Perspective-taking in digital nature: Deepening the understanding of the effects of spacious and

dense environments combined with perspective-taking in a digital setting.

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Abstract

This study investigates the effects of digital nature exposure on mental well-being, focusing on the interplay between spatial characteristics (spacious vs. dense) and engagement (perspective-taking vs. mere exposure) in digital environments. Using a 2x2 factorial design, 160 participants were exposed to digitally simulated landscapes and evaluated for outcomes such as connectedness, stress reduction, environmental appreciation, anxiety, selflessness, positive affect, immersion, and perceived body boundaries. Results revealed that spacious environments significantly increased positive affect and decreased anxiety. While the perspective-taking exercise did not directly enhance connectedness or positive affect, it facilitated a reduction in perceived body boundaries, promoting a sense of unity with the environment. Mediation analyses indicated that perceived body boundaries mediated the effects of spaciousness on selflessness, anxiety and positive affect, underscoring the importance of embodiment in digital nature experiences. These findings provide insights for designing therapeutic and organizational digital environments, highlighting digital nature's potential to support mental well-being and psychological immersion.

Keywords: Digital Nature, Mental Well-being, Spaciousness, Perspective-taking, Body Boundaries

Introduction

In an era marked by the presence of digital technologies, individuals find themselves increasingly immersed in digital landscapes, often at the expense of their engagement with the natural world. The rapid advancement of technology has led to profound shifts in societal dynamics, with individuals becoming more inactive and disconnected from the physical environment (Cacioppo et al., 2017; Qualter et al., 2015). Consequently, concerns have been raised regarding the impact of this digital society on the mental well-being and connectedness of young adults, resulting in symptoms of self-centeredness, excessive worrying, and stress (Bratman et al., 2015; Kelly et al., 2018; Patalay & Gage, 2019). The increasing prevalence of mental health problems has surged in recent years, underscoring the urgent need to explore interventions that foster mental resilience and connectedness.

One promising avenue for addressing these concerns lies in the realm of environmental design, specifically through nature nudging. Studies have suggested that exposure to natural environments can promote a sense of connectedness to the world, which fosters positive affect and selflessness (van Rompay et al., 2023). Building upon this foundation, researchers have sought to unravel the mechanisms through which environmental cues influence human cognition and behavior, though oftentimes using mere exposure to pictures as the approach (Hartig et al., 2011; Li et al., 2021; Riches et al., 2023; van Rompay et al., 2023; Yin et al., 2022).

Mindfulness stems from ancient traditions and has garnered increasing attention in contemporary research for its potential to enhance mental well-being. Defined as 'the awareness that emerges through paying attention on purpose, in the present moment, and without judgment', mindfulness practices have been linked to reductions in stress, improvements in emotional regulation, and heightened levels of self-awareness (Kabat-Zinn, 2003). However, an additional active approach, such as perspective-taking exercises, may further deepen this engagement with natural environments. Van Gordon et al. (2018) depict this construct as 'mindfulness-enhanced nature connectedness', which emphasizes actively engaging with nature rather than passively observing it. Perspective-taking exercises involve adopting different viewpoints to heighten awareness and connection with the environment. Current research on this topic shows that this more active approach to engaging with the natural world, particularly through sensory immersion and direct interaction, yields greater levels of

nature connectedness and subsequent enhancements in well-being (Richardson et al., 2022). For instance, Zappalà (2014) emphasizes the importance of active participation and perspective-taking in workplace environments, suggesting that these techniques can heighten awareness and connectedness. Edwards et al. (2017) further demonstrate how perspective-taking exercises can alter implicit associations and enhance relational understanding, increasing the effectiveness of environmental cues. Yet, there remains a gap in understanding how digital nature experiences, combined with mindfulness and perspective-taking, influence connectedness and mental well-being. Given the growing role of digital environments in daily life and the potential to replicate natural benefits in digital settings, this study explores how digital nature may offer a practical alternative for those unable to access real nature.

Thus, this study seeks to address this gap by investigating the impact of perspective-taking on individuals' experiences of digital nature and how mindfulness comes into play. Drawing upon research testifying to the importance of spaciousness, this study aims to extend this line of inquiry by introducing a perspective-taking exercise as a potential moderator of these effects. Specifically, I hypothesize that individuals who engage in the perspective-taking exercise while immersed in digital natural environments will report greater levels of connectedness and mental well-being compared to those who do not receive such interventions. Arguably, the positive effects found for perspective-taking in previous research are more pronounced when participants engage in spacious nature rather than dense nature.

2. Nature interaction and the state of mind

Human interaction with nature has long been recognized as a profound influence on mental well-being (Ulrich et al., 1991). Nature possesses a unique ability to captivate the human mind, evoking feelings of tranquility, awe, and connectedness (van Rompay et al., 2023). Exposure to natural environments has been associated with a myriad of beneficial outcomes such as, stress reduction, improved mood, and enhanced cognitive function (Hartig et al., 2011; Li et al., 2021; Riches et al., 2023; van Rompay et al., 2023; Yin et al., 2022). Moreover, the restorative components of nature experiences have been well-documented, highlighting its capacity to replenish cognitive resources and alleviate mental fatigue (Kaplan, 1995). Central to this framework is the concept of Attention Restoration Theory (ART) and feelings of awe, which underscores the importance of expansive natural landscapes in fostering feelings of openness and connectedness (Gatersleben & Andrews, 2013; Herzog & Kropscott, 2004; van Rompay & Jol, 2016; Yaden et al., 2019).

