

Why does nature enhance psychological well-being? A Self-Determination account

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ABSTRACT

This research proposes a novel account for the established benefits of nature on psychological well-being from the perspective of Self-Determination Theory. That is, nature enhances psychological well-being by satisfying the basic psychological needs of autonomy, competence and relatedness. Compared with non-nature control settings, two field experiments consistently showed that participants who were exposed to nature scenes manifested higher levels of positive affect, life satisfaction and meaning in life; and satisfaction of the three psychological needs mediated these nature effects. Three laboratory studies replicated these findings by exposing participants to digital nature scenes (vs. non-nature ones) or indoor plants (vs. control setting without indoor plants) or engaging them in nature-related activities (vs. non-nature related ones), with the exception of a non-significant effect of nature on satisfaction of relatedness. Taken together, these studies provided convergent evidence for our proposition, shedding light on the mechanisms underlying the benefits of nature on psychological well-being.

1. Introduction

Nature is crucial for humans to survive and thrive, providing not only resources for survival but also psychological nourishments for thriving. As a result, humans have developed an innate tendency to become attached to nature across the long history of evolution (Baxter & Pelletier, 2019; Wilson, 1984). Research has established that exposure to nature is beneficial for humans in many ways, such as aiding in recovery from diverse deficits and boosting psychological well-being in general (for meta-analysis, see McMahan & Estes, 2015). While some accounts have attempted to understand the restorative effects of nature (Joye & van den Berg, 2011; Kaplan, 1995; Ulrich et al., 1991), the mechanisms underlying its enhancing effect on well-being remain largely unknown. In this research, we propose that nature can enhance psychological well-being by satisfying basic psychological needs of autonomy, competence and relatedness, as suggested by Self-Determination Theory (SDT; Deci & Ryan, 1985; 2000; Ryan & Deci, 2017). We conducted two field experiments and three laboratory experiments to test this hypothesis.

1.1. Nature and psychological well-being

Nature includes all types of physical environments and natural phenomena as opposed to human-built things (Soanes & Stevenson, 2005). Although nature could be threatening in some circumstances, most existing works have focused on non-threatening, pleasant natural environments (Baxter & Pelletier, 2019; Hartig et al., 2011). Notably, in examining the effect of nature, although pure nature without any social elements (e.g., people) is ideal, environments involving primarily nature with some social elements (e.g., urban parks, cultivated plants) are not rare, particularly in field studies about nature.

Decades of research has documented numerous benefits of nature for human beings. An important one is nature's restorative function, that is, helping people recover from various deficits and return to a baseline well-being. To date, numerous studies have demonstrated that exposure to nature can not only reduce stress and mental fatigue, but also ameliorate distress (Berman et al., 2012; Berto, 2005; Bratman, Hamilton, & Daily, 2012; Bratman, Hamilton, Hahn, Daily, & Gross, 2015; Corazon, Sidenius, Poulsen, Gramkow, & Stigsdottir, 2019; Hartig,

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Evans, Jamner, Davis, & Gärling, 2003; Moore & Van Vliet, 2022; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Schertz & Berman, 2019; Tsunetsugu et al., 2013; Tyrväinen et al., 2014; Ulrich et al., 1991).

Relevant to our current research is nature's function of enhancing well-being. A large body of research has found that nature can promote positive emotion, life satisfaction, subjective vitality and so on (Berman, Jonides, & Kaplan, 2008; Nisbet, Zelenski, & Murphy, 2011; Passmore, Yang, & Sabine, 2022; Passmore & Holder, 2017; Ryan et al., 2010; White, Pahl, Ashbullby, Herbert, & Depledge, 2013; for meta-analyses, see Bratman, Olvera-Alvarez, & Gross, 2021; McMahan & Estes, 2015). These effects have been demonstrated with real nature such as parks, forests, and indoor plants (e.g., Berman et al., 2008; Hartig et al., 2003; Ryan et al., 2010), digital nature such as images and videos (e.g., Bielinis, Simkin, Puttonen, & Tyrväinen, 2020; Browning, Saeidi-Rizi, McAnirlin, Yoon, & Pei, 2021; Ulrich et al., 1991), and in-nature activities (e.g., Passmore & Holder, 2017; Van den Berg, 2017).

1.2. Understanding the benefits of nature

To understand nature's positive effects on human beings, several theories have been proposed, including Stress Reduction Theory (SRT; Ulrich et al., 1991), Attention Restoration Theory (ART; Kaplan, 1995) and Perceptual Fluency Account (PFA; Joye & van den Berg, 2011).

SRT posits that humans have evolved a biologically determined capacity to recover from stress by themselves when exposed to nature, including both physiological and psychological responses (Ulrich et al., 1991). ART holds that some characteristics in nature (e.g., being away, soft fascination) endow humans with a special capability to replenish their voluntary attention by capturing their involuntary attention (Kaplan, 1995). Obviously, both SRT and ART assume that the restorative capability of humans was formed during the course of evolution.

Unlike SRT and ART, the Perception Fluency Account (PFA) argues that nature's positive effects (i.e., attention restoration and stress reduction) are by-products of perceptual fluency (Joye & van den Berg, 2011). According to PFA, fractals in natural objects render their natural elements highly like each other, thus enabling humans to easily predict other components in the scene and to fluently process the whole natural object with minimal cognitive resources (i.e., directed attention). As a result, deficits can subsequently be recovered.

These existing theories have mainly focused on the restorative functions of nature, or how nature can help people recover from diverse deficits. Less is known about the mechanisms underlying the enhancement of well-being function of nature. Extant research has identified several possible mediators, such as awe (McMahan, 2018; Shiota, Keltner, & Mossman, 2007), meaning in life (Howell, Passmore, & Buro, 2013) and positive social experiences (Coley, Kuo, & Sullivan, 1997). Solid empirical evidence for these possibilities, however, is still lacking and a sophisticated theory is needed.

1.3. A Self-Determination account: The role of basic psychological needs satisfaction

We propose that the benefits of nature on well-being can be understood from the perspective of Self-Determination Theory (SDT; Deci & Ryan, 1985; 2000; Ryan & Deci, 2017), an influential theory about human motivation, emotion and personality that has emerged over the past decades (Deci & Ryan, 1985; Van den Broeck, Ferris, Chang, & Rosen, 2016). SDT holds that humans strive to behave in a self-motivated and self-determined way. Three basic needs are critical for achieving this goal: 1. Autonomy (i.e., feeling volitional in making one's own decisions and actions), 2. Competence (i.e., feeling capable of accomplishing desired outcomes), and 3. Relatedness (i.e., feeling connected to and accepted by others). When these psychological needs are satisfied, humans can acquire determination and wellness or optimal function. Otherwise, ill-being and non-optimal functioning occur.

