

## Lose yourself: Spacious nature and the connected self

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### ABSTRACT

A crucial but thus far overlooked dimension of mental health benefits of nature interaction involves the extent to which the self is experienced as a separate, stand-alone identity cut off from its surroundings or rather as a fluid entity connected to the world at large. Based on research findings that hint at the importance of spaciousness for promoting a selfless (rather than self-centered) mode of psychological functioning, an experimental study was conducted using VR-simulations of natural landscapes varying in the extent of spaciousness and type of nature. Results show that spacious, rather than dense, landscapes promote selflessness and related measures including connectedness and positive affect. Subsequent mediation analyses indicate that effects of spaciousness on selflessness and positive affect are mediated by an embodied process in which perceived body boundaries loosen up. These findings testify to the importance of nature interaction for counteracting self-centeredness and related mental health issues.

### 1. Introduction

In our digital society, people have unprecedented means to connect with others using (social) media. Paradoxically, more people than ever before feel trapped inside their body and mind and cut off from others and society (e.g., Cacioppo et al., 2017; Qualter et al., 2015). As a result, many people live their lives in a self-centered mode, which is associated with low psychological well-being, and negative affect (Bangee et al., 2014; Layden et al., 2017). Not only older adults with shrinking social networks, but also young adults are increasingly prone to mental health problems (Kelly et al., 2018; Patalay & Gage, 2019) and symptoms indicative of self-centeredness, including stress and excessive worrying (i.e., rumination; Bratman et al., 2015).

Different explanations for these mental ails have been proposed. For instance, for young adults in developed countries, excessive social media consumption has been pointed out as a driver of mental health issues, in part because of its emphasis on social comparison and idealized self-presentation (Clark et al., 2018; Valkenburg, 2017); factors which promote competition and self-centeredness rather than selflessness and connectedness to others (McCain et al., 2016). Confirming this 'trend', research shows that in developed countries in particular, a worldview is gaining momentum in which the self is considered as separate from (rather than connected to) others (Santos et al., 2017).

Self-centeredness, disconnect and related (cognitive) processes including rumination have proven highly difficult to counteract using

traditional (cognitive-behavioural) therapies and (pharmaceutical) interventions (Watkins & Roberts, 2020). Although it is difficult to pinpoint why this is the case, cross-disciplinary findings from research on nature experience (Bratman et al., 2019; Kaplan, 1995; Van den Berg & Beute, 2021), awe (Chirico & Gaggioli, 2021; Keltner & Haidt, 2003; Yaden et al., 2018), and environmental design (Van Houwelingen et al., 2020a; 2020b) indicate the potential of exposure to both outdoor and simulated nature settings for mental health promotion in general, and for promoting a more selfless, rather than self-centered, mode of psychological functioning in particular. In general, selflessness appears positively associated with subjective and psychological well-being and transpires in positive affect and feeling connected (e.g., Dambrun & Ricard, 2011; Hanley et al., 2017; Leary et al., 2008).

However, two fundamental research questions remain largely unanswered: (1) Which specific types of people-environment interactions can promote selflessness and related positive states? and (2) What are the working mechanisms involved? Based on cross-disciplinary research findings which testify to the importance of *spaciousness* (also referred to as *openness*) and *vastness* in people-environment interaction (Gatersleben & Andrews, 2013; Herzog & Kropscott, 2004; Van Rompay & Jol, 2016; Yaden et al., 2018), this study seeks to demonstrate that spacious (rather than dense) settings are particularly suited for promoting selflessness, connectedness, and positive affect on the one hand, and for reducing negative affective states (i.e., stress and anxiety) on the other.

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As for the working mechanisms involved, research suggests that a selfless mode of functioning involves the dissolution of perceived body boundaries, whereas a self-centered mode of psychological functioning is underlined by a strong sense of separation between body and world (Dambrun, 2016). In other words, effects of spaciousness on selflessness, connectedness and affective states may be mediated by the (embodied) experience of having less salient body boundaries. Before elaborating on the details of this study, we will first discuss the key notions involved.

## 2. Nature interaction and the connected self

'Nature is an under-recognized healer', a report of the Institute for European Environmental Policy says (Ten Brink et al., 2016). Gazing out over a scenic landscape stretching out under a vast sky, tracing the outlines of glowing hills and green valleys, or contemplating a vast blue ocean; why do so many of us describe such nature experiences as intensely satisfying and wholesome (Cohen et al., 2010; Shiota et al., 2007)? We propose that part of the reason why these experiences are so wholesome may lie in the fact that they allow us to lose ourselves and simultaneously feel connected to others and the world at large.

### 2.1. Previous theorizing on nature and mental health

Longstanding theories in nature research have focused on attention restoration (Kaplan & Kaplan, 1989) and stress recovery (Ulrich et al., 1991) as two main mental health benefits of people-environment interaction. These two seminal theories, and the empirical evidence supporting their claims about the importance of nature for mental health, have been discussed extensively elsewhere (e.g., Hartig et al., 2011). Here we will only highlight aspects that are relevant for our research.

Within the framework of Attention Restoration Theory (ART), especially the idea of 'extent', deserves mention. As stated by Kaplan and Kaplan (1989, p. 190) this component of restorative nature experiences involves a remarkable sense of feeling 'at one' that "*promises a continuation of the world beyond what is immediately perceived*". Although people may experience extent in nearby settings, Kaplan and Kaplan also state that the "*sheer physical scale contribute[s] to this sense of extent*". Thus, ART, as leading theory in people-environment research, not only recognizes the value of vastness and spaciousness as spatial properties that contribute to a sense of extent, but also as key components of restorative nature experience conducive to mental health (cf. Gatersleben & Andrews, 2013; Herzog & Kutzli, 2002).

Within the framework of Stress Recovery Theory (SRT), spatial properties of the natural environment are considered of crucial importance to stress reduction. In a first formulation of the theory (Ulrich, 1983) especially the component of 'spaciousness' (also referred to as 'depth') seems relevant. As stated on p. 100 "*The framework proposes that depth/spaciousness influences both the initial reaction to a scene and the ensuing process of cognitive appraisal*"; two steps that, according to SRT, are crucial for the stress-reducing effects of contact with nature.

