Awe and Well-Being: The Role of Nature Connectedness in Enhancing Student Well-Being through Virtual Reality Nature

Milan Karam Menkhaus (s2405997)

Faculty Behavioural, Management & Social Sciences, University of Twente

202000384: M12 Bachelor Thesis

Department of Positive Clinical Psychology & Technology

First Supervisor: Lina Bareisyte

Second Supervisor: Shenja van der Graaf

June 18th, 2024

Abstract

Introduction: This study investigates the extent to which exposure to awe-inducing virtual reality (VR) nature has an effect on the subjective well-being of university students, while particularly focusing on how this relationship is moderated by nature connectedness. This is done in the context of the university student population potentially facing negative health consequences in the form of decreased well-being caused by restricted access to nature due to urbanization. **Methods:** A total of 40 students participated in the study and were exposed to two VR nature environments with one depicting an awe-inducing nature scenery and one control VR nature environment. The measures used consisted of the Nature Relatedness Scale Short Form (NR-6), Awe Scale (AWE-S), and WHO-5 Wellbeing Index. **Results:** The results showed a significant increase in perceived awe after the intervention. However, no significant impact of these increased awe levels on the subjective well-being of the participants was observed. Additionally, the relationship between awe and well-being was not significantly moderated by nature connectedness contrary to initial expectations. **Discussion:** These findings emphasize the capability of VR to elicit feelings of awe, even though a connection between heightened awe levels and well-being was not established nor moderated by nature connectedness. This challenges the academic consensus that awe generally positively contributes to well-being. Considering this, this study highlights the need for further research within this complex domain to further optimize VR interventions targeted at well-being enhancement leading to optimal exploitation of VR`s potential as a therapeutic tool in this context.

Table of Contents

Awe and Well-Being: The Role of Nature Connectedness in Enhancing Student Well-Being through Virtual Reality Nature

Since the dawn of humanity, people have depended on nature and their connection to it to ensure their survival. Living, working, and being exposed to nature was simply unavoidable (Soga & Gaston, 2016). Kellert and Wilson (1993) summarize this inherent and evolutionarily justified connection to nature and people's need to surround themselves with other living beings under the term "biophilia hypothesis". The affinity with nature, which has influenced and determined people's lives for the majority of human history, has only recently decreased in significance due to urbanization (Soga & Gaston, 2016). Nowadays in times of urbanization, most people live and work in large cities and densely populated areas (Cox et al., 2018), where access to nature is often very limited due to dense real estate development (Soga & Gaston, 2016). As a result, people spend less and less time in nature. This trend is especially noticeable among university students, who, due to the strategic location of universities in densely populated areas, often find themselves with limited access to natural settings (Brennan & Cochrane, 2019; Down et al., 2021). Research by Hartig and Kahn (2016) as well as Feral (1998) indicates positive effects of exposure to nature on well-being and adverse effects on health caused by a lack of exposure to nature. Consequently, university students are potentially facing detrimental health consequences caused by a lack of exposure to natural environments that will negatively impact their well-being. A potential solution to this problem would be to find a way that allows the students to somehow spend more time in nature environments, even though access is limited.

Browning et al. (2020) aimed to explore whether exposure to awe-inducing nature and its benefit to well-being can be substituted by Virtual reality (VR) technology. Their research, revolving around how VR nature exposure affects mood and well-being among

undergraduate students suggest that this can indeed be the case, as they noticed reduced levels of anxiety caused by VR nature exposure.

In the VR technology domain, there have been substantial advancements, and its area of use has expanded rapidly, also including the research and healthcare sector (Anthes et al., 2016) as well as multiple fields of application in different sectors like education or the gaming industry among others (Gu & Wang, 2022). One of its possible uses is to serve as a form of digital teleportation, allowing individuals to experience accurately simulated nature settings (Bohil et al., 2011). This is essential in the quest to explore the link between experiencing nature virtually and the impact on students' well-being. VR, as defined by Bryson (2013), "is the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence" (p. 4). It requires physical immersion and sensory stimulation in the form of VR goggles/headset that allow the user to access the virtual environment (Souza et al., 2021). The optional use of handheld controllers allows for simulated hand movements like throwing or grabbing objects within the virtual environment. This close resemblance to actual nature environments and the immersive experience of using VR gear, provide a platform for investigation into how virtual nature encounters may affect the well-being of students in comparison to physical nature exposure, which's positive influence on well-being has been previously established (Hartig and Kahn, 2016).

Not only is VR technology capable of providing simulated experiences of exposure to nature (Browning et al., 2023), but also, positive effects of VR nature exposure on well-being, which "can be understood as how people feel and how they function both on a personal and social level, and how they evaluate their lives as a whole" (Michaelson et al., 2012, p.8), have been indicated (Yu et al., 2018). These findings are supported by Li et al. (2021), who confirm the potential role of virtual nature exposure in the promotion of well-

being in urban and certain special populations. These positive effects in the form of increased mood levels have been observed after as little as 6 minutes of VR nature exposure (Browning et al., 2020). In contrast, some researchers like Mostajeran et al. (2021) and Palanica et al. (2019) argue that VR exposure can be less or only equally as beneficial to well-being as exposure to traditional 2D nature environments like photos or videos for example. Still, research by Browning et al. (2020) indicates that exposure to VR nature has similar effects on aspects contributing to well-being as exposure to real nature environment has, underlining the potential of VR nature exposure on well-being.

Exposure to specifically extraordinary natural environments like mountain sceneries, oceans, or similar nature phenomenons can even induce an emotion which is called “awe” (Zhang & Keltner, 2016). As suggested by Shiota et al. (2007), awe is “an emotional response to perceptually vast stimuli that overwhelm current mental structures yet facilitate attempts as accommodation” (p.944). Awe can be induced by numerous of these vast stimuli like certain types of auditory experiences for example (Pilgrim et al., 2017) but is particularly common as a result of exposure to unusual or remarkable natural environments (Quesnel & Riecke, 2018). Due to the difficulty of accurately describing the sensation of experiencing awe, it is hard to universally define this emotion. Still, the definition by Shiota et al. (2007) is in accordance with research conducted by Keltner and Haidt (2003), who analyzed awe more in-depth and claim that it comprises two components: vastness and accommodation. Vastness describes experiences perceived as larger than oneself, extending beyond one's usual frames of reference. It can manifest in physical, social, or symbolic dimensions, triggering a sense of presence in the face of something immense. The accommodation reflects the process of adjusting mental structures to comprehend vast experiences (Keltner & Haidt, 2003). Although relatively little research has been conducted on the topic of awe (Darbor et al., 2015), studies conducted by Quesnel and Riecke (2018) link the experience of the emotion of

awe to positive effects on well-being. These findings are also confirmed by Büssing (2021), suggesting that experiencing awe can lead to higher levels of well-being and life satisfaction.

Considering these findings and recognizing the intricacies of awe, exploring what kind of influence exposure to awe-inducing VR nature environments may have on the well-being of university students in the context of this research is close at hand. Firstly, because self-transcendent experiences of awe could become increasingly accessible to people with the aid of VR (Quesnel & Riecke, 2018). Second, the aforementioned capabilities of VR technology to accurately simulate exposure to real nature environments, allow for the possibility to create fictive nature sceneries as well as to mimic existing landmarks. This makes interactive VR an effective tool when it comes to evoking awe (Quesnel & Riecke, 2018) and therefore interesting to explore in the context of improving student well-being.

The term well-being is used to describe a broad construct that involves an individual's overall health and sanity (Galderisi et al., 2015). This definition makes evident how the term well-being encompasses many facets of human health. A distinction between these different facets is made by dividing them into different subcategories dealing with the different areas of health. An example relevant to this study is subjective well-being (Jarden & Roache, 2023). As soon as an individual gives information about their own well-being, it is a matter of subjective well-being, hence why focusing on their subjective well-being in the context of this research is reasonable. Subjective well-being, as defined by Kim-Prieto et al. (2005), involves components like happiness, life satisfaction, and stress among others, and focuses on how people assess their lives. One of the factors that is suggested to have an impact on well-being, apart from the previously discussed emotion of awe, is said to be the so-called “nature connectedness” (Mayer & Frantz, 2004).

