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The overview effect and nature-relatedness

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Climate scientists increasingly agree that human behavior significantly contributes to global warming and biodiversity decline. Recent research emphasizes the importance of human-nature connectedness as a reliable predictor of psychological wellbeing and increased engagement in pro-environmental behavior. While evidence supports a positive correlation between human-nature connectedness and pro-environmental behavior, establishing causation remains elusive. Nevertheless, exploring this link is crucial, given its potential to enhance pro-environmental behavior. Armed with this understanding, stakeholders can design and implement successful sustainability interventions that promote wellbeing on individual and collective levels. One psychological phenomenon believed to have a strong effect on human-nature connectedness and pro-environmental behavior is "The Overview Effect," a term used to describe the shift in awareness some astronauts experience when viewing Earth from outside its atmosphere. This pilot study explored whether a 180-degree virtual reality Overview Effect experience created by EarthscapeVR® influences human-nature connectedness and whether a correlation exists between participants' average human-nature connectedness scores and openness to experience scores. 60 student participants took part in the study. The results showed significant increases on human-nature connectedness ($p < 0.0021$) in the experimental condition compared to the control group ($p = 0.97$), with no correlation ($r = 0.137$) between participants' average human-nature connectedness scores and openness to experience scores. While these results are not conclusive and further research is necessary, the initial findings support translating the Overview Effect into virtual reality to promote human-nature connectedness in people.

KEYWORDS

the overview effect, virtual Reality, human-nature connectedness, VR4Good, sustainability

Introduction

This paper presents the findings of a pilot study conducted at Stirling University involving 60 participants exploring whether an immersive 180-degree virtual reality Overview Effect (VROE) intervention can strengthen human-nature relatedness (HNR). The term HNR is used herein, as the human-nature relatedness scale was used to measure human connection with the natural environment. The study complements another study carried out by the University of Amsterdam titled "Does Experiencing the Overview Effect Increase Sustainable Consumer Behavior" (Van Horen et al., 2024). The paper begins with an overview of the definitions of human-nature-connectedness (HNC) and human-nature relatedness (HNR). It subsequently establishes the connection between HNC and pro-

environmental behavior (PEB), followed by an introduction to the concept of the "Overview Effect" and briefly explores how virtual reality (VR) technology can be leveraged to broaden the accessibility of this experience to a wider populace to improve HNC. The paper culminates with a summary of the study's key insights and contributions.

The link between HNC and pro-environmental behaviour (PEB)

Human-nature connectedness (HNC) encompasses various definitions, with overlaps observed (Schultz, 2002). In the context of this paper, HNC is characterized by a sense of "oneness" that people feel with the natural world (Barragan et al., 2021), often arising from the integration of nature within an individual's self-concept (Capaldi et al., 2014). Notably, metrics evaluating HNC exhibit substantial correlations among themselves (e.g., Mayer and Frantz, 2004; Nisbet et al., 2009; Tam, 2013; Balundė et al., 2019), suggesting potential synonymous usage (Capaldi et al., 2014). Within this paper, HNC serves as a comprehensive term encompassing humans' connection with the natural world. The Nature Relatedness (NR) scale (Nisbet et al., 2009) is utilized under this umbrella. The NR Scale gauges both affective and cognitive facets of HNC, capturing emotions, thoughts, interests, and fascination tied to nature, along with the yearning for nature interactions.

There is a growing body of research indicating HNC as a strong predictor of pro-environmental worldviews, attitudes, behaviors, and psychological wellbeing (Nisbet et al., 2010; Zelenski et al., 2014; 2015; Schmitt et al., 2019; Mellor et al., 2022; Forstmann et al., 2023). A recent meta-analysis carried out by Barragan et al. (2021) examined over 147 correlational studies, confirming that HNC as a strong predictor of PEB. The researchers concluded that targeted practices aimed at increasing HNC (e.g., outdoor education and weekly mindfulness sessions) could be implemented by policymakers and other professionals to improve conservation and sustainability. This evidence highlights the potential of HNC to be used as a mechanism in various prosocial campaigns to promote PEB and improve overall mental health, which in turn could help us achieve a set of important social priorities as identified under the Sustainable Development Goals (SDGs). In support of this, Riechers et al. (2021) suggest that HNC is a "key societal trait" that can play an important role in preventing further environmental degradation and achieving sustainability goals.

Many studies have demonstrated the extent to which self-definition influences goals, behaviors, and attitudes (Tajfel and Turner, 1979; Baumeister, 1999; Brändl et al., 2018; Roderer et al., 2022). The integration of nature into self-definition is likely to expand self-view and encourage a heightened sense of awareness about how personal behaviors are affecting the natural world (Mackay and Schmitt, 2019). The term "eco-self" refers to an individual's sense of self or identity that is intertwined with their ecological or environmental surroundings. It represents a conceptualization of the self that acknowledges the interconnectedness between a person and the natural world, emphasizing the role of the environment in shaping one's identity, values, and perceptions. In other words, individuals begin to associate damage to nature as damage to themselves. This is in line with value theory, which suggest positioning personal self-interest alongside the interest of the environment and the planet can cultivate a stronger engagement with self-transcendent causes such as protecting the environment. Therefore, those who feel a strong connection to nature are more likely to take environmental threats more seriously compared to those who feel a weaker connection (Schmitt et al., 2019). This in turn, could serve as a mechanism that increases PEB to prevent or mitigate these threats (Schmitt et al., 2018).