2.1 The connection between nature and mental health

Research exploring the connection between nature and mental health has underscored the restorative properties of natural environments. Kaplan's Attention Restoration Theory (ART) posits that replenishing of cognitive resources can come from exposure to nature, leading to improved attentional capacity and reduced stress levels (Kaplan & Kaplan, 1989 as cited in Van Rompay et al., 2023). ART is recognized as the leading theory in research examining the interaction between people and environments. It not only recognizes the value of dense and spaciousness as spatial properties that stimulate a sense of extent, but also how it impacts restorative nature experiences that are conducive to mental health (van Rompay et al., 2023). This sense of vastness and awe has been identified as critical in improving mental well-being (Gatersleben & Andrews, 2013; Herzog & Kutzli, 2002). Moreover, studies have shown that both real-world and digital nature environments can evoke similar mental health benefits, offering an accessible alternative for our increasingly digital lifestyles (Chirico & Gaggioli, 2021; van Houwelingen-Snippe, van Rompay, & Ben Allouch, 2020; van Houwelingen-Snippe, van Rompay, de Jong, et al., 2020).

Furthermore, exposure to nature has emerged as an approach with a myriad of benefits on one's mental health. Berman et al. (2008) conducted experiments comparing the impact of physical exposure to nature with exposure to natural elements through pictures showing that both improve directed-attention abilities. Extending this, Chirico & Gaggioli (2021) revealed that emotions elicited by exposure to virtual nature (VR) and real-life nature conditions did not significantly differ, suggesting that digital nature can come a long way in potentially replicating the effects of real-life nature. The results indicated that nature exposure, irrespective of its form, selectively improved attention if the participants can immerse themselves in the simulations. Nature nudging emphasizes the deliberate design of environments to encourage interaction with nature, thereby promoting mental well-being(Hartig et al., 2011; Li et al., 2021; van Houwelingen-Snippe, van Rompay, & Ben Allouch, 2020; van Rompay et al., 2023).

The concept of spaciousness was considered as a crucial component within the Stress Recovery Theory framework, according to the framework it is suggested that spaciousness (also referred to as 'depth') influences both the immediate reaction to an environment as well as the following process of cognitive appraisal (Ulrich, 1983). Spaciousness, as investigated by van Rompay et al. (2023), represents an important factor of nature nudging, with expansive natural landscapes facilitating feelings of awe. For this study, the term spaciousness encompasses open landscapes and is put in contrast to dense landscapes. This factor is implicated by altering the amount of tree density.

2.2 Awe and the Connected Self

Awe, characterized by feelings of wonder and reverence in the face of something vast and transcendent, has emerged as significant mechanism for mental health promotion (Cohen et al., 2010; Keltner & Haidt, 2003; Shiota et al., 2007).Van Rompay et al. (2023) state that one significant advantage of human-environment interaction for mental well-being may be associated with the capacity of environmental contexts to mitigate the perception of the 'self' as an isolated entity disconnected from the external world. In their study they focus on the sense of 'awe' which is defined as 'a sense of being in the presence of something greater than oneself' (van Rompay et al., 2023).

Research consistently shows that awe can diminish self-focus and enhance social connection (Keltner & Haidt, 2003; Yaden et al., 2019). Other studies show that the feeling of awe creates a positive effect on prosocial and pro-environmental behaviors and attitudes. For example, Piff et al. (2015) conducted a series of experiments demonstrating that awe can lead to increased prosocial behaviors such as generosity, helping, and ethical decision-making. In their research, participants who were induced to feel awe by viewing videos of nature, experiencing live scenarios, or recalling awe-inducing experiences were more likely to exhibit behaviors that benefit others, such as offering help or sharing resources, compared to participants who experienced more neutral emotions. This suggests that awe diminishes the focus on the self and expands individuals' attention towards others and the larger community, fostering a greater sense of social connection and responsibility. Chirico & Gaggioli (2021) demonstrated the profound effects of awe on mental well-being, highlighting its potential to foster feelings of interconnectedness and purpose. By eliciting a sense of humility and perspective, awe experiences can transcend the boundaries of the self, leading to greater feelings of connectedness with others and the natural world. However, awe, selflessness, and connectedness might also be explained by simulations of more common nature settings as shown in van Houwelingen-Snippe, van Rompay, de Jong, et al. (2020). They compared awe-inducing environments with fairly normal nature settings and found that while both types of environments enhanced feelings of connectedness and well-being, awe-inducing environments had a stronger impact on promoting self-transcendence and reducing self-focused attention. These environments, characterized by their vastness and beauty, not only captivated participants but also led to greater prosocial behaviors compared to more typical natural settings. This distinction highlights the unique role of awe in fostering a deeper sense of connection and altruism.

Research has shown that the experience of selflessness and connectedness to the environment is often accompanied by the dissolution of perceived body boundaries (Dambrun, 2016). The concept of body boundaries stems from mindfulness practice and it means that individuals feel less distinction between their body and the surrounding environment, leading to a more integrated and holistic sense of self. Furthermore, more mindful states are oftentimes connected with loosened body boundaries. Van Rompay et al. (2023) highlight that spacious natural environments, by promoting a sense of vastness, can lead to a loosening of these body boundaries. According to their study, this embodied process is

crucial as it mediates the effects of spaciousness on selflessness and positive affect. In contrast, environments that feel more confined may reinforce a sense of separation and self-centeredness. Therefore, understanding how different environmental settings impact perceived body boundaries can provide deeper insights into the mechanisms driving the mental health benefits of nature interaction. In this study, these spatial elements are manipulated in a digital environment by altering tree density to create either spacious or dense settings, providing a controlled way to test their effects.