The concept of nature connectedness describes the relationship an individual has with their natural surroundings (Martin et al., 2020). This is not limited to the amount of time

spent in nature and feelings about certain aspects like nature's aesthetics and the condition of certain objects in nature, as Braun and Dierkes (2016) consider it to be a stable character trait with varying intensity among all humans. Schultz (2002) defines it as “the extent to which an individual includes nature within their cognitive representation of self” (p.67). Schultz (2002) also suggests that the concept of nature connectedness comprises 3 components. The cognitive component, dealing with the individual's sense of integration with nature, while the affective component is reflected in a heightened sensitivity towards the protection of the natural environment. The behavioral component encompasses active personal involvement in activities related to nature conservation (Schultz, 2002). Nature connectedness is said to be positively correlated with well-being as studies found that individuals with a strong sense of nature connectedness had higher levels of well-being (Mayer & Frantz, 2004). Although the positive impact of nature connectedness on well-being seems to be generally agreed upon, it does not exclusively benefit well-being. According to Nisbet et al. (2010), nature connectedness can also account for negative emotions which are mostly based on a person's knowledge of environmental problems. Some people who have a strong connection to nature may experience negative effects in certain situations when they are concerned about what they perceive to be a declining environment. Understanding and considering the potential of awe to elicit both positive and negative emotions is important as it may help when tailoring interventions aimed at well-being improvement.

Studies conducted by Liu et al. (2023) yielded results that suggest a connection between awe, well-being, and nature connectedness. They indicate that experiencing awe improves well-being mainly through increasing nature connectedness. Liu et al. (2023) consequently state that nature connectedness can be seen as an important factor when it comes to the process of awe enhancing an individual's well-being. Considering these findings were yielded based on real-world nature experience, the extent to which they are transferable to a virtual

nature setting is important to explore. If exposure to awe-inducing VR nature indeed has similarly positive effects on nature connectedness and its interplay with well-being, this would greatly emphasize the potential of VR as a therapeutic tool.

The interplay between VR nature and well-being with a focus on the emotion of awe and a possible moderating effect of nature connectedness within this context remains mostly unexplored as of now. Motivated by this gap in research, this study aims to investigate the possible application of awe-inducing VR nature environments, exploring their effect on the subjective well-being levels of university students and the role of nature connectedness as a moderating variable in this process.

The research question that was set forth according to this is as follows: To what extent does nature connectedness have an effect on subjective well-being as experiencing awe-inducing VR nature?

According to the research question this thesis aims to answer, the hypotheses are as follows:

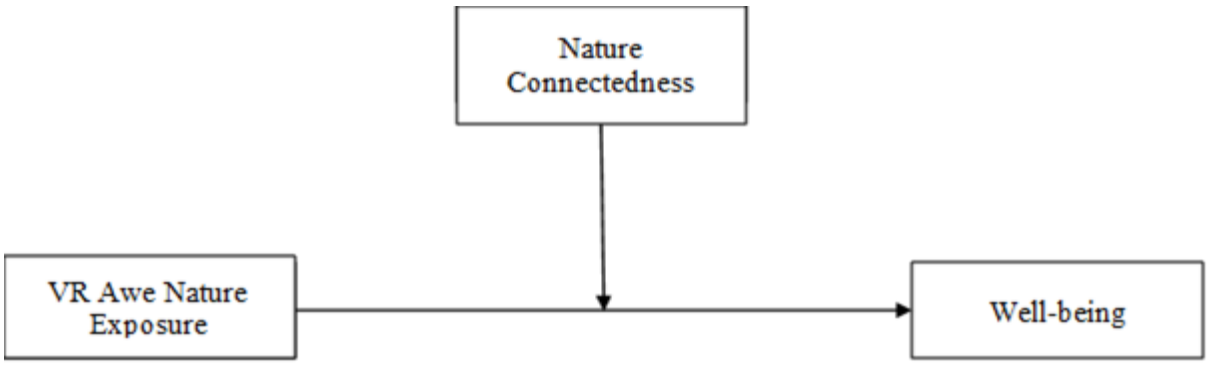
1. Exposure to the awe-inducing VR Nature environment will induce significantly more awe than the control VR Nature environment.

2. Exposure to awe-inducing VR nature has a significant positive effect on subjective well-being.

3. Nature connectedness will have a significant moderating effect on the relationship between exposure to awe-inducing VR nature and student subjective well-being (see Figure 1).

Figure 1

Moderation effect of nature connectedness on the relationship between awe-inducing VR nature and well-being



Methods

Study design

This research utilized a within-subject design to examine the relationship between exposure to awe-inducing VR nature and subjective well-being, with nature connectedness as a moderating variable. Each participant was exposed to both the control VR nature environment as well as the awe-inducing VR nature environment so that effects could be directly compared within the same individual

Participants

To find participants, a combination of convenience sampling and voluntary sampling methods was considered the most reasonable data collection method. More concretely, the researchers published and advertised participation links to the study in several university WhatsApp groups, directly asked students on the university campus to participate, and also contacted their friends and university acquaintances. Additionally, a link to the survey was

uploaded to the University of Twente's BMS faculty Sona-System test subject pool, where students were able to earn 1 Sona credit point for participating in the study. The study was conducted at the University of Twente and received approval from the BMS Ethics Committee.

As the survey was written in English, participants were required to fluently speak the English language to fully understand the questions and be able to participate. Also, participants were required to be enrolled students at the University of Twente. To guarantee the participant's safety in terms of health, two other exclusion criteria were determined. As the use of VR equipment is known to elicit motion sickness in some of its users (Chattha et al., 2020), participants with a history of motion sickness were excluded from the study. Finally, participants with a history of epilepsy were excluded from the study due to epileptic seizures potentially being triggered by flickering lights in the virtual environment (Tychsen & Thio, 2020).

The sample ranged in age from 18 to 25. Of the total 40 participants in the final sample all having signed the informed consent, 57.5 % (*n*= 23) were male, and 42.5 % were female (*n*= 17). Furthermore, 52.5 % (*n*= 21) were German, 20 % (*n*= 8) of the respondents were Dutch, and 27.5 % (*n*=11) were of other nationalities. During the study, all participants were allowed to withdraw their consent without having to provide a reason for this.

Materials

Demographics Questionnaire

The demographic questionnaire used comprised out of three questions revolving around age, gender, and nationality. Regarding age, participants were required to indicate which age group they belonged to. Answer possibilities ranged from 17 and younger to 55 and older with an additional option that said, "prefer not to say". Overall, there were seven possible options to choose from. Regarding gender, participants were required to choose their gender

out of four answer possibilities, being either male, female, other, or prefer not to say. Lastly, participants had to indicate their nationality. Here, there were five possible answers to choose from, being German, Dutch, other European country, other country outside of Europe, and prefer not to say.

Nature Relatedness Scale Short Form (NR-6)

The *NR-6* serves as the very first component of the questionnaire and is designed by Nisbet and Zelenski (2013) to assess the degree of a participant's connectedness to nature. It consists of 6 items and serves as a short form of the 21-item long "nature relatedness scale". Four of the items, for example: "*I always think about how my actions affect the environment",* measure feelings of unity with nature, awareness or subjective knowledge of the surroundings, a sense of closeness that may be expressed in spirituality, and self-identification with nature. Two further items assess the variations among individuals in their need for nature, how comfortable they are in the wilderness, and their awareness of local wildlife (Nisbet & Zelenski, 2013) an exemplary item would be: "*I take notice of wildlife wherever I am"*. The items are rated on a 5-point Likert scale ranging from "disagree strongly" to "agree strongly". The short form was chosen over the original scale due to research conducted by Nisbet and Zelenski (2013) suggesting a similar performance to the full scale, while retaining good psychometric properties, demonstrating good reliability and validity.