In general, experimental research guided by ART and SRT provides some indications for the relevance of vastness and spaciousness when it comes to wholesome effects of nature interaction on (mental) health and wellbeing (e.g., Gatersleben & Andrews, 2013). However, these theories focus primarily on affective and cognitive pathways leading from vastness or spaciousness to restoration but are (relatively) silent on how these relate to a crucial component of mental health: the experience of 'self'.

What is clear from the discussion presented so far is that across studies, different terms have been used to label spaciousness, including openness (clear field of vision/visual access; Herzog & Kutzli, 2002), prospect (Appleton, 1975; Gatersleben & Andrews, 2013), depth (Ulrich, 1983), and vastness (Yaden et al., 2018). Here we will use the term spaciousness and distinguish between spacious landscapes that are open and provide a clear field of vision and dense landscapes that are

enclosed and provide limited visibility.

### 2.2. Awe and selflessness

One of the major benefits of people-environment interaction for mental health might relate to the opportunities environmental settings provide for counteracting the experience of the 'self' as a separate entity cut off from the world outside. Empirical evidence for this idea is provided by research indicating that interactions with vast settings inspire awe, defined as a sense of being in the presence of something greater than oneself (e.g., Cohen et al., 2010; Keltner & Haidt, 2003; Shiota et al., 2007). Although vastness is readily associated with spaciousness (as defined here in terms of openness), it can also denote ruggedness or wildness (see Klatzky et al., 2017 for research on the perceptual underpinnings of vastness perceptions).

Awe is often accompanied by feelings of selflessness and increased connectedness with other people, the community, and the world at large (Keltner & Haidt, 2003; Yaden et al., 2018). As a result, awe is positively related to prosocial behaviors and pro-environmental attitudes (Nisbet et al., 2009; Piff et al., 2015). More recently, researchers have begun to investigate the potential role of awe for mental health promotion (e.g., combatting depression; Chirico & Gaggioli, 2021).

Arguably, an embodied process in which perceived boundaries between body and environment loosen up lies at the root of selflessness and connectedness (cf. Ardelt, 2008; Ataria, Dor-Ziderman, & Berkovich-Ohana, 2015; Dambrun, 2016; Van Rompay & Jol, 2016). Evidence for the relation between the experience of self and perceived body boundaries comes from mindfulness research (Dambrun, 2016), indicating that selflessness elicits happiness via dissolution of perceived body boundaries. The notion that nature interaction can also loosen up boundaries between self and environment finds support in research showing that contact with nature reduces rumination and lowers activity in related brain areas (i.e., subgenual prefrontal cortex activation; Bratman et al., 2015).

Although people-environment interaction benefits might, at first glance, seem reserved to vast, awe-inspiring natural environments, research indicates that more mundane types of nature interaction may likewise promote selflessness and connectedness (Kaplan & Kaplan, 1989; Van Houwelingen et al., 2020a; 2020b). For instance, Van Houwelingen et al. (2020b) showed that simulations of everyday nature settings can inspire awe and related feelings of connectedness.

### 2.3. Connectedness to nature and selflessness

Another line of research that supports the relationship between nature experience and selflessness comes from work on nature connectedness and its link to wellbeing of both the planet and the individual (Lengieza & Swim, 2021; Nisbet et al., 2009). That is, people who feel connected to nature, and by consequence include nature in their sense of self, are more likely to engage in pro-environmental behaviors (e.g., Davis & Gatersleben, 2013; Dong et al., 2020) and enjoy higher psychological wellbeing (Mayer et al., 2009). For instance, a recent study showed that people living near trees reported better mental health perceptions and a greater sense of connectedness to the natural world around them (Nisbet et al., 2020). Furthermore, people with a greater connection to nature not only spend more time in it; they also show more care and willingness to protect it (e.g., Weinstein et al., 2009; Whitburn et al., 2019).

These findings suggest that nature experience not only makes us feel more connected to nature, but also expands our sense of self by including the natural world in our self-concept, resulting in a sense of oneness or unity rather than a sense of duality or separation. Hence, like awe experiences, nature connectedness involves an element of self-transcendence (Lengieza & Swim, 2021) that may not only encompass the nearby natural world, but that may also include other people, the community, and the world at large (Piff et al., 2015; Yaden et al., 2018).

However, although research has firmly established linkages between different types of nature contact and nature connectedness (including VR-mediated exposure, e.g., Spangenberg et al., 2022) and situational (e.g., weather) and related individual differences (including age and openness to experience, e.g., Nisbet & Zelenski, 2013), understanding of how this self-transcendent aspect of nature connectedness develops and which types of nature experience support this process are limited (see Lengieza & Swim, 2021 for a recent review).

#### 2.4. The present research and hypotheses

The combined findings of research on restoration, awe, and connectedness to nature suggest that spaciousness in nature scenery might promote selflessness, connectedness, and related measures because it provides the opportunity to experience oneself as 'small' vis-a-vis something that is experienced as being much larger than the self (i.e., an expansive, open landscape in which one's body only takes in a very small portion of the total scene). Or, in the words of the philosopher Emerson (1836/1982): "Standing on the bare ground, my head bathed by the blithe air and uplifted into infinite space, all mean egotism vanishes" (p. 39). In more dense nature settings, on the other hand, there is no such element of openness that can prompt the experience of feeling small (i.e., there is no [visual] sensation of space extending infinitely beyond the confines of the body) and can trigger a selfless mode of experience. Hence:

**H1.** Spacious, rather than dense, nature scenery inspires selflessness, connectedness, and related affective states.

In line with the notion that effects of spaciousness might be rooted in the embodied experience of dissolving (less salient) body boundaries, it is argued that:

**H2.** Effects of spaciousness on selflessness, connectedness, and related affective states are mediated by salience of perceived body boundaries.