2.3 Being aware through mindfulness and nature connectedness

Research has increasingly recognized the vital role of mindfulness in enhancing experiences within natural environments by bringing focused attention to the present moment. Ballew & Omoto (2018) conducted an experimental study to investigate the impact of brief experiences in nature on specific positive emotions, such as happiness, joy, and feelings of awe. Participants were randomly assigned to either spend 15 minutes in a natural environment, such as a local arboretum, or in a built environment, such as an outdoor stadium, while focusing their attention on their surroundings. Ones the participants sat down, they got a clipboard and pen with a set of instructions. These instructions were as follows: *"Look at all of your surrounding features and pay attention to all of its details. Notice the colors and textures. Use all of your senses to take in everything around you. Use this sheet of paper to jot down words to describe the features you notice."* Their research demonstrated that actively engaging with nature leads to increased positive emotions, such as happiness and awe, compared to passive engagement (mere exposure). This highlights the unique benefits of integrating mindfulness, especially where attention is brought to the present moment, into experiences in digital nature settings.

Empirical evidence further supports the notion that interventions prompting individuals to actively notice and appreciate nature and/or their surroundings can lead to improvements in nature connectedness and mental well-being (Ballew & Omoto, 2018; McEwan et al., 2019; Passmore & Holder, 2017; Richardson et al., 2022; Richardson & Sheffield, 2015). Richardson et al. (2022) emphasized the distinction between merely being in nature and actively engaging in activities that are closely associated with nature connectedness, suggesting that the latter fosters a closer relationship with nature. Notably, active sensory engagement with nature in green spaces has been found to explain higher

levels of nature connectedness, well-being, and pro-nature behaviors compared to passive engagement (McEwan et al., 2019; Richardson et al., 2022; Van Gordon et al., 2018).Thus, it can be expected that by integrating a perspective-taking exercise into exposure in digital natural environments could result in promoting a deeper connection with nature, which leads to enhanced well-being and nature connectedness. This relationship underscores the importance of considering perspective-taking exercises and nature connectedness as potential moderators in understanding individual well-being and environmental attitudes. In this study, participants take part in a perspective-taking exercise during their exposure to the digital environment. Specifically, they are asked to envision themselves walking towards a specific point in the digital setting. This approach aims to deepen their immersion with the environment, promoting enhanced well-being and nature connectedness.

2.4 Current research and proposed hypotheses

The combined findings of research on attention restoration, awe, nature connectedness, and spaciousness in nature scenery suggest that exposure to natural environments promotes selflessness, connectedness, and related measures by fostering feelings of awe in comparison with the vastness of the natural world. However, it is important to consider that spacious and dense nature settings may differentially impact mental well-being. Spaciousness may evoke feelings of awe and connectedness compared to more dense landscapes. Building upon this framework, I hypothesize the following,

H1: Exposure to spacious (rather than dense) digital nature will report greater feelings of connectedness, selflessness, environmental appreciation, and improved mental well-being,

As research shows, being in the present moment often leads to a positive influence on mental well-being. Therefore, I hypothesize that integrating an perspective-taking exercise into digital nature experiences will further enhance these effects.

H2: Participants who engage in the perspective-taking exercise will show a significant difference in mental well-being compared to those who are merely exposed to a digital landscape.

As an explorative research question, I aim to investigate to what extent the effects of spacious nature scenery combined with active engagement differentiate from the effects of dense nature combined with mere exposure. Next to that, I will examine how body boundaries, mindfulness and

immersion play a role in the effects of this research. The following section outlines the experimental

procedure to test these theoretical constructs.

3. Methods

This study employs a 2x2 factorial design (nature: dense vs. spacious; engagement: perspective-taking vs. mere exposure) to explore the effects and interaction between environmental design and cognitive interventions. This design allows for an analysis of how spatial properties and active cognitive engagement jointly influence mental well-being and connectedness, addressing gaps in current research on digital nature. Measures included in this research are selflessness, connectedness, stress reduction, anxiety, positive affect, environmental appreciation, body boundaries, immersion and mindfulness.

3.1 Pretesting

Prior to the main experiment, pretests were conducted to verify the effectiveness of the manipulations. Participants were presented with videos of digital landscapes categorized as either spacious or dense. Each of the four landscapes was created using the Nature Recording 2.0-2 build AR tool, selected for its ability to simulate natural landscapes with high fidelity (See Figure 1). This tool ensured similarity in landscape settings and weather conditions (e.g., sunny weather, season, vegetation), with tree density being the sole manipulated factor. This level of control in a digital setting provides a unique opportunity to isolate the effects of spatial properties on mental well-being.

In this pretest, 11 participants (8 female, 3 male; mean age = 42.5 years, SD = 4.7) rated the spaciousness and density of the four digital landscapes. Results indicated that 54.5% of participants defined digital environment 1 as the most spacious (mean = 4.2, SD = 1.3), and 91% defined digital environment 4 as the most dense (mean = 5.7, SD = 1.1). These results served as the foundation for constructing the digital environments as close replicas.

