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Understanding experiences in metaverse: How virtual nature impacts affect, pro-environmental attitudes, and intention to engage with physical nature

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ABSTRACT

The metaverse which is constructed by virtual reality (VR) can afford immersive experiences that are more vivid and attractive than those in the physical world. In this research, we focus on virtual nature experiences in the metaverse, and investigate how its exposure influences affective states and attitudes towards physical nature. Two studies were conducted, and results consistently showed that through the mediation of connectedness to nature, experiencing virtual nature resulted in more positive affect, pro-environmental attitudes, and intention to engage with physical nature, compared to experiencing a virtual art museum. These findings highlight how experiences in the metaverse may affect our emotions and behaviors in the physical world and have important implications for human-nature relations in the age of the metaverse.

1. Introduction

The metaverse refers to a parallel universe constructed by virtual reality (VR) where people can work, play, and socialize. It is envisioned as having the potential to unleash the next wave of technological disruption, which will redefine the line between our physical and digital experiences. Market research done by McKinsey (2022) reported that over $120 billion was invested in building metaverse technology and infrastructure within the first 5 months of 2022, and that the economic value of the metaverse could generate up to $5 trillion by 2030. While excitement around the metaverse is rapidly growing, little is known about the psychological impacts of experiences in the metaverse. The metaverse will afford experiences that the physical world cannot – from the way one chooses to look, to the types of places that one can visit. What impacts will this have on people's emotions and attitudes toward the physical world?

In this research, we examine the effects of virtual nature experiences in the metaverse (henceforth "virtual nature") on affective states, pro-environmental attitudes, and intention to engage with physical nature. We pursued this research direction for three reasons. First, humans have an innate desire to feel connected with nature (Kellert & Wilson, 1993), and nature exposure has been shown to promote psychological well-being (McMahan & Estes, 2015; H. Roberts, van Lissa, et al., 2019). However, mass urbanization is associated with various mental health issues and has caused many people to be deprived of nature exposure (Cox et al., 2017; Turner et al., 2004). Virtual nature has the potential to compensate for the loss of exposure to physical nature and enhance well-being. Second, it is now widely accepted that human activities such as the burning of fossil fuels and deforestation have caused climate change and brought about the existential environmental crisis that the world faces today (Cook et al., 2016; Díaz et al., 2019; Trenberth, 2018). The "environmental problem" is at its root a human behavior problem, and there is great urgency to foster pro-environmental attitudes to discourage unsustainable consumption and other wasteful and polluting behaviors (Amel et al., 2017). Third, concerns have been raised that virtual nature may replace physical nature (Kahn et al., 2009; Levi & Kocher, 1999). Virtual nature can provide more vivid and attractive experiences than those in physical nature. Moreover, the convenience of VR enables virtual nature to be accessed from the comforts of one's home. It is crucial to examine how virtual nature may impact people's intention to engage with physical nature.

To address the foregoing research gaps, we conducted two between-

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subject experiments to examine the effects of virtual nature on affect, pro-environmental attitudes, and intention to engage with physical nature. Our studies reveal the impacts of virtual nature on physical nature and advances our understanding of the connection between experiences in the metaverse and attitudes towards the physical world.

2. Literature review

2.1. Biophilia and its implications for virtual and physical nature

The biophilia hypothesis (Kellert & Wilson, 1993) posits that humans have an innate desire to focus on and affiliate with "life and life-like processes". These inclinations are viewed to be a product of human's bio-cultural evolution in the natural environment (Lumsden & Wilson, 1985; Wilson, 1993). The theory is supported by a large body of empirical evidence which shows that people are more attracted to and show a preference for natural over built environments (van den Berg et al., 2003; White et al., 2010), a finding that is robust across ages and cultures (Falk & Balling, 2010; Hartmann & Apaolaza-Ibáñez, 2010). The fact that the theory includes "life-like" is an important point, given that this may not always refer to something natural (Joye & De Block, 2011). For example, in a field study, plasma displays featuring natural outdoor scenery were installed in windowless offices (Friedman et al., 2008). The study found that participants evaluated the experience positively and reported that the plasma "windows" made them feel more connected to the natural world. Another study found that children interacted with a robotic dog similarly to how they interacted with a live dog (Melson et al., 2009). This has implications for understanding virtual nature experiences in the metaverse. A key concept in VR is *presence*, which refers to a user's subjective sense of being there in the virtual environment (Slater & Wilbur, 1997). That is, despite being cognizant of the artificiality of one's virtual surroundings, virtual nature is experienced as actual objects and environments (Lee, 2004). Thus, biophilic inclinations towards physical nature would apply to virtual nature as well.

Virtual nature is, however, more than a mere simulation or surrogate of physical nature. It can offer more vivid and novel experiences than those provided by physical nature (Yeo et al., 2020). For example, users can experience spectacular and awe-inspiring activities like standing on the peak of a snowy mountain, flying over waterfalls, and exploring the depths of volcanoes. Experiencing such extraordinary nature may cause people to be less interested in physical nature, since research has found that viewing beautiful nature scenes caused people to devalue their affective experiences of common nature found in their local areas (Levi & Kocher, 1999). On the other hand, there are still many sensory cues in physical nature that cannot yet be provided in VR (Depledge et al., 2011). Experiencing virtual nature may thus increase one's motivation to engage with physical nature for its holistic experience. Qualitative interviews conducted after experiencing 360° videos of a physical natural environment found that participants reported feeling more motivated to travel to the scene they had experienced in VR (Yu et al., 2020).

Unlike 360° videos, virtual nature in the metaverse is likely to be composed of computer-generated imagery which can afford experiences impossible in the real world. How might such surreal experiences influence the way people perceive, value, and interact with physical nature in the real world? Would people appreciate physical nature more and be motivated to protect it, or would it cause people to devalue their experiences with physical nature? As an example of the types of virtual nature that would be available in the metaverse, this research uses computer-generated VR environments that allow participants to come up-close and walk alongside wild animals.

