Exploring the Relaxation Effect of Green vs Blue Nature Environments in Virtual Reality in a Student Sample

Johanna Völkening (s2795566)

Faculty of Behavioural, Management, and Social Sciences

University of Twente

202000384: BSc Thesis PSY

Positive Clinical Psychology and Technology (PCPT)

First supervisor: Lina Bareisyte

Second supervisor: Matthijs Noordzij

June 25, 2024

Abstract

Many students frequently experience stress, especially when this stress is persisting longer, it can be harmful to mental and physical health. An effective way to relieve stress is exposure to nature. Nature, however, is becoming scarcer and is not reachable for everyone. VR research is therefore promising to students and other target groups. This study set out to find the different effects of blue and green nature. It was hypothesized that both would have a significant effect on relaxation and that the blue environment would have a stronger effect. An experiment was conducted where 34 students watched a video of a green and blue nature environment in VR and had to fill out the Relaxation State Questionnaire at the beginning and after each video. Additionally, they were asked to name their preferred environment and the reason for the preference. The findings showed no significant relaxation effect of either condition, therefore both hypotheses were rejected. Participants preferred the conditions to almost even parts naming different reasons, ranging from finding one more relaxing, familiarity to enjoying the view. The results were not in line with previous research. Reasons for this point towards the importance of sound, sufficient video quality, and the stress level the participants entered the experiment with. Based on this, recommendations for further research were the use of sound and inducing stress in participants before watching the videos. Implications included the future use of VR nature for elderly people in retirement homes and patients in hospitals.

Keywords: Virtual reality, blue nature, green nature, relaxation, students, experiment

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University students often struggle with stress as they face many challenges at the same time. This includes a high workload and the many new challenges that come with moving out from home (Selvi & Rajaprabha, 2020). This can lead to negative health consequences concerning both mental and physical health (Marshall, 2011). To reduce these negative outcomes, methods to reduce stress are crucial. One way to relieve stress is to increase relaxation (Hamdani et al., 2022). This can be achieved in different ways, one being exposure to nature (Ulrich et al., 1991). Hereby, different types of nature might have different effects (White et al., 2021). The different types of nature therefore need to be investigated to determine the best way to increase relaxation as a way to reduce harmful stress.

Stress

Stress, even though very common, is harmful to physical as well as mental health. When stress becomes chronic and persists over long periods it can lead to several adverse effects (Marshall, 2011). It can lead to immune-based dysfunctions including increased vulnerability to infections, allergic diseases, and asthma (Marshall, 2011). Additionally, stress can lead to increased mortality due to cancer, HIV infections, or inflammatory bowel disease (Marshall, 2011). Next to that stress has been found to increase activity in the sympathetic nervous system which can lead to increased blood pressure, heart rate, platelet aggregation, and catecholamine secretion (Marshall, 2011). Long-term exposure to stress can also increase the risk of anxiety, depression, insomnia, substance abuse, or other mental health problems (Centre for Addiction and Mental Health, n.d.). Therefore, stress is not only harmful physically but mentally and emotionally as well.

One group of people who are in a situation that often leads to stress is university students. They face many challenges at the same time including a heavy study load, new social contacts, and managing their lives without parents (Selvi & Rajaprabha, 2020). Currently, not enough is done to help students reduce stress, as many experience stress frequently. A study done by Alkhawaldeh et al. (2023) found that students are generally prone to stress. The study explored student's stress levels, stressors, and coping styles. Overall, the stress level of two-thirds of the sampled students was reported as moderate. This was higher among students, with chronic illness, living alone, with a low GPA, and taking exams soon (Alkhawaldeh et al., 2023). Since some of these stressors such as living alone and having exams occur very frequently among university students, they are at an increased risk of frequent stress.

This experience of high stress levels can lead to a higher level of mental health problems. Over 60% of students fulfill the criteria for at least one mental health problem (Lipson et al., 2022). This can have many negative effects on their well-being as well as their academic success. Stress has been found to decrease academic achievement as well as overall life quality (Ribeiro et al., 2018; Talib & Zia-ur-Rehman, 2012). If students learn methods to reduce stress during their university time, they can benefit from this later in life. This way chronic stress can be reduced, and health improved (Conley et al., 2013). Targeting students could therefore be very beneficial as they are at risk for stress and could benefit from methods to reduce stress later in their life.

Relaxation

One way to reduce stress and improve mental well-being is relaxation. Relaxation is defined by the American Psychology Association (2018) as: "abatement of intensity, vigor, energy, or tension, resulting in calmness of mind, body, or both" (para. 1). This can be achieved with several relaxation techniques which are described as a set of methods to reduce the body's physiological reaction to stress. The goal hereby is to decrease stress, tension, or anxiety (Hamdani et al., 2022; Norelli et al., 2023). Some of these like progressive muscle relaxation, yoga, relaxation imagery, autogenic training, or applied relaxation often require the help of a trained professional (Hamdani et al., 2022; Klainin-Yobas et al., 2015). Others can easily be practiced at home such as exposure to music, positive imagery, breathing techniques, counting, or exposure to nature (Hyland et al., 2016; Ulrich et al., 1991). Relaxation therefore has the goal of releasing tension and stress, which can be done with or without the help of a professional.

This study will focus on exposure to nature, which does not require the help of a professional. For most people and students, nature is part of the environment around them and easily reachable (Day, 2023). Nature such as parks are mostly located within cities giving people a place to enjoy nature close to them, other nature such as lakes or oceans are often commonly visited vacation places. Relaxation has been found to decrease stress and reduce anxiety and depression among many benefits (Hamdani et al., 2022; Klainin-Yobas et al., 2015; Manzoni et al., 2008). Therefore, nature is something that could be used to help not only students but many different groups of people.

