The Effect of Exposure to VR-Nature on Feelings of Awe: A Comparison Between Blue and Green Nature Environments

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Abstract

Exposure to nature has many benefits for all individuals as they are born with an innate connection to nature. Feelings of awe is a lesser known and less researched emotion caused by nature exposure and describes a profound emotional response encompassing a sense of wonder and is often accompanied by a change of reference to include significantly new information into existing mental schemas (Yaden et al., 2018). Virtual Reality (VR) is able to replicate nature experiences to a certain degree. How this feeling might be induced through the use VR is the central question of this study. To do so an experiment was designed comparing two VR nature environments in their ability to induce this difficult to measure feeling. The environments differed in the prevalence of blue (water) or green (plants) elements. The aim was to gain further understanding of the underlying mechanisms influencing the different factors of awe, how the two environments differ and ultimately whether VR would be successful in inducing feelings of awe. The conducted experiment compared the answers of 33 students to the established AWE-S questionnaire, assessing perceived feelings of awe, following a presentation of two different nature environments. The analysis revealed that the two chosen environments could not induce significant feelings of awe and therefore deviate greatly from the current body of research. The further investigation of the results revealed multiple underlying factors for this and this work will discuss this deviation and its causes.

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Introduction

Humans have historically spent a lot of time in close contact with nature, leading them to develop an innate connection towards nature known as biophilia (Owens & Bunce, 2023). Biophilia describes an inborn tendency and need to surround oneself with living things (Kahn, 1997). Also today we benefit greatly from exposure to nature but many individuals spend up to 90% of their lives indoors (Owens & Bunce, 2023). Nature has a multitude of positive effects on us which can already arise after only a few minutes. Exposure to nature increases emotional resilience, lowers stress and increases regenerative as well as restorative abilities of individuals (Haluza et al., 2014). Nature exposure counteracts fatigue and anger, increases relaxation, mood, and attention, and even benefits individuals with depressive symptoms (Browning et al., 2020). It is also reported that individuals feel more at ease with themselves after being in nature and that higher subjective wellbeing scores are indicated compared to a control condition (White et al., 2017). Especially water and plants seem to have a positive effect on us (White et al., 2017b). Nature exposure not only improves many indicators for wellbeing it can also cause individuals to feel a certain sense of wonder and fascination for something greater than oneself (in most cases nature). It can change one's frame of reference and be a spiritual experience (Ballew & Omoto, 2018) which usually arises when an individual sees something impressive or new that forces them to implement this new experience into their existing frame of reference. This multifaceted feeling is described as feelings of awe, which is a distinct and difficult to measure construct that is mostly induced through emotionally significant nature experiences.

The whole awe experience is made up by six factors (altered time perception, self-diminishment, connectedness, perceived vastness, physical sensations and need for accommodation) (Yaden et al., 2018b). While experiencing awe altered time perception means that the individual perceives time as going faster or slower compared to his or her usual feeling of time. Self-diminishment describes the feeling of being small or of less significance, especially in regard to something else, something larger than oneself and a shift of focus away from yourself. Connectedness especially concerns a connection to the whole world, nature and all living things. Perceived Vastness is caused by perceiving something much greater than yourself. Either as a concept or in physical terms. Examples would be a vast ocean, great open landscapes or the night sky. The experience usually also brings a certain novelty. Physical sensations are the most concrete factor making up awe, as it is about bodily reactions to a stimulus, such as goosebumps. Lastly, Need for Accommodation

describes the need to include new experiences in one's mental schemas as the experience is too new and too significant to be implemented into existing schemas without expanding them.

Exposure to nature, especially when inducing awe can have profound effects on individuals but despite knowledge about the benefits of nature exposure few individuals reach the recommended time of 120 minutes per week (Meredith et al., 2020) and fewer have profound awe experiences. Due to urbanisation green areas and especially natural areas are vanishing, making it increasingly difficult for many to visit natural spaces (Capaldi et al., 2015) and to profit from their effects. This is not always due to a lack of motivation or awareness about this connection. For many, it is simply impossible to immerse in a natural environment (Browning et al., 2020). This concerns for example hospital patients, handicapped individuals, and prison inmates (Browning et al., 2020). Besides that many individuals simply can not afford to go out and experience nature due to a lack of availability and funds (White et al., 2017). Even without active prevention, individuals like e.g. students often struggle to spend sufficient time in nature. Even though the groups mentioned before are the ones for who it is most difficult to experience nature the possible benefits of increased nature exposure can be applied across groups. Besides that, these target groups are very sensitive and therefore this study will focus on students as a target group since results will be significant for other groups as well. No matter the reason for the nature deprivation, experiencing nature in some way is beneficial for all groups.

This raises the question of how people deprived of natural environments can experience and benefit from their effects, fulfilling an innate evolutionary need. One possibility might be nature simulations (Browning et al., 2020). A simulation can generally be described as a technique used to imitate reality (Browning et al., 2020). In this regard, digital simulations of nature, precisely 2-D natural scenes as well as more immersive Virtual-Reality-Environments might be a promising technology (Browning et al., 2020). The digital simulations of nature can generally range from simply looking at pictures to fully immersive, interactive animated or recorded worlds. VR headsets allow such a fully immersive experience as the screen covers 100% of the visual field and reacts according to head movements. This makes the experience much more realistic and authentic for its user (Lee et al., 2019).