There is mounting evidence supporting SDT. Much of this evidence has involved the consequences and supportive conditions of basic needs satisfaction. One important consequence is the benefit of satisfying the three basic needs for psychological well-being. This benefit has been documented by a sub-theory of SDT, Basic Psychological Need Theory (BPNT; Ryan & Deci, 2000), which holds that an individual's psychological well-being relies on the satisfaction of the three basic needs. This benefit has also been empirically demonstrated through diverse indicators of well-being, including positive affect, satisfaction with life, meaning in life and subjective vitality (Leversen, Danielsen, Birkeland, & Samdal, 2012; Patrick, Knee, Canevello, & Lonsbary, 2007), with cross-sectional, longitudinal, and experimental designs (Leversen et al., 2012; Patrick et al., 2007; Savard, Joussemet, Emond Pelletier, & Mageau, 2013; Simoes & Alarcao, 2014; Tian, Chen, & Huebner, 2014; Veronneau, Koestner, & Abela, 2005), and in diverse cultures and domains (Chen et al., 2015; Ng et al., 2012; Van den Broeck et al., 2016; Vansteenkiste, Lens, & Deci, 2006).

As to the supportive conditions, although most studies have focused on social environments (for reviews, see Deci & Ryan, 2000; Ryan & Deci, 2017), some studies suggest that nature can also satisfy basic psychological needs, at least to some extent (Landon, Woosnam, Kyle, & Keith, 2021; Lee, Maillet, & Grouzet, 2022; Qusted, Thøgersen-Ntoumani, Uren, Hardcastle, & Ryan, 2018; Weinstein, Przybylski, & Ryan, 2009). Below, we elaborate on the relevant evidence.

First, nature can help satisfy individuals' need for autonomy. Compared with social environments, natural environments pose fewer social demands or constraints, thereby enabling people to behave more autonomously (Passmore & Howell, 2014). Research has shown that people tend to describe nature as a place which allows them to escape from everyday routines as well as from social judgement and offers them freedom to be themselves (Birch, Rishbeth, & Payne, 2020; Moore & Van Vliet, 2022; Oh, Shin, Khil, & Kim, 2020). Indeed, humans are more likely to express themselves freely, make decisions independently and engage in challenging activities in nature (Hartig et al., 2011; Kaplan, 1995; Landon et al., 2021). A latest finding that autonomous motivation is associated with engagement with nature also suggests a fit between autonomy and nature (Lee et al., 2022).

Second, nature may strengthen people's sense of competence. In contrast to social situations, pleasant natural environments are less stressful, thus endowing people with a stronger sense of control, a prerequisite of competence. Research thus far has shown that engaging with nature can help participants gain more control over their lives and improve their sense of self-worth, capability and vitality (Oh et al., 2020; Ryan et al., 2010; Swami, Barron, Hari, Grover, & Furnham, 2019). Earlier studies have also indicated that people with a high-trait connection to nature evaluate their self-image at a higher level (Swami, Barron, Weis, & Furnham, 2016) and feel more capable of maintaining control over and coping with life events (Fabio, Palazzeschi, & Duradoni, 2019).

Third, nature can satisfy the human need for relatedness (Howell, Dopko, Passmore, & Buro, 2011; Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009). Although this need for relatedness is primarily fulfilled through interaction with people, according to SDT (Deci & Ryan, 2000; Ryan & Deci, 2017), it can also be satisfied in other ways, as in contact with nature. One explanation for nature fulfilling the need for relatedness lies in the possibility for people to connect with other living things (Kaplan, 1995; Maas, van Dillen, Verheij, & Groenewegen, 2009; Wilson, 1984). Moreover, in a larger world, connection to nature itself represents a special form of relatedness because nature is a special social entity (Cleary, Fielding, Bell, Murray, & Roiko, 2017; Zelenski & Nisbet, 2014). Accordingly, other empirical studies have revealed that mere exposure to nature can improve a sense of connectedness with both other persons and nature (Passmore & Holder, 2017) as well as help humans regain a sense of belonging after being ostracized (Yang et al., 2021).

In summary, the existing theory and studies have established a link

between the three basic needs and psychological well-being, and at the same time, also suggested a link between nature and the satisfaction of the three basic needs (Landon et al., 2021). Together, these links suggested a mechanism for the benefits of nature on psychological well-being: nature satisfies the basic needs of autonomy, competence and relatedness, and thereby promotes psychological well-being. This mechanism generated a mediation model as illustrated in Fig. 1. Some preliminary evidence for this model was previously available (e.g., Landon et al., 2021; Lee et al., 2022; Quested et al., 2018). For instance, a recent study showed that exposure to outdoor natural environments in the form of gardening may enhance subjective vitality by satisfying basic needs (Quested et al., 2018). Yet, this study is a qualitative analysis limited to a small sample of gardeners ($N = 15$). Our series of studies submit this model to direct, systematic examination (see Fig. 1).

1.4. Overview

We aimed to examine the self-determination account for the benefits of nature on psychological well-being by testing the mediating role of basic psychological needs (i.e., autonomy, relatedness and competence) in the relation between nature and psychological well-being. We conducted two studies. Study 1 includes two field experiments that were conducted in either actual parks replete with nature scenes or plazas surrounded by human-built commercial (rather than historical) buildings (Scopelliti, Carrus, & Bonaiuto, 2019) (Studies 1a & 1b); Study 2 comprises three laboratory experiments (Studies 2a, 2b & 2c). Across these studies, we tested whether nature would enhance psychological well-being and whether satisfaction of basic psychological needs could mediate the effect (see Fig. 1). This research was approved by the Ethics Committee of the first author's affiliation. The data are available at: <https://osf.io/7gzhx>.

2. Study 1 field experiment

Study 1 consisted of two field experiments. Study 1a was a quasi-experimental study, in which we spontaneously recruited participants onsite from a park composed of nature scenes (e.g. trees, flowers and birds) and a plaza of human-built structures (e.g. shopping center, restaurants). Study 1b was a randomized experiment, whereby we randomly assigned participants to a park of nature scenes and a plaza featuring concreted areas and buildings. In both studies, we assessed whether nature would enhance psychological well-being and whether satisfaction of basic psychological needs would mediate this effect.

2.1. Study 1a: A quasi experiment

2.1.1. Participants and procedure

According to previous meta-analysis (McMahan & Estes, 2015), the effect of nature on psychological well-being was moderate. We thus expected a medium effect size of nature in the current study (i.e., $d = 0.5$). A power analysis suggested that 128 participants were needed to ensure 80% statistical power (G*Power 3.1; Faul, Erdfelder, Lang, & Buchner, 2007). We used the same approach in the following studies to determine our sample size.

For this experiment, two types of fields are involved (for sample images, see Fig. 2): parks of nature scenes (nature condition) and plazas of buildings (non-nature or control condition). We recruited a total of 186 participants onsite, ranging from 13 to 58 years old ($M = 25.80$, $SD = 9.33$; 94 females and 92 males). Of them, 94 were in the park and 92 in the plaza. All participants were asked to sign a written consent at the beginning and then complete the measures on basic psychological needs and psychological well-being (i.e. positive affect, life satisfaction and experience of meaning in life) in sequence along with some demographic items at the end. Finally, they were thanked, debriefed and given a gift for compensation (worth 5 Chinese Yuan) before leaving.