Nature

Physical exposure to nature has been found to have effects on mood, cognition, and well-being (Ulrich et al., 1991). It was found to improve mood by reducing negative emotions like anger and sadness (Bowler et al., 2010). As a cognitive effect it was found to

restore attention from mental fatigue (Mason et al., 2022). Additionally, nature has been found to have a relaxing effect (Kaplan, 1995; Ulrich et al., 1991). This relaxing effect is both psychological and physiological (Park et al., 2007). Students often spend long hours working and neglecting breaks, which leads to mental fatigue, stress, and negative emotions (Yoken, 2022). Exposure to nature could therefore be very beneficial to help students to increase relaxation and cope with stress.

When spending time in nature it is relevant to specify how much time this includes. The ideal time spent in nature to achieve the greatest benefits is not clearly established. Previous research focused on anything between several minutes, to hours, to longitudinal studies tracking exposure over years (Bratman et al., 2012). A study done by Barton and Pretty (2010) analyzed previous studies to find the most effective amount of time spent doing exercise in green nature to have the greatest improvement in mood and self-esteem. Their results were not clear, with 5 minutes being the most effective, an entire day being the second, and the lowest improvement after 10 minutes (Barton & Pretty, 2010). It is therefore not clear yet what the ideal time is, but as little as 5 minutes already has a significant positive effect.

When talking about nature there are many types of nature ranging from forests and jungles, over beaches and snow to deserts. Much research is conducted into blue and green nature (see Jo et al., 2019 and Yao et al., 2021). Green nature means forests, parks, or other vegetation. Blue nature, on the other hand, describes landscapes with bodies of water such as oceans, lakes, or rivers (Jo et al., 2019; White et al., 2021).

While there is support for the positive effects of green and blue natural environments, there is not much research on extreme environments such as deserts (Jo et al., 2019; Yao et al., 2021). A study done by Yin et al. (2022) compared the exposure of a desert to the exposure to a green environment or an office space. This was done in virtual reality. They found that the desert condition had a significant stress-reducing effect on participants and this effect was even stronger than the one from the green environment when the participants indicated that they liked the desert (Yin et al., 2022). However, this study was only done on male residents of Texas, who are all familiar with the dessert. It is therefore not clear if the same effect could be observed in residents who are not familiar with such environments or of different gender. However, this research will focus on green and blue environments since there is not enough support for the effectiveness of brown nature. Additionally, blue and green environments are more familiar and accessible to most people than brown

environments. Therefore, the effects of these environments are a bigger interest in the search for effective relaxation methods.

The effects of green nature are well-researched and include many positive mental health benefits. White et al. (2021) compared green and blue nature and found that visiting green nature was positively associated with higher well-being, lower mental distress, and the use of anti-depression medication (White et al., 2021). Other research regarding nature environments that has been conducted compared green landscapes such as urban green spaces or forests to urban spaces (Bratman et al., 2012). They found an increased positive effect, reduced anger, lower stress, feelings of comfort, feeling refreshed and calm, and relaxation of body and mind (Hartig et al., 2003; Lee et al., 2009; Park et al., 2007). Green nature therefore offers many positive effects, which are mostly derived from comparing green nature to urban spaces.

Blue nature, on the other hand, is less researched but has also been found to have some significant benefits. The study by White et al. (2021) found that visiting coastal nature spaces was positively associated with using anxiety medication. They suspected that people with anxiety use these places as a form of self-management for their calming effects (White et al., 2021). Another study by Yin et al. (2023) found that blue nature was effective in reducing the activity of the sympathetic nervous system. Since this system is responsible for the fight or flight response of the body, a reduction of activity will lead to a relaxing effect and a reduction of stress (Alshak & M Das, 2023). Based on this research, blue most of all seems to have a significant calming and relaxing effect.

There are therefore some suspected differences in the effects of blue and green nature, with blue being more relaxing and green having different effects on mood. Exposure to nature can be an efficient intervention especially attractive to students as it includes no costs, is easy to reach, and is time efficient. However, not all of nature is easily accessible for everyone and this accessibility could also change in the future due to climate change and further destruction of nature (United Nations, 2019). This is why new technologies using a display of nature are promising tools for research and to induce relaxation.

Virtual Reality

Virtual Reality (VR) describes the use of computer technology to show a 3D image of an environment (Bryson, 2013). This makes it possible to show nature realistically. VR has several advantages compared to classical 2D pictures as well as outdoor environments. Compared to outdoor nature, it makes it easier to explore places that are far away or hard to reach. In this context, it also makes it possible to explore different environments in less time

and at a lower cost. Another factor is the increased destruction of rare nature, which leads to environments that might be lost in the future (United Nations, 2019). That is why looking for alternatives is crucial to secure the positive effects of nature in the future. VR offers an opportunity to visit these places and makes them accessible. In the context of research, VR also has the benefit of providing a controlled comparable environment across participants. Especially when looking at the future and the accessibility of nature, VR is a promising tool.

Another advantage of using VR is that it is potentially suitable for target groups that have impaired movement or other health problems such as elderly people or people in hospitals. Since it is not possible to test interventions on these target groups directly as they are sensitive, oftentimes skeptical or scared of new technologies, and hard to reach, testing this on healthy students is an effective solution (Nymberg et al., 2019). Students can help explore the benefits and possible barriers of VR nature to finally present a simple and user-friendly solution to sensitive groups. In this way, sensitive target groups as well as students could benefit from the exposure and experiments with VR nature.

VR also has benefits over older, more established technology. Compared to 2D pictures, VR shows more complex and realistic visual stimuli, which have been found to lead to psychological benefits including a relaxation effect (Jo et al., 2019). Another study done by Reece et al. (2022) compared the effects of VR on well-being compared to flatscreen exposure. They found anxiety-reducing effects for both conditions but suggested a higher immersion for the VR condition. VR is therefore more suitable to induce positive effects such as relaxation than traditional 2D pictures and videos are.

VR nature can be used to effectively induce relaxation. A literature review done by Jo et al. (2019) looked at several different indoor experiments on the effect of nature. They found that relaxation effects and stress reduction were the results reported by most of these studies. Additionally, Browning et al. (2020) found similar effects for real nature and VR nature especially related to positive mood levels and restoration. They compared the same nature environments in VR and outdoors. In conclusion, VR has been found to show similar effects to real nature and to induce relaxation. In combination with the accessibility, the threat of lost nature in the future, and the promise for future usability besides students, it makes VR a promising research and therapy tool for relaxation.