2.2. Effects of nature exposure on affect and pro-environmental attitudes

Research shows that like physical nature, virtual nature promotes positive shifts in affective states (Browning, Mimnaugh, et al., 2020; Nukarinen et al., 2022). These positive shifts in mood are commonly referred to as nature's restorative effects. Restorativeness reflects the tendency for nature exposure to replenish personal resources like physiological states and cognitive capacity (Berto, 2014). Two prominent theories that explain nature's restorative effects are the stress recovery theory which posits that humans have evolved to respond positively to natural elements that were important for our ancestors' survival (Ulrich et al., 1991), and the attention restoration theory which posits that nature elicits effortless attention that restores cognitive capacities (Kaplan, 1995). Both theories are grounded in an evolutionary framework, and are complementary to and consistent with the biophilia hypothesis (Gaekwad et al., 2022). The theories' prediction that nature exposure enables recovery from negative affective states has received ample empirical support (Berto, 2014; Moll et al., 2022). For example, participants who walked in a nature reserve reported lower anger and higher positive affect compared to those who walked in an urban environment (Hartig et al., 2003). Similarly, after completing a cognitively demanding task, participants who walked in nature showed greater mood improvements compared to those who walked in a downtown setting (Berman et al., 2008). Importantly, these findings have been replicated with virtual nature. In one study, participants who experienced a 360° video of a natural environment reported higher positive affect compared to those who experienced a 360° video of an urban town (Schutte et al., 2017). In addition, improvements in mood have been found after participants experienced a computer-generated virtual forest (Mattila et al., 2020). Similarly, participants reported lower negative affect after a walk in a computer-generated virtual forest compared to a virtual urban scene (Chan et al., 2021).

Nature exposure also plays an important role in fostering pro-environmental attitudes. Research shows that the amount of time spent in physical nature is associated with stronger pro-environmental attitudes and behaviors (DeVille et al., 2021). Moreover, living in neighborhoods with higher levels of greenery predicted pro-environmental behaviors (Alcock et al., 2020; Whitburn et al., 2018). Studies have also found that having a rural childhood is associated with stronger pro-environmental attitudes (Martin & Czellar, 2017), compared to having an urban childhood with less nature exposure. While this provides cross-sectional evidence for the link between physical nature experiences and pro-environmental outcomes, few experimental studies have been conducted. Hence, it remains unclear if short doses of nature exposure can lead to pro-environmental outcomes. Moreover, physical nature experiences may be associated with greater awareness of environmental issues (Duerden & Witt, 2010; Prévot et al., 2018), compared to virtual nature experiences. In their research, Klein and Hilbig (2018) showed that while watching videos of destroyed nature increased pro-environmental behaviors, videos of intact nature did not. In the metaverse, virtual nature is unlikely to feature nature destruction. Without an awareness of the severity of the environmental crisis, people may not be motivated to protect physical nature, resulting in an erosion of pro-environmental attitudes. On the other hand, research shows that VR experiences can translate into positive changes in real-world attitudes and behaviors in domains such as health behaviors (Fox & Bailenson, 2009), pro-social behavior (Rosenberg et al., 2013; Ventura et al., 2020), and tourism-related visitation intentions (Tussyadiah et al., 2018). Virtual nature might therefore have the potential to improve pro-environmental attitudes as well. Limited studies have examined the impact of virtual nature on pro-environmental attitudes and mixed results have been found. In one study, participants who were exposed to physical nature or 360° videos of nature exhibited greater pro-environmental behaviors, compared to those in the control condition without any nature exposure (Deringer & Hanley, 2021). Similarly, comparable levels of pro-environmental intentions were found between participants who underwent a real-life snorkeling experience and those who experienced it through a 360° video in VR (Hofman et al., 2022). In contrast, no differences in pro-environmental intentions were found between participants who watched a

video-recording of a nature vs. urban scene in VR (Soliman et al., 2017).

2.3. The role of connectedness to nature

Connectedness to nature refers to the feeling of being emotionally connected to the natural world (Mayer & Frantz, 2004). According to the biophilia hypothesis, humans are predisposed to have an innate desire to feel such a connection (Kellert & Wilson, 1993; Wilson, 1993). For many, however, the lack of opportunities to experience nature leads to the development of a weak sense of connectedness to nature (Soga & Gaston, 2016). Connectedness to nature is important because it is a pathway that can promote both affective and environmental outcomes. Feeling connected is a basic human need, which is reflected in well-established psychological theories such as the need for affiliation postulated by motive disposition theory (McClelland, 1985) and the need for relatedness postulated by self-determination theory (Ryan & Deci, 2000). By extension, feeling connected to nature can fulfil one's psychological need for affiliation, thus contributing towards well-being (Mayer et al., 2009). At the same time, closeness of relationships and feeling connected lead to greater levels of empathic concern and willingness to help (Cialdini et al., 1997). Accordingly, a sense of connectedness to nature forms the basis for one to care about and want to protect nature (Nisbet et al., 2009). In support of this, research shows that connectedness to nature is associated with positive affect and other related well-being outcomes such as life satisfaction and meaning in life (Capaldi et al., 2014; Pritchard et al., 2020). In addition, connectedness to nature is also associated with pro-environmental attitudes (Mackay & Schmitt, 2019; Whitburn et al., 2020) and the amount of time spent in natural environments (Cheng & Monroe, 2012; Nisbet et al., 2009).

Studies have shown that connectedness to nature is malleable and can be promoted through experiences with both physical and virtual nature. For example, higher connectedness to nature was reported after visits to rural and coastal locations compared to urban greenspaces (Wyles et al., 2017). Participants who walked outdoors in nature reported high connectedness compared to those who walked indoors (Nisbet et al., 2019). Likewise, participants reported higher connectedness to nature after a virtual nature experience, compared to a virtual urban experience (Chan et al., 2021). Connectedness to nature was also found to be higher following nature exposure through VR compared to a flat-screen display (Yeo et al., 2020). Therefore, by promoting connectedness to nature, virtual nature may be able to positively impact affective and environmental outcomes.

