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Extended Abstract—Implementation of an Immersive Sensory Room for Autistic Individuals: Enhancing Therapeutic and Learning Experiences Through Technology

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Abstract. Autistic individuals experience sensory sensitivity to stimuli, such as sound, light, and touch. Traditional sensory rooms have long been used as therapeutic tools to help autistic individuals regulate sensory input and promote emotional balance. These environments, equipped with calming lights, sounds, and textures, allow individuals to explore sensory stimuli in a controlled, non-threatening manner. In recent years, immersive technologies have been integrated into sensory room designs providing a more adaptable sensory environment that can be tailored to the unique needs of each user. The aim of this work-in progress paper is to present the potential of immersive sensory rooms as a therapeutic and educational tool for autistic individuals while targeting multiple senses. The immersive sensory room will be customizable so that autistic participants can tailor it to their specific needs and preferences. A user study will be conducted with autistic participants and autism experts to examine the influence of immersive sensory rooms on sensory overload and self-regulation. A mixed-method design will be used to collect both quantitative and qualitative data, follow up with performing descriptive and inferential statistical analyses to assess the data, and further discuss the need for customizable immersive sensory rooms.

Keywords: Autism Spectrum Disorder, Virtual Reality, Traditional Sensory Room, Immersive Technology, Immersive Sensory Room.

1 Introduction

Autism is a neurodevelopmental condition characterized by challenges in communication, social, and behavioral skills. One common feature of autism is sensory processing differences, in which individuals may be hypersensitive or hyposensitive to sensory inputs such as light, sound, touch, or smell. Research suggests that 90-95% of autistic individuals have sensory processing difficulties [1, 2]. These sensory challenges can lead to sensory overload, causing distress and anxiety, making it difficult for autistic individuals to function in everyday environments. Sensory rooms have emerged as specialized spaces designed to address these challenges, offering a therapeutic environment tailored to the sensory needs of autistic individuals. These rooms are equipped with sensory tools designed to regulate and balance sensory inputs in autistic individuals with sensory processing difficulties. These rooms serve a dual purpose: they provide a calming environment to help autistic individuals manage sensory overload, and they offer controlled sensory stimulation to support sensory integration and emotional regulation. Sensory rooms include a variety of elements such as soft lighting, soothing sounds, tactile surfaces, and interactive sensory tools, which can be adjusted to the individual's preferences [3].

Sensory rooms for autistic individuals serve multiple purposes, primarily to address their unique sensory processing challenges. These spaces, such as the Snoezelen multisensory environment [4], offer customized sensory stimulations that assist autistic children in integrating their senses, thus improving their interactions with others and their surroundings. These environments are designed to provide various sensory modalities, including visual, auditory, and tactile stimuli, which can be utilized separately or in combination for sensory training and comfort [4]. The main objective is to establish a therapeutic space that can either soothe hyper-reactive children or activate hypo-reactive ones, based on their specific sensory requirements [5]. Sensory rooms are an integral part of sensory integration therapy, a widely used intervention for autistic children. This approach employs

sensory-rich activities in an engaging and interactive manner to promote adaptive responses and functional behaviors, thereby enhancing a child's ability to engage in desired activities and develop skills [6]. Sensory rooms play a vital role in therapeutic strategies for autistic individuals, providing a controlled environment where sensory integration can be practiced and improved, ultimately leading to enhanced functional outcomes and quality of life [7].

While conventional sensory rooms equipped with physical elements, such as bubble tubes, lights, and tactile panels, have demonstrated efficacy in facilitating sensory regulation and emotional management, emerging technologies, including virtual reality (VR) and augmented reality (AR), present enhanced opportunities for customization, interaction, and adaptability. The static nature of traditional sensory spaces may not adequately address the diverse sensory requirements of autistic individuals. By contrast, immersive technologies, particularly VR, enable the creation of tailored environments that can be adjusted in real-time to meet specific needs. This level of personalization is essential for addressing the wide spectrum of sensory profiles observed in autistic individuals [8]. Immersive technologies can enhance sensory therapies by incorporating interactive and gamified elements, that are challenging to implement in traditional settings. For instance, VR environments can promote active exploration and participation, potentially increasing user engagement and improving the efficacy of therapeutic interventions. Tools such as "Sensory Space Work" in VR have been developed to enhance motivation and sustain interest, leading to improved engagement, particularly among children [9]. Traditional sensory rooms require dedicated physical space and equipment, which can be costly and inaccessible to many educational and healthcare facilities. In contrast, VR-based sensory rooms can replicate various therapeutic environments without the need for additional physical resources, thereby offering a more scalable solution. This approach is particularly advantageous for institutions with space or budget constraints, providing a cost-effective alternative for delivering sensory therapy [10].