Aims/Current study

Relaxation is an important strategy to reduce stress and negative mental well-being in university students and potentially other target groups later. One way of achieving this is by exposure to nature. Blue nature has been suggested to be more relaxing than green nature,

which could lead to a higher reduction in stress. Since different nature environments are not always accessible, VR can be used to replace real nature. The difference between green and blue nature in the context of VR, however, has not been researched.

This study will focus on the relaxation effect of blue compared to green nature environments in VR. The research question of this paper is: What are the effects of blue compared to green virtual reality environments on relaxation in university students?
The hypotheses are:

1) Both VR nature environments will induce a significant relaxation effect in students.
2) Blue VR nature environments will induce a significantly higher relaxation effect compared to green environments in students.

Methods

Participants

34 participants were recruited with volunteer and convenience sampling using the platform SONA from the University of Twente and personal contacts. The sample consisted of 16 female (47%) and 18 male (53%) students. The mean age was 22, with an age range from 18 to 27. The majority, 23 (67.7%) of the participants studied psychology followed by 5 participants studying business (11.8%), and seven studied other subjects (20.6%). The nationalities of the participants were mostly German (47%), and equally as many Dutch (26.5%) as other nationalities (26.5%).

To account for order effects, participants were allocated to two conditions (blue and green). Both conditions watched both environments but in a different order. Both conditions, the green and blue one had 17 participants. All participants signed an informed consent and were informed that they could withdraw from the study at all times. The study was approved by the ethics committee of the University of Twente.

Materials

A quiet room with a chair and table for the participants was used to conduct the experiments. They were presented the questionnaire in the software Qualtrics using a computer or laptop. This questionnaire included study information (see Appendix A), informed consent (see Appendix B), demographic questions, and the Relaxation State Questionnaire (RSQ) (see Appendix C). The demographic questions included age, gender, nationality, and study field. After those, the participants had to indicate how much they agree on a Likert scale ranging from “strongly disagree” to “strongly agree” to the following statements: “I enjoy spending time in nature.” and “I have experience with virtual reality”.

The RSQ was used to measure relaxation. It measures the current subjective relaxation of people and can be used to assess the effectiveness of relaxation exercises (Steghaus & Poth, 2022). The questionnaire consists of 10 statements, where the participant has to indicate how much they agree with the statement on a Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5). An example of such a statement is: "Right now, I feel completely calm" or "My muscles feel relaxed". The questionnaire was found to have high reliability ($\alpha = .86$) and good construct validity. It was validated using a sample of university students and non-students in Germany (Steghaus & Poth, 2022). In this sample, a low reliability ($\alpha = .45$) was found.

To present nature environments, YouTube videos were used and presented to the participants using the Meta Quest 2 headset with controllers. The video used for the green environment is titled: "Poppy Field, Armenia. Relaxation video in 8K." from the channel "AirPano VR" (AirPanoVR, 2022). It shows a poppy field with mountains in the background (see Figure 1). The video is two minutes and 17 seconds long and includes music, for this study, it was played at 0.5 speed and muted, which means the participants saw it for four minutes and 34 seconds. For the blue environment the video "Malibu Beach - VR 360 - 4K Video - Soothing Surround Beach Sounds - ASMR CaliScapes" from the channel "Highway Forty Productions" was used (Highway Forty Productions, 2019). It shows a beach and the ocean (see Figure 2). The video is 31 minutes and 56 seconds long and includes ocean sound, however, for this experiment, only the first 5 minutes were shown and the video was muted.

Figure 1

Green VR Environment

Figure 2

Blue VR Environment

Verbally, the participants were asked two questions: “Which environment did you prefer?” and “Why, which aspects did you prefer?”. These were open questions and the participants were free to reply. There were no probes or follow-up questions. The responses were noted down in a Word document.

Design

The dependent variable relaxation was measured using the RSQ. To investigate the differences in relaxation, the independent variable nature environment had two levels. These were green (“Poppy Field, Armenia. Relaxation video in 8K.”) and blue (“Malibu Beach - VR 360 - 4K Video - Soothing Surround Beach Sounds - ASMR CaliScapes”). For this, a within-groups/ repeated measures design was used. All participants were exposed to both levels of the independent variable, but in a different order to avoid order effects. This led to two conditions. The green one (the ones who viewed the green environment first) and the blue one (the ones who viewed the blue environment first). However, both conditions so all participants, watched both environments and filled out the same questionnaires.

Procedure

The experiments were conducted in a lab room of the University of Twente, personal environments of the researchers or the participants. Before the participants arrived, the videos were prepared. They were both muted, and the green video was put on 0.5 speed. After that, the participant was assigned to one of the two conditions. They were allocated taking turns so that one participant watched the green environment first (green condition) and the next participant watched the blue environment (blue condition) first. This was repeated for all participants to make sure the conditions were equal. When the allocation led to uneven distributions, this was evened out by allocating more participants to the conditions with fewer participants. When the participants arrived, they were informed about the study, what they

were expected to do, how long it would take, and that they could ask questions or leave at any time. They were shown the laptop or computer where the software Qualtrics was open, which was used for the entire questionnaire.

The questionnaire started with study information, informed consent, and some demographic questions. Then participants were asked how much they enjoyed spending time in nature and if they had experience with VR. After that, they filled out the RSQ. At this point, a message was shown asking them to inform the researcher since the first part of the questionnaire was completed. Participants were then shown the VR headset, which was adjusted to their heads. After that, it was put on and they were shown the first nature environment. Depending on the condition this was either the green or blue environment first. For their safety, they were told to remain seated and encouraged to only look around. After 5 minutes (or 4.34 minutes for the green environment), the participants were asked to take off the headset and continue the survey. This time, only the RSQ was to be filled out. After completing this, participants were shown the second environment for 5 or 4.34 minutes. This process was the same as with the first environment where the participant was asked to stay seated but encouraged to look around. Afterward, the RSQ was filled out one more time. Following the completion of the survey, the participants were verbally asked which environment and what aspects of it they preferred. After thanking them for participation the participant received credits on the platform SONA if they signed up using it. The whole process took about 25 to 30 minutes. The collected data was anonymous and only the researcher had access to it.