For individuals that have difficulties to spend sufficient time outside these technologies could be an alternative. First studies have clearly identified multiple similar effects when comparing simulated nature exposure and real physical exposure to nature (Browning et al., 2020). An extensive review by Browning et al. (2020) found that 95% of the 175 experiments analysed

reported positive effects, especially concerning the restorative effects of the VR-exposure. Other effects were improvement in mental health, cognitive performance, stress reduction and improved attention. Hence, they might provide a possible alternative to real-world nature and seem to produce overlapping positive effects while even bearing some advantages. Scenes can be chosen freely from all over the world, personal preferences can be adjusted (especially water and plants seem to have a positive effect). Despite these advantages, and the possibility to at least visually and auditorily completely immerse in VR, the other senses are not stimulated. Also, other factors that positively influence the nature experience like for example fresh air or sunlight cannot be replicated by the VR experience and therefore might mediate the effects (Li et al., 2021). Using VR simulations individuals that are deprived of access to real-world nature might substitute this and still profit from the benefits of nature but not every nature environment seems to cause similar effects.

Water and plants are examples of two different kinds of nature environments. Water is considered a blue nature environment while plants are part of a green nature environment (Reece et al., 2022). Gao et al. (2019) found that environments with water features were preferred over other natural features as plants and bushes and resulted in higher restorative effects. Nevertheless, both seem to have positive effects on overall wellbeing, restoration, mindfulness and most importantly feelings of awe. Even awe might also be induced through exposure to VR-nature especially if the environment chosen accordingly. Environments that trigger these factors are very successful in inducing awe.

Current Study

Whether or not also VR nature can induce feelings of awe and how blue and green spaces might differ in there successfulness to do so is still not well researched. Additionally, despite extensive research on the benefits of nature exposure, the specific differences in how various nature environments, such as blue and green spaces, affect feelings of awe remain underexplored (Richardson et al., 2020). This study will investigate the relationship between the exposure to green and blue VR-nature environments and its effect on feelings of awe. Since first studies have identified comparable effects of exposure to VR-nature and real world nature (Gao et al., 2019; Browning et al., 2020) it is also expected that chosen environments for this study induce feelings of awe. Lastly it was also mentioned that blue environments would be preferred over green ones and they differ in their effects on the six factors, which is why it is believed that for this experiment there will be differences between the factors and environments.

The research question investigated is: How do green and blue VR-nature-environments differ in their ability to induce feelings of awe?

H1: Exposure to Blue and Green VR-Environments will produce significant positive awe scores.

H2: Participants will indicate significantly higher awe scores for exposure to the blue environment compared to the green.

H3: There will be significant differences between the scores of the different subscales of the AWE-S questionnaire within each environment. Altered time perception will be highest.

Methods

Participants

To answer the research question a test was designed which was completed by 33 participants, who all gave given informed consent before the start of the experiment. The inclusion criteria for participation were as follows: participants had to be at least 18 years of age so they could legally participate in the experiment without a caretaker, they had to understand and speak fluent English as the questionnaires were all in English and lastly the had to have no visual impairments that would make it impossible for them to perceive the scenes or differentiate between blue and green. The mean age was 22 with a *SD* of 2.39. The sample for this experiment consisted of 33 participants, 48% (16) females and 52% (17) males. Most of them were Psychology students 67% (22) whereas 12% (4) were Business and 9% (3) were Physiotherapy students. Besides that Health and Food (1), Communication science (2) and Curative Education (1) students participated. 45% (15) were German and 27% (9) were Dutch. Other nationalities were American (1), Bulgarian (1), Finnish (1), Mauritian (1), Namibian (1), Norwegian (1), Polish (1), Romanian (1) and Turkish (1). Most of the participants were recruited through convenience sampling as they were approached by us directly. The remainder of the participants signed up for the study voluntarily via a university system "Sona". All of the gathered data was anonymised and handled confidentially. The ethics committee of the University of Twente approved of the study beforehand.

Design

To answer the research question a within-participant experiment was designed during which the participants were exposed to two different nature environments in VR (one green environment and one blue environment). All participants were exposed to both environments but in different order to avoid order effects. Therefore, there were two orders in which the environments could have been presented (Blue first and Green first). The independent variable was exposure to VR nature while the dependent variable was perceived feelings of awe.

Materials

To invite the participants an invitation form was used which included relevant information about the experiment, its aim and procedure, how to participate and how long it will take, as well as contact information of the researchers. To see this form and fill out the ones following either a smartphone or PC was needed. For a successful conduction of the experiment, the participant needed to be in a calm and quiet surrounding. Besides the absence of distractions, only a chair for the participant to sit was needed. Participants were sent a questionnaire, created using the Qualtrics software (software used for data collection). This is the only questionnaire used and the participant answered it section by section, the first being informed consent (Appendix B), the second being demographic questions and lastly the questions assessing awe scores. Included in the informed consent form are all information about the aim of the experiment, the procedure, its risks for and the rights of the participant during and after the experiment. In the same section, the participant indicated whether or not he or she would agree to these conditions. The demographic questions included questions about Age, Gender, Field of Study, Nationality, How much time is spent outdoors and whether or not the participant was experienced with the use of VR.

