DOI: https://doi.org/10.56198/U6C0WT2K1

Immersive Learning Research Network

Doctoral Colloquium—Involving Individuals with Autism in Design of an Immersive Learning Environment

Gunjan Kumari

Ilmenau University of Technology, 98693 Ilmenau, Germany
gunjan.kumari@tu-ilmenau.de

Abstract. The aim of this research is to investigate the potential of individuals with autism to participate in the design of an immersive learning environment (ILE). It will involve enlisting high-functioning individuals with autism to contribute to the design process of an ILE and select their preferred design elements. To gather this information, a virtual reality (VR) application will be developed in collaboration with individuals with autism in which individuals with autism can rate different design elements based on their preferences. Both quantitative and qualitative data will be collected, and descriptive and inferential statistical analyses will be applied to compare these design elements. The research findings are anticipated to provide statistically significant insights into the preferences and experiences of individuals with autism and offer guidelines and techniques for involving them in the design process and to guide future researchers in the development of an ILE for individuals with autism. This doctoral colloquium paper presents an overview of user-centred research design and aims to initiate further discussions in the field regarding the preferred design elements of individuals with autism.

Keywords: Virtual Reality, Autism Spectrum Disorder, Inclusive Design, Immersive Learning Environment.

1 Introduction

Autism is a neurodevelopmental disorder that is characterized by deficits in social interactions, communication, and behavioural skills. It is classified as an autism spectrum disorder (ASD), which can vary widely in severity, ranging from low-functioning individuals with limited or no verbal communication to high-functioning individuals with an IQ above average. While it was once thought to be a very rare condition, it is now estimated that approximately 1 in 100 children globally is diagnosed with autism [1]. Individuals with autism require specialized education and support from both conventional and specialized institutions to address their unique needs.

In recent years, research has shown that the use of computers and computer technology in children with autism has both positive and beneficial effects. According to [2], parents and clinicians frequently report that children with autism are drawn to technological devices. Furthermore, a substantial body of evidence suggests that computer-based interventions are beneficial for students with autism [3]. Virtual reality (VR) has emerged as a popular tool for the training, and intervention of individuals with autism [4]. The use of VR in these contexts is widespread due to the human brain's propensity for learning through the visual, auditory, and tactile senses. Individuals with autism are thought to benefit from this approach because of their strong visual memory [5]. Training in VR offers several advantages for individuals with autism, particularly those who are high functioning. VR allows for practice in a safe environment, provides the ability to control and gradually increase task complexity and reinforces learning through repetition [4]. They feel more comfortable in stable/unchanging environments. Additionally, VR reduces stress because individuals with autism can interact with the system independently and increases focus by isolating individuals with autism from their surroundings in the real world. It has no severe real-life consequences of mistakes and has no or minimal human interactions. It is appealing to this technology-savvy population, which is highly visual-based and exploits their attribution to strong visual memory.

Designing an autism-friendly immersive learning environment (ILE) raises several challenges, such as choosing the appropriate color scheme, font size and shape, and presentation method such as choosing between a human or computer-generated voice. It is important to consider the optimal amount of content to avoid overwhelming individuals with autism and causing cognitive overload [6]. Although there are many guidelines provided by autism researchers for real-life scenarios, only a few can be implemented in computer-generated ILEs. Given the heightened sensory sensitivity of individuals with autism, it is crucial to design an ILE that helps them to focus on the environment rather than creating overstimulation. Previous research has been conducted with individuals with autism participating in the design process, but most of these studies have relied on lessons learned, participant statements, and observations from researchers, practitioners, teachers, and family members. However, these observations were not based on comparative user studies or statistical data. Furthermore, the design considerations reported thus far have been heavily dependent on the context of the task or characteristics.

This research aims to address this gap by proposing an approach that includes a virtual reality (VR) application with a rating system to gather preferences and a comparative study of design elements and their effect on learning performance and also aims to derive methods and guidelines to involve individuals with autism in design process of ILEs.

2 Related Work

The importance of involving users in the design process of technology has been highlighted by numerous authors [1]. According to [2], participatory design is not merely an option, but a necessity when designing for individuals with special abilities. The exclusion of individuals with autism from the software development process has resulted in products that do not adequately meet their needs [3]. Participatory design methodologies can help address this issue by ensuring that representative users are included in the design and development process from the start [9]. Although various stakeholders such as parents and teachers can offer valuable perspectives and insights, the process should not disregard the views of the primary users. The primary users of autism-specific technology are individuals with autism, and their contributions should not be overlooked.