Awe Scale (AWE-S)

The AWE Scale (*AWE-S*), created by Yaden et al. (2018), was the second main survey component for this study. Its purpose was to assess each participant's perceived emotion of awe. The AWE-S comprises 30 items revolving around 6 different factors including altered time perception, measured by items like "*I sensed things momentarily slow down*"; self-diminishment, measured by items like "*I felt that my sense of self was diminished*";

connectedness, measured by items like "*I experienced a sense of oneness with all things*"; perceived vastness, measured by items like "*I perceived vastness*"; physical sensations, measured by items like "*I felt my eyes widen*"; need for accommodation, measured by items like "*I felt challenged to understand the experience*" (Yaden et al., 2018). The 30 items are evenly distributed, with 5 items per factor. Each item is rated on a 7-point Likert scale ranging from "strongly disagree" to "strongly agree". Considering psychometric properties, Yaden et al. (2018) deem the *AWE-S* a reliable and valid measure for the emotion of awe, with each factor demonstrating strong internal reliability with altered time perception α = .91; self-diminishment α = .89; connectedness α = .87; vastness α = .85; physical sensations α = .81; need for accommodation α = .80. The scale total also showed strong reliability (α = .93). According to Yaden et al. (2018), *AWE-S* also demonstrated adequate convergent, divergent, and construct validity.

World Health Organization (WHO)-5 Wellbeing Index

The *WHO-5 Well-being Index* is a short self-report index that was produced by the WHO to assess subjective well-being (Topp et al., 2015). It comprises five items and is employed to screen for general psychological wellness. The scale differentiates between several dimensions of well-being, being positive mood, vitality, rest, relaxation, or overall satisfaction with life, measured by items like for example: "*My daily life has been filled with things that interest me*". Participants are asked to rate how well each of the 5 statements applies to them when considering the last 14 days. Each item is scored on a 6-point Likert scale ranging from "all of the time" and "at no time". The 5-item WHO index is considered to have good psychometric properties with good internal consistency, test-retest reliability, and adequate convergent validity (Topp et al., 2015).

Hardware

The VR gear used for the study was a VR headset called Oculus Rift 2 from the brand Meta. The equipment was borrowed from the BMS Lab located on the University of Twente campus. The room in which the study was conducted was a private room free from any external distractions and came equipped with a stationary computer as well as a chair with casters and the ability to spin 360 degrees to ensure enhanced immersiveness when using the VR gear as well as participants' comfort.

Software

Two 360-degree nature videos were chosen based on their resolution (8k hd) and based on what kind of nature they were showing. The first video showed a recreational park in South Korea (see Figure 2) and had a duration of five minutes. The second one showed a hike in the Swiss Alps (see Figure 3) and had a duration of over 12 minutes. As participants were only needed to watch five minutes per video, the second video was started exactly at the two-minute mark and participants were told to take off the headset after exactly five minutes of watching time. Both videos were watched on the YouTube VR application that was pre-installed on the VR equipment.

Figure 2

Control VR nature environment

Figure 3

Awe-inducing VR nature environment

The questionnaire was created with the software Qualtrics.com. This tool was not only used to create the survey but also to have participants administer it on the website and gather their data. The software automatically records each participant's responses and allows to save the complete dataset in order to further analyze it.

Procedure

Before the participants physically showed up at the lab to participate in the study, they decided on an open time slot on the SONA website, so both parties, participants as well as the researchers knew when an appointment was made. This way, the researchers could prepare the laboratory and the equipment in advance to ensure a smooth process and short waiting times for the participants. Upon arrival of the participants, they were greeted friendly and briefly introduced to the experiment and equipment. Afterward, they were asked to take a seat in front of the computer, where the survey had already been opened in advance by the researchers and told to start with the survey. As soon as the participants accessed the survey, they were immediately presented with the opening statement. This statement comprised an explanation of the study's purpose, the risks of participating, procedures of withdrawal as well as information on how the participant's data will be processed. Following this, the participants were asked to provide their informed consent followed by indicating their age, nationality, and gender, before being able to start the actual questionnaire. After completing this, participants started answering the first out of three blocks making up the questionnaire. The first block entailed the NR-6 Scale measuring nature connectedness and the spirituality scale measuring the participant's degree of spirituality. After having finished this first block, participants were shown a screen asking them to contact their student researcher. As they did, they were handed the VR equipment along with a short explanation of what they needed to do with it. A 5-minute 360-degree YouTube video of a recreational Korean park (see Figure 2) was already opened on the VR equipment and participants were instructed to start it and

watch the video while looking around. After 5 minutes, they were told to take off the VR equipment and start working on the second block of the questionnaire. This consisted of the AWE-S questionnaire, measuring the intensity of awe experienced by the participants as well as the WHO-5, measuring the participant's well-being. Following this, participants were handed the VR gear once again and were instructed to watch a 360-degree YouTube video of a hike across a mountain path in the Swiss Alps (see Figure 3) for 5 minutes. In Between uses, the headset was wiped down with wet wipes. Lastly, after being told to stop watching the video and hand back the VR gear, participants were asked to fill out the third and final block of the questionnaire. Here, they were once again presented with the exact same combination of AWE-S and WHO-5 questionnaires that they worked on in the second block.

The whole experiment including watching the VR nature videos and answering the survey required around 30 minutes to complete. The respondents were shortly debriefed, assured that their answers would be kept confidential, and given the final opportunity to withdraw consent.

Data Analysis

Data analysis for this study was performed using R Studio. Several packages were utilized to execute different analyses, such as readr, psych, janitor, tidyverse, dplyr, mirt, modelr, broom, foreign, and lme4.

Descriptive statistics were computed to describe the characteristics of the sample and their scores for the measured variables. To provide a comprehensive overview of the data, measures such as mean and standard deviation were computed. Before the main effect of VR nature environments on subjective well-being was investigated with a linear mixed model, the assumptions of normality, homoscedasticity, linearity, and independence were checked. Subjective well-being was set as the dependent variable whereas virtual reality nature exposure became the independent variable controlling for potential confounding factors.

Additionally, a moderation analysis was performed to assess whether the relationship between exposure to awe-inducing VR nature environments and subjective well-being was moderated by nature connectedness. An interaction effect between exposure to awe and nature connectedness was computed and its significance was assessed.

Results

Descriptive Statistics

The scores for pre-intervention sense of awe had a minimum of 44, a maximum of 156 and a mean of 99.08 (*SD*= 29.66), while the mean of post-intervention awe scores was 120.65 (*SD*= 33.35), a maximum of 187 and a minimum of 59. The maximum obtainable score for the AWE-S was 210. The mean scores for nature connectedness reflect that the level of connectedness to nature was fairly moderate among the participants with a mean of 3.43 (*SD*= 0.71) (Nisbet & Zelenski, 2013), while the maximum was 5 and the minimum 2. The maximum obtainable score for the NR-6 was 5. The pre-intervention well-being scores had a mean of 15.62 (*SD*= 4.65), with a minimum of 7 and a maximum of 25 while the mean of post-intervention well-being scores was 14.85 (*SD*= 4.99), with a minimum of 6 and a maximum of 25. The maximum obtainable score for the WHO-5 well-being scale was 30.