2.4. Present research

We conducted two between-subject experiments to investigate the effects of virtual nature on affect, pro-environmental attitudes, and intention to engage with physical nature. In the first study, these outcomes were measured after participants experienced either the nature or control condition. In the second study, the outcomes were measured at both pre-test and post-test, and as a further extension, different VR environments were used. Both studies used virtual museums as the control condition since prior research suggests that museums can be as restorative as natural environments (Kaplan et al., 1993; Packer & Bond, 2010). In most past studies (e.g., Chan et al., 2021; Schutte et al., 2017; Soliman et al., 2017; Yu et al., 2020), nature has been compared to non-restorative urban settings. In the metaverse, people will have the option for other virtual experiences that can be as restorative as nature. It is therefore important to examine if virtual nature has additional affective benefits compared to other restorative virtual experiences. Based on the reviewed literature, virtual nature can promote connectedness to nature (Chan et al., 2021; Yeo et al., 2020). In turn, cross-sectional evidence shows that connectedness to nature is positively associated with psychological well-being (Capaldi et al., 2014), pro-environmental attitudes (Davis et al., 2009; Hoot & Friedman, 2011) and intention to engage with the natural environment (Hinds & Sparks, 2008). To date, however, the mediating role of connectedness to nature on all three constructs has not been examined within a single experimental design. In this research, we therefore constructed and tested the following hypotheses:

H1. Virtual nature will increase positive affect, and this effect will be mediated by connectedness to nature.

H2. Virtual nature will decrease negative affect, and this effect will be mediated by connectedness to nature.

H3. Virtual nature will increase pro-environmental attitudes, and this effect will be mediated by connectedness to nature.

H4. Virtual nature will increase intention to engage with physical nature, and this effect will be mediated by connectedness to nature.

3. Study 1

3.1. Participants and procedure

Based on an effect size of $d = 0.68$ for the effects of virtual nature on connectedness to nature (Chan et al., 2021), a power analysis performed with G*Power 3.1 (Faul et al., 2009) for alpha = .05 and power = 0.80 indicated a sample size of n = 70 for a between-subject design. A total of 71 students participated in exchange for SGD$5 (females = 33; age M = 23.2, SD = 2.0). Prior to the experiment, 40.2% of participants had never tried VR with an head-mounted device (HMD) before.

Participants were randomly assigned to the nature condition (n = 36) or museum condition (n = 35). After providing consent, participants wore a wireless HTC VIVE-Pro VR headset and were given 5 min to freely explore the virtual environment using a handheld controller. They sat on a swivel chair which enabled them to turn 360° while remaining seated. After the VR experience, participants completed a survey. Finally, participants were debriefed. The study protocol was approved by the University ethics committee.

3.2. VR environments

The nature condition used *Nature Treks VR*[1] which allows users to explore various natural environments. The study used the 'Green Meadows' environment which features grassy hills, a river, and animals like rabbits and deer (Fig. 1). The scene featured calming instrumental music with the sounds of nature. The museum condition used *Mocove Arts VR*.[2] The scene features a large art museum with various themed rooms housing artwork done by famous artists like Pablo Picasso (Fig. 1). The scene featured instrumental classical music. In both scenes, participants used the point-and-click teleportation method to freely explore the environment.

3.3. Measures

Affect was measured with the Scale of Positive and Negative Experience (Diener et al., 2010). The scale consists of six items that measure positive affect (e.g., happy, good; α = 0.89) and six items that measure negative affect (e.g., sad, bad; α = 0.68). Participants indicated the extent that they felt each emotion (1 = not much or not at all, 5 = very much so).

Pro-environmental attitude was assessed using five items that measure how much an individual is willing to sacrifice their own needs for the sake of the environment (α = 0.92; Davis et al., 2011). Sample items include "I am willing to give things up that I like doing if they harm the

[1] Available at https://store.steampowered.com/app/587580/Nature_Treks_VR/.

[2] Available at https://store.steampowered.com/app/652540/Mocove_Arts_VR/.

Fig. 1. VR scenes for nature condition (left) and museum condition (right) in Study 1.

natural environment" and "I am willing to take on responsibilities that will help conserve the natural environment". Participants indicated their extent of agreement on a 9-point Likert scale (1 = do not agree at all, 9 = agree completely).

Intention to engage with physical nature was measured with three items adapted from past research (α = 0.94; Hinds & Sparks, 2008). Participants were shown the following definition: "Engaging with the physical natural environment" refers to being *in* and actively participating *in* real-world areas and settings containing a high degree of nature (e.g., gardens, parks, nature reserves, reservoirs, beaches) That is, to physically visit these places and engage with the nature present". They then indicated their response to each item (e.g., "I intend to engage with the physical natural environment whenever I have spare time") on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree).

Connectedness to nature was measured with the 13-item state version of the Connectedness to Nature Scale (α = 0.88; Mayer & Frantz, 2004; Mayer et al., 2009), which measures the extent that an individual feels connected to physical nature. Sample items include "Right now, I am feeling deeply aware of how my actions affect the natural world" and "Right now, I feel as though I belong to the earth just as much as it belongs to me". Participants indicated their extent of agreement (1 = strongly disagree, 7 = strongly agree).

We included several other measures that were of relevance to VR experiences. We expected that the conditions would not differ on these variables. First, presence was measured with the 14-item igroup presence questionnaire (α = 0.87; Schubert et al., 2001). The 11-item Perceived Restorativeness Scale (α = 0.83; Hartig et al., 1997; Pasini et al., 2014) was used to measure restorativeness. Three items ("I enjoyed the VR experience", "I would like to repeat the VR experience", "I will recommend the VR experience to a friend") were used to measure liking of the VR experience (α = 0.90). Lastly, the degree of cybersickness was measured using one item on a 5-point Likert scale, and whether participants had prior VR experience before the study was measured (0 = no, 1 = yes).

Table 1
Descriptive statistics and main effects in Study 1.

	Nature (n = 36)	Museum (n = 35)	Main effects
	M (SD)	M (SD)	Test statistic, *p*, effect size
Positive affect	4.11 (0.73)	3.60 (0.86)	$t(69) = 2.71$, $p = .01$, $d = .64$
Negative affect	1.17 (0.33)	1.11 (0.20)	$t(69) = 0.89$, $p = .38$, $d = .21$
Connectedness to nature	5.04 (0.86)	4.29 (0.79)	$t(69) = 3.82$, $p = < .001$, $d = .91$
Pro-environmental attitudes	6.45 (1.26)	6.09 (1.31)	$t(69) = 1.19$, $p = .24$, $d = .28$
Intention to engage with physical nature	5.63 (1.14)	5.21 (1.22)	$t(69) = 1.50$, $p = .14$, $d = .36$

Table 2
Results from mediation analysis in Study 1.