2.1.2. Measures

Basic psychological needs. The *Basic Psychological Needs Scale*, developed by Sheldon, Elliot, Kim, and Kasser (2001), was used to assess the extent to which the three basic psychological needs were satisfied. It contained 6 items, measuring three basic needs of autonomy, competence and relatedness, respectively. The items for autonomy were "Right now, I feel that my choices are based on my true interests and values" and "Right now, I feel free to do things my own way." For competence, the items included, "Right now, I feel that I successfully completed difficult tasks and projects" and "Right now, I feel very capable of what I did." Finally, those for relatedness were "Right now, I feel close and connected with other people who are important to me" and "Right now, I feel a strong sense of intimacy with the people I spent time with". Participants were asked to rate the extent to which they agreed or disagreed with each of these statements based on their momentary feelings (1 = *strongly disagree*; 7 = *strongly agree*). In this experiment, the scale had high reliability ($\alpha = .88$ for the whole scale and 0.91, 0.81, 0.86 for subscales of autonomy, competence and relatedness, respectively).

Positive affect. We assessed participants' affective well-being with four positive items selected from the *Scale of Positive and Negative Experience* (i.e., pleasant, joyful, happy, contented) (Diener et al., 2010). Participants were asked to indicate the extent to which they experienced these four positive affects on a seven-point Likert scale (1 = *not at all*, 7 = *very strong*) according to their current feelings. An average score was obtained as the indicator of the positive affect ($\alpha = .96$).

Life satisfaction. We assessed life satisfaction with the five-item *Satisfaction with Life Scale* (Diener, Emmons, Larsen, & Griffin, 1985) (e.g., *I am satisfied with my life*). Participants indicated how much they agreed or disagreed with each statement on a 7-point Likert scale according to their feelings at that moment (1 = *strongly disagree*, 7 = *strongly agree*). We used the average score across the five items as the index of a state of satisfaction with life ($\alpha = .89$).

Meaning in life. We used the presence subscale in the *Meaning in Life Questionnaire* to assess sense of meaning in life (Steger, Frazier, Oishi, & Kaler, 2006). The subscale includes five items, one example being "I understand the meaning of my life." Participants indicated their agreement with the five statements on a seven-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). The ratings on the five items were averaged to form an indicator of a sense of meaning ($\alpha = .87$).

2.1.3. Results¹

A series of independent *t*-tests using the *emmeans* function in R package were conducted to test the effect of nature on basic psychological needs satisfaction and psychological well-being. As expected, participants in the nature condition scored higher on all outcome variables than those in the control condition (for details, see Table 1), indicating that exposure to real nature enhanced the satisfaction of psychological needs and psychological well-being.

We proceeded to test mediation models as mentioned above (Fig. 1), using the mediation function in R package. In these models, we used positive affect, life satisfaction and meaning in life as outcome variables and the experimental condition as the independent variable (*nature* = 1, *control* = 0). We first tested the mediation role of the overall satisfaction of basic psychological needs. To do so, we utilized the bootstrap method to estimate the model (model 4) (sample size = 5000) (Hayes, 2013). If the 95% bootstrap confidence interval of the indirect effect does not include a zero, the mediating effect is significant. Results showed that the mediation effect was significant for all three well-being outcomes (see Table 2).

Next we separately tested the mediating role of the three specific psychological needs with the same bootstrap methodology. As shown in

¹ Preliminary analysis showed that neither age nor gender made a significant difference, both $ps > 0.05$. Hence, we did not consider them in subsequent analyses.

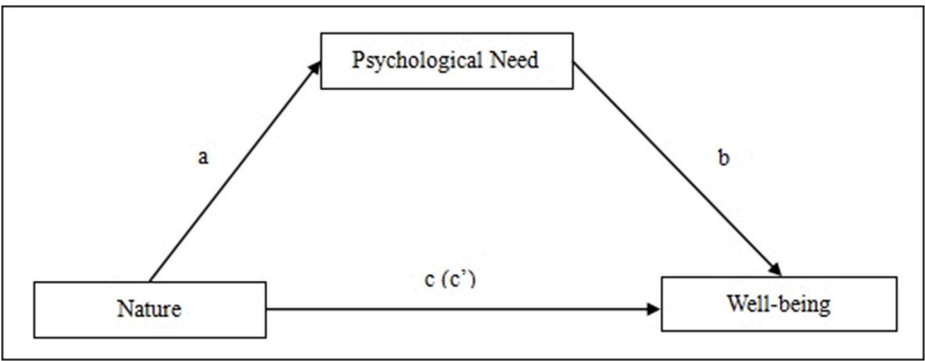


Fig. 1. The self-determination mediation model.
Note. a = simple path coefficient from nature to mediator; b = simple path coefficient from mediator to outcome; c = simple path coefficient from nature to outcome; c' = path coefficient from nature to outcome, adjusting for mediator.



Fig. 2. Example images of environments in Study 1. The left is the nature condition (urban park), while the right served as the control condition (urban plaza).

Table 1
Statistics for t-tests of Study 1a.

	<i>M (SD)</i>		<i>t</i> (184)	<i>p</i>	Cohen's <i>d</i> 95% CI
	Nature (<i>N</i> = 92)	Control (<i>N</i> = 94)			
BPN	5.16 (.92)	4.74 (1.13)	2.80	.006	.41 [.121, .700]
Autonomy	5.32 (1.04)	4.81 (1.42)	2.75	.007	.40 [.113, .691]
Competence	5.33 (1.01)	4.97 (1.27)	2.13	.035	.31 [.022, .601]
Relatedness	4.84 (1.32)	4.43 (1.29)	2.15	.033	.32 [.026, .604]
Positive affect	4.83 (1.23)	4.30 (1.29)	2.86	.005	.42 [.130, .709]
Satisfaction with life	4.78 (1.10)	4.20 (1.20)	3.42	<.001	.50 [.212, .791]
Meaning in life	4.72 (.86)	4.29 (1.00)	3.12	.002	.46 [.169, .748]

Note. BPN = Basic Psychological Need.

Table 2, the effects of exposure to nature on all three outcomes of psychological well-being could be mediated by satisfying all three basic needs.²

It is notable that after partialing out the mediation effects, most of the direct effects were still significant, suggesting that the effects of nature on psychological well-being could not be totally explained by satisfaction of basic needs. One reason for this partial mediation might be because the participants had not been randomly assigned to the two conditions, and the participants in the park had a higher initial level of psychological well-being than those in the plaza. Another possible reason might be that some other mediators were not examined.

In summary, Study 1a provided initial evidence for the Self-Determination account for the benefits of nature on psychological well-being. Study 1a, however, was a quasi-experimental field study, which did not allow for complete causal inference. Study 1b overcomes this limitation with a randomized experimental design.

² We also tested the unique mediating role of satisfaction of the three specific psychological needs by conducting parallel mediation analyses (see Table 1 in the Supplementary file). In the subsequent four studies, we conducted similar parallel mediation analyses and presented the results in Tables 2–5 in the Supplementary file. The total mediation effects in all five studies were significant, indicating that the three basic needs as a whole could account for the enhancing effect of nature on subjective well-being, which was consistent with the findings of mediation analyses with sum score of three subscales as the index of basic psychological need. Nevertheless, the unique mediating effect of each need varied across studies.

Table 2

Path Coefficients for mediation models in Study 1a.

