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EFFECTS OF IMMERSIVE VIRTUAL REALITY IN ENHANCING CREATIVITY

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ABSTRACT

In recent years, the use of virtual reality (VR) has been a promising opportunity to improve the immersive experience in virtual environments. In this study, we explore the effectiveness of immersive VR experiences on an individual's creativity. To do this, we first identified the characteristics of VR that are closely related to creative performance. Considering these factors, we designed and implemented the interaction method and the three outdoor and indoor virtual environments (Wilderness, City Park, and Office). We evaluated the effectiveness of the virtual environments with 12 participants. The user study results show that outdoor and indoor immersive virtual experiences improved their creativity skills. We concluded by analysing how factors such as simulator sickness and perceived workload influence creativity levels. Moreover, our study showed the potentiality of using immersive virtual environments to enhance individuals' creative performance.

Keywords: Extended Reality, Creativity, Virtual reality, User centred design, Immersive Virtual Environments

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1 INTRODUCTION

Virtual Reality (VR) refers to a wide range of computing technologies that present the computer-generated simulation of the real environment in a form that allows the user to interact with some aspects of the simulated setting using a dedicated input system. In VR, the immersive virtual environments (VE) and 3D objects offer the user visual information that can be seen using a head-mounted display (HMD) device and auditory, tactile, and movement information. The user can naturally interact with the VE using a pair of VR controllers, such as Oculus Touch, Vive or Valve Index controllers.

In recent years, the use of Virtual Reality (VR) combined with computers and/or smartphones has gained much interest and is increasingly used in various applications (e.g., (Lu et al., 2022)), including improving individuals' creativity (e.g., (Bourgeois-Bougrine et al., 2022; Graessler & Taplick, 2019; Yang et al., 2018)). VR technology enables individuals to deal with real-life scenarios by increasing immersion feeling in interactive applications. Typical immersive VR environments are interactive simulation or game-like systems that provide motivation and encourage active exploration and enjoyment (e.g., (Monteiro et al., 2018)), ultimately allowing users to improve specific or overall creativity levels (e.g., (Gong et al., 2022; Hu et al., 2021; Jou & Wang, 2013)). A standard VR system to enhance creativity includes three main components: virtual environments such as games or simulations, an immersive display, and an input system to interact in the virtual world.

Prior studies have shown that VR has the potential to enhance individuals' creativity skills (e.g., (Guan et al., 2021; Obeid & Demirkan, 2020)). However, immersive VEs can visually induce motion sickness (e.g., (Monteiro et al., 2018)). Further, the complexity of the interactive tasks, such as 3D manipulations in the VE using the VR controllers, can increase the perceived workload load of the individual, thus resulting in the outcome of their creative skills. Nevertheless, little research has been done to explore the role of the simulator and the perceived workload of the immersive outdoor and indoor natural VEs in enhancing creativity levels. Our study set out to address these.

The research presented in this paper aims to explore whether immersive, realistic virtual environments supported by a simple virtual walking or locomotion technique could increase immersion, and minimise interaction, thus supporting the imagination of the user, which enhances their creativity levels. To this end, we developed three virtual environments and conducted a user study to investigate whether immersive virtual environments help improve individuals' creativity skills by minimising the simulator-related sickness and perceived workload of the environments. Moreover, we investigated whether there is a relationship between the time spent in the VR, the simulator sickness and the perceived workload of the virtual environments in influencing individuals' creativity skills. The main contributions of this paper are the outdoor and indoor immersive virtual environments and methods for virtual navigation for enhancing individuals' creativity skills.

2 METHODOLOGY

This study explored the scenario where immersive, realistic, outdoor, and indoor virtual environments would be available for users to support enhancing their creative skills. Initially, we explored the characteristics of VR, such as immersive, interaction, and imagination, that are closely related to creative performance (Burdea & Coiffet, 2003). Immersion or immersive experience in VR is the essential characteristic that isolates the individual from the real world; this is highly connected with the users' state of flow (Bhatt, 2004). Thus, interactive experiences with highly immersive virtual environments are likely to produce more innovative ideas (e.g., (Csikszentmihalyi, 2013; Lee et al., 2021; Witmer & Singer, 1998)). Imagination increases in natural, calm environments. Thus, by considering these three critical VR characteristics related to creative performance, we designed and implemented the three outdoor and indoor virtual environments and the interaction method for the same.

