The Impact of Nature Realism on the Restorative Quality of Virtual Reality Forest Bathing

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Virtual reality (VR) forest bathing for stress relief and mental health has recently become a popular research topic. As people spend more of their lives indoors and have less access to the restorative benefit of nature, having a VR nature supplement has the potential to improve quality of life. However, the optimal design of VR nature environments is an active area of investigation with many research questions to be explored. One major issue with VR is the difficulty of rendering high-fidelity assets in real time without causing cybersickness, or VR motion sickness, within the headset. Due to this limitation, we investigate if the realism of VR nature is critical for the restorative effects by comparing a low-realism nature environment to a high-realism nature environment. We only found a significant difference in the perceived restorativeness of the two environments, but after observing trends in our data toward the stress reduction potential of the high-realism environment, we suggest exploring more varieties of high and low-realism environments in future work to investigate the full potential of VR and how people respond.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; **Virtual reality**;

Additional Key Words and Phrases: Virtual reality, realism, forest bathing, biophilia, nature

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1 Introduction

Stress is a prevalent issue in society at large, yet in some areas, resources to effectively address and mitigate stress are lacking. In fact, some living environments are even conducive to stress increase, and urban, indoor lifestyles have been linked to chronic stress [10]. Furthermore, people spend 86.9% of their time indoors, with 6% more in vehicles, and only 7% outside [21], leading to a lifestyle of increased stress and cognitive overload [46].

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Considering the widespread presence of stress and associated negative impacts, innovative ways of relieving stress are essential to research.

A key technique for countering the mental resource exhaustion and stress of cognitive overload is forest bathing. Forest bathing is a mental health practice where one becomes immersed in a forest environment to experience stress reduction and mental resource restoration [29]. While the benefit of the practice is perfect for counteracting the stress of indoor life, many people have little access to the nature needed for the practice. For example, people in large urban areas or nursing homes cannot access nature at any time. Thus, the people with the most dire need for this nature practice have rare access to it. **Virtual reality (VR)** has the unique potential to deliver highly immersive nature environments to people without access to live nature.

Research into the potential of VR is even more prevalent now that affordable VR **head-mounted displays (HMDs)** like the Oculus Quest 2 are accessible. At the same time, engines like Unity and Unreal Engine are improving to offer more lifelike experiences. Through the immersivity of VR and the continually improving graphics offered by game engines, it is possible to create an effective nature environment in VR. In fact, a subject of current research investigates what benefits VR forest bathing can provide for those with limited access to nature [8]. While VR nature immersion experiences can provide benefits similar to those of real nature, VR nature does not provide the exact benefits of real nature. Regardless, VR can act as a substitute when real nature is not directly accessible. Then, the question becomes how to create an optimally effective virtual nature experience.

Since VR nature is different than real nature due to its technical aspect, there are issues that call for research when investigating an optimal environment. One of these issues is realism [27]. Due to technological limitations, it is impossible to reproduce reality exactly in VR. Despite this, since VR is an immersive experience of another "world," it is possible that realism operates differently when creating an immersive experience. For example, while VR games are not entirely realistic and sometimes even contain very low detail models, they can be very immersive and enjoyable. Similarly, high-realism models can cause users to become disoriented and experience VR motion sickness, known as cybersickness, due to the "visual flow" of the environment [42]. However, the biophilia hypothesis, the creation of psychologist Erich Fromm [11], implies that the connection that humans have to nature is a connection to the living organisms in nature. It is unclear how our connection to living plants translates into VR, or if the realism affects how "alive" people perceive the plants to be. This article investigates future work proposed by Masters et al. [25], contributing new knowledge on the role of plant realism in VR nature environments for the restorative effect.

Since realism is a complex issue not yet addressed in detail with respect to VR nature, it is necessary to investigate. This work examines the question: To what extent is the benefit of VR nature dependent on the realism of the virtual environment? In the following sections of this work, we cover existing literature on VR forest bathing and VR realism factors, then detail the methods for our experiment, then present our results, and discuss their implications. All supplementary materials associated with this work, including our surveys and the stressor test, are available on GitHub at https://github.com/NuiLab/NatureProjectV2.2.

In the rest of this work, related literature, methodology, results, discussion of results, experiment limitations, and direction of future work are all presented.

1.1 Contributions

(1) We contribute deeper understanding of the importance of realism for the immersive and restorative qualities of a virtual forest bathing application.
(2) We explore which level of realism participants prefer and how well that level matches with realistic nature, further investigating how VR simulations compare and differ.
(3) We uncover knowledge on how realistic nature needs to be for people to derive benefits, which can potentially spur the creation of optimized nature environments for accessible platforms to help more people find stress relief.

2 Related Work

Two key theories are critical for nature restoration research. **Attention restoration theory (ART)**, created by Kaplan and Kaplan, is related to cognition and the idea that extended focus can exhaust mental resources, and passive interest, or "fascination" can restore those mental resources [18]. Furthermore, Kaplan and Kaplan associate nature with having the ability to engage people in a way where they are passively interested in their surroundings, and that "nearby nature," which refers to keeping plants in non-natural spaces like urban and indoor areas, can elicit a similar, yet less impactful response [19]. In response to Kaplan and Kaplan, Hartig et al. developed a scale to measure the impact described by ART called the **perceived restorativeness scale (PRS)** [15]. It has four categories: Being Away, Extent or Coherence, Fascination, and Compatibility [18, 19], all of which contain Likert scale questions and measure the restorative quality of an environment. **Stress reduction theory (SRT)** is the other critical theory for this research, and it is based on the concept that natural areas can alter people's emotional experiences for stress reduction and restoration [44]. Recently, there has been more interest in SRT and ART related to how nature can be used to improve quality of life [26]. Relevant topics include stress reduction within nature [29], in VR nature [3], and comparisons between the two [26]. There is also interest in using VR as a nature supplement for those who lack access to nature [23]. This interest presents the topics of nature realism's relationship with stress reduction and immersion [27], optimal environment designs, and issues caused by HMDs like VR sickness [48].

2.1 Nature Influencing Stress Reduction

The restorative potential of nature has been a research topic of interest for some time. Research has been conducted with a variety of nature environments, comparing them to urban areas, to investigate the effect of nature on stress and restoration. Forest bathing, or shinrin-yoku, was a term specifically invented to describe the restorative impact of immersion in forest environments [29]. Furthermore, the biophilia hypothesis also describes the biological need that people have for nature interaction [6]. Research by Brown et al. and Park et al. has shown that natural environments have greater stress reduction and mental resource restoration qualities than urban environments [6, 29]. The presence of biomass, or living green plant life, has also shown a positive, restorative effect both in natural environments and in indoor spaces. [20, 50]. Additionally, the diversity of green plant life may also play a role in perceived restorativeness, though more research is needed on the topic. Marselle et al., Aerts et al., and Wood et al. investigated biodiversity and found indications of potential restorative benefit, but the study by Wood et al. was the only study of the three to report that biodiversity predicted restorative benefit [1, 24, 49]. Research thus far shows that nature has the promising restorative benefits outlined by shinrin-yoku and the biophilia hypothesis. However, the essential components of restorative nature experiences need further investigation to understand.

