# 360° view of nature: virtual reality 3D nature environments versus 360° nature videos and their effects on positive and negative affect levels, sense of presence, and nature connectedness in university students

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**Abstract**

This paper examines the differences between a 360° video of a real forest and a 3D model of a forest in virtual reality and their effects on affect levels, nature connectedness, and sense of presence on university students. Momentarily and in the past, university students have been a population at risk of lower general wellbeing as they struggle with high academic pressure, the after-effects of COVID-19, and financial burden while receiving little support. Spending time in nature can provide multiple benefits to one's wellbeing, such as increasing positive affect, vitality, and life satisfaction. However, not every student has access to nature.

Literature shows that virtual nature environments can provide an alternative to real nature exposure with short exposures such as 5 minutes, thus this study compares two mediums to investigate their differences. The population included mixed gender and nationality students of the University of Twente within the same age range (18-28) who were recruited via SONA and convenience sampling. The 3D-VR condition was comprised of 21 students, while the 360-VR condition was comprised of 20. The participants filled out a survey including three questionnaires, two of which were administered before and after the exposure. The exposure lasted 5 minutes.

The study demonstrates that both mediums are effective at decreasing negative affect levels and increasing nature connectedness, while the 3D environment elicited a higher sense of presence in virtual reality than the 360° video environment. An interpretation of the findings suggests that sense of presence might be a deciding factor for seeing differences between the conditions, particularly the subscale of involvement, as the environments could not be interacted with. Incentive for further research was given, particularly to investigate the role of sense of presence.

## Introduction

### *Wellbeing Among University Students*

The wellbeing of students among higher education is a topic discussed worldwide, and unions like the European Students' Union aim to tackle and support the mental health of students in higher education (Kars et al., 2022). In their comparative analysis, the authors demonstrate how student wellbeing has been increasingly gaining a priority status on local, national, and institutional levels in most countries. This can be traced back to the growing prevalence of mental illnesses by university students such as depression or anxiety in higher educational settings (Rückert, 2015; Kars et al., 2022). Moreover, due to the forced changes that the COVID-19 pandemic brought about, university students have had to adapt to a new academic environment as well as the changes that were made to their everyday lives, e.g., limited social contact, financial burden as many lost their jobs, and personal health threats due to the virus (Allen et al., 2022). The effects of these changes can be observed in the cross-sectional study by Allen and colleagues (2022), who compared psychological distress, anxiety, flourishing and wellbeing in European university students and found that all students reported considerably poorer mental health contrasted to pre-pandemic norms.

While the struggles of university students are increasingly being made aware of, not much has yet been done to counteract this phenomenon (Balon et al., 2015; Kars et al., 2022). Most student unions in European countries, when asked "to what extent [they] feel supported by the higher education institutions in [their] work on mental health" (Kars et al., 2022, p. 11), report that while students' mental health is being discussed and their general point of view is being supported, no developed partnerships have yet been formed to tackle this problem. Moreover, the counselling services that are provided as support by institutions lack sufficient resources and information about what services are available, which prevents students from knowing what support they can expect. Therefore, students hesitate to seek help in the first place (Kars et al., 2022). This paired with the fact that larger-scale interventions such as those asked for by student unions take time, coordination, and training – thus, something that can mitigate these important struggles in the short-term could act as a bridge so that students do not have to wait long periods of time to get support for their wellbeing. Indeed, a short-term preventative measure could help students to counteract some of the negative effects they experience due to their studies and/or post-covid times.