2.1 Immersive virtual environments

In order to decide on immersive virtual environments, we considered the following two aspects. For some, spending time in nature, particularly wilderness, increases their imagination. At the same time, urban city environments increase the imagination of others. We wanted to consider these two aspects in designing immersive virtual environments. Though wilderness or urban outdoor environments

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increase individuals' imagination, subsequently, creative performance, on most occasions, creative tasks are performed inside indoor office spaces. Therefore, we developed three immersive virtual environments: outdoor and indoor, with urban and wilderness settings. We utilised the Unity game engine to design and implement all three VEs. The 3D virtual objects are placed in a way allowing users to navigate around and explore the VEs naturally.

2.2 Virtual navigation

Navigation in immersive VR can be achieved in various ways, broadly grouped as *locomotion* (Al Zayer et al., 2020). With devices that support 6 degrees of freedom (DoF), it is possible to navigate the VEs similar to walking in the real world. However, the primary problem with this approach is the available room space and device used, such as the lengths of the cables. On the other hand, controller-based locomotion allows users to navigate around VR easily (e.g., (Al Zayer et al., 2020; Liang et al., 2018)). Typical VR controllers have various input methods that can be used for navigation (e.g., (Liang et al., 2018)) and manipulating virtual 3D objects (e.g., (Nanjappan et al., 2018). Most have Joysticks similar to traditional game controllers, particularly Oculus Touch controllers. Input from these can be directly translated into movement in the VE. This kind of movement system can be disorienting and even nauseating for some users because of the illusions of self-motion (Monteiro et al., 2018). To mitigate these issues, in this work, we followed an approach of smooth increments of forward and rotational movements in VR using two separate Joysticks.

3 SYSTEM DESIGN

The design of our virtual environments aims to achieve two main goals: 1) provide a realistic, immersive navigational experience and 2) minimise the interaction aspects within the VR. All three environments consist of a similar degree of detail. We used Unity to design and implement the three VEs. The data logging system logs the current time in seconds to produce a log file for each environment.

3.1 Virtual environments

3.1.1 Wilderness

It is a natural pine forest bordered by mountains. In addition to a very high concentration of pine trees, the navigation path is also surrounded by muddy patches. The users begin their experience in the middle of the forest with the aim of finding their way to the destination, the campfire spot, which produces smoke, serves as a cue for the users (see Figure 1a). A wooden arrow sign, without any text, supports their navigation in the wilderness. Invisible walls are implemented to prevent users from deviating from the path leading to the destination.

Figure 1. The virtual environments: (a) Wilderness, (b) City Park, (c) Office.

3.1.2 City park

An urban city park encircled by streets with high-raised buildings is considered for this environment. The park environment also includes gardens, trees, fences, benches, and a food cart. The users begin at the bus stop, at the entrance of the park, and proceed towards the food court inside the park (see Figure 1b). Iron fences restrict the navigation path for the users inside the park. Several signs with texts, invisible walls and obstructing objects are also used t are used to help the users find their way to their destination.

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3.1.3 *Office*

It is an indoor environment consisting of medium-sized modern office space. Unlike the previous two outdoor environments, the office has no invisible walls. The walls, office cubicles, partitions, chairs, and tables are used as fences and provide a way for users to find their destination (see Figure 1c). The users are required to find the Rose Room, which is decorated with roses in flowerpots, in this environment. Signs with texts are used to help them find their way.

3.2 Navigation

The navigation around all three virtual environments is achieved using the Joysticks on the Oculus Touch controllers. While the left Joystick is used to control the smooth movement (both forward and backwards), the right is used for the rotation (turning around the environment), which increments in steps of 45 degrees to avoid any potential motion sickness.

4 USER STUDY

The main objective of the user evaluation experiment was to explore how navigating around the immersive virtual environments would support the users in increasing their creativity skills. The volunteered participants were asked to experience the virtual environments in a dedicated laboratory space. Their creativity levels were assessed before and after the VR experience.

4.1 Participants

Twelve (3 females) participants (age ranges from 18 - 33) volunteered for the study. They were recruited through the university participant recruitment system. Thus, all of them were associated with the university, either as a student or staff, from different backgrounds, including Electronics Engineering, Software Engineering, Information Technology, Education, and Applied Sciences, at the time of the study. Nine had participated in VR studies before. 6 of them participated in other VR studies a few days before this study. All of them were familiar with VR; further, only one had never used a VR headset prior to the experiment. All participants received a 10 Euro Amazon voucher for their participation.

