Evaluation of a Serious VR Game Designed to Promote the Sustainable Development Goals

Louis Nisiotis
School of Sciences
University of Central Lancashire, Cyprus
Larnaca, Cyprus
LNisiotis@uclan.ac.uk

Andriani Piki
School of Sciences
University of Central Lancashire, Cyprus
Larnaca, Cyprus
APiki@uclan.ac.uk

Panayiotis Theodorou
School of Sciences
University of Central Lancashire, Cyprus
Larnaca, Cyprus
PTheodorou@uclan.ac.uk

Susana Leal
Management and Technology, CIEQV
Polytechnic Institute of Santarém
Santarém, Portugal
Susana.Leal@esg.ipsantarem.pt

Luís CS Barradas
Informatics and Quantitative Methods
Polytechnic Institute of Santarém
Santarém, Portugal
Claudio.Barradas@esg.ipsantarem.pt

João AM Nascimento
Informatics and Quantitative Methods
Polytechnic Institute of Santarém
Santarém, Portugal
Joao.Nascimento@esg.ipsantarem.pt

2024 IEEE Gaming, Entertainment, and Media Conference (GEM) | 979-8-3503-7453-7/24/$31.00 ©2024 IEEE | DOI: 10.1109/GEM61861.2024.10585543

***Abstract*—This paper presents an evaluation of a serious Virtual Reality (VR) game designed to promote awareness and understanding of the Sustainable Development Goals among Higher Education students. The evaluation assesses user experience in terms of usability/playability, play engrossment, enjoyment and visual aesthetics of the VR environment. It also explores the onset of VR Sickness symptoms among users after their experience with the VR game. Players positively evaluated the game's usability, its ability to engross them in gameplay, and the environment's enjoyment and visuals. The results concerning VR sickness indicate that the game was generally well-received, while also highlighting areas where improvements could be implemented to mitigate the reported symptoms and further improve the user experience. The findings can inform future game-based endeavours supporting education for sustainable development.**

***Index Terms*—Usability, User Experience, Serious VR Games, VR Sickness, Education for Sustainable Development**

I. Introduction

The Sustainable Development Goals (SDGs), formulated as part of the universal 2030 Agenda for Sustainable Development (SD), constitute a comprehensive and integrated framework that aims to address a wide range of pervasive and global challenges. The 17 SDGs are indivisible and bridge the three dimensions of sustainability: social, economic, and environmental [1]. Addressing these challenges requires making collective efforts and taking *"bold and transformative steps [...] to shift the world on to a sustainable and resilient path"* and ensuring that no one is left behind [1]. The success of such efforts requires the coordination and multilateral cooperation [2] of several sectors, education being one of them.

The central role of Education for Sustainable Development (ESD) is to empower learners to reflect on their actions [3], make informed and responsible decisions about societal and environmental integrity [4], and act in a sustainable manner [5]. To attain this goal, Higher Education Institutions (HEIs) embrace innovative pedagogies and digital technologies to help learners develop key sustainability competencies and become responsible citizens. To this end, serious VR games and digital game-based learning (DGBL) approaches hold immense opportunities for knowledge acquisition, skills development, self-reflection, and behavioural change. However, despite recent developments, sustainability-oriented games are still a long-way from attaining a diffusion level comparable to entertainment games [6]. Furthermore, recent studies reveal that current efforts focus primarily on environmental sustainability [7], [8]. This presents a gap in serious games that address all dimensions of SD: environmental, social, and economic - a gap that the proposed serious VR game presented in this paper attempts to fill. At the same time, a significant constraint hindering the adoption and applicability of VR games in educational contexts involves negative effects such as VR Sickness (VRS) [9]. The aim of this study is to evaluate the 'Sustainable Futures' serious VR game through playtesting, for assessing the users' VRS symptoms and their overall gaming experience in terms of usability/playability, play engrossment, enjoyment and visual aesthetics.

II. Background

A. Digital Game-Based Learning and VR Games

DGBL involves integrating educational content, activities, and challenges into a game [10], allowing learners to engage in experiential learning by progressing through the game narrative. Playing games is associated with emotional, social, and cognitive benefits [6], such as activating learner motivation and engagement, facilitating skills development and knowledge acquisition, and enhancing sustainability competencies [3], [6], [7], [10]. Various studies have discussed the positive contribution and educational value of serious games toward raising awareness on SD and SDGs [6], [7], suggesting that digital games can promote ESD [3] and act as motivators and enablers of sustainability-oriented citizen action [6].

