user interface was designed to be minimalistic and intuitive. Large, easily recognizable icons and a limited color palette were utilized to avoid overstimulation. Additionally, the user interaction was designed to be optional and low-pressure, allowing children to explore at their own pace. Sensory sensitivities were a major consideration, particularly regarding visual overload, sound sensitivity, and motion sensitivity. The application simulates a calming virtual environment where children can interact with calm and tranquility, visually attractive surroundings.

2.3. Personalization features

The personalization phase of the VR therapy solution implies tailoring the experience according to each child's preferred animals and background sounds to ensure a relaxed nature environment. In this step, five fictitious user profiles were created, each specifying the corresponding preferred animals and background sounds to inform the implementation process. More details and descriptions of these profiles will be provided in the next section.

3. RESULTS AND DISCUSSION

In exploring the intersection of VR and autism therapy, our findings demonstrate the transformative potential of personalization in creating meaningful therapeutic experiences. This section outlines how our PVRT addresses the unique needs of autistic children, focusing on the design, implementation, and early observations of our application.

3.1. Design of personalized virtual reality therapy application

In response to the particular needs of autistic children, we propose a PVRT that would reduce anxiety and promote emotional well-being. Rodgers *et al.* [19] provides the foundational architecture for this research. Our proposed solution presents a personalized experience that consider each child's unique sensory sensitivities, providing a more engaging and individualized therapeutic experience guiding them to a calm forest setting where they can explore and interact with nature. Loftus *et al.* [20] suggests that exposure to natural environments can benefit children with autism, though parents often face barriers, such as inappropriate behavior and safety concerns. Our approach addresses these issues by providing a safe method for children to explore beautiful environments in virtual mode [25]. To illustrate the key aspects of our virtual environment, Table 2 summarizes the design elements and therapeutic benefits integrated into the PVRT.

Table 2. Key design elements of the proposed PVRT solution

Aspect	Description
Visuals	Nature space with sunlight filtering through trees
Auditory	Birds chirping, water trickling in a nearby stream
Sensory experience	Light and airy, soft wind
Therapeutic benefits	Promotes relaxation and stress relief
Personalization	Display the animated favorite animal enable, sound preferences, enable/disable background sounds

Relaxation is encouraged through the serene backdrop of the virtual world, featuring a picturesque woodland landscape with lush trees. Guided by research on sensory preferences in children with autism, five simulated user profiles were created to customize elements like background audio and preferred animal aligning with each profile's sensory sensitivities. Table 3 provides a detailed overview of the users' favorite animals and preferred sounds.

Table 3. User profiles

Users	Favorite animal	Preferred sounds
1	Dogs	Water sounds
2	Birds	Soft music (birds sound)
3	Cats	Cats sound
4	Fish	Nature sounds
5	Horses	horse sounds

3.2. Development and implementation

The application was developed using unity 2021.3.40f1, a powerful game engine that enables the creation of immersive VR experiences. Game assets were sourced from the unity asset store, and the "Sketchfab" platform was utilized for character creation and animation. In this section, we will illustrate how user profiles integrate with the therapeutic design. The five user profiles, mentioned previously, ensure a personalized therapeutic experience based on the specific preferences of each profile. The application also includes an admin profile as the primary interface for managing user interactions. The admin is responsible for selecting a child's username from a predefined list provided in the application menu as seen in Figure 1. Once a child's username is selected, the application automatically configures the appropriate VR environment based on the child's individual needs and preferences.

Figure 2 illustrate the environments created for each of the five users, Figures 2(a) to 2(e) showcase the unique settings that reflect their preferences. By showcasing these visual representations, we emphasize the flexibility and customization options of the VR therapy application, which enhances user engagement and improves therapeutic outcomes. This automated approach guarantees a tailored and consistent virtual environment that encourages relaxation and alleviates anxiety.