Additionally, 13 participants (9 female, 4 male; mean age = 35.4 years, SD = 6.2) were asked to rate the suitability of several mindfulness exercises. 30.8% of participants agreed that walking meditation would be the most beneficial exercise for maintaining attention to the environment (mean = 4.1, SD = 1.2). This was followed by 15.4% who preferred breathing meditation (mean = 3.6, SD = 1.3) and another 15.4% who preferred mindfulness meditation (mean = 3.4, SD = 1.4).

Based on these results, the engagement chosen for the study was a perspective-taking exercise, where participants envision themselves walking towards a specific point in the digital environment.

Figure 1:

Digital Nature Environments during the pre-test

Note. 1 = spacious I; 2 = spacious II; 3 = dense I; 4 = dense II

3.2 Participants and Procedure

Ethical approval was obtained on the 21st of June (2024) from the Ethics Committee at the University of Twente (240954). 160 participants were recruited from various organizations. Before participation, they were fully informed about the study's aims and procedures and provided informed consent.

Participants completed a pre-stress test to establish baseline stress levels. They were then exposed to a digital environment (dense or spacious) for 120 seconds, a duration chosen based on prior studies demonstrating significant responses to short exposures (Van Rompay et al., 2023). Participants were randomly assigned to one of the four experimental conditions using a computerized randomization tool, ensuring equal distribution. Participants assigned to the perspective-taking exercise were asked to envision themselves walking in the digital environment ('imagine that you are walking past the trees').

Following their exposure, participants underwent a post-test to measure stress levels and body boundaries, next to the other outcome measures. Other outcome measures include selflessness, connectedness, stress reduction, anxiety, positive affect, environmental appreciation, immersion, and

mindfulness. As most participants were able to experience the digital environment on mobile phones rather than more immersive devices, the richness of the immersive experience may have been limited.

3.3 Measures

After collecting sample data, the measures employed in this study include:

*3.3.1 Stress-levels (pre/post)*

Stress-levels were measured using a pre-post test with four items adapted from the Perceived Stress Questionnaire (Levenstein et al., 1993). Items included 'I feel overwhelmed by deadlines,' 'I experience tension,' 'I am burdened with worries,' and 'I feel frustration' ($\alpha = .86$).

3.3.2 Body Boundaries (pre/post)

Body boundaries were measured using a visual analogue item (Figure 2) adapted from Dambrun (2016). Participants indicated their perception of body boundaries on a scale ranging from no boundaries to strong boundaries ($\alpha = .83$). A pre-test and post-test were conducted to measure changes in body boundaries perception.

Figure 2:

Visual scale assessing perceived body boundaries.
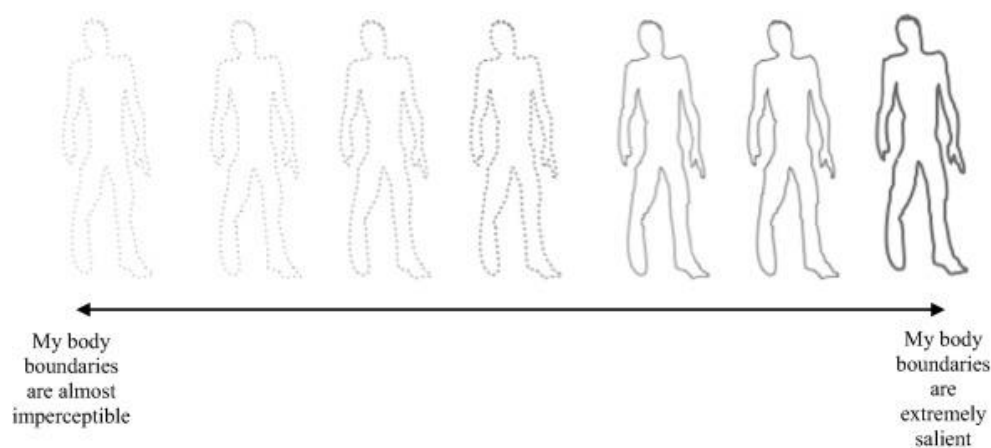
Note. Measured on a 7-point Likert scale. 1 = Imperceptible Body Boundaries, 7 = Extremely salient Body Boundaries.

3.3.3 Connectedness

Connectedness was assessed using the connectedness subscale of the Awe Experience Scale (Yaden et al., 2019). Items included 'I sensed a profound connection with all existence,' 'I felt a communion with every living entity,' 'I experienced a unified connection with all things,' 'I felt closely linked to humanity as a whole,' and 'I felt entirely interconnected with everything' (α = .90).

3.3.4 Selflessness

Selflessness was measured using the self-loss subscale of the Awe Experience Scale (Yaden et al., 2019). Items included 'I perceived a diminishment of my ego,' 'My sense of self appeared to diminish,' 'I experienced a reduction in my sense of self,' 'I sensed a shrinking of myself,' and 'I felt small in comparison to the vastness around me' (α = .87).

3.3.5 Mindfulness

Mindfulness was assessed using the brief version of the Mindful Attention Awareness Scale (MAAS) (Brown & Ryan, 2003). Items included 'I am aware of my thoughts and feelings without getting lost in them', 'I can focus on the present moment without distraction', 'I am able to observe my thoughts and emotions calmly', 'I pay attention to what is happening here and now', and 'I am conscious of the small details of my experience' (α = .79).

3.3.6 Anxiety

Anxiety was measured using a shorter version of the State-Trait Anxiety Inventory (STAI) (Zsido et al., 2020). Items included 'I feel disturbed,' 'I sense fear,' 'I experience nervousness,' 'I feel restless,' and 'I am perplexed' (α = .85).