DGBL initiatives utilise a variety of emerging technologies including VR, Artificial Intelligence (AI), and mobile learning [11]–[13]. One example is the 'VR for SDGs' platform which has been launched to help articulate and overcome key SD challenges through VR videos [14]. VR has gained significant attention over the past few years, with implementation in a plethora of educational domains. The integration of VR spaces with experiential and game-based learning can form the foundation for a new action-oriented pedagogy that can help raise awareness on SDGs and equip learners with a deep understanding of complex, and inherently cross-disciplinary concepts and knowledge, necessary for taking responsible action [3], [6], [7]. However, when DGBL environments are designed to run in VR spaces, it is essential to address key challenges such as VRS, which may hinder the users' experience and the educational efficacy of the game.

B. VR Sickness - symptoms, theories, techniques, guidelines

VRS, also known as VR-Induced Motion Sickness (VRIMS), is a type of Motion Sickness (MS) described as an effect that occurs due to stimulus from the physical world causing disorders of the senses while moving, for example when travelling with a car or riding a rollercoaster [15]. VRS is a form of discomfort that may occur while or after a user's experience with VR, causing symptoms of varied severity including headaches, vertigo, disorientation, nausea, eye strain and accommodation issues, vomiting, pallor, stomach awareness, and fatigue, among others [15]–[17].

The causes for VRS are not yet completely understood, and the effect is commonly explained through the sensory conflict theory, poison theory and postural instability theory [18]. VR games are a type of virtual experiences known to cause VRS [9]. The VR environment design and nature of the activities are two important factors influencing VRS [19], however the domain is still under exploration [20]. In an attempt to address VRS, several techniques and strategies have been developed such as teleportation, dynamic alteration of the Field of View (FoV), blurring, rest frame, visual FoV alterations, and dynamic Depth of Field (DoF) simulations, among others. Although these techniques may reduce the effects of VRS, they may result in loss of visual information during the experience [21].

A series of best practices and guidelines have also been identified to help designing and implementing virtual environments to mitigate VRS symptoms [22]. Three key categories of factors leading to VRS have been identified: i) the hardware device and its configuration; ii) the VR software used and its content, and iii) individual user's susceptibility to VRS [23]. Recent advancements in VR hardware technology (increased resolution and graphical fidelity, higher frame rates, etc.) are increasingly improving user experience and VRS [24]. Given that the subjective susceptibility to VRS cannot be controlled, the design on the VR content, the game mechanics and the user interactions should be carefully implemented. This relates to study fields around VR environment design, development and mechanics implementation, which extends to the broader field of Human Computer Interaction (HCI). In particular, VRS and usability are two key HCI factors that affect the efficacy of virtual environments [25]. Depending on the approach of measuring usability, there are several definitions [25]. In VR in particular, a VR interface with high usability is providing the user with complete accessibility and freedom in managing and accomplishing tasks in the virtual environment [26].

C. Game Experience and User Satisfaction

There is a range of factors contributing to the development of successful games that yield a positive game experience and user satisfaction. The usability of the game, its visual appeal, the challenges and game mechanics employed to trigger player engagement, the degree of immersion and flow are commonly researched aspects which have attracted attention in recent years [27]. Understanding what drives the satisfaction and enjoyment of video games is crucial for game designers and developers for creating immersive interactive experiences relevant to the context of use (entertainment, education, gamification, training, etc.) [28]. To assist game designers, developers, and researchers, a wide range of data collection tools and heuristics have been developed over time measuring key aspects of players' gaming experiences from various perspectives (a comprehensive list is provided in Phan et al. [27]). This indicates that factors such as usability, enjoyment, immersion, creativity, personal satisfaction, social interaction, and the game's visual appeal are essential for game development experts. Developing this understanding helps to know their audience better, meet their gaming needs, accommodate their gaming style, develop engaging and interactive games, and attract new players [29]. In an educational context, additional aspects need to be considered including the expected learning outcomes, the learning content and context, and the aspects affecting cognitive, emotional, and behavioural engagement. The notion of 'engagement by design' [13] applies here, highlighting the subtle synergies that need to be established between the technological qualities and design features of an educational game, the pedagogical context, and human-centered factors toward achieving the desired level of learner engagement [13].