Model	Path Coefficients and <i>p</i> value				SE	Indirect effect <i>ab</i> 95% CI
	<i>a</i> (<i>p</i>)	<i>b</i> (<i>p</i>)	<i>c</i> (<i>p</i>)	<i>c'</i> (<i>p</i>)		
Nature→BPN→PA	.42 (.006)	.53 (<.001)	.53 (.005)	.30 (.075)	.09	.22 [.073, .426]
Nature→Autonomy→PA	.50 (.007)	.34 (<.001)	.53 (.005)	.36 (.045)	.10	.17 [.047, .380]
Nature→Competence→PA	.36 (.035)	.35 (<.001)	.53 (.005)	.40 (.024)	.07	.12 [.018, .293]
Nature→Relatedness→PA	.41 (.033)	.41 (<.001)	.53 (.005)	.36 (.036)	.09	.17 [.022, .404]
Nature→BPN→LS	.42 (.006)	.67 (<.001)	.58 (.001)	.29 (.036)	.11	.29 [.100, .511]
Nature→Autonomy→LS	.50 (.007)	.44 (<.001)	.58 (.001)	.36 (.020)	.09	.22 [.070, .440]
Nature→Competence→LS	.36 (.035)	.45 (<.001)	.58 (.001)	.42 (.007)	.08	.16 [.029, .352]
Nature→Relatedness→LS	.41 (.033)	.52 (<.001)	.58 (.001)	.36 (.009)	.12	.21 [.022, .475]
Nature→BPN→ML	.42 (.006)	.46 (<.001)	.43 (.002)	.23 (.055)	.08	.19 [.061, .369]
Nature→Autonomy→ML	.50 (.007)	.32 (<.001)	.43 (.002)	.27 (.037)	.07	.16 [.048, .322]
Nature→Competence→ML	.36 (.035)	.35 (<.001)	.43 (.002)	.30 (.017)	.07	.13 [.013, .279]
Nature→Relatedness→ML	.41 (.033)	.29 (<.001)	.43 (.002)	.31 (.016)	.07	.12 [.011, .303]

Note. BPN = Basic Psychological Need; PA = Positive Affect; LS = Life Satisfaction; ML = Meaning in Life. *a* = simple path coefficient from nature to mediator; *b* = simple path coefficient from mediator to outcome; *c* = simple path coefficient from nature to outcome; *c'* = path coefficient from nature to outcome, adjusting for mediator.

2.2. Study 1b: A randomized experiment

2.2.1. Method

Participants. The sample size was determined as in Study 1. One hundred and fifty-two college students aged from 18 to 24 were invited to take part in the field study ($M = 18.93$, $SD = 0.99$; 89 females and 63 males).

Procedure. After signing the consent form, participants were randomly assigned to one of the two testing sites: a park of nature scenes (nature condition; $n = 75$) and an urban plaza of buildings (control condition; $n = 77$). After arriving at the testing sites, they were first asked to rest and observe the surroundings of the testing site for 5 minutes. Then they were invited to write down details about the surroundings based on their observations. After the writing task, participants completed a package of questionnaires as noted below, along with other measures unrelated to the present research. Finally, all of the participants were thanked and debriefed. For compensation, they received a partial course credit.

Measures. We used the same scales, basic psychological needs ($\alpha = .82, .85, .83$ for the three subscales: *autonomy*, *competence* and *relatedness*, respectively, and 0.92 for the whole scale), life satisfaction ($\alpha = .88$) and meaning in life ($\alpha = .79$) as used in Study 1a.

In order to assess participants' emotional well-being, we used the Chinese version of the Positive and Negative Affect Scale (PANAS) (Qiu, Zheng, & Wang, 2008). Participants were asked to indicate their immediate feelings in terms of nine positive affects (e.g., *enthusiastic*, *determined* and *interested*) on a 5-point Likert scale (1 = *very slight*, 5 = *very strong*). We used the mean score of the nine items as the index of positive affect ($\alpha = .96$).

2.2.2. Results

As predicted, participants in the nature condition scored higher on all outcome variables than those in the control condition (see Table 3), indicating that nature can enhance satisfaction of psychological needs as well as well-being.

We then conducted a series of mediation tests, as in Study 1a. Results showed that the effects of nature on all three outcomes of psychological well-being were significantly mediated by satisfaction of basic needs, either as a whole or separately (see Table 4). Again, in some cases (i.e., when the outcome was a positive affect), psychological needs satisfaction only partially mediated the effect of nature, suggesting the existence of other possible mechanisms.

Taken together, Studies 1a and 1b provide consistent evidence of the Self-Determination account for the benefits of nature on psychological well-being. These two studies were conducted in real, natural environments. Next, we conducted another series of studies to examine whether these findings could be replicated in diverse laboratory settings, in

Table 3Statistics for *t*-tests of Study 1b.

	<i>M</i> (<i>SD</i>)		<i>t</i> (184)	<i>p</i>	Cohen's <i>d</i> 95% CI
	Nature (<i>N</i> = 75)	Control (<i>N</i> = 77)			
BPN	5.36 (1.05)	4.97 (.91)	2.49	.014	.40 [.084, .725]
Autonomy	5.53 (1.08)	5.10 (.98)	2.60	.010	.42 [.102, .743]
Competence	5.34 (1.09)	4.94 (1.14)	2.23	.027	.36 [.042, .683]
Relatedness	5.21 (1.19)	4.86 (.97)	1.99	.048	.32 [.002, .643]
Positive affect	3.61 (.83)	3.08 (.83)	3.96	<.001	.64 [.321, .962]
Satisfaction with life	4.96 (1.13)	4.49 (1.14)	2.57	.011	.42 [.097, .738]
Meaning in life	4.99 (.89)	4.59 (1.06)	2.47	.015	.40 [.079, .721]

Note. BPN = Basic Psychological Need.

which participants were only exposed to limited natural elements.

3. Study 2 laboratory studies

Study 2 included three laboratory experiments. Each of these studies employed a specific way to engage participants with nature, such as watching a video related to nature (vs. a video unrelated to nature; Study 2a), completing the survey in a room with indoor plants (vs. without indoor plants; Study 2b) and creating an artwork using items from nature (vs. geometry objects; Study 2c). While Study 2a only used positive affect as the outcome, Studies 2b and 2c used the same three outcomes (i.e., positive affect, life satisfaction, and meaning in life) as used in Study 1.

3.1. Study 2a: The effect of digital nature

3.1.1. Method

Participants. A total of 177 undergraduates (127 females and 50 males) participated in the current study, their age ranging from 18 to 35 years ($M = 20.05$, $SD = 1.62$; six participants did not report their age). Each of them was paid 10 Chinese Yuan as compensation.

Procedure and materials. After signing a consent form, participants were randomly assigned to the nature or non-nature control condition. They were first asked to watch a 5-min video depicting either natural scenes (i.e., *forests*, *rivers*, *beaches*, *meadows*, and *mountains*; nature condition) or urban scenes (i.e., *streets*, *roads*, *buildings*, and *plazas*;

Table 4

Path Coefficients for mediation models in Study 1b.

