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Into the wild . . . or not: Virtual nature experiences benefit well-being regardless of human-made structures in nature

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Immersive nature experiences increase human well-being. There is now an increasing number of studies suggesting that virtual nature experiences—e.g., within a virtual reality (VR) environment—can evoke comparable benefits. In the current study using VR, we tested whether human-made structures within nature settings hinder such effects of virtual nature experience on well-being. To do so, 67 participants were led through a VR nature surrounding that was either wild and untouched by humans, or was characterized by few inconspicuous human structures (i.e., paths, buildings, walls, bridges). Before and after the intervention, we measured subjective vitality and after the intervention, we assessed perceived restorative outcome as two indicators of well-being. Results revealed that both virtual nature experiences improved participants' subjective vitality. Across both groups, participants reported relatively high—and similar—levels of restoration. These findings suggest that (virtual) nature experiences can be beneficial for well-being even when human-made structures interfere. Thus, irrespective of how pristine the environment is, the beneficial effects of immersive VR nature experiences provide opportunities for well-being when physical nature is inaccessible.

KEYWORDS

virtual reality, well-being, restoration, vitality, urban nature, nature

1 Introduction

Nature experiences promote human health (e.g., Hartig et al., 2014). On an individual level, people reported and showed physiological as well as psychological benefits when they stayed in nature surroundings (for reviews, see Berman et al., 2008; Bratman et al., 2019; Hartig et al., 2014; M. Kuo, 2015; for a meta-analysis, see Menardo et al., 2019). For example, Ryan et al. (2010) showed in a multimethod approach (using vignettes, physical outdoor experiences and diary writing) that nature experiences increased participants' subjective vitality. In a qualitative study, Shrestha and colleagues (2021) showed that students reported being more energetic and self-aware when they walked through a natural rather than urban university campus setting. On a higher level of abstraction, societies as a whole also seem to benefit when citizens spend time in natural environments. For example, previous studies suggest that the amount of green space was associated with lower spending for medical care (Becker et al., 2019) and lower rates of aggression (F. E. Kuo & Sullivan, 2001). The benefits of nature for human well-being are thus uncontested.

With its possibility to design and experimentally control immersive nature exposure, Virtual Reality (VR) research can be helpful to underscore the conditions under which real and virtual natural environments increase human well-being (for a direct comparison between virtual and physical natural environment, see Reese et al., 2022; Browning et al., 2020). We are unaware of previous research testing whether human-made structures in nature affect the beneficial outcomes of nature. This question has practical implications because evidently, for most people, pristine nature is out of reach, with only less than three percent of earth's terrestrial surface providing untouched environments (Plumptre et al., 2021). Yet, even natural environments with human-made structures may be inaccessible for many. We deem it imperative to understand the effectiveness of virtual nature experiences on well-being, as these virtual experiences allow controlled experimental variation of potentially benefitting (or hampering) conditions. In the current study, whether a short VR nature intervention increased peoples' well-being, and whether human-made structures in the landscape make a difference for well-being.

Nature experiences and well-being

The World Health Organization (WHO) defines health as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (as is delineated in the first principle of the Preamble to the WHO Constitution; Grad, 2002). Thus, well-being that we focus on in this work is an important part of health. It is characterized by affective and cognitive components (Bratman et al., 2019). Theories addressing the benefits of nature for well-being often focus on subjective restoration (Menardo et al., 2019), stress reduction (Ulrich et al., 1991; Kondo et al., 2018a), affect changes (McMahan and Estes, 2015), and improvement of cognitive functioning (i.e., in terms of attention and memory capacity; Kaplan, 1995; Stevenson et al., 2018). In the current experiment, we follow these theories and assess restoration and subjective vitality as indicators of well-being.

