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Doctoral Colloquium—Investigating Preferred Design Elements by Autistic Individuals in an Immersive Learning Environment

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Abstract. This doctoral colloquium paper aims to actively engage autistic individuals in the design process of an immersive learning environment (ILE), ensuring that the ILE aligns with their specific sensory needs and preferences. A Virtual Reality (VR) application is developed to collect feedback on the favored design elements of autistic individuals while performing learning tasks within an ILE. Autistic individuals with low support needs will be recruited for a user study to evaluate their preferences and experiences with the VR application. Prior to the user study, autism experts will assess the suitability of the application to ensure its adequacy for autistic users. Additionally, an immersive sensory room is designed to assist participants in self-regulating their sensory needs during the study, targeting their visual, auditory, and tactile senses. Through analysis of feedback from autistic individuals on the design elements, this research aims to develop a customizable ILE tailored to their specific sensory preferences. The findings of this study will contribute to the development of more inclusive and effective educational tools, emphasizing the importance of incorporating input from autistic individuals into the design process.

Keywords: Autism, Autistic Individuals, Immersive Learning Environment, Customizable Immersive Learning Environment, Virtual Reality, Inclusive Design, Sensory Sensitivity.

1 Introduction

Autism is a lifelong neurodevelopmental condition characterized by significant challenges in social interactions, communication, and behavioral skills [1, 2]. Autistic individuals often exhibit repetitive behaviors, strict routines, and heightened sensitivity to sensory stimuli such as sound, light, and texture. Recent studies have shown that autism affects approximately 1 in 100 children worldwide, a figure rising due to increased awareness, broader diagnostic criteria, and improved diagnostic methods [3, 4]. This condition affects individuals differently, ranging from high support needed in day-to-day routine to low support needed and having an IQ above average.

In recent years, Virtual Reality (VR) has emerged as a tool with potential for addressing some core traits associated with autism [5]. VR provides immersive, simulated environments in which users interact with digital objects in real-time. For autistic individuals, VR offers a safe and controlled space to practice essential skills such as communication, social interaction, and daily tasks [6]. This minimizes the unpredictability and sensory overload of real-life situations, making it easier for them to engage. Research shows that VR can help autistic individuals develop life skills through structured, repetitive, and customizable experiences tailored to their unique learning styles [7]. Moreover, VR's immersive nature enhances user engagement and focus, qualities that are particularly beneficial for autistic individuals who often struggle with distractions in real-world settings. The structured nature of VR environments helps reduce anxiety and stress, enabling autistic individuals to focus better on the task at hand. Studies have shown that the reduction of extraneous stimuli such as background noise or unpredictable environmental changes leads to improved learning outcomes [8].

Although VR shows great potential for autism interventions, it poses challenges, particularly regarding the sensory sensitivities of autistic individuals [9]. Sensory sensitivity is a key characteristic of autism, with many individuals reacting intensely or weakly to stimuli such as light, sound, and touch. In VR settings, bright lights, loud sounds, or excessive visual input can lead to sensory overload, causing anxiety and discomfort that hampers engagement and learning. Moreover, cognitive overload can overwhelm autistic learners, making it difficult for them to process information, reduce focus, and lead to disengagement. This can significantly impact learning outcomes, as students may struggle to concentrate and retain information [10].

Designing effective ILEs for autistic individuals requires addressing sensory and cognitive challenges. Few established guidelines exist for creating suitable ILEs, and many are based on developers' experiences rather than scientific studies. While some studies have involved stakeholders, as in [11], the direct input of autistic individuals is crucial. By including autistic individuals in the design process, designers can better tailor environments to minimize overwhelming stimuli, provide simple navigation, and structure interactions predictably. This inclusive approach can reduce sensory and cognitive overload and improve engagement and learning [12]. One of the key strengths of VR is its customizability, which is particularly beneficial for autistic individuals. Customization allows users to adjust elements such as brightness, volume, and task complexity to suit their sensory and cognitive needs, thereby creating an environment conducive to learning. This adaptability also helps learners build confidence at their pace [13].