Model	Path Coefficients and <i>p</i> value				SE	Indirect effect <i>ab</i> 95% CI
	<i>a</i> (<i>p</i>)	<i>b</i> (<i>p</i>)	<i>c</i> (<i>p</i>)	<i>c'</i> (<i>p</i>)		
Nature→BPN→PA	.40 (.014)	.40 (<.001)	.53 (<.001)	.37 (.003)	.07	.16 [.037, .317]
Nature→Autonomy→PA	.44 (.010)	.27 (<.001)	.53 (<.001)	.41 (.002)	.05	.12 [.032, .244]
Nature→Competence→PA	.40 (.027)	.35 (<.001)	.53 (<.001)	.39 (.002)	.07	.14 [.027, .303]
Nature→Relatedness→PA	.35 (.048)	.38 (<.001)	.53 (<.001)	.40 (.001)	.07	.13 [.001, .291]
Nature→BPN→LS	.40 (.014)	.69 (<.001)	.47 (.011)	.20 (.190)	.11	.28 [.062, .522]
Nature→Autonomy→LS	.44 (.010)	.53 (<.001)	.47 (.011)	.24 (.145)	.10	.23 [.065, .444]
Nature→Competence→LS	.40 (.027)	.61 (<.001)	.47 (.011)	.23 (.133)	.11	.25 [.048, .495]
Nature→Relatedness→LS	.35 (.048)	.59 (<.001)	.47 (.011)	.27 (.085)	.11	.20 [.002, .429]
Nature→BPN→ML	.40 (.014)	.71 (<.001)	.39 (.015)	.11 (.339)	.11	.28 [.073, .511]
Nature→Autonomy→ML	.44 (.010)	.58 (<.001)	.39 (.015)	.14 (.285)	.10	.25 [.070, .474]
Nature→Competence→ML	.40 (.027)	.61 (<.001)	.39 (.015)	.15 (.215)	.11	.25 [.038, .474]
Nature→Relatedness→ML	.35 (.048)	.58 (<.001)	.39 (.015)	.19 (.129)	.10	.20 [.007, .415]

Note. BPN = Basic Psychological Need; PA = Positive Affect; LS = Life Satisfaction; ML = Meaning in Life. *a* = simple path coefficient from nature to mediator; *b* = simple path coefficient from mediator to outcome; *c* = simple path coefficient from nature to outcome; *c'* = path coefficient from nature to outcome, adjusting for mediator.

control condition) (see Fig. 3). The video was played on mute in order to eliminate possible confounds arising from other sounds. While watching, participants were instructed to immerse themselves in the environment depicted in the video.

After the video-viewing task, participants immediately completed the basic psychological needs scale and thereafter a positive affect scale. They received 10 Chinese yuan in compensation and were thoroughly debriefed.

The basic psychological needs scale was identical to the one used in Study 1a. In this study, the alpha coefficient was 0.89 for the full scale and 0.79, 0.87 and 0.83 for the subscales of needs for autonomy, competence and relatedness, respectively. The positive affect subscale of the Chinese version of the Positive and Negative Affect Scale (PANAS) (Qiu et al., 2008) was adopted as in Study 1b ($\alpha = .93$).

3.1.2. Results and discussion

As compared to those who watched the urban scene video, a series of independent *t*-tests revealed that participants who watched a nature scene video reported higher levels of positive affect. They also reported higher levels of satisfaction of needs in general. Notably, however, the manipulation produced a significant effect on the need for autonomy and competence as expected but not on the need for relatedness (for details, see Table 5).

We proceeded to test the mediating role of basic needs satisfaction as a whole and need for autonomy and competence, separately, using the same procedures as in Study 1. As shown in Table 6, the indirect effects of all three mediation models were significant. Overall, the nature (vs. control) scenes promoted positive affect through satisfying psychological needs. Besides, satisfaction of the need for autonomy and competence could also significantly and independently mediate the effect. Again, in some cases, the mediators only partially explained the effect of

Table 5Statistics for *t*-tests of Study 2a.

	<i>M</i> (<i>SD</i>)		<i>t</i>	<i>p</i>	Cohen's <i>d</i> 95% CI
	Nature (<i>N</i> = 88)	Control (<i>N</i> = 89)			
BPN	4.81 (1.11)	4.43 (1.09)	2.29	.023	.34 [.048, .641]
Autonomy	5.22 (1.31)	4.48 (1.19)	4.20	<.001	.63 [.334, .928]
Competence	4.81 (1.32)	4.39 (1.28)	2.12	.036	.32 [.022, .615]
Relatedness	4.41 (1.43)	4.42 (1.26)	−0.03	.974	.01 [−.302, .292]
Positive affect	2.95 (.72)	2.50 (.82)	3.85	<.001	.58 [.282, .876]

Note. BPN = Basic Psychological Need.

nature (see Table 6).

In summary, Study 2a replicated most of the findings in Study 1, albeit in a laboratory setting. The one exception was a null effect of nature on satisfying the need for relatedness.

3.2. Study 2b: The effect of indoor plants

3.2.1. Method

Participants. We recruited 157 college students to ensure 80% statistical power (97 females and 60 males). Their ages ranged from 17 to 25 years ($M = 19.86$, $SD = 1.76$).

Procedure. Following a previous study (Study 4, Weinstein et al., 2009), participants were randomly assigned to one of two conditions. In the nature condition ($N = 78$), the lab room was furnished with six



Fig. 3. Example images of scenes in nature vs. urban video (Study 2a).

Table 6

Path Coefficients for mediation models in Study 2a.

Model	Path Coefficients and <i>p</i> value				SE	Indirect effect <i>ab</i> 95% CI
	<i>a</i> (<i>p</i>)	<i>b</i> (<i>p</i>)	<i>c</i> (<i>p</i>)	<i>c'</i> (<i>p</i>)		
Nature→BPN→PA	.38 (.023)	.42 (<.001)	.45 (<.001)	.29 (.003)	.07	.16 [.024, .309]
Nature→Autonomy→PA	.73 (<.001)	.36 (<.001)	.45 (<.001)	.18 (.074)	.07	.26 [.139, .423]
Nature→Competence→PA	.41 (.036)	.31 (<.001)	.45 (<.001)	.32 (.002)	.06	.13 [.013, .261]
Nature→Relatedness→PA	-.01 (.974)	.29 (<.001)	.45 (<.001)	.45 (<.001)	.05	-.002 [-.121, .114]

Note. BPN = Basic Psychological Need; PA = Positive affect.

plants of varying types and sizes. The control condition ($N = 79$) used a lab room of the same arrangement, minus the plants (for the layouts of the rooms, see Fig. 4). In both conditions, participants were first asked to rest for 5 minutes before completing the basic psychological needs scale and well-being measures in sequence. After completing the tests, participants received 10 Chinese yuan in compensation and were thoroughly debriefed.

We assessed basic psychological needs ($\alpha = .80$ for the full scale 0.82, 0.76, 0.83 for subscales of autonomy, competence and relatedness, respectively), positive affect ($\alpha = .95$), life satisfaction ($\alpha = .86$) and meaning in life ($\alpha = .87$) with the same scales as used in Study 1b.

3.2.2. Results and discussion

As expected, a series of independent *t*-tests showed that participants in the nature condition reported higher levels across all of the outcome variables than those in the control condition (for details, see Table 7), the one exception being the need for competence. That is, the presence of indoor plants proved to be sufficient to satisfy participants' psychological needs overall in addition to the specific psychological needs of autonomy and relatedness (but not competence), and to also enhance their psychological well-being.

