Repeated immersion in a virtual forest: stability of benefits across multiple sessions

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DOI: 10.54337/aau.icdvrat26.29

Abstract

Forest environments reliably reduce stress and improve mood, and virtual forests are proposed as an accessible substitute when the real ones are out of reach. Most evidence, however, comes from single sessions, often between-subjects, leaving the durability of the benefit across repeated use untested. In this feasibility study, 11 adults (3 men, 8 women) from a university community completed 5–10-minute immersions in the same photorealistic virtual forest, one per week for 5 consecutive weeks. Restoration (ROS), mood (POMS-SF), heart rate, blood pressure, and cybersickness (VRSQ) were recorded before and after each session. Linear mixed-effects models indicated that psychological benefits remained stable across the five weeks, however the heart-rate benefit was modestly attenuated. Cybersickness did not diminish the psychological benefits. The findings tentatively support that repeated short VR-forest exposure provides a stable well-being intervention.

1. Introduction

Spending time in forests is associated with reduced stress, improved mood, and increased subjective restoration (Kotera et al., 2022). When access to real forests is limited, virtual renderings of natural environments have been proposed as an alternative (Frost et al., 2022; Spano et al., 2023). A growing body of work shows that single virtual nature sessions can reduce negative affect and elicit a restorative effect, although such effects tend to be smaller than those of real nature exposure (Hejtmánek et al., 2022; Reese et al., 2022). Most of this evidence relies on single-session designs, often between-subjects. Whether the benefit of virtual nature exposure persists with repeated use is poorly documented. We can assume two competing predictions. On the one hand, the novelty and unfamiliarity of the virtual forest may build fascination and interest, as per attention restoration theory (Kaplan & Kaplan, 1989), thereby contributing to the observed effects. In this case, repeated exposure should produce a fading benefit. On the other hand, repeated exposures may build a stable dosing effect comparable to that reported for repeated outdoor walks (Browning et al., 2023). Recent reviews note that longitudinal designs in virtual nature research remain scarce and that most studies use exposures of five minutes or less (Bolouki, 2024). In our previous study (Hejtmánek et al., 2022), we showed that a 20-minute exposure to a digital twin of a real forest produced restorative gains and reductions in negative affect. Building on that work, the present study asks a different question: when participants are repeatedly immersed in the same virtual forest, do the within-session benefits remain stable, fade, or grow?

2. Methods

2.1. Participants

Twelve participants were recruited from the university community and participated for bonus credit. Only 11 (with complete pre- and post-session data for at least one session) were retained for analysis (3 men, 8 women;age range 20–25), as one participant did not return after the first session. The study followed the Declaration of Helsinki and was approved by the Institutional Review Board of the Institute of Psychology of the Czech Academy of Sciences.

2.2. Procedure

Participants completed five immersion sessions in the same virtual forest, scheduled every Wednesday for five consecutive weeks. Three participants missed one session, but their data were retained for the analyses. Sessions were administered in a quiet, windowless, temperature-controlled room on a university campus. At the beginning of each session, participants completed questionnaires, and the researcher collected physiological measures (see 2.3 Outcome measures). Then, they were seated on a camping chair within an approximately 4x4-meter space and given the Meta Quest 3s tethered head-mounted display (HMD). During the intervention, they could stand at any time and walk within the area, or remain seated, as they chose to mimic similar experiences in forest bathing practice. A researcher silently walked behind them, making sure they did not trip over furniture or the cable. The duration of the intervention was set to 10 minutes as a compromise between session lengths typical of VR-nature studies (often short, few-minute interventions) and longer real-forest bathing protocols, while keeping the sessions tolerable (30 minutes including all measurements). The virtual forest was the same environment used in our previous research (Hejtmánek et al., 2022. It was a digital twin of a Central European oak-hornbeam forest, reconstructed from LiDAR scans of tree positions and dimensions, with spatialized ambient audio recorded on location. After the session, participants' physiological measures were taken, and questionnaires were administered.

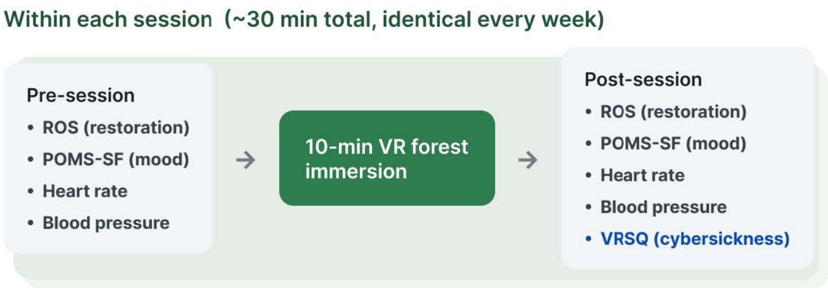

Figure 1: Session intervention overview. VRSQ was collected only post-session.