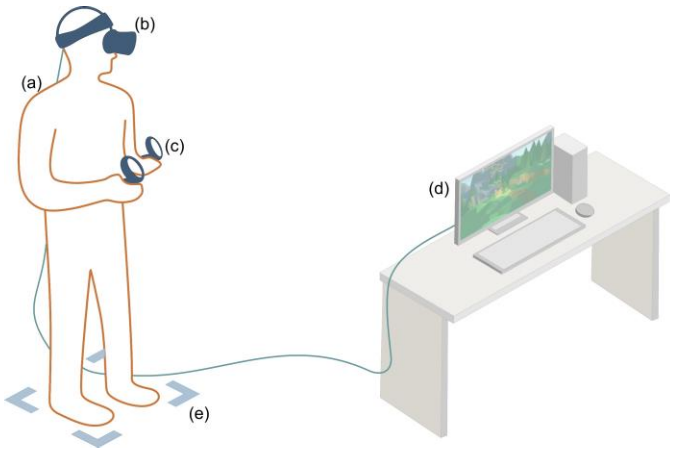

Figure 2. Illustration of the experiment setup: (a) Participant, (b) VR headset (Oculus Rift), (c) Oculus Touch controllers, (d) Desktop (Virtual Environments), and (e) Marked area.

4.2 Measures

The measures used in the user evaluation study included online creativity test scores, questionnaires, logged data, observations, and semi-structured interviews.

1. Participants' creativity was evaluated before and after the VR experience using a generic online creativity test[1] (CT). We chose this online test because it includes a wide range of factors, such as *abstraction*, *connection*, *perspective*, *curiosity*, *boldness*, *paradox*, *complexity*, and *persistence*, and it is easy to use. It includes a set of 40 questions and provides a score between 0 and 100 (which indicates more creativity) by computing answers from these questions.

[1] http://www.testmycreativity.com/

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2. To assess the simulator-related sickness induced by the virtual environments, we adopted the standard 16-item Simulator Sickness Questionnaire (SSQ) for our evaluation (Kennedy et al., 1993). Each item is rated with a 4-point scale from none (0), slight (1), moderate (2), to severe (3). Four representative scores for the symptoms (Nausea, Oculomotor, and Disorientation) are computed using pre-defined values and calculations. The overall severity of simulator sickness experienced by users is represented as the Total Severity score.
3. We used the NASA Task Load Index (TLX) to assess the users' subjective workload of the three virtual environments (Hart, 2006; Hart & Staveland, 1988). The NASA TLX derives an overall workload score based on subscales of mental, physical and temporal demand, performance, effort and frustration. Each subscale is rated within a 100-points range with 5-point steps.
4. Navigation Time calculates the time, in seconds (Unity), spent by the participants exploring each virtual environment.
5. Participants' subjective assessment of the *visual*, *navigational*, and *overall* experience of the three virtual environments was collected as a rating between 1 (very poor) and 7 (very good).

4.3 Apparatus

The user evaluation study was conducted in a dedicated laboratory space, where participants were asked to stand in a pre-marked area on the floor, as depicted in Figure 2. We used an Oculus Rift S VR headset with a pair of Oculus Touch controllers connected to a VR-read PC. In addition, a laptop was used to allow the participants to complete the online creativity tests and questionnaires. A Cleanbox UV[2] steriliser was used during the study to disinfect the VR headset and controllers.

4.4 Procedure

The experiment process included three phases for each participant: pre-, immersive VR experience, and post-experiment. During the pre-experiment phase, the participants were instructed to complete their demographic, background, and experience using VR, followed by an online creativity test (CT). They were instructed to complete the 40 questions but not to submit the form to retrieve their CT score. This approach was followed to prevent them from being aware of their creativity score as the same questionnaire (and the questions appear in the same order in the system) was later used after the immersive VR experience phase. However, participants were not initially informed that they needed to complete the creativity test twice. Following the pre-experiment phase, each participant was given a short introduction to the apparatus and the three virtual environments. During the immersive VR experience, the participants were presented with the three virtual environments in a pre-defined Latin square design. They were instructed to explore the virtual environments until they reached the final destination (verbally mentioned for each virtual environment during the study). Participants were encouraged to spend as much time as they wanted in each environment. After this phase, participants were asked to complete the creativity test again without knowing their CT score, followed by other questionnaires. During the semi-structured interview, all participants were encouraged to share their experiences interacting with the virtual environments. After each user, the VR headset and controllers were disinfected using a Cleanbox UV steriliser. The entire experiment process lasted about 30-40 minutes for each participant. Figure 3 illustrates the whole experiment process, including the phases and data collection methods.