Next, we tested the mediation model using the same approach as used in Study 1 (see Fig. 1). The results are displayed in Table 8. The effects of exposure to nature on all three outcomes of psychological well-being can be mediated by satisfaction of the three psychological needs as a whole and separately, through the specific needs for autonomy and relatedness. Again, in some cases, the mediators only partially mediated the benefits of nature (see Table 8).

Overall, we replicated all findings from Study 1 in a novel laboratory setting, except for the null effect of nature on satisfying the need for competence.

3.3. Study 2c: The effect of nature-engaged activity

3.3.1. Method

Participants. A total of 161 college students participated in the experiment (137 females and 24 males; $M = 19.30$, $SD = 1.01$).

Procedure. After giving their consent to take part in the study,

Table 7Statistics for *t*-tests of Study 2b.

	<i>M</i> (<i>SD</i>)		<i>t</i> (155)	<i>p</i>	Cohen's <i>d</i> 95% CI
	Nature (<i>N</i> = 78)	Control (<i>N</i> = 79)			
BPN	5.15 (1.01)	4.73 (.94)	2.71	.008	.43 [.117, .747]
Autonomy	5.64 (1.08)	5.25 (1.03)	2.34	.021	.37 [.058, .689]
Competence	5.25 (1.17)	4.90 (1.15)	1.90	.059	.30 [-.012, .618]
Relatedness	4.55 (1.63)	4.03 (1.50)	2.07	.040	.33 [.016, .646]
Positive affect	2.73 (.97)	2.42 (.86)	2.11	.037	.34 [.021, .652]
Satisfaction with life	4.14 (1.21)	3.71 (1.25)	2.21	.029	.35 [.037, .667]
Meaning in life	4.70 (1.26)	4.19 (1.12)	2.65	.009	.42 [.107, .738]

Note. BPN = Basic Psychological Need.

participants were randomly assigned to the nature condition or control condition. All participants were provided with the same tools for creating or drawing, including a piece of A4 paper, a box of crayons, and a bottle of glue. Participants in the nature condition were instructed to create a picture consisting of natural objects (e.g., fallen leaves, twigs, petals, flowers) as shown in the sample pictures (the left one in Fig. 5). Participants in the control condition were asked instead to draw a picture consisting of geometric shapes (e.g., triangles, circles, rectangles, polygons) as shown in the sample pictures (the right one in Fig. 5).

The instructions for those in the nature condition read: "Here are crayons, tape, a sheet of paper and nature objects (e.g., fallen leaves, twigs, petals, flowers). Please create a nature picture within 10 minutes using the utensils and materials provided. Inform the experimenter when you are finished."

The instructions for participants in the control condition directed: "Here are crayons, a ruler, a sheet of paper and geometric shapes (e.g., triangles, circles, rectangles, polygons). Please create a geometric picture within 10 minutes using the utensils and materials provided. Inform the experimenter



Fig. 4. Images of the laboratory rooms. The left one with indoor plants represents the nature condition, while the right one without any plants served as the control condition.

Table 8

Path Coefficients for mediation models in Study 2b.

Model	Path Coefficients and <i>p</i> value				SE	Indirect effect <i>ab</i> 95% CI
	<i>a</i> (<i>p</i>)	<i>b</i> (<i>p</i>)	<i>c</i> (<i>p</i>)	<i>c'</i> (<i>p</i>)		
Nature→BPN→PA	.42 (.008)	.34 (<.001)	.31 (.037)	.16 (.245)	.07	.15 [.038, .295]
Nature→Autonomy→PA	.39 (.021)	.20 (.005)	.31 (.037)	.23 (.114)	.05	.08 [.010, .195]
Nature→Competence→PA	.35 (.059)	.26 (<.001)	.31 (.037)	.22 (.122)	.06	.09 [-.002, .224]
Nature→Relatedness→PA	.52 (.040)	.17 (<.001)	.31 (.037)	.22 (.125)	.05	.09 [.013, .217]
Nature→BPN→LS	.42 (.008)	.42 (<.001)	.43 (.029)	.26 (.180)	.08	.18 [.055, .380]
Nature→Autonomy→LS	.39 (.021)	.28 (.003)	.43 (.029)	.32 (.098)	.06	.11 [.030, .263]
Nature→Competence→LS	.35 (.059)	.20 (.016)	.43 (.029)	.36 (.067)	.05	.07 [.001, .216]
Nature→Relatedness→LS	.52 (.040)	.25 (<.001)	.43 (.029)	.30 (.112)	.07	.13 [.021, .328]
Nature→BPN→ML	.42 (.008)	.40 (<.001)	.51 (.009)	.33 (.072)	.08	.17 [.044, .361]
Nature→Autonomy→ML	.39 (.021)	.19 (.036)	.51 (.009)	.43 (.026)	.06	.08 [.004, .223]
Nature→Competence→ML	.35 (.059)	.30 (<.001)	.51 (.009)	.40 (.032)	.07	.10 [.008, .271]
Nature→Relatedness→ML	.52 (.040)	.22 (<.001)	.51 (.009)	.39 (.037)	.07	.11 [.011, .307]

Note. BPN = Basic Psychological Need; PA = Positive Affect; LS = Life Satisfaction; ML = Meaning in Life. *a* = simple path coefficient from nature to mediator; *b* = simple path coefficient from mediator to outcome; *c* = simple path coefficient from nature to outcome; *c'* = path coefficient from nature to outcome adjusting for mediator.

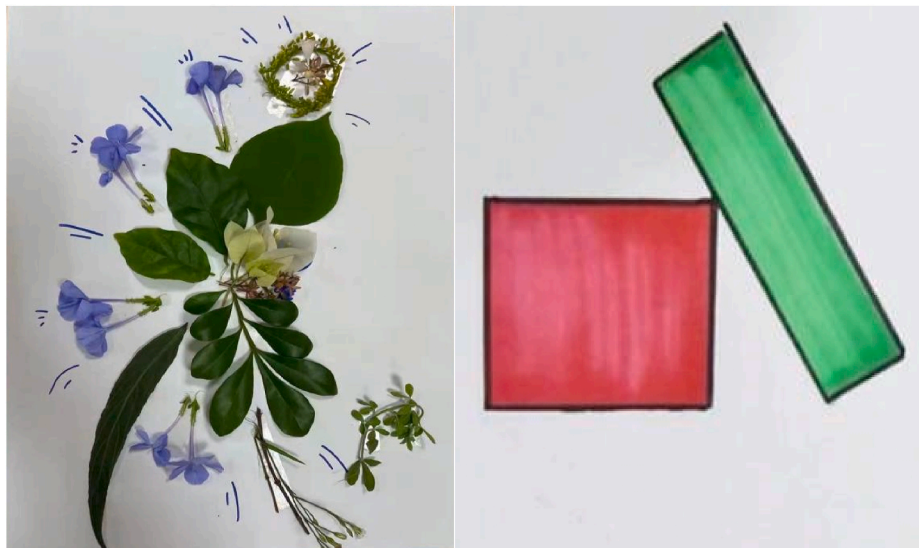


Fig. 5. Sample works made by the participants. The left sample was created in the nature condition, while the right was created in the control condition.

when you are finished.”