2.3. Outcome measures

Before and after each session, participants completed the Restoration Outcome Scale (ROS; Korpela et al., 2008) and the short form of the Profile of Mood States (POMS-SF; Curran et al., 1995), from which we derived six subscale scores (anger, confusion, depression, fatigue, tension, vitality) and a total mood disturbance score (TMD). Heart rate and systolic and diastolic blood pressure were recorded with OMRON Evolve. Additionally, after each session, participants completed the Simulator Sickness Questionnaire (Kennedy et al., 1993), from which we calculated VRSQ subscores (disorientation and oculomotor) (Kim et al., 2018).

2.4. Analysis

Analysis of the intervention's effect during the first session was conducted using a paired t-test comparing pre-and post-session scores for each individual outcome. While the sample was small and the Shapiro-Wilk tests showed violations of normality in many psychological outcomes, the physiological measures and some psychological measures demonstrated fairly normal distributions, and Wilcoxon paired tests showed no differences in significance in any outcome measure from the parametric one, we opted to use the paired t-test to simplify results communication. To analyze stability across sessions, we fitted a linear mixed-effects model with the difference between post- and pre-session scores as the dependent variable (denoted as Δ in the results below), session as the fixed effect, and participant as the random effect. We also fitted a moderation model with VRSQ to see whether simulator sickness affected the results. With n = 11, results should be treated as exploratory, and effect sizes with 95% confidence intervals should be emphasized over p-values.

3. Results

3.1. Within-session effects at the first session

Looking only at the very first session, immersion produced expected reductions in total mood disturbance (Δ = −7.27, 95% CI [−11.70, −2.85], p = .004), tension (Δ = −2.27 [−3.62, −0.93], p = .004), and fatigue (Δ = −3.55 [−5.82, −1.27], p = .006). Restoration showed a positive but non-significant change (ROS Δ = +3.73 [−0.54, +8.00], p = .080), as did POMS vitality (Δ = +0.27 [−0.53, +1.07], p = .465). Other psychological values showed expected reductions, albeit non-significant in anger (Δ = −0.27 [−0.59, +0.04], p = .082), depression (Δ = −0.36 [−0.98, +0.26], p = .221), and confusion (Δ = −0.55 [−2.06, +0.97], p = .441). Heart rate showed an expected reduction at the first session (Δ = −4.36 bpm, 95% CI [−8.55, −0.18], p = .043), as did systolic blood pressure (Δ = −5.91 mmHg [−11.57, −0.24], p = .042). Diastolic blood pressure showed reductions but did not reach significance (Δ = −1.09 mmHg [−5.65, +3.47], p = .606).

3.2. Stability across sessions

The slope of Δ in the session was indistinguishable from zero for all psychological outcomes (all 95% CIs straddled zero), suggesting neither fading nor improvement of the effect. However, the change in heart rate Δ across sessions was small and positive (+1.37 bpm per session, 95% CI [+0.24, +2.51], p = .019), indicating a modest attenuation and suggesting that the positive benefits observed in the initial session faded over time. Systolic and diastolic blood pressure showed no significant slope, although they also showed a slight increase over time. The overall evolution of the main scales is shown in Fig 2.

3.3. Cybersickness as a moderator

For psychological outcomes, cybersickness did not significantly moderate session benefits, neither for the first session, nor across all measurements, although effects were mostly in the expected direction (i.e., higher VRSQ scores reduced benefits). Specifically, both restoration (ROS, First session: β = −0.264, 95% CI [−0.638, +0.111], p = .146; All-sessions: β = -0.023 [−0.372, +0.327], p = .896) and total mood disturbance (TMD, First session: β = 0.213 [−0.621, +0.196], p = .269; All-sessions: β = 0.034 [−0.256, +0.187], p = .754) showed no moderation by VRSQ scores. All other psychological outcomes similarly yielded no moderation effects. For physiological outcomes during the first session, VRSQ scores did not significantly moderate improvements in heart rate (β = 0.212, 95% CI [−0.596, +0.171], p = .242), systolic blood pressure (β = -0.163, 95% CI [−0.385, +0.711], p = .519), or diastolic blood pressure (β = -0.087 95% CI [−0.361, +0.534], p = .671). Across all sessions, pooled within-person cybersickness did not significantly moderate heart rate (β = -0.137 [−0.165, +0.438], p = .366) or systolic blood pressure (β = 0.246 [−0.808, +0.316], p = .380). However, a significant moderation effect was found for diastolic blood pressure across all sessions (β = 0.311 [−0.574, −0.049], p = .022), indicating that higher-than-usual sickness was associated with significantly lesser physiological benefit during those sessions.