2.2 Virtual Reality as a Nature Supplement

Despite the great benefits that nature immersion can provide, some individuals may not have the opportunity to experience the outdoors as often or at all. Several studies have been conducted on the potential of VR to aid populations that struggle to get outdoors, such as those in residential care facilities [23], graduate students [3], and even during the COVID-19 quarantine [33]. All three studies found that VR nature environments have the potential to positively influence individual well-being. Additionally, Mattila et al. and Reese et al. found that VR nature environments have the potential to restore moods and increase physiological arousal to a similar extent to real nature in as little as 5 minutes within a headset [26, 32]. The use case of VR as a nature supplement is promising, and many questions surround the components and qualities of an optimally restorative nature environment given the limits of the technology. For example, in order to have an accessible nature supplement, it has to be deployable on a portable, affordable headset like the Oculus Quest. Since the Oculus Quest struggles to render high-realism environments efficiently, it is worth exploring the importance of realism in the simulation.

2.3 Realism within VR Design

When designing any VR environment, three primary concerns are immersion [39], presence [17], and realism [27]. VR is unique because it uses virtual worlds to transport people into different realities. Immersion, presence, and realism are all critical elements of delivering a VR environment that will affect people. Immersion describes how well the computer simulation delivers a realistic and detailed depiction of reality and involves aligning simulations with expectations of what would really happen [39]. Presence is the response that people have to immersion, or a feeling of being inside of the simulation [17]. Realism is how well a simulation mirrors real life.

Immersion is a critical variable in understanding how realism is related to stress reduction. Immersion influences stress reduction in the sense that if an individual's immersion remains consistent during a virtual natural environment, there are positive results in the treatment of trauma and stressful symptoms [12]. Kaplan's [19] ART has demonstrated the benefits and consequences of relying on immersion for a therapeutic reaction. The benefits include the recovery of stress when immersed in natural environments. Unfortunately, consequences include immersion being previously proven to be broken easily due to distractions, consistent direct attention, or when the participant perceives danger. Thus, it is essential to explore the extent to which biomass realism may be influencing nature immersion, as it will ultimately influence stress restoration.

Realism impacts immersion in the sense that the more real a nature environment appears, the stronger the immersive effects are. This was demonstrated in a study done by Newman et al. [27] where his team had shown that a high-realism environment produced a greater sense of both presence and restoration than a low-realism environment. There is both conflicting and supporting evidence of this in the study completed by Gisbergen et al. [45], who discovered that certain elements of realism may or may not induce immersion. For example, as demonstrated in Gisbergen's experiment, participants moving their bodies intensified the realism aspect, whereas the avatars did not due to their failed attempt at looking as realistic. This brings up an interesting conflict known as the uncanny valley [43], the uneasy human response to an object that has a humanistic resemblance. This relationship shows that virtual assets may not behave the same as their real counterparts, which calls for further work investigating how realism matters.

Realism design in our virtual environments was also considered in the design of audio, lighting, and camera angle. It is argued that since humans are multi-modal beings, we may be more immersed when several senses are being addressed, such as audio [38]. Multiple studies have shown that the addition of relevant audio in virtual environments strengthened the individual's presence [16, 35, 40]. One study conducted by Annerstedt et al. [2] showed that besides audio strengthening presence, it also allowed for a sense of safety, which is the same result as daytime lighting.

Lighting in VR environments will play an important role in the decision of the time of day utilized as brightness levels not only influence degrees of safety but also stress recovery speed. Li et al. [22] demonstrated that high amounts of light promoted perceived safety and stress recovery via psychophysiological responses when using VR headsets. This finding of bright light-induced stress recovery and safety is consistent with the finding that humans prefer bright and sunny nature in the real world [4]. Comparing the lighting between real-world and virtual environments is valid since it has been demonstrated that VR lighting is similar to real-world lighting, at least for well-lit scenes [34]. Daytime lighting is beneficial for virtual scenes not just for stress recovery and a sense of safety but also for the ease of camera work.

Camera work within the virtual world is an essential consideration when maintaining realism. Christie et al. [7] advise that camera rules and properties are addressed from the beginning to address aesthetic and cognition properties. Without the option of having an avatar to refer to for camera position, the properties include angles, orientation, distance from objects, and height location. Ultimately, all camera characteristics, especially from a first-person perspective, influence emotional response according to Christie et al. [7]. Besides an emotional response, camera positions can influence cybersickness.

3 Methods

In this experiment, our goal was to test if the realism of the biomass in a VR nature environment impacts restorative quality via comparing the restorativeness of two environments, one high-realism and one low-realism. We accomplished this through inducing stress followed by observing the restorative benefits of the environments. This experiment was approved by the Institutional Review Board. Our hypotheses are as follows:

H_1. Both nature environments are more restorative than the control condition.
H_2. The high-realism nature environment is more restorative than the low-realism nature environment.

3.1 Participants

Forty-eight student participants were recruited from the Colorado State University community after exclusion. Participants were excluded if their self-reported vision was below 20/60, if they had a previous self-reported history of heart conditions, or if they had a history of seizures, all of which were detailed in the participant recruitment message as well as the consent form. Twenty-seven participants were male (56.3%), 20 participants were female (41.7%), and 1 participant was non-binary (2.1%). The mean (M) age for participants was 23 years old with a SD of 4 years. 81.3% of participants had used a VR headset before, and 18.8% had not. Participants were also asked to report the average number of hours per week spent on the computer, which yielded a M of 40.2 hours and a SD of 20.2 hours. Participants reported how many hours per week they spend using VR, and 12 reported a non-zero number. The M was 1.17 hours with a SD of 2.82 hours.

3.2 Materials

The experiment was conducted at a desk using an Alienware computer with 128 GB memory, an Nvidia GeForce RTX 3090 graphics card, and an 11th Gen Intel i9-11900F processor. The experiment was conducted using an HTC Vive Pro 2 VR headset in a lab environment. The environments were created and administered using Unreal Engine 4. All questionnaires were administered via Google Forms and completed at the desk on an HP Pavilion laptop. There was an air vent blowing cool air at the experiment location, simulating an outdoor breeze.

3.3 Procedure

3.3.1 Psychological and Physiological Measurements. The PRS was used to measure presence in the environments [15]. The **Positive and Negative Affect Schedule (PANAS)** [47] and the **Zuckerman Inventory of Personal Reactions (ZIPERS)** [51] were used to measure people's emotional responses to the environments. All questionnaires were Likert scales, integrated into Google Forms [14] for easy administration. For PANAS, participants were asked to report how they felt at the current moment that they were taking the survey. In addition to the psychological measures taken, blood pressure and heart rate were also taken as indicators of stress. We also measured **electrocardiogram (ECG)** and **electrodermal activity (EDA)** but could not get reliable readings for all participants due to the technology and could not use the data as a result.

3.3.2 Stressor Test. The stressor test we used was an adaptation of the MPAtest [30]. It is a researched math stressor test that induces stress via delivering challenging problems that take a lot of mental energy followed by easy problems that keep users motivated to finish the test. We used the implementation of the test used in [25].