*Positive Psychology and Wellbeing in Nature*

One approach to this problem might be found within the field of Positive Psychology – a field of psychology focused on the positives that surround an individual as well as groups. In Positive Psychology, nature is often treated as one of our resources to ground ourselves and even heal us (Chowdhury, 2022). This can be attributed to the *biophilia hypothesis* by Fromm (1973, as cited by Rogers, 2019) who proposed that humans have an innate affinity for nature and other life-forms. In Positive Psychology, nature as a *quiet environment with living systems such as plants and non-human animals* is thus associated with improvement in psychological wellbeing (Chowdhury, 2022; Monk, 2022). An example of how wellbeing can be affected by nature is in the study by Neill and colleagues (2019), where the researchers investigated the effects of contact with nature in university students on both hedonic and self-transcendent emotions, as well as seeing whether the duration of contact affects the mood improvements. Self-transcendent emotions can be awe, gratitude, wonder, and feeling as though one is part of something greater than oneself – which is typically associated with positive experiences that are not directed towards one's own interests and pleasures. *Hedonic emotions*, on the other hand, are associated with direct attention towards oneself and refer to individual comfort and pleasure – these can be measured through *positive and negative affect levels* and are associated with *mood*. Both hedonic and self-transcendent emotions independently affect wellbeing, but hedonic emotions have the greatest impact on affect levels *directly after* intervention exposure. In Neill et al.'s (2019) first study, 123 university students were assigned to either the indoor condition where they sat in a windowless laboratory room or the outdoor condition where they sat on a bench in an urban park near the border of the university campus for about 5 minutes. Results showed that this duration was ample to increase both positive affect and self-transcendent emotions but did not significantly decrease negative affect. In the second study, they examined whether a longer exposure would result in increased benefit. For this, 70 university students sat quietly in a natural environment for either 5 or 15 minutes – additionally to affect levels, measures of stress, anxiety and depression were taken. Results showed that the exposure length did not increase affect level benefits, thus suggesting that even brief exposure to nature is beneficial to a student's short-term affect levels.

In a recent survey study, Trevino et al. (2022) assessed the impact of nature interactions in student mental health during the COVID-19 pandemic. They found that both active (like walking in nature) and passive interactions (window view) with nature are associated with benefits to students' academic performance, mental health as well as satisfaction with their

academic course. Moreover, higher outdoor exposure was related to lower depression, stress, and academic stress scores. This effect in university students can also be seen in the meta review by Mason et al. (2021), who found that natural spaces like green spaces on campuses or walking in parks with flora and streams lead to short-term increases in both cognition and affect levels. Thus, nature might be a suitable short-term solution to help with students' affect levels. However, nature is not accessible to everyone – many people do not have resources to spend time in natural environments, either because of inaccessibility or due to time constraints. University students are not an exception to this considering their generally tight schedules and having to live in mostly urban or metro environments to be close to their educational institution (Munro et al., 2009).

*Virtual Reality as An Alternative*

Since nature is not easily accessible to students because of time constraints and students typically living in urban environments with little nature, Virtual Reality (VR) can be used to simulate it. Virtual Reality is an immersive technology that aims to give its user an experience through a simulated environment that enables exploration of and interaction with this environment (Sheldon, 2022). Typically, these environments are created with computer hardware and software which can be interacted with through wearable devices such as helmets or goggles. There are different types of VR with varying degrees of immersion, but the one most used in multiple fields of research is *fully immersive VR*. Fully immersive VR completely immerses its user in the simulated 3D environment through sight, sound, and sometimes touch or smell. For this type of VR, special equipment is needed such as a head-mounted display (HMD), controllers, or gloves that are then used to fully interact with the environment and move around. Since VR can be accessed anywhere where the headset is, this makes the medium a suitable, convenient alternative to real nature.

The types of VR often used by nature environment studies are immersive 360° videos (360-VR) or simulated 3D virtual reality (3D-VR) (Yeo et al., 2020; Newman et al., 2022). 360° videos are typically recorded with either a special rig of multiple cameras (e.g., MoooVR), a camera that contains multiple lenses (e.g., Go Pro Max 360) or they are recorded with simultaneous overlapping angles (Donnelly, 2021). This means that they are realistic, since they are a direct, recorded depiction of real nature. Simulated virtual 3D environments are usually models built by humans using specialised programs (e.g., Unity) that one can use on an adequately powered PC. These environments tend to be less realistic, since the costs of making

a 3D model are high (Newman et al., 2022). One advantage to 3D-VR environments is their malleability – since they are built by programmers, they can be adjusted and built upon, unlike 360-VR environments, as these are real depictions of nature. Moreover, 3D-VR environments can be interactive, thus opening up more possibilities to the amount of engagement with and attention given to the environment, allowing for possibly more beneficial effects (Yeo et al., 2020; Ionescu et al., 2021).