D. Usability Testing, Heuristic Evaluation, and Play-testing

Usability testing, heuristic evaluation, and play-testing are frequently used evaluation techniques for assessing video games, providing valuable insights into various aspects of player gaming experience [27]. Usability testing provides an understanding of the players' interactions which may hinder the gaming experience. Heuristic evaluation allows the assessment of games based on established usability principles to identify areas for improvement (e.g., [30]). Play-testing involves observing players' behaviour while engaging with the game and collecting feedback and data based on their experience, attitudes, and preferences. These methods facilitate the collection and analysis of important data that can help to refine gameplay, support and enhance the players' experience, and ensure that the game meets their expectations [27].

III. The 'Sustainable Futures' VR Game

The 'Sustainable Futures' is a serious VR game developed to help educate learners about the 17 SDGs. The game is designed to enhance awareness and understanding of sustainability challenges through a thematic educational gaming experience in VR (Fig. 1). When users launch the game, they initially go through the Orientation Level to familiarize with the system controls and game mechanics. They then experience three thematically organized levels, dedicated to Environmental, Social, and Economic sustainability. Each level is equipped with scenarios, challenges, and tasks that simulate sustainability issues relevant to each thematic domain. To complete the game, the Final Level features a comprehensive Q&A session, assessing the players' understanding and encouraging them to reflect on the lessons learned during the game. The game prototype is designed using open access learning materials and publicly available 3D assets. The game is developed in Unity3D, targeting Meta Quest 2 Head Mounted Displays (HMD) in un-tethered mode.

IV. Evaluation Methodology

To determine how prepared the game prototype is for deployment and public release, a user evaluation study was conducted. The purpose was to assess the 'Sustainable Futures' serious VR game in terms of usability/playability, play engrossment, enjoyment, visual aesthetics, and potential VRS symptoms experienced after their VR exposure, in preparation of releasing the game for use.

A. Data Collection Instruments

To collect data relevant to the users' experience with the VR game, the Game User Experience Satisfaction Scale (GUESS) developed and validated by Phan et al. [27] was used. This is a psychometrically validated questionnaire specifically designed to evaluate computer games, consisting of 55 questions and organized in 9 sub-scales (factors) namely: Usability/Playability, Narrative, Play Engrossment, Enjoyment, Creative Freedom, Personal Gratification, Social Connectivity, Audio Aesthetics, and Visual Aesthetics. The items comprising each scale are rated on a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). The overall GUESS score is calculated by i) averaging, ii) aggregating all items comprising each factor, and iii) computing the total. For the needs of this evaluation study, the factors of Usability/Playability, Play Engrossment, Enjoyment, and Visual Aesthetics have been adopted to assess the user experience of the environment.

The Usability/Playability factors investigate how easy the environment is to use, the clarity of its goals and objectives, and the extent to which there are cognitive distractions from the User Interface (UI) and the controls of the environment. Play Engrossment factor measures the degree to which the game can hold the player's attention and interest. Enjoyment factor concerns the user's perceptions around pleasure and enjoyment as a result of playing the game, and Visual Aesthetics factor focuses on the graphical elements of the environment and their attractiveness. In the statistical analysis of the questionnaire, the overall average and aggregated score of each factor/sub-scale were considered, together with the overall score for all scales. The score to be interpreted in the analysis will be in the range of 11 to 77 points for Usability/Playability, 8 to 56 for Play Engrossment, 5 to 35 points for Enjoyability, and 3 to 21 points for Visual Aesthetics. The total aggregated score of the combined factors will be ranging from 27 to 189.

To evaluate the participants' VRS symptoms following their interaction with the VR game, the Simulator Sickness Questionnaire (SSQ) developed by Kennedy et al. [31] was utilised. The SSQ is a well-validated and commonly used tool to quantify simulator sickness in various simulations or simulated environments [31]. The SSQ categorizes symptoms into four distinct scores: Nausea (N), Oculomotor (O), Disorientation (D), and Total Severity (TS). Each category's score is calculated by summing its individual scores, multiplied by a specific weighting factor (9.54 for Nausea, 7.58 for Oculomotor, and 13.92 for Disorientation). The Total Severity score is derived as a cumulative result of these three categories, further multiplied by a scaling factor of 3.74. SSQ requests users to rate 16 symptoms on a 4-point scale ranging from 0-3 (0 no perception – 3 severe perception) before and after their exposure with the VR system. The higher scores on each scale indicate stronger VRS symptoms. For interpreting the SSQ results, the overall scores are categorized as follows: negligible (<5), minimal (5–10), significant (10–15), and severe symptoms (15–20). An overall score above 20 indicates a high level of VRS. Demographic data was also collected to understand users' previous experience with VR and gaming. The questionnaires were administered online before and after the users exposure with the VR game.