3.3.3 Virtual Environments. Two **virtual nature environments (VNEs)** were created using Unreal Engine 4, one with high-realism as seen in Figure 1 and one with low-realism as seen in Figure 2. The low-realism environment used the "Dreamscape Nature: Meadows—Stylized Open World Environment" package from the Unreal Engine marketplace [41]. The high-realism environment referenced from the tutorial offered by Serge Ramelli Photography [31]. The user was stationary in the environments, sitting on a stump surrounded by a virtual forest. Originally, the idea was to make the experience more immersive by giving participants hands and an avatar despite the fact that there were no controls or movement allowed. However, after implementing the avatar

Fig. 1. High-realism nature environment.

and hands, we realized that neither were as realistic as the real forest condition and may have led to some uncanny valley effects, so we removed the avatar and hands and positioned the camera to give the user the appearance of sitting on a stump. The forest included ground plants and trees that moved, making the environment dynamic though the user was stationary. During the creation of the virtual environments, similar looking assets were found for each environment in order to ensure that realism was the only environmental difference. Different asset packs of different realism yet similar shape and color were used for the different environments with the goal of making both as equal in beauty, rather than reducing the level of detail of the high-realism assets to create fuzzy trees that were not beautiful. The high-realism map was created first. The low-realism map was made by copying the high-realism map and then replacing the trees and ground cover assets individually. This was done to ensure the maps were structured identically aside from realism. Both environments were constructed using identical daytime lighting because VR lighting has been shown to be similar to real-world lighting for well-lit environments [34], and identical fog effects were used to make the background forest seem endless since it was difficult to render large amounts of highly realistic trees in VR. After taking these measures to create the environments while maintaining reasonable performance, the high-realism environment had an average frame rate of 90 **frames per second (FPS)** and the low-realism 115 FPS.

3.3.4 Control Condition. In order to compare the restorative potential of a virtual environment to the alternative of having no special treatment for stress reduction, a control condition was created. After careful consideration of

Fig. 2. Low-realism nature environment.

introducing a VR control condition, we decided that the goal of our control condition would be to simulate the absence of stressful visual stimuli in the absence of VR, since the goal of our VR environments was to introduce the presence of relaxing visual stimuli via VR. We wanted to model what a potential solution for handling everyday stress would be given no helpful alternatives or guidance. Thus, for the control condition, we had participants close their eyes and do nothing, very much like how one may close their eyes to take a break from the stressful visual stimuli on their computer screen and the stress of the task they were given in everyday life [13].

3.3.5 Preference Questionnaire. Ideally, having a control condition where people are compared to their own performance should be enough to control for any personal preference differences. However, the preference questionnaire was included as a check to ensure that personality preferences were not skewing the results, as prior research has shown that personal experience can affect the ways that people react to different nature environments [36]. Our preference questionnaire was implemented similarly to [25], but we changed the images to be more fitting to the context of our experiment. We included two real images taken of the forest in Olympic National Park, two images of less realistic video game forests, an image of the high-realism forest environment, and an image of the low-realism forest environment.

3.3.6 Open Response Exit Survey. An open-response exit survey was suggested in the pilot of this experiment to collect feedback and insights from participants. In order to further observe participant experience and how it affects results, we created a three-question exit survey. We asked the participants what they liked, what could be

improved, and if they experienced cybersickness. We chose to incorporate cybersickness into the open response questionnaire rather than administering a full sickness questionnaire in order to avoid survey fatigue and give the participants the opportunity to elaborate on the details of their experience. These questions gave us further insight into how participants perceived their experience as well as if their experience was confounded by VR sickness, which breaks immersion and can cause stress.

3.3.7 Experiment Procedure. This experiment followed a mixed design. Each participant was randomly exposed to one of the two environments and the control condition in random order. Thus, there was a within-subjects comparison between how participants reacted in the control environment versus the experiment condition they were assigned to, then there was a between-subjects comparison between the two different nature environments. Participants completed two sessions of the experiment on different days, one in the control condition and one in the environment condition.

Participants arrived at the laboratory and were informed that physiological measures and psychological measures would be collected. Before participating in the experiment, subjects were informed of the potential risks and benefits of participation in the experiment and that they could leave the experiment at any time. The subjects then signed an informed consent form. The experiment was completed with no more than one participant in the room at one time. The participants were each assigned an experiment number that they used to fill out the questionnaires. The participant began by filling out a demographics questionnaire. Then, their ECG, EDA, blood pressure, and heart rate were taken, and then they filled out the baseline psychological questionnaire. After this, they completed the math stressor test, had their ECG, EDA, blood pressure, and heart rate measured again, and filled out a post-stressor psychological questionnaire. Then, they entered either an environment or the control condition. Exposure time in both environments and for the control condition was ten minutes, and heart rate was measured at each minute of the exposure time. After exposure, the participant had their ECG, EDA, blood pressure, and heart rate measured and completed the psychological questionnaire for the respective environment or the control condition. At the end of the second session, participants completed two more steps. They filled out a preference questionnaire where they rated different real, realistic, and low-realism nature environments using the PRS. After this, they answered an open-ended exit survey where they gave feedback on the experiment. They were then debriefed and dismissed. The experiment lasted approximately one hour per session for two sessions on different days (environment and control), so the total experiment duration was two hours.

4 Results

We had two hypotheses: H_1 Both nature environments are more restorative than the control condition. H_2 The high-realism nature environment is more restorative than the low-realism nature environment. Each participant had physiological measures taken three times during each session of the experiment: once after entering the room (baseline), once after completing the MPAtest (post-stressor), and once after the experiment condition they were exposed to, whether that be the control (post-control), the high-realism environment (post-high), or the low-realism environment (post-low). We were able to measure heart rate and blood pressure, but ECG and EDA were not usable as we could not get readings for every participant. Each participant also completed the psychological questionnaire with the ZIPERS, PANAS, and PRS three times after the physiological measures were recorded. The responses from these surveys were analyzed separately for the ZIPERS, PANAS, and PRS.

ZIPERS can be split into positive and negative emotion scoring. ZIPERS is a five-point Likert scale that has six positive affect and six negative affect questions. To compute positive and negative subscale scores, we summed the scores from the questions in the respective subscales. Both the positive and negative subscales has a range from 0 to 30. PANAS is similarly divided into Positive and Negative Score, and each subscore has 10 questions that are added up to calculate the subscale score. PANAS is also a five-point Likert scale with subscore ranges from 0 to 40. PRS is a more complex measure. The PRS is also a five-point Likert scale, but it has four subcategories, Being Away, Fascination, Coherence, and Compatibility, with component questions that are added to calculate the subscale

score. Being Away has a range of 0–12 and measures if the experience is an escape experience. Fascination has a range from 0 to 30 and measures passive attention in the environment. Coherence has a range from 0 to 24 and assesses if the environment is overwhelming. Compatibility has a range from 0 to 30 and measures how well the user fits in with the environment. While these subscale scores can be observed by themselves, in the case of this article, General Restorativeness is a more relevant score to consider. General Restorativeness is calculated by summing the subscale scores from Being Away, Fascination, and Compatibility to measure the overall restorative quality of the experience on a scale from 0 to 72.