Data Analysis

At first, the dataset was exported from Qualtrics as a csv file. It was then imported into RStudio. The packages “dplyr”, “tidyr”, “ggplot2”, “readr”, “magrittr”, “psych” and “lmtest” were loaded. Then the data was cleaned and renamed. For this, variables that were not relevant were deleted and variables were renamed to make it recognizable what they measure. After that, the descriptives of the sample were calculated.

The data was then prepared for analysis. For this, only the variables for the condition (blue or green) and the questionnaire (RSQ result of pre-measure, post-blue, and post-green) were kept. First, the descriptives of the variables (pre-measure, post-green, and post-blue) were calculated. This included mean, standard deviation, median, and range. The data was then further prepared. For this, the condition variable was recoded into numeric responses and the questionnaire was scored. This was done by re-coding the statement responses into numeric responses, herby “strongly disagree” was counted as a 1 and “strongly agree” as a 5.

For four items, the scores were reversed. This means that, the higher the score is, the more relaxed a person is. After that, the scores for each variable (pre-measure, post-green relaxation, and post-blue relaxation) were added up and made into a new dataset. This dataset then only included the sum for each of the three relaxation variables and the variable condition.

Normality Testing

After that, the dataset was checked for normality. First, the normal distribution of residuals was tested by making a histogram and Quantile-Quantile (Q-Q) plot. The results were then tested again with a Shapiro-Wilk test. Homoscendacity was tested by plotting the residuals. If the results of this are not clear enough, a Breusch-Pegan test will be done to confirm them. To rule out autocorrelation, a Durbin-Watson test was done. After that, boxplots were done to test for outliers. Lastly, a scatter plot and Pearson Correlation testing were done to test for a linear relationship. All of these were done for all variables.

Order Effects

Before the analysis of the hypothesis, a linear regression analysis was conducted to control for order effects. Hereby, the effect of the variable condition on the post-green and post-blue relaxation was checked.

Analysis of the Hypothesis

For both hypotheses, the same analysis was conducted. If the data were normal, a linear regression was conducted to test if the independent variables post-green and post-blue had a significant negative effect on the dependent variable relaxation. After this, the output was analyzed in two ways. First to assess the first hypothesis, that both have a significant negative effect on relaxation. After that to assess the second hypothesis, that blue will have a significantly higher negative effect.

If the data was non-parametric a Spearman rank-order test was conducted. This was done for the relationship of the pre-measure to the post-blue and then again for the relationship to the post-green condition. If the results were significant, the second hypothesis was assessed by comparing the strengths of the relationships.

Results

Descriptives

The descriptives of the three variables, pre-measure, post-green, and post-blue are shown below in Table 1.

Table 1

Descriptives of pre-measure, post-green, and post-blue variables

	M	*SD*	*Mdn*	Range	Possible Range
Pre-measure	32.55	4.1	33	22-39	10-50
Post-green	33.88	6.4	33	19-47	10-50
Post-blue	37.42	4.4	36	31-49	10-50

Note. The possible range describes the minimum and maximum score that could be reached in the RSQ.

Normality

The results of the normality tests indicated a non-parametric dataset. To test the normal distribution of residuals a histogram was done. This did not make clear if the green condition had a normal distribution (see Appendix D), to clarify this, a Q-Q plot was done. This shows that the residuals follow a normal distribution, as they follow the reference line, representing a perfect normal distribution, closely (see Appendix E). To confirm this a Shapiro-Wilk normality test was done. This resulted in $p = .535$ for the blue condition, $p = .664$ for the green condition, and $p = .223$ for the pre-measure. Since all the p-values are higher than the significance level $p > .05$, the null hypothesis failed to be rejected, which led to the conclusion that the residuals are approximately normally distributed.

The assumption of homoscedasticity was assessed by plotting the residuals (see Appendix F). There was no clear pattern or trend and the scatter appeared random. To rule out a pattern in the blue condition, a Breusch-Pegan test was done. Since the outcome showed no significant *p*-levels (blue $p = .914$ and green $p = .413$), it was concluded that this assumption was correct.

To test if there were violations of independence, autocorrelation was tested. For this, a Durbin-Watson test was done. The test gave a dw = 1.56 with a $p = .115$. This shows no violation of independence.

The dataset was then checked for outliers. For this, a boxplot was used (see Appendix G). This indicated one outlier for condition blue, since it was only one outlier, which was not extreme, the dataset can still be considered as normal.

Lastly, to assess if there was a linear relationship between the variables pre-relaxation and post-green and the variables pre-relaxation and post-blue a scatter plot was done. The results for blue (see Appendix H) as well as for green (see Appendix I) did not show a linear relationship. To confirm this, a Pearson correlation test was done. This showed a Pearson correlation coefficient of $r = .29$ for blue and $r = .13$ for green. Blue, therefore, has a weak linear relationship, while green has none. The dataset can therefore not be considered normal.

Order effects

The results of the linear regression analysis indicated no significant effect of the order of environments (condition variable) on the relaxation measures post-green ($R^2 = -.02$, $F(0.47,1) = 32$, $p = .497$) and post-blue ($R^2 = .01$, $F(1.41,1) = 32$, $p = .244$).

Analysis of the Hypotheses 1 and 2

For the first hypothesis, to determine if the environments induced a significant relaxation effect, two Spearman rank correlation tests were done (see Table 2). This was done since the assumption of linearity was violated. The Spearman correlation of the relationship between the pre-measure and the post-green was positive but not significant (r_s (32) = 0.13, p = .448) (see Figure 3). The second Spearman correlation was done for the relationship of the pre-measure and the post-blue measure. The results indicated a positive non-significant relationship (r_s (32) = 0.26, p = .143) (see Figure 4).