In a meta-analysis of 75 correlational studies and 17 experimental manipulations, Mackay and Schmitt (2019) examined the relationship between HNC and PEB and noted two key limitations of the research carried out so far. Firstly, aside from HNC and the emotional aspects of it, other variables can influence PEB, e.g., identification with activist groups and causes, moral responsibility (Schmitt et al., 2019), and empathic concern (McIntyre and Schmidt, 2012). Secondly, although brief exposure interventions have been shown to increase HNC, some studies reveal inconsistency in results (Scott, 2010; Zelenski et al., 2015), suggesting that brief contact with nature alone might not be adequate to facilitate the conditions required for increasing HNC, particularly the deep sense of oneness and identity that is characteristic of the state. The authors conclude that stronger manipulations focusing on creating a deep sense of oneness and development of an eco-identity are necessary to establish a causal relationship between interventions and HNC. They recommend that future studies focus on manipulating self-definition as this is a vital component of the construct. Research also suggests that individual factors can influence the direction and strength of HNC, for example, the personality trait "openness to experience" is positively correlated with HNC, with one study by Nisbet et al. (2009) finding a moderate positive correlation between openness and the NR construct specifically (r = 0.38).

The "overview effect" and associated psychosocial benefits

One psychological phenomenon believed to have a strong effect on self-definition, HNC, and PEB is "The Overview Effect," a term used to describe the cognitive shift in awareness astronauts experience when seeing the Earth from outside its atmosphere (White, 1987; 2021). The following characteristics are described as markers of the Overview Effect: feelings of awe, compassion, reverence, and gratitude, an understanding of the deep interconnection of all life, seeing the Earth as a "tiny, fragile ball of life," and increased feelings of responsibility for protecting the planet (White, 2021, *p*. 5).

More broadly, the Overview Effect can be understood as a psychological state that is akin to transcendent states that emerge when human beings witness remarkable natural landscapes from expansive vantage points. Earth gazing from orbit or from space is the "pinnacle" of this experience (Yaden et al., 2016; Nezami et al., 2021). Yaden et al. (2016) propose three primary psychological constructs for understanding the positive benefits of the OE: (1.) awe, (2.) self-transcendence, and (3.) schema changes. In attempting

to account for how awe impacts astronauts' behavior post spaceflight, Yaden et al. (2016) use qualitative research data to propose that when the Earth is seen from a distance, it prompts astronauts to think globally about humanity; leading to further contemplation about life on the planet.

Research and post-flight astronaut accounts consistently indicate that the Overview Effect is a meaningful experience that can result in shifts in perception, attitudes, and behaviors associated with HNC and PEB (Yaden et al., 2016; Nezami, 2017; Quesnel and Riecke, 2018; Kanas, 2020; White, 2021). There is also a growing body of research that supports the view that the Overview Effect can have salutogenic benefits, e.g., eliciting prosocial emotions such as awe and wonder (Gallagher et al., 2015; Nezami, 2017), and positively impact astronauts' worldviews and values (Brcic and Della-Rossa, 2012; Yaden et al., 2016; Nezami, 2017; Kanas, 2020; White, 2021), including universalism and spirituality (Suedfeld et al., 2010). Ihle et al. (2006) suggest that the Overview Effect can positively impact astronauts' overall mental health and support personal growth. Astronauts who experience the Overview Effect also report increases in PEB following spaceflight (Gallagher et al., 2015; Nezami, 2017; Kanas, 2020), with some space veterans joining sustainability-focused or humanitarian causes upon returning to Earth (Ihle et al., 2006; Garan, 2015; White, 2021).

Although awe is a prevalent characteristic of the Overview Effect and can explain some of the positive changes that take place, it cannot account for them all (Yaden et al., 2016). For example, Cohen et al. (2010) found that spiritual and self-transcendent experiences are more likely to lead to longer-lasting changes than awe alone. Accordingly, Vaillant (2008) argues that people tend to search for symbolic value in personal experiences and that "particularly intense" experiences can motivate further exploration of how they fit into one's current life narrative (assimilation), which can lead to an update of pre-existing "schemas" (accommodation).

Virtual environments that can improve HNC

New developments in VR technology have enabled the development of simulated versions of the Overview Effect that capture some of its aesthetic and emotive elements, allowing researchers opportunities to investigate its potential benefits without requiring space-travel (Yaden et al., 2016; Nezami, 2017; Stepanova, 2018; Stepanova et al., 2018; Nezami et al., 2021).

VR is increasing in accessibility and is already applied to improve patient outcomes in mental health settings (Riva et al., 2016; Freeman et al., 2017; Park et al., 2019; Riva and Serino, 2020), and as an effective treatment for depression and anxiety (North and North, 2017). Meta-analyses have found VR interventions to be effective for creating psychological change, particularly when coupled with existing treatments (Turner and Casey, 2014; Riva et al., 2016; Dellazizzo et al., 2020). Moreover, recent research indicates that VR could be an effective tool for facilitating self-transcendent experiences and awe states (Yaden et al., 2016; Chirico et al., 2017; Stepanova, 2018; Stepanova et al., 2018; White et al., 2018).