*Current Use of Virtual Reality as an Alternative*

The similarities between a virtual nature and a real nature environment were investigated by Reese and colleagues (2022), who compared nature experiences in a virtual forest to a physical forest on stress reduction and increase in wellbeing. To do this, 50 participants were randomly assigned to either the physical forest walk or the virtual forest walk, and pre- and post-measurements were taken of their reported affect levels, subjective vitality, and stress. Participants were told to take as much time as needed but took around 5.7 minutes (physical) and 6.93 minutes (virtual reality) on average to return from their walk. Their findings show that there were no statistically significant differences between the settings on the variables, but stronger effect sizes were found within the physical condition over time. Thus, virtual nature provides a similar experience to real nature even with a short amount of time spent in the environment. Moreover, multiple studies have shown that being in the virtual nature environment for as little as 4 minutes can have significant effects on multiple different variables such as creative thinking, affect levels, or perceived realism in participants (Palanica et al., 2019; Yeo et al., 2020; Newman et al., 2022). Since virtual reality can be accessed anywhere where the headset is, this makes the medium a suitable, convenient alternative to real nature. Moreover, with this technology it is also possible to bring different types of nature to the user, e.g., aquatic environments as done in the study by Yeo and colleagues (2020), which has been shown to reduce boredom and negative affect levels, while increasing positive affect levels. Thus, this technology can also bring new experiences to the user that are harder to experience in real life, and with 3D-VR environments these natural environments can be made interactive, too. But this is more expensive and takes more time than a 360-VR environment would need (Newman et al., 2022).

*Wellbeing in Nature, Virtual Nature, and Nature Connectedness*

Another aspect of the benefits of nature is the aspect of *nature connectedness*. As part of the biophilia hypothesis mentioned earlier, nature connectedness refers to the "individual difference in cognitive, affective, and experiential connection with the natural environment" (Capaldi et al., 2014, p.1). Nature connectedness and its related concepts (such as inclusion of nature in self and nature relatedness) have been found to be positively correlated with subjective wellbeing in terms of positive affect, vitality, and life satisfaction as demonstrated in the meta-analysis by Capaldi and colleagues (2014). An example of this can be found in the study by Nisbet and colleagues (2019), who tested the effect of mindfulness on nature connectedness and affect levels in nature and urban settings with a 20-minute guided walk. To do this, 100 university students were randomly assigned to either a 20-minute guided walk outdoors, one with and one without mindfulness practice, or a 20-minute walk indoors. They found that participants in either outdoor condition reported higher nature connectedness as well as higher mood than the indoor condition, and that participants in the mindfulness outdoor condition reported higher awareness of their surroundings, stronger nature connectedness as well as less negative affect compared to both conditions, but not higher positive affect. Thus, even spending time in nature without being mindful has positive effects on human wellbeing due to higher connectedness to nature.

Since nature connectedness is an important factor for the benefits nature environments can provide, it is necessary that nature connectedness is elicited by virtual nature environments as well. In the study by Yeo and colleagues (2020), the researchers measured nature connectedness before and after exposure to the TV, 360-VR, and 3D-VR condition and found that nature connectedness was increased across all conditions, and that 3D-VR elicited significantly higher nature connectedness than the TV condition, and marginally significantly higher than the 360-VR condition. But this study had an interactive 3D environment, thus the involvement of the participants within the environment was different across conditions.

Chan and colleagues (2021) explored the effects of being in either a natural 3D environment or urban 3D environment on young adults' (study 1) and senior citizens' affect levels and stress (study 2). In study 1 the participants were invited to walk in the same spot, while in study 2 the participants were seated and moved their hands up and down. Study 1 showed that the participants had reduced negative affect as well as reduced stress after the exposure to the natural environment, and study 2 showed improved positive affect, which the

authors contribute to enhanced nature connectedness. Thus, nature connectedness is as important in the virtual nature environment as it is in a natural, non-virtual setting and can be elicited as well.

