Virtual Reality Forest Bathing for Mental Health

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Figure 1: High and Low Realism Nature Environments from [15]

ABSTRACT

In a world where the burden of stress increasingly steals human health and productivity, it is crucial to investigate new solutions for stress reduction. Nature Immersion, or forest bathing, is a powerful tool for reducing stress and replenishing cognitive resources, but a big challenge is that many high stress environments are the same environments that lack reliable nature access. For situations where access is the barrier, virtual reality (VR) has already shown potential for bridging the gap by bringing some of nature's benefits to people in an immersive way. However, while VR has potential, VR nature environment (VNE) research is a new field with many unanswered questions because even in real nature, there is limited understanding of how individual nature elements affect restorative outcomes. Overall, more attention is needed to the individual and personalized design elements of nature environments and how they affect the perception of VNEs, as we have limited understanding both with respect to how individual nature elements affect perception and how effective VR can be at delivering real world nature benefits.

Index Terms: Virtual Reality, Nature Immersion, Stress Reduction, Attention Restoration, Forest Bathing

1 INTRODUCTION

Stress has become a growing burden worldwide, costing the workforce 12 billion days a year [25], with around 1 billion people suffering from mental illness worldwide [5]. While part of this was due to pandemic isolation and stress [8], the negative impact of excess stress has continued to increase at an alarming rate, generating increased interest in how to manage stress and address its negative impacts. Nature immersion is an excellent way of reducing stress, as being in nature has been shown to reduce stress and restore attention, improving mood while fighting burnout for overall mental health recovery [19]. Unfortunately, many of the highest stress environments like hospitals [1] are also the environments with the least reliable access to nature. For these use cases, virtual reality (VR) has the capacity to be a promising mental health supplement via delivering restorative benefits similar to real nature in an immersive, digital context. VR nature environments (VNEs) have already shown promise in several applications addressing mental health conditions [3], but there are challenges in this relatively new field of research. First, even in real nature research, the impact of individual natural elements and factors like individual preference on perception are not well understood because they are difficult to control. VR offers a unique opportunity to control for these elements, which is especially of great interest to urban green space (UGS) designers and those interested in nature conservation [7]. Second, it is not well understood to what degree VR can replicate the benefits of real nature, so more work on the perception of elements specific to VR needs to be conducted. The following position paper highlights current research on potential mental health applications of the technology, research on the technology itself, then advocates for filling specific gaps in the literature that are important for driving future research.

2 VIRTUAL NATURE APPLICATIONS LITERATURE

Various promising VNE applications for mental health are being researched. One popular avenue is using VNEs with older adults, as it has shown potential benefits such as better cognitive functioning and emotion regulation, decreased anxiety and depression, as well as physical factors such as strength improvement and pain reduction [23]. For example, one study compared effects of urban, real and virtual nature exposure on community dwelling older adults, assessing attention, mood, heart rate variability, and blood pressure. The digit span test and Positive and Negative Affect Schedule (PANAS) showed significant differences between urban and virtual nature, and the PANAS positive affect was significantly different between urban and real nature, illustrating how VNEs can be beneficial for older populations with limited nature access [4]. Beyond older populations themselves, Lehto et al. conducted a feasibility pilot study to determine if ten-minute VR nature exposures over five-day could help quality of life for hospice family caregivers, evaluating treatment using the Acceptability of Intervention Mea-

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sure and Feasibility of Intervention Measure Scales, Virtual Reality Sickness Questionnaire, and the Patient Reported Outcomes Measurement Information System (PROMIS-29). Overall, participants indicated strong feasibility and acceptability, and significant results were identified on the Anxiety and Overall Scores for the PROMIS-29 [20, 10]. While initial research into VNE support for older adults and caregivers, there has been little work done to account for individual differences between health conditions and lived experiences, and it is also not well understood how the environments are causing restorative effects.

VNEs have also gained more attention as aides for those with specific neurological conditions. One study investigated using VNEs with Highly Sensitive Persons, using a controlled, cross-over study comparing results from forty-minute exposures to a real and 360 video forest on different days. The Change in subjective self-perception (CSP-14) Scale showed significant preference for the forest across Balance, Integration, and Vitality. The Basel Well-Being Scale showed significant preference for the forest across Vitality, Intrapsychic Balance, and Vigilance. State Trate Anxiety Inventory Short Form (STAI-S) significantly favored the forest, and heart rate decreased significantly after the forest, though there were no changes in blood pressure or the pulse-respiration quotient. Open response questions identified that movement restrictions, lack of multisensory detail, lack of visual realism, air quality, and the physical ground variations were limitations of the VR simulation, but nature sounds were also reported to strengthen the positive effects of the simulation, though visual elements were identified as most important [9]. This feedback highlights elements and challenges unique to VR that need further exploration so that optimal VNEs can be designed for target applications. Additionally, a proposed protocol aims to compare real and VR nature expose across participants who are neurotypical and who have Attention Deficit/Hyperactivity Disorder (ADHD) to understand restorative effect differences between populations, starting with an initial in-lab study followed by eight week follow-up questions to see if effects are maintained [26]. This proposed study is one of few that aims to investigate an element of individual difference by comparing ADHD and neurotypical participants.