This study proposes a VR-based approach that uses a rating system to gather feedback on design elements from autistic individuals and organize a comparative study of design elements and will incorporate those preferences in an ILE in future work. The aim is to create guidelines to make VR environments more inclusive and effective for autistic learners through comparative studies of design elements and learning performance.

2 Literature Review

Involving autistic individuals in the design process of an ILE offers numerous benefits, primarily by ensuring that the ILE is tailored to their unique needs and preferences. As highlighted in various studies, participatory design (PD) methods emphasize the importance of engaging autistic individuals directly to create more effective and user-friendly technologies [14]. For instance, the COSPATIAL project demonstrated that involving autistic children in the design process led to the development of interactive technologies that were both enjoyable and useful for enhancing social skills [15]. Similarly, the Autism & Uni online toolkit project showed that engaging autistic students as co-designers helped address their specific challenges in transitioning to higher education, thereby creating a more supportive and relevant tool [16]. The involvement of autistic individuals also helps to overcome communication barriers, as seen in the collaboration between "The Helen Hamlyn Center for Design" and "The Kingwood Trust", which adapted design methods to include autistic adults with limited speech, ensuring that their life experiences and needs were considered [17] . Moreover, the use of VR systems, such as VR4VR, for vocational training highlights the importance of designing with the autistic population in mind, as it allows for the creation of environments that cater to their sensory and interaction preferences, ultimately leading to better training outcomes [18, 19]. Involving autistic individuals in the design process not only leads to the creation of more effective and inclusive learning environments but also empowers them by valuing their input and experiences, ultimately contributing to their personal and educational growth [20, 21].

As autism is a broad spectrum, it is very difficult to generalize the sensory preferences of autistic individuals as they have diverse needs and learning preferences. Customizable ILEs allow users to adjust sensory elements in real-time to minimize potential triggers, create a more comfortable and engaging learning environment and, tailor the level of task complexity and pacing, ensuring that learning experiences are manageable and aligned with cognitive processing abilities. This study aims to develop a customizable ILE that addresses cognitive overload and sensory sensitivities commonly experienced by autistic individuals. To achieve this objective, the research will seek to answer the following questions:

RQ 1: What are the critical factors to consider when designing an ILE for autistic individuals?

RQ 2: How can autistic individuals be effectively involved in the design process of an ILE?

RQ 3: How do different design elements influence the learning performance of autistic individuals within an ILE?

By exploring these questions, this study will contribute to a deeper understanding of how to create more effective and inclusive learning environments tailored to the unique needs of autistic individuals.

3 Research Methodology

This section provides a comprehensive explanation of the research design, followed by the criteria for participant recruitment in the user study. It includes a description of the apparatus employed in the design and development processes, followed by the development of the VR application and the immersive sensory room. The section also details the data collection and analysis methods and provides an overview of the ethical considerations that will be implemented to ensure the safety and comfort of autistic participants throughout the study.

3.1 Research Design

In this study, we rely on self-reported data to capture the subjective preferences and experiences of autistic individuals regarding design elements, as this approach is uniquely suited to understanding their personal perspectives and sensory needs. To mitigate biases such social desirability, qualitative insights from semi-structured interviews will be collected to provide contextual depth, while behavioral observations will cross-validate responses. This multi-method approach enhances data credibility by integrating quantitative, qualitative, and observational methods.

3.2 Participants

The user study will involve recruiting participants from diverse educational and healthcare organizations. Autistic individuals must meet specific inclusion criteria, including either a formal clinical diagnosis of autism or a score of 29 or higher on the Autism Spectrum Quotient (AQ) [22], a widely used self-report measure for assessing autism traits in individuals aged 16 years and older. Additionally, participants will be required to possess the ability to comprehend and follow instructions during the study. Simultaneously, autism experts will be involved in the design and development phases of the VR application, immersive sensory room, and customizable ILE. These experts will be recruited from local institutions and medical facilities to ensure that the VR application and the sensory room are appropriately tailored to the sensory and cognitive needs of autistic individuals and that its design aligns with established best practices in autism intervention.