Table 2

Spearmans rank correlation rho

	rs	*S*	*p*-value
Pre-measure and post-green	0.134	5664.9	0.448
Pre-measure and post-blue	0.256	4867.1	0.143

Figure 3

Scatterplot of variables pre-measure and post-green

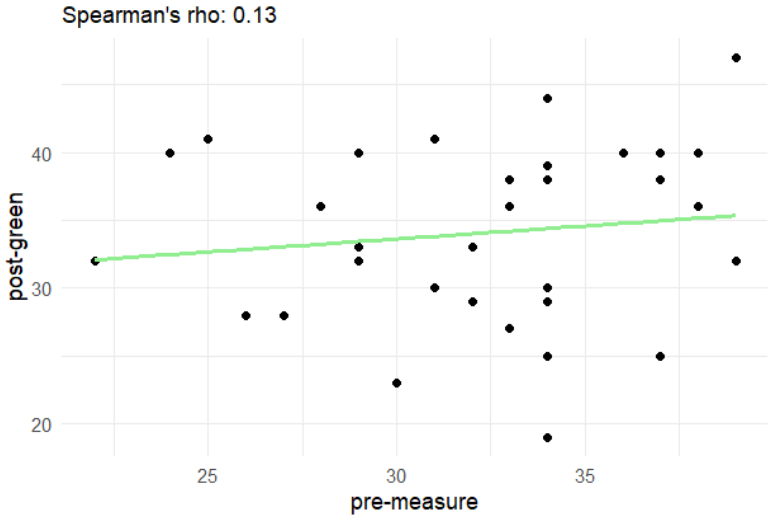
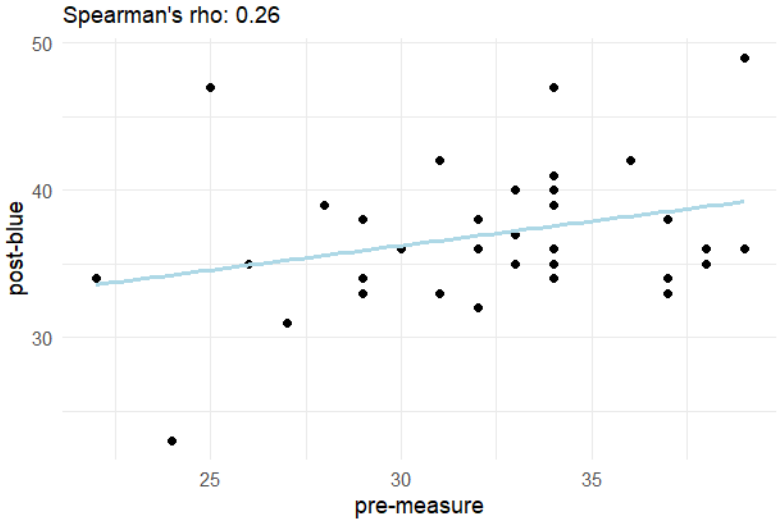


Figure 4

Scatterplot of variables pre-measure and post-blue



Preference of Environment

Out of the 34 participants, 29 expressed a preference for one of the environments. The other five participants did not state one they liked more. 13 (45%) participants liked the blue environment better and 16 (55%) preferred the green one. The reasons for this varied a lot and some participants gave more than one reason. For the blue environment the most common reason, reported by 7 people, was that the participants experienced it as calmer or more relaxing. Other reasons, as reported by two people, were their love for the sea or childhood memories. One person mentioned that this environment felt more real to them,

while another stated that they simply did not like the other environment. Two people did not have a reason for their preference.

The most common reasons as mentioned by four people, for preferring the green environment over the blue one were the far view and the flying over the valley. Three people mentioned that it reminded them of home and it was familiar. Other reasons were just a preference for green generally, not liking the other videos, liking the mountains in the video and mountains generally, experiencing it as calmer, more real, or being more impressed. Each of these reasons were mentioned by two people. One person said it makes them happier and another one expressed that it portrays what beauty means to them.

Additionally, seven participants mentioned that they missed sound to fully feel integrated and immersed in the environment. Two participants also mentioned missing smell and two others mentioned wishing to have more time in the green environment. Next to that, four participants mentioned not liking (part of) the green environment since the flight over the canyon frightened them and mentioned a fear of heights which was triggered. They said that this experience made the video less relaxing than it was in the middle part, where the viewer was simply sitting on a poppy field.

Discussion

Summary of Findings

The results of the experiment showed no significant increase in relaxation after exposure to either a blue or green environment. Therefore, the first hypothesis was rejected. Since neither of the conditions had a statistically significant effect, they cannot be compared. No greater relaxation effect of the blue environment was therefore found, which means the second hypothesis was rejected as well. The research question of this study was: What are the effects of blue compared to green virtual reality environments on relaxation in university students? Based on the results obtained during the experiment, the question cannot be fully answered, since no differences in blue and green nature could be established. This could either mean that there are no differences or that this study was not able to find them.

This experiment divided participants into two groups, who differed only in the order they watched the two nature environments. However, there were no order effects found. This means that the condition variable (watching blue or green first) did not have an effect on the relaxation measure after the blue and green environment.

The findings that there were no significant effects of the green and blue VR environment on relaxation are not in line with other research. Green VR nature has been shown to increase relaxation in many studies (see Jo et al., 2019). There is also a significant

amount of research pointing towards the relaxing effect of real green nature (Lee et al., 2009; Park et al., 2007). The same can be said for blue nature, where research suggests a significant effect, specifically of the ocean, on relaxation (Anderson et al., 2017; Jo et al., 2019). In this research, there were no significant effects found, however, seven out of the 13 people who preferred the blue environment, mentioned that it made them feel calm and relaxed. Exposure to real, blue nature has also been repeatedly found to increase relaxation (White et al., 2021; Yin et al., 2023). There therefore has to be another explanation as to why this was not transferable to VR environments in this study. The research question can therefore not be answered in this study, since important variables were missing or other factors caused that this study did not find the same results as previous research.