For the VR setup, a Meta Quest 2 was used to display different VR-Nature scenes. The participant only needed to wear them and use the controllers once to start the video of the blue or green environment. The nature scenes were displayed through the YouTube VR application. This medium was chosen as it allowed choosing from a very large body of freely accessible videos and its straightforward use. Since it was not possible to download both, a stable internet connection was necessary for the application as well. The shown green nature scene displayed a vast green field with a 360° view for a little more than four and a half minutes and was named: “Poppy Field, Armenia. Relaxation video in 8K.” by AirPano (see Figure 1). The blue nature scene displayed the first ~ 4:30 minutes of a wide and open ocean, watched from a sandy beach with a 360° view and was named: “Malibu Beach - VR 360 - 4K Video - Soothing Surround Beach Sounds - ASMR CaliScapes” by Highway Forty Productions (see Figure 2)**.**

Figure 1

Green Environment

Figure 2

Blue environment

The Awe-Experience-Scale (Appendix C) (developed by Yaden et al., 2018b) was used to measure feelings of awe after the display of the scenes. The questionnaire consists of 30 questions, with five questions per factor (Factor 1 = altered time perception, Factor 2 self-

diminishment, Factor 3 = connectedness, Factor 4 = perceived vastness, Factor 5 = physical sensations, Factor 6 = need for accommodation). The scales were found to have strong internal reliability and good internal validity (Yaden et al., 2018b). Initially, they identified a six-factor structure of awe using Exploratory Factor Analysis (EFA) on participant statements about their awe experiences. This confirmed the six-factor structure. A different sample's Confirmatory Factor Analysis (CFA) confirmed the structure and revealed good model fit indices (CFI =.905; RMSEA =.054), suggesting that the scale's structure accurately captures awe. The internal consistency of each factor was strong, with Cronbach's alpha values all above .80, suggesting that the items within each factor coherently measure the same construct of awe (Yaden et al., 2018b). Additionally, the AWE-S factors showed significant correlations with items on other established scales, specifically the modified Differential Emotions Scale (mDES) and the Dispositional Positive Emotion Scale (D-PES). The answer possibilities were provided on a 7-point Likert scale, ranging from strongly disagree to strongly agree (Strongly disagree, moderately disagree, somewhat disagree, neutral, somewhat agree, moderately agree, strongly agree).

Procedure

After arrival at the test location, the participant was sent the questionnaire which first showed the informed consent form. While he or she was filling out the informed consent the researcher prepared the headset and loaded the first video so that as soon as the participant was ready he or she only had to press play once. There was only one questionnaire in use with different sections, that the participant filled out one after another, always until it was indicated he or she finished the section, the first being informed consent. The next part of the questionnaire contained the demographic questions and one question to assess how much the participant enjoys spending time in nature and one whether they have experience with VR. After completing this first round of questions the participants were introduced to the headset and its controls. When the participant was ready for the first scene they put on the VR-Headset with the loaded video, had to press play and saw the first nature scene. Whether the first environment was green or blue was randomised to avoid ordering effects and was switched after every participation. Both videos were 4:30 minutes long and in at least 4K resolution. After finishing the first nature scene the participant answered the AWE-S questionnaire to assess the first condition. While doing so the researcher loaded the second environment. For the second environment, the procedure was simply repeated and the same

questionnaire was filled out again. During all displays, it was possible for the participant to look around freely but not walk around freely. Completing the whole experiment took most participants about 30 minutes.

Data analysis

Once the data collection was finished the data was exported from Qualtrics, transferred in a CSV file and first opened with Excel. Means per factor were quickly calculated to get an overview of the data. The data was cleaned, and some variables were renamed to make the analysis easier. The data was divided and sorted by condition and participant to make comparisons between the scores possible and analysis more straightforward. One participant was excluded as the wrong first shown environment was indicated and it was not possible to allocate him or her correctly. For the statistical analysis, unnecessary variables (e.g. time of participation) were excluded before analysing the data with RStudios. For the analysis the following packages were needed: tidyverse, matrixStats, psych, ggpubr, ggplot2, readxl.

Hypothesis 1 – Inducing Feelings of awe

The first hypothesis investigated whether both environments would induce significant feelings of awe. This was tested by assessing the total awe score means and comparing them to the neutral position. A value of 4 indicated the neutral position (neither agree nor disagree). To accept the hypothesis the mean total awe score would need to be significantly higher than 4.0. This score was chosen as it indicates no particular feelings of awe. This was done using a one-sample t-test as it is well suited to compare single mean scores to a known value (4). Additionally, the data met all necessary assumptions for this test. The data was normally distributed across both environments, each observation was independent from one another, it met the requirements for homogeneity and there were no extreme outliers in the dataset. Each participant answered all 30 questions of the AWE-S questionnaire. The scores were summed up and the mean was calculated and compared whether it was significantly higher than the neutral position of 4. The test was performed for each environment separately.

Hypothesis 2 – Significantly higher Awe Scores for Exposure to the Blue Environment

The second hypothesis answered the question of whether the blue VR-Environment would induce significantly more feelings of awe compared to the green environment. To

answer this hypothesis, a paired t-test was conducted. The test compared the total mean awe scores of participants in the blue condition to the total mean awe scores of the same participants in the green condition as well as the respective mean scores of each factor between the two environments. This allowed an assessment of the differences in awe-inducing ability between the environments while controlling for individual differences.

Hypothesis 3 – Significant Differences within each Environment between Factors

Hypothesis 3 tested whether there would be significant differences between the different factors making up the total awe score within each environment. Whether or not there are significant differences between the subscales was assessed through the Friedman test. To identify which factors differed from which a pairwise comparison (Wilcoxon Signed-Rank test) was performed.