Since the early studies by [3–6] on incorporating individuals with autism in the design process of ILEs, there has been a setback in research. However, in recent times, there has been a revived focus on prioritizing the perspectives of individuals with autism and their stakeholders by integrating them into the design process.

In a research endeavour for the COSPATIAL project, research studies [7, 8], were conducted to develop and design interactive and collaborative technologies for children and young individuals within the autism spectrum, aiming to enhance their collaboration and social conversation skills. To accomplish this, the project incorporated a participatory design process that comprised a core design team consisting of teachers and groups of neurotypical children and those with autism. Through a series of workshops, the team built upon initial discussions and generated ideas to establish collaborative virtual environments (CVEs) that offered promising benefits for learning, social skills development, and greater understanding.

A pilot study was conducted by [9] to explore the effect of involving autistic youth in the co-design of a game aimed at enhancing their geographical knowledge. The study focused on the design process, learning outcomes, and social engagement of participants. Participants reported positive experiences related to enjoyment, motivation, and social engagement. The game mechanics were found to be effective in helping participants increase their knowledge of geography. This study emphasizes the significance of incorporating the perspectives of individuals with autism in the design of safe and comfortable online spaces, rather than relying on neurotypical assumptions.

In another study, [10] developed a virtual environment prototype for autistic children, utilizing face-to-face interviews and the Picture Exchange Communication System (PECS) methodology for data collection. Subsequently, quantitative evaluations were executed to analyse the data obtained from the virtual environment prototype. This research offers significant recommendations for addressing the communication and learning difficulties experienced by children with autism, while also providing insights into the development of effective e-learning strategies. Additionally, [11] found that including individuals with autism and stakeholders in the development process improved their accessibility, acceptability, and transparency of the adapted VR job interview training for transitioning autistic youths. In these two studies, a participatory design methodology was employed in which individuals with autism, or their parents and teachers were actively engaged, but the final decisions were made by non-autism experts, thereby raising questions about the appropriate balance between incorporating the perspectives of stakeholders with autism and leveraging the expertise and knowledge of non-autistic professionals.

The lack of research on the development of ILEs with input from individuals with autism is noteworthy. To create ILEs that are both state-of-the-art and accessible, effective, and educationally valuable, it is necessary to establish processes, guidelines, methods, and tools that guide their development. User-centred and participatory design principles stress the importance of involving users in determining and negotiating requirements, making joint decisions and trade-offs, and evaluating prototypes, among other things. However, it is unclear how best to achieve this with the user population of individuals with autism, and it is also uncertain which methodologies, processes, and principles are most suitable. Many of the previously mentioned studies have primarily derived guidelines based on subjective observations rather than conducting scientific comparative studies. Furthermore, there is a scarcity of literature documenting or justifying the methods and techniques used in participatory, user-centred design with individuals with autism.

Our research is focused on addressing the issues mentioned above, and we seek to utilize a novel approach to gather design preferences from individuals with autism during the conceptualization phase of an ILE. Our goal is to create an ILE tailored to their preferences while allowing for necessary modifications. Furthermore, during the evaluation phase, we aim to compare various design elements and establish guidelines on how and to what extent individuals with autism can participate in the design process of an ILE and how their feedback can be incorporated into the development process.

3 Methodology

3.1 Sampling Strategy

For user studies, participants will be recruited from various educational institutions and medical facilities. To be eligible for the user study, participants must have a diagnosis of autism and the ability to comprehend and follow instructions. Our aim is to enhance the generalizability of the findings by keeping the sample size at the same autism level and age range while targeting high-functioning individuals aged 12 to 20 years.

We also plan to involve autism experts in the development and design phases of ILE. These experts possess specialized knowledge in diagnosing, assessing, and providing interventions for individuals with autism. To assemble a team of autism experts, we intend to contact local institutions and medical facilities, and invite them to collaborate with us on this research initiative.

3.2 Research Design

We have divided our research into three phases: conceptualization phase, development phase and evaluation phase of an ILE. During the conceptualization phase, we will conduct a user study and seek inputs from individuals with autism utilizing a custom created VR application to investigate their preferred design elements while performing learning tasks. Autism experts will also be involved in the conceptualization phase, first to make sure the VR application is adequate for individuals with autism and later to understand the design choices made by individuals with autism.