*Virtual Environments and Sense of Presence*

Immersion and more specifically *sense of presence* is an important piece to VR environments. In the opinion paper by Weber and colleagues (2021), the authors define what presence in VR is and the importance of perceived realism. They describe presence in VR as a two-dimensional construct which consists of the subjective experience of being bodily or physically located in a mediated environment ("being there") and one's perceived realism which is the user's individual judgment on the degree of realism of the virtual environment. Perceived realism can include virtual objects, sounds and scenes, the credibility and plausibility of the story and its' characters, and the naturalness and ease of interaction with the environment. Since the technology makes use of multiple brain areas which are crucial for spatial processing, navigation, and sensory information integration, the user accepts the environment as real, making the potential effects more effective (Sutton, 2022).

Yeo and colleagues (2020) conducted a study where they tested what type of virtual nature is most effective at improving mood. To do this, they compared 3 conditions: a 2D video that was viewed on a high-definition TV screen, a 360° video in VR viewed with an HMD and interacted with using a hand-held controller, and lastly an interactive computer-generated 3D-VR environment which was delivered in the same way as the 360° video. In the study, 96 adult participants took part in a boredom induction task simulating the emotional state of people in healthcare settings and were then randomly assigned to view and/or interact with a virtual underwater coral reef for 5 minutes. They took measurements of boredom, affect levels, nature connectedness and prior VR experiences. The researchers found that while reductions in boredom and negative affect levels were similar in all three conditions, the computer-generated virtual environment showed the greatest improvements in positive affect than the TV condition, which were mediated by higher experienced presence and higher nature connectedness. Thus, presence in the virtual environment is a key factor in the effectiveness of the potential benefits that virtual nature can offer.

*Current Study*

Following from the previous sections, virtual nature environments can possibly make nature and its beneficial aspects more accessible to university students. Yet it is unclear what type of virtual environment can bring the greatest benefits to its user in a cost-benefit efficient way. A 3D environment must be crafted by professionals who are familiar with programming and can use game engine programs like Unity, thus researchers usually rely on 360° videos because they require less skill, time, and money. Nevertheless, researchers point out the potential of 3D-VR due to it being malleable to the individual user's preferences, thus being able to immerse the user even further and enhancing the benefits of the experience (Yeo et al., 2020; Ionescu et al., 2021). Therefore, this study aims to investigate the effects of a 3D virtual reality nature environment in comparison to a 360° nature video on affect levels, sense of presence and nature connectedness of university students. Thus, this research will address the following questions:

a. How does a 3D-VR nature environment affect positive and negative affect levels in comparison to a 360-VR nature video in university students?
b. How does a 3D-VR nature environment affect nature connectedness in comparison to a 360-VR nature video in university students?
c. How does a 3D-VR nature environment affect sense of presence in comparison to a 360-VR nature video in university students?

Following from the research questions, the specific hypotheses were as follows:

1. Positive affect levels will be higher after the exposure to the virtual environment in each condition.
    1.1. Positive affect levels will be higher in the 3D-VR condition than in the 360-VR condition.
2. Negative affect levels will be lower after the exposure to the virtual environment in each condition.
    2.1. Negative affect levels will be the same across conditions.
3. Nature connectedness will be higher after the exposure to the virtual environment in each condition.
    3.1. Nature connectedness will be higher in the 3D-VR condition than in the 360-VR condition.
4. Sense of presence will be higher in the 3D-VR condition than in the 360-VR condition.

With these questions the differences within and between the two mediums will be investigated.

## Methods

### *Participants*

In total 49 students from the University of Twente were recruited in the study using convenience sampling and via SONA Systems, a test subject pool that is used by the University of Twente whose participants are students of the Behavioural, Management and Social Sciences (BMS) faculty. The participants received one test subject hour credit for their participation. On the SONA study overview, the eligibility requirements were "Must be a university student. Cannot have motion sickness and/or a sensitivity to rapidly changing lights". This was also checked with the participants recruited by the researcher using convenience sampling. Due to extreme outliers, eight cases were deleted. Of the remaining 41 participants 13 were male (31.7%), 27 were female (65.9%), and 1 chose to withhold their gender identity (2.4%). The mean age of the participants was 20.41 ($SD$ = 1.802), ranging from 18 to 28 years. Moreover, 5 participants were of Dutch nationality (12.2%), 24 were of German nationality (58.5%), and 12 were of "other" nationality (29.3%). Students who signed up in the first two and a half weeks of data collection were assigned to the 3D-VR condition [$N$ = 21] and students who signed up in the latter two and a half weeks were assigned to the 360-VR condition [$N$ = 20]. Participants gave informed consent prior to the study and could withdraw their consent at any time. Moreover, after participation the participants were debriefed on the two different conditions of the study and could withdraw their consent as well. Ethical approval was granted by the Behavioural, Management and Social Sciences Ethics Committee at the University of Twente.