4.1 Data Analysis

Python was used to clean, sort, and visualize the results. Specifically, the pandas, numpy, and scipy statistics libraries were used to sort and clean the data, then the seaborn library was used to visualize the data. We used a **linear mixed model (LMM)** fit by restricted maximum likelihood with estimated marginal means contrasts, and we adjusted p-values using a Bonferroni correction to investigate the interaction effects between Treatment and Time. R was used for these analyses. Before analyzing experimental results related to the hypotheses, we verified that the MPAtest induced stress via comparing baseline and post-stressor results. To observe H_1, the low-realism and high-realism results were compared to control. Then, to observe H_2, the measures for low-realism and high-realism are compared. The variance between participants and within participants was high for a random effect. We did not analyze any additional demographic effects because we had no hypotheses that related to the responses of different groups, and people were verified against their own performance in this experiment.

4.2 Verifying the Stressor Test

To verify that the MPAtest induced stress, baseline and post-stressor scores were compared. For ZIPERS negative affect, the estimated marginal means contrast revealed a statistically significant difference ($p < 0.0001$), indicating that participants scored higher on the ZIPERS Negative Affect survey after exposure to the MPAtest than their baseline scores ($estimate = 2.06, SE = 0.328, t = 6.294$). Additionally, for ZIPERS positive affect, the estimated marginal means contrast revealed a statistically significant difference ($p < 0.0001$), indicating that participants scored lower on the ZIPERS Positive Affect survey after exposure to the MPAtest than their baseline scores ($estimate = -3.215, SE = 0.57, t = -5.636$). There were no significant differences in PRS General Restorativeness scores or PANAS scores for participants between their baseline and post-stressor. A significant difference was found for systolic blood pressure ($p = 0.017$). The contrast test revealed that systolic blood pressure decreased after the stress test ($estimate = -3.19, SE = 1.25, t = -2.564$). Heart rate and diastolic blood pressure showed no significant differences.

4.3 Comparing Low-Realism to Control

To observe H_1, The low-realism environment was compared to the control environment. No significant results were found doing this comparison on ZIPERS, PANAS, and PRS responses. There were also no significant differences in heart rate or blood pressure between the control and low-realism environment for participants.

4.4 Comparing High-Realism to Control

In addition to comparing the low-realism environment to the control environment, the high-realism environment was compared to the control environment. For PRS General Restorativeness, after applying Bonferroni correction for multiple comparisons, a significant difference was observed between the control and high-realism conditions, with an adjusted significance level set at $\alpha = 0.05/3 = 0.017$. The estimated marginal means contrast revealed a statistically significant difference ($p < 0.001$), indicating that participants subjected to the control condition exhibited a marked decrease in General Restorativeness compared to their scores in the high-realism treatment ($estimate = -9.121, SE = 1.95, t = -4.684$). Additionally, for ZIPERS Positive Affect, the estimated marginal

means contrast revealed a statistically significant difference ($p = 0.0121$), indicating that participants subjected to the control condition provided lower positive affect scores compared to their scores in the high-realism treatment ($estimate = -2.833, SE = 0.976, t = -2.902$). Other surveys did not show significant results. There were no significant differences in heart rate or blood pressure between the control and high-realism environment for participants.

4.5 Comparing Low- and High-Realism

To observe H_2, the low and high-realism environments were compared. For PRS General Restorativeness, the estimated marginal means contrast revealed a statistically significant difference ($p < 0.006$), indicating that participants subject to the high-realism condition exhibited a marked increase in General Restorativeness compared to those in the low-realism condition ($estimate = 7.576, SE = 2.43, t = 3.113$). There were no other significant differences.

4.6 Preference Questionnaire

One of the final steps in the procedure for the participants was to complete the preference questionnaire, which included six different images depicting both nature environments from the experiment, real nature images from Olympic National Park [37], and lower realism VNEs from games. Each participant rated the images using the PRS, which we then used to calculate the General Restorativeness for each image on a scale of 0–72. This preference questionnaire was administered to understand user preference better and observe any influence personal preference may have had on the results. The M and SD for General Restorativeness were calculated for each image provided. The highest-rated image was an open area in a video game forest from the game Legend of Zelda, Breath of the Wild [28] ($M = 42.25$, SD = 7.042). The second highest preference rating was an image of an open area in a real forest in Olympic ($M = 41.13$, SD = 7.207044). The third highest preference-rated image was a similar image of a forest path in Olympic ($M = 38.17$, SD = 8.563488). This was followed by the realistic forest virtual environment screenshot ($M = 33.10$, SD = 7.697028). The second to last preferred rated image was a lower realism virtual forest path from the game World of Warcraft [9] ($M = 32.00$, SD = 8.079393). Finally, the lowest rated image was the screenshot of the low-realism nature environment ($M = 28.06$, SD = 7.820884). These preferences illustrate that all high-realism images, including the high-realism screenshot, were preferred to the low-realism screenshot, which follows Section 4.5 where the high-realism environment performed better than the low-realism with respect to PRS General Restorativeness. Additionally, it is interesting that the low-realism environment screenshot ranked below other low-realism VNEs. This may indicate that future work is needed to better understand the design of low-realism environments, since one of the low-realism environments ranked highest and our screenshot ranked lowest, and this trend may also contribute to the lack of significant results between low-realism and control. Overall, more work is needed to understand the merits of different realism levels in VNEs.

4.7 Open Response Exit Survey

At the end of the experiment, an open-ended exit survey was administered in order to gain additional insights into the experiment design and process from participants. Three questions were administered, asking about cybersickness, improvements to the experiment, and things participants liked about the experiment. A thematic analysis following the approach of Braun and Clarke [5] was performed on the responses and is detailed below for each question.

4.7.1 Did You Experience Any Cybersickness? Cybersickness, or motion sickness within a VR environment, is important to minimize as it can cause stress and confound results, as explained in Section 1. The question for all participants was, "Did you experience any cybersickness?" All 48 participant responses were recorded. Participants were asked if they experienced cybersickness in order to observe the extent to which cybersickness

may have affected experimental results. A thematic analysis was performed on the open-ended questionnaires that our participants received to understand better what type of environment introduces cybersickness. Of our 48 participants, 72.92% claimed they did not experience cybersickness, 48.57% of which underwent our low-realism environment. Of our participants, 25% claimed that they experienced some cybersickness, 50% of which underwent our low-realism environment. Our remaining participant, 2.08%, claimed to experience cybersickness within the low-realism environment. These results indicate that the participants who claimed to experience some cybersickness were almost evenly distributed between the high and low-realism environments.