In the development phase, we will incorporate the preferences of individuals with autism collected during the conceptualization phase and if needed, from the perspective of a computer scientist, make the required modifications to make the application more engaging and meet the need of all users.

Afterwards, during the evaluation phase, we will involve individuals with autism again in the process as testers to obtain their feedback in terms of the usability of the application and user experience. This research project will employ a standalone headset for its testing. The use of standalone headsets is considered to be safer than wired headsets, especially for individuals with autism [12]. The ILE and VR application will be designed using Blender [19] and Unity3D game engine [20], incorporating custom-created and purchased assets. During the evaluation phase, participants will be required to complete questionnaires within the VR environment.

Table 1. Different design elements to be investigated.

Environmental elements		Instructional elements	
Visual	***Auditory***	***Video***	***Audio***
Realism	Background audio	Virtual human being	Human voice
Size	Interaction audio	Animated character	Synthetic voice
Color	Instruction audio		
Movement			

The design elements that will be investigated throughout the PhD are divided into two categories: environmental design elements and instructional design elements. Both categories are further subdivided into visual and auditory elements for environmental design elements and video and audio for instructional design elements. The categorization of the different design elements that need to be investigated is presented in Table 1. A VR application will be developed to investigate various design preferences of individuals with autism, such as the preference for static or dynamic 3D models, inclusion or exclusion of background audio while performing tasks, and preference for human or synthetic voices in instructions.

3.3 Application

A VR application will be developed using Unity3D [20] to gather information on the preferred design elements of individuals with autism, as depicted in Fig. 1. The application will present various options for visual and auditory elements that can be utilized in environmental design or video and audio methods for instructional design, such as video tutorials and verbal instructions in synthetic voice. Participants with autism will be requested to rate these elements on a Likert scale ranging from 1 to 7. The scaling method for rating will be employed to measure the extent to which a design element is liked or disliked.

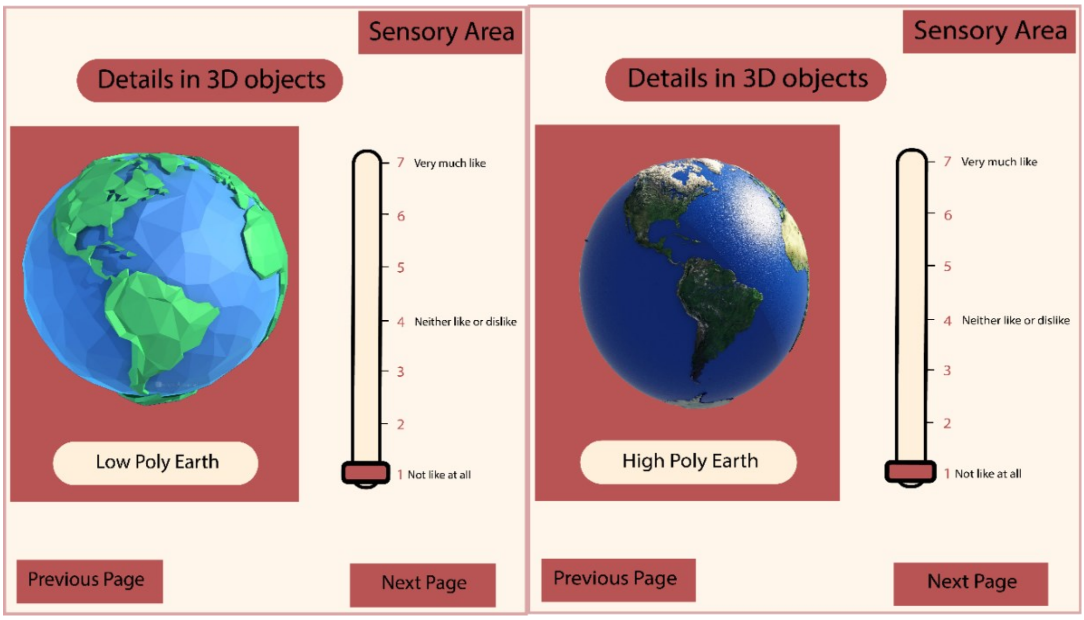

Fig. 1. Sample of planned VR application for rating different design elements.