According to two major theories in the field, the mental benefits resulting from nature experiences can be explained with both cognitive and affective explanations. Attention restoration theory (ART; Kaplan, 1995) focuses on cognitive dimensions, and claims that voluntary attention (i.e., attention directed to specific events, tasks, surroundings) depletes in urban environments or by conducting cognitively demanding (everyday) tasks. Once depleted, these attentional resources could be restored in natural environments. According to Kaplan (1995), this restoration derives from feelings of fascination, being-away, coherence, and compatibility that are inherent to natural surroundings.

The other influential theory—stress reduction theory (SRT, Ulrich et al., 1991)—argues that natural environments influence affective states and therefore facilitate recovering from stressors: Nature comprises of elements and structures that increase positive affect, which in turn improves well-being. Both theories—ART and SRT—received supporting research, both in real-life settings as well as in virtual nature settings (through VR, videos, or pictures; e.g., Brown et al., 2013; Gladwell et al., 2012; Valtchanov & Ellard, 2010; for meta-analyses on various aspects of restoration, see Menardo et al., 2019; Ohly et al., 2016; Stevenson et al., 2018; but see Johnson et al., 2021, for mixed evidence regarding cognitive performance). The beneficial effects of virtual nature are fascinating, as these virtual nature experiences—unlike physical nature experiences—usually lack natural odors, a more beneficial air composition, and a natural terrain underfoot (Alvarsson et al., 2010; Franco et al., 2017; Kuo, 2015). Thus, the visual input seems sufficient to evoke restoration effects, and thereby associations with nature seem particularly important (see Menzel & Reese, 2021, 2022; Egner et al., 2020).

Virtual nature and well-being

There is ample evidence that immersive VR nature experiences can reduce pain, stress, negative affect, heart rate, and blood pressure while at the same time, they can increase restoration, vitality, and positive affect (Anderson et al., 2017; Tanja-Dijkstra et al., 2018; Yu, Lee, & Luo, 2018; see; Browning et al., 2019; Hedblom et al., 2019; Mattila et al., 2020; Brivio et al., 2021; Reese et al., 2021, 2022; Frost et al., 2022). A study by Scates et al. (2020) even suggests beneficial effects on patients' well-being in the context of cancer treatment, as a VR nature experience can distract patients, reduce their frustration, increase relaxation, and induce a feeling of peace.

Comparing the effectiveness of VR nature experiences with physical nature experiences, a meta-analysis on six studies (Browning et al., 2020) found that positive affect increased more strongly after a physical compared to a virtual nature experience; for negative affect, there was no significant difference observed. However, all reviewed studies were limited to people watching videos or pictures, rather than guiding them through an environment. Recent work directly comparing a VR and a physical nature walk provided evidence that VR nature experiences can have similarly strong effects on well-being outcomes than physical nature experiences: For example, Reese and colleagues (2022) experimentally varied whether participants conducted a physical nature walk or a VR nature walk. The VR nature walk was constructed to match the physical environment as closely as possible. Results suggested that the VR experience was similarly effective in improving well-being compared to the physical nature experience (Reese et al., 2022). However, corroborating the meta-analysis by Browning and colleagues (2020), several effects in the study by Reese et al. (2022) were slightly (yet non-significantly) stronger in the physical condition. In another study, Mattila and colleagues (2020) asked participants to explore a VR environment for five minutes. Following this brief intervention, participants reported better well-being (indicated through stronger restoration and vitality) as well as more positive affect than before. The authors could compare their results with data from another study assessing responses after visiting a physical forest (Hauru et al., 2012), suggesting that the VR environment was seen as equally restorative as a comparable physical forest, yet even more fascinating and coherent. It is likely that the high degree of realism that highly powered virtual environments allow contributes to the effectiveness of such interventions (Newman et al., 2022). Taken together, findings suggest that VR nature experiences can evoke well-being benefits that resemble those of real nature.