4.7.2 What Could Be Improved About This Experiment? A thematic analysis was performed on suggestions to improve the experiment in order to discover the limitations of our study better. The question for all participants was, "What could be improved about this experiment?" All 48 participant responses were recorded. Some participants answered the open-response questions with multiple different features that could be improved. These seven responses with multiple areas of improvement were broken into 19 responses. There are 60 total responses for features that could be improved. The improvement areas are almost equally dispersed among experiment design, room distractions, arithmetic test, VR environment design, psychological questionnaire, and one comment on the control condition. Making up 13% of responses are experiment design concerns with instruction clarity, informing participants about the math test, having to wear a Fitbit, and duration. This is the most diverse group of responses, invoking us to review instructions better. However, not informing participants about the math test and wearing the Fitbit are necessary features of the study in order to prevent priming. The participants were informed about the duration of the experiment in both the advertisement and consent forms. Another 13% of responses requested that we remove other people from the experiment space as it introduced distraction and discomfort. This prompted us to acquire a more isolated room for the other experiments at the time and for future experiments. An additional 13% of responses had comments about the math test being stressful, too long, and including annoying car sounds. This was the intent of the math test and helped demonstrate the arithmetic test's success. However, one participant requested that we have more variation in the questions as they remember the question being asked. Another participant asked if we could show the correct answer. This is odd as we do flash the correct answer on the screen after every user input, which may contribute to the users memorizing answers from previous sessions. 5% of responses were in regard to the psychological questionnaire, one of which also mentioned that they found themselves memorizing previous answers. To reduce the need for memorization, we plan to randomize the order of questions on the questionnaire each time it is given. One response was providing a suggestion for the control condition to include audio that had nature sounds or white noise. Audio is mentioned in 31.6% of responses that were in regard to the VR nature environments. These improvements are not necessarily considered limitations but things to consider for future studies. The audio came from a response where they could not tell if the audio or the environment was relaxing. This prompts future considerations of a control condition with audio. Multiple users requested a way to move in the environment. This feature was not included in order to minimize cybersickness but prompts future work to incorporate movement in a way that does not induce sickness. Three responses were in regard to poor performance and how blurriness, black borders, and poor optimization may have influenced their restorativeness. All three of these responses are from individuals that were in the high-realism environment. Thus, this may be a limitation for the restorativeness experienced in the high-realism environment. As for visual appearance in the environments, there were several requests for animals, details for observation, and even water sources, all of which are things that we plan to look further into for future designs.

4.7.3 What Were Some Things You Liked in This Experiment? A thematic analysis was performed on the features participants enjoyed to discover this study's strengths and personal preferences. The question for all participants was, "What were some things you liked in this experiment?" All 48 participant responses were recorded. Some participants answered the open-response questions with multiple different aspects that they enjoyed. These 14 responses with multiple comments about things they liked were broken into 30 responses.

Thus, there were 64 total responses for features that participants enjoyed. The areas that participants liked most about the experiment were the overall ease, the struggle of the math challenge questions, the relaxation of the conditions, and mostly the VR experience. The overall design of the experiment in terms of user ease and the 2-day structure was promoted in this section by 9.3% of responses. Noting that no one mentioned these areas for improvement, this is a structure we may continue to utilize for future studies. Other design features include 7.8% of participants enjoying the devices and frequency of measurements. It is unclear if the participants appreciated the physiological or psychological measurements. However, 3.1% of participants did note that they liked the preference questionnaire survey with varying images. Beyond experiment design, 15.6% of participants were found trying to find explanations for the arithmetic test, claiming that although they enjoyed it, it was stressful, which they determined was the point. Users claimed that they were focused on answering, trying to figure out tricks, acknowledging personal improvement, and being displeased with themselves when they were wrong, all of which contribute to stress and help support that the arithmetic test induced stress. Most of the responses, 42.18%, claimed they enjoyed the VR experience the most. There is some variety in what VR experience may mean. 44.4% of these are generalized to mean the virtual experience, such as getting to wear the Vive Pro, using VR for the first time, or enjoying the time spent in VR. Whereas the remaining 55.6% of participants are referring to the environment of itself, such as the nature ambiance, features in the distance, landscape, trees, lighting, and colors. 40% of the responses regarding appreciation of the environment are from individuals who experienced a low-realism environment. This encourages that there are some differences in participant preference that individuals may prefer the high-realism environment more than the low-realism. This finding provides some support for H_2, that the high-realism environment is perceived as more restorative than the low-realism environment.

5 Discussion

The MPAtest was observed to induce some stress, as there were significant results between the baseline and post-stressor consistently on ZIPERS Positive and Negative Score, verifying the findings of Masters et al. [25]. However, the lack of significant findings on the PANAS and PRS as well as the significant decrease in systolic blood pressure indicate that the stressor may need to be redesigned for greater efficacy in the future. H_1 yielded mixed results. When comparing the low-realism condition to the control condition, there were no significant results, which indicates that there was no difference in the restorative quality of the low-realism condition versus the control condition. When comparing the high-realism and control conditions, there were significant results. A significant increase in ZIPERS Positive Affect as well as PRS General Restorativeness was observed, indicating that the high-realism environment had higher perceived restorative value than the control condition, which provided some support for H_1. However, given the mixed results, H_1 is not fully supported. H_2 is also complex. Comparing the two environments yielded a significant increase in PRS General Restorativeness in the high-realism environment when compared to the low-realism environment, partially supporting H_2. However, due to the lack of significant results on other surveys, future work is needed to better understand the role of realism for the restorative effect. Also, since the low-realism environment was not better than the control, whereas the high-realism environment did show some restorative potential, the low-realism environment would likely need to be redesigned before a valid comparison between the two can be made, which could be an avenue for future work.

Additionally, since the variance between participants and within participants was high for a random effect, more work is needed to understand individual affective states. While random intercepts generated by the LMM account for individual differences, they may not capture all sources of variability. Individuals may have unique baseline affective states that influence their responses independently of treatment and time effects, and by understanding and modeling individual variability, future results are more likely to generalize to broader populations or settings beyond this specific sample.

5.1 Limitations

There are a few limitations in this experiment that may have had an effect on the mixed results observed. First, since the Fitbit was not recording data reliably, in some cases, participants did the EDA and ECG tests multiple times before getting results. Since heart rate and blood pressure were taken after EDA and ECG, the time taken to record EDA and ECG may have had unintended effects on the readings of heart rate and blood pressure, and participants may have experienced additional stress trying to get the technology to work. Also, since the Fitbit itself is designed for a single wearer, it is unclear whether it is reliable enough to use in future studies. Another thing that may have affected physiological data was the posture of the participants. Some crossed their legs while their blood pressure was being taken, and some moved their arms around while in the environment, which may have affected heart rate readings. Thus, the physiological data may not be fully reliable. However, given this limitation, it is also important to recognize that decreases in physiological measures are not necessarily congruent with stress reduction and attention restoration. For example, while stress reduction can be reflected in low blood pressure and heart rate, attention restoration may involve excitement about the experience, which can correspond to increased heart rate.

Additionally, the open exit survey provided some insights into participant experience that exposed some limitations. First, some people reported being affected by people and noise in the room during the experiment. This may have caused stress and broke immersion, which could confound results. Some reported that movement would improve the experience, so it is possible that if people were more actively involved, then they may have had a different experience. The ability to be more active without getting sick in environments that are less visually complex may be the advantage that those environments have over high-realism environments. Given that people still experienced cybersickness, it is worthwhile in future studies to explore the tactful incorporation of motion in order to capture passive attention. Additionally, the lighting in the low-realism environment was identical to the high-realism environment, but that lighting may be non-optimal for lower resolution assets. A lot of low-realism nature experiences in VR use very intentional lighting that is manipulated to create atmosphere, which may have been necessary for the comparison of two equally beautiful environments yet lost in this experience. Finally, in the high-realism forest, the trees were at such a level of detail that the user could identify more places where the light passed through the trees, and more of the background trees were visible.