Finally, we aimed to investigate (explorative research question) to what extent effects of spaciousness would vary as a function of whether scenery shows signs of human intervention (i.e., tended versus wild nature). That is, research suggests that whereas wild nature (e.g., forest settings) appeals to needs for exploration and provides a greater sense of "being away" (Fredrickson & Anderson, 1999; Kaplan, 1995), tended nature (e.g., green settings comprising signs of human intervention such as benches or a path) is more readily associated with safety and security (Gatersleben & Andrews, 2013; Herzog & Kropscott, 2004; Van Houwelingen et al., 2020a; 2020b).

As feeling safe might be an important precondition for a selfless rather than a self-centered mode of experience (i.e., perceived threat might rather promote a focus on the self rather than selflessness; Liu et al., 2021), nature type might qualify effects of spaciousness. On the other hand, wild nature has also been linked to spiritual experiences (Fredrickson & Anderson, 1999), and in another study, mystery (usually higher in wild nature) was a positive predictor of both danger and preference (Herzog & Miller, 1998). Hence, it is an open question to what extent tended nature promotes or counteracts feelings of selflessness and connectedness.

### 3. Method

A 2 (spaciousness: dense versus spacious) X 2 (nature type: wild versus tended) between-subjects design was employed to test the hypotheses presented. Measures included selflessness and connectedness measures, positive and negative affective states, environmental appreciation, and perceived body boundaries.

#### 3.1. Pretest

A pretest was conducted to verify the effectiveness of the

manipulations. To this end, ten 360° videos were recorded (in the same rural region in the east of the Netherlands) that varied in the extent to which they a) portray a spacious landscape, i.e., an open field, or rather a dense scene with high levels of tree density, and b) comprise a path, indicative of human intervention. To reduce effects of potential confounds, all videos were recorded within three days under similar weather conditions.

Four videos (one video for each of the experimental conditions; see Fig. 1) were pre-selected in an informal session in which participants indicated whether they considered the videos appropriate for the respective conditions (e.g., does the video come across as spacious?). Additionally, exposure time was investigated by asking participants to indicate when they felt like they had seen enough of the environment and were inclined to take off the headset.

In discussing the VR-environments, conceptualizations of *spaciousness* differed considerably across participants. Hence, for the pretest, we used precise statements that tap into the conceptualization of spaciousness as reflecting landscapes that are *open* (rather than *dense*) and *provide a clear field of vision*. To this end, 12 participants (5 male, 7 female; mean age 26.5 years) indicated whether the scenes present an *unobstructed view*, were perceived as *open*, and were considered *dense* (reverse coded;  $\alpha = .96$ ). In addition, participants indicated to what extent the scenes included *manmade elements* and *afforded hiking* ( $\alpha = .78$ ). All responses were recorded on 7-point rating scales. Results confirmed that the open scenes were perceived as more spacious compared to the dense scenes,  $M = 6.36$ ;  $SD = 0.69$  versus  $M = 1.83$ ;  $SD = 0.73$ ;  $p < .001$ , and that the scenes containing a path were perceived as indicative of human intervention and hence as *tended*, rather than *wild*, nature,  $M = 5.98$ ;  $SD = 0.97$  versus  $M = 2.19$ ;  $SD = 0.76$ ;  $p < .001$ . Finally, exposure time was set at 120 s for the main study.

#### 3.2. Participants and procedure

The research was approved by the Ethics Committee at the University of Twente (ethics committee request number: 210513; date: 04-02-2021). 80 participants (40 males, 40 females; mean age 24.6) were recruited at the university campus. Participants were informed that the aim of the experiment was to gather impressions of natural environments. Prior to participation, participants filled out an informed consent form and a pre-test stress measure. Next, they were informed by the experimenter about the use of the VR headset and potential side-effects (i.e., nausea). After ensuring correct and comfortable setup of the headset, they could start the video with a controller and entered the environment for a duration of 120 s while being able to look around (by changing orientation and viewing angle). After the video had ended, the headset was taken off and participants were asked to fill out the questionnaire comprising the post-test stress measure and the other dependent (post-test only) variables. Upon completion, participants were thanked for participation and received a voucher for use at the University's coffee shop.

#### 3.3. Measures

**Selflessness.** To measure selflessness, the self-loss subscale of the awe experience scale (Yaden et al., 2018) was used. Items include 'I felt that my sense of self was diminished', 'I felt my sense of self shrink', 'I experienced a reduced sense of self', 'I felt my sense of self become somehow smaller', and 'I felt small compared to everything else' ( $\alpha = .80$ ).

**Connectedness.** Connectedness was measured using the connectedness subscale of Yaden et al.'s (2018) awe experience scale. Items include 'I had the sense of being connected to everything', 'I felt a sense of communion with all living things', 'I experienced a sense of oneness with all things', 'I felt closely connected to humanity', and 'I had a sense of complete connectedness' ( $\alpha = .93$ ).

**Connectedness to community.** As a second connectedness measure, we used the Inclusion of Community in the Self Scale (see Fig. 2; Aron





Fig. 1. Screenshots of 360° videos used in the main experiment  
 Note. a = spacious-wild; b = spacious-tended; c = dense-wild; d = dense-tended.

Circle the picture that best describes your relationship with the community at large. (S = Self; C = Community at large)



Fig. 2. The inclusion of community in the self scale (ICS).

et al., 1992; Mashek et al., 2007). This visual analogue measure consists of six pairs of overlapping circles, each pair overlapping slightly more than the preceding pair. Respondents were asked to select the pair of circles that best portrays their relationship to the community.

**Stress Reduction.** A *pre-post* test (state) measure was used for perceived stress, using four items adapted from Levenstein et al.'s (1993) perceived stress questionnaire. Before and after the VR-intervention, participants indicated level of agreement (using 7-point rating scales) with the statements 'I feel under pressure from deadlines', 'I feel tense', 'I feel like I have a lot of worries', and 'I feel frustrated' (alpha = .88).

**Anxiety.** State-anxiety was measured using a short version of the Spielberger State-Trait Anxiety Inventory (STAI; Zsido et al., 2020). Items include 'I feel upset', 'I feel frightened', 'I feel nervous', 'I am jittery', and 'I am confused' (alpha = .88). Using 7-point rating scales, participants indicated level of agreement.