3.3 Apparatus

The VR application employed in this study utilizes a standalone headset. The choice of a standalone headset is motivated by its safety advantages over wired alternatives, particularly for autistic individuals, who may be more sensitive to physical constraints associated with wired systems [23]. For the development of the VR application, two primary software tools are used: Blender [24] for 3D modeling and the Unity3D [25] game engine for developing the VR application and immersive sensory room. To design these virtual environments, custom-created, free and paid assets were used.

3.4 Design Elements

The study is structured into three main stages: conceptualization/design, development, and testing/evaluation of an ILE. During the initial conceptualization stage, a VR application will be designed and developed to collect feedback from autistic individuals on their sensory preferences while engaging in learning activities. Autism experts will be involved in this stage of the research to ensure the application is suitable for autistic users. The development phase will incorporate these preferences, and any necessary adjustments will be made from a computer science perspective to improve engagement and meet diverse user needs. In the evaluation phase, ILEs featuring different design elements will be compared to provide scientifically validated design preferences specific to autistic individuals.

This study examines two categories of design elements: those related to the virtual environment and those used in instructional design. The environmental design category is further subdivided into visual and auditory components, whereas the instructional design category encompasses video, audio, and textual elements. Tables 1 and 2 provide a comprehensive depiction of the various design elements under investigation in this study.

Table 1. Environmental design elements to be investigated.

Environmental elements				
Visual elements			Auditory elements	
3D Model	Background color	Animation	Background audio	Interaction audio
Realistic	Red	Static	With audio	With audio
Abstract	Green	Normal Speed	Without audio	Without audio
	Blue	Fast speed		
	Pink			
	Brown			
	White			
	Grey			

	Orange

A VR application has been developed to examine diverse design preferences of autistic individuals, such as the preference for human beings or realistic avatars in video tutorials or background colors. The options for background colors, text colors, and text fonts are carefully curated based on recommendations from existing literature. To minimize sensory overstimulation, more subdued and less saturated color shades have been chosen, resulting in a more neutral visual appearance.

Table 2. Instructional design elements to be investigated.

Instructional elements				
Video based		Audio based	Text based	
Appearance	Familiarity		Font Type	Text Color
Realistic avatar	Self	Human voice	Consolas	Raspberry
Abstract avatar	Stranger	Synthetic Voice	Comic Sans	Cyan green
Human being	Familiar		Courier New	Cyan blue
			Roboto	Magenta
			Verdana	Brown
			Arial	Beige
			Calibri	

3.5 Development

The VR application will be used to assess preferences in the design elements of autistic individuals while performing a learning task. The primary objective is to provide participants with the opportunity to directly engage with these design elements in an immersive environment, rather than merely rating them in a non-immersive medium. Given the challenges that autistic individuals may face in expressing their preferences, the VR application offers them a range of choices. Participants will engage in activities within each subcategory, as shown in Fig.1, during which they will focus on specific tasks and rate how each design element affects their experience.

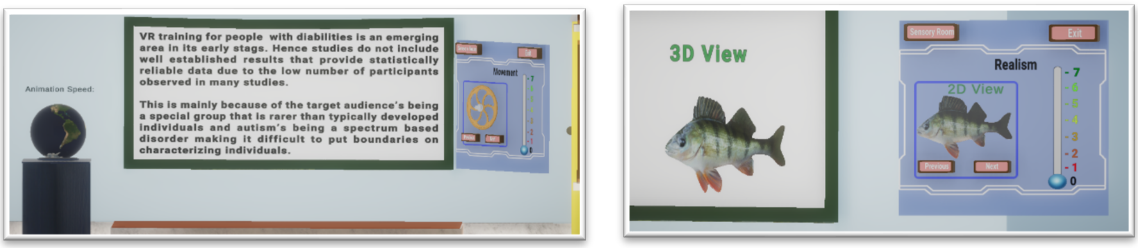

Fig. 1. Snippets from the VR application: Investigating (Left) Preference for animation, (Right) preference for model style.