After the creation task, participants were invited to complete the basic psychological needs scale first and thereafter the well-being measures. Upon finishing, all participants received 15 Chinese yuan in compensation, and then were thoroughly debriefed.

All scales were identical to those employed in Study 1b. For the basic psychological needs scale, the alpha coefficient was 0.67 for the full scale and 0.83, 0.69, and 0.79 for the subscales of autonomy, competence and relatedness, respectively. For psychological well-being, the alpha coefficient was 0.90 for the positive affect, 0.76 for life satisfaction and 0.88 for meaning in life.

3.3.2. Results and discussion

Consistent with our expectations and findings in Studies 2a and 2b, participants in the nature condition gave higher ratings for all of the outcome measures than those in the control condition except for the need of relatedness (see Table 9). That is to say, engaging in nature-related activities promoted the satisfaction of basic psychological needs overall and the specific psychological needs of autonomy and competence, and simultaneously, enhanced psychological well-being.

Table 9Statistics for *t*-tests of Study 2c.

	<i>M</i> (<i>SD</i>)		<i>t</i> (159)	<i>p</i>	Cohen's <i>d</i> 95% CI
	Nature (<i>N</i> = 81)	Control (<i>N</i> = 80)			
BPN	4.91 (.71)	4.61 (.89)	2.40	.018	.38 [.067, .689]
Autonomy	5.95 (.99)	5.42 (1.13)	3.14	.002	.49 [.184, .806]
Competence	5.23 (.97)	4.83 (1.20)	2.34	.021	.37 [.057, .680]
Relatedness	3.56 (1.26)	3.58 (1.49)	−0.06	.952	.01 [−.321, .302]
Positive emotion	3.12 (.81)	2.87 (.66)	2.16	.032	.34 [.030, .652]
Satisfaction with life	4.74 (.82)	4.35 (1.01)	2.71	.007	.43 [.117, .739]
Meaning in life	4.74 (.98)	4.33 (1.04)	2.55	.012	.40 [.090, .713]

Note. BPN = Basic Psychological Need

Next, we tested the mediation model using the same approach as used in Study 1 (see Fig. 1). The results showed that the enhancing effects of engagement in nature-related activities on all three outcomes of psychological well-being can be mediated by satisfaction of the three psychological needs as a whole, as well as by the separate needs of autonomy and competence (see Table 10). Similar to previous studies, in some cases, the mediators only partially accounted for the benefits of nature.

Overall, Study 2c replicated nearly all of the findings from Study 1, apart from the null effect of nature on satisfying the need for relatedness.

3.4. Summary of study 2

Study 2 included three experiments, each using a specific nature manipulation procedure: viewing digital nature scenes, exposure to indoor plants and engaging in nature-related activities. In general, we replicated the main findings of Study 1, suggesting that the Self-Determination account also works in a laboratory situation where natural elements are limited. A few exceptions arose, however, involving the needs of competence and relatedness. Specifically, we found null effects of nature on satisfying the need for relatedness in Study 2a and Study 2c and on satisfying the need for competence in Study 2b. Meta-analyses on findings about the satisfaction of these two needs across the three laboratory experiments revealed that nature produced a significant effect on the satisfaction of the need for competence ($d = 0.33$, $p < .001$, 95% $CI = [0.15, 0.51]$) but not on satisfaction of the need for relatedness ($d = .10$, $p = .380$, 95% $CI = [-0.12, 0.32]$). Further meta-analyses on their mediation effects indicated that the mediation effect was significant for satisfaction of the need for competence but not for relatedness (see Table 11). Further discussion of the null effect follows.

4. General discussion

It is well established that nature is beneficial to the psychological well-being of human beings. What is less known are the underlying mechanisms (Quested et al., 2018). Inspired by previous researchers (e. g., Passmore & Howell, 2014; Quested et al., 2018), we proposed that nature may enhance psychological well-being through self-determination or fulfillment of the three basic human needs for autonomy, competence and relatedness, as suggested by Self-Determination Theory (Deci & Ryan, 1985, 2000; Ryan & Deci, 2017). We conducted two field studies and three laboratory studies to test this hypothesis.

4.1. Main findings

The field studies provide consistent support for our proposition:

Table 10
Path Coefficients for mediation models in Study 2c.

Model	Path Coefficients and p value				SE	Indirect effect ab 95% CI
	a (p)	b (p)	c (p)	c' (p)		
Nature→BPN→PA	.31 (.018)	.35 (<.001)	.25 (.032)	.15 (.188)	.05	.11 [.025, .229]
Nature→Autonomy→PA	.53 (.002)	.24 (<.001)	.25 (.032)	.13 (.266)	.05	.13 [.046, .238]
Nature→Competence→PA	.40 (.021)	.20 (<.001)	.25 (.032)	.17 (.130)	.04	.08 [.019, .179]
Nature→Relatedness→PA	-.01 (.952)	.09 (.025)	.25 (.032)	.25 (.029)	.02	-.001 [-.051, .046]
Nature→BPN→LS	.31 (.018)	.40 (<.001)	.39 (.007)	.27 (.052)	.06	.12 [.028, .261]
Nature→Autonomy→LS	.53 (.002)	.19 (.005)	.39 (.007)	.29 (.074)	.05	.10 [.032, .224]
Nature→Competence→LS	.40 (.021)	.25 (<.001)	.39 (.007)	.29 (.040)	.05	.10 [.020, .235]
Nature→Relatedness→LS	-.01 (.952)	.14 (.009)	.39 (.007)	.40 (.006)	.03	-.001 [-.065, .067]
Nature→BPN→ML	.31 (.018)	.45 (<.001)	.41 (.012)	.27 (.078)	.06	.14 [.033, .286]
Nature→Autonomy→ML	.53 (.002)	.17 (.026)	.41 (.012)	.32 (.052)	.05	.09 [.010, .223]
Nature→Competence→ML	.40 (.021)	.26 (<.001)	.41 (.012)	.30 (.056)	.05	.01 [.022, .235]
Nature→Relatedness→ML	-.01 (.952)	.19 (.001)	.41 (.012)	.41 (.009)	.04	-.003 [-.089, .084]

Note. BPN = Basic Psychological Need; PA = Positive Affect; LS = Life Satisfaction; ML = Meaning in Life. a = simple path coefficient from nature to mediator; b = simple path coefficient from mediator to outcome; c = simple path coefficient from nature to outcome; c' = path coefficient from nature to outcome adjusting for mediator.

Table 11

Meta-analysis results for mediation effects in Study 2.

Path	ab	SE	p	95% CI
Nature→Competence→PA	.09	.03	.001	[.037, .151]
Nature→Relatedness→PA	.02	.03	.454	[-.033, .067]
Nature→Competence→LS	.09	.04	.016	[.016, .154]
Nature→Relatedness→LS	.04	.06	.476	[-.077, .164]
Nature→Competence→ML	.10	.04	.014	[.020, .180]
Nature→Relatedness→ML	.04	.05	.450	[-.064, .144]

Note. PA = Positive Affect; LS = Life Satisfaction; ML = Meaning in Life.

nature enhances psychological well-being, including positive affect, subjective life satisfaction and meaning in life, which can be significantly mediated by fulfillment of the three basic psychological needs, be it examination of these needs as a whole or each of them separately. The three laboratory studies replicated all of these findings with one exception (i.e., a null effect of nature on satisfying the need for relatedness). Overall, our five experiments provide convergent evidence for our account based on Self-Determination Theory for the enhancing effects of nature on psychological well-being.