### *Materials*

Participants completed the study on campus of the University of Twente. The survey was completed on the platform Qualtrics (https://www.qualtrics.com) using the computer Dell Alienware Aurora, which was provided by the BMS lab. The computer was used to run Unity, the program the 3D-VR environment was built in, as well. The device had an Intel® Core™ i7-8700K CPU at 3.70 GHz with a RAM of 32GB on a 64-bit operating system. The Windows edition was Windows 10 Enterprise version 21H2, OS build 19044.2130. The survey included the informed consent form, demographics, a debriefing form and three questionnaires, two of which (PANAS and IINS) were given twice (see Appendix A).

**Positive and Negative Affect Levels**

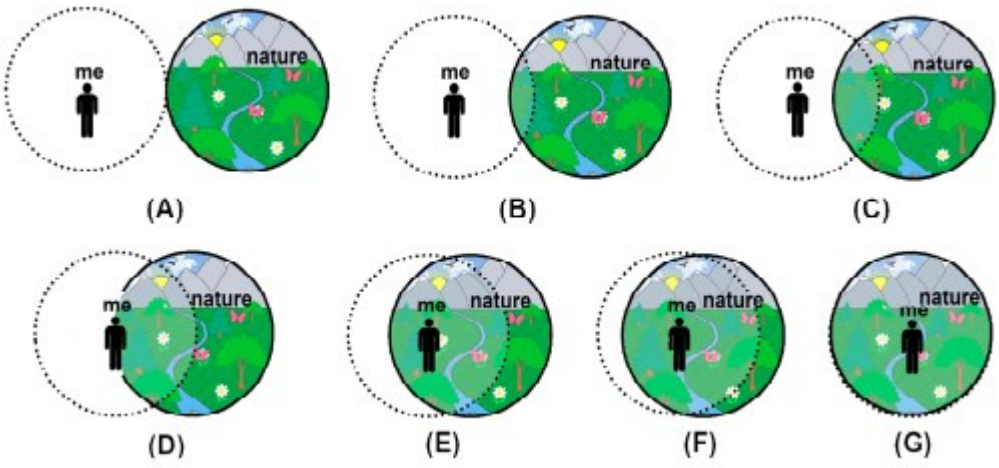
The first questionnaire was the momentary version of the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) with the following instruction: "This scale consists of a number of words that describe feelings and emotions. Read each item and indicate to what extent you are feeling this way right now." This questionnaire was used to measure *positive and negative affect levels.* The scale consisted of 20 items on a 5-point Likert scale (1-5) with 1 being "very slightly or not at all" and 5 being "extremely" (e.g., Positive: item 1: "Interested", item 17: "Attentive"; Negative: item 2: "Distressed", item 7: "Scared"). This 20-item scale has strong psychometric properties with good internal consistency on both positive (α = .89) and negative (α = .85) scales. Test-retest reliabilities of the scales were .54 (positive) and .45 (negative) respectively (Watson et al., 1988). The factors account for 62.8% of the common variance in the moment solution, indicating high scale validity.

**Illustrated Inclusion of Nature in Self Scale**

The second questionnaire used was the Illustrated Inclusion of Nature in Self Scale (IINS), which measures *nature connectedness* (Kleespies et al., 2021). This scale has 7 Venn-Diagrams used as a singular item which have two circles: one with a person inside named "me" and one with an illustration of nature including a forest, river, flowers, clouds, mountains, and the sun as shown in Figure 1. Each letter corresponds to a scale of 1-7.