Diagnostic Evaluation of the Regression Model

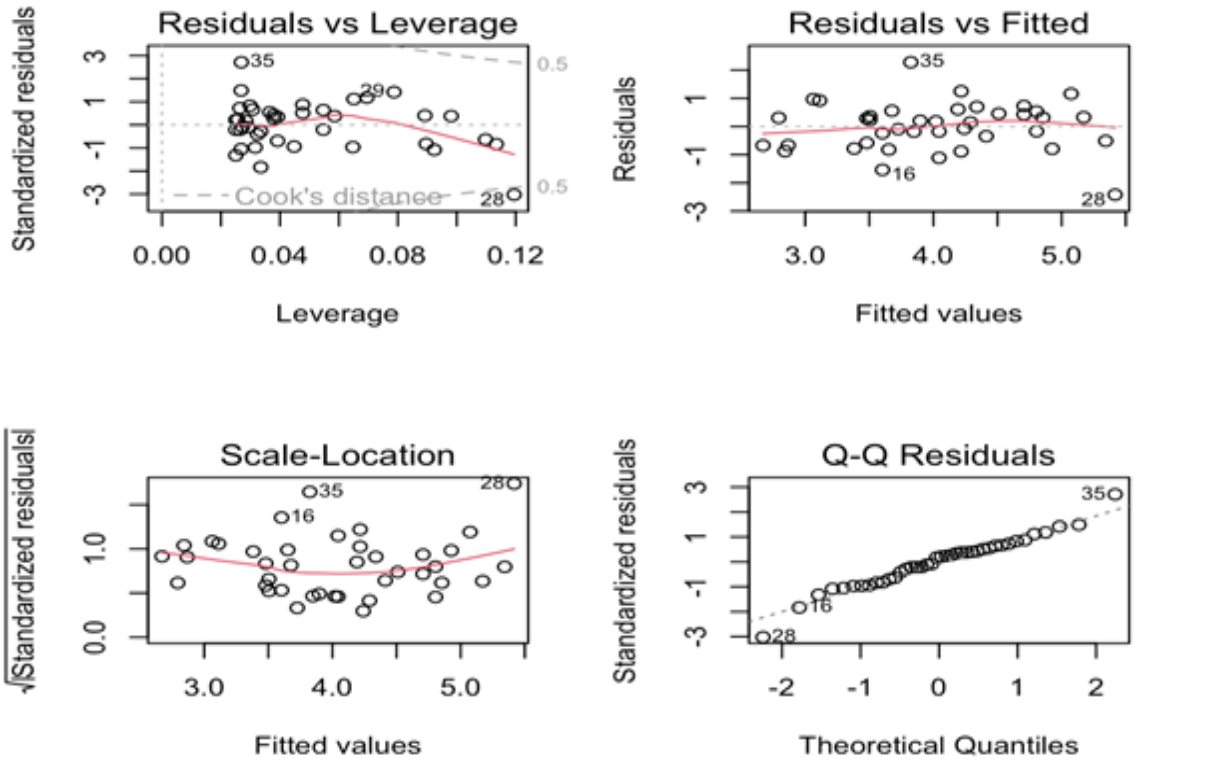
Numerous diagnostic tests were carried out with respect to this regression model. These have also been visualized in the form of plots (see Figure 4). For the assumption of linearity, there was no pattern observed, hence the fitted values versus the residuals showed a linear relationship. Regarding the assumption of homoscedasticity, the scale-location plot showed a homogenizing variance of the residuals. Thirdly, the assumption of normality was checked. The normal Q-Q plot of the residuals pointed out that the residuals fall in a straight line, showing normal distribution. Lastly, checking for the assumption of independence, the plots

of the residuals versus leverage combined with the Cook's distance showed no influential outliers.

The normality of the distribution of key variables was further tested using the Shapiro-Wilk test. The results indicated that the distribution of awe scores before the intervention was normal (W= 0.98, p= .61), as was the distribution of well-being scores after the intervention (W= 0.97, p= .33). Since the assumptions of normality were met, parametric tests were deemed appropriate for subsequent statistical analysis.

Figure 4

Plots of diagnostic tests



Hypothesis 1: Awe-inducing VR nature versus control VR nature

A paired t-test indicated a significant increase from pre- to post-intervention in scores on the Awe Scale ($t(39) = 5.165$, $p < .001$, 95% *CI* [0.438, 1.001]). These results are evidence that the awe-inducing VR nature environment significantly enhanced participants' levels of experienced awe compared to the control VR nature environment.

Hypothesis 2: Awe-inducing VR nature effect on subjective well-being

A linear regression model was used to examine whether changes in awe scores predicted changes in well-being scores. The overall model was not significant *(B = -0.05256*, $p = .486$), indicating that the increase in awe did not significantly predict changes in well-being. An ANOVA was also conducted, and the results indicated that neither the pre-intervention awe scores, post-intervention awe scores, nor their interaction were significant predictors of changes in well-being. These results suggest that the increase in awe did not significantly impact well-being (see Table 1)

Table 1

ANOVA Results for the Impact of Awe on Well-Being

Variables	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
Pre-intervention awe	1	0.0	0.015	0.001	0.980
Post-intervention awe	1	3.1	3.146	0.135	0.715
Interaction term	1	1.1	1.134	0.049	0.827
Residuals	36	839.1	23.308		

Hypothesis 3: Nature Connectedness as a moderator

Additional analyses that tested for the moderating effect of connectedness to nature on the relationship between awe induction and changes in well-being showed no significant effect with the interaction term (B = -0.2058, p = .343). The overall model fit was poor with the adjusted r squared being 0.02, $F(3,36)$= 1.25, p= .31**.** A Box-Cox transformation was applied to improve the model fit, however, the model fit remained poor, with an adjusted r squared of 0.05, $F(3,36)$= 1.71, p= .18 and the interaction term remained nonsignificant (B = -0.05, p = .27)

Discussion

The present study explored how an awe-inducing VR nature environment affected the subjective well-being of university students and whether this relationship was moderated by nature connectedness. As the awe scores significantly increased post-intervention, the first hypothesis can be accepted. Following this, the second hypothesis was investigated. This hypothesis stands rejected based on the insignificant results yielded. Lastly, this study investigated whether nature connectedness moderates the relationship between exposure to awe-inducing VR nature exposure and student well-being. As no significant moderation could be established, the hypothesis can be rejected. To answer the research question conclusively, exposure to awe-inducing VR nature environments did increase levels of perceived awe, but neither did this contribute to subjective well-being, nor was this relationship moderated by nature connectedness.

The Effectiveness of VR in Inducing Awe

The results of the study showed a significant increase in the awe scores post-intervention, indicating that VR is indeed an effective tool when it comes to inducing awe. This result is in line with past findings suggesting that VR can be similarly immersive and capable of eliciting certain emotions like for example awe compared to real-world nature

experiences (Miller et al., 2023). The significantly increased awe scores recorded after participants watched the second video suggest that the VR environment that was supposed to induce awe by showing a hike with panoramic mountain views as suggested by Lu et al. (2017) as well as Quesnel & Riecke (2018), indeed triggered some strong emotional reactions regarding the increased levels of awe compared to the control VR nature environment. Even though this study did not establish a relationship between awe and well-being, the fact that this relationship is still indicated by Büssing (2021) as well as Quesnel & Riecke (2018), still endorses VR as a suitable medium for interventions targeting well-being enhancement.

Impact of awe on well-being levels

Contrary to expectations, well-being scores did not significantly change post-VR intervention. A number of explanations might be given for this finding. First, the novelty and intensity of the VR experience may have been overwhelming to some participants, thereby becoming counterproductive to the initially expected increase in well-being (Condon, 2014). The feeling of being overwhelmed is said to be related to feeling stress and an inability to cope (Condon, 2014). If participants actually felt overwhelmed with the intervention, the possible counteraction of increased well-being scores could be explained by this, as the negative effect of experiencing stress on well-being is well documented (Cohen, 2000).

Second, it is possible that the experience of VR was simply too short to be effective in generating a lasting change in well-being. VR research conducted by Lee et al. (2019) for example suggests that a longer duration of VR use is associated with a larger effect size. Williams and Riches (2023) for example conducted a study aimed at increasing well-being through VR relaxation and reported a mean time spent in VR environments of about 27 minutes per session, deeming the intervention successful.

Another interesting approach to potentially explaining this result is rooted within the biophilia hypothesis by Kellert and Wilson (1993). They propose that more natural

environments of higher "quality" would signal a greater diversity of food sources and, due to the presence of multiple support structures, a more robust ecology to therefore better resist shocks, like temperature changes. These environments would have been more conducive to human survival during evolutionary history, which has resulted in an innate preference for ecologically rich settings. Findings by Tarolli and Straffelini (2020) suggest that in mountain areas, massive soil loss occurs by surface erosion or very high-intensity mass movements, both of which evidence hydrogeological instability. Unsustainable agricultural practices as well as harsh climate conditions further contribute to these issues (Tarolli & Straffelini, 2020). The fact that a mountainous scenery like the one shown in this studies VR intervention likely does not qualify as an environment of higher quality according to the biophilia hypothesis, may be able to give an alternative explanation for the absence of significant change in well-being scores post-VR intervention.