5.2 Future Work

Since the results of this experiment are mixed, it is worth observing trends in the raw psychological data that indicate a need for further investigation. ZIPERS and PANAS both measure stress via affective responses. Figures 3 and 4 plot the *M*s for ZIPERS Negative and Positive Scores across surveys and across conditions, and Figures 5 and 6 plot the *M*s for PANAS Negative and Positive Scores. The first main trend is that the Negative Score increased and the Positive Score decreased after the math test, followed by the Negative Score decreasing and the Positive Score increasing after all conditions. These trends are more pronounced on the ZIPERS than the PANAS, which may indicate a future need to consider which survey provides the most relevant information on stress responses. The overall shapes of these graphs show that the stressor is stressing people, and people are recovering from the stress to some extent, which follows from the work done by Masters et al. [25]. For ZIPERS Negative Scores, the participants in the high-realism group were slightly less negative in the high-realism environment than the control condition, but not significantly so. This trend is also reflected in PANAS Negative Scores, as illustrated in Figure 5. This trend extends to ZIPERS Positive Scores and PANAS Positive Scores, where participants in the high-realism group were more positive in the high-realism environment than in the control condition, though only ZIPERS was significant. Additionally, for ZIPERS Negative Score, participants in the low-realism trend towards being slightly less negative in the control environment than the low-realism environment, which is also reflected in PANAS Negative Scores. This is a surprising trend that needs future investigation to better understand why it occurred, as there is currently little research on aesthetic, lower realism VNEs. Additionally, this trend

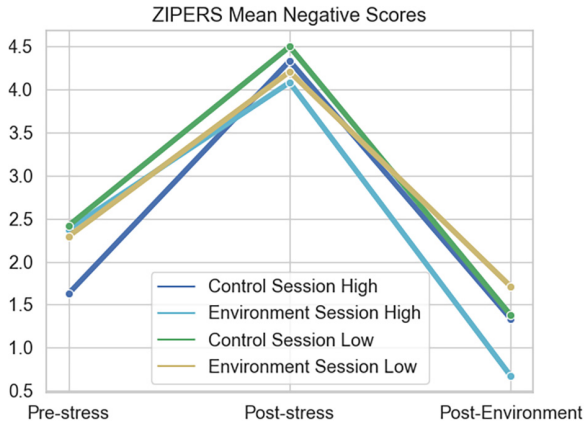

Fig. 3. ZIPERS *M* negative affect scores.

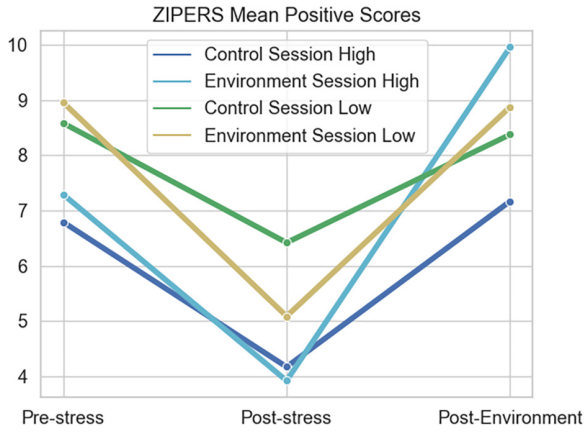

Fig. 4. ZIPERS *M* positive affect scores.

does not extend to the ZIPERS and PANAS Positive Scores, as participants in the low-realism group were more positive in the low-realism environment than in the control condition. Results across all surveys show trends of participants being more positive and less negative in the high-realism environment than the low-realism environment, but not significantly so across many surveys. Furthermore, since the results are mixed, future work that focuses on environment realism in additional detail is needed in order to truly understand the trends and the extent to which they are meaningful.

The PRS measures restoration as shown in Figure 7. Overall, the noteworthy trends are that both the high- and low-realism groups were more restored in the virtual environment than the control condition, but only the high-realism was significant. Also, the high-realism group was significantly more restored than the low-realism group. These trends are what we expected, but we expected the differences to be significant. One reason mixed results may be occurring is due to the design of the environments, calling for future work into the details of the design of beautiful high and low-realism environments. Future work can also aim to improve upon the limitations of this work in order to minimize potentially confounding variables. One interesting avenue would be to understand how physiological and psychological measures deliver different insights into the restorative quality of the experience. Another interesting avenue would be to research aesthetics to understand what beauty

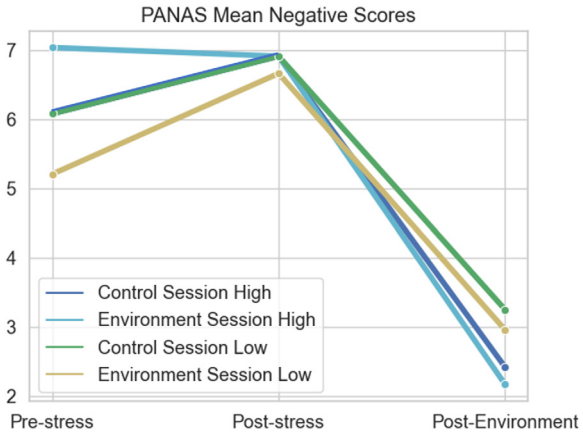

Fig. 5. PANAS *M* negative affect scores.

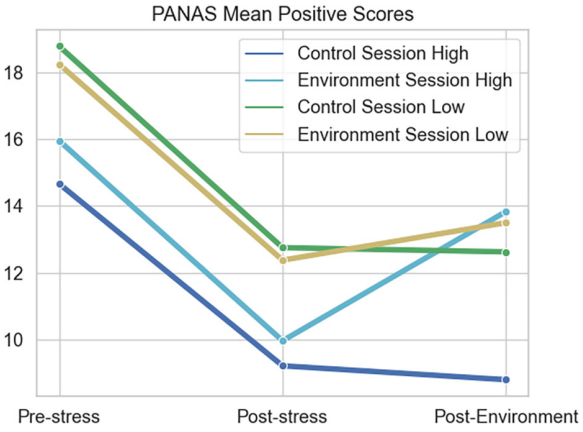

Fig. 6. PANAS *M* positive affect scores.

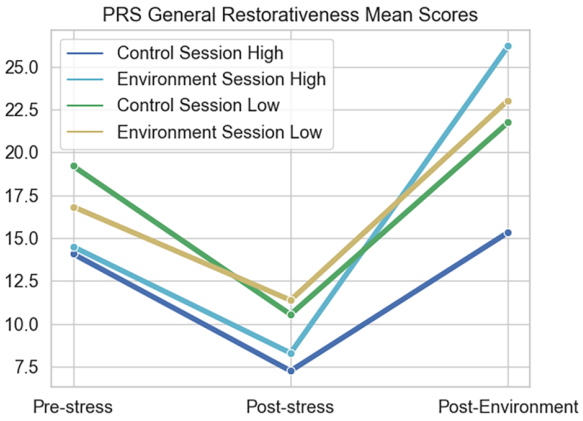

Fig. 7. PRS General Restorativeness *M* scores.

means for virtual assets and design environments that are equally beautiful, which may also clarify some of the results observed on the preference questionnaire. Finally, work is needed to understand, control for, and report how individual differences in affective states affect experiences in the environment, which can help contextualize results for a broader audience. This may look like using more specific psychological questionnaires or carefully crafted open response questions to understand personal experience. Overall, this contribution serves as a starting point for the research on the role of realism in restorative VNEs, and there are many future paths to pursue before understanding optimal VNE design.