A growing body of evidence suggests that exposure to VR, even for short periods of time, can affect individuals' beliefs, attitudes, and actions, e.g., increasing prosocial and PEB (Rosenberg et al., 2013; Tussyadiah et al., 2018; Aitamurto et al., 2021; Chirico et al., 2023), and reducing stereotyping (Maister et al., 2015), and racial biases (Hasler et al., 2017). Studies have also found VR to be effective for enhancing HNC and PEB, For example, Ahn et al. (2014) found that immersion in perceptually rich VR experiences leads to a 20% reduction in paper consumption, and White et al. (2018) found that nature-themed VR experiences provide similar wellbeing benefits as time spent in actual nature for mobility-challenged individuals. Furthermore, awe is an emotion that can arise from vast stimuli, including nature and VR has emerged as an effective medium to elicit it, with one study by Chirico et al. (2023) showing that awe-inspiring immersive nature scenes can influence socially engaging pro-environmental attitudes and behaviors but not personally engaging ones.

Although immersive environments are not able to fully recreate the direct experience of the Overview Effect, recent research suggests that they can recreate aspects of it (Chirico et al., 2018). Stepanova et al. (2019) compared the effects of a virtually induced Overview Effect experience among members of the public with astronauts' experiences during spaceflight. Results found similarities between the experiences, leading to the recommendation that the virtual Overview Effect should be studied as a phenomenon. Building on this, a quantitative study of 188 school children in the Netherlands demonstrated that aspects of the Overview Effect can be elicited in young people in schools when using a VR simulation (van Limpt - Broers et al., 2020).

The utilization of VR as a technology for inducing HNC through Overview Effect simulations holds promise due to its unique advantages compared to other technologies and even direct nature-exposure. Firstly, the direct Overview Effect experience remains inaccessible to a significant portion of individuals due to the impracticality of space travel. Secondly, VR can provide a high level of immersion by creating a visually captivating and all-encompassing environment, enabling users to feel as if they are truly present in the natural setting (Weech et al., 2019; Mostajeran et al., 2021). Thirdly, 360 VR allows for a sense of exploration and agency within the virtual nature environment. Users have varying degrees of autonomy in navigating their surroundings and can direct their attention to specific aspects of the environment. This interactivity is a distinguishing feature that enhances engagement and, in turn, the potential for inducing nature relatedness (Skarbez et al., 2017). Comparatively, while real nature exposure has its own benefits, such as multisensory experiences and the actual physical connection with the environment, it poses challenges due to geographical, health, logistical, or time constraints (Hartig et al., 2014), for example, for people with limited access to nature such as the elderly in nursing homes, hospital patients, or prison inmates (Mostajeran et al., 2021). Moreover, in comparison to other emerging technologies, VR stands out due to its simplicity and accessibility. Unlike fully immersive systems that require specialized equipment and space, VR can be experienced using widely available devices such as smartphones and basic VR headsets. This accessibility ensures that a broader audience can engage in the virtual Overview Effect experiences, potentially contributing to wider utilization.

Fourthly, the concept of the Overview Effect closely parallels the notion of self-transcendence as outlined by Yaden et al. (2016). Employing a 180 VR video depicting Earth from a distant space perspective, in tandem with transcendental meditation and

soundscape, aims to evoke a sense of unity and interconnection. Specific scenes can be strategically designed to evoke awe-inspiring responses. In a similar way to the astronauts who directly experience the Overview Effect, the VR encounter encourages observers to perceive Earth as a cohesive and interconnected planetary system, encompassing humanity, diverse life forms, and the environment.

By immersing users within an expansive and extraordinary setting, the VR experience engenders a personal sense of expansiveness which can elicit awe (Chirico et al., 2023). Moreover, this encounter imparts the observer with a perception of Earth as a distinct entity within space-time, distinguished by its unique characteristics. This novel perspective can facilitate a heightened connection with Earth and its encompassing elements.

The distant vantage point of the Overview Effect and specific meditation practices share similarities, offering unique insights. Astronauts experiencing the Overview Effect often report a sense of interconnectedness, transcending borders, and divisions. Similarly, certain meditative practices can help transcend individual boundaries, fostering awareness of life's interconnectedness. Both experiences can evoke awe, humility, and empathy, prompting a shift from the individual to the collective. They can also lead to attunement to nature and a desire to contribute positively to the world. Essentially, both experiences demonstrate potential for expanding conscious awareness and deepening the connection with the natural world (Yaden et al., 2016; Nezami, 2017; Yaden et al., 2017).

Finally, the potential of VR to enhance HNC extends beyond being a standalone tool. VR can be utilized to complement existing technologies and integrated into a broader spectrum of strategies aimed at fostering HNC.

While VR appears to be promising for making the Overview Effect more accessible, further research is necessary to test which components can create the desired outcome and its overall efficacy in achieving HNC (Stepanova et al., 2019). To date, the research carried out with VR simulations of the Overview Effect has mainly focused on its ability to elicit awe in participants (Gallagher et al., 2014; Chirico et al., 2018; Stepanova et al., 2019). However, despite numerous reports from astronauts indicating that the Overview Effect increases HNC (Yaden et al., 2016; Nezami, 2017; Voski, 2020; White, 2021), there is a lack of empirical research exploring whether VR simulated versions of the Overview Effect can increase HNC.

The existing evidence indicating the potential of nature-based VR simulations to enhance HNC (Rosenberg et al., 2013; Ahn et al., 2014), alongside the established correlation between HNC and PEB, and the anecdotal research on the impact of the direct Overview Effect experience on HNC and PEB, underscores the need for further research relating to correlations between these concepts. This accumulation of evidence supports the notion that a thoughtfully designed virtual reality simulation of the Overview Effect could similarly yield a positive effect on HNC (Nezami, 2017; Stepanova et al., 2019).