Effects of human-made structures in nature on well-being

The goal of this experiment was to test whether a short VR nature intervention increased peoples' well-being, and whether human-made structures in the landscape make a difference for well-being. Previous work highlights that the dichotomy of "nature" vs. "city" applied in many studies assessing the well-being benefits of nature may not always be useful (Staats et al., 2016; Weber & Trojan, 2018). Most natural spaces in densely populated countries, in particular in urban areas, are characterized by human structures. In fact, many studies on restoring effects of nature were conducted in urban green spaces such as parks (Kondo et al., 2018b; Mygind et al., 2021; Mygind et al., 2019). In how far human-made structures influence nature-based health benefits remains to be answered, and the current study seeks to provide first empirical evidence. We expected that a natural environment without human-made structures would increase well-being more than the environment with human-made structures because built elements are typically associated with negativity (such as stress, noise, crowding; Egner et al., 2020; Menzel & Reese, 2021). Also, built elements alter visual properties of a scene and therefore influence processing fluency, which is discussed to be related to restorativeness (Joye & van den Berg, 2011) and discomfort in urban environments (Wilkins et al., 2018). Furthermore, previous studies suggest that managed nature seems to be less preferred than wild nature (Van den Berg and Koole, 2006). Moreover, human-made structures may reduce feelings of coherence, fascination, or being carried away (cf. Kaplan, 1995), because they (primarily) serve humans by providing shelter (e.g., walls, huts) or enable to trespass natural structures (e.g., bridges, paths).

However, one could argue that human-made structures do not hamper the beneficial effects of nature. For example, people may perceive human structures in nature as compatible with their goals (e.g., hiking over paths or seeking shelter for lunch). As Kaplan (1995) argued, "the setting must fit what one is trying to do and what one would like to do" (p. 173). Also, people in highly industrialized countries (who are often representing the samples of previous studies) are hardly confronted with untouched nature so that managed nature with human-made structures could represent the "preferred places" for everyday restoration (Korpela et al., 2008). Taken together, while there is evidence for both hampering and benefitting effects of human-made structures in nature, we deem the evidence for hampering effects as more convincing. The current research may thus contribute to recent theoretical advances in understanding how various levels of nature characteristics affect the quality of well-being. It may also represent a starting point for understanding the conditions in VR that are particularly effective, complementing work on the types and extent of physical nature relevant for human well-being (Ekkel & de Vries, 2017). Specifically, the current experiment set out to provide a first test on whether human influence within nature affects well-being.

The present research

We conducted a VR-experiment with two different virtual nature settings: wild nature and nature with human-made structures. Based on the arguments developed above, we tested the following two hypotheses:

(1) In both the "wild nature" and "nature with human-made structures" VR environments, participants report higher subjective vitality after compared to before the intervention.
(2) The effect in (1) is more pronounced in the "wild nature" condition.
(3) Participants in the "wild nature" condition report higher levels of restoration than those in the "nature with human-made structures" condition.

We used subjective vitality and restoration as indicators of well-being. Subjective vitality (Ryan & Frederick, 1997) is seen as an eudaimonic construct that refers to experiences and feelings of having energy and vigor, and thereby reflecting intrinsic well-being (Shreshta et al., 2021). Vitality enables individuals to actively seek purposive actions, and it covaries with physical conditions (such as brain activation; see Barrett et al., 2004), so that it can be seen as a valid measure of well-being (Ryan and Frederick, 1997). Restoration was used, because it has been proved to be highly suitable for measuring perceived change in psychophysiological and mental restoration (Han, 2018). Both measures were successfully implemented in previous VR studies (e.g., Mattila et al., 2020; Reese et al., 2021, 2022; for a review, see Browning et al., 2020). For exploratory reasons, we assessed motion sickness among participants. We expect no differences in motion sickness across conditions, but previous studies suggested that motion sickness can reduce well-being effects of virtual nature experiences (e.g., Reese et al., 2022).