DV and paths	Direct and total effects				Indirect effects (*ab*)		
	b	SE	*t*	*p*	*B*	boot SE	boot 95% CI
Positive affect					0.28	0.11	[.10, .51]
IV → M (*a*)	0.75	0.20	3.82	<.001			
M → DV, controlling for IV (*b*)	0.38	0.11	3.53	<.001			
IV → DV, controlling for M (*c*)	0.23	0.19	1.18	0.24			
IV → DV (*c*')	0.51	0.19	2.71	0.01			
Negative affect					0.01	0.04	[-.06, .09]
IV → M (*a*)	0.75	0.20	3.82	<.001			
M → DV, controlling for IV (*b*)	0.01	0.04	0.29	0.78			
IV → DV, controlling for M (*c*)	0.05	0.07	0.68	0.50			
IV → DV (*c*')	0.06	0.07	0.89	0.38			
Pro-environmental attitudes					0.50	0.19	[.18, .90]
IV → M (*a*)	0.75	0.20	3.82	<.001			
M → DV, controlling for IV (*b*)	0.66	0.17	3.88	<.001			
IV → DV, controlling for M (*c*)	−0.13	0.31	−0.43	0.67			
IV → DV (*c*')	0.36	0.31	1.19	0.24			
Intention to engage with physical nature					0.27	0.15	[.02, .60]
IV → M (*a*)	0.75	0.20	3.82	<.001			
M → DV, controlling for IV (*b*)	0.36	0.17	2.14	0.04			
IV → DV, controlling for M (*c*)	0.15	0.30	0.50	0.62			
IV → DV (*c*')	0.42	0.28	1.50	0.14			

Note. IV = condition (1 = nature, 0 = museum); M = connectedness to nature.

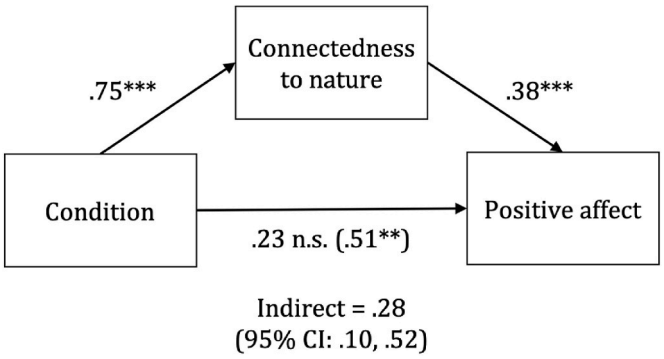

Fig. 2. Indirect effects of virtual nature on positive affect in Study 1. Unstandardized path coefficients are shown. The effect reported in parentheses represents the effect of condition on the dependent variable when the mediator is excluded. *$p < .05$, **$p < .01$, ***$p < .001$.

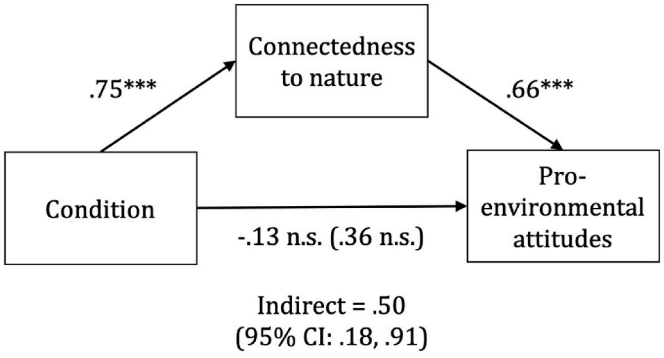

Fig. 3. Indirect effects of virtual nature on pro-environmental attitudes in Study 1. Unstandardized path coefficients are shown. The effect reported in parentheses represents the effect of condition on the dependent variable when the mediator is excluded. *$p < .05$, **$p < .01$, ***$p < .001$.

3.4. Results

Descriptive statistics for the main outcome variables are reported in Table 1. There were no significant differences between conditions for any of the VR-related variables (results provided in supplementary material).

We first examined the main effect of virtual nature by conducting independent samples *t*-tests. As reported in Table 1, virtual nature had a significant effect on positive affect and connectedness to nature. In contrast, no significant main effects were found for negative affect, pro-environmental attitudes, and intention to engage with physical nature.

To test our hypotheses, we examined the indirect effects of virtual nature through connectedness to nature. Based on statistical guidelines (Hayes, 2009; Shrout & Bolger, 2002) and methodological research (O'Rourke & MacKinnon, 2015), an indirect effect can exist despite the absence of a main effect. To test indirect effects, mediation analysis using bootstrap confidence intervals was conducted with Model 4 of the PROCESS macro (version 3.5) in SPSS (Hayes, 2013). A mediation analysis with 10,000 bootstrap samples was conducted to examine the indirect pathway from condition (IV) on the respective outcome variables (DV), with connectedness to nature as the mediator. Mediation is assessed by a single test of the indirect effect (Hayes & Scharkow, 2013) – confidence intervals (CI) that do not contain zero imply that mediation has taken place.

The indirect effect of virtual nature on positive affect was significant, supporting H1. Condition significantly predicted connectedness to nature. Connectedness to nature in turn significantly predicted positive affect, while controlling for condition. The results are reported in Table 2 and displayed in Fig. 2.

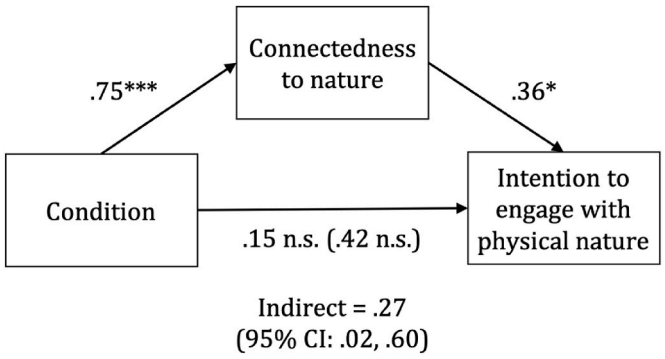

Fig. 4. Indirect effects of virtual nature on intention to engage with physical nature in Study 1. Unstandardized path coefficients are shown. The effect reported in parentheses represents the effect of condition on the dependent variable when the mediator is excluded. *$p < .05$, **$p < .01$, ***$p < .001$.