Theoretical Implications

One implication is the importance of a holistic experience of picture and sound. A missing variable of the experience of nature in this study could have been sound. Some participants mentioned that they missed sound to fully feel integrated into the environments. Since sound is a vital part of our experience of nature and is always present in real life, this might be a variable that needs to be added. Nature sounds in green nature have been found to increase relaxation (Song et al., 2023). When combining VR nature and nature sounds, higher relaxation measures are therefore possible. A Study by Annerstedt et al. (2013) compared the exposure to a VR forest with and without sound to a control group. With the help of a virtual stress test, stress was induced in all three groups. After that, they were exposed to the environment. They found that the group with visual and audible nature stimuli showed a stress reduction, while the other two showed no significant changes (Annerstedt et al., 2013). The same has been found for blue nature, where listening to ocean sounds can reduce stress and induce relaxation (Largo-Wight et al., 2016). When combining sound and visuals in VR nature it might be possible to increase relaxation in a significant way.

The results of this study also point towards a difference in the effectiveness of exposure to nature in people with low or no stress. This might also be another possible reason for the lack of significant results. The highest possible score in the RSQ was 50, when looking at the mean of the pre-relaxation measure, this is an elevated score (see Table 1). This indicates that participants were already somewhat relaxed when they arrived at the experiment. As mentioned earlier other research such as the one done by Annerstedt et al. (2013) induced stress in the participants before conducting the experiment. This was not done in this study, which could explain the lack of significance. It also shows that exposure to

nature might only induce significant relaxation when the person is stressed, for people with low stress, nature might not have a similar effect.

Limitations and Strengths

Limitations

This study has several limitations which might have impacted the results and need to be remembered when interpreting these. One problem was that the questionnaire in this sample had low reliability. In the study done by Steghaus & Poth (2022) it showed high reliability, this was, however, not the case in this sample. The questionnaire is relatively new as it was only used by two other studies (see Dietze & Poth, 2023 and Schmidt et al., 2024). These did not report the reliability of the questionnaire, which is why it is uncertain if the reliability was only low in this study or if it is a problem with the questionnaire. If the questionnaire has low reliability the results have to be treated with caution and might not be accurate.

Another problem that arose during the selection of the videos as well as during the experiments was the lack of sufficient quality. The selected videos were 4k (blue) and 8k (green), which is sufficient (see Wu et al., 2018). However, with the internet that was accessible, it was not always possible to display the video at this quality. Therefore, the picture was not as sharp and clear as hoped. As summarized by Jo et al. (2019) VR provides a benefit over 2D measures since it provides more realistic and detailed stimuli. When this is, however, not given due to the lack of quality, the advantage could be lost.

Additionally, there were very divided opinions about the video of the green environment. This video, unlike the blue nature one of the ocean, was not stationary but moved in the beginning and end. In these sequences, the viewer was “flying” over a canyon. Some participants described this as: “more interesting” and, “seeing more” or expressed that they enjoyed it. Others, on the other hand, mentioned a fear of heights, or even described it as “frightened”. This could have led to a reduction in relaxed feelings. Since fear of heights, which includes feelings of anxiety and unsettlement, can be induced by VR, this could have caused a less relaxing experience for some participants (Krupić et al., 2021). Since this video had different parts and ended with the experience of flying, this could have reduced the relaxation that was induced in the middle, stationary, part.

Strengths

Besides these limitations, this study also had some strengths which could benefit future research. The study design allowed participants to explore two different environments and later express their opinions on which one they preferred. As a reason many participants

named personal reasons such as connecting the environment to a childhood memory, familiarity, personal definition of beauty, or just a feeling of preference. This could support the findings of Tsutsumi et al. (2017). Their study measured the participants' preferences using the Visual Analogue Scale (VAS). The participants then viewed only their preferred environment, which could be a forest or the sea. The results showed that viewing their preferred environment led to an increase in several relaxation measures.

In this study, however, participants got to explore both environments and then express their opinions and preferences. By following this setup, it could be further investigated if preference induced a higher relaxation or if the difference is not significant. There is already some research suggesting this effect (Anderson et al., 2017; Yin et al., 2022). Anderson et al. (2017) suggested that the preference of the environment matters in how strong the effect is. Yin et al. (2022) also found that people who liked the desert had a stronger relaxation effect than from a green environment. This study was not able to find significant results, the study setup however could be used to further asses the role preference plays in the effects of VR nature.

Another strength of this study was, that it was relatively easy to set up, which makes it easy to replicate and adjust. It also took relatively little time, since participants only spent 25 to 30 minutes viewing environments and filling out the questionnaire. Since the RSQ measures subjective, perceived relaxation, no other measurements were needed. This makes it possible to have a bigger group of participants in future studies, include more variables, and still have reasonable requests for participants.

Directions for Future Research

Based on the findings and limitations of this study, there are a couple of directions and ideas for future research. Firstly, the inclusion of nature sounds would be important in further studies. Sound of nature environments has been found to increase relaxation (Largo-Wight et al., 2016; Song et al., 2023). Additionally, it was mentioned by participants in this study, as missing. By adding it to studies researching the effects of VR nature, VR could be made even more realistic and potentially have more significant results (Annerstedt et al., 2013). When implementing sound into this study, the research design could be done with four instead of two groups. Herby, two groups (one watching blue first and one green first) would receive sound, and two would not. It could then be assessed what the benefits of sound are and if there is a difference in sounds of green nature compared to sounds of blue nature.

Additionally, a prior stress test could be done with participants to induce stress in them. In this study, the participants were already moderately relaxed when they started the

experiment, which could be part of the explanation for why the increase in relaxation was not significant. By inducing stress before, an increase in relaxation could be better measured. Especially since the RSQ measures perceived relaxation, this difference might be easier for the participant to recognize. Additionally, it might be closer to the later application as people using relaxation methods often seek to reduce stress levels (Hamdani et al., 2022; Norelli et al., 2023). The research then would have to be a between-groups design with one group viewing the blue environment and one viewing the green one. This was done by Annerstedt et al. (2013), however, they did not compare blue and green nature, which is the goal of this study. By adding a stress test before viewing the environments, the effects of blue and green nature on stressed people and the effect of relaxation could be measured better.