Present study

Methods

This study aimed to explore whether a targeted 180 VR "Overview Effect" (VROE) intervention (experimental condition) designed by EarthscapeVR® could increase participants' HNC scores. To evaluate this, the Nature Relatedness Scale (NR-Scale) serves as an appropriate measure. The study engaged participants in a non-interactive 180 VROE intervention, specifically chosen to minimize the likelihood of adverse outcomes such as cyber sickness (LaViola, 2000; Chattha, 2020; Mostajeran et al., 2021) and visual discomfort (Cash and Prescott, 2019). Furthermore, prolonged exposure to VR environments that are highly immersive can lead to a sense of disconnection from the real world, potentially affecting the user's sense of time and presence (Witmer and Singer, 1998). The deliberate choice of a non-interactive approach for the VROE intervention aimed to alleviate potential distractions from the intended meditative nature of the experience, which was carefully constructed to foster a sense of connectedness with the environment.

Based on Nisbet et al. (2009) findings, this study also explored the relationship between participants' openness and average NR scores, with the secondary research question representing this: Does openness to experience correlate positively with participants' average NR scores? It was hypothesized that a moderate positive correlation would be found between average NR scores and openness, and the differences would be more significant than those found in the control condition (relaxation) (Nisbet et al., 2009). This discrepancy is expected because the VROE intervention aims to recreate the key aspects of the Overview Effect, including awe, self-transcendence, and schema changes via the mechanism of cognitive dissonance (Yaden et al., 2016; Miller et al., 2023), all of which can contribute to increased HNC (Nezami, 2017; Quesnel and Riecke, 2018; White, 2021; Chirico et al., 2023). As the control condition's content is primarily designed for relaxation and does not include these elements, it is anticipated that the increases in HNC will be less substantial.

Research questions

The following research questions were explored: (1) Do participants' Nature Relatedness (NR) (Nisbet et al., 2009) scores increase immediately after viewing the intervention and are differences more pronounced in the VROE condition than in the control condition? (2) Is there a moderate positive correlation between participants' average NR scores and openness to experience?

Participants and procedures

The research was carried out as a pilot study due to it being a new field of inquiry investigating the relationship between a VROE intervention and HNC. The sample consisted of 60 participants (37 women, 23 men), recruited from social media, Stirling University's "Psych-Web" system and recruitment stand. In exchange for participation, students were offered 1 year of free membership to The Weekend University's video-library of academic lectures, normally valued at $330. All participants had normal vision and were screened for contraindications to VR beforehand. Participants were also advised to contact a medical physician before participating if they had any serious pre-existing physical or mental health conditions.

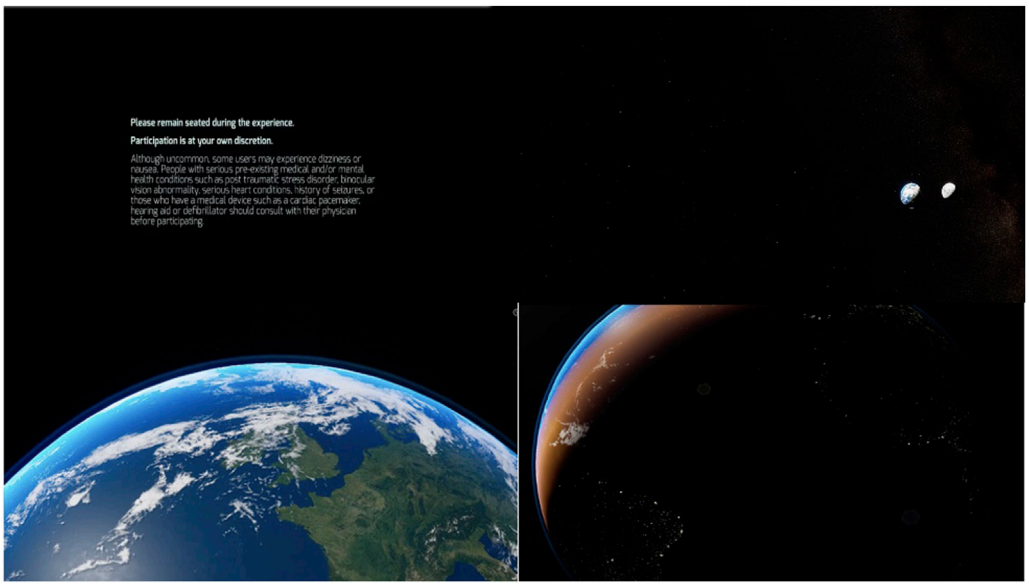

FIGURE 1
Immersive VROE Snapshot Images from EarthScape VR.

The University of Stirling granted ethical approval and all participants were required to complete an online consent form. Prior to the experiment, participants completed the NR Scale (Nisbet et al., 2009) and the Ten Item Personality Inventory (TIPI; Gosling et al., 2003). Immediately after the intervention, they completed the NR scale, but this time with the omission of the TIPI. Consent forms and questionnaires were administered via Qualtrics software.

Participants were randomly assigned to either the VROE group (viewed a simulated version of the Overview Effect) or the control group (viewed a VR guided meditation of the same length). Blinding was applied, meaning participants were informed they were taking part in an experiment that used VR to measure their connection to nature but were not informed whether they were in the control or the VROE condition. Both groups contained 30 participants.