**Figure 1**

*Illustrated Inclusion of Nature in Self Scale*



*Note.* From "Measuring Connection to Nature – A Illustrated Extension of the Inclusion of Nature in Self Scale," by M. W. Kleespies, T. Braun, P. W. Dierkes and V. Wenzel, 2021, *Sustainability* **2021**, *13,* p.5. Copyright 2021 by the authors.

The instructions for this scale were: "Please indicate which diagram best describes how you feel right now about your connection with nature environments". The participants then put the best matching Venn-Diagram's assigned letter into the survey. This questionnaire was meant to illustrate the original Inclusion of Nature in Self Scale (INS) for people who struggle with abstract concepts. The results showed that there is no statistically significant difference between the original INS and the IINS ($p$ = .247), meaning that the IINS measures nature connectedness as well as the original INS. Moreover, it was shown to correlate moderately positively with other nature connectedness measures such as the CNS ($r$ = 0.570) and NR-6 ($r$ = 0.605) (Kleespies et al., 2021). This version of the scale was chosen because it visualises nature well and replicates what is shown in the VR environments.

**Igroup Presence Questionnaire**

The last questionnaire was the Igroup Presence Questionnaire (IPQ), which measures *sense of presence* in a virtual environment using 14 items on a 7-point Likert scale ranging from -3 to 3. The variable is measured on three subscales – Spatial presence: the sense of being physically present in the virtual environment (e.g., "Somehow I felt that the virtual world surrounded me"; -3 = fully disagree, 3 = fully agree), Involvement: measuring the attention devoted to the virtual environment and the involvement experienced (e.g., "I was completely captivated by the virtual media."; -3 = fully disagree, 3 = fully agree), Experienced realism: measuring the subjective experience of realism in the virtual environment (e.g., "How real did the virtual world seem to you?"; -3 = about as real as an imagined world, 3 = indistinguishable from the real world). There was also one item to measure general sense of being in the virtual environment ("In the computer generated world I had a sense of 'being there'"; -3 = not at all, 3 = very much). The scale showed moderate to high reliability with α ranging from .68 to .87 and has a moderately high construct validity with most items loading above .6 (www.igroup.org – project consortium, n.d.).

*Virtual Environments*

The environment for the 3D-VR condition was provided by the BMS lab and built in Unity 2020.3.28f1. The scenery was of a forest in sunshine with a mountain, flowers, grass, and bushes (see Appendix B). The environment sound was added as an object to the scene and

including rustling leaf noises, wind, and bird tweeting. The video for the 360-VR condition was a 360° video from Youtube recorded and edited by Frederik M. Salhus (https://www.youtube.com/watch?v=NgjkcDNi-jo) and later edited by the researcher in VideoProc Vlogger to incorporate the same sound that was used in the 3D-VR condition. The video itself was recorded in a forest on the mountain Fløyen near Bergen city using a 6-camera GoPro rig and edited in Kolor. The scenery was of a sunny Norwegian forest with bushes, coniferous trees, grass, and wood (see Appendix C). Both conditions were displayed through a Meta Quest 2, which was linked into the computer using the Quest link cable for the 3D-VR condition, but not for the 360-VR condition, thus the 360-VR condition was wireless.

*Design*

This study had a 2 condition between-subjects design, with the conditions being different types of virtual nature environments namely 360-VR and 3D-VR. The independent variable was the condition the participants were assigned to, and the dependent variables were "positive and negative affect levels", "nature connectedness", and "sense of presence". Positive and negative affect levels as well as nature connectedness were measured before and after the exposure, thus a between-and-within-subjects design was employed here.