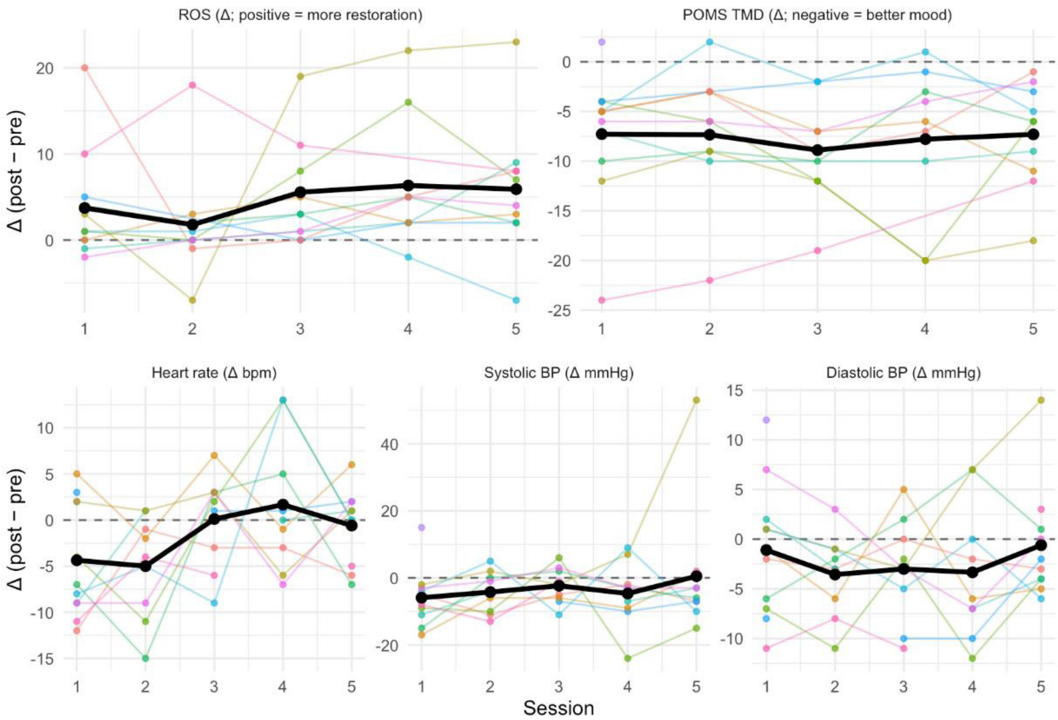

Figure 2: Evolution of the session benefits denominating pots– pre- session scores for the main outcome measures. Individual lines show participant trajectories, and the black line shows the general trend averaged across all participants.

4. Discussion

We observed first-session improvements in most psychological and physiological measures, although not all reached significance, and no detectable fading of these benefits across the five weeks, except for heart rate change, which increased in participants over the course of the study. However, in psychological measures, the change of the benefits across sessions was statistically indistinguishable from zero. Our limited data, therefore, do not show a significant attenuation of psychological benefits.

These findings support the use of repeated short VR-forest exposure as a simple well-being intervention. They also address a methodological concern raised in our previous work, in which individual responses to virtual and real forest exposure were only weakly correlated. Stability of the within-session benefit across sessions makes it less likely that the average effect of virtual nature is caused by a simple novelty response in a limited subset of participants.

Several limitations should, however, be considered. The sample (n = 11) is very small and may lead to false negatives for small attenuation effects. We omitted a control condition, so within-session change cannot be separated from rest or expectancy effects. Sessions were spaced one week apart, and we cannot speak to denser or sparser schedules. Replication with a larger sample and longer follow-up will be necessary as the next step.

Acknowledgements

This work was supported by the Cooperatio Program (research area PSYC) and by the Johannes Amos Comenius Program (PJAC) provided by MŠMT (reg. no. CZ.02.01.01/00/23_025/0008715)

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