As reported in Table 2, the indirect effect of virtual nature on negative affect was not significant. Although condition significantly predicted connectedness to nature, connectedness to nature in turn did not predict negative affect while controlling for condition. Thus, H2 was not supported.

The indirect effect of virtual nature on pro-environmental attitudes was significant. Condition significantly predicted connectedness to nature. Connectedness to nature in turn significantly predicted pro-environmental attitudes while controlling for condition. Thus, H3 is supported. The results are reported in Table 2 and displayed in Fig. 3.

The indirect effect of virtual nature on intention to engage with physical nature was significant. Condition significantly predicted connectedness to nature. Connectedness to nature in turn significantly predicted intention to engage while controlling for condition. Thus, H4 was supported. The results are reported in Table 2 and displayed in Fig. 4.

4. Study 2

A limitation of Study 1 was that it did not include a pre-test survey to assess baseline levels. To address this, Study 2 used a mixed design with condition (nature vs. museum) as a between-subject factor, and time (pre vs. post) as a within-subject factor. In addition, different VR environments from Study 1 were used to test the generalizability of our findings. Lastly, we kept the background audio consistent across both conditions since nature sounds have been found to promote mood and pro-environmental intentions (Ratcliffe, 2021; Spendrup et al., 2016).

4.1. Participants and procedure

A Monte Carlo power analysis for indirect effects (Schoemann et al., 2017) based on Study 1's results indicated a sample size of n = 75 to detect the mediational effect of condition on pro-environmental attitudes through connectedness to nature. We recruited 80 students who participated in exchange for SGD$10. One participant could not complete the study due to technical failures with the VR equipment. The final sample consisted of 79 participants (females = 54; age M = 24.85, SD = 2.85). Prior to the experiment, 31.6% of the participants had never tried VR with an HMD before. Participants were randomly assigned to the nature condition (n = 40) or museum condition (n = 39). They followed the same procedure as Study 1 with the addition of a pre-test survey before VR exposure. The study protocol was approved by the University ethics committee.

4.2. VR environments

The nature condition used *Nature Treks VR* as in Study 1 but with a

Fig. 5. VR scenes for nature condition (left) and museum condition (right) in Study 2.

Table 3
Descriptive statistics and main effects in Study 2.

	Nature (n = 40)		Museum (n = 39)		Main effects
	Pre-test M (SD)	Post-test M (SD)	Pre-test M (SD)	Post-test M (SD)	Test statistic, *p*, effect size
Positive affect	3.54 (0.72)	4.10 (0.73)	3.27 (0.84)	3.77 (0.90)	t (77) = 0.25, p = .81, d = .06
Negative affect	1.62 (0.73)	1.31 (0.56)	1.88 (0.91)	1.40 (0.81)	t (77) = 1.22, p = .23, d = .27
Connectedness to nature	4.73 (0.72)	5.52 (0.56)	4.84 (0.62)	5.17 (0.66)	t (77) = 3.57, p = .001, d = .80
Pro-environmental attitudes	6.46 (1.20)	7.38 (1.04)	6.72 (1.06)	6.88 (1.09)	t (77) = 3.95, p < .001, d = .89
Intention to engage with physical nature	5.24 (1.12)	5.95 (0.90)	5.19 (1.30)	5.47 (1.28)	t (77) = 2.67, p = .01, d = .60

different scene. The 'Red Savannah' scene features a savannah landscape with trees and various animals like zebra and giraffe (see Fig. 5). The museum condition used *The VR Museum of Fine Art*.[3] The scene features a museum housing historical artwork and sculptures (see Fig. 5). The same calming instrumental audio clip was played in both conditions. Participants used the point-and-click teleportation method to freely explore the environments.

4.3. Measures

Participants completed a pre-test and post-test survey containing the same measures from Study 1 for positive affect (pre-test α = 0.88, post-test α = 0.92), negative affect (pre-test α = 0.91, post-test α = 0.92), pro-environmental attitudes (pre-test α = 0.87, post-test α = 0.90), intention to engage with physical nature (pre-test α = 0.95, post-test α = 0.93), and connectedness to nature (pre-test α = 0.78, post-test α = 0.80).

We included four filler measures in the pre-test survey to prevent participants from guessing the purpose of the study. These measures assessed willingness to sacrifice for close others, loneliness, dispositional awe, and interest in art.

Finally, the post-test survey included the same VR-related variables as Study 1. These were presence (α = 0.83), restorativeness (α = 0.86), liking of the VR experience (α = 0.90), cybersickness, and prior VR experience.

4.4. Results

Descriptive statistics for the main outcome variables are reported in Table 3. The conditions did not significantly differ on any of the filler or VR-related variables (results provided in supplementary material), except for perceived restorativeness which was significantly higher in the museum condition (M = 5.15, SD = 0.74) compared to nature condition (M = 4.71, SD = 0.98), t (77) = −2.26, p = .03, d = −0.51.

To test main effects, we first computed the change in each outcome (post-test minus pre-test). Then, we conducted independent samples *t*-tests on the change scores to examine if changes in the nature condition significantly differed from the museum condition. Results are reported in Table 3. The nature condition increased connectedness to nature, pro-environmental attitudes, and intention to engage with physical nature to a significantly greater extent than the museum condition. No differences in positive or negative affect were found between the conditions.

To test our hypotheses, we examined the proposed pathway of condition on the different outcome variables, through the mediation of connectedness to nature. In line with Study 1, mediation analysis was conducted with bootstrap confidence intervals using Model 4 of the PROCESS macro in SPSS. Each model examined the effects on post-test scores, controlling for pre-test scores.

The indirect effect of virtual nature on positive affect was significant, supporting H1. Condition significantly predicted connectedness to nature. Connectedness to nature in turn significantly predicted positive affect while controlling for condition. The results are reported in Table 4 and displayed in Fig. 6.

As reported in Table 4, the indirect effect of virtual nature on negative affect was not significant. Although condition significantly predicted connectedness to nature, connectedness to nature in turn did not predict negative affect while controlling for condition. Thus, H2 was not supported.