3.3.7 Positive affect

Positive affect was measured using items from Larsen and Diener's (1992, as cited in Van Rompay et al. 2023) two-dimensional circumplex model of affect. Participants rated the extent to which they felt joyful, peaceful, calm, and content (α = .84).

3.3.8 Environmental appreciation

Environmental appreciation was assessed using the fascination subscale of Hartig et al.'s (1997) Perceived Restoration Scale'. Items included 'The environment possesses captivating qualities,' 'My attention is captivated by numerous intriguing aspects,' 'I am inclined to explore and learn more about this place,' 'There is ample to investigate and uncover here,' and 'I desire to spend more time observing the surroundings' ($\alpha = .85$).

3.3.9 Immersion scale

After conducting the post measurements for stress-levels and body boundaries, immersion was measured using the Immersive Tendencies Questionnaire (Rózsa et al., 2022). Items included 'I felt like I was "inside" the digital environment,' 'I felt completely absorbed in the experience,' 'I was not aware of my surroundings outside the digital environment,' 'I felt like I was part of the digital environment,' and 'I was deeply engaged with what I was experiencing' ($\alpha = .93$).

4. Results

For all multi-item constructs, items were summarized and averaged to arrive at a total score for each outcome measure. Table 1 presents the Kendall's Tau correlations between the outcome measures: connectedness, selflessness, anxiety, positive affect and environmental appreciation. Additionally, Table 2 provides an overview of the main and interaction effects from the ANOVA results for each outcome measure. To analyse the effects of nature type (spacious vs. dense) and engagement (perspective-taking vs. mere exposure) on the outcome measures, ANOVA and non-parametric tests (Scheirer-Ray-Hare, Wilcoxon signed-rank tests) were conducted. In the case of significant interaction effects, pairwise comparisons (Tukey's post-hoc) were used to determine group differences.

Table 1: Kendall's Tau correlations between the dependent variables.

	1	2	3	4	5	6	7
1. Selflessness	1.000						
2. Connectedness	0.481***	1.000					
3. Stress Reduction	0.312*	0.368**	1.000				
4. Anxiety	-0.341**	-0.419***	-0.542***	1.000			
5. Positive Affect	0.332**	0.625***	0.462***	-0.752***	1.000		
6. Environmental Appreciation	0.214	0.684***	0.342**	-0.353**	0.444***	1.000	
7. Body Boundaries	-0.441***	-0.294*	-0.270*	0.392**	-0.370**	-0.127	1.000

Note. N = 160. Kendall's Tau correlations are presented between the dependent variables. Significance is denoted as follows: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Table 1 shows several significant relationships. Stress levels were negatively correlated with positive affect ($\tau = -0.37$, $p < .001$) and connectedness ($\tau = -0.29$, $p < .05$). Positive affect was positively correlated with connectedness ($\tau = 0.62$, $p < .001$), selflessness ($\tau = 0.33$, $p < .01$), and environmental appreciation ($\tau = 0.44$, $p < .001$). Anxiety was negatively correlated with connectedness ($\tau = -0.42$, $p < .001$) and positive affect ($\tau = -0.75$, $p < .001$). Connectedness and selflessness were also positively correlated ($\tau = 0.48$, $p < .001$).

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Table 2: Overview of ANOVA results

Outcome Measure	Nature Type (F, p)	Engagement (F, p)	Interaction (F, p)
Stress Levels (Pre)	$F(1,156) = 2.25$, $p = 0.135$	$F(1,156) = 0.01$, $p = 0.936$	$F(1,156) = 0.16$, $p = 0.695$
Stress Levels (Post)	$F(1,156) = 0.29$, $p = 0.590$	$F(1,156) = 0.05$, $p = 0.828$	$F(1,156) = 0.47$, $p = 0.495$
Body Boundaries	$F(1,156) = 0.01$, $p = 0.927$	$F(1,156) = 11.81$, $p < 0.001$	$F(1,156) = 4.21$, $p = 0.042$
Connectedness	$F(1,156) = 0.81$, $p = 0.371$	$F(1,156) = 0.09$, $p = 0.760$	$F(1,156) = 0.05$, $p = 0.826$
Selflessness	$F(1,156) = 0.46$, $p = 0.501$	$F(1,156) = 0.78$, $p = 0.380$	$F(1,156) = 0.06$, $p = 0.816$
Mindfulness	$F(1,156) = 0.12$, $p = 0.725$	$F(1,156) = 2.73$, $p = 0.100$	$F(1,156) = 2.07$, $p = 0.152$
Anxiety	$F(1,156) = 1.46$, $p = 0.229$	$F(1,156) = 0.32$, $p = 0.574$	$F(1,156) = 0.11$, $p = 0.742$
Positive Affect	$F(1,156) = 5.52$, $p = 0.020$	$F(1,156) = 0.14$, $p = 0.705$	$F(1,156) = 0.11$, $p = 0.747$
Environmental Appreciation	$F(1,156) = 1.67$, $p = 0.198$	$F(1,156) = 1.17$, $p = 0.280$	$F(1,156) = 0.21$, $p = 0.645$
Immersion	$F(1,156) = 4.02$, $p = 0.047$	$F(1,156) = 1.04$, $p = 0.310$	$F(1,156) = 1.11$, $p = 0.295$

Note. N = 160. This table presents the F-statistics and p-values for the main and interaction effects of nature type and engagement on the outcome measures. Significant effects are marked with p-values less than 0.05.