2 Materials and methods

Design and instruments

In order to test our hypotheses, we used a 2(Condition: Wild VR nature vs. human-structure VR nature) × 2(Time: before vs. after) experimental design, with between variation on the first factor. We used the following measures to test our hypotheses: subjective vitality, measured before (t1) and after (t2) the intervention and restoration measured after the VR experience.

Subjective vitality

A feeling of energy and liveliness was measured with the Subjective Vitality Scale (SVS; Ryan & Frederick, 1997; German version by Bertrams et al., 2020; sample item: "I feel energized right now"). It consists of six items measured on a 6-point-Likert-type scale (from 1—I fully disagree to 6—I fully agree; $\alpha_{t1} = 0.75$, $\alpha_{t2} = 0.90$).

Restoration

We measured restoration as the subjectively experienced reduction of stress with the restoration outcome scale (ROS), adapted to the VR setting (Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008; Sample item: "My concentration and alertness clearly increased after the VR experience"). Using a 6-point-Likert-type scale (from 1—I fully disagree to 6—I fully agree); the scale was reliable ($\alpha = 0.89$).

Demographic information

We asked participants to indicate their gender, age, formal education, study major, and where they grew up. In addition, we asked them whether they experienced motion sickness during the intervention (yes vs. no). For a research question unrelated to the current study, we also assessed, but do not report here, participants' "universalism" and "power" value orientations and political orientation, and whether they grew up and lived in rather rural or urban settings.

Sample and procedure

Sample

Sixty-seven participants (52 female, 15 male, $M_{age} = 22.8$ years, $SD_{age} = 6.2$), 82% of them students from different study programs, were recruited *via* messenger services and social network sites as well as on-campus of the research facility. Participants aged 18 or older without glasses or impaired, uncorrected vision could participat. The study was conducted in January and February 2019. Twenty-two participants reported feelings of motion sickness. We provide analyses of motion sickness in the exploratory results section.

Virtual reality setup

The study was conducted in the departments' VR lab, which is a quiet closed room with artificial light. A high-performance PC with a Zotac GeForce GTX 1080 graphics card (8 GB RAM) and an Intel i7-7700K main processor with 4 GHz and 16 GB RAM, running with Windows 10, was used with an OculusRift head-mounted-display with its two-hand controlling device and sensors. The nature environments presented were selected from the commercial software "Nature Trek VR" (Greener Games, 2019) that provides a range of natural environments. For this study, we selected the "Green Meadows" environment that resembles a wild nature setting, and the "Green Bamboo" environment that resembles a nature setting with some human made structures (see Figures 1A-F, respectively). Both nature environments represent wide open natural spaces, with a variety of trees, meadows, and rocks, and with visible mountain scenery in the background. The main difference between both environments refers to the depiction of human-made structures. In the Green Meadows environment, no human impact is visible, while in the Green Bamboo environment, paths, walls, a bridge and a building are visible during the walk.

The experimenter set up the VR display together with the participant to ensure comfort and sharpness of the application. Any sound effects, including music, were muted. Participants were told that the experimenter would lead them through the scenery for around five minutes. Participants in both conditions were seated throughout the intervention. The path was the same for all participants, but they could move their heads freely to look around while the experimenter led them through the landscape. After giving the participants the opportunity to familiarize with the setting and environment for around 30 s, the guided five minute walk through the environment started.

Procedure

The study was advertised as a study including "a virtual walk through nature". They were randomly assigned to either the "wild nature" condition or the "nature with human-structures" condition, resulting in 32 participants in the former and 35 participants in the latter condition. Participants met the experimenter on campus and learned that they were going to the VR lab for a "short Virtual Reality nature walk". They were