The experimental group viewed a 25-min VROE experience in a virtual reality setup inspired by the Overview Effect and based on Nezami's (2017) research. It provides a simulated version of spaceflight that attempts to harness some of the emotive qualities and characteristics associated with the Overview Effect, such as awe, self-transcendence, cognitive dissonance, and nature-connectedness. The VR presentation provides a 180-degree immersive experience, allowing participants to travel around the planet and view the Earth in the context of space–providing both a daytime and night-time view (see Figure 1). The experience is accompanied by binaural beats, a soundscape, and a voice-over designed to enhance the aesthetics and emotional responses in those who experience it. The aim of this type of intervention is to strengthen nature-connectedness and elicit prosocial emotions. This is in line with research suggesting that communication needs to go beyond the rational processing of information if it is to motivate lasting behavior change (Pooley & O'Connor, 2000; Buijs and Lawrence, 2013; Reeves et al., 2021; Miller et al., 2023). The soundscape was inspired by the philosophical concept "The Music of the Spheres," and the meditative audio and content include six central elements, four of which have been identified as central aspects of the Overview Effect: 1) introduction–grounding, 2) familiarity and belonging, 3) motion and flux, 4) awe and gratitude, 5) cosmic consciousness, and 6) grounding–ending (Nezami, 2017).

Participants in the control condition viewed the immersive VR 360-degree Guided Meditation Experience designed by Aquilay (2019), which was chosen for three main reasons. Firstly, it is specifically designed to induce relaxation in participants–the confounding variable being controlled for in this study (Gallagher et al., 2015; Chirico et al., 2017). Secondly, with a duration of 24 minutes and 59 seconds, it is the same length as the VROE experience, thereby ruling out time as a confounding variable. Thirdly, it shares many features with the VROE, including a voice-over, emotive music, and a 360-degree visual experience (Aquilay, 2019), also allowing these to be ruled out as confounds. The visual imagery showed holographic projections while the voice-over content (see appendix) is designed to induce a sense of deep relaxation in participants. With a title of "Who Are You?" and phrases like "Can you understand a reality where you are not your body?" and "Is what's happening in your imagination right now any less real than your physical reality?," the content also challenges the viewer's self-definition, particularly their identification with their physical body. Therefore, as both VR experiences focus on the self-definition aspect of the HNC construct, comparing the results between the two conditions will help answer whether it is the Overview Effect intervention specifically that is leading to changes in NR, or if the observed changes are attributable to viewing any kind of VR content designed to alter the viewer's self-definition.

All other conditions were kept the same, including the length, setup procedure, instructions, headset, and debrief, leaving the VR content as the only difference between the two groups' experiences.

Participants in both conditions watched the content on the same commercial virtual reality headsets—the Oculus Go, chosen because of accessibility and ergonomics. The device weighs 468 g, has dimensions of 190 mm × 105 mm × 115 mm, contains a fast-switching LCD 2560 × 1,440 resolution (1,280 × 1,440 per eye) and has a refresh rate of 60–72 Hz.

Upon arrival, participants were brought into a cubicle, asked to take a seat, and make themselves comfortable. They were given instructions on how to start the video and then provided with the VR headset and headphones. Next, they watched the 25-min VR video from start to finish. After viewing the content, the final step involved completing the NR scale (Nisbet et al., 2009).

Measures

There are numerous scales available for measuring HNC, several of which were considered for this study. The NR scale was chosen for two reasons. Firstly, it is an empirically supported, ecologically valid, and reliable measure. In addition to being stable across time and internally consistent, NR correlates positively with other HNC constructs such as time spent in nature, environmental concern, and PEB across a wide range of studies (Nisbet et al., 2009).

The NR Scale was developed by Nisbet et al. (2009) to measure individuals' sense of connection to the natural world. It is a self-report measure consisting of 21 items, rated on a five-point Likert Scale. The scale is broken down into affective (9 items), cognitive (6 items), and experiential aspects (6 items).

The Big-Five Model (BFI; John and Srivastava, 1999) has become one of the most influential scales among psychology researchers seeking a universally accepted and validated personality measure (Romero et al., 2012; Nunes et al., 2018). Along with conscientiousness, extraversion, agreeableness, and neuroticism, openness to experience is part of the Big-5 Model. There are several scales used to measure the Big Five, such as the 44-item Big-Five Inventory (Woods and Hampson, 2005), the 60-item NEO-Five Factor Inventory, and the 240-item Revised NEO Personality Inventory (Costa and McCrae, 1992). However, since this study focused solely on openness, the Ten Item Personality Inventory (TIPI) scale (Gosling et al., 2003) was chosen as it provided an empirically validated and brief measure of personality (taking approximately 1 minute to complete) (Nunes et al., 2018). The TIPI shows high temporal stability and strong correlations with more extensive personality measures like the BFI (Nunes et al., 2018). A factorial analysis from Romero et al. (2012) validated its five-factor structure, suggesting it to be an effective brief measure of the Big-Five Personality Model. It breaks personality down into five distinct traits: openness, conscientiousness, extraversion, agreeableness, and neuroticism and contains 10 items, two of which focus on openness. A seven-point Likert Scale is used, with the following response options: (1) Disagree strongly, (2) Disagree moderately, (3) Disagree a little, (4) Neither agree nor disagree, (5) Agree a little, (6) Agree moderately, and (7) Agree strongly.