**Positive Affect.** Positive affect was measured with items derived from Larsen and Diener's (1992) two-dimensional circumplex model of affect. Participants indicated (using 7-point rating scales) to what extent they felt happy, serene, relaxed, and cheerful (alpha = .89).

**Perceived body boundaries.** Dambrun's (2016) perceived body boundaries (visual analogue) measure depicts seven states of perceived body boundaries, ranging from almost 'not sensible' to 'extremely sensible' (see Fig. 3). Participants had to indicate which one of the figures best captures their current experience of body boundaries.

**Environmental appreciation.** To ensure that the VR environments were appreciated equally, the extent to which the nature scenes were perceived as attractive was measured using the fascination subscale of Hartig et al.'s (1997) 'Perceived Restoration Scale'. Items include 'The setting has fascinating qualities', 'My attention is drawn to many interesting things', 'I would like to get to know this place better', 'There is much to explore and to discover here', and 'I would like to spend more time looking at

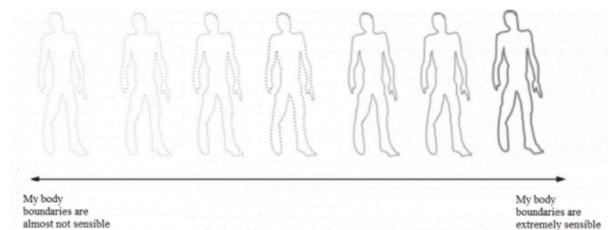


Fig. 3. Perceived body boundary scale (Dambrun, 2016).

the surroundings' (alpha = .86).

**Nature Relatedness.** Finally, nature relatedness was included as a covariate and measured using Nisbet and Zelenski's (2013) nature relatedness scale. This scale consists of six items such as 'My ideal vacation spot would be a remote, wilderness area', and 'My connection to nature and the environment is a part of my spirituality' (alpha = .82).

#### 4. Results

For all multi-item constructs, items were summarized and averaged to arrive at a total score for each outcome measure. Table 1 gives an overview of the correlations between the dependent variables (selflessness, connectedness, connectedness to community, stress reduction, anxiety, positive affect, environmental appreciation, and perceived body boundaries) and the covariate nature connectedness.

Multivariate analyses of covariance (MANCOVA) with spaciousness and nature type as independent variables and nature relatedness as covariate were conducted across the dependent variables to analyse main and interaction effects. For stress reduction (*pre-post* test measure) a repeated measure ANOVA was conducted. In case of significant interaction effects, pairwise comparisons were used to determine which group differences were statistically significant.

For spaciousness, the MANCOVA was significant, Wilks's  $\Lambda = 0.51$ ,  $F(8,68) = 8.31$ ,  $p < .001$ ,  $\eta^2 = 0.49$ . For type of nature, the effects were non-significant, Wilks's  $\Lambda = 0.90$ ,  $F < 1$ , *ns*. The MANCOVA revealed a significant interaction between spaciousness and type of nature, Wilks's  $\Lambda = 0.75$ ,  $F(8,68) = 2.79$ ,  $p = .01$ ,  $\eta^2 = 0.25$ .

**Table 1**  
Pearson correlations for the dependent variables and nature connectedness.

	1	2	3	4	5	6	7	8	9
1. Selflessness	-								
2. Connectedness	.47***	-							
3. Connectedness to community	.31**	.36***	-						
4. Stress reduction	.23*	.34**	.34**	-					
5. Anxiety	-.33**	-.41***	-.53***	-.48***	-				
6. Positive affect	.34**	.62***	.44***	.34**	-.72***	-			
7. Environmental appreciation	.20	.67***	.32**	.44***	-.36***	.43***	-		
8. Perceived body boundaries	-.46***	-.28*	-.38***	-.26*	.38***	-.38***	-.12	-	
9. Nature connectedness	.27*	.29**	.16	.09	.04	.14	.16	-.04	-

Note.  $N = 80$ . \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

#### 4.1. Selflessness

Examination of a univariate ANCOVA showed a significant main effect of spaciousness on selflessness,  $F(1,75) = 10.17$ ,  $p = .002$ ,  $\eta^2 = 0.12$ ; participants experienced a greater loss of self in the spacious,  $M = 4.06$ ,  $SD = 1.38$ , compared to the dense condition,  $M = 3.23$ ,  $SD = 1.00$ . The main effect of type of nature was not significant,  $F < 1$ , *ns*, neither was the interaction between spaciousness and type of nature,  $F(1,75) = 2.17$ ,  $p = .15$ ,  $\eta^2 = 0.003$ .

#### 4.2. Connectedness

For connectedness the ANCOVA likewise showed a significant main effect of spaciousness,  $F(1,75) = 5.88$ ,  $p = .02$ ,  $\eta^2 = 0.07$ , indicating that participants felt more connected in the spacious condition,  $M = 4.06$ ,  $SD = 1.70$ , compared to the dense condition,  $M = 3.27$ ,  $SD = 1.34$ . Again, the main effect of type of nature was not significant, neither was the interaction between spaciousness and type of nature, both  $F$ 's  $< 1$ , *ns*.

#### 4.3. Connectedness to community

For our second (visual analogue) connectedness measure, a strong effect of spaciousness emerged,  $F(1,75) = 55.03$ ,  $p < .001$ ,  $\eta^2 = 0.43$ ; participants felt more connected to the community in the spacious,  $M = 4.00$ ,  $SD = 1.04$ , compared to the dense,  $M = 2.30$ ,  $SD = 1.02$ , condition. The main effect of type of nature was (again) not significant, neither was the interaction between spaciousness and type of nature (both  $F$ 's  $< 1$ , *ns*).