To prevent overwhelming participants with information, it is planned to present only one design element on the screen at a time, as individuals with autism are known to be highly attentive to details and may struggle to process excessive visual information. Before conducting the user study in conceptualization phase with the VR application, we will solicit feedback from autism experts to ensure that the VR application can be utilized by individuals with autism without causing sensory stimulation.

We intend to employ the VR application to investigate preferred design elements, shown in Table 1, with the aim of providing individuals with autism the opportunity to experience these design elements in an immersive environment, rather than simply rating them for a different medium.

3.4 Experiment Design

After completing our conceptualization user study on design elements using the VR application, we will conduct a series of at least four distinct comparative studies within each category for evaluation phase to measure the effect of different design elements on learning performance. For instance, in the category of instructional design elements, we plan to conduct a comparative study of audio instructional elements in ILE. This study will entail two separate activities: the first will involve human-generated voice instructions for a learning task, while the second will utilize synthetic voice audio instructions. Our ultimate goal is to statistically validate the findings of our study and provide statistically proven guidelines for future research, rather than relying solely on observations.

All user studies will follow the same procedure map shown in Fig. 2: Before the experiment begins, the researcher will provide a concise, hands-on-assisted guide on the operation of the virtual reality system, along with instructions on how to perform the assigned activities.

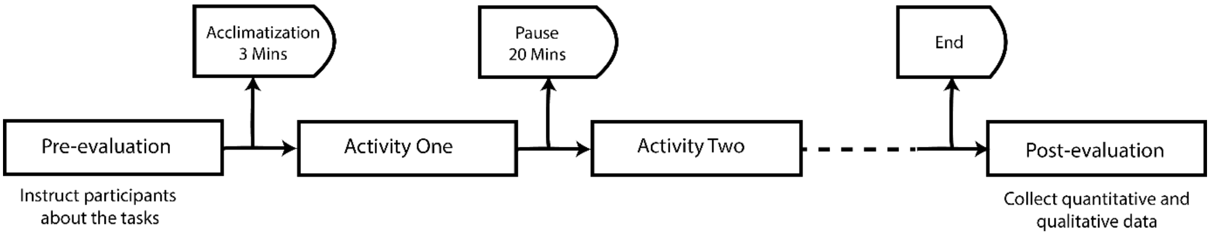

Fig. 2. Visual description of experiment procedure.

The session will commence with the participants donning the VR headset and entering a designated "sensory" area as seen in Fig. 3. This sensory area is a virtual environment that we have designed for participants to take breaks between tasks during a user study. Participants will be allotted a period of approximately two minutes to become familiar with the sensory area and feel comfortable within it. After that, participants will be moved to another ILE to perform tasks. Each participant will engage in two or more activities, each with a duration of approximately 10 minutes, depending on the parameters set for the study.

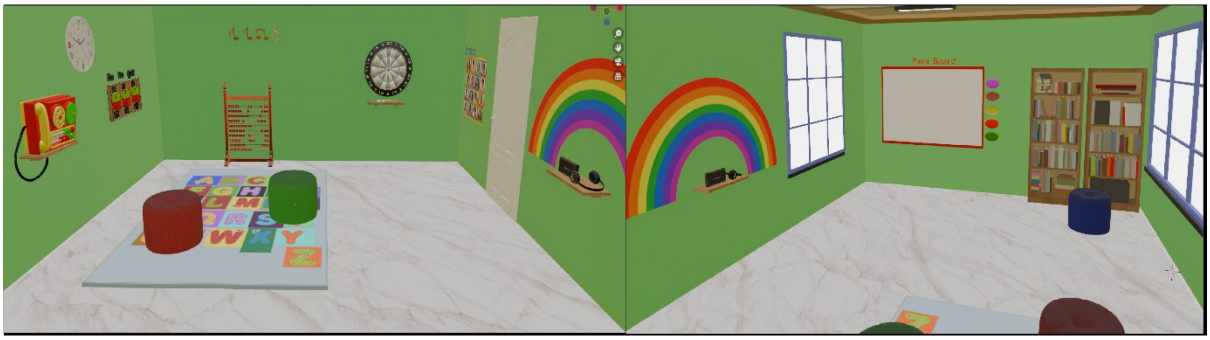

Fig. 3. Illustration of sensory area (work-in-progress).