Statistical analysis

To assess the relationship between NR and the VROE and control interventions, a two × 2 Mixed Repeated-measures ANOVA design was chosen. Self-report measures were collected from the VROE condition and the control condition (CON) both before and after the intervention. The independent variables were the time the scale was administered (pre- and post-experiment) and groups (VROE and CON). The dependent variable was the participants' self-reported scores on the NR Scale (Nisbet et al., 2009). The 2-way time × group interaction was further investigated by post-hoc *t*-tests with Tukey correction applied.

We also examined a possible correlation between "openness" and NR. A Shapiro-Wilk test indicated that the openness scores were not normally distributed [W (60) = .951, p = .018]. Thus, we employed a Spearman correlation test to assess the relationship between participants' average NR scores and openness scores. An independent samples *t*-test was conducted to identify whether openness had any effect on the difference in results found between the VROE and control conditions and to assess if openness might have been a confounding variable. Jamovi software (v.2.4.8.0) was used to conduct all parts of the analysis.

Results

Out of the 88 participants who completed the pre-experiment questionnaire, 28 were excluded because they were absent on the day of the experiment, leaving a total sample size of n = 60 (30 in the experimental condition and 30 in the control condition). To assess whether VROE enhances HNC, NR was operationalized using the following process. First, high-scoring items (i.e., "agree strongly") that correlated negatively with HNC were identified and subsequently reversed. For example, strongly agreeing with the statement in item 13 that: "Some species are just meant to die out or become extinct" would not be an indicator of HNC; in these instances, scores were reversed, e.g., a five would be reversed to 1, four to 2, and so on. In total, eight items (9, 10, 11, 12, 13, 14, 16, and 19) were reversed. Once these scores had been reversed, total scores across all 21 items were calculated for each participant, giving a total NR score.)

To examine the relationship between openness and NR, each participant was given a total "openness" score, calculated using the following process. First, scores for item 10, which measured openness, were reversed as a low score on this statement ("Conventional, uncreative") indicated high openness, whereas a high score equated to low openness. The TIPI uses a seven-point Likert Scale, meaning a score of seven would become 1, a six would become 2, 5 s became 3 s, etc. Second, after scores were reversed, they were added together with participants' scores on item five of the TIPI ("Open to new experiences, complex") to produce a total openness score (O) for each participant. The other variable used in this part of the analysis was the average NR score (NR-Avg) for each participant.

VROE and nature relatedness

The two × 2 Mixed ANOVA was performed to analyze the effect of the VROE intervention and a guided meditation (control) intervention on NR scores. The analysis revealed a significant

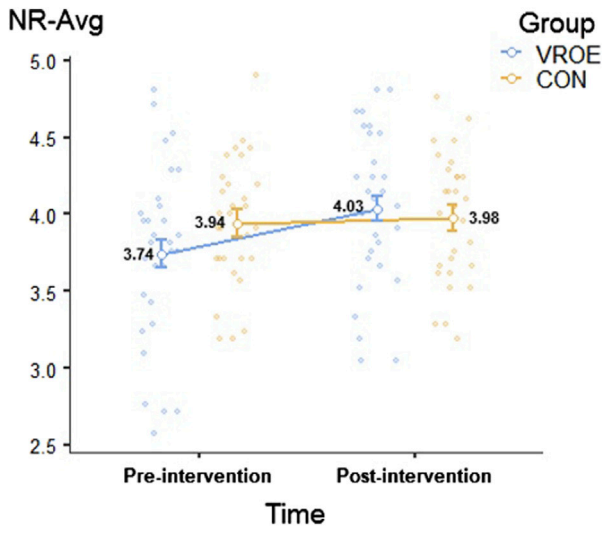

FIGURE 2
Nature Relatedness Average scores pre- and post-intervention. The graph shows a clear, statistically significant increase in feelings of nature relatedness for the group who watched the VROE video; no such increase was recorded for the Control group who watched the Virtuality Reality guided meditation video. The average scores for each group pre- and post-intervention are shown in the graph; the error bars represent the standard error of mean.

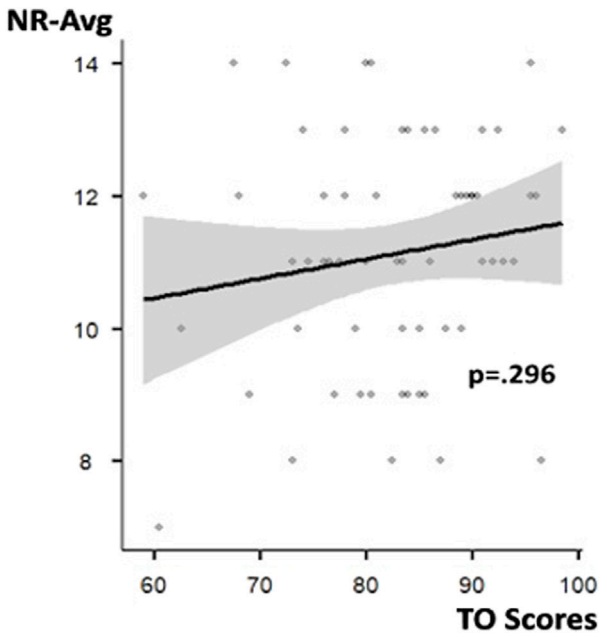

FIGURE 3
Non-statistically significant Correlation between Participants' Nature Relatedness Average Scores and Total Openness Scores.

main effect of Time [F (158) = 9.13, p = .004, η_p^2 = .136] because there was an overall increase in NR scores post-intervention, but no significant effect of Group (p = .53). In addition, the analysis revealed a significant interaction between Time (pre/post) and Group (VROE/Control) [F (1, 58) = 5.64, p = .021, η_p^2 = .089]. Regarding the hypotheses of our study, post-hoc t-tests showed that there was a significant increase in the NR scores post-intervention only in the VROE group [t (58) = −3.816, p = .002], but not in the control group (p = .65) (Figure 2). No other post-hoc comparisons reached statistical significance (all ps > .247).