4.1 Stress Levels

A 2x2 repeated measures ANOVA was conducted to analyze stress levels before and after the intervention. There was a significant main effect of time, $F(1,156) = 10.76$, $p < .001$, indicating that stress levels decreased from pre-test (M = 3.98, SD = 1.36) to post-test (M = 3.24, SD = 1.31). However, no significant main effects of nature type, $F(1,156) = 0.29$, $p = 0.590$, or engagement, $F(1,156) = 0.05$,

p = 0.828, were found. The interaction between nature type and engagement was also not significant, F(1,156) = 0.47, p = 0.495. The greatest reduction in stress was observed in the spacious-active condition (Pre = 3.82, SD = 1.52; Post = 3.08, SD = 1.41).

4.2 Body Boundaries

The ANOVA revealed a significant main effect of engagement on body boundaries, $F(1,156) = 11.81$, $p < .001$, and a significant interaction between nature type and engagement, $F(1,156) = 4.21$, $p = 0.042$. The main effect of nature type was not significant, $F(1,156) = 0.01$, $p = 0.927$. Participants in the spacious-active condition reported reduced body boundaries ($M = 3.63$, $SD = 0.97$) compared to those in the spacious-passive condition ($M = 4.55$, $SD = 0.93$).

4.3 Connectedness

For connectedness, the ANOVA indicated no significant main effect of nature type, $F(1,156) = 0.81$, $p = 0.371$, or engagement, $F(1,156) = 0.09$, $p = 0.760$. The interaction between nature type and engagement was also not significant, $F(1,156) = 0.05$, $p = 0.826$. The mean scores for connectedness were as follows: spacious-passive ($M = 3.59$, $SD = 1.44$), spacious-active ($M = 3.61$, $SD = 1.46$), dense-passive ($M = 3.37$, $SD = 1.36$), and dense-active ($M = 3.47$, $SD = 0.97$).

4.4 Selflessness

A univariate ANOVA showed no significant main effect of nature type on selflessness, $F(1,156) = 0.46$, $p = 0.501$, nor a significant main effect of engagement, $F(1,156) = 0.78$, $p = 0.380$. The interaction between nature type and engagement was also not significant, $F(1,156) = 0.06$, $p = 0.816$. Participants reported similar levels of selflessness across all conditions: spacious-passive ($M = 3.29$, $SD = 1.39$), spacious-active ($M = 3.52$, $SD = 1.51$), dense-passive ($M = 3.48$, $SD = 1.20$), and dense-active ($M = 3.61$, $SD = 0.91$).

4.5 Mindfulness

The ANOVA revealed no significant main effects of nature type, $F(1,156) = 0.12$, $p = 0.725$, or engagement, $F(1,156) = 2.73$, $p = 0.100$. The interaction between nature type and engagement was also not significant, $F(1,156) = 2.07$, $p = 0.152$.

4.6 Anxiety

The ANOVA revealed no significant main effect of nature type, $F(1,156) = 1.46$, $p = 0.229$, or perspective-taking, $F(1,156) = 0.32$, $p = 0.574$. The interaction between nature type and engagement was also not significant, $F(1,156) = 0.11$, $p = 0.742$. Anxiety levels were similar across conditions: spacious-passive ($M = 2.58$, $SD = 1.13$), spacious-active ($M = 2.62$, $SD = 1.36$), dense-passive ($M = 2.76$, $SD = 1.16$), and dense-active ($M = 2.93$, $SD = 1.23$).

4.7 Positive Affect

For positive affect, the ANOVA showed a significant main effect of nature type, $F(1,156) = 5.52$, $p = 0.020$, indicating that participants reported higher positive affect in the spacious condition compared to the dense condition. No significant main effect of engagement, $F(1,156) = 0.14$, $p = 0.705$, or interaction effect, $F(1,156) = 0.11$, $p = 0.747$, was found. Positive affect scores were higher in the spacious-passive condition ($M = 5.11$, $SD = 0.87$) and spacious-active condition ($M = 5.11$, $SD = 1.00$) compared to dense-passive ($M = 4.77$, $SD = 0.96$) and dense-active ($M = 4.66$, $SD = 1.31$).

4.8 Environmental Appreciation

The ANOVA revealed no significant main effects of nature type, $F(1,156) = 1.67$, $p = 0.198$, or engagement, $F(1,156) = 1.17$, $p = 0.280$. The interaction between nature type and engagement was also not significant, $F(1,156) = 0.21$, $p = 0.645$.

4.9 Immersion

The ANOVA revealed a significant main effect of nature type, $F_{(1,156)} = 4.02$, $p = 0.047$, indicating higher immersion scores in the spacious condition compared to the dense condition. Perspective-taking, $F_{(1,156)} = 1.04$, $p = 0.310$, and the interaction effect, $F_{(1,156)} = 1.11$, $p = 0.295$, were not significant.

4. 10 Mediation analyses for engagement and nature

The mediation analyses emphasize the importance of perceived body boundaries, immersion, and connectedness in explaining the effects of the perspective-taking instruction and nature on various psychological outcomes such as stress, selflessness, and connectedness. Mediation was tested using nonparametric bootstrapping with 5000 resamples. A mediation effect was considered significant when the 95% confidence interval (CI) around the indirect effect (IE) did not include zero.