Nature Connectedness as a moderator

Thirdly, and contrary to existing research by Liu et al. (2023) who proposed that experiencing awe increases well-being mainly through increasing nature connectedness, no significant moderating effect of nature connectedness was found on the effect presented by awe on well-being. This could be interpreted as meaning that the well-being effects of awe do not depend on a person's self-reported level of nature connectedness. This result would then contribute to the question of whether there is a necessity to have comparatively high levels of nature connectedness for deriving benefits from natural environments. A potential explanation for this result might also be that the immersiveness of the VR experience was perceived as such a good experience in its own right that awe was common, regardless of participants' reported levels of nature connectedness. Alternatively, the nonsignificance of moderation by the level of nature connectedness would argue for other moderating variables

being in a more powerful position in determining response to VR nature environments, for example, attitudes or identification with technology in general (Starr et al., 2019).

Theoretical implications

Theoretical implications, therefore, are to further investigate the hypothesis that experiencing awe would automatically increase well-being and not accept it as academic consensus without further ado. Now, it is a very important theoretical implication since it shows it might not be as direct to think that awe and well-being are both related to each other as proposed by the findings of Monroy and Keltner (2022) or Quesnel and Riecke (2018). These results thus prove to be an interesting addition to the existing body of literature by providing just this novel point of view seemingly challenging the consensus in this matter. The results yielded during this study subsequently highlight the need for a more in-depth understanding of how exactly the emotion of awe affects well-being. Potential mediating mechanisms might be, among others: the duration of the awe experience as suggested by Lee et al. (2019), physical environment, and the type of setup/gear used as suggested by Van Der Veer et al. (2018), who proposed that different types of VR gear lead to a difference in self-perception and awareness in the virtual world and therefore may alter the degree of perceived immersiveness, and individual differences in emotional regulation (Miller et al., 2023). Miller et. al. (2023) strongly emphasized the difficulty of creating a generalized approach or VR design guaranteeing the elicitation of awe in participants due to their individual differences and the overall difficulty to even universally define transcendent emotions like awe. Gaining insight into these mechanisms will likely help to further clarify effective ways to utilize awe in improving well-being.

Practical Implications

Despite the unexpected results in well-being, this study, in agreement with Li et al. (2021) does point to the potential of VR as a therapeutic tool in situations where the real nature is either unattainable or impossible to access. As indicated by significantly increased levels of awe post-intervention, VR technology is indeed capable of being applied in ways that can induce a feeling of awe in humans and, therefore, have critical applications in both therapeutic and educational programs, especially for those with limited accessibility to natural setting according to Li et al. (2021) and Yu et al. (2018) who found a connection between high levels of perceived awe and increased levels of well-being. If contrary to this study's findings, this connection can be further established by future research, the use of VR nature environments for therapeutic purposes could be even more diversified. This may involve but not be limited to the use of restorative experiences that may positively enhance well-being in hospitals, care facilities, and urban areas. Another institution that could potentially benefit from the employment of VR are universities. To help with student well-being, VR gear could be made accessible for students to use in recreational contexts in order to help improve their well-being and associated with this, maybe even academic performance (Egan et al., 2021). These practical uses shine a light on the potential that such technology has for positive psychological and emotional functions.

Strengths and Limitations

The study showed multiple strengths. One of the study's strengths were the established and well-tested questionnaires used. With the NR-6, WHO-5 as well as the AWE-S, well-validated instruments have been used in order to ensure the robustness of the collected data (Nisbet and Zelenski, 2013; Topp et al., 2015; Yaden et al., 2018).

Also, the overall experimental paradigm of the study was suitable for investigating the effect of awe-inducing VR nature on student well-being. The environment in which the study

was conducted was controlled and private, ensuring equal experiences for all participants. Also, the experiment was well structured, facilitating replication of the study by other researchers, which is important for further validation of the findings.

Despite these strengths, there are various limitations to consider when interpreting the results yielded during this study. Firstly, there may be a few biases when asking participants about their awe and well-being, such as social desirability or inaccurate self-assessment. According to De Mortel et. al. (2008), self-report questionnaires are extremely vulnerable to social desirability-driven responses. The degree of social desirability bias within the questionnaire could have been monitored by implementing a so-called social desirability scale (De Mortel et al., 2008), which has not been done in this study. These subjective measurements solely depend on the current mood, memory recall, and willingness to disclose the true feelings of the person (Fadnes et al., 2009). In the case of this study, each participant conducted the experiment and administered the questionnaire in the presence of a researcher, maybe even increasing their need to give socially desirable answers.

Further, even if the visual qualities were 8k resolution in both VR videos, still some participants mentioned that the quality was poor comparatively. It may be, therefore, that some users felt that the quality of the visuals was lacking, and this subsequently influenced their experience, perceived degree of immersiveness, and hence the effectiveness of the intervention. This supposition is supported by the research of Anwar et al. (2020) who claim that the user's experience when watching 360-degree videos is strongly influenced by sudden changes in bit rate. Immersion and enjoyment of the VR environments may also have been hampered by potential technical limitations, such as screen resolution or refresh rates (Anwar et al., 2020).

Future Research

Employing a longitudinal design might be a reasonable idea for future research within this branch, at least when evaluated for financial burden and time expenditure (Caruana et al., 2015). This would allow researchers to check whether so far unknown effects of repeatedly exposing a person to VR nature will arise and also give better insights into the actual long-term effectiveness of such an intervention aimed at potentially increasing participants' well-being (Caruana et al., 2015). This research could perhaps provide answers as to whether sustained or repeated exposure generally fosters whatsoever enduring improvement of well-being after exposure to VR nature environments.

Further research into different types of VR environments will establish which ingredients make that particular environment most effective in raising awe and enhancing well-being. For instance, it could compare the effects of being in forests or near oceans and mountains, which, when considered vast or great to some degree, are likely to evoke awe (Zhang & Keltner, 2016), and the impacts of different sensory modalities, like visual or auditory elements, as according to Pilgrim et al. (2017), awe is also frequently evoked by listening to certain types of music. It might therefore also be interesting to draw comparisons between different music genres to gain a deeper understanding of how exactly the emotion of awe is elicited when it comes to auditory experiences. This of course would be equally applicable to a comparison of the previously mentioned awe-evoking environments in order to see whether there are nature environments that evoke significantly more or less awe than a mountain scenery similar to the one used in this study. Indeed, also other potential moderators like possible individual differences in openness to experience (Silvia et al., 2015), previous exposure to nature (Chung et al., 2018), or even the degree to which an individual is concerned with the state and condition of nature (Kellert and Wilson, 1993) could help

further understand the conditions under which VR-induced awe affects well-being. Such knowledge could help further increase the effectiveness of VR interventions.

Conclusion

The current study aimed to examine the effects of exposure to an awe-inducing VR nature environment on subjective well-being in university students and the moderating role of nature connectedness. The significant increase in awe scores supports VR as effective in eliciting awe, while the unexpected yet insignificant changes in well-being question assumptions of beneficial effects of such experiences, signifying that the insignificant moderating effect of nature connectedness indicates that the influence of awe on well-being can be more complex and related to other factors beyond nature connectedness. Indeed, there is much need for future research to unravel such complexity in realizing the potential of VR technology for improving the well-being of university students.