The Indirect effect of virtual nature on pro-environmental attitudes was significant, supporting H3. Condition significantly predicted connectedness to nature. Connectedness to nature in turn significantly predicted pro-environmental attitudes while controlling for condition. The results are reported in Table 4 and displayed in Fig. 7.

The indirect effect of virtual nature on intention to engage with physical nature was significant, supporting H4. Condition significantly predicted connectedness to nature. Connectedness to nature in turn significantly predicted intention to engage while controlling for condition. The results are reported in Table 4 and displayed in Fig. 8.

5. General discussion

In the future, people will be spending a significant portion of their time in the metaverse which offers fantastical experiences that transcend the boundaries of what is possible in the physical world. What impacts will this have on people's attitudes towards and behaviors in the physical world? In this research, we conducted two studies to investigate the impact of virtual nature on affect and attitudes towards physical nature. We found consistent support for three out of the four proposed hypotheses. Both studies found that through the mediation of connectedness to nature, virtual nature promoted positive affect (H1), pro-environmental attitudes (H3), and intention to engage with physical

[3] Available at https://store.steampowered.com/app/515020/The_VR_Museum_of_Fine_Art/.

Table 4
Results from mediation analysis in Study 2.

DV and paths	Direct and total effects				Indirect effects (*ab*)		
	b	SE	*t*	*p*	*b*	boot SE	boot 95% CI
Positive affect					0.20	0.10	[.02, .41]
IV → M (*a*)	0.38	0.11	3.40	0.001			
M → DV, controlling for IV (*b*)	0.53	0.17	3.17	0.002			
IV → DV, controlling for M (*c*)	−0.01	0.17	−0.07	0.95			
IV → DV (*c*')	0.19	0.17	1.11	0.27			
Negative affect					0.04	0.05	[-.07, .15]
IV → M (*a*)	0.42	0.11	3.76	<.001			
M → DV, controlling for IV (*b*)	0.08	0.13	0.65	0.52			
IV → DV, controlling for M (*c*)	0.02	0.14	0.16	0.88			
IV → DV (*c*')	0.06	0.12	0.46	0.65			
Pro-environmental attitudes					0.40	0.13	[.18, .68]
IV → M (*a*)	0.41	0.11	3.77	<.001			
M → DV, controlling for IV (*b*)	0.97	0.15	6.65	<.001			
IV → DV, controlling for M (*c*)	0.27	0.15	1.76	0.08			
IV → DV (*c*')	0.67	0.17	3.83	<.001			
Intention to engage with physical nature					0.29	0.09	[.13, .49]
IV → M (*a*)	0.41	0.11	3.72	<.001			
M → DV, controlling for IV (*b*)	0.72	0.13	5.58	<.001			
IV → DV, controlling for M (*c*)	0.17	0.13	1.24	0.22			
IV → DV (*c*')	0.46	0.15	3.16	0.002			

Note. IV = condition (1 = nature, 0 = museum); M = connectedness to nature. Pre-test score for connectedness to nature and pre-test score for the respective DV were controlled for in all analyses.

nature (H4). In contrast, no effects were found for negative affect (H2). It is worth noting that we additionally tested for the main effects of virtual nature (i.e., not taking into account the mediating effect of connectedness to nature) and found mixed results with the exception of negative affect which did not differ between conditions in either study. Study 1 found that virtual nature increased positive affect while it had no significant main effects for pro-environmental attitudes and intention to engage with physical nature. Study 2 employed a repeated-measures design and found the opposite pattern – virtual nature promoted pro-environmental attitudes and intention to engage with physical nature to a greater extent than the virtual museum experience, while levels of positive affect did not significantly differ. It is not uncommon to detect indirect effects in the absence of main effects, and this could be indicative of a small main effect (not enough power to detect) or that there are other processes (other mediating or moderating variables not included in this study) that explain the link between the independent and dependent variables (O'Rourke & MacKinnon, 2015; Shrout & Bolger, 2002).

Our findings show that virtual nature experiences can have a positive impact on pro-environmental attitudes and intention to engage with physical nature, but that the size of the main effect may be small. This could explain the mixed findings obtained in past research on virtual nature where some studies found that 360° videos of nature in VR could promote pro-environmental attitudes (Deringer & Hanley, 2021; Hofman et al., 2022) while others found no effects (Soliman et al., 2017). Corroborating past research (Chan et al., 2021; Yeo et al., 2020), the current studies provide strong empirical evidence that virtual nature promotes connectedness to nature. Importantly, the findings underscore the crucial mediating role that connectedness to nature plays in promoting pro-environmental attitudes and intentions to engage with physical nature. Research has documented a growing physical and psychological disconnection between people and nature (Soga & Gaston, 2016). Studies have also found that excessive consumption of electronic media is associated with less time spent outdoors in nature (Pergams & Zaradic, 2006) and greater psychological disconnectedness from nature (Larson et al., 2018). Our findings highlight how the metaverse can combat these worrying trends by providing virtual nature experiences that foster greater connectedness to nature which in turn can promote willingness to protect and engage with physical nature. Research demonstrating the relations between connectedness to nature, pro-environmental attitudes, and intention to engage with nature have

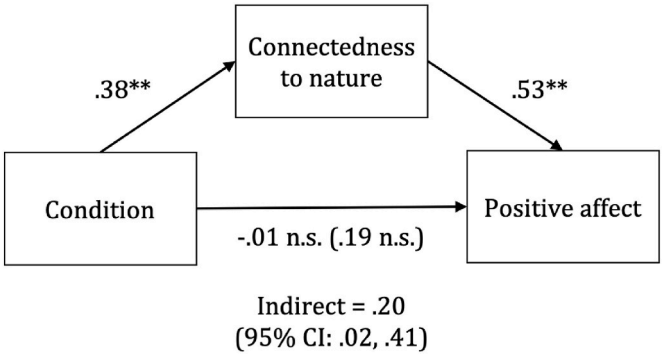

Fig. 6. Indirect effects of virtual nature on positive affect in Study 2. Pre-test connectedness to nature and positive affect are controlled for in the analysis. Unstandardized path coefficients are shown. The effect reported in parentheses represents the effect of condition on the dependent variable when the mediator is excluded. *$p < .05$, **$p < .01$, ***$p < .001$.