Two possible reasons could explain the inconsistency between the field study and the laboratory study. First, the laboratory studies employed far fewer nature elements so that they may not have produced an effect on all outcomes as strongly as in the field studies, where participants were totally surrounded by and immersed in nature. Second, compared with the need for autonomy and competence, the need for relatedness is more distal due to its social implications; thus, the effect of nature on fulfilling the need of relatedness is not as strong as autonomy and competence. Nevertheless, these exceptions should not imply that our findings are unreliable. Rather, they indicate that experimentation is limited when examining the effects of nature in a laboratory setting and that enhancing fulfillment of the need for relatedness entails more exposure to nature (i.e., immersion in actual nature).

4.2. Strengths

We have conducted both field (Studies 1a & 1b) and laboratory (Studies 2a, 2b, 2c) studies so that our findings have both laboratory and ecological validity. We have used an experimental design in multiple studies so that we can draw causal conclusions on the effects of nature on psychological well-being. Furthermore, we have examined distinct types of engagement with nature, including actual nature (Studies 1a & 1b), access to nature through indoor plants (Study 2b), virtual digital nature (Study 2a) and using elements from nature to create pictures (Study 2c). We also used multiple indicators of psychological well-being, including positive affect, subjective life satisfaction and meaning in life, so that our

findings are not limited by specific forms of nature and well-being.

4.3. Limitations

Although our two series of studies demonstrated that fulfilment of basic psychological needs can account for the benefits of nature on psychological well-being (Deci & Ryan, 1985, 2000; Ryan & Deci, 2017), it may not be the only mechanism. Many other factors may play a role. For example, natural environments may also offer more fresh air and promote physical activity (Frumkin et al., 2017) and strengthen nature connectedness, thereby promoting psychological well-being (Capaldi, Dopko, & Zelenski, 2014; Pritchard, Richardson, Sheffield, & McEwan, 2020). Extraordinary views of nature may additionally arouse strong feelings of awe and, in turn, happiness (Goldy & Piff, 2020; Joye & Bolderdijk, 2015). A recent study found that individuals' preference for nature could account for nature's effect on positive affect (Meidenbauer et al., 2020). Actually, in our research, we found that, in some cases, the satisfaction of basic needs only partially mediates the effects of nature. Future studies may consider other possible mechanisms, especially when special elements of nature are considered.

Besides, there are many different types of natural environments, pleasant versus unpleasant nature and mundane versus extraordinary nature being only a sampling of the range. It is well known that different environments may exert different impacts on an individual's mental health (Joye & Bolderdijk, 2015; Wyles et al., 2019). For instance, while pleasant natural scenes can autonomously attract and captivate an individual's attention, unpleasant or threatening nature may trigger avoidance tendencies and thwart the individual's needs (Koole & Van den Berg, 2005). Similarly, extraordinary nature can elicit more intense positive emotions (Collado & Manrique, 2020; Joye & Bolderdijk, 2015) and a tendency toward prosocial behavior than mundane nature (Joye & Bolderdijk, 2015). We have only examined one kind of nature, that being pleasant. Future studies may examine whether our findings can be generalized to other natural environments as well as the difference between them (e.g., mundane and extraordinary).

Finally, people in different cultural contexts may have distinct understandings or conceptualizations about nature (Descola, 2013). A favorite type of nature may also vary with culture (Buijs, Elands, & Langers, 2009). We have conducted all of our studies in China; it remains to be determined whether these findings can be generalized to other cultures.

4.4. Implications

Our findings contribute to the existing literature about SDT (Deci & Ryan, 1985, 2000; Ryan & Deci, 2017). We replicated previous findings that satisfaction of the needs for autonomy, competence and relatedness may boost human psychological well-being, thus providing novel evidence for SDT, particularly one of its sub-theories, BPNT, which posits that an individual's well-being relies on satisfaction of the basic psychological needs for autonomy, competence and relatedness (Ryan & Deci, 2000). Moreover, we demonstrate that the contexts that can satisfy people's needs are not limited to social environments. Previous work has mainly focused on social settings, such as family, school and place of work, to satisfy psychological needs (Ryan & Deci, 2000, 2017). Our research highlights the importance of natural environments, providing direct evidence for an early claim that non-social stimuli may also satisfy an individual's psychological needs (Deci & Ryan, 2000) and for the observation that natural environments have the potential to fulfill psychological needs (Landon et al., 2021; Qusted et al., 2018; Weinstein et al., 2009).

More importantly, our findings shed light on mechanisms underlying the enhancing effect of nature on well-being. It is well known that nature not only aids in human recovery from diverse psychological deficits but also enhances psychological well-being in general. Although several theories have been proposed to understand the restorative function of

nature (Joye & van den Berg, 2011; Kaplan, 1995; Ulrich et al., 1991), convincing theories about the enhancing function of well-being are still lacking and thus in need of research (McMahan, 2018). Although potential mediators such as awe (Goldy & Piff, 2020; McMahan, 2018; Shiota et al., 2007), meaning in life (Howell et al., 2013), social connection (Coley et al., 1997) and connection to nature (Mayer et al., 2009; Nisbet et al., 2011) have been suggested, we proposed a novel account from the perspective of SDT: satisfaction of the three basic human psychological needs may account for the positive effect of nature on well-being (Deci & Ryan, 1985, 2000; Ryan & Deci, 2017). Our five studies provide consistent and convergent evidence in favor of this Self-Determination account.

Our findings also have practical implications. As indicated by many nature-based interventions or therapies, nature can help people gain additional benefits (Van den Berg, 2017). Our research provides novel supportive evidence for these practices. Above all, we provide an account for an underlying mechanism: nature can serve as a special kind of resource to fulfill people's psychological needs and further cultivate people's well-being. Based on these findings, future intervention practices may be better designed. For instance, researchers may opt for natural environments and interventions that are more likely to promote people's satisfaction of needs for autonomy, competence and relatedness.

5. Conclusion

In summary, SDT provides a novel account to understand the benefits of nature on psychological well-being, that is, nature can satisfy basic human psychological needs and foster psychological well-being. Future work may examine the diverse boundary conditions of the Self-Determination account such as nature type and culture.

Open science practice

The data and analyses codes are available at: <https://osf.io/7gzhx>.

Statement of ethics

This research was approved by the Ethics Committee of Institute of Psychology, Chinese Academy of Sciences.

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Author contributions

Ying Yang: Conceptualization, Methodology, Investigation, Formal analysis, Writing-Original Draft; Huajian Cai: Supervision, Conceptualization, Methodology, Writing-Review & Editing, Funding acquisition; Ziyang Yang: Methodology, Formal analysis; Xiaochong Zhao: Investigation; Mei Li: Investigation; Rui Han: Investigation, Sylvia Xiaohua Chen: Writing-Review & Editing, Funding acquisition. All the authors have read and approved the final paper.

Declarations of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvp.2022.101872>.

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