B. Experimental Procedure

This study was carried out over three weeks and included a total participation of 32 users (20 male and 12 female) with ages ranging between 18 to 38 years (M=21.3, SD=3.4). Recruitment was done through an open call for participation.

Participants were first requested to submit a short demographic questionnaire and the pre-experience SSQ questionnaire in order to measure their physical state before their exposure to VR. They were then provided with a Meta Quest 2 VR headset, and asked to play the game for 15-25 minutes. Immediately after their exposure with the VR game, they were guided to submit the post-experience SSQ and GUESS questionnaires.

Analysis of the demographic data indicated that the majority of the participants had limited familiarity with VR technology (Mdn=2). Specifically, 34.4% of the participants have never used VR before, and 18.8% reported very minimal experience with the technology. Only a small proportion considered themselves to be experienced VR users (12.5%). Additionally, a significant 84.4% of participants had little to no experience

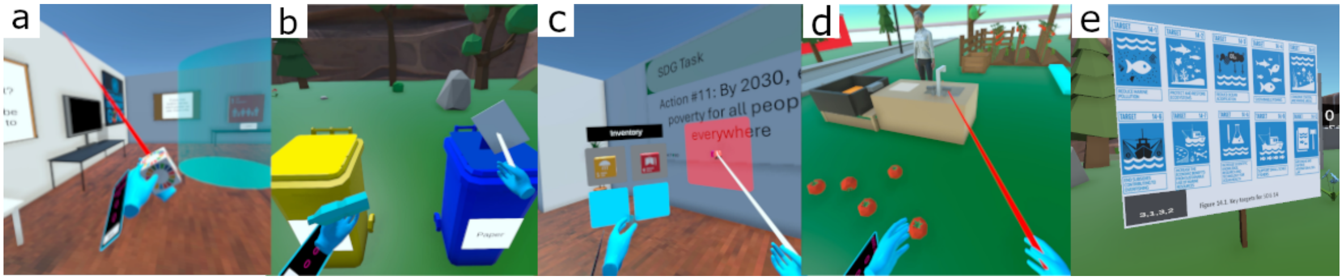

Fig. 1. In-game screenshots during gameplay. (a) User interactions with game objects. (b) Gamified activities with virtual objects. (c) Personal inventory system. (d) Interacting with virtual agents. (e) Visual information panel - infographic with secret code.

using VR for gaming; 53.1% never used VR for gaming, while 31.3% only use VR very rarely. The participants were mostly PC gamers, who engaged in gaming for about 1-3 hours, approximately 4-5 times a week.

V. Results and Discussion

Prior to conducting any statistical analyses, the data distribution for GUESS and SSQ were tested for normality using the Kolmogorov-Smirnov test. GUESS data were approximately normally distributed, apart from Enjoyment scale ($p<.05$). Visual and numerical inspection indicated a positively skewed distribution. We decided to proceed with parametric descriptive statistics reporting Means and Standard Deviations, but results about Enjoyment should be considered with caution. The SSQ data were not normally distributed, which is common [32], therefore, SSQ was explored using non parametric descriptive statistics presented as Median (Mdn), in Inter-Quartile Range (IQR), and through and visual techniques. To ensure the validity and reliability of the results, a reliability test was conducted on all scales using the Cronbach's Alpha coefficient, revealing high level of internal consistency among the elements comprising each scale, corroborating the previously established reliability of the GUESS and SSQ scales, as documented by their original creators [27], [33].