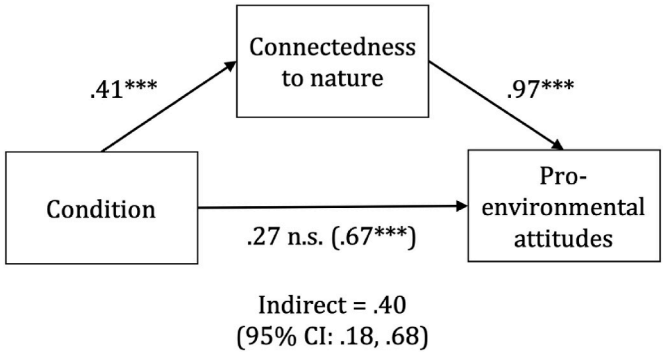

Fig. 7. Indirect effects of virtual nature on pro-environmental attitudes in Study 2. Pre-test connectedness to nature and pro-environmental attitudes are controlled for in the analysis. Unstandardized path coefficients are shown. The effect reported in parentheses represents the effect of condition on the dependent variable when the mediator is excluded. *$p < .05$, **$p < .01$, ***$p < .001$.

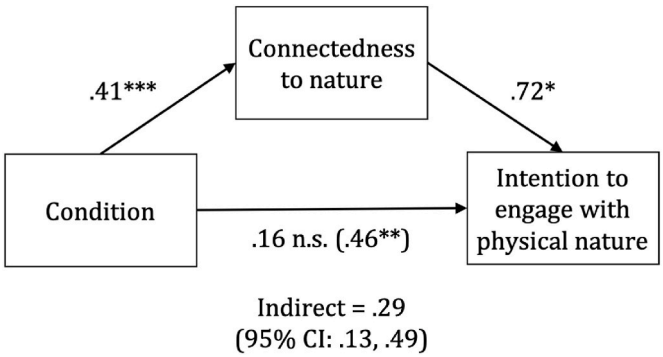

Fig. 8. Indirect effects of virtual nature on intention to engage with physical nature in Study 2. Pre-test connectedness to nature and intention to engage are controlled for in the analysis. Unstandardized path coefficients are shown. The effect reported in parentheses represents the effect of condition on the dependent variable when the mediator is excluded. *$p < .05$, **$p < .01$, ***$p < .001$.

been largely confined to cross-sectional studies (Davis et al., 2009; Hinds & Sparks, 2008; Hoot & Friedman, 2011). Extending upon them, the current studies provide one of the first experimental evidence that connectedness to nature mediates the effects of virtual nature on these positive environmental outcomes. The current research also contributes to the scant literature on the effects of virtual nature on pro-environmentalism and is the first study to explicitly examine the effects of computer-generated virtual nature on attitudes towards physical nature. While our findings highlight the advantages of virtual nature in the metaverse, there are also drawbacks that should be considered. For example, it is important to note that our samples consist of young and educated adults who are likely attuned to the severity of the on-going environmental crisis. Furthermore, these participants would have had much more experiences with physical nature, compared to virtual nature. Studies show that preference for different types of nature experiences are influenced by cultural and personal experiences (Falk & Balling, 2010; Hartmann & Apaolaza-Ibáñez, 2010). If people spend more time in the metaverse, this could lead to them preferring virtual over physical nature. In turn, this may increase intention to engage with and protect virtual nature, instead of physical nature. Given a limited amount of resources, people may choose to spend their money on virtual nature instead of donating that money towards conservation efforts in the real world. Moreover, when digital twins of physical natural landscapes become commonplace, people may become indifferent towards the destruction of nature in the real world since such places would be forever "preserved" in the metaverse. The promising results found in the present study should therefore be interpreted with caution and more research is needed to examine the downsides of virtual nature as well. In particular, future studies can investigate the impact of virtual nature on perceived severity of the environmental crisis and responses (or the lack thereof) towards environmental destruction.

With regards to affect, our studies found that virtual nature promotes positive affect through the mediation of connectedness to nature. This aligns with past studies (Chan et al., 2021; Yeo et al., 2020) and adds support for the close link between connectedness to nature and psychological well-being (Capaldi et al., 2014). However, no evidence was found for virtual nature reducing negative affect, compared to the control condition. This differs from systematic reviews (Browning, Shipley, et al., 2020; Frost et al., 2022) which have found that virtual nature tends to decrease negative affect but often has no corresponding increase in positive affect. It is however important to note from Study 2 that positive affect did increase while negative affect did decrease following the virtual nature experience, but that these beneficial changes were similarly found after the virtual museum experience. Compared to past studies on virtual nature (Chan et al., 2021; Schutte et al., 2017; Valtchanov et al., 2010), the current studies provide a conservative test of virtual nature by using a museum as the control condition. The museum condition was perceived to be as restorative as the nature condition in Study 1, while the museum condition was unexpectedly found to be perceived as significantly more restorative than the nature condition in Study 2. In addition, presence and liking of the VR experience were not found to differ between the conditions in either study. All of this is important because restorativeness is a key explanation for nature's effects on affect (Berto, 2014; Schutte et al., 2017), presence has been found to predict affective responses in VR (Meehan et al., 2002; Riva et al., 2007), and preference ratings have been found to account for affective responses to nature scenes (Meidenbauer et al., 2020). Not finding additional affective benefits for virtual nature over the museum condition is therefore not entirely surprising. Although the current research is primarily interested in the effects of virtual nature, an additional contribution is that it highlights the potential for museums to be used as restorative virtual environments to improve affective states in the metaverse. This is a promising area for future research in light of the growing demand for digital art and virtual museums (Choi & Kim, 2017; Giannini & Bowen, 2019).