Openness to experience and nature relatedness

The study also examined whether there was a relationship between openness to experience and participants' average NR scores. Previous research by Nisbet et al. (2009) had indicated that individuals higher in the trait "openness to experience" tend to have higher NR scores. A Spearman correlation test revealed a weak, non-statistically significant, positive correlation [r (58) = .137, p = 0.296] between participants' openness scores and their average NR scores (Figure 3].

An independent samples t-test (see Table 1) was conducted to determine if differences in openness scores had any impact on the disparity in results observed between the VROE intervention and control conditions. This analysis aimed to assess if openness was as a confounding variable. The results indicated a mean difference of −0.4 between the groups, with no significant effect (p = 43), thus confirming that openness did not function as a confound in this study.

Discussion

The primary hypothesis was supported, with results indicating that the VROE intervention led to an increase in participants' HNC. Specifically, participants in the VROE condition exhibited significant increases in NR (p < 0.0021), and these increases were more substantial than those observed in the control group (p = 0.97).

However, the secondary hypothesis, which posited a moderate positive correlation between participants' average NR scores and openness to experience, was not supported. In this study, no correlation (r = 0.137) was found. This finding contradicts previous research (e.g., Nisbet et al., 2009; Tam, 2013; Zhang et al., 2014; Di Fabio and Kenny, 2018) that had reported a moderate positive correlation between HNC and openness.

In examining how this study aligns with existing literature, several points warrant consideration. Firstly, the findings lend support to previous research indicating that: (1) exposure to the Overview Effect can lead to shifts in attitudes toward the environment (Voski, 2020), (2) VR, when employed alongside other interventions, shows promise as an effective tool for facilitating psychological change (Turner and Casey, 2014; Riva et al., 2016), and notably, (3) VR technology holds potential for replicating aspects of the direct Overview Effect experience (Chirico et al., 2018; Stepanova et al., 2019; van Limpt - Broers et al., 2020). However, further investigation is warranted to substantiate these findings and to explore the extent and duration of observed changes.

Secondly, it is worth noting that NR correlates positively with PEB (see Barragan et al., 2021). However, meta-analytic research conducted by Mackay and Schmitt (2019) has highlighted the need for more interventions that directly focus on manipulating the "self-definition" aspect of the HNC construct to establish correlations and

TABLE 1 Independent samples *T*-Test.

		Statistic	Df	*p*	Mean difference	SE difference		Effect size
O-Score	Student's t	−0.801	58.0	0.426	−0.367	0.458	Cohen's d	−0.207

predict causation. Anecdotal findings suggest that the Overview Effect can bring about changes in astronauts' self-definition through psychological mechanisms such as awe, self-transcendence, schema changes, and cognitive dissonance (Yaden et al., 2016; Nezami, 2017). This experiment aimed to address this gap by providing an intervention with a strong focus on HNC, which could be considered as one of the characteristics of eco-self.

The findings from this research project can contribute to the existing literature in the following ways. A growing body of research (e.g., Chirico et al., 2018; Stepanova et al., 2019; van Limpt - Broers et al., 2020) has shown that VR can evoke some of the aspects of the Overview Effect (e.g., awe), however there appears to be limited research specifically focused on HNC. This study builds upon early evidence and provides an empirical "first step" in examining VROE as a potential intervention for increasing HNC.

In terms of potential, longer-term, and broader societal implications, there is a growing consensus within the scientific community that human behavior is the central cause of environmental degradation (Allen et al., 2018; Brondizio et al., 2019; Díaz et al., 2019). This necessitates interventions to guide individuals toward more sustainable attitudes and behavioral patterns. Meta-analyses (Mackay and Schmitt, 2019; Barragan et al., 2021) have demonstrated positive correlations between HNC and PEB, with some studies suggesting causation (Zelenski et al., 2015). Thus, it is plausible that interventions increasing HNC may also lead to increases to PEB. Moreover, with predictions that VR will become increasingly accessible in the coming decade (Marr, 2020; Vynz Research, 2021), interventions like those offered by EarthscapeVR® may effectively promote PEB. These interventions could be employed in schools, as demonstrated by van Limpt - Broers et al. (2020), integrated into cultural venues such as museums, planetariums, and galleries, as suggested by Stepanova (2018), or utilized in sustainability workshops and applied psychology to strengthen the human-nature connection, as proposed by Nezami (2017).

Limitations

This study examined the potential impact of immersive Overview Effect experiences through Virtual Reality (VROE) on HNC. While the initial findings suggest a possible connection, several questions remain unanswered. The following sections explore the study's limitations, identify knowledge gaps, and propose directions for future research.