In the perspective-taking condition, perceived body boundaries significantly mediated the relationship between perspective-taking and post-stress levels, as illustrated in Figure 3. The indirect effect of perspective-taking on post-stress levels through body boundaries was significant, $B = -0.1445$, $SE = 0.07$, 95% CI = [-0.3202, -0.02]. When body boundaries were included in the model, perspective-taking was no longer a significant predictor of post-stress levels, indicating full mediation. However, mediation analyses for pre-stress levels were excluded, as pre-stress was measured prior to the manipulation and could not logically be mediated by body boundaries.

Similarly, in the perspective-taking condition, an indirect effect was observed for connectedness. The indirect effect of perspective-taking on connectedness through body boundaries was significant, $B = 0.1266$, $SE = 0.06$, 95% CI = [0.0111, 0.27]. Including body boundaries in the model reduced the direct effect of perspective-taking on connectedness, suggesting partial mediation.

In the nature condition, immersion significantly mediated the relationship between nature exposure and multiple psychological outcomes. For selflessness, the indirect effect of nature via immersion was significant, $B = 0.190$, $SE = 0.10$, 95% CI = [0.0006, 0.38]. Including immersion in the model rendered the direct effect of nature on selflessness non-significant, indicating full mediation. For connectedness, the indirect effect of nature via immersion was significant, $B = 0.251$, $SE = 0.13$, 95%

CI = [0.0041, 0.51]. Similarly, for environmental appreciation, the indirect effect of nature through immersion was significant, B = 0.187, SE = 0.09, 95% CI = [0.0012, 0.39].

Main effects and interaction effects for the nature condition showed that immersion significantly interacted with nature exposure to predict connectedness (F(1, 158) = 6.22, p = .014), selflessness (F(1, 158) = 4.87, p = .029), and environmental appreciation (F(1, 158) = 5.34, p = .023).

Table 2: Mediation Models for Significant Results

Dependent Variable	Mediator	Indirect Effects B	SE	Lower Bound	Upper Bound
PostStressTest	Body Boundaries	-0.1445	0.07	-0.3202	-0.0200
Connectedness	Body Boundaries	0.1266	0.06	0.0111	0.2700
Selflessness	Immersion	0.1900	0.10	0.0006	0.3800
Connectedness	Immersion	0.2515	0.13	0.0041	0.5100
Environmental Appreciation	Immersion	0.1874	0.09	0.0012	0.3900

Note. N = 160. The table presents unstandardized indirect effects (B), standard errors (SE), and bootstrapped 95% confidence intervals (Lower and Upper Bound) for the mediation models. Mediation is significant when the confidence interval does not include zero. Partial mediation occurs when the direct effect remains significant after including the mediator, whereas full mediation occurs when the direct effect becomes non-significant.

Mindfulness was hypothesized to play a mediating role in the relationship between perspective-taking, nature, and various outcomes. However, the mediation analyses did not yield significant results for mindfulness. For example, the indirect effect of perspective-taking on immersion via mindfulness was non-significant, B = 0.0282, SE = 0.04, 95% CI = [-0.0468, 0.10]. Similarly, the indirect effect of nature on immersion via mindfulness was non-significant, B = 0.0303, SE = 0.03, 95% CI = [-0.0264, 0.10]. Mindfulness also did not significantly mediate the relationships between the perspective-taking instruction and connectedness, anxiety, or selflessness, nor between nature and these outcomes.

5. General discussion

This study explored the effects of spacious and dense digital nature environments, combined with a perspective-taking exercise, on mental well-being outcomes such as positive, anxiety, stress reduction, and other outcome measures such as, environmental appreciation, immersion, selflessness, connectedness, and body boundaries. The findings partially supported the hypotheses and provided valuable insights into how digital nature and perspective-taking influence enhancing mental well-being.

5.1 Interpretation of the results

The results demonstrated that spacious digital nature significantly increased positive affect, aligning with established theories on environmental preference and attention restoration (Gatersleben & Andrews, 2013; Kaplan, 1995). Spaciousness, by providing a sense of prospect—the ability to see one's surroundings clearly—fosters emotional well-being by alleviating negative affect. However, no significant effects of nature type on anxiety were found, indicating that while spaciousness supports positive emotional states, its effects on reducing negative emotions such as anxiety may require additional factors, such as prolonged exposure or active engagement.

Connectedness was not significantly influenced by spatial conditions, challenging the assumption that openness alone fosters environmental connectedness. This non-significance may stem from the brevity of the intervention or the lack of multi-sensory elements that could enhance the sense of connection to the environment. Future research might explore whether prolonged exposure or the inclusion of soundscapes and interactive features could improve connectedness outcomes. This suggests that deeper sensory engagement or a sense of social presence may be required to enhance connectedness. Additionally, the simplicity and brevity of the perspective-taking exercise may have limited its effectiveness. Prior studies highlight that mindfulness often requires more prolonged or immersive interventions to achieve noticeable effects (Brown & Ryan, 2003; Kabat-Zinn, 2003). Future research should explore how richer sensory elements or more/detailed instructions could improve engagement.