3.5 Data Collection and Analysis

During the course of our study, we will collect a substantial amount of both quantitative and qualitative data using various techniques. The data collection methods and analyses methods are explained below:

Quantitative Data. We will collect demographic data of the participants such as their age, gender, education, VR experience by creating a custom questionnaire.

To measure user-experience, we will utilize the User Experience Questionnaire (UEQ) [13], which is a swift and reliable questionnaire for evaluating the user experience of interactive products. The questionnaire covers a broad range of user experience by measuring classical usability aspects such as attractiveness, efficiency, perspicuity and dependability and user experience aspects such as novelty and stimulation. The UEQ consists of 26 items, and we will employ the data analysis tool provided in the UEQ handbook for our analysis.

To measure cybersickness in VR, we will use Simulator Sickness Questionnaire (SSQ) [22]. SSQ measures the subjective severity of 16 symptoms on a scale from 0 (none) to 3 (severe), after the user-study. It assesses different types of simulator sickness symptoms categorized in three categories: nausea, disorientation and oculomotor. Total score (TS) will be calculated by using the formula provided by [22]. TS represents the overall severity of cybersickness experiences by the participants in VR applications.

We will check the data for normality and apply ANOVA to test for variance within different categories. We will also apply Pearson's correlation analyses to perform an investigation between cybersickness in VR and user-experience in VR for individuals with autism.

Qualitative Data. A semi-structured interview will be conducted with autism experts to seek their opinions on the design of the ILE and the guidelines to follow in the inclusion process for individuals with autism. This will be audio recorded for later transcriptions and analysis. Additionally, screen, video and audio recordings will also be captured during the conceptualization and evaluation phase, and these will also be transcribed for analysis. Throughout the conceptualization and evaluation phases, the researchers will take notes on the participants' responses and any notable comments made during the sessions. The researchers may also ask follow-up questions based on their observations. These notes will be used for subsequent analysis. For analysis of the qualitative data, we will utilize an inductive approach, which involves examining the data to identify patterns and themes.

3.6 Research Ethics

All participants must provide informed consent, and if they are under 18 years of age, their parents must agree to their child's participation in the study. Approval from the faculty's ethics committee will be sought for the participation of individuals with autism in the user study. All procedures involving human beings will be conducted in accordance with the ethical standards of the institute. Confidentiality of personal information will be maintained, and participation will be completely voluntary, with participants having the freedom to withdraw from the study at any time.

3.7 Limitations

One of the most significant challenges is the need to recruit a larger sample of participants. To address this, we are collaborating with several institutions that have access to individuals with autism. Another challenge is to ensure that the design process remains engaging and does not become overwhelming for individuals with autism given their limited communication skills and tendency to become easily distracted. To prevent participants from becoming overwhelming, we intend to conduct at least four distinct evaluation studies for the design elements outlined in Table 1. For each subcategory, we will divide the study into multiple sessions, limiting the maximum number of activities in a session to three to avoid sensory overstimulation. In the event of mild sensory overload, participants may retreat to the sensory area, as shown in Fig. 3, to regulate their senses and calm themselves. To evaluate each design element, we will incorporate one activity that lasts approximately ten minutes followed by a 20-minute break before the next activity as shown in Fig. 2. Furthermore, finding the appropriate location for user studies is essential because individuals with autism are highly sensitive to disruptions in routine and environmental conditions.

4 Future Plan

The development of a VR application for rating design elements by individuals with autism is currently underway. After completion, we will conduct a user study and gather data on the preferences of high-functioning individuals with autism using the said VR application. This data will be used in development phase to develop an ILE that will tailor to their preferences. Following this, we will conduct semi-structured interviews with autism experts to gather their feedback and modify the ILE as necessary. Once the conceptualization and development phase are finished, we will conduct a series of user studies comparing the different design elements discussed earlier in Table 1. After each user studies, we will analyse the data collected to compare the results. In addition to the quantitative and qualitative results from the user studies, we will also derive guidelines that provide recommendations on how and to what extent individuals with autism can be involved in the design process of an ILE.

5 Conclusion

In this paper, we have shown that there is a research gap between autism researchers who are experts in the needs and preferences of individuals with autism and computer scientists who develop ILEs for individuals with autism. Therefore, we present a plan to fill this research gap and explain the steps taken to bridge this gap. Our research aims to gain insight into the specific needs and requirements of individuals with autism by investigating various design elements and their impact on the learning performance of individuals with autism and establishing guidelines and techniques on how to involve individuals with autism in the design process of an ILE, and to what extent their feedback can be incorporated in the implementation of ILE. These guidelines and techniques can serve as valuable reference for future applications and contribute to the development of more effective and user centered ILEs for individuals with autism.