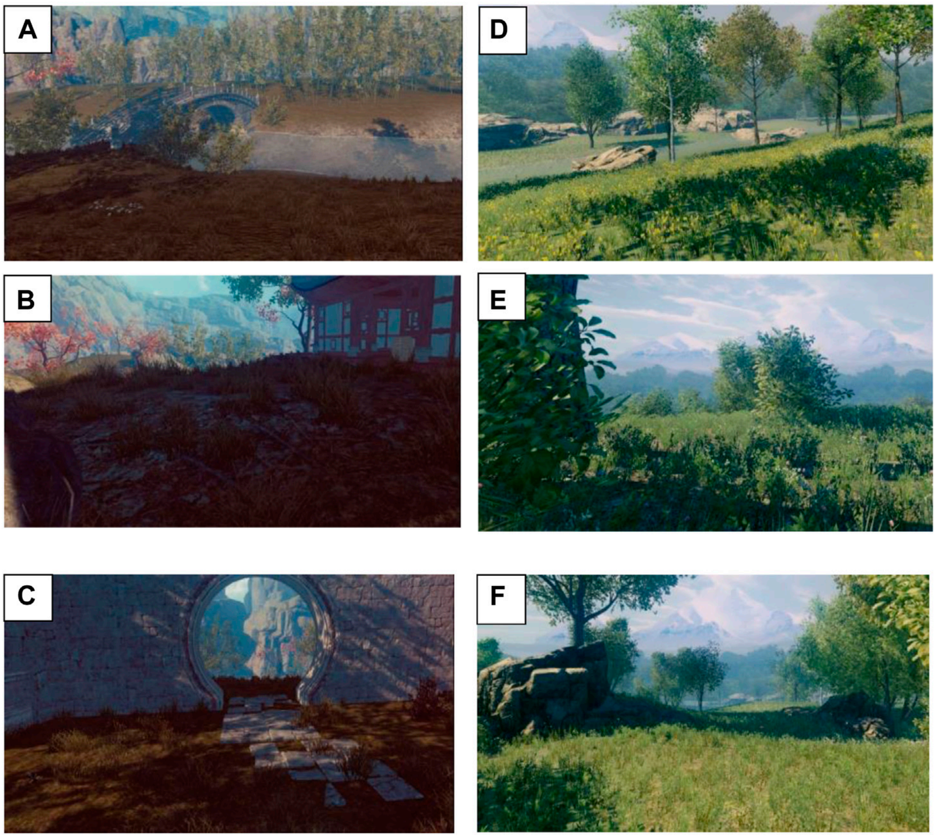

FIGURE 1
Screenshots of virtual environments "Green Bamboo" **(A–C)** and "Green Meadow" **(D–F)**. ©NatureTrek VR/Greener Games. Displayed with permission.

TABLE 1 Descriptive statistics of the outcome variables (*N* = 67).

Nature environment

Measure	Wild		Human-structures	
	M	SD	M	SD
Subjective vitality t1	4.05	0.83	3.82	0.97
Subjective vitality t2	4.61	0.86	4.35	1.03
Restoration outcome	4.65	0.84	4.51	1.04

explicitly told that they could withdraw at any time if they desired, but all participants remained in the study. Before either intervention started, participants were briefed, signed a consent form, and filled in a questionnaire (t1) that included the measure of subjective vitality. Subsequently, the VR intervention was conducted. After the intervention, participants again filled in the subjective vitality (t2) questionnaire, as well as the restoration outcome scale, an item on experienced motion sickness (i.e., "Did you experience motion sickness during the VR experience? Response option: Yes vs. No"), and demographic variables. At the end, participants were thanked, debriefed, and received course credit when desired.

3 Results

Means (*M*) and standard deviations (*SD*) of the main study variables are displayed in Table 1.

Effects of wild and human-modified virtual reality nature experience on subjective vitality

Using a 2 × 2 ANOVA with time as within-subjects factor and environment (wild vs. with human-made structures) as between-subjects factor revealed a significant effect of time, $F(1, 65) = 80.13$, $p < 0.001$, $\eta^2_p = 0.55$. Across both conditions, participants reported higher subjective vitality after the VR experience (M = 4.48, SD = 0.95) than before the VR experience (M = 3.93, SD = 0.91). There was no main effect of environment, F (1, 65) = 1.22, p = 0.273, η^2_p = 0.02, and no significant interaction, $F < 1$, p = 0.750, $\eta^2_p < 0.01$.