3.3. Initial findings and future directions

The proposed VR application is designed to incorporate personalization features, aiming to create a flexible and adaptable virtual environment that enhances user engagement and accommodates individual

preferences. While no formal evaluation has been conducted yet, the approach shows promise in tailoring the experience to the unique needs of children with autism. However, the limitation of the proposed VR application is the potential for technical challenges, children, parents and psychotherapists may face when using the application in real-world settings. To address this, future directions will focus on gathering expert evaluations to assess the application's effectiveness and suitability for therapeutic use. Moreover, additional improvements will be applied to improve the usability to ensure intuitive experience that allows users to fully focus on the patient's needs without facing technical difficulties [26].

Figure 1. Application menu

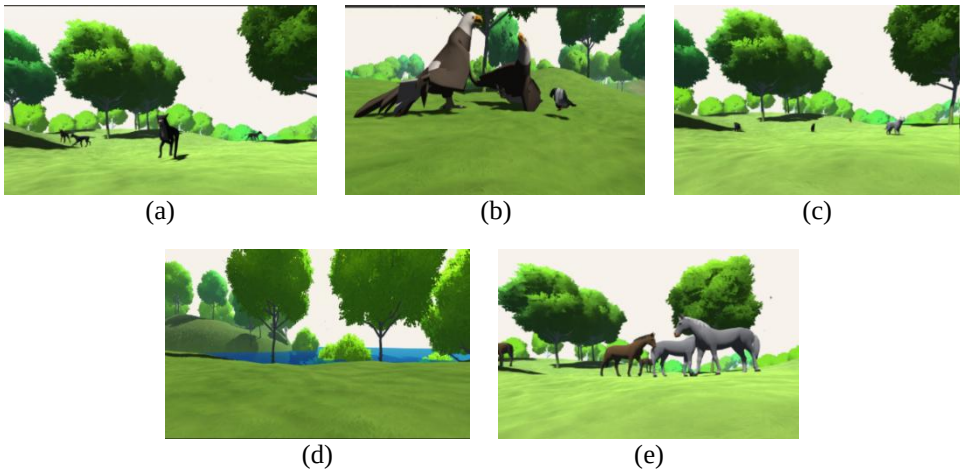

Figure 2. Personalized VR therapy environments for five users: (a) user 1, (b) user 2, (c) user 3, (d) user 4, and (e) user 5

We look forward to integrate more personalized aspects into this solution, gathering expert evaluations to ensure its effectiveness and suitability for children with autism. This feedback will guide us in refining the application before applying it in therapeutic context, enhancing its overall impact on children's well-being. VR integration in autism therapy is important, as it provides a safe, controlled space for role-playing, rule learning, and repetition training tailored to each child's unique needs [27]. Additionally, personalized VR experiences can include sensory elements like sound, which significantly affect children's behavior during therapy [28]. This personalized approach demonstrates promise in improving therapy outcomes and contributes to the growing body of research on VR's potential to enhance the well-being and development of children with autism [29].

4. CONCLUSION

In this paper, we have proposed a novel approach to addressing the therapeutic needs of children with autism through PVRT. We identified critical need for interventions that specifically target the reduction of anxiety and stress, which are important obstacles to effective learning and therapy for children with autism. Then, we reviewed some existing research on the application of emerging technologies in autism therapy, highlighting the benefits and limitations of these approaches. Our findings suggest that successful therapy or learning intervention for children with ASD must consider, as a high priority, creating a calming

environment where the child can feel relaxed and open to participating in further activities. This highlights the necessity of personalized relaxation therapies as an important element in any therapeutic or educational program. We can successfully address the individual obstacles that every child has in therapy and learning by providing individualized VR experiences. This personalization encourages significant therapeutic exchanges, which may lead to better outcomes. Looking ahead, creating self-sufficient and flexible VR systems is an attractive area for further research. Investigating how these systems can assist children with ASD deal with day-to-day difficulties and improve their problem-solving abilities may lead to a new advancement in autism treatment. In conclusion, our research contributes to the growing understanding of how VR might be used in therapy and highlights its potential to improve the lives of children with autism. By offering experiences and tools adapted to their needs, we can help them develop in their social and personal lives.

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AUTHOR CONTRIBUTIONS STATEMENT

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Ahlam Belmaqrout	✓	✓	✓			✓			✓					
Btihal El Ghali	✓	✓		✓	✓					✓				
Najima Daoudi	✓	✓		✓	✓					✓		✓		
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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