To solve the problem with the differences in videos, two stationary or two moving videos should be used in further research. When selecting the videos it should also be considered that people might experience fear of heights and therefore no cliffs or flying sequences should be included. By making the videos better comparable and taking out the stressing effect of "flying" experience, more accurate measures of relaxation could be taken.

Another topic for future research could be green exercise. Green exercise means doing exercise in nature (Barton & Pretty, 2010). Nature as well as exercise, such as yoga, has been found to increase relaxation and other measures of well-being (Agarwal, 2013; Shephard, 1997; Ulrich et al., 1991). This was also investigated by Barton and Pretty (2010) who found that green exercise led to improvements in self-esteem and mood. They also found that when water was present, the effects were greater. This was, however, done in real nature, therefore the effects of green exercise in VR could be explored in future studies. Therefore, exploring the effects of green exercise in blue or green nature are not researched yet, but could potentially increase the effects of simply watching nature.

Lastly, the sample of this study consisted of only students as is also the case in much of the VR research done so far, as summarized by Jo et al. (2019). In future research, this sample should be expanded to include other demographics to make the findings generalizable.

Practical Implications

Some practical implications result from this study. First, the quality of the videos plays a significant role. Important to consider here, are not only the quality of the video used but also the internet quality that is accessible. This is important to consider when using VR technology in areas with no or only slow Wifi connection. Other options such as downloading video could be used to ensure the swift usage of VR nature.

VR nature has some potential benefits for target groups who are not able to access nature regularly. This includes elderly people or people in hospitals. Even though this research did not find significant results, other research did (see Jo et al., 2019). Since there is a lot of research proving the effectiveness of green nature, and mixtures of green and blue nature, it can be assumed that it is effective and this study simply did not include all relevant variables. A literature review by Ulrich (2002) found that gardens in hospitals decrease stress and improve clinical outcomes in patients. For patients who cannot leave their bed to go to a garden, VR nature might be beneficial to provide them with the positive effects of nature without the strain of leaving their bed.

In the same way, elderly people in retirement homes could benefit from VR nature. Gardens have been found to increase well-being and health outcomes (Ali et al., 2020; Rappe, 2005). As an addition to gardens, for people whose mobility is restricted or for winter or bad weather, VR nature could be used to achieve the positive benefits nature has to offer. Elderly people often are reluctant to use new technology as they are unsure of how to use it (Nymberg et al., 2019). However, when research is more established and the benefits clear, it could be explained and assistance given to elderly people to learn new technologies such as VR. Therefore, in the future VR nature could be used in retirement homes to increase the mental and physical health of residents.

Conclusion

The research question about the different effects of blue compared to green VR nature on relaxation cannot be answered in this paper. Instead of replicating and expanding on previous research, this study pointed toward the difference in the effect of nature on already relaxed people compared to stressed people, the importance of sufficient video quality, the inclusion of sound, and the role of preference when using VR nature videos to increase relaxation. Future VR research can focus on these aspects to use the advantages of VR nature to benefit many people.

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Appendix

AI statement

During the preparation of this work, I used Grammarly for spell and grammar checks, EndNote21 for citations, RStudio for data analysis, ChatGPT to understand and solve error messages in RStudio and Scopus, and Google Scholar as search engines. After using these tools and services, I thoroughly reviewed and edited the content as needed, taking full responsibility for the final outcome.

Appendix A

Study Information

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 continue 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:

Johanna Völkening (j.b.volkening@student.utwente.nl)

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

Appendix B

Informed Consent

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

Relaxation States Questionnaire

My breathing is faster than usual. (R)

My heart is beating faster than usual. (R)

My muscles feel tense and cramped (clenched fist and/or jaw; furrowed brow). (R)

My muscles feel relaxed.

My muscles feel loose.

I'm feeling very relaxed.

Right now, I am completely calm.

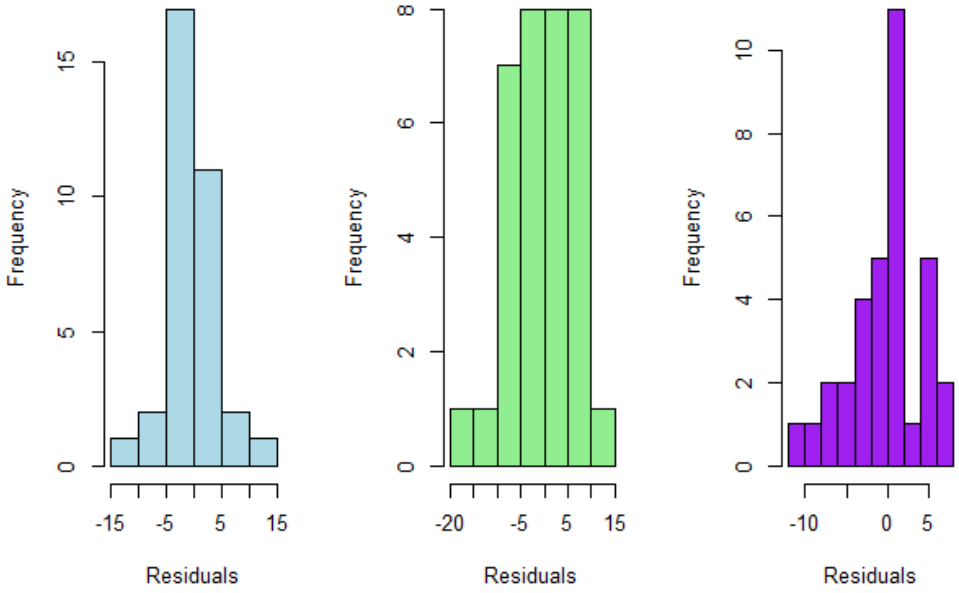
I'm feeling sleepy and tired.

I'm about to doze off.