Like any research endeavor, this study has limitations that affect the extent of conclusions drawn from the collected data. For instance, the concept of "novelty effects," as proposed by Clarke and Sugrue (1991), suggests that individuals may demonstrate improved performance due to heightened interest in novel stimuli. The potential presence of novelty effects was not explicitly addressed in the pre-questionnaire, as participants' prior VR experience was not assessed. While this could have been a confounding variable, the existence of a control group and random assignment minimizes its impact, ensuring any influence remains consistent across groups.

Another factor, known as "demand characteristics," as suggested by Orne (2009), posits that participants may modify their responses based on their perception of the experiment's objectives. Social desirability bias, the inclination to provide socially favorable responses, could also influence the results (Devaux and Saussi, 2016). However, the control group's unchanged scores suggest minimal influence from these factors. Recency effects, which give undue weight to recently presented information, might have impacted immediate post-intervention responses (Baumeister, 2007). Additionally, employing the same scale twice in one experimental session introduces the possibility of results being affected by order effects (Carlsson, Mørkbak, and Olsen, 2012). Given that administering the follow-up questionnaire immediately post-intervention raises concerns about recency and order effects, future researchers building on this work may want to use longitudinal designs to address these limitations. Another potential limitation concerns the difference in the content of the two conditions. While both interventions contained audio designed to influence "self-definition," only the VROE explicitly mentions nature connectedness. As the control did not, it is possible that this influenced the findings. Therefore, future researchers may want to use a VR intervention for the control condition containing audio which specifically addresses HNC.

Ecological validity, which refers to the generalizability of results to real-world settings (Andrade, 2018), is another limitation. Conducting the study in a controlled laboratory environment may raise questions about the applicability of findings to settings such as schools or museums where these interventions might be implemented. However, this issue can be addressed through replication or extended research over time. Holleman et al. (2020) advocate for context-specific understanding of human behavior and cognition, a goal fulfilled by this study's focus on the emotional, cognitive, and experiential dimensions of HNC using the NR-Scale.

Sample size also emerged as a limitation, affecting the results of the secondary analysis regarding the relationship between average NR scores and openness. With a smaller sample size compared to previous studies, the generalizability of the findings might be compromised. Nevertheless, as a pilot study, it establishes a foundational platform for future researchers to build upon.

Like all emerging technologies, VR also has limitations. For instance, some immersive experiences have been observed to trigger negative emotions and rumination (Lavoie et al., 2021). Additionally, due to the current cost and some scalability issues, the technology could remain somewhat inaccessible to large groups of people (Phillips, 2020).

Finally, advocates of the ecopsychology movement view technology as one of the root causes of our disconnection from the natural world (Milton, 2016), and some are therefore reluctant to embrace this technology. Moreover, the materials used to manufacture VR headsets have been demonstrated to be challenging to acquire and even more difficult to dispose of (Green Journal, 2019). Thus, critics may argue that it is

counterproductive to use technology that is harmful for the environment to stimulate pro-environmental behaviour. As a counter to this, Lombardo (2006) contends that we have no option but to co-evolve with technology and ensure that we consciously shape its development in a way that benefits society and the planet at large.

Future research

To enhance the depth and breadth of understanding, future research should address several aspects. A longitudinal study could establish the durability of NR changes induced by VROE interventions over time. Simultaneously measuring PEB alongside HNC will determine if self-reported changes in HNC translate into observable behavior.

Comparative research contrasting astronaut experiences of the Overview Effect during spaceflight with those of the general population undergoing VROE interventions offers valuable insights into the distinctions and commonalities between the two.

Examining age-related impacts of VROE interventions is another fruitful avenue. Neuroplasticity and brain development vary across the lifespan, suggesting that impacts might differ among different age groups (Park and Bischof, 2013; Voss et al., 2017; Del Maschio et al., 2018). Cross-cultural investigations, contrasting Western, Educated, Industrialized, Rich, and Democratic (WEIRD) cultures with non-WEIRD populations, would also enrich our understanding of the effects' universality (Heinrich et al., 2010).

The evidence identifying emotions and self-definition as mechanisms for increasing PEB and the moderating effects of individual differences (Nisbet et al., 2009; McIntyre and Schmidt, 2012; Mackay and Schmitt, 2019; Barragan et al., 2021) calls for "stronger" experimental manipulations targeting the emotional and "self-definition" aspects of the HNC construct.

Lastly, revisiting the cautionary note concerning the potential for certain VR experiences to induce adverse states (Lavoie et al., 2021), it would be advantageous to investigate the involvement of solastalgia—a term used to describe distress and emotional unease that individuals experience when witnessing negative environmental changes (Albrecht, 2016).

In conclusion, this study represents a step towards understanding the relationship between VROE intervention and HNC. While more research is necessary, the initial findings suggest that the VROE intervention used in this study has the potential to enhance human-nature connectedness (Chirico et al., 2018; Stepanova et al., 2019; van Limpt - Broers et al., 2020). By acknowledging the study's limitations and addressing the open questions, researchers can further clarify the mechanisms, long-term effects, and real-world applications of interventions like this.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Stirling University, DK. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

NM: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing–original draft, Review and editing, Project administration. AN: Conceptualization, Provision of VROE software, Methodology, Review and editing of original draft, Project administration, Supervision. DK: Conceptualization, Methodology, Review and editing of original draft, Supervision.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2024.1196312/full#supplementary-material

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