Another study on individuals with mild to moderate depression and anxiety used electrocardiogram (ECG) during exposure to a VNE, finding activation of the prefrontal lobe which indicated participants experienced cognitive recovery [12], supporting the use case of VR for treating mental illness. Even more generally, a Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) review on the effectiveness of VNEs on university students identified 25 articles from 2013 to 2025 and found that overall VNEs had a positive effect via inducing relaxation and improving psychological state, and multisensory environments were more consistent [18], though a challenge was the lack of consistency in design, methodology, measures, and considerations between studies, indicating a need for additional research on VNE design with the goal of creating a framework for studying future VNE applications.

One other fascinating application of VNEs is distraction from pain. An article on using VNEs during burn treatment did a within-subjects comparison where on study day one participants spent five minutes looking at VR nature, then nature image, then nature sounds. On day two, they spent five minutes with no intervention, then five minutes in VR. On day one, VR increased positive affect, and on day two, pain decreased and positive affect increased in VR. [21].

3 Virtual Nature Design Literature

VR nature design literature focuses on individual design aspects of the VNE, and research is limited across design aspects. For example, Goates et al. conducted a PRISMA review on papers from 2017 to 2024 specifically on visual elements unique to VNEs and whether they evoke the calm emotion, including lighting, color, material surfaces, and geometry. Only six papers related to geometry were identified, all mentioning the emotions of awe or calm. Only three papers related to lighting were identified, and two mentioned calm, and none mentioned shadows. Only two papers related to material surface were identified, discussing reflections and textures being linked to calm. Only two articles related to color and calm were identified, relating to values and tones. The review may be limited as it searches for "emotions" as a keyword with no variations like "affect" or "feeling"; however, the research itself is also limited [6]. The most expansive review on virtual nature and well-being identified 124 articles that illustrate that VNEs generally have a positive effect on well-being, but the literature itself had more limitations. Most studies offered passive experiences, few offered active experiences, and only one study compared the two design choices. Most nature environments were 360 video rather than 3D visualization, which leads to less control over individual design aspects. Furthermore, the review found that while many VNEs were designed for people with vastly different motivations, there was not consideration of those individual factors in the VNE design. The authors advocated that future work needs to consider what VR is capable of rather than simply trying to mimic real nature, incorporate more continuous measures, consider cultural differences, and reflect more real-world well-being needs in the research rather than isolated lab scenarios [2].

Beyond these review articles, a few research articles have explored nuanced design factors in VNEs. An eyetracking study ranked seven VR forest simulations with differing levels of brightness, exposing participants to each environment for 60 seconds in a random order. The authors found that passive unobtrusive interaction and saccade duration decreased when brightness increased, whereas fixation duration increased when brightness increased, all indicating that brighter environments increase alertness whereas darker environments decrease arousal. Moderate brightness was best for the State Trait Anxiety Inventory Short Form (STAI-S) and Perceived Restorativeness Scale (PRS), though short scene exposure time may limit results [11]. While this study investigates an underresearched topic, more work is needed to understand what defines "moderate brightness" in a VNE, as the brightness ratings were determined by expert opinion rather than varying lux levels in a controlled way. Additionally, much like brightness, multisensory stimulation can also have positive effects when implemented correctly, but further work is needed to investigate the incorporation of olfaction and tactile cues into VNEs since the technology has limited this research avenue in the past [16].

A few articles explored the nuanced design of green elements for restorative effect. As a baseline comparison, one article compared green and brown VNEs to understand if nature that is not green can be restorative. The authors did not find significant differences between the environments despite finding trends towards the green environment being more restorative, but the experiment was limited by cybersickeness, so more work is needed [14]. Meng et al. investigated differences between an urban park, semi-urban park, and nature area, finding that the natural area was significantly worse for positive affect and perceived restorativeness, though actual quantity of green elements were not controlled between environments [17], so more work is needed. Another article compared institutional, urban and residential areas with four different levels of biodiversity, finding that more biodiverse environments were perceived as more biodiverse, but the environments were also designed so that it was easy to tell which environment had more different green elements [22], so future investigation into controlled levels of biodiversity in forest environments are needed. Masters et al. compared biomass realism in VNEs (see Figure 1), interested in whether green elements could still be restorative if less realistic. The authors did not find a significant difference between high and

low realism despite trends towards high realism being preferred, so future work into realism is needed [15], specifically aiming to understand the mechanisms by which VR worlds can be restorative and if game-style worlds can also be restorative by similar or different mechanisms than nature simulations.