Results

Descriptive Statistics

Descriptive statistics were calculated for overall (total) responses and across the different awe factors and all participants (see Table 1). The mean awe scores indicate scores slightly higher than the neutral baseline. The mean of the overall average awe scores was 4.03 (*SD* 0.85) for the blue and 4.17 (*SD* 0.87) for the green environment. The mean total sum scores were 121 for blue (ranging from 73 to 183) and 127 for green (ranging from 77 to 191). Highest and lowest possible scores were 210 and 30 respectively. A representation of the answers per participant can be found in the appendix (Appendix E)

Table 1

Descriptive Statistics Blue

Environment	Blue				Green			
	M	*SD*	Median	Range	*M*	*SD*	Median	Range
Total Awe	4.03	0.85	4.0	2.8 - 6.1	4.17	0.87	4.2	2.6 - 6.3
Altered Time Perception	5.09	1.23	5.0	3.4 - 7.0	5.17	1.15	5.0	3.4 - 7.0
Self diminishment	4.12	1.57	3.8	2.0 - 7.0	4.45	1.34	4.8	1.8 - 7.0
Connectedness	4.08	1.50	4.4	2.0 - 6.4	4.08	1.46	4.4	1.0 - 6.8
Perceived Vastness	4.42	1.58	4.6	2.0 - 7.0	4.96	1.47	5.0	2.2 - 7.0
Physical Sensations	3.12	1.29	2.6	2.0 - 5.4	3.20	1.75	3.2	1.0 - 6.0
Need for Accommodation	3.36	1.33	3.4	2.0 - 5.8	3.47	1.54	3.6	1.0 - 5.8

Hypothesis 1 – Inducing Feelings of awe

When comparing the means of the two environments it becomes apparent that the means only differ by a score of 0.14. To get a statistically relevant result a one-sample t-test was performed. The test showed no significant difference between the mean awe scores the participants indicated and the neutral score of 4. This was the case for the blue (M = 4.03, SD = 0.85) t(32) = 0.197, p = .845 and green (M = 4.17, SD = .87) t(32) = -1.121, p = .271.The Shapiro Wilk test showed the normality of the dataset as none of the p-values surpassed the significance threshold of 0.05 (see Table 2) while the Levene's Test showed its homogeneity, F(1,64) = 0.002, p = .965.

Table 2

Shapiro-Wilk test results

Condition	Shapiro-Wilk Stat.	*p*-value
Blue	0.98	0.65
Green	0.97	0.52

Hypothesis 2 – Significantly Higher Awe Scores for Exposure to the Blue Environment

To answer the second hypothesis, a paired t-test was conducted. This test showed non-significant differences in the total awe scores between the blue environment (M = 4.03, SD = 0.85) and green (M = 4.17, SD = 0.87); t(32) = -1.01, p = .32. Additionally, it showed no significant differences between the two environments across all factors except Perceived Vastness (M = 4.42, SD = 1.58) for blue and (M = 4.96, SD = 1.47) for green; t(32) = -2.12, p = .04. (see Table 3).

Table 3

Paired t-test results

Factor	t-statistic	p-value
Overall	-1.01	0.32
Altered time perception	-0.38	0.70
Self diminishment	-1.14	0.26
Connectedness	0.02	0.98
Perceived Vastness	-2.12	0.04
Physical sensations	-0.30	0.76
Need for accommodation	-0.56	0.58

Note. The scores compare the blue to the green environment

Hypothesis 3 – Significant differences within each environment between factors

To determine whether there were significant differences between the single factors within one environment the Friedman test was performed. In both environments, the "Altered Time Perception" subscale had the highest mean scores (Blue: $M = 5.09$, Green: $M = 5.17$) and the Friedman test identified significant differences between the factors within each environment. It rendered a Chi-square value of 66.22, $p < 0.001$ for the blue environment and a Chi-square value of 58.94, $p < 0.001$ for the green. A post hoc pairwise comparison (Wilcoxon Signed-Rank test) identified multiple significantly different comparisons (see Table 4).

Table 4

Significant Differences between each Factor within each Environment according to Wilcoxon signed Rank Test

Factor	Altered Time perception	Self diminish-ment	Connected-ness	Perceived Vastness	Physical sensations	Need for Accom-dation
Altered time perception		Yes + Yes +	Yes + Yes +	Yes + Yes +	Yes + Yes +	Yes + Yes +
Self diminishment			No Yes +	No No	Yes + Yes +	No No
Connectedness				Yes - Yes -	Yes + Yes +	Yes + Yes +
Perceived Vastness					Yes + Yes +	Yes + Yes +
Physical sensations						Yes + No
Need for accommodation						

Note. Blue Condition shown in blue, Green Condition shown in green. *Plus sign (+) indicated the factor on the left scored significantly higher than the one at the top. Minus sign (-) indicating the opposite.*

Discussion

Key Findings

The purpose of this experiment was to gain a better understanding of the ability to induce feelings of awe through exposure to VR-Nature. The comprehensive analysis of awe responses to blue and green VR environments did show that neither of the environments were successful in inducing feelings of awe and there were no significant differences in their successfulness to induce awe. Statistical tests did not show any statistically significant differences between the two environments and only the factor mean within each environment differed significantly from one another. Nevertheless, these findings bear interesting implications for the creation of awe inducing VR experiences.

The first hypothesis tried to determine if the exposure to the two chosen environments would lead to feelings of awe. This experiment could not show a significant effect of the exposure on perceived feelings of awe and has therefore been rejected. The same was the case for hypothesis 2 as it tried to answer whether the blue environment would be more successful in inducing awe compared to the green, as theorised by Gao et al. (2019) who predicted that humans tend to prefer blue features in nature and that blue environments would be more successful in inducing awe. In this experiment only Perceived Vastness showed a significant difference between the two environments but contrary to the hypothesis in favour of the green environment. Also, the overall mean for the green environment was contrary to the hypothesis higher for the green environment and not the blue. Lastly, the third hypothesis could be accepted as the Friedman test showed significant differences in the scores of the different subscales and when comparing the means, Altered Time Perception scored the highest. It also scored significantly higher than every other factor in both environments.