References

Anthes, C., Hernández, R. J. G., Wiedemann, M., & Kranzlmüller, D. (2016). State of the art of virtual reality technology. *2016 IEEE Aerospace Conference*. https://doi.org/10.1109/aero.2016.7500674

Anwar, M. S., Wang, J., Ullah, A., Khan, W., Ahmad, S., & Fei, Z. (2020). Measuring quality of experience for 360-degree videos in virtual reality. *Science China. Information Sciences/Science China. Information Sciences*, *63*(10). https://doi.org/10.1007/s11432-019-2734-y

Bohil, C. J., Alicea, B., & Biocca, F. (2011). Virtual reality in neuroscience research and therapy. *Nature Reviews Neuroscience*, *12*(12), 752–762. https://doi.org/10.1038/nrn3122

Braun, T., & Dierkes, P. W. (2016). Connecting students to nature – how intensity of nature experience and student age influence the success of outdoor education programs. *Environmental Education Research*, *23*(7), 937–949. https://doi.org/10.1080/13504622.2016.1214866

Brennan, J., & Cochrane, A. (2019). Universities: in, of, and beyond their cities. *Oxford Review of Education*, *45*(2), 188–203. https://doi.org/10.1080/03054985.2018.1551198

Browning, M. H., Shin, S., Drong, G., McAnirlin, O., Gagnon, R. J., Ranganathan, S., Sindelar, K., Hoptman, D., Bratman, G. N., Yuan, S., Prabhu, V. G., & Heller, W. (2023). Daily exposure to virtual nature reduces symptoms of anxiety in college students. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-28070-9

Browning, M. H., Mimnaugh, K. J., Van Riper, C. J., Laurent, H. K., & LaValle, S. M. (2020). Can simulated nature support mental health? comparing short, Single-Doses of 360-Degree nature videos in virtual reality with the outdoors. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02667

Bryson, S. T. (2013). Virtual Reality: A Definition History - A personal essay. *arXiv (Cornell University)*. https://doi.org/10.48550/arxiv.1312.4322

Chung, K., Lee, D., & Park, J. Y. (2018). Involuntary attention restoration during exposure to Mobile-Based 360° Virtual nature in healthy adults with different levels of restorative experience: Event-Related Potential study. *JMIR. Journal of Medical Internet Research/Journal of Medical Internet Research*, *20*(11), e11152. https://doi.org/10.2196/11152

Cohen, J. I. (2000). STRESS AND MENTAL HEALTH: a BIOBEHAVIORAL PERSPECTIVE. *Issues in Mental Health Nursing*, *21*(2), 185–202. https://doi.org/10.1080/016128400248185

Condon, B. B. (2014). The living experience of feeling overwhelmed. *Nursing Science Quarterly*, *27*(3), 216–225. https://doi.org/10.1177/0894318414534487

Cox, D. T. C., Shanahan, D. F., Hudson, H. L., Fuller, R. A., & Gaston, K. J. (2018). The impact of urbanisation on nature dose and the implications for human health. *Landscape and Urban Planning*, *179*, 72–80. https://doi.org/10.1016/j.landurbplan.2018.07.013

Chattha, U. A., Janjua, U. I., Anwar, F., Madni, T. M., Cheema, M. F., & Janjua, S. I. (2020). Motion sickness in virtual reality: an Empirical evaluation. *IEEE Access*, *8*, 130486–130499. https://doi.org/10.1109/access.2020.3007076

Darbor, K. E., Lench, H. C., Davis, W. E., & Hicks, J. A. (2015). Experiencing versus contemplating: Language use during descriptions of awe and wonder. *Cognition & Emotion*, *30*(6), 1188–1196. https://doi.org/10.1080/02699931.2015.1042836

De Mortel, V., & F, T. (2008). Faking it: Social desirability response bias in self-report research. *The Australian Journal of Advanced Nursing*, *25*(4), 40–48. http://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1001&context=hahs_pubs

Diener, E. (1984). Subjective well-being. *Psychological bulletin*, *95*(3), 542.

Down, M., Chivers, P., Kirsch, P., & Picknoll, D. (2021). Wellbeing and nature connectedness for emerging adult undergraduates after a short expedition: A small pilot study. *Health Promotion Journal of Australia*, *33*(3), 912–919. https://doi.org/10.1002/hpja.555

Egan, H., O'Hara, M., Cook, A., & Mantzios, M. (2021). Mindfulness, self-compassion, resiliency and wellbeing in higher education: a recipe to increase academic performance. *Journal of Further and Higher Education*, *46*(3), 301–311. https://doi.org/10.1080/0309877x.2021.1912306

Fadnes, L. T., Taube, A., & Tylleskär, T. (2009). How to identify information bias due to self-reporting in epidemiological research. *The Internet Journal of Epidemiology*, *7*(2), 28-38.

Feral, C. (1998). The connectedness model and optimal development: Is ecopsychology the answer to emotional well-being? *The Humanistic Psychologist*, *26*(1–3), 243–274. https://doi.org/10.1080/08873267.1998.9976975

Galderisi, S., Heinz, A., Kastrup, M., Beezhold, J., & Sartorius, N. (2015). Toward a new definition of mental health. *World Psychiatry/World Psychiatry*, *14*(2), 231–233. https://doi.org/10.1002/wps.20231

Gu, Y., & Wang, Q. (2022). Application of virtual reality in different fields. *2022 IEEE 2nd International Conference on Data Science and Computer Application (ICDSCA)*. https://doi.org/10.1109/icdsca56264.2022.9988426

Hartig, T., & Kahn, P. H. (2016). Living in cities, naturally. *Science*, *352*(6288), 938–940. https://doi.org/10.1126/science.aaf3759

Jarden, A., & Roache, A. (2023). What is wellbeing? *International Journal of Environmental Research and Public Health*, *20*(6), 5006. https://doi.org/10.3390/ijerph20065006

Kellert, S. R., & Wilson, E. O. (1993). *The biophilia hypothesis*. https://ci.nii.ac.jp/ncid/BA22551329

Keltner, D., & Haidt, J. (2003). Approaching awe, a moral, spiritual, and aesthetic emotion. *Cognition & Emotion*, *17*(2), 297–314. https://doi.org/10.1080/02699930302297

Lee, H. S., Park, Y. J., & Park, S. W. (2019). The Effects of Virtual Reality Training on Function in Chronic Stroke Patients: A Systematic Review and Meta-Analysis. *BioMed Research International*, *2019*, 1–12. https://doi.org/10.1155/2019/7595639

Li, H., Zhang, X., Wang, H., Yang, Z., Liu, H., Cao, Y., & Zhang, G. (2021). Access to nature via Virtual Reality: A Mini-Review. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.725288

Lu, D., Liu, Y., Lai, I., & Yang, L. (2017). AWE: an important emotional experience in sustainable tourism. *Sustainability*, *9*(12), 2189. https://doi.org/10.3390/su9122189

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J. (2020). Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *Journal of Environmental Psychology*, *68*, 101389. https://doi.org/10.1016/j.jenvp.2020.101389

Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*, *24*(4), 503–515. https://doi.org/10.1016/j.jenvp.2004.10.001

Michaelson, J., Mahony, S., & Schifferes, J. (2012). Measuring wellbeing: A guide for practitioners. *New Economics Foundation, London*.

Miller, N., Stepanova, E. R., Desnoyers-Stewart, J., Adhikari, A., Kitson, A., Pennefather, P., Quesnel, D., Brauns, K., Friedl-Werner, A., Stahn, A., & Riecke, B. E. (2023). Awedyssey: Design Tensions in Eliciting Self-transcendent Emotions in Virtual Reality

to Support Mental Well-being and Connection. *DIS '23: Proceedings of the 2023 ACM Designing Interactive Systems Conference*. https://doi.org/10.1145/3563657.3595998

Monroy, M., & Keltner, D. (2022). Awe as a pathway to mental and physical health. *Perspectives on Psychological Science*, *18*(2), 309–320. https://doi.org/10.1177/17456916221094856

Mostajeran, F., Krzikawski, J., Steinicke, F., & Kühn, S. (2021). Effects of exposure to immersive videos and photo slideshows of forest and urban environments. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-83277-y

Nisbet, E. K., & Zelenski, J. M. (2013). The NR-6: a new brief measure of nature relatedness. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00813

Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2010). Happiness is in our Nature: Exploring Nature Relatedness as a Contributor to Subjective Well-Being. *Journal of Happiness Studies*, *12*(2), 303–322. https://doi.org/10.1007/s10902-010-9197-7

Palanica, A., Lyons, A., Cooper, M., Lee, A., & Fossat, Y. (2019). A comparison of nature and urban environments on creative thinking across different levels of reality. *Journal of Environmental Psychology*, *63*, 44–51. https://doi.org/10.1016/j.jenvp.2019.04.006

Pilgrim, L., Norris, J. I., & Hackathorn, J. (2017). Music is awesome: Influences of emotion, personality, and preference on experienced awe. *Journal of Consumer Behaviour*, *16*(5), 442–451. https://doi.org/10.1002/cb.1645