Nuanced waterscape design has also been a topic of interest. Liu et al. created ten water landscapes: control (only vegetation), circular pond, rectangular pond, irregular pond, water with birds, water with fish, water with aquatic plants, single-tier fountain, irregular waterfall, and multi-tier cascade environments. Overall, while there were significant differences observed using t-tests within an environment for some environments, there were no differences in the Kruskal–Wallis H test between environments, though some inconsistencies in results reporting, measuring heart rate with a watch rather than ECG, and lack of verification of stress test efficacy may affect results [13]. Another article created high fidelity images of the River Thames and Seine, using Random Forest models to analyze links between perceptive outcomes (affluence, vibrancy, scenic beauty, and sense of boredom) and design elements. The study found that affluence and vibrancy were affected by high building density and vertical enclosure, indicating that openness may not always be necessary. Scenic beauty was affected by High Green View Index combined with beautiful build elements like bridges. However, this study has limitations, including that participants evaluated 20 images in 20 minutes, images were evaluated with custom likert scale items rather than standard perceptive outcomes, and the heavy focus on UGS design rather than psychological effects [24]. Both studies indicate that with environment generation tools and artificial intelligence, future work can vary environmental factors more easily to allowed for controlled exploration of VNE elements.

4 Position: VNE Perception Needs More Granular Investigation

Overall, there are few articles related to VNE element design, and within the available literature, there is high variation in controls taken, measures used, results, and limitations. Given the limitations of the current literature and the relative newness of the field, further investigation is needed into several elements of VR design. Like the authors in [2] advocated for, research needs to understand what VR is actually capable of, how perception of VNEs differs from perception of real nature environments, and how individual differences contribute to perceptual differences that affect restorative outcomes.

4.1 Understanding VR Capability

Most current research aims to mimic real world nature environments then test those, but it is possible that doing so undervalues what VR offers. In many cases, mimicking real nature environments leads to VNEs that are heavyweight, run poorly on portable systems, and cause cybersickness. In many studies, cybersickness affects immersion in the environments, confounding the observation of restorative effects. Future work on VR's capabilities takes two main directions. First, VR gives researchers the opportunity to control for nuanced VNE design elements, such as quantity of rocks vs quantity of trees, or even how much moss is on one rock. Exploring these variables will enable researchers to design balanced VNEs that achieve the most restorative potential while also maintaining a reasonable level of computational complexity, and both of these aspects will be quantifiable based on the research. This will drive the future of VNE applications research because applications researchers will have the understanding necessary to craft ideal environments for their applications. Second, VR gives researchers the opportunity to simulate environments people cannot generally access, such as underwater or cave environments. There is limited understanding of the restorative potential of these environments, and future exploration is needed to determine the variety of VNEs that can be provided for mental health benefit.

4.2 Understanding Perceptual Differences in VR

Some elements of real nature are difficult or imposible to simulate in VR, such as microorganisms or air quality. Similarly, there are some things that are easy to simulate in VR that are difficult to implement in real nature, such as gamified interaction, low realism artistic environments, or even nature environments with plants of specific color tones that are not usually seen together, like an environment dominated by purple plants. Currently, it is not well understood how people perceive VR in the context of how they perceive reality. VR can mimic reality, but do people perceive that mimicry as close to reality or close to an artificial world. By investigating where VR exists perceptually on the spectrum of reality and digitality, we can better understand what design elements should be leveraged to create optimally restorative VNEs, as realism in VR may be closer to creating a convincing simulation that transports people to a new and immersive, different world than reality rather than simply trying to convince people that VR is the same as the real world.

4.3 Understanding Individual Differences in Perception

A variety of factors influence how people perceive the world around them. Gender, culture, socioeconomic status, upbringing, and even factors like the environment people grow up in and whether they were fond of it influence both their emotional reactions and perception of nature. Prior literature has done little to investigate these factors, and future work is needed to understand the individual participant's experience. Open response surveys are a good way to collect initial data on experience, and responses can help create informed questionnaires that are designed for each individual application group of interest. With this work, VNEs for mental health will be able to be readily created for the populations that need them most.

5 Conclusion

VNEs have shown great potential for the management of mental health via their stress reduction and attention restoration benefits. Having a research-informed understanding of how to design VNEs will enable future researchers to create intentional VNEs with nuanced design elements targeted towards their specific application. Additionally, further understanding of VNE design and how to conduct VNE research will allow for a more standardized model for conducting research that can be applied to reduce the variation in research approach and quality that currently exists in the literature. Further understanding of VNEs will also expose situations where VNEs should and should not be used, allowing for education of more general populations on how VNEs can be integrated as a supplement without negatively impacting or reducing interactions with real nature.

Figure Credits

Figure 1 image credit: Masters et al. from [15].

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