Interpretations

Hypothesis 1 - Inducing Feelings of awe

To understand the findings of this experiment it is most important to understand why it did not find the same findings as other research. For this hypothesis more precisely why neither of the environments were able to properly induce feelings of awe. Owens & Bunce (2023) found that VR environments can replicate the effects of real-world exposure but focus mostly on general wellbeing rather than awe. Taking only the results of this experiment into account it would need to be concluded that according to the t-test, awe cannot be induced

through VR. However, Brown et al. (2020) did find that exposure to VR-nature can induce feelings of awe especially if the scene creates an experience of grandeur/greatness and vastness and other studies find similar results. Also in this experiment vastness had one of the highest means and played a crucial role in the total awe score. Most other factors however did not score very high. Also, an experimental study by Chirico et al. (2018) clearly showed the effectiveness of VR in inducing awe. This study identified among others immersion, vastness, complexity and novelty as key features when trying to induce awe through VR. Except for vastness, the two chosen environments did not seem to address these aspects in practice. The focus was put on choosing vast, wide and empty landscapes but might not have been complex, immersive or novel enough in order to significantly induce feelings of awe.

Participants indicated especially low scores for physical sensations. Yaden et al., (2018) identified all factors as equally important for the total awe experience and it, therefore, is especially interesting how low scores (physical sensations and need for accommodation) might be increased. According to a study by Quesnel & Riecke (2018), increased in physical interaction with the environment might lead to more frequent physical responses such as goosebumps (which is one question assessing physical sensations) and might therefore lead to higher scores for this factor in general. Since need for accommodation describes the need to include new experiences in one's mental schemas as the experience is too new and too significant, novelty might influence these scores (Yaden et al., 2018b). Focusing on these elements might therefore improve the total experience.

Hypothesis 2 - Significantly Higher Awe Scores for Exposure to the Blue Environment

The second hypothesis also had to be rejected as only Perceived Vastness showed a significant difference between the two environments but in the opposite direction than expected. Current study identified blue environments as more successful because blue environments like oceans represent a space with no boundaries and therefore lead to high scores in perceived vastness. Also, Gao et al. (2019) found that water, in general, would influence other factors facilitating the individual ability to experience awe (calming effects of and soothing sound of water). It becomes apparent that the sound of water was absent in this experiment as only the effect of visual stimuli was tested. This might have lead to less immersion or an incomplete experience, resulting in lower awe scores for both environments. The absence of sound might have affected the blue environment more because green

environments do not have a distinct, e.g. “grass sound” while water has a “water sound”. This absence of an expected stimulus might have caused lower scores (Chirico & Gaggioli, 2019). Additionally, the blue environment might have been less immersive than the green one as it lacked quality, movement, changing views, presence and it did not require a lot of attention, which were all identified as important elements of immersiveness (Gao et al., 2019).

Despite the vastness enhancing boundlessness of ocean perceived vastness was significantly higher for the green environment. This discrepancy could be due to several factors. First, the seemingly empty, lonely and expansive grassy field chosen for this experiment might have left the participant feeling much more exposed and small compared to the secluded beachy bay (important for the degree of immersiveness). As found by Rauhoeft et al. (2015) expansiveness and how far one can see has a significant influence on perceived vastness. The ocean view on the other hand was confined by rocks and cliffs, closing it off behind the participant so that the bay was only open forward and with no changing POVs resulting in a lower sense of vastness (Rauhoeft et al., 2015). In the green environment, there was also more camera movement, giving the participant the feeling he or she would fly or glide through the environment, which also contributed to higher feelings of vastness and a sense of novelty in the green environment.

Hypothesis 3 – Significant differences within each environment between factors

The Friedman test identified significant differences between the different factors indicating some aspects of awe being triggered more by the exposure to the environment than others. When comparing the scores similarities between relations of factors and the environments arose. For both altered time perception was rated the highest and the only factor that was significantly different (higher) to all other factors in both environments. Indicating a changes in this factor more prominently than other factors.

In both environments, participants indicated higher scores for perceived vastness than for most other factors while physical sensations and need for accommodation scored significantly lower than most other factors. These similarities imply that both environments alter time perception more effectively than they could influence other factors. Especially Physical sensations and need for accommodation were much less influenced compared to most other factors, implying that these concepts were not sufficiently addressed by both environments. This might be due to the nature of the two environments. Need for accommodation is especially triggered when presented with unfamiliar and new stimuli. Even though both environments were technically new to the participant all of them most likely

experienced similar environments in their life multiple times. Need for accommodation only arises if the existing frame of reference can not comprehend the new input which was not sufficient in both environments (Keltner & Haidt, 2003). Additionally, both environments lacked profound or surprising events and interactive features which were identified as important predictors of physical sensations (Chirico & Gaggioli, 2019). The same study also found the emotional and cognitive context to be very important in eliciting physical sensations, which was also not the case for the two environments.