#### 4.4. Stress reduction

A 2 x 2 repeated measure ANOVA was performed to investigate whether the effects of spaciousness and type of nature had an impact on stress levels before and after the VR nature exposure (T1 and T2). First, there was a significant main effect of time,  $F(1,76) = 15.58$ ,  $p < .001$ ,  $\eta^2 = 0.17$ , with stress levels lower after the VR experience,  $M = 3.97$ ,  $SD = 1.82$ , than before,  $M = 4.50$ ,  $SD = 1.51$ . Second, there was a significant interaction between time and spaciousness,  $F(1,76) = 4.17$ ,  $p = .045$ ,  $\eta^2 = 0.05$ , indicating that stress reduction (i.e., stress level before [T1] versus after [T2] nature exposure) was higher in the spacious, T1;  $M = 3.94$ ,  $SD = 1.57$  versus T2;  $M = 3.13$ ,  $SD = 1.57$ , compared to the dense condition, T1;  $M = 5.06$ ,  $SD = 1.22$  versus T2;  $M = 4.80$ ,  $SD = 1.67$ . The interaction between time and type of nature was not significant,  $F(1,75) = 1.80$ ,  $p = .183$ ,  $\eta^2 = 0.02$ , neither was the interaction between spaciousness and type of nature,  $F(1,75) = 1.35$ ,  $p = .25$ ,  $\eta^2 = 0.02$ .

#### 4.5. Anxiety

For anxiety, the ANCOVA yielded a significant main effect of spaciousness,  $F(1,75) = 24.43$ ,  $p < .001$ ,  $\eta^2 = 0.25$ , indicating that anxiety was lower in the spacious condition,  $M = 2.55$ ,  $SD = 1.06$ , compared to the dense condition,  $M = 3.94$ ,  $SD = 1.55$ . This time, the

main effect of type of nature was also significant,  $F(1,75) = 4.14$ ,  $p = .045$ ,  $\eta^2 = 0.05$ , indicating that anxiety was lower in the tended,  $M = 2.97$ ,  $SD = 1.39$ , compared to the wild,  $M = 3.52$ ,  $SD = 1.56$ , nature condition. The interaction between spaciousness and type of nature was also significant,  $F(1,75) = 8.69$ ,  $p < .001$ ,  $\eta^2 = 0.10$ . Pairwise comparisons show that the effect is significant in the wild nature condition (where anxiety is markedly higher in the dense compared to the spacious condition;  $F(1,75) = 31.07$ ,  $p < .001$ ,  $\eta^2 = 0.29$ ), but not in the tended nature condition,  $F(1,75) = 1.96$ ,  $p = .17$ ,  $\eta^2 = 0.03$ ; see Fig. 4.

#### 4.6. Positive affect

The main effect of spaciousness on positive affect was significant,  $F(1,75) = 16.56$ ,  $p < .001$ ,  $\eta^2 = 0.18$ , showing that positive affect was higher in the spacious,  $M = 4.93$ ,  $SD = 1.24$ , compared to the dense,  $M = 3.88$ ,  $SD = 1.12$ , nature condition. The effect of nature type was not significant,  $F < 1$ , *ns*, neither was the interaction between spaciousness and type of nature,  $F(1,75) = 3.29$ ,  $p = .07$ ,  $\eta^2 = 0.04$ .

#### 4.7. Environmental appreciation

The main effects of spaciousness,  $F(1,75) = 3.72$ ,  $p = .06$ ,  $\eta^2 = 0.05$ , and type of nature,  $F(1,75) = 3.79$ ,  $p = .06$ ,  $\eta^2 = 0.03$ , on environmental appreciation were non-significant, neither was the interaction between spaciousness and type of nature,  $F(1,75) = 1.94$ ,  $p = .17$ ,  $\eta^2 = 0.03$ .

#### 4.8. Perceived body boundaries

Finally, for perceived body boundaries, a significant main effect of spaciousness emerged,  $F(1,75) = 18.90$ ,  $p < .001$ ,  $\eta^2 = 0.20$ , indicating that participants sensed less salient body boundaries in the spacious condition,  $M = 3.65$ ,  $SD = 1.53$ , compared to the dense condition,  $M = 5.00$ ,  $SD = 1.30$ . The main effect of type of nature was not significant,  $F(1,75) = 2.04$ ,  $p = .16$ ,  $\eta^2 = 0.03$ . The interaction between spaciousness and type of nature was significant,  $F(1,75) = 4.38$ ,  $p = .04$ ,  $\eta^2 = 0.06$ . Pairwise comparisons show that the effect of spaciousness on perceived body boundaries is significant in the tended nature condition,  $F(1,75) = 20.72$ ,  $p < .001$ ,  $\eta^2 = 0.22$ , where spacious scenery is particularly effective in reducing perceived salience of body boundaries, but not in the wild nature condition,  $F(1,75) = 2.51$ ,  $p = .12$ ,  $\eta^2 = 0.03$ ; see Fig. 5.

#### 4.9. Mediation analyses

The results testify to the importance of spacious scenery for reducing negative states (i.e., stress and anxiety) on the one hand and promoting selflessness, connectedness, and positive affect on the other. As argued, perceived body boundaries may play a key role as they might mediate effects of spaciousness on our outcome measures.

Following Hayes' (2013) Macro Process via bootstrapping method, perceived body boundaries can be considered a mediator when (1) the indirect effect (IE) of spaciousness on the respective dependent variable via perceived body boundaries is significant, and (2) when the bias