A. Game Experience Results

Data analysis began by investigating the descriptive statistics of GUESS, and the scaled average and aggregated results are shown in Table I. The Usability/Playability aspect of the VR game received very favorable ratings (M=6.01, SD=0.83), suggesting that players engaged with the game with clear objectives and minimal cognitive disruption caused by the user interface and environmental controls. Play Engrossment was also viewed positively (M=5.41, SD=0.93), indicating that the game managed to effectively capture and maintain the player's attention and interest during the experience. Additionally, the Enjoyment factor was highly perceived (M=6.03, SD=0.93), suggesting that players have enjoyed participating in the game's activities. Moreover, the visual elements, including the design, 3D graphics, and their appeal, were also rated positively (M=5.87, SD=0.96). The aggregated average score (M=157.21, SD=20.79) was notably high, considering the maximum possible score of 189, indicating a very positive overall experience.

The individual items that make up each scale were then analysed, providing a detailed evaluation of user responses. Users reported that learning to play the game (M=6.03, SD=0.9) and using its controls (M=6.31, SD=0.93) was easy, positively rated the user friendliness of menus (M=6.19, SD=0.96), and perceived navigating the UI elements as straightforward (M=6.37, SD=0.75), without the need for an extensive tutorial (M=6.25, SD=0.92). Results indicate that the game provides users clear information on how to accomplish in-game goals (M=6.06, SD=1.21), leading to a sense of confidence during gameplay (M=6.13, SD=1.15).

However, the results also showed lower perceptions and variety of responses regarding how the game effectively trains players in all controls (M=5.69, SD=1.23), ability to provide clarity on the next goal after completing an event (M=5.37, SD=1.5), and understanding how to achieve specific goals or objectives within the game (M=5.56, SD=1.3). These findings suggest that incorporating a more comprehensive tutorial on controls, providing more structured feedback for user actions, and enhancing visual clarity regarding subsequent tasks could be considered in future development of the game. To improve user understanding of what to do next, it might be effective to redesign and implement additional visual cues, such as arrows, or a task list, in future versions of the environment design.

Regarding Play Engrossment, players were highly immersed during the experience (M=5.69, SD=1.4), expressing detachment from the outside world while playing the game (M=5.63, SD=1.45). They showed little interest in checking real-world events while gaming (M=5.25, SD=1.54), were unaware of fatigue while engaged in the game (M=5.25, SD=1.54), and positively rated the item regarding loosing track of time sometimes while playing (M=6.41, SD=1.36). They perceived that the game provided a temporary escape from their everyday worries (M=5.44, SD=1.62), generally leading to spending more time playing than initially planned for the majority of the users (M=5.06, SD=1.86). They were also able to block out most distractions (M=5.75, SD=1.14) and there was positive interest to resume playing the game whenever they stopped (M=5.09, SD=1.7). Users found the VR experience fun (M=6.16, SD=1.02) and enjoyable (M=6.22, SD=0.94), with low feelings of boredom during gameplay (M=6.22, SD=1.07), indicating a high likelihood of recommending the game to others (M=6.69, SD=1.38) and desire to play the game again if given the opportunity (M=5.87, SD=1.36).

Furthermore, users positively rated enjoyment of the game's graphics (M=5.36, SD=1.34), and found the game to be visually appealing (M=5.97, SD=0.93), indicating that the visual style and mood of the game were a good fit (M=6.03, SD=0.93).

TABLE I
DESCRIPTIVE AND AGGREGATED STATISTICS

Category	**Mean**	**SD**	**Min**	**Max**
Scaled Results				
Usability/Playability	6.01	0.83	3.91	7
Play Engrossment	5.41	1.10	2.88	7
Enjoyment	6.03	0.93	3.80	7
Visual Aesthetics	5.87	0.96	4.00	7
Aggregated Results				
Usability/Playability	66.12	9.11	43	77
Play Engrossment	43.31	8.83	23	56
Enjoyment	30.16	4.63	19	35
Visual Aesthetics	17.62	2.89	12	21
Total score	157.22	20.79	114	184

B. VR Sickness

The VRS results measured by the SSQ are detailed in Table II and illustrated in Fig. 2. The analysis examined the relative differences of the SSQ scores before and after the VR experience to evaluate the effect of the intervention. In cases where relative scoring resulted in negative values, indicating that post-VR exposure scores were lower than pre-exposure scores, the intervention was interpreted as having no impact on the participants, rather than a positive one, in line with Bimberg et al. [34] recommendation. Due to the non-normal distribution of the SSQ data, the analysis was conducted using Medians and Interquartile Ranges. However, Means and Standard Deviations for all sub-scales and the total severity score were also provided, following Bimberg et al. [34] suggestion, to develop a comprehensive view of VRS symptoms.