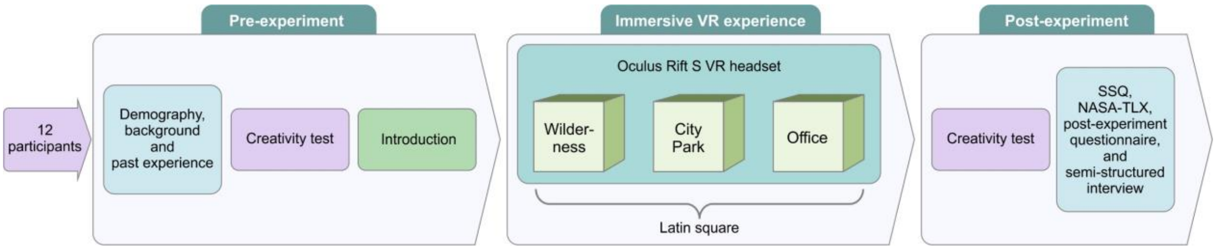

Figure 3. The experiment procedure (including the data collection instruments).

[2] https://cleanboxtech.com/

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5 RESULTS

Our results include all participants' pre- and post-VR experience creativity scores, SSQ, NASA-TLX scales, subjective feedback, and suggestions.

5.1 Creativity scores

Our participants’ creativity scores varied between 43.18 and 73.89 (*Mean*=60.22, *SD*=7.42) before and between 46.52 and 80.29 after (*Mean*=63.04, *SD*=9.03) VR experience on a scale from 0 to 100 – the higher score means more creative. Dependent T-Test results revealed a closely significant improvement in their creativity score following the VR experience with the three virtual environments ($t_{(11)}$=2.118, p=0.058).

5.2 Time spent in the virtual environments

Our participants spent more time (in seconds) navigating around the Wilderness (*Mean*=161.77, *SD*=57.8) than in City Park (*Mean*=137.77, *SD*=47.9) and Office (*Mean*=137.76, *SD*=56.4) environments. One-way ANOVA revealed no significant effect on participants’ navigation time between the three virtual environments. Nevertheless, our results also showed that time spent in the three virtual environments was not correlated significantly with the post-VR creativity scores ($p>0.05$).

5.3 Simulator sickness

Figure 4 presents the four relative SSQ sub-scores for all three virtual environments. Only disorientation (*Mean*=42.92, *SD*=41.94) related sub-scores were slightly higher than the other three sub-scores for the virtual environments. Our results also showed that the four simulator sickness symptoms were not correlated significantly with the creativity scores after navigating the three virtual environments ($p>0.05$).

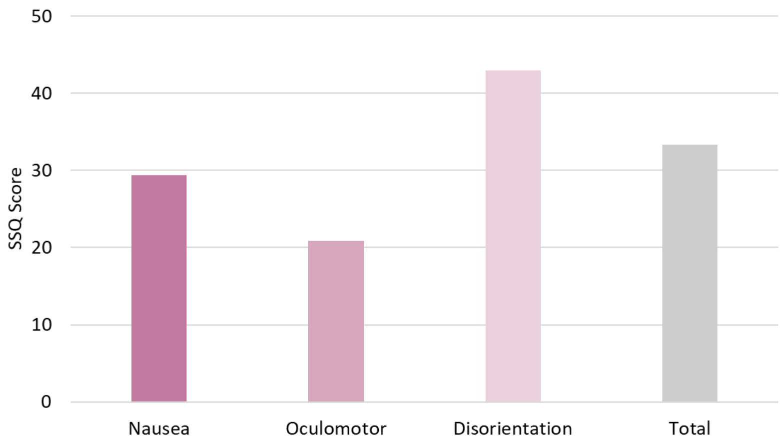

Figure 4. The four relative simulation sickness questionnaire (SSQ) sub-scores.

5.4 Perceived workload of the virtual environments

The results of NASA TLX for the individual workload factors and the sum of individual workload factors as the overall workload of all three virtual environments can be seen in Figure 5. Only the mental demand of the three virtual environments is slightly higher than the other factors. The city park environment produced more physical and temporal demands, making the users put more effort into navigating around than the other two environments. Notably, the performance factor for all three environments was almost the same. Nevertheless, one-way ANOVA showed that there was no significant difference in the workload factors between the three virtual environments ($p>0.05$). Moreover, none of these factors was correlated with the creativity scores after the VR experience.