The analysis also showed differences in the relations between the factors. Connectedness was rated significantly higher than vastness in the blue environment but significantly lower in the green environment and self-diminishment did not significantly differ from most factors in the blue environment but in the green environment self diminished was rated as significantly higher than connectedness and physical sensations. These differences show that in relation to other factors, connectedness played a more important role in the blue environment than it did in the green one. Against Gao et al. (2019) findings the ocean scene did not cause significant feelings of connectedness and scored higher in connectedness than vastness even though oceans were explicitly named as particularly effective in vastness.

Strengths and Limitations

The findings need to be considered in terms of strengths and limitations. Since the environments effectively failed in producing significant feelings of awe it is important to look at the limitations that might have caused the deviation from other studies.

A strength of the experiment lies in its within-participant design which allowed to assess differences in the environments independent from individual differences in susceptibility to awe-eliciting events as it only compared the scores of each participant with the scores of the same. Additionally, the fact that for most analyses all the different factors were assessed individually and in relation to one another and not only the total awe scores allowed a much more exhaustive analysis than comparable studies only focusing on the total awe score. This allowed also to investigate certain differences in factors between the two environments. Lastly, the experiment used established psychometric tools (AWE-S questionnaire) and was conducted in a controlled setting.

Due to a mix of convenience and random sampling some of the participants knew the researcher which could have motivated them to behave in a desirable way. This is also the

first limitation. Even though all test locations fulfilled all necessary requirements they might have influenced the participant as some of them e.g. feel more comfortable at home than others. In other cases, the experiment was conducted in different quiet rooms e.g. an experiment room on campus which even though fulfilling the same requirements could have had an impact on receptivity to awe. Secondly, this experiment only tested for awe scores in relation to a set neutral score. This makes it possible to answer whether awe was induced but not how it changed compared to a previous measure. In this regard, it would have been useful to assess a baseline measure at the beginning of the experiment. Third, the environments did address some factors of awe but not all. Especially physical sensations and need for accommodation were not addressed through the chosen environments. Besides that, this experiment only encompassed a single quite short exposure which even though ought to be able to induce awe, might not be as successful as longer exposures and especially simulations which create some sort of personal relevance (Chirico et al., 2016). Lastly, both environments lacked immersiveness and interactivity which is an important predictor for multiple factors.

Implications

The findings of this experiment showed that the two chosen environments could not induce significant feelings of awe. This is not in line with other research and is most likely due to the limitations of the experiment design and most importantly due to the selection of environments. The results challenge current research in how nuanced VR experiences need to be to induce awe. It showed that ideally all six factors are addressed specifically in order to elicit awe. It also showed that some of the different factors are influenced by similar elements, such as vastness is a factor itself but also influences other factors like physical sensations. It stressed the importance of underlying mechanisms making up each factor, namely novelty, immersion, interactivity and complexity. These findings help future research in designing awe inducing VR experiences. For real world applications the experiment showed limited ability for VR nature to create meaningful awe experiences but suggests that with the right adjustments it could be a useful tool for different nature experiences including ones that induce awe. It could be applied as a substitute for nature deprived individuals but generally, better understanding in how stimuli work together to create awe or maybe other experiences as well could allow to selectively induce emotions or experiences.

Future research

For future research, it is advised to choose different environments that precisely target all factors. Through the current body of literature, multiple important elements could be identified that might have been missing or not been addressed sufficiently in this experiment. The absence of awe might have been due to a lack in complexity, novelty, greatness immersion and interactivity of the environments. Simulations that align closer with these concepts are likely to induce more awe. Future research should therefore identify through which elements these concepts are best included to create awe inducing environments.

The chosen environments for this experiment especially lacked stimulation of physical sensations. This factor was identified as especially difficult to trigger by other studies as well and would therefore benefit most from particular research and insights in this factor. For this experiment, seemingly the absence of novelty and cognitive challenge was most responsible for the low scores in physical sensations and need for accommodation. Future research should therefore use environments with better more interactive personally relevant elements and surprising events that challenge the participant's frame of reference (e.g. a dive underwater).

Additionally, future research should choose environments with a higher “real” resolution. Even though advertised as at least 4k resolution the nature scenes lacked a certain degree of detail which can impair the feeling of presence and immersiveness (Cummings & Bailenson, 2015). This was the case for most simulations found through YouTube VR which is why it might be recommended to use a different application.

Conclusion

Contrary to the body of literature, this experiment could not show that exposure to VR nature would induce feelings of awe, nor did the blue and green environment differ significantly in their ability to do so. This was most likely due to a lack of novelty, immersion, and interactivity in the simulations. Nevertheless, if these elements are addressed effectively exposure to VR nature most likely can induce feelings of awe.

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Appendix

Appendix A

AI-Statement

"During the preparation of this work, I used ChatGPT, Grammerly and Word to help with idea generation, assistance in literature search, assistance in overcoming error messages and spelling (no generative text or suggestions of any of the engines was included in my work). After using these tools/services, I thoroughly reviewed and edited the content as needed, taking full responsibility for the final outcome."

Appendix B

Informed Consent

Q1

A Quest for well-being in virtual reality nature - Study Information

Dear student,
In this study we are interested in the effects different virtual reality nature environments can have. More specifically, we are interested in self-esteem, relaxation and awe. We will measure this with questionnaires. During this survey you will be asked twice to stop and let the researcher know that you have reached this point. Please do so! At that point you will be shown a VR environment and then contunue the survey.
Please fill out the questionnaires as honest as possible. The collected data is anonymous and can not be connected to a specific person.