I'm feeling refreshed and awake. (R)

Appendix D

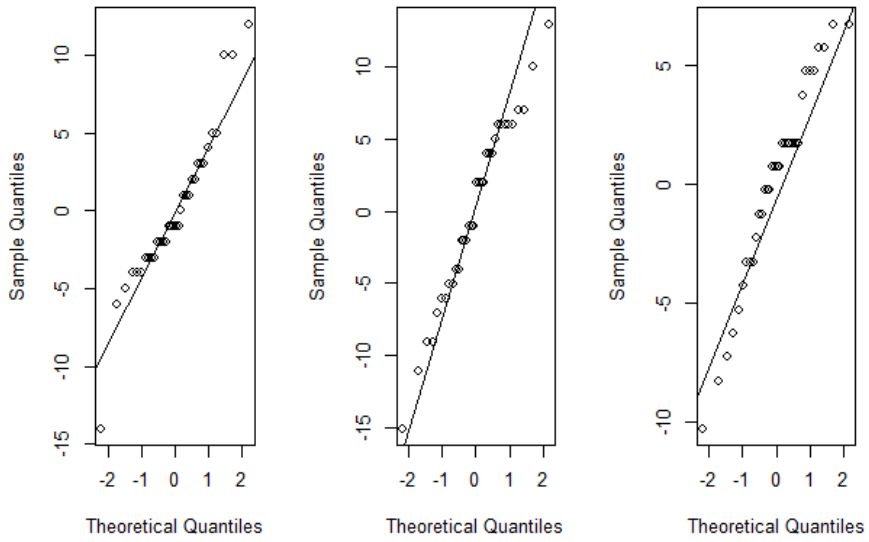
Histogram of the Distribution of Residuals



Note. In the order blue, green, pre-measure.

Appendix E

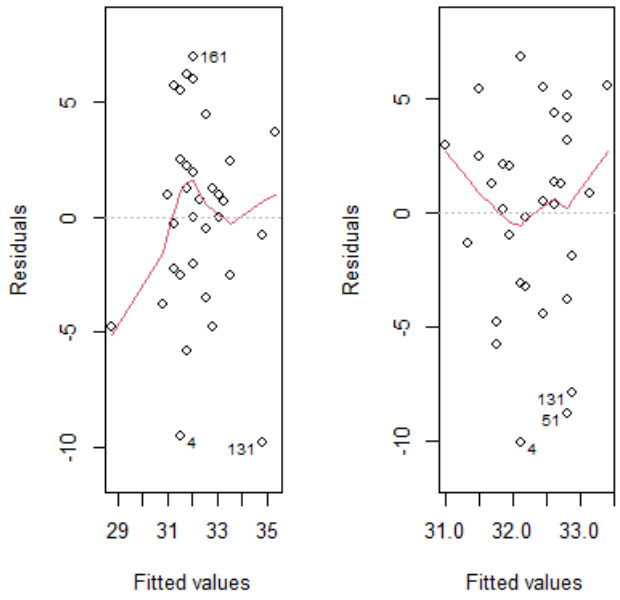
Normal Quantile-Quantile Plot of Residuals



Note. In the order blue, green, pre-measure

Appendix F

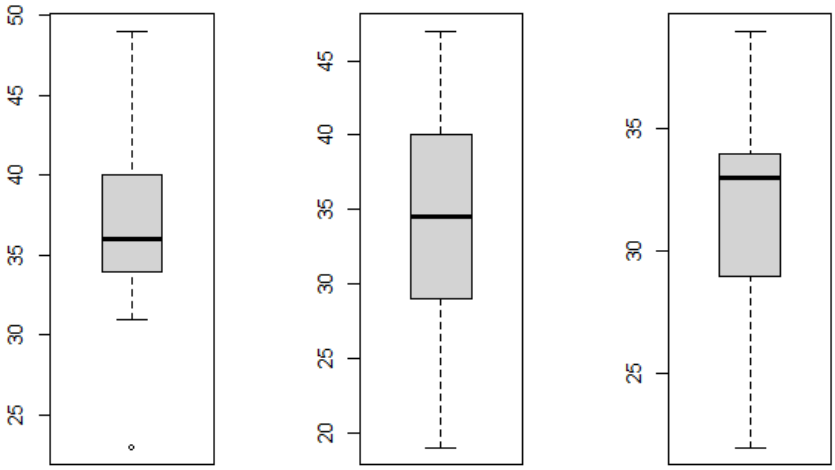
Plot of Variance of Residuals (Residuals vs Fitted)



Note. In the order blue, green.

Appendix G

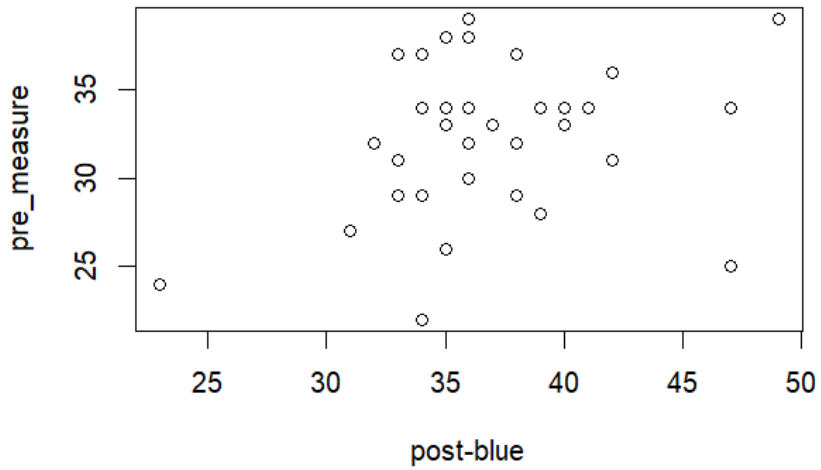
Boxplots



Note. In the order blue, green, pre-measure.

Appendix H

Scatterplot of the variables pre-measure and post-blue



Appendix I

Scatterplot of the variables pre-measure and post-green