6 Conclusion

In conclusion, some results were expected, and some were not. Results partially supported the efficacy of the MPAtest, which was expected, but the MPAtest also decreased systolic blood pressure, which was surprising. The high-realism environment was expected to be more restorative than the control condition, which results partially supported. It was unexpected that the low-realism environment did not outperform the control condition, and it was also unexpected that the high-realism environment only significantly outperformed the low-realism environment on PRS General Restorativeness. Given these results, it is important to address key challenges, opportunities for future improvement, and the next steps in this line of research. A variety of factors can be improved and investigated in future experiments, which are detailed in our limitations and future work. Overall, this research contribution is an initial investigation into the importance of realism for VNEs that effectively reduce stress and restore mental resources, and it opens new avenues for deeper research into the topic.

References

[1] Raf Aerts, Olivier Honnay, and An Van Nieuwenhuyse. 2018. Biodiversity and human health: Mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin* 127, 1 (2018), 5–22.

[2] Matilda Annerstedt, Peter Jönsson, Mattias Wallergård, Gerd Johansson, Björn Karlson, Patrik Grahn, Åse Marie Hansen, and Peter Währborg. 2013. Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. *Physiology & Behavior* 118 (2013), 240–250.

[3] Tatiana Nikolaevna Berezina, Anna Temirkanova, Anna Vladimirovna Litvinova, and Alexey Vladimirovich Kokurin. 2022. Using virtual reality techniques to alleviate cognitive fatigue in graduate students working while in college. *European Journal of Contemporary Education* 11, 1 (2022), 36–46.

[4] Femke Beute and Yvonne A. W. de Kort. 2013. Let the sun shine! Measuring explicit and implicit preference for environments differing in naturalness, weather type and brightness. *Journal of Environmental Psychology* 36 (2013), 162–178.

[5] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101.

[6] Caroline Brown and Marcus Grant. 2005. Biodiversity and human health: What role for nature in healthy urban planning? *Built Environment* 31, 4 (2005), 326–338.

[7] Marc Christie, Patrick Olivier, and Jean-Marie Normand. 2008. Camera control in computer graphics. *Computer Graphics Forum* 27, 8 (2008), 2197–2218. DOI: https://doi.org/10.1111/j.1467-8659.2008.01181.x

[8] Yvonne de Kort, A. L. Meijnders, Anne-mie A. G. Sponselee, and Wijnand A. IJsselsteijn. 2006. What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology* 26, 4 (2006), 309–320. DOI: https://doi.org/10.1016/j.jenvp.2006.09.001

[9] Blizzard Entertainment. 2004. World of Warcraft. Retrieved from https://worldofwarcraft.blizzard.com/en-us/

[10] World Health Organization. Regional Office for Europe. 2016. *Urban Green Spaces and Health*. Technical Documents. viii, 80 pages.

[11] Erich Fromm. 1964. *Psicoanálisis de la sociedad contemporánea: hacia una sociedad sana*. Fondo de cultura económica.

[12] Sharon Frost, Lee Kannis-Dymand, Vikki Schaffer, Prudence Millear, Andrew Allen, Helen Stallman, Jonathan Mason, Andrew Wood, and Jalasayi Atkinson-Nolte. 2022. Virtual immersion in nature and psychological well-being: A systematic literature review. *Journal of Environmental Psychology* 80 (2022), 101765. DOI: https://doi.org/10.1016/j.jenvp.2022.101765

[13] Tian Gao, Tian Zhang, Ling Zhu, Yanan Gao, and Ling Qiu. 2019. Exploring psychophysiological restoration and individual preference in the different environments based on virtual reality. *International Journal of Environmental Research and Public Health* 16, 17 (2019), 3102. DOI: https://doi.org/10.3390/ijerph16173102

[14] Google. 2021. Google Forms. Retrieved from https://www.google.com/forms/about/

[15] Terry Hartig, Kalevi Korpela, Gary W. Evans, and Tommy Gärling. 1996. *Validation of a Measure of Perceived Environmental Restorativeness*. University of Göteborg, Department of Psychology.