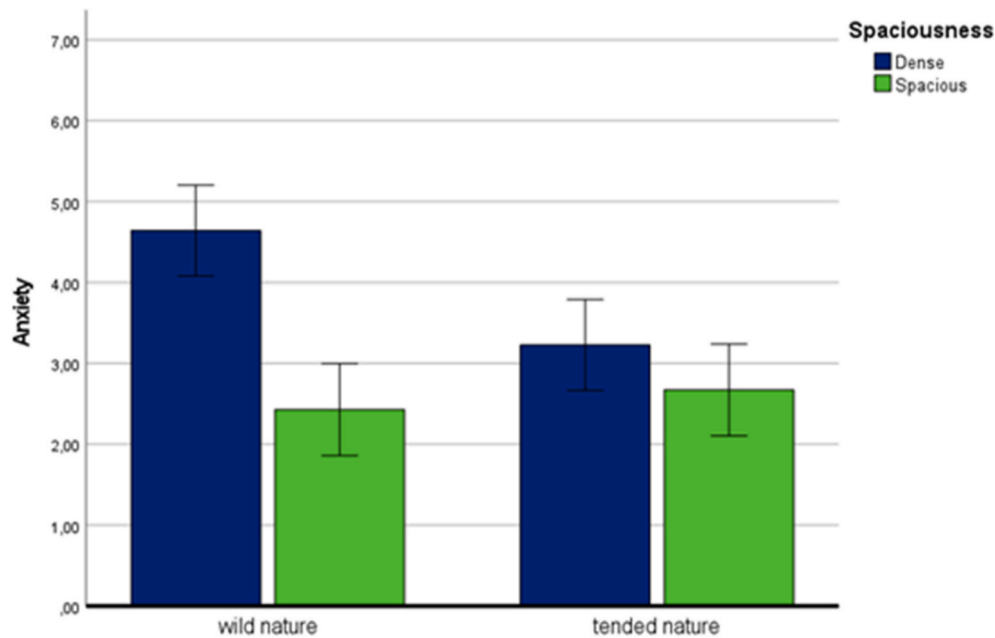


Fig. 4. Interaction between spaciousness and nature type on anxiety  
Note. Error bars represent standard errors.

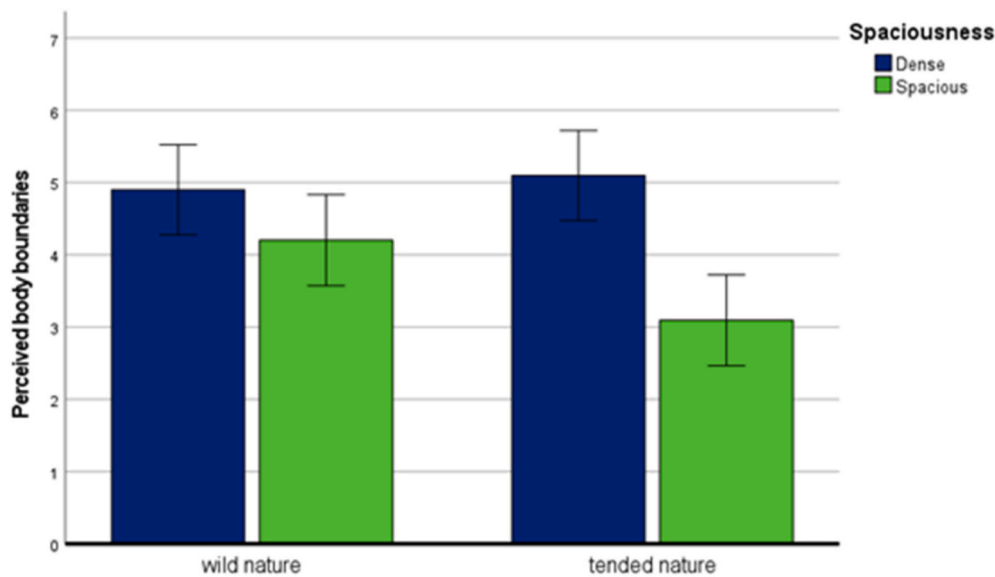


Fig. 5. Interaction between spaciousness and nature type on perceived body boundaries  
Note. Error bars represent standard errors.

corrected 95% CI around the IE from 5000 bootstrap re-samples excludes zero. The indirect effects of the mediation analyses are presented in Table 2.

As shown in Table 2, the direct effect of spaciousness on selflessness is fully mediated by perceived body boundaries (see Fig. 6); an indirect effect was found for spaciousness on selflessness,  $B = 0.42$ ,  $SE = -0.17$ , with 95%  $CI = [0.1330, 0.8115]$ , excluding zero. When including perceived body boundaries in the model, spaciousness was no longer a significant predictor of selflessness.

An indirect effect was also found for spaciousness on positive affect,  $B = 0.28$ ,  $SE = 0.17$ , with 95%  $CI = [0.0222, 0.6877]$ , excluding zero. As can be seen in Fig. 7, including perceived body boundaries in the model reduced the unstandardized path from spaciousness to positive affect from 1.05 ( $p < .001$ ,  $CI = [0.5247, 1.5753]$ ) to 0.77 ( $p = .01$ ,  $CI =$

$[0.2025, 1.3396]$ ). Note however that the direct effect of spaciousness remains significant (indicative of partial rather than full mediation).

Thus, in line with hypothesis 2, perceived body boundaries fully mediated the effect of spaciousness on selflessness, and additionally (partially) mediated the effect on positive affect. These findings lend support to the argument that the embodied experience of dissolving (less salient) body boundaries may explain wholesome effects of spaciousness. However, effects of spaciousness on connectedness (both measures) and negative affect (stress and anxiety) are *not* mediated by perceived body boundaries. (Note: Although the confidence interval around the indirect effect of spaciousness on anxiety excluded zero, the path from perceived body boundaries to anxiety was non-significant,  $B = 0.21$ ,  $SE = 0.32$ ,  $p = .05$ ,  $CI = [-0.0022, 0.4134]$ ).

**Table 2**  
Mediation models for the effects of spaciousness on selflessness, connectedness, connectedness to community, stress reduction, anxiety and positive affect mediated by perceived body boundaries.

	Indirect effects <i>B</i>	<i>SE</i>	Bootstrapping BC 95% CI		Type of mediation
			Lower bound	Upper bound	
Selflessness	0.42	0.17	.1221	.7943	Full mediation
Connectedness	0.28	0.21	-.0637	.7515	-
Connectedness to community	0.15	0.12	-.0649	.4028	-
Stress reduction	0.22	0.14	-.0061	.5545	-
Anxiety	-0.28	0.17	-.6925	-.0298	-
Positive affect	0.28	0.17	.0222	.6877	Partial mediation

*Note.* The table gives the bootstrap point estimates (unstandardized regression coefficients *B*), standard errors (*SE*) and 95% confidence intervals (*CI*, lower and upper bounds) for the indirect effects of the mediation model between spaciousness on the dependent variables via perceived body boundaries.