To overcome these issues, we aim to implement an immersive sensory room that has a customizable environment and can be tailored to individual preferences, making use of them more engaging and accessible. There is limited research on the use of immersive sensory rooms for training and education, and we aimed to bridge this gap and answer the following research questions in our research study:

1. How can immersive sensory environments be designed to minimize the risk of overstimulation in autistic individuals with hypersensitivity to sensory input?
2. What types of sensory stimuli (visual, auditory, tactile) are the most effective in promoting sensory regulation in autistic individuals in an immersive sensory room?
3. How do immersive technologies influence sensory overload and self-regulation in autistic individuals?
4. What are the perceptions of autism experts regarding the effectiveness of immersive sensory rooms in improving therapeutic outcomes in autistic individuals?

2 Literature Review

The concept of sensory rooms, also known as multisensory environments (MSEs), was first developed in the late 1970s in the Netherlands under the term "Snoezelen," a Dutch word combining "snuffelen" (to sniff) and "doezelen" (to doze) [11]. Initially created for people with intellectual disabilities, the Snoezelen rooms provided a safe and controlled environment for relaxation and exploration. Over time, the application of sensory rooms has expanded to various therapeutic contexts, particularly for autistic individuals, who often experience sensory processing challenges [12]. By the 1990s, sensory rooms had gained recognition as a key tool in autism therapy, and their use spread globally. Today, sensory rooms are widely used in schools, hospitals, therapy centers, and even private homes. Their continued evolution has seen more personalized and adaptable designs to cater to the diverse sensory profiles of autistic individuals, highlighting the importance of customization to maximize therapeutic outcomes [13].

Traditional sensory rooms are designed to engage multiple senses including visual, auditory, tactile, and sometimes olfactory, offering individuals a therapeutic space for sensory regulation and emotional balance. Common components include bubble tubes, fibre-optic lights, tactile panels, soft seating, weighted blankets, soothing music, and aroma diffusers. These elements work together to create a calming or stimulating environment depending on an individual's sensory needs [2, 3, 14]. For autistic individuals, sensory rooms are particularly beneficial because they address sensory processing difficulties, such as hyper- or hyposensitivity to stimuli. A controlled environment allows individuals to explore and interact with sensory stimuli at their own pace, reduce anxiety and promote emotional regulation. Research has shown that regular exposure to sensory rooms can improve mood, behavior, and engagement in therapy, especially for those overwhelmed by traditional therapeutic settings [3]. Sensory rooms also support the development of motor skills, spatial awareness, and communication by offering a space where individuals can engage in structured, multisensory activities.[7]

The incorporation of advanced technology into sensory rooms designed for autistic individuals has transformed therapeutic interventions significantly. Digital sensory rooms leverage cutting-edge technologies to create highly customizable and interactive environments that cater to the specific sensory processing needs of autistic individuals. These technologically enhanced spaces often integrate elements, such as virtual reality (VR), Internet of Things (IoT) devices, and interactive simulations, providing controlled multisensory experiences that allow users to engage with realistic simulations, practice social skills, and process sensory stimuli in a highly personalized and customizable manner [6]. These interventions enable precise calibration of sensory stimuli based on an individual's sensory profile and preferences, ensuring that the environment meets their unique needs. Therapists can make real-time adjustments to enhance the flexibility and effectiveness of sensory interventions.