[16] Marcus Hedblom, Bengt Gunnarsson, Behzad Iravani, Igor Knez, Martin Schaefer, Pontus Thorsson, and Johan N. Lundström. 2019. Reduction of physiological stress by urban green space in a multisensory virtual experiment. *Scientific Reports* 9, 1 (2019), 1–11.
[17] Wijnand A. IJsselsteijn. 2004. *Presence in Depth*. Technische Universiteit Eindhoven Eindhoven, The Netherlands.
[18] Rachel Kaplan and Stephen Kaplan. 1989. *The Experience of Nature: A Psychological Perspective*. Cambridge University Press.
[19] Stephen Kaplan. 1995. The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology* 15, 3 (1995), 169–182.
[20] Eunsoo Kim, Sujin Park, Soojin Kim, Yeji Choi, Junghee Cho, Sung-il Cho, Hae-ryoung Chun, and Geonwoo Kim. 2021. Can different forest structures lead to different levels of therapeutic effects? A systematic review and meta-analysis. *Healthcare* 9, 11 (2021), 1427. DOI: https://doi.org/10.3390/healthcare9111427
[21] Neil E. Klepeis, William C. Nelson, Wayne R. Ott, John P. Robinson, Andy M. Tsang, Paul Switzer, Joseph V. Behar, Stephen C. Hern, and William H. Engelmann. 2001. The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Science & Environmental Epidemiology* 11, 3 (2001), 231–252.
[22] Chang Li, Changan Sun, Minkai Sun, Yu Yuan, and Pengcheng Li. 2020. Effects of brightness levels on stress recovery when viewing a virtual reality forest with simulated natural light. *Urban Forestry & Urban Greening* 56 (2020), 126865.
[23] Rikard Lundstedt, Carita Håkansson, Mare Lõhmus, and Mattias Wallergård. 2021. Designing virtual natural environments for older adults in residential care facilities. *Technology and Disability* 33, 4 (2021), 305–318.
[24] Melissa R. Marselle, Terry Hartig, Daniel T. C. Cox, Siân de Bell, Sonja Knapp, Sarah Lindley, Margarita Triguero-Mas, Katrin Böhning-Gaese, Matthias Braubach, Penny A. Cook, Sjerp de Vries, Anna Heintz-Buschart, Max Hofmann, Katherine N. Irvine, Nadja Kabisch, Franziska Kolek, Roland Kraemer, Iana Markevych, Dörte Martens, Ruth Müller, Mark Nieuwenhuijsen, Jacqueline M. Potts, Jutta Stadler, Samantha Walton, Sara L. Warber, and Aletta Bonn. 2021. Pathways linking biodiversity to human health: A conceptual framework. *Environment International* 150 (2021), 106420.
[25] Rachel Masters, Victoria Interrante, Madeline Watts, and Francisco Ortega. 2022. Virtual nature: Investigating the effect of biomass on immersive virtual reality forest bathing applications for stress reduction. In *Proceedings of the ACM Symposium on Applied Perception (SAP '22)*. ACM, New York, NY, Article 6, 10 pages. DOI: https://doi.org/10.1145/3548814.3551459
[26] Osmo Mattila, Arto Korhonen, Essi Pöyry, Kaisa Hauru, Jani Holopainen, and Petri Parvinen. 2020. Restoration in a virtual reality forest environment. *Computers in Human Behavior* 107 (2020), 106295.
[27] Mark Newman, Birgitta Gatersleben, Kayleigh J. Wyles, and Eleanor Ratcliffe. 2022. The use of virtual reality in environment experiences and the importance of realism. *Journal of Environmental Psychology* 79 (2022), 101733.
[28] Nintendo. 2017. The Legend of Zelda: Breath of the Wild. Retrieved from https://www.zelda.com/breath-of-the-wild/
[29] Bum Jin Park, Yuko Tsunetsugu, Tamami Kasetani, Takahide Kagawa, and Yoshifumi Miyazaki. 2010. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine* 15, 1 (2010), 18–26.
[30] Madelon L. Peters, Guido L. R. Godaert, Rudy E. Ballieux, Marja Van Vliet, Jacques J. Willemsen, Fred C. G. J. Sweep, and Cobi J. Heijnen. 1998. Cardiovascular and endocrine responses to experimental stress: Effects of mental effort and controllability. *Psychoneuroendocrinology* 23, 1 (1998), 1–17.
[31] Serge Ramelli. 2022. Unreal Engine Beginner Tutorial Making a Forest with the New Quixel Megascans Trees. Retrieved from https://www.youtube.com/watch?v=Vd6hAK3HlCM
[32] Gerhard Reese, Jasmin Stahlberg, and Claudia Menzel. 2022. Digital shinrin-yoku: Do nature experiences in virtual reality reduce stress and increase well-being as strongly as similar experiences in a physical forest? *Virtual Reality* 26, 3 (2022), 1245–1255.
[33] Giuseppe Riva, Luca Bernardelli, Matthew HEM Browning, Gianluca Castelnuovo, Silvia Cavedoni, Alice Chirico, Pietro Cipresso, Dirce Maria Bengel de Paula, Daniele Di Lernia, Javier Fernández-Álvarez, Natàlia Figueras-Puigderrajols, Kei Fuji, Andrea Gaggioli, Jose Gutiérrez-Maldonado, Upyong Hong, Valentina Mancuso, Milena Mazzeo, Enrico Molinari, Luciana F. Moretti, Angelica B. Ortiz de Gortari, Francesco Pagnini, Elisa Pedroli, Claudia Repetto, Francesca Sforza, Chiara Stramba-Badiale, Cosimo Tuena, Clelia Malighetti, Daniela Villani, and Brenda K. Wiederhold. 2020. COVID feel good—An easy self-help virtual reality protocol to overcome the psychological burden of coronavirus. *Frontiers in Psychiatry* 11 (2020), 563319.
[34] Siobhan Rockcastle, Megan Danell, Evon Calabrese, Galen Sollom-Brotherton, Alen Mahic, Kevin Van Den Wymelenberg, and Robert Davis. 2021. Comparing perceptions of a dimmable LED lighting system between a real space and a virtual reality display. *Lighting Research & Technology* 53, 8 (2021), 701–725.
[35] Jøran Rudi. 2021. Designing soundscapes for presence in virtual reality exhibitions: A study of visitor experiences. *Visitor Studies* 24, 2 (2021), 121–136.
[36] Vincenzo Paolo Senese, Aniello Pascale, Luigi Maffei, Federico Cioffi, Ida Sergi, Augusto Gnisci, and Massimiliano Masullo. 2020. *The Influence of Personality Traits on the Measure of Restorativeness in an Urban Park: A Multisensory Immersive Virtual Reality Study*. Springer Singapore, Singapore, 347–357. DOI: https://doi.org/10.1007/978-981-13-8950-4_31
[37] National Park Service. 2023. Olympic National Park Washington. Retrieved from https://www.nps.gov/olym/index.htm
[38] Mel Slater, Beau Lotto, Maria Marta Arnold, and Maria V. Sanchez-Vives. 2009. How we experience immersive virtual environments: The concept of presence and its measurement. *Anuario de psicología* 40, 2 (2009), 193–210.

[39] Mel Slater and Sylvia Wilbur. 1997. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments* 6, 6 (1997), 603–616.
[40] Russell L. Storms and Michael J. Zyda. 2000. Interactions in perceived quality of auditory-visual displays. *Presence: Teleoperators & Virtual Environments* 9, 6 (2000), 557–580.
[41] Polyart Studio. 2021. Dreamscape Nature: Meadows—Stylized Open World Environment in Environments—UE Marketplace. Retrieved from https://www.unrealengine.com/marketplace/en-US/product/dreamscape-nature-meadows
[42] Arttu Tiiro. 2018. *Effect of Visual Realism on Cybersickness in Virtual Reality*, Vol. 350. University of Oulu.
[43] Angela Tinwell. 2014. *The Uncanny Valley in Games and Animation*. CRC Press.
[44] Roger S. Ulrich. 1983. Aesthetic and affective response to natural environment. In: Irwin Altman, M. Powell Lawton, Joachim F. Wohlwill (Eds.), *Behavior and the Natural Environment*. Springer, 85–125.
[45] Marnix van Gisbergen, Michelle Kovacs, Fabio Campos, Malou van der Heeft, and Valerie Vugts. 2019. *What We Don't Know. The Effect of Realism in Virtual Reality on Experience and Behaviour*. Springer International Publishing, Cham, 45–57. DOI: https://doi.org/10.1007/978-3-030-06246-0_4
[46] Gary R. VandenBos. 2007. *APA Dictionary of Psychology*. American Psychological Association.
[47] David Watson, Lee Anna Clark, and Auke Tellegen. 1988. Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology* 54, 6 (1988), 1063.
[48] Séamas Weech, Sophie Kenny, and Michael Barnett-Cowan. 2019. Presence and cybersickness in virtual reality are negatively related: A review. *Frontiers in Psychology* 10 (2019), 415654.
[49] Emma Wood, Alice Harsant, Martin Dallimer, Anna Cronin de Chavez, Rosemary R. C. McEachan, and Christopher Hassall. 2018. Not all green space is created equal: Biodiversity predicts psychological restorative benefits from urban green space. *Frontiers in Psychology* 9 (2018), 2320.
[50] Jie Yin, Jing Yuan, Nastaran Arfaei, Paul J. Catalano, Joseph G. Allen, and John D. Spengler. 2020. Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environment International* 136 (2020), 105427.
[51] Marvin Zuckerman. 1977. Development of a situation-specific trait-state test for the prediction and measurement of affective responses. *Journal of Consulting and Clinical Psychology* 45, 4 (1977), 513.

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