The findings also have important implications for VR applications in the metaverse. In today's post-pandemic era, many organizations have transitioned into hybrid workplaces where technology has enabled people to work across various locations including the traditional office, coworking spaces, and their own homes (Petani & Mengis, 2023). A hybrid workplace offers many advantages such as work-life balance and increased productivity but comes with its disadvantages too such as employee isolation and reduced opportunities for connection and collaboration. VR applications in the metaverse have the potential to address some of these disadvantages. For example, VR meeting applications such as *Microsoft Mesh* and *Meta Horizon Workrooms* feature personalized avatars and other spatial-audio tools that support real-time collaboration. Building upon our findings, such experiences may foster a sense of connectedness towards the workplace and promote positive attitudes towards colleagues and the organization. The benefits of VR meetings can be further enhanced with the integration of virtual nature. Exposure to nature not only promotes well-being as our studies show, but has also been found to enhance vitality (Ryan et al., 2010) and creativity (Palanica et al., 2019), all key elements that can boost productivity. VR meeting applications can create customized nature experiences ranging from brainstorming sessions in lush gardens to informal recreational retreats on a tropical island. While this highlights the exciting potential of VR applications in the metaverse, there are still many challenges ahead. As noted by Dincelli and Yayla (2022), a key challenge is the development of VR content and availability of highly skilled programmers and designers. In addition, the adoption of VR technologies will involve substantial investments in terms of both costs and training efforts. Finally, the adoption of VR applications at the workplace will ultimately depend on the willingness of employees. An important area for future research is to assess employees' acceptance of VR technologies in the workplace. Research has found that although both younger and older adults hold positive views towards VR, older adults did not feel like it was necessary for their lives (Liu et al., 2020), suggesting that there are likely age differences towards VR acceptance.

As we enter the age of the metaverse, the present research also brings attention to an important existential question about whether virtual experiences in the metaverse will substitute and replace experiences in the physical world. Our present findings and that of others (A. Roberts, van Lissa, et al., 2019; Wiederhold & Rizzo, 2005) have shown that virtual experiences can elicit similar responses as physical experiences. Nonetheless, VR and the metaverse is still be considered a novelty today. As technology continues advancing and VR becomes mainstream, essential daily activities like socialization, recreation, and learning will eventually take place in the metaverse. Once virtual experiences are perceived to be similar and capable of meeting the same needs as physical experiences, substitution may occur (Deng et al., 2019). Taking the basic psychological needs (Ryan & Deci, 2000) as an example, a

user's need for relatedness might be satisfied through virtual social interactions in the metaverse – whether it is via interactions with avatar representations of real people in the physical world, or with completely fictional agents simulated through computer algorithms and artificial intelligence. Drawing from microeconomic theory, demand for substitute goods share an inverse relationship – an increase in the consumption of one will lead to a decrease in the consumption in the other. If the metaverse and physical world become seen as substitute goods that satisfy the same need, then increasing 'consumption' (e.g., time spent, resources invested) of the metaverse would decrease 'consumption' of the physical world. While an increase in virtual social interactions may provide benefits like reducing loneliness and promoting well-being, on the flipside, however, a corresponding decrease in physical social interactions may have detrimental consequences like weakening community ties and enabling hostility. The repercussions of substituting physical experiences with virtual ones are far from being understood and much more research is needed. One direction for future research is to investigate the types of experiences that can fulfil needs similarly in both the metaverse and physical world, and how this would shift consumption behaviors. Linking back to social interactions and the need for relatedness, a systematic review found mixed findings on the effects of interacting with avatars of real people vs. computerized agents in VR, with some studies finding no differences while others finding that interacting with avatars increased social presence (Oh et al., 2018). Future studies should investigate how these virtual social interactions impact later intentions to interact with real people in the physical world. Furthermore, the effects of individual differences can also be considered such as personality traits (e.g., extraversion) and relationship satisfaction.

Our findings have important practical implications. Firstly, it contributes to the on-going endeavor of designing virtual experiences for psychotherapy (Riva, 2005; White et al., 2018). The affective benefits of virtual nature can be easily incorporated into therapy applications and other well-being interventions. Secondly, it also contributes to the growing research interest around educational applications in the metaverse (Kye et al., 2021). Based on the current findings, virtual nature can be incorporated into environmental education programs to supplement traditional methods. Virtual nature provides a fun and safe way for students to gain skills and knowledge about the natural world while fostering connectedness to nature and pro-environmental attitudes. Lastly, the findings shed insights for content creators and developers of virtual experiences. The scenes used in the present studies are commercially available online and serve as examples of positive affective experiences in the metaverse. This has applications from gaming to online social spaces and even virtual travel experiences.

There are several limitations in our research. One limitation is that it involved a single short virtual nature immersion. Research shows that novelty effects are stronger than familiarity effects in predicting visual preference of natural scenes (Park et al., 2010). Future research should employ longitudinal designs to examine the long-term effects of experiencing nature in the metaverse. In addition, the current studies only used computer-generated nature in VR. The metaverse is not restricted to VR experiences and may also include other virtual experiences like live 360° videos of physical places and augmented reality. Nevertheless, we chose to include only computer-generated imagery as this can be classified as the furthest removed from physical reality relative to other metaverse experiences. Another limitation is that the current studies examined self-reported pro-environmental attitudes. Research has documented an environmental values-behavior gap (Higham et al., 2016; Kennedy et al., 2009), whereby strong pro-environmental attitudes do not always result in corresponding action being taken. Researchers warn that virtual nature may inadvertently widen this gap if users overestimate the efficacy of passive actions (e.g., signing an online petition) (Fletcher, 2017). An important extension of the current findings is to examine if the positive effects found would translate into actual pro-environmental behaviors in the real world. Finally, although the current research shows promising results for attitudes towards physical nature, it did not examine corresponding attitudes towards virtual nature. Thus, it remains to be seen which type of nature people will choose if they are given a choice to engage with physical nature in the real world or virtual nature in the metaverse. Future studies should investigate how preferences for virtual nature relates to preferences for real nature.

6. Conclusion

In the metaverse, immersive virtual experiences will transform the way we interact in and with our physical world. This research shows that virtual nature experiences enhance connectedness to nature which in turn promotes positive affect, pro-environmental attitudes, and intention to engage with physical nature in the real world. As more investment is poured into building new virtual worlds in the metaverse, our findings underscore the importance of understanding how virtual experiences may impact the well-being of people as well as the physical world they live in.

Credit author statement

Sarah **Chan:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft.; Lin **Qiu:** Conceptualization, Methodology, Writing – Review & Editing, Supervision.; Tian **Xie**: Conceptualization, Methodology, Writing – Review & Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Research data is available at: https://osf.io/jrsde/.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2023.107926.

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