Technological innovations in sensory room design, such as the IoT-enabled "Magic Room," demonstrate how body motion and object manipulation can facilitate interaction with smart objects, offering a customizable range of multisensory activities that stimulate various sensory systems. This model opens up new possibilities for interventions aimed at children with neurodevelopmental disorders [15]. These rooms can also foster creativity and exploration, as demonstrated by environments such as MEDIATE, which utilizes real-time visual, aural, and vibrotactile stimuli to provide children with a sense of agency and encourages non-repetitive actions [16]. Such environments are particularly advantageous in addressing sensory dysfunction, which affects 80-90% of autistic individuals and can hinder participation in social, self-care, and learning activities [9]. By integrating multiple sensory modalities into a single experience, these technologies enhance the overall therapeutic impact and promote improved sensory integration and emotional well-being [17].

SnoezelenCAVE employs immersive virtual reality technology to provide a therapeutic setting that stimulates visual, auditory, and tactile senses through natural free-hand interaction methods and voice recognition systems, thereby offering a relaxing virtual environment [18]. The multisensory program Snoezelen® provides tailored sensory stimulations that help autistic children integrate their senses, enhancing their interactions with people and the environment [4]. Sensory gardens, a variety of sensory rooms, have been shown to enhance language and communication skills, modify behaviors, and improve learning focus in autistic students by offering multisensory stimulation [10]. These interventions are in high demand among parents and are considered crucial for enhancing the quality of life for both autistic children and their caregivers, who often experience social isolation and stress due to their child's sensory challenges [6].

There is a scarcity of research on the influence of the customization of immersive sensory rooms on sensory and cognitive overload in autistic individuals. In this study, we aim to bridge this gap and investigate how allowing autistic individuals to tailor their immersive environment according to their unique sensory needs impacts their sensory and cognitive overload and emotional imbalance.

3 Research Methodology

In this section, we explain the research design, the criteria to recruit participants for our user study, the description of immersive sensory room and equipment used in designing the room, followed up by data collection methods and analyses methods we will use and ending up with ethical considerations we will be taking to make this user study safe and comfortable for autistic participants.

3.1 Research Design

This research study will implement a one-group post-test-only design where all participants will use the immersive sensory room, and assessment will be conducted after the use of immersive sensory room. In this research study, the main aim is to obtain quantitative data from autistic individuals and experts and qualitative data will serve as a justification for feedback received through quantitative data. This methodology is particularly useful in fields such as autism research, where understanding both the measurable outcomes and personal experiences of participants is crucial for developing effective therapeutic strategies.

3.2 Participants

To participate in the user study, we aim to recruit autistic individuals and experts from various educational institutions and medical facilities. Autistic individuals must have either a clinical diagnosis or have a score of 29 or higher on the Autism Spectrum Quotient (AQ) [19]. We plan to use AQ, a self-report measure to assess autism traits in individuals aged > 16 years, as not all autistic individuals have a clinical diagnosis. As AQ is a self-report measure, it might include potential self-report bias and diagnostic inaccuracy. To address these challenges, we will complement the AQ with input from autism experts, clearly define inclusion criteria, and conduct pilot testing

to refine its use. Autism experts will also be involved in the evaluation study to assess the adequacy of the immersive sensory room and determine which sensory tools would be most beneficial for autistic individuals or whether the sensory tools provide sufficient stimulation for visual, auditory, and tactile senses.

3.3 Sensory Room Setup

The immersive sensory room was designed with consideration for Meta Quest 2 [20], which has six degrees of freedom and inside-out tracking. We have also incorporated tactile feedback to give a more realistic feeling. We used Blender [21] as the 3D modelling software and Unity3D [22] as the game engine to develop a sensory room in VR. The immersive sensory room we designed replicates a physical sensory room in which users can freely engage with items on their own agenda and timeline. Various custom created, free and paid 3D models were used to design the immersive sensory room. We incorporated various activities to stimulate auditory, visual and tactile senses. This sensory room will be integrated into other VR activities for autistic individuals so that it can be used either separately or while performing other tasks in VR. While performing the tasks, if they feel overwhelmed or stimulated, they can pause and come to this immersive sensory area to compose themselves and regulate their emotions.