Researcher Contact Details:
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Lieve van der Valk (l.s.vandervalk@student.utwente.nl)
Markus Kaiser (m.kaiser@student.utwente.nl)

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

○ Yes, I understand

Informed Consent

	Yes	No
I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves looking at VR environments and filling out questionnaires.	○	○
I understand that taking part in the study involves the following risks: motion sickness	○	○
I understand that information I provide will be used for educational purposes.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. age, nationality, study field], will not be shared beyond the study team.	○	○
I give permission for the collected data that I provide to be archived on the UT drive so it can be used for future research and learning.	○	○
I agree that my information may be shared with other researchers for future research studies that may be similar to this study. The information shared with other researchers will not include any information that can directly identify me. Researchers will not contact me for additional permission to use this information.	○	○

Appendix C

Awe Questionnaire

Example Question from Factor 1

Q1.1

I sensed things momentarily slow down

- ○ Strongly disagree
- ○ Moderately disagree
- ○ Somewhat disagree
- ○ Neutral
- ○ Somewhat agree
- ○ Moderately agree
- ○ Strongly agree

Example Question from Factor 4

Q4.5

I perceived vastness

- ○ Strongly disagree
- ○ Moderately disagree
- ○ Somewhat disagree
- ○ Neutral
- ○ Somewhat agree
- ○ Moderately agree
- ○ Strongly agree

Items of AWE-S questionnaire

1. I sensed things momentarily slow down.
2. I noticed time slowing.
3. I felt my sense of time change.
4. I experienced the passage of time differently.
5. I had the sense that a moment lasted longer than usual.
6. I felt that my sense of self was diminished.
7. I felt my sense of self shrink.
8. I experienced a reduced sense of self.
9. I felt my sense of self become somehow smaller.
10. I felt small compared to everything else.
11. I had the sense of being connected to everything.
12. I felt a sense of communion with all living things.
13. I experienced a sense of oneness with all things.
14. I felt closely connected to humanity.
15. I had a sense of complete connectedness.
16. I felt that I was in the presence of something grand.
17. I experienced something greater than myself.
18. I felt in the presence of greatness.
19. I perceived something that was much larger than me.
20. I perceived vastness.
21. I felt my jaw drop.
22. I had goosebumps.
23. I gasped.
24. I had chills.

25. I felt my eyes widen.

26. I felt challenged to mentally process what I was experiencing.

27. I found it hard to comprehend the experience in full.

28. I felt challenged to understand the experience.

29. I struggled to take in all that I was experiencing at once.

30. I tried to understand the magnitude of what I was experiencing.

Note: These are all 30 Items of the AWE-S questionnaire (Yaden et al., 2018b)

F1: 1-5

F2: 6-10

F3: 11-15

F4: 16-20

F5: 21-25

F6: 26-30

Appendix D

Nature Environments

Green Nature Environment

Note: “Poppy Field, Armenia. Relaxation video in 8K.” by AirPano VR, https://www.youtube.com/watch?v=C9zTx6xW7LY