Quesnel, D., & Riecke, B. E. (2018). Are you awed yet? How virtual reality gives us awe and goose bumps. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.02158

Reddon, J. R., & Durante, S. B. (2018). Nature exposure sufficiency and insufficiency: The benefits of environmental preservation. *Medical Hypotheses*, *110*, 38–41. https://doi.org/10.1016/j.mehy.2017.10.027

Schultz, P. W. (2002). Inclusion with Nature: The Psychology Of Human-Nature Relations. In *Springer eBooks* (pp. 61–78). https://doi.org/10.1007/978-1-4615-0995-0_4

Shiota, M. N., Keltner, D., & Mossman, A. (2007). The nature of awe: Elicitors, appraisals, and effects on self-concept. *Cognition & Emotion*, *21*(5), 944–963. https://doi.org/10.1080/02699930600923668

Silvia, P. J., Fayn, K., Nusbaum, E. C., & Beaty, R. E. (2015). Openness to experience and awe in response to nature and music: Personality and profound aesthetic experiences. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(4), 376–384. https://doi.org/10.1037/aca0000028

Soga, M., & Gaston, K. J. (2016). Extinction of experience: the loss of human–nature interactions. *Frontiers in Ecology and the Environment*, *14*(2), 94–101. https://doi.org/10.1002/fee.1225

Souza, V. C., Maciel, A., Nedel, L., & Kopper, R. (2021). Measuring Presence in Virtual Environments: a survey. *ACM Computing Surveys*, *54*(8), 1–37. https://doi.org/10.1145/3466817

Starr, C. R., Anderson, B. R., & Green, K. A. (2019). "I'm a computer scientist!": Virtual reality experience influences stereotype threat and STEM motivation among undergraduate women. *Journal of Science Education and Technology*, *28*(5), 493–507. https://doi.org/10.1007/s10956-019-09781-z

Tarolli, P., & Straffelini, E. (2020). Agriculture in hilly and mountainous landscapes: Threats, monitoring and sustainable management. *Geography and Sustainability*, *1*(1), 70–76. https://doi.org/10.1016/j.geosus.2020.03.003

Topp, C. W., Østergaard, S. D., Søndergaard, S., & Bech, P. (2015). The WHO-5 Well-Being Index: A Systematic Review of the literature. *Psychotherapy and Psychosomatics*, *84*(3), 167–176. https://doi.org/10.1159/000376585

Tychsen, L., & Thio, L. L. (2020). Concern of Photosensitive Seizures Evoked by 3D Video Displays or Virtual Reality Headsets in Children: Current Perspective *Eye And Brain*, *Volume 12*, 45–48. https://doi.org/10.2147/eb.s233195

Van Der Veer, A. H., Alsmith, A. J. T., Longo, M. R., Wong, H. Y., & Mohler, B. J. (2018). Where am I in virtual reality? *PloS One*, *13*(10), e0204358. https://doi.org/10.1371/journal.pone.0204358

Williams, G., & Riches, S. (2023). Virtual reality relaxation for staff Wellbeing on a Psychiatric Rehabilitation ward: A Feasibility and Acceptability study. *Journal of Psychiatric Intensive Care*, *19*(1), 51–58. https://doi.org/10.20299/jpi.2023.006

Yaden, D. B., Kaufman, S. B., Hyde, E., Chirico, A., Gaggioli, A., Zhang, J. W., & Keltner, D. (2018). The development of the Awe Experience Scale (AWE-S): A multifactorial measure for a complex emotion. *the Journal of Positive Psychology*, *14*(4), 474–488. https://doi.org/10.1080/17439760.2018.1484940

Yu, C., Lee, H., & Luo, X. (2018). The effect of virtual reality forest and urban environments on physiological and psychological responses. *Urban Forestry & Urban Greening*, *35*, 106–114. https://doi.org/10.1016/j.ufug.2018.08.013

Zhang, J., & Keltner, D. (2016). Awe and the Natural Environment. In *Elsevier eBooks* (pp. 131–134). https://doi.org/10.1016/b978-0-12-397045-9.00045-8

Appendix A

AI Statement

During the preparation of this work, I used Deepl.com to translate from German to English and vice versa as well as to find synonyms for certain words to improve readability. I used Chatgpt.com to enhance the overall structure of my thesis as well as to troubleshoot when I had coding issues. Scribbr.com was used to help with my reference list. Grammarly was used to check for grammatical issues. Gofactr.com was used to help create tables according to the APA standard. After using these tools, I thoroughly reviewed and edited the content as needed, taking full responsibility for the final outcome.

Appendix B

Informed Consent

Purpose of the Research:

The purpose of this research study is to investigate the impact of virtual reality (VR) nature exposure on wellbeing among university students. Also factors like spirituality, awe and nature connectedness are being explored within this context. By participating, you will contribute to advancing our understanding of how virtual nature experiences in interplay with the previously mentioned factors may affect individuals' wellbeing.

Risks of Participating:

Participation in this research project may provide you with the opportunity to explore innovative methods of experiencing nature through VR technology. However, it is important to note that there may be minimal risks associated with VR use, such as motion sickness or discomfort. Additionally, please be informed that this research project has been reviewed and approved by the BMS Ethics Committee of the University of Twente.

Procedures for Withdrawal:

You have the right to withdraw from the study at any time without penalty or consequences. If you choose to withdraw, you may do so by contacting the researcher directly using the provided contact details or directly addressing the researchers while the experiment is being conducted.

Processing of Personal Information:

Any personal information collected during this study will be kept confidential and used solely for research purposes. Your data will be anonymized to protect your privacy. You have the

right to request access to, rectification, or erasure of your personal data at any time.

Usage and Safeguarding of Data:

Research data will be used exclusively for research purposes and will be stored securely. Personal information will be safeguarded. Data may be archived and reused for future research endeavours, following ethical guidelines and procedures.

Retention Period for Research Data:

The research data will be retained for a specified period, after which it may be securely disposed of. The criteria for determining the retention period will adhere to ethical standards and legal requirements.

Contact Information: For any questions, concerns, or to request withdrawal from the study, please contact: Audrey Hernandez (a.a.hernandez@student.utwente.nl) or Milan Karam Menkhaus (m.k.menkhaus@student.utwente.nl)

For inquiries or complaints regarding ethical considerations, please contact the BMS Ethics Committee: ethicscommittee-hss@utwente.nl [Contact Information for BMS Ethics Committee/domain Humanities & Social Sciences]

Appendix C

Demographic Questionnaire

Question	Possible Answers
Gender	Female, Male, Other, I prefer not to say
Age	17 and younger, 18-25, 26-35, 36-45, 46-55, 55 and older, I prefer not to say
Nationality	German, Dutch, Other European country, Other country outside Europe, I prefer not to say

Note. Participants were required to select only one option for each of the three demographic questions.