The overall SSQ results indicate a variety in symptom severity underscoring diverse range of individual reactions to VR exposure. 12 participants (37.5%) did not report any VRS symptoms after their exposure with the VR experience. 6 participants (18.75%) experienced minimal VRS symptoms within the 5-10 VRS range, 10 reported symptoms of moderate intensity (31.25%), and 4 participants experienced severe symptoms (12.9%), reporting Total Severity scores higher than 20. Visual inspection of data (Fig. 2) suggests that in general, the majority of the VRS symptoms are within the mild symptoms range with scores between 5-10, and Total Severity has been moderately rated.

However there is some variability in severity for some outliers. The Median scores for Nausea and Disorientation are 0 with some variation, but with a very small number of outliers. Disorientation category has the widest IQR range between 0 and 13.92 and an extreme outlier. The Median scores of Oculomotor (Mdn=7.58), including 3 outliers, points to the most significant symptom experienced by players. This suggests that the game was causing visual strain or difficulties with eye movement control to some users. This could be due to the nature of the VR experience, through the extensive use of close-up visuals (e.g., infographics) and textual content within the environment that require constant eye movement and focus to read. Possible ways could focus on decreasing visual strain by reducing the textual content as part of the activities within the environment, optimizing graphics and reducing flicker, as well as incorporating more frequent breaks during the gameplay.

In addition, while most participants did not experience severe symptoms during or post the VR session, one participant did report significant symptoms and withdrew from the VR experience during the data collection stage. The results were further investigated to determine the extent to which there were differences in the SSQ results among different genres. A Mann-Whitney test was conducted revealing no statistically significant differences. Overall, the SSQ results revealed that i) some users did not experience any VRS symptoms from the VR experience, while the majority reported mild symptoms,ii) the Total Severity of VRS results were within acceptable and relatively minimal levels for most players, and iii) the VR experience caused higher Oculomotor symptoms for some users.

TABLE II
VR SICKNESS DESCRIPTIVE RESULTS

	Nausea	**Oculomotor**	**Disorientation**	**Total Severity**
Median	0	7.58	0.0	3.74
IQR	9.54	7.58	13.92	11.22
Mean	5.96	6.87	12.2	9
SD	8.3	8.69	18.62	11

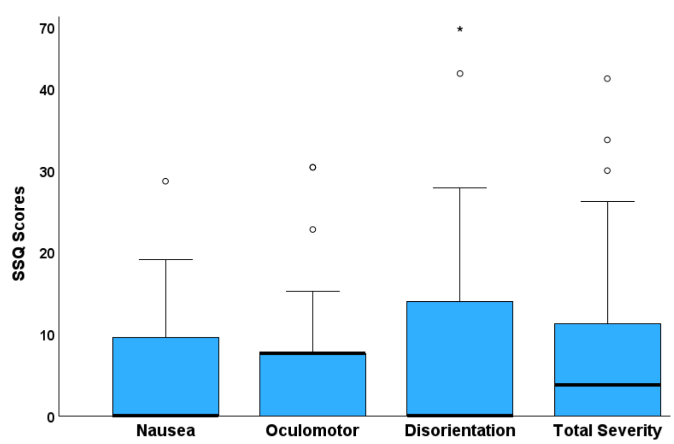

Fig. 2. SSQ Results.

VI. DISCUSSION AND CONCLUSIONS

The results of this evaluation study revealed that most participants had a positive user experience with the 'Sustainable Futures' VR game environment. Users found the VR game usable and playable, with no significant issues impeding their ability to engage with and navigate the environment. The design of the environment included clear goals and objectives, and users encountered minimal cognitive distractions or interference from the environment's user interface. The gameplay was positively rated, successfully maintaining the players' attention and interest throughout. Users also reported high level of enjoyment in their experience. This was also supported by the visually appealing 3D graphics, which received positive feedback for their contribution to the overall aesthetic appeal of the VR experience. Most users did not experience any VRS symptoms or found them to be minimal, and this is a strong positive indicator that the current state of the VR Game was generally well-received and was comfortable for the majority of users. However, the development team will focus on Oculomotor comfort since the SSQ results indicated higher occurrence of Oculomotor symptoms relevant to eye strain, difficulty focusing, headaches and other causes, and the results highlights the need for improvement. Future research is under way to evaluate the educational efficacy of the VR game, and to further explore the impact of these constraints not only on the overall user experience but also on learning effectiveness, and cognitive, behavioural, and emotional engagement.