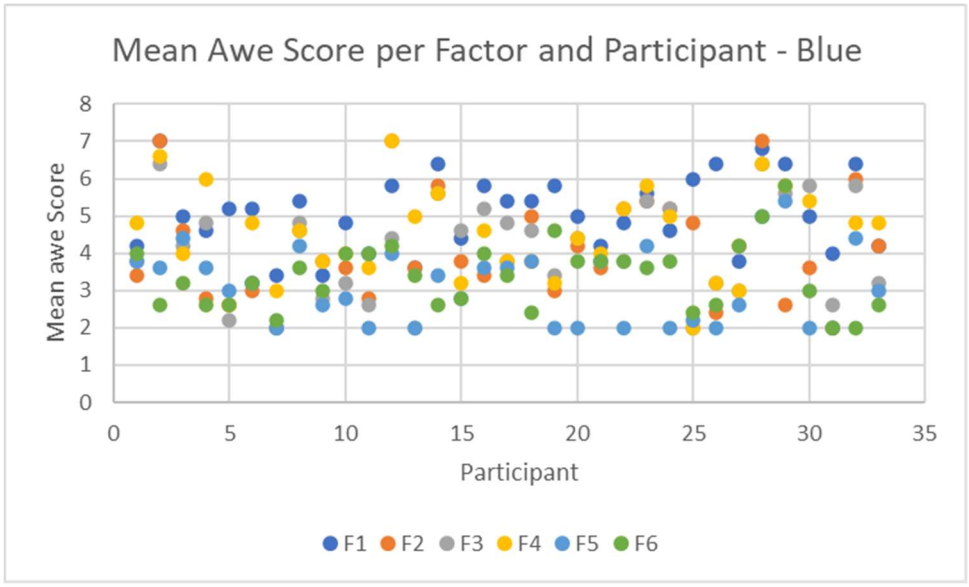
Blue Nature Environment

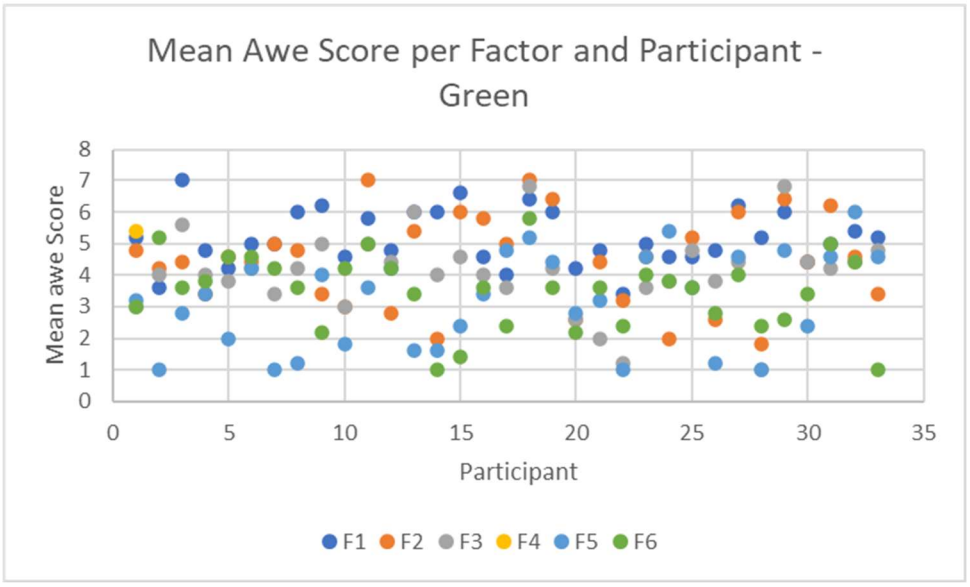
Note: “Malibu Beach - VR 360 - 4K Video - Soothing Surround Beach Sounds - ASMR CaliScapes” by Highway Forty Productions https://www.youtube.com/watch?v=bW9VYhytk-c

Appendix E

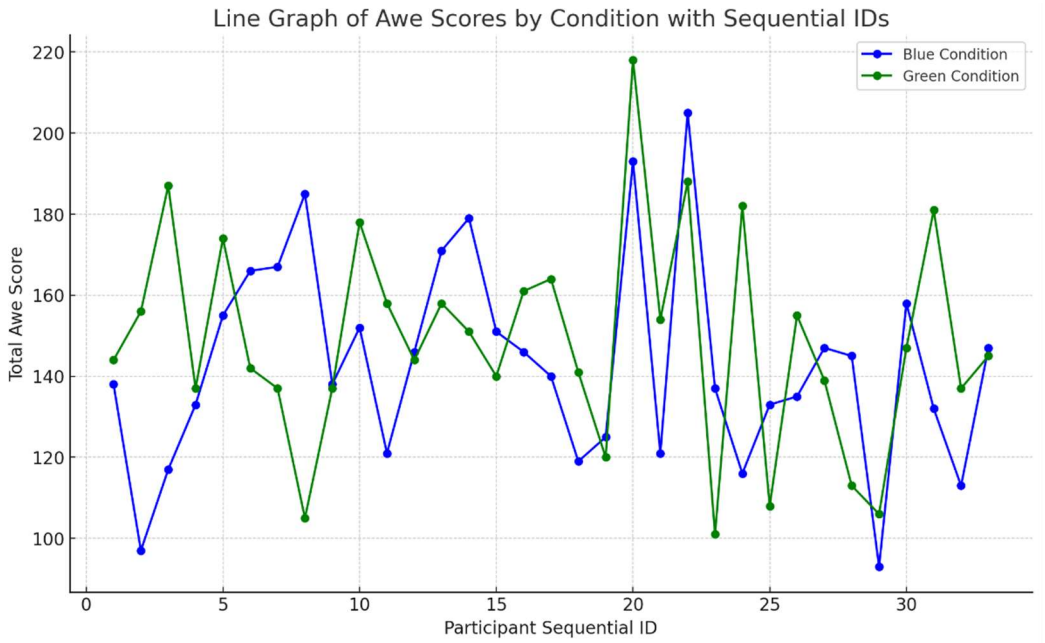
Graphical Representation of Data

Mean Awe Score per Factor and Participant – Blue and Green

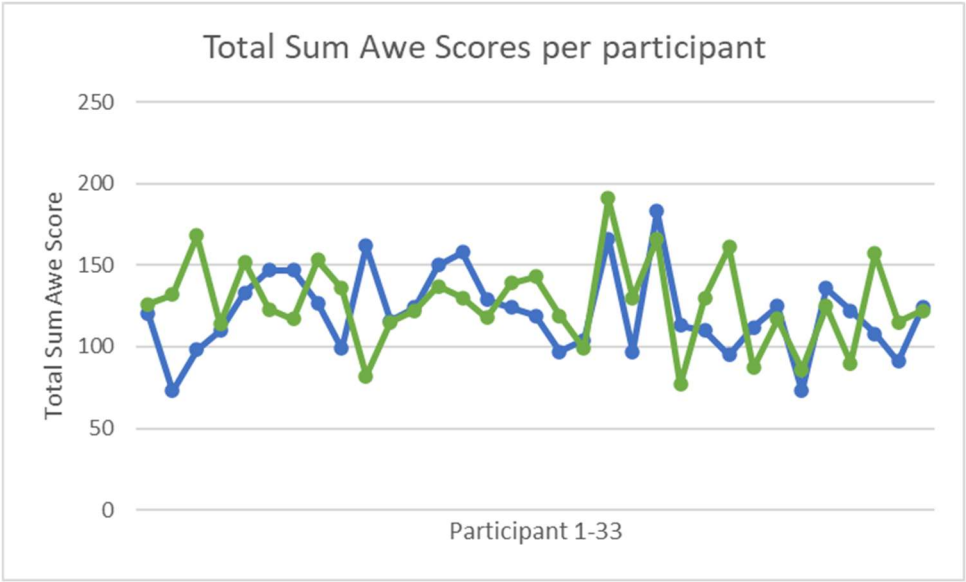




Responses per questions and condition



Total Sum of Awe Scores per Participant – Glue and Green



Average Awe Score per Factor and Condition