As autistic people are often visual learners and visual input can be quite overwhelming, we added an interactive light panel with different light settings, as shown in Fig. 1, based on literature recommendations, which might be helpful to them. There are four different light settings: natural light, white light, dim light, and dim light with glow lights. For auditory stimulation, we added a music corner, as shown in Fig. 1, where the participants can play piano if they want or listen to some music and go through the next or previous songs in the music library, increasing or decreasing the volume based on their preference and mood. We also added an immersive aquarium experience, as studies suggest that natural scenery helps autistic individuals regulate their emotions [26]. A 360° video of an aquarium was imposed on a sphere to create an immersive aquarium. This aquarium targets visual and auditory senses. We have also added a painting area, as shown in Fig. 2, where participants can draw, to work on their motor skills and their hand-eye coordination.

Sensory bubble tubes were created to stimulate multiple senses, see Fig. 2. Sensory bubble tubes are essential tools in multisensory environments and are particularly beneficial for autistic individuals because of their ability to promote relaxation and sensory regulation. These tubes provide visual, auditory, and tactile stimulation through a dynamic display of rising bubbles and changing colors, creating a calming atmosphere. Their versatility allows them to be used in both calming and interactive spaces, offering a focal point that aids in sensory integration and emotional regulation. The captivating visual effects and soothing sounds of bubble tubes make them valuable therapeutic devices for creating engaging and relaxing environments.

Fig. 1. Sensory tools present in immersive sensory room: (Left) interactive light panel to customize light settings, and (Right) music area with piano and a menu to interact with music library.

3.4 Data Collection Methods

We will involve both autism experts and autistic individuals in the evaluation process of the immersive sensory room. Our research will involve gathering significant quantitative and qualitative data through various questionnaires and interviews. We will collect the demographic data of the participants, such as their age, gender, tech-savviness, and VR experience, using a custom-created questionnaire. We will use the User Experience Questionnaire (UEQ) [23] to assess the user experience. The UEQ is a reliable questionnaire to evaluate the user experience of interactive products. To measure simulator sickness in VR, we will use the Simulator Sickness Questionnaire (SSQ) [24]. It measures the subjective severity of 16 symptoms on a scale from “none” to “severe”

post user-study. We will also use the NASA-TLX questionnaire to evaluate participants perceived cognitive overload [25]. For autism experts, we will create a custom-created questionnaire and assess the usability of the application from their perspectives.

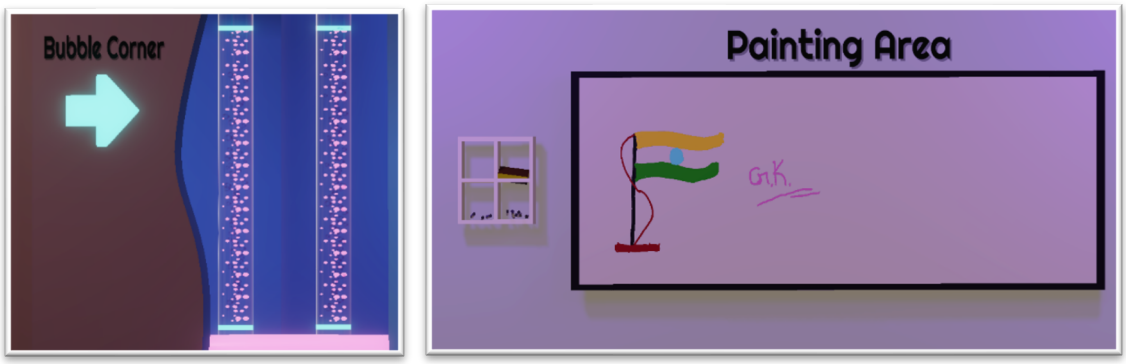

Fig. 2. Sensory tools: (Left) Bubble/Sensory Tube, (Right) a painting board for motor skills.

We will also collect qualitative data to understand our results better. A one-to-one interview will be conducted with autism experts and autistic individuals to get their feedback on the design of the immersive sensory room and their preferred sensory tool. The interviews will be recorded to use later for analysis. During the user study, participants will be encouraged to use the think-out loud method so the researchers can take notes on the participants' responses and any notable comments made during the sessions.