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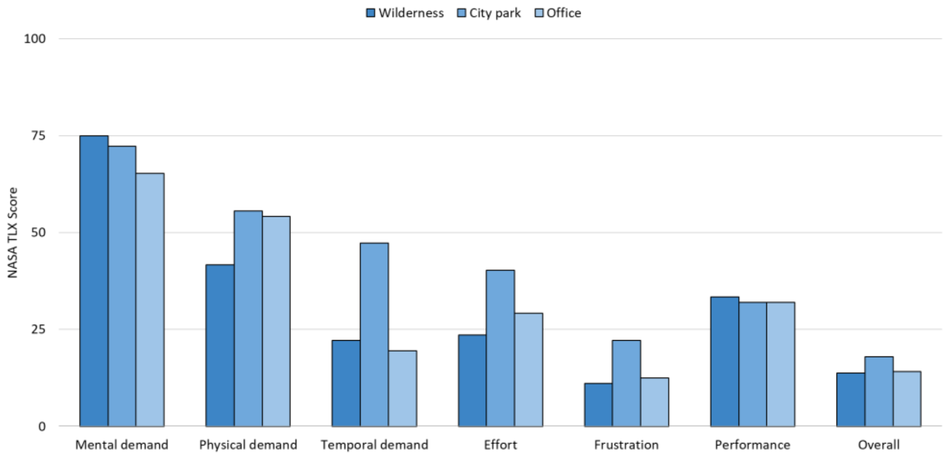

Figure 5. The perceived workload (NASA TLX scores) of the three virtual environments.

5.5 The subjective rating on visual, navigation, and overall experience

Figure 6 shows the subjective rating for visual, navigation, and overall experience of the three virtual environments. Our participants enjoyed the visual experience in the wilderness (*Mean*=5.33, *SD*=1.18) more than in the city park (*Mean*=4.58, *SD*=1.60) and office (*Mean*=4.25, *SD*=1.58) environments. On the other hand, they reported enjoying navigating around the virtual city park (*Mean*=6.16, *SD*=1.07) more than the office (*Mean*=5.25, *SD*=1.30) and wilderness (*Mean*=5.08, *SD*=1.50) environments. However, their overall experience was higher in the wilderness (*Mean*=6, *SD*=1.15) than in the city park (*Mean*=5.58, *SD*=1.25) and office (*Mean*=5, *SD*=1.73) environments. Nevertheless, there was no significant difference in participants' visual, navigational, and overall experience between the three virtual environments ($p>0.05$).

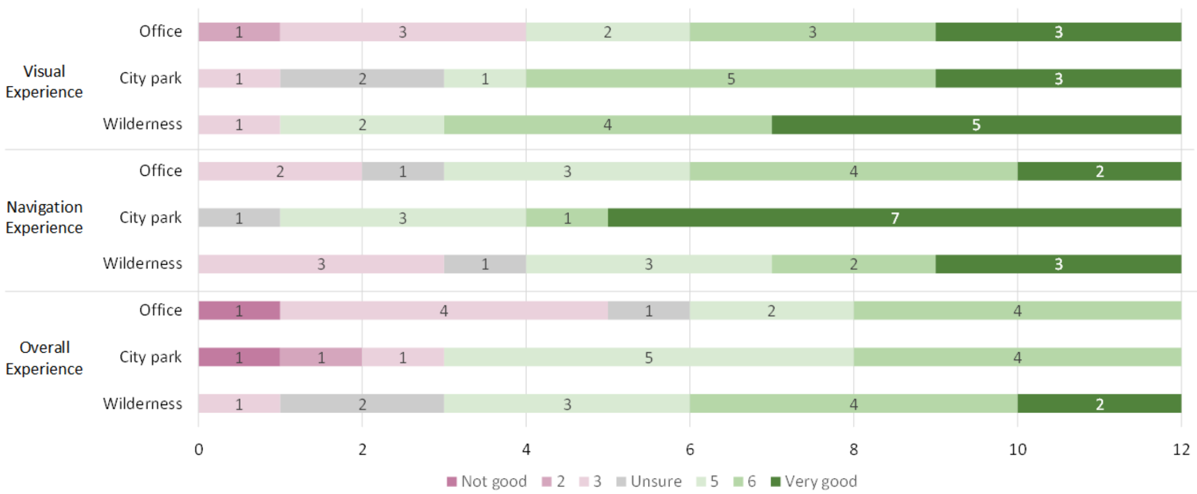

Figure 6. The subjective rating for visual, navigation, and overall experience of the three virtual environments.