Effects of wild and human-modified virtual reality nature experience on restoration

To test the difference between wild and human-modified VR nature experience, we submitted the ROS score to a t-test for independent samples. There was no significant effect between the groups, $t < 1$, $p = 0.54$, $d = 0.15$. ROS scores were similar between the "wild nature" (M = 4.65, SD = 0.84) and the "nature with human-made structures" (M = 4.51, SD = 1.04) conditions. In both conditions, the ROS score was significantly above the scale mean of $M_{scale} = 3.5$ ($t\,[31]_{\text{wild}} = 7.79$, $p < 001$, and $t\,[34]_{\text{modified}} = 5.77$, $p < 0.001$).

Explorative analysis: Effects of motion sickness

In order to test whether motion sickness affected the effectiveness of the VR intervention, we compared the t2 subjective vitality score and the ROS score between those participants who experienced motion sickness (n = 22) and those who did not (n = 45). Results revealed that there was no significant difference between both groups, both with regard to ROS ($M_{\text{motion sickness}} = 4.45$, $SD = 0.78$; $M_{\text{No motion sickness}} = 4.65$, $SD = 1.02$), $t < 1$, and with regard to subjective vitality at t2 ($M_{\text{motion sickness}} = 4.34$, $SD = 0.99$; $M_{\text{No motion sickness}} = 4.54$, $SD = 0.94$), $t < 1$.

4 Discussion

The reported study supports previous research showing that VR nature experiences can increase well-being. The increase in subjective vitality as well as evoked restoration were similar for both VR environments that primarily differed in the visibility of human-made structure. Thus, regardless of whether participants saw human influence within nature or not, the virtual reality nature experience had a positive effect on participants' well-being, corroborating to Hypothesis 1. The relatively high levels of restoration that were significantly above the scale mean and comparable in size to previous studies using VR and comparing it to real nature (e.g., Mattila et al., 2020; Reese et al., 2021, 2022) emphasize the restorative value VR nature exposure can provide. However, rejecting Hypotheses 2 and 3, there was no difference between the conditions with regard to subjective vitality and restoration. Thus, overall, this study suggests that VR nature experiences may be an appropriate path to increase well-being—regardless of human-made structures—for people who cannot visit real nature for whatever reason, resonating with previous studies (Chirico & Gaggioli, 2019; Mattila et al., 2020; Reese et al., 2022).

The current experiment suggests that it does not really make a difference, at least in the current setting, whether natural VR environments include human-made structures or not. As we argued above, it is likely that people see human-made structures as compatible with their (restoration) goals. Furthermore, they may be signals of safety for people mainly growing up in urban settings. In a post-hoc analysis comparing participants grown up in rural settings with those in more urban settings, however, we did not find any clue that this plays a role. Possibly, because growing up rurally in Germany also means being constantly surrounded by human-made structures. Anyhow, as intended, the human-modified condition still represented a natural environment, and therefore, associations evoked by natural environments (likely shaped by previous experiences in such environments) may be similar for both conditions—regardless of interspersed human-made structures. As such, for landscape planners this result is useful as it suggests that human-made elements within urban park or forest surroundings may not be detrimental to the goal of restoration.

As we did not find a significant difference between both conditions, our results suggest that other factors, such as visual appeal of the natural environment or specific needs for restoration, (additionally) affect how people respond to nature with human-made structures (Twedt et al., 2019; see also Allard-Poesi et al., 2022). Future studies should systematically vary quality and quantity of human-made structures in natural environments to study under which conditions human structures may hinder (or even facilitate) well-being, and thereby provide valuable information for urban and landscape planners.