3.5 Data Analysis Techniques

To evaluate feedback for the UEQ [23], we will use the data analysis tool provided in the UEQ handbook. For the simulator sickness data [24], we will calculate the total score using the provided formula. To analyze the quantitative data, we will check the normality and apply ANOVA to test for variance within data from autistic individuals and autism experts. Additionally, we will measure the activity on which the participants spend the most and the least time. To analyze the qualitative data, we will use an inductive approach and assess the data to find any patterns and themes that can justify our quantitative results.

3.6 Ethical Considerations

To participate in the user study, autistic individuals and autism experts are required to provide informed consent. In the case of minor participants, parental or guardian consent is necessary for participation in the user study. The conduct of the user study will be subject to approval from the university's ethics committee and will adhere to all ethical standards established by the institute involving human subjects. Participants will be assured of the confidentiality of their personal information. The participants retain the right to withdraw from the user study at any time. No incentives will be offered to autistic individuals or autism experts for their participation in the user study, and their involvement will be strictly voluntary.

4 Discussion

The immersive sensory room, although still in progress and not yet subjected to user study, promises to offer significant advancements over traditional sensory room setups. By incorporating VR, the immersive sensory room allows for greater flexibility, customization, and control of the sensory stimuli. This approach aligns with the existing literature which emphasizes the need for tailored, adaptive environments for autistic individuals. However, it deviates by providing a more dynamic and technologically advanced experience than static, traditional setups. The immersive room offers a multisensory experience that can be personalized in real-time by autistic individuals based on their needs, potentially enhancing engagement and therapeutic outcomes. This sensory room holds great potential for integration into schools and care centers, where it could be used as an educational tool or for therapeutic purposes. Its interactive and customizable features make it suitable for supporting the development of social skills, cognitive abilities, and emotional regulation in autistic students. Schools could integrate it into their special education programs, providing students with a more engaging and flexible learning environment.

5 Challenges and Limitations

One major challenge we will face is ensuring the activities integrated in the sensory room are engaging and not overwhelming autistic participants given their tendency to easily get distracted. To overcome this, we have added the free play method so that they can perform any activity in any order of their interest. Another major challenge would be to ensure that the immersive sensory room is adaptable to individuals with varying levels of sensory sensitivity. Managing overstimulation in individuals sensitive to specific sensory inputs, such as flashing lights or loud sounds, could be challenging in an immersive environment. Additionally, we will encounter another challenge with the sample size of the participants. To generalize our findings, we need a larger sample size, and for that, we are collaborating with multiple institutes and doing publicity for the user study via social media.

6 Future Work

This immersive sensory room will be further developed to enable the real-time customization of the environment to accommodate the specific sensory needs and preferences of autistic individuals. Participants will have the flexibility to adjust sensory settings (audio, visual, and environmental factors) and maintain control over the sensory environment, thereby ensuring their comfort and focus. Additionally, we aim to compare the effectiveness of immersive sensory rooms with traditional sensory rooms, which may provide valuable insights regarding user engagement, emotional outcomes, and sensory regulation between the two setups. Furthermore, we intend to conduct long-term efficacy studies to assess the therapeutic benefits of immersive sensory rooms for autistic individuals, such as their impact on emotional regulation, sensory processing, and cognitive development over time.

7 Conclusion

As autistic individuals are prone to sensory sensitivity, sensory rooms play a pivotal role in allowing them to self-regulate their senses. In this study, we have shown that immersive sensory rooms can help autistic individuals balance and stimulate their senses. The immersive sensory room we implemented targets the visual, auditory, and tactile senses. We will conduct a user study in which autistic individuals and autism experts will be recruited to participate. Our research aims to gain insight into the unique sensory preferences of autistic individuals and, in the future, allow them to customize the immersive room based on the specific preferences of autistic individuals. In the future, we will compare the use of immersive sensory rooms with traditional rooms and assess their influence on emotion regulation and cognitive load in autistic individuals.

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