5.6 Users' feedback

At the end of the experiment, participants informed us of their suggestions and feedback on the virtual environments, experiment setup and procedure. All participants perceived that navigating around the three virtual environments was comfortable, pleasant, and enjoyable. They all liked the three environments. When asked for their suggestions for other environments, they came up with different suggestions. Four participants expressed interest in a virtual beach environment with visuals such as the sea, sand, restaurants, and cafes. While two suggested including familiar daily life environments, particularly university cafeterias, playgrounds, and stationery items, one participant preferred Open Market, including 3D visuals of different fruits and vegetables. One participant recommended a virtual

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gym environment. Two participants experienced mild motion sickness during the experiment; notably, one mentioned that she felt like losing her balance while moving very fast in the virtual environment.

6 DISCUSSION

Our investigation of the immersive VR environments provided insights into how the VR experience supported our participants to enhance their creativity levels. We investigated three different virtual environments supported in their effectiveness in increasing creativity levels. Multiple analyses (both quantitative and subjective) revealed that the VR experience correlated with the users' creativity scores. In particular, there was a closely significant improvement in the user’s creativity score after the VR experience. The results showed that our participants spent more time navigating around the wilderness than in the city park and office environments. However, our results showed that the time spent in the virtual environments was not correlated significantly with the creativity scores after the VR experience ($p>0.05$).

Only disorientation-related sub-scores were slightly higher than the other three sub-scores for the virtual environments. We also found that the four simulator sickness symptoms were not correlated significantly with the creativity scores after navigating the three virtual environments. The results of NASA TLX for the individual workload factors revealed that the performance factor was the same and frustration demand was smaller for all three virtual environments. However, only the mental demand of the three virtual environments is slightly higher than the other factors. Out of all three environments, the city park environment produced more physical and temporal demands, making the users put more effort into navigating around than the other two environments. Nevertheless, one-way ANOVA showed that there was no significant difference in the workload factors between the three virtual environments ($p>0.05$). Moreover, a Pearson-movement correlation revealed that none of these perceived workload factors was correlated significantly with the creativity scores after the VR experience.

All participants perceived that navigating around the three virtual environments was comfortable, pleasant, and enjoyable. They all liked the three environments. The subjective ratings on the visual, navigation and overall experience of the three virtual environments indicated that 5 participants reported a very good visual experience in the wilderness. Seven users reported that the navigation experience around the virtual city park was very good than the office and wilderness environments. Only two users reported a very good overall experience in the wilderness. Nevertheless, participants' visual, navigational, and overall experience was not statistically significantly different between the three virtual environments.

Our study has shown the potential of using immersive virtual environments to increase creativity. In particular, our findings suggest that designers should consider using either naturalistic or familiar virtual environments with appropriate visual objects when designing VR environments to increase users' creativity levels. It also means that the designers should consider cultural elements associated with the chosen virtual environments by including the appropriate/more relevant visual elements. It is also essential that the visual elements and how they are visualised in the environments are critical when designing VR environments for improving creativity skills. We also found that further to improve creativity skills through the immersive virtual experience, it is important to minimise the cognitive demand of the users. This can be achieved by minimising the navigation process and providing sufficient time for the participants to explore the virtual environments. Our findings can be helpful for designing any other types of virtual environments, such as beaches, restaurants, and supermarkets.

6.1 Limitations

The performed study utilised the virtual locomotion technique to navigate around the virtual environments. Thus, the participants were asked to stand in the pre-marked area on the floor. They were only allowed to stand with closed legs (feet together) or slightly opened legs with the marked area. However, this approach caused balancing issues for some users while navigating the virtual environments. Though there was a closely significant improvement in the users' creativity scores after the VR experience, we did not investigate how each virtual environment influenced their creativity scores. Understanding the influence of each virtual environment on the creativity scores will help improve the design and realisation of the visual elements.

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7 CONCLUSION

This research explored the use of three virtual environments by examining how navigating around them would help users increase their creativity levels. We first identified suitable indoor and outdoor environments and designed (a) Wilderness, (b) City Park and (c) Office immersive environments. We investigated the effectiveness of these environments with 12 participants. The results showed that the VR experience increased the users' creativity levels. We also found that simulator sickness did not influence the creativity scores of the users. All three environments produced equal performance on perceived workload factors. Moreover, our study showed the potentiality of using immersive virtual environments to increase creativity levels.

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