Acknowledgment

This work is co-funded under the Erasmus+ Program for the project 'TIME2ACT@SD: Time to Act through Sustainable Experiences for Higher Education Students', Grant Agreement: 2022-1-PT01-KA220-HED-000087984.

References

[1] UN, "Transforming our world: The 2030 agenda for sustainable development," 2015.

[2] UNDP, "United Nations development programme strategic plan 2022-2025," 2021.

[3] L. Pombo, "Exploring the role of mobile game-based apps towards a smart learning city environment–the innovation of educity," *Education + Training*, vol. 65, no. 2, pp. 253–264, 2023.

[4] T. Konrad, A. Wiek, and M. Barth, "Embracing conflicts for interpersonal competence development in project-based sustainability courses," *Int. J. of Sustainability in Higher Ed.*, vol. 21, no. 1, pp. 76–96, 2020.

[5] M. Rieckmann, "Learning to transform the world: Key competencies in education for sustainable development," *Issues and trends in education for sustainable development*, vol. 39, pp. 39–59, 2018.

[6] S. Floricel, "Understanding the nature and effects of digital games in promoting sustainability," *Gl. Ec. Obs.*, vol. 8, no. 2, pp. 125–134, 2020.

[7] S. J. Ho, Y. S. Hsu, C. H. Lai, F. H. Chen, and M. H. Yang, "Applying game-based experiential learning to comprehensive sustainable development-based education," *Sustainability*, vol. 14, no. 3, 2022.

[8] P. Hallinger, R. Wang, C. Chatpinyakoop, V. T. Nguyen, and U. P. Nguyen, "A bibliometric review of research on simulations and serious games used in educating for sustainability," *Journal of Cleaner Production*, vol. 256, no. 120358, 2020.

[9] M. L. Ibánez, F. Peinado, and O. Palmieri, "Walking in VR: measuring presence and simulator sickness in first-person virtual reality games," in *Proc. 3rd Congress of Spanish Society for Video Games Sciences*, 2016.

[10] J. L. Plass, B. D. Homer, and C. K. Kinzer, "Foundations of game-based learning," *Educational psychologist*, vol. 50, no. 4, pp. 258–283, 2015.

[11] A. Piki, L. Nisiotis, and L. Alboul, "A preliminary exploration of the learning and engagement potential of an intelligent virtual environment," *IEEE 2nd International Conf. on Intelligent Reality*, pp. 27–30, 2022.

[12] L. Nisiotis and L. Alboul, "Work-in-progress-an intelligent immersive learning system using ai, xr and robots," *7th International Conference of the Immersive Learning Research Network (iLRN)*, 2021.

[13] N. Kasenides, A. Piki, and N. Paspallis, "Exploring the user experience and effectiveness of mobile game-based learning in higher education," *Human Computed Interaction International*, 2023.

[14] vr4sdgs.org, "VR for SDGs platform." Online: https://vr4sdgs.org/en/, Last Accessed: 13/03/2024.

[15] S. Davis, K. Nesbitt, and E. Nalivaiko, "A systematic review of cybersickness," in *Proceedings of the 2014 Conference on Interactive Entertainment*, IE2014, (New York, NY, USA), p. 1–9, ACM, 2014.

[16] B. Keshavarz, B. E. Riecke, L. J. Hettinger, and J. L. Campos, "Vection and visually induced motion sickness: how are they related?," *Frontiers in Psychology*, vol. 6, 2015.

[17] S. M. LaValle, *Virtual reality*. Cambridge University press, 2023.

[18] Z. Zhao, Y. Li, and H.-N. Liang, "Leanon: Simulating balance vehicle locomotion in virtual reality," in *IEEE International Symposium on Mixed and Augmented Reality*, (USA), IEEE Computer Society, 2023.

[19] D. Monteiro, H.-N. Liang, J. Wang, H. Chen, and N. Baghaei, "An in-depth exploration of the effect of 2D/3D views and controller types on first person shooter games in virtual reality," in *IEEE International Symposium on Mixed and Augmented Reality*, pp. 713–724, Nov 2020.