A limitation of the current study refers to the comparability of the two landscapes used. Although we believe that both virtual environments were very similar in terms of visual appearance, content, and number of natural elements, it is possible that one might have led to more intense feelings of being away or other relevant differences. For example, the colors in the nature setting with human-made structures were somewhat more muted than the saturated green colors of the wild environment. In fact, it would have been informative to assess the perceived restorativeness (Hartig et al., 1997) of both environments to gain insights into potential processes underlying the benefitial well-being effect (e.g., evoked feelings of being away). In addition, future research could address in how far different natural environments and depictions in VR or in augmented reality motivate people to act in favor of such places (e.g., Blythe et al., 2021; Dunn et al., 2021; Silk et al., 2021). For example, while our study provides a first step towards understanding potential differences between more pristine versus more man-made natural settings, we suggest that future research systematically varies the extent and amount of man-made structures. Natural scenes share characteristics, including measures of fractality, that are likely altered by human-made structures (e.g., Braun et al., 2013; Menzel & Reese, 2021). Although it is suggested that differences in such characteristics are associated with restorativeness (Joye & van den Berg, 2011), evidence is scarce (Menzel & Reese, 2021, 2022). To address such gaps in the literature, researchers could use custom-built virtual surroundings (as in Mattila et al., 2020, or Reese et al., 2022) rather than existing and only proximating environments, and distribute low, medium or high numbers of human-made structures within the visible natural environment. A more rigorous setting would also allow to compare these with a control group (e.g., an urban setting or indoor environment) without any indication of nature. In fact, this may allow developing a continuum perspective that more explicitly delineates the mechanisms that link (urban) nature to well-being (cf. Marselle et al., 2021, for a discussion about the role of different levels of biodiversity for well-being; see also Ekkel & de Vries, 2017).

Another limitation of the current experiment is the relatively homogeneous sample of young, educated participants. It is likely that these "digital natives" are more prone and used to computer-mediated interventions so that future research on the effects of virtual nature exposure on well-being should implement more diverse samples. However, other studies in the field with more age-diverse samples come to very similar conclusions regarding the effectiveness of VR nature interventions (see for example Tanja-Dijkstra et al., 2018, Study 2). Also related to the sample, statistical power is often a problem in VR studies (for a brief overview on samples sizes, see Browning et al., 2020; Reese et al., 2022). In the current study, the achieved statistical power (post-hoc) of the subjective vitality effect from t1 to t2 was $1\text{-}\beta > 0.95$; for the between-subjects effect on restoration, it was $1\text{-}\beta = 0.09$. As a consequence, between-subjects effects, in VR studies, should be treated with caution and further investigated in future studies. However, we would like to note that VR research as well as other resource intensive research setups often require a balance between samples size and feasibility.

Finally, we suggest that future research more closely inspects the role of motion sickness (e.g., Dziuda, Biernacki, Baran, & Truszszynski, 2014; Kim, Park, Choi & Choe, 2018) with regard to restoration effects, although in our current study no negative influence was found (but caution is needed due to the exploratory character of our analysis). A recent study by Reese and colleagues (2022), however, suggests that a lack of motion sickness may amplify restoration effects (as do the descriptive statistics in the current study). Therefore, it would be helpful when motion sickness can be reduced in future applications.

Taken together, the current experiment set out to test whether human-made structures within nature environments can hamper well-being outcomes. Apparently, they do not, and thus experiences in nature—both in physical and virtual—can be means to help people increase their well-being, regardless of subtle human influence.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

All authors consented to the submission and publication of this manuscript. GR—Conceptualization, methodology, formal analysis, data curation, writing (original draft, review, editing), visualization, project administration; MM—Investigation, formal analysis, data curation, writing (editing); IN—Investigation, formal analysis, data curation, writing (editing); JS—Investigation, formal analysis, data curation, writing (editing); CM—Formal analysis, writing (original draft, editing, review).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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