3.6 Data Collection Methods

To collect quantitative data, a custom questionnaire will be used to collect demographic data such as age, gender, education, and VR experience. The User Experience Questionnaire (UEQ) [26] will be employed to measure aspects such as "attractiveness, efficiency, perspicuity, dependability, novelty, and stimulation of the user experience in VR". The Simulator Sickness Questionnaire (SSQ) [27] will assess simulator sickness symptoms such as nausea, disorientation, and oculomotor experiences in VR. The NASA-TLX questionnaire [28] will be used to assess cognitive overload. Additionally, qualitative data will also be collected. One-to-one interviews will be organized with autism experts to gather feedback on the design of the ILE and guidelines for inclusion. These interviews will be audio-recorded and later assessed to capture expert insights. Observational data will be collected through screen, video, and audio recordings during the design and testing phases. Instructors will take notes and ask follow-up questions to gather real-time feedback from participants. Different methods will be integrated to provide a comprehensive understanding of the application's effectiveness and usability.

Fig. 2. Snippets from the immersive sensory room. (Left) music area, (Right) bubble corner with bubble tube.

3.7 Data Analysis Techniques

To analyze the quantitative data, statistical methods such as ANOVA will be applied to test for variance within different sub-categories of design elements, and Pearson's correlation analysis will investigate the relationships between design elements and cognitive overload. The data from the UEQ [26] and SSQ [27] will be analyzed using the tools and formulas provided in respective handbooks. An inductive approach will be used to analyze qualitative data, focusing on thematic coding of interview transcriptions, notes, and recordings. Patterns and themes will be identified from the opinions of autism experts and participants' interactions with the ILE to inform future design improvements.

3.8 Ethical Considerations

Ethical considerations will be rigorously upheld throughout the study to safeguard the protection and well-being of participants. Informed consent will be obtained from all participants prior to their involvement in the study. For participants under the age of 18, consent will be secured from a parent or legal guardian. To ensure adherence to ethical guidelines for research involving human participants, particularly those with autism, the study will seek approval from the university's ethics committee. This process will confirm that the research aligns with established ethical standards. Participants will retain the right to withdraw from the study at any point without facing any consequences. Confidentiality will be strictly maintained, with all personal data anonymized and securely stored to protect participants' privacy. No financial incentives or rewards will be provided, reinforcing the voluntary basis of participation in the research.

4 Limitations and Challenges

Involving autistic individuals in the design process of an ILE presents several challenges and limitations. A primary constraint is the small sample size, as recruiting a substantial number of autistic participants is often difficult. This limitation may restrict the generalizability of the findings and hinder the ability to fully capture the diverse sensory preferences across the autism spectrum. Furthermore, the findings may be context-specific due to the unique and varied needs of autistic learners. To address this, the methodology will be thoroughly documented, and replication studies in diverse settings will be encouraged. Additionally, the unfamiliarity of virtual reality technology may initially impede adoption and engagement. To mitigate this, comprehensive training sessions will be provided for both autistic participants and autism experts, alongside user-friendly guides and support materials. Given that autistic individuals may require time to adapt to the ILE, iterative testing and feedback loops will be incorporated to refine the design and enhance usability.

5 Future Work

VR application has been developed for evaluating design elements. Next, a user study will be conducted to collect data on the design preferences of autistic individuals using the aforementioned VR application, where qualitative and quantitative data will be collected on the sensory preferences of autistic individuals. Based on the feedback from the VR application user study, various design elements will be incorporated into the ILE, and multiple comparative studies will be conducted. Using this ILE the impact of design elements on learning outcomes and performance such as skill development, knowledge acquisition, and transferability will be investigated. For certain design elements, ILEs will be made customizable to allow autistic individuals to adapt them according to their specific needs. Concurrently, efforts will be directed towards making the immersive sensory room customizable, enabling autistic individuals to make real-time modifications to the environment based on their unique sensory preferences.

6 Conclusion

This study addresses a research gap concerning the customization of ILEs for autistic individuals. To bridge this gap, we outlined a research plan aimed at gaining deeper insights into the unique needs of autistic individuals by assessing how various design elements impact their learning performance using a custom-created VR application. Additionally, we implemented a sensory room to help autistic individuals manage their sensory sensitivities and engage their visual, auditory, and tactile senses, providing a means to self-regulate. At the end of the study, we will provide guidelines and methods for involving autistic individuals in the conceptualization or design process of ILEs. These guidelines will serve as crucial resources for future research, fostering the creation of more inclusive and efficient ILEs tailored to the unique needs of autistic users.

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