References

1. Zeidan, J. et al.: Global prevalence of autism: A systematic review update. Autism Res. 15(5), 778–790 (2022), doi: 10.1002/aur.2696.
2. Goldsmith, T. R., LeBlanc, L. A.: Use of technology in interventions for children with autism. J. Early Intensive Behav. Interv. 1(2), 166 (2004).
3. Hardy, C., Ogden, J., Newman, J., Cooper, S.: Autism and ICT: A guide for teachers and parents. Routledge (2016).
4. Quill, K. A.: Instructional considerations for young children with autism: The rationale for visually cued instruction. J. Autism Dev. Disord. 27(6), 697–714 (1997).
5. Strickland, D.: Virtual reality for the treatment of autism. Stud. Health Technol. Inform. 44, 81–86 (1997).
6. Bozgeyikli, L., Raij, A., Katkoori, S., Alqasemi, R.: A Survey on Virtual Reality for Individuals with Autism Spectrum Disorder: Design Considerations. IEEE Trans. Learn. Technol. 11(2), 133–151 (2018).
7. Lewis, C.: HCI and cognitive disabilities. Interactions 13(3), 14–15 (2006).
8. Fischer, G., Sullivan, J. F.: Human-centered public transportation systems for persons with cognitive disabilities (2002).
9. Parsons, S., Mitchell, P.: The potential of virtual reality in social skills training for people with autistic spectrum disorders. J. Intellect. Disabil. Res. JIDR 46(Pt 5), 430–443 (2002).
10. Parsons, S. et al.: Development of social skills amongst adults with Asperger's Syndrome using virtual environments (2000).
11. Kerr, S., Neale, H., Cobb, S.: Virtual environments for social skills training: The importance of scaffolding in practice. In: Annual ACM Conference on Assistive Technologies, pp. 104–110 (2002), doi: 10.1145/638249.638269.
12. Rutten, A. et al.: The AS interactive project: single-user and collaborative virtual environments for people with high-functioning autistic spectrum disorders. J. Vis. Comput. Animat. 14(5), 233–241 (2003), doi: 10.1002/vis.320.
13. Parsons, S., Millen, L., Garib-Penna, S., Cobb, S.: Participatory design in the development of innovative technologies for children and young people on the autism spectrum: the COSPATIAL project. J. Assist. Technol. 5(1), 29–34 (2011), doi: 10.5042/jat.2011.0099.
14. Millen, L., Cobb, S., Patel, H.: Participatory design with children with autism. Int. J. Disabil. Hum. Dev. 10, (2011), doi: 10.1515/IJDHD.2011.048.
15. Bossavit, B., Parsons, S.: Outcomes for Design and Learning when Teenagers with Autism Co-Design a Serious Game: a pilot study. J. Comput. Assist. Learn. in press (2018).
16. Ramachandiran, C. R., Jomhari, N., Thiyagaraja, S., Maria, M.: Virtual Reality Based Behavioural Learning for Autistic Children. Electron. J. E-Learn. (2015).
17. Smith, M. J. et al.: Using community-engaged methods to adapt virtual reality job-interview training for transition-age youth on the autism spectrum. Res. Autism Spectr. Disord. 71, 101498 (2020).
18. Dautenhahn, K.: Design issues on interactive environments for children with autism. In: Procs of ICDVRAT 2000, the 3rd Int Conf on Disability, Virtual Reality and Associated Technologies, pp. 153–161. University of Reading (2000).
19. Blender Homepage, https://www.blender.org/, last accessed 2024/04/29.
20. Unity3d Homepage, https://unity.com/, last accessed 2024/04/29.
21. Schrepp, M., Hinderks, A., Thomaschewski, J.: Construction of a Benchmark for the User Experience Questionnaire (UEQ). Int. J. Interact. Multimed. Artif. Intell. 4, 40–44 (2017), doi: 10.9781/ijimai.2017.445.
22. Kennedy, R. S., Lane, N. E., Berbaum, K. S., Lilienthal, M. G.: Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. Int. J. Aviat. Psychol. 3(3), 203–220 (1993), doi: 10.1207/s15327108ijap0303_3.