The perspective-taking exercise did, however, lead to a significant reduction in perceived body boundaries, aligning with the ANOVA results which showed a significant main effect of engagement on body boundaries ($F(1,156) = 11.81$, $p < .001$). This supports Dambrun's (2016) findings on self-transcendence. Immersion partially explained the effects of spaciousness on selflessness. Positive affect was mediated by environmental appreciation, reinforcing the role of sensory engagement in enhancing emotional well-being (Liu et al., 2022). Mediation analyses provided additional insights into the mechanisms underlying these effects. Immersion, the sense of being fully absorbed in the environment, was partially mediated by reductions in anxiety, increases in selflessness, and changes in stress levels. These mediators underscore the importance of emotional regulation and self-transcendent experiences in fostering immersion. Positive affect was partially mediated by environmental appreciation, reinforcing the idea that engaging and prior connectedness to nature environments enhance emotional well-being (Liu et al., 2022). However, body boundaries did not mediate the relationship between spaciousness and connectedness or negative affect, reflecting Dambrun's (2016) observation that body boundary dissolution influences happiness but not anxiety.

Mindfulness, though hypothesized as a mediator, did not significantly mediate the effects of spaciousness on the outcomes. This suggests that while mindfulness affects body boundaries, its broader impact may require more extensive or immersive interventions.

5.2 Theoretical implications

These findings contribute to the literature on environmental psychology and digital nature in several ways. First, they affirm the role of spaciousness in fostering positive affect, extending theories like Kaplan's (1995) Attention Restoration Theory. By emphasizing the role of embodied experiences, this study suggests that spaciousness facilitates emotional well-being through sensory richness and selflessness rather than visual preference alone.

Second, the mediating role of body boundaries aligns with Dambrun's (2016) work on self-transcendence, emphasizing the importance of embodiment in digital nature experiences. However, the lack of significant effects for connectedness and mindfulness underscores the need for multi-sensory,

prolonged, or interactive interventions (Van Gordon et al., 2018). Future research could integrate soundscapes, tactile feedback, or social components to maximize the benefits of digital nature.

5.3 Practical implications

The study's insights have practical relevance for designing digital environments in therapeutic, organizational, and educational contexts. For example, therapeutic interventions could leverage spacious digital landscapes paired with guided perspective-taking exercises to reduce anxiety and foster selflessness. These could be implemented in virtual therapy platforms or relaxation apps.

In educational settings, immersive digital nature experiences could be used as mindful breaks to reduce stress and enhance focus, particularly in remote learning contexts. For instance, virtual classrooms could integrate guided sensory exercises to promote emotional regulation.

Organizational wellness programs could incorporate spacious digital environments into virtual wellness sessions, providing employees with structured exposure to stress-reducing landscapes. Practical guidelines for such programs might include recommendations on duration, spatial features, and sensory prompts to optimize the benefits.

Finally, VR-based interventions could take digital nature experiences further by incorporating richer sensory feedback. These setups could be used across therapeutic, organizational, and educational domains to enhance immersion and promote well-being.

5.4 Limitations and future research

Several limitations should be acknowledged. First, the mean age of participants (35.8 years, SD = 12.5) and the predominantly Dutch sample (132 of 160 participants) may limit the generalizability of the findings. Cultural preferences for spaciousness and restorative environments might differ, potentially influencing outcomes like connectedness and mindfulness. For example, cultures with less emphasis on openness as a restorative element might exhibit weaker effects for spacious environments, whereas mindfulness practices might need to be culturally tailored to resonate more effectively across diverse groups. For example, connectedness may depend on culturally specific interpretations of spaciousness, while mindfulness might require tailored approaches to resonate across different

demographics. Future studies should aim to include more diverse participant pools to better capture these nuances.

Second, the reliance on mobile phones for exposure likely constrained the sensory engagement necessary for fostering connectedness, as smaller screens inherently limit immersive experiences as screen size can have different effects (Otten et al., 2023). While device-specific effects were not directly measured in this study, the descriptive data indicate a predominant use of mobile phones (142 out of 160 participants), which may have reduced the capacity for participants to fully engage with the digital environments, as smaller screens inherently limit the immersive quality compared to larger or interactive devices like laptops or VR headsets. Future research should explore how these technologies impact outcomes such as connectedness and mental well-being.

A notable limitation is the proximity of the pre- and post-tests. Few participants indicated that the close timing led some participants trying to replicate or mimic their answers, potentially influencing the reliability of stress-levels and body boundaries. For instance, participants may have attempted to maintain consistency in their responses rather than reflecting genuine changes. While the tests were spaced as far apart as feasible, alternative designs—such as follow-ups conducted after a delay—could mitigate this issue and better capture changes in these psychological states. Or perhaps notifying them that some will occur twice instead of ones.

Finally, this study did not manipulate spatial features or perspective-taking instructions beyond their current forms, as was explicitly outlined in the study design. This limitation should be viewed within the scope of the study's objectives, which prioritized testing the baseline effects of these variables. Future research could explore alternative spatial manipulations (e.g., varying visual complexity) and more detailed or interactive perspective-taking exercises to enhance participant engagement. Additionally, non-significant findings for mindfulness highlight the need for future studies to consider longer interventions or the integration of multi-sensory stimuli to deepen engagement and impact.

5.5 Conclusion

This study demonstrates that spacious digital nature environments can significantly enhance positive affect, while perspective-taking exercises can reduce perceived body boundaries. These findings highlight the potential of digital nature to foster mental well-being and suggest that, amidst the growing digitization of society, technology can be used not only for practical purposes but also to promote emotional and psychological health. Future research should explore more immersive interventions and diverse contexts to further understand and leverage the benefits of digital nature.

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During the preparation of this work the author(s) used OpenAI tool ChatGPT in order to change the
given advice for statistical analysis from SPSS to R-studio as suggested by the supervisor. After using
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