**5. General discussion**

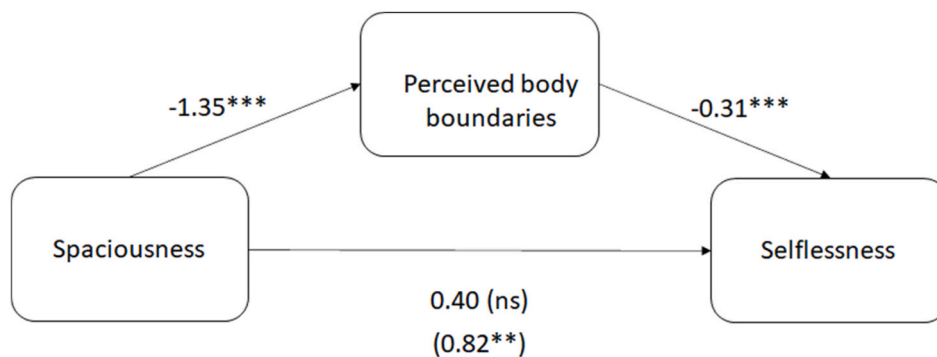
The results presented underscore the wholesome effects of nature interaction on mental health, thereby adding to the ever-growing evidence base stressing the significance of nature interaction for various facets of wellbeing. Importantly, our findings indicate that when it comes to the experience of *self* (comprising dimensions of selflessness and connectedness), spacious (rather than dense) landscapes provide a platform for a selfless mode of experience in which self-centeredness is

reduced and a greater sense of connectedness with the world at large is experienced.

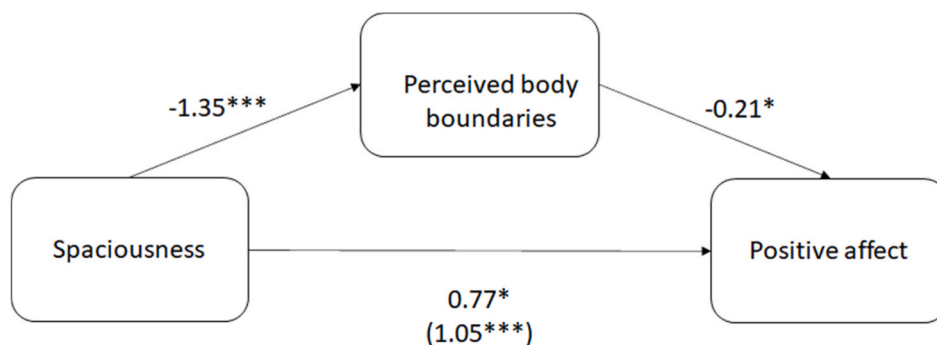
Previous research demonstrated influences of spaciousness (or related constructs such as openness, visual access, and legibility) on preference and danger perceptions (e.g., Herzog & Kropscott, 2004; Herzog & Leverich, 2003). These findings align with research stressing the importance of prospect in landscape experience and environmental preference (i.e., ‘to see without being seen’ Appleton, 1975; Gatersleben & Andrews, 2013). For instance, Gatersleben and Andrews (2013) showed that exposure to natural settings with high levels of prospect (similar to our spacious landscapes) and low levels of refuge (i.e., places to hide) are restorative, whereas landscapes low in prospect (similar to our dense landscapes) are not restorative and may increase stress and attention fatigue. Likewise, a recent review comprising both natural environments and indoor environments underscores the importance of prospect for environmental preference (whereas the empirical base for refuge is far less consistent; Dosen & Ostwald, 2016). Importantly, our findings show that spaciousness is important for another reason besides aesthetics, preference, and safety considerations; it allows us to let go of self-referential modes of (negative) thoughts and negative affect and to feel connected to our surroundings.

However, our findings are less conclusive when it comes to the working mechanism involved. Whereas mediation analyses showed that effects of spaciousness on selflessness and positive affect are mediated by perceived body boundaries, effects of spaciousness on connectedness and negative states are *not* mediated by salience of perceived body boundaries. With respect to negative affect, these findings mirror findings from Dambrun (2016) who likewise showed a mediating role for perceived body boundaries on happiness, but not for anxiety.

Arguably, spacious scenery can counteract negative affect via a different pathway, perhaps along the lines of stress reduction theory (Ulrich et al., 1991) and related bio-physiological processes involved (e.



**Fig. 6.** Mediation analysis on the effects of spaciousness on selflessness with perceived body boundaries as mediator  
*Note.* Unstandardized coefficients are given and significant values (\**p* < .05, \*\**p* < .01, \*\*\**p* < .001) with the effect neglecting the mediator between brackets.



**Fig. 7.** Mediation analysis on the effect of spaciousness on positive affect with perceived body boundaries as mediator  
*Note.* Unstandardized coefficients are given and significant values (\**p* < .05, \*\**p* < .01, \*\*\**p* < .001) with the effect neglecting the mediator between brackets.



g., Mochizuki-Kawai et al., 2020). Although our findings are far from conclusive on this issue, they do hint at a relationship between nature scenery and anxiety reduction. That is, anxiety was significantly lower in the tended nature condition and highest in the wild and dense nature condition where signs of human intervention were absent, and prospect (i.e., overview over surroundings) was very low. These findings also align with aforementioned research on the relationship between prospect, stress, and restoration (e.g., Gatersleben & Andrews, 2013). It should be noted, however, that nature type (tended versus wild nature) did not influence selflessness and connectedness ratings.

As for the two dimensions of selfless functioning addressed in this research (i.e., *selflessness* and *connectedness*), perceived body boundaries fully mediate effects of spaciousness on *selflessness*. However, we did not find mediation (by perceived body boundaries) for *connectedness*. On a conceptual level, the relationship between perceived body boundaries and selflessness seems most direct as a reduced salience of body boundaries quite literally implies the cessation of the self as a separate entity clearly demarcated from its surroundings. Feeling connected in spacious surroundings on the other hand might not so much relate to loosened body boundaries but perhaps rather to having visual access to elements in one's surroundings (both close-by and in the far distance) or by the (related) experience of being in the same place as others (Biocca et al., 2003; Hartig, 2021).