Appendix D

Nature Relatedness Scale Short Form (NR-6)

		disagree strongly	*disagree a little*	*neither agree nor disagree*	*agree a little*	*agree strongly*
1.	*My ideal vacation spot would be a remote, wilderness area*	*1*	*2*	*3*	*4*	*5*
2.	*I always think about how my actions affect the environment*	*1*	*2*	*3*	*4*	*5*
3.	*My connection to nature and the environment is a part of my spirituality*	*1*	*2*	*3*	*4*	*5*
4.	*I take notice of wildlife wherever I am*	*1*	*2*	*3*	*4*	*5*
5.	*My relationship to nature is an important part of who I am*	*1*	*2*	*3*	*4*	*5*
6.	*I feel very connected to all living things and the earth*	*1*	*2*	*3*	*4*	*5*

Appendix E

Awe Scale (AWE-S)

Awe Experience Scale	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
I sensed things momentarily slow down	○	○	○	○	○	○	○
I experienced a reduced sense of self	○	○	○	○	○	○	○
I had chills	○	○	○	○	○	○	○
I experienced a sense of oneness with all things	○	○	○	○	○	○	○
I felt that I was in the presence of something grand	○	○	○	○	○	○	○
I felt that my sense of self was diminished.	○	○	○	○	○	○	○
I noticed time slowing	○	○	○	○	○	○	○
I had the sense of being connected to everything	○	○	○	○	○	○	○
I felt small compared to everything else	○	○	○	○	○	○	○
I perceived vastness	○	○	○	○	○	○	○
I felt challenged to understand the experience	○	○	○	○	○	○	○
I felt my sense of self shrink	○	○	○	○	○	○	○
I felt closely connected to humanity	○	○	○	○	○	○	○
I gasped	○	○	○	○	○	○	○
I felt my sense of self become somehow smaller	○	○	○	○	○	○	○
I had a sense of complete connectedness	○	○	○	○	○	○	○
I struggled to take in all that I was experiencing at once	○	○	○	○	○	○	○
I felt my eyes widen	○	○	○	○	○	○	○
I experienced something greater than myself	○	○	○	○	○	○	○
I found it hard to comprehend the experience in full	○	○	○	○	○	○	○
I perceived something that was much larger than me	○	○	○	○	○	○	○
I felt my sense of time change	○	○	○	○	○	○	○
I felt my jaw drop	○	○	○	○	○	○	○
I felt challenged to mentally process what I was experiencing	○	○	○	○	○	○	○
I had the sense that moment was lasting longer than usual	○	○	○	○	○	○	○
I felt in the presence of greatness	○	○	○	○	○	○	○
I felt a sense of communion with all living things	○	○	○	○	○	○	○
I had goosebumps	○	○	○	○	○	○	○
I experienced the passage of time differently	○	○	○	○	○	○	○
I tried to understand the magnitude of what I was experiencing	○	○	○	○	○	○	○

Appendix F

World Health Organization (WHO)-5 Wellbeing Index

Please respond to each item by marking one box per row, regarding how you felt in the last two weeks.		All of the time	Most of the time	More than half the time	Less than half the time	Some of the time	At no time
WHO 1	I have felt cheerful in good spirits.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0
WHO 2	I have felt calm and relaxed.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0
WHO 3	I have felt active and vigorous.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0
WHO 4	I woke up feeling fresh and rested.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0
WHO 5	My daily life has been filled with things that interest me.	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0

Appendix G

R-Script used for Data Analysis

```
library(broom)
library(psych)
library(dplyr)
library(tidyverse)
library(readr)
Milan_R <- read_csv("BSC.csv")
View(Milan_R)
R <- Milan_R
R <- subset(R , select = -c (1:18))
R <- subset(R , select = -c (10:32))
R <- subset(R , select = -c (46))
#Remove top two rows
R <- R[-c(1, 2), ]
R <- na.omit(R)
R <- R %>% sapply (as.numeric)
R22 <- R %>% subset (select = -c (4:79))
describe(R)
#1-3 demographics, 4-9 nature connectedness, 10-39 AWE PRE, 40-44 WELLBEINGPRE,
45-74 AWE POST, 74-78 wellbeing POST
AWEPRE <- R %>% dplyr:: select(10:39)
AWEPRE <- sapply(AWEPRE, as.numeric)
avrgpreawe <- rowSums(AWEPRE, na.rm = TRUE)
```

```
R$AWEPRE = avrgpreawe

AWEPOST <- R %>% dplyr:: select(45:74)

AWEPOST <- sapply(AWEPOST, as.numeric)

avrgpostawe <- rowSums(AWEPOST, na.rm = TRUE)

R$AWEPOST = avrgpostawe

Nature <- R %>% dplyr::select(4:9)

Nature <- sapply(Nature, as.numeric)

avrgnature <- rowMeans(Nature, na.rm = TRUE)

R$NatureConnectedness = avrgnature

WBPRE <- R %>%dplyr::select(40:44)

WBPRE <- sapply(WBPRE, as.numeric)

avrgwbpre <- rowSums(WBPRE, na.rm=TRUE)

R$PreWellBeing = avrgwbpre

WBPOST <- R %>% dplyr::select(74:78)

WBPOST <- sapply(WBPOST, as.numeric)

avrgwbpost <- rowSums(WBPOST, na.rm=TRUE)

R$PostWellBeing = avrgwbpost

#remove now unnecessary columns

R2 <- subset(R , select = -c (4:79))

R2 <- subset(R2, select = -c (1:3))

#descriptive statistics

describe(R2)

psych::describe(R2$AWEPRE)

psych::describe(R2$AWEPOST)

psych::describe(R2$NatureConnectedness)
```

```
psych::describe(R2$PreWellBeing)
psych::describe(R2$PostWellBeing)
#Checking Assumptions
model <- lm(R2$AWEPOST ~ R2$AWEPRE, data = R2)
summary(model)
model.diag.metrics <- augment(model)
head(model.diag.metrics)
ggplot(model.diag.metrics, aes(R2$AWEPOST, R2$AWEPRE)) +
  geom_point() +
  stat_smooth(method = lm, se = FALSE) +
  geom_segment(aes(xend = R2$AWEPRE, yend = .fitted), color = "red", size = 0.3)
par(mfrow = c(2, 2))
plot(model)
library(ggfortify)
autoplot(model)
#Explanation for which plot checks what: he diagnostic plots show residuals in four different
ways:
#Residuals vs Fitted. Used to check the linear relationship assumptions. A horizontal line,
without distinct patterns is an indication for a linear relationship, what is good.
#Normal Q-Q. Used to examine whether the residuals are normally distributed. It's good if
residuals points follow the straight dashed line.
#Scale-Location (or Spread-Location). Used to check the homogeneity of variance of the
residuals (homoscedasticity). Horizontal line with equally spread points is a good indication
of homoscedasticity.
```

```
#Residuals vs Leverage. Used to identify influential cases, that is extreme values that might influence the regression results when included or excluded from the analysis.
#Check linearity
plot(model, 1)
#Check Homogeniety Of Variance
plot(model, 3)
#Check normality of residuals
plot(model, 2)
#Check for outliers
plot(model, 5)
#Shapiro test for normality
# Shapiro-Wilk test for normality of HrsOfSoc
shapiro_test_AWEPRE <- shapiro.test(R2$AWEPRE)
print(shapiro_test_AWEPRE)
# Shapiro-Wilk test for normality of MentalWellBeing
shapiro_test_wellbpost <- shapiro.test(R2$PostWellBeing)
print(shapiro_test_wellbpost)
# hyp 1
# Perform paired t-test
t_test_result <- t.test(R2$AWEPOST, R2$AWEPRE, paired = TRUE)
# View the results
t_test_result
model_hyp2 <- lm(R2$PostWellBeing - R2$PreWellBeing ~ R2$AWEPOST - R2$AWEPRE, data = R2)
summary(model_hyp2)
```

```
#model does not provide support for the hypothesis that exposure to awe-inducing VR nature has a positive effect on subjective well-being. The coefficient for the change in awe experienced is not statistically significant, and the model's overall fit is poor.
# Perform ANOVA
anova_result <- aov(R2$PreWellBeing ~ R2$ AWEPRE * R2$AWEPOST, data = R2)
# Display the summary of the ANOVA result
summary(anova_result)
#Hyp 3
# Fit the moderation model
model_mod <- lm(R2$PostWellBeing ~ R2$AWEPOST - R2$AWEPRE +
R2$NatureConnectedness + AWEPOST:NatureConnectedness, data = R2)
# View the summary of the model
summary(model_mod)
install.packages ("MASS")
library("MASS")
boxcox_model <- boxcox(model_mod)
optimal_lambda <- boxcox_model$x[which.max(boxcox_model$y)]
transformed_data <- R2$PostWellBeing^optimal_lambda
model_boxcox1 <- lm(transformed_data ~ R2$AWEPOST - R2$AWEPRE +
R2$NatureConnectedness + AWEPOST:NatureConnectedness, data = R2)
summary(model_boxcox1)
write.csv(R2, "~/Desktop/output.csv")
# the predictors, including their interaction term, do not have a significant effect on the transformed outcome variable. Additionally, the model itself does not provide a good fit for the data, as indicated by the low adjusted R-squared value and the non-significant F-statistic.
```