[20] T. Porcino, E. O. Rodrigues, F. Bernardini, D. Trevisan, and E. Clua, "Identifying cybersickness causes in virtual reality games using symbolic machine learning algorithms," *Entertainment Computing*, vol. 41, p. 100473, 2022.

[21] J. Wang, H.-N. Liang, D. Monteiro, W. Xu, and J. Xiao, "Real-time prediction of simulator sickness in virtual reality games," *IEEE Transactions on Games*, vol. 15, no. 2, pp. 252–261, 2023.

[22] A. Kemeny, J.-R. Chardonnet, and F. Colombet, *Getting Rid of Cybersickness in Virtual Reality, Augmented Reality, and Simulators*. Springer, 2021.

[23] S. Davis, K. Nesbitt, and E. Nalivaiko, "A systematic review of cybersickness," in *Proceedings of the 2014 Conference on Interactive Entertainment*, IE2014, (New York, NY, USA), p. 1–9, ACM, 2014.

[24] D. Saredakis, A. Szpak, B. Birckhead, H. A. D. Keage, A. Rizzo, and T. Loetscher, "Factors associated with virtual reality sickness in head-mounted displays: A systematic review and meta-analysis," *Frontiers in Human Neuroscience*, vol. 14, 2020.

[25] M. Mousavi, Y. H. Jen, and S. N. B. Musa, "A review on cybersickness and usability in virtual environments," in *Current Trends in Ergonomics*, vol. 10 of *Advanced Engineering Forum*, pp. 34–39, Trans Tech Publications Ltd, 12 2013.

[26] I. Kossyk, J. Dörr, L. Raschendörfer, and K. Kondak, "Usability of a virtual reality system based on a wearable haptic interface," in *2011 IEEE/RSJ Int. Conf. on Intel. Robots and Systems*, pp. 3474–3479, 2011.

[27] M. H. Phan, J. R. Keebler, and B. S. Chaparro, "The development and validation of the game user experience satisfaction scale (GUESS)," *Human factors*, vol. 58, no. 8, pp. 1217–1247, 2016.

[28] O. Schaffer and X. Fang, "Digital game enjoyment: A literature review," in *HCI in Games* (X. Fang, ed.), (Cham), pp. 191–214, Springer International Publishing, 2019.

[29] J. R. Keebler, W. J. Shelstad, D. C. Smith, B. S. Chaparro, and M. H. Phan, "Validation of the GUESS-18: A short version of the game user experience satisfaction scale (GUESS)," *J. Usability Studies*, vol. 16, p. 49–62, nov 2020.

[30] H. Desurvire and C. Wiberg, "Game usability heuristics (play) for evaluating and designing better games: The next iteration," in *Online Communities and Social Computing* (A. A. Ozok and P. Zaphiris, eds.), (Berlin, Heidelberg), pp. 557–566, Springer Berlin Heidelberg, 2009.

[31] K. S. B. Robert S. Kennedy, Norman E. Lane and M. G. Lilienthal, "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness," *The International Journal of Aviation Psychology*, vol. 3, no. 3, pp. 203–220, 1993.

[32] G. Lucas, A. Kemeny, D. Paillot, and F. Colombet, "A simulation sickness study on a driving simulator equipped with a vibration platform," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 68, pp. 15–22, 2020.

[33] K. M. Stanney and R. S. Kennedy, "Aftereffects from virtual environment exposure: How long do they last?," *Proc. of the Human Factors and Ergonomics Soc. An. Meet.*, vol. 42, no. 21, pp. 1476–1480, 1998.

[34] P. Bimberg, T. Weissker, and A. Kulik, "On the usage of the simulator sickness questionnaire for virtual reality research," in *2020 IEEE Conf. on VR and 3D User Interfaces*, pp. 464–467, 2020.

Reference: Nisiotis, L., Piki, A., Theodorou, P., Leal, S., Barradas, L. C., & Nascimento, J. A. (2024). *Evaluation of a serious VR game designed to promote the Sustainable Development Goals*. In *Proceedings of the 2024 IEEE Gaming, Entertainment, and Media Conference (GEM)* (pp. 1–6). IEEE. https://doi.org/10.1109/GEM61861.2024.10585543