A recent review addressing measures and modalities used in research on restorative virtual natural environments (Nukarinen et al., 2022) showed that although physiology and affective measures are well represented in literature, transcendent elements of nature experiences are mostly or entirely missing. The findings presented here warrant future research further exploring the role of perceived body boundaries in nature interaction and how they may underlie self-transcendent dimensions of experience, including selflessness and connectedness.

When turning to awe research, our findings align with the notion that vastness is an important antecedent of awe components (i.e., selflessness and connectedness), but importantly show that such effects are not limited to prototypical awe-inspiring landscapes such as the Grand Canyon or panoramic views of nature typically used in awe research (e.g., Chirico et al., 2017). This is far from a trivial finding considering the limited availability of such environments to people living in urbanized regions (Hartig & Kahn, 2016).

### 5.1. Limitations and follow-up research

Although a *pre-post* test procedure was used for recording stress, we did not adopt the same procedure for our other outcome measures, including the *connectedness* and *selflessness* measures adopted from Yaden et al. (2018). In the latter, scale items are presented as *post-test* measures as they assume that participants have been exposed to an (awe-inducing) intervention (e.g., "I felt my sense of self somehow become smaller"). Although one could rephrase these items to allow for a *pre-post* test procedure, doing so would result in overly abstract items that would be difficult to reflect on, especially if these questions are asked within a short period of time. On the other hand, linking these questions to a specific experience (i.e., our VR-experience; *post-test*) avoids such pitfalls.

However, it would be worthwhile to consider alternative *pre-post* test measures for follow-up research. For instance, for measuring perceptions of body boundaries, biophysiological measures (e.g., related to goosebumps or shivers associated with awe or muscle tension [as discussed by Stepanova et al., 2019]) could be considered. For instance, does a greater sense of overlap between body and environment transpire in muscle relaxation? Such (additional) biophysiological measures do not pose difficulties in a *pre-post* test procedure and would provide additional evidence for our claims.

As for the landscapes in our study (which were pretested and in which potential confounds were excluded as much as possible) we cannot rule out that landscape features including the presence of salient

landmarks and an unimpeded view on the horizon influenced our findings. For instance, when comparing the spacious landscapes, arguably the tended spacious landscape not only provides more 'legibility' through the presence of a path (a highly legible scene is one that is easy to oversee and to form a cognitive map of; Kaplan, 1995) but arguably also by the presence of more visually salient landmarks such as the two pronounced trees in the right part of the scene (see Fig. 1). Additionally, although both open and spacious, the wild spacious landscape does not provide an unimpeded view on the horizon whereas in the tended landscape, no such blockage by a line of trees in the far distance occurs. Finally, although our landscapes differed in terms of wildness as indicated by a pretest, even the *wild* landscapes arguably still come across as relatively tended when compared to truly wild, untended nature settings.

Additionally, the landscapes selected for this study were either very high or very low on spaciousness with no mixed or more balanced landscapes included. Apart from including a larger variety of landscapes in follow-up research, it would also be more than worthwhile (in line with a suggestion by Appleton [1984] in a revision of his prospect-refuge theory) to test whether effects of spaciousness could be further enhanced by offering contrasting experiences "involving the successive experiences of exposure to strongly contrasting landscape types" (p. 102). Hence, would the impact of spaciousness be more pronounced when a viewer first needs to travel through a dense forest? Considering the potential of VR technology for staging such dynamic experiences, clearly follow-up studies testing such scenarios are called for.

Although our findings underscore the potential of VR-technology for simulating natural landscapes (Chirico & Gaggioli, 2019) and for staging dynamic nature experiences aimed at mental health promotion (e.g., Yin et al., 2022; Yu et al., 2020), obviously they do not compare to real life nature interaction in terms of interactivity (e.g., feeling the ground beneath our feet as we walk) and multi-sensory perception (e.g., the smell of blossom) which very much contribute to the richness of real nature interaction (Li et al., 2021). On the other hand, considering the importance of spaciousness and the fact that large nature areas in cities and urbanized regions become increasingly scarce (Hartig & Kahn, 2016), arguably VR-technology has great potential as a *complementary* means (rather than replacement) of interaction with wholesome (spacious) landscapes (cf. Browning et al., 2020).

Although our overall findings stress the importance of spaciousness, it should be acknowledged that sample size in our study was relatively low because of the restrictions and studying at home policy enacted during the recent COVID-19 pandemic (during which the study was conducted) and the labor-intensive nature of our VR-setup. Related to the latter issue (and the practical difficulties of switching VR-environments across participants), participants were *not* randomly assigned to one of the four experimental conditions, but instead the conditions were completed in serial order. Although we took utmost care to ensure that data collection circumstances (e.g., time of day and outside weather conditions) were similar throughout the data collection period, we cannot rule out that this influenced our findings. Additionally, our target group consisted of (mostly) students recruited at the university campus. Considering the (potential) importance of safety perceptions and that preferences for spaciousness may accordingly vary between different age groups (Van Houwelingen-Snippe, Van Rompay, De Jong, & Ben Allouch, 2020; Van Houwelingen-Snippe, Van Rompay, & Ben Allouch, 2020), clearly our findings should be interpreted with caution.

In sum, although the empirical findings reported here do not warrant strong conclusions, they do point at a more than worthwhile direction for nature research by 1) following up on early suggestions made in ART (Kaplan & Kaplan, 1989), 2) integrating findings from across disciplines in the context of mental health promotion stressing the importance of spaciousness and its embodied basis, and 3) by capitalizing on the potential of VR-technology to stage immersive nature experiences that might provide an important antidote to the increasing number of



(young) adults battling with self-centeredness, negative affect, and related feelings of disconnect.

## Author statement

**Thomas van Rompay:** Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Writing - Review & Editing, Supervision. **Sandra Oran:** Conceptualization, Methodology, Investigation, Software. **Mirjam Galetzka:** Formal Analysis, Writing - Original Draft, Writing - Review & Editing. **Agnes van den Berg:** Writing - Original Draft, Writing - Review & Editing.

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