*Procedure*

All participants were invited to the University of Twente campus to complete the experiment. Every piece of equipment and all surfaces were thoroughly disinfected, and the room was aired out for 5 minutes before and after each participant. The participants were sat in one of the experimental rooms of the BMS lab where they had access to a rotatable chair, a computer for the surveys and an HMD (Meta Quest 2) which was used to play the 360-degree nature video or show the 3D virtual nature environment. The room was quiet and closed off, with windows. The researcher was in a room next to the research participant, but they were not able to see each other. The participant could alert the researcher if they had any questions. Before the exposure, information about the research and informed consent were provided, and data on the participant's demographics were collected followed by their current state of nature connectedness which was measured with the IINS. Afterwards the participant filled out a questionnaire about their current emotional state, which was done using the PANAS questionnaire. Then, the participant was asked to put on the Meta Quest 2 and the exposure to each condition began, lasting for 5 minutes. The participant wore a facial mask that covered the upper face area (forehead – nose tip) for hygienic purposes while they used the HMD. For the

3D-VR condition, the nature scene was played in Unity, and for the 360-VR condition the participants played the video from the Quest TV app installed on the device. In each condition the nature environment was a European forest in summer with the same natural sounds including birds, wind, and leaves rustling. The volume of the sound could be adjusted to the participants' preferences using the volume button that was shown to them, so that they would have a comfortable experience. The 3D-VR condition used a model of a forest whereas the 360-VR condition was a video of a real forest. After the exposure, the participant filled out the PANAS and IINS questionnaires again, as well as the IPQ. Finally, the participants were debriefed on the aims of the study and were asked to confirm or withdraw their initial consent. After the participants finished the survey, they came out of the room and were asked to briefly give their thoughts on the experiment and their experience.

*Data Analysis*

To test the hypotheses, statistical tests were carried out in SPSS 28.0.0.0. Before conducting the analyses, the data set was prepared.

After checking for normality using the Shapiro-Wilk as well as the Kolmogorov-Smirnov tests, the data has been found to be non-normally distributed, thus mostly non-parametric tests were chosen, except for the questions concerning nature connectedness and affect levels, as these variables were measured twice and had to be compared within as well as between conditions.

To use the Wilcoxon Signed Rank Test, the assumption of the distribution of paired differences had to be checked. Thus, the differences in positive and negative affect levels, and nature connectedness pre- and post-exposure were calculated and explored with boxplots to check for symmetry. These boxplots revealed extreme outliers (four in each condition) and were thus removed from the final dataset.

For negative affect levels, the assumption of normality has been violated. However, due to ANOVAs being robust to violations of normality (Blanca et al., 2017, as cited by Newman et al., 2021) and the concern that further reducing the sample size could negatively affect the validity of the results, the mixed ANOVA was carried out regardless. All other assumptions were met.

*Tests*

Three Wilcoxon Signed Rank Tests were carried out for each condition to see whether there is a statistically significant difference in positive and negative affect levels, and nature connectedness before and after 5 minutes of exposure to the virtual nature environment. Affect levels were measured once before and once after the exposure to the virtual environment, the independent variable. To compare affect levels between the two conditions, two mixed ANOVAs were conducted to see whether there is a statistically significant difference between the positive affect and negative affect mean scores and nature connectedness mean score of the two experimental groups. Lastly, a Mann-Whitney U test was conducted to see whether there is a statistically significant difference of the sense of presence mean scores on each of the three subscales as well as the general item between both experimental groups.

**Results**

**1.** *Positive affect levels will be higher after the exposure to the virtual environment in each condition.*

The 5-minute exposure to the 3D-VR environment did not elicit a statistically significant change in positive affect levels in university students ($Z$ = -1.667, $p$ = 0.096, see Table 1).

The 5-minute exposure to the 360-VR environment did not elicit a statistically significant change in positive affect levels in university students ($Z$ = -1.667, $p$ = 0.096, see Table 1). Thus, this hypothesis is rejected.

**1.1.** *Positive affect levels will be higher in the 3D-VR condition than in the 360-VR condition.*

There was no significant main effect of time on positive affect levels ($F$ (1, 39) = 1.95, $p$ = 0.171, $\eta_p^2$ = 0.048). This means that positive affect levels did not differ significantly pre- and post-exposure.

There was no significant main effect of condition on positive affect levels ($F$ (1, 39) = 0.18, $p$ = 0.671, $\eta_p^2$ = 0.005). This means that at the time at which the measurements were taken, positive affect levels were not statistically significantly different across conditions. Thus, the hypothesis is rejected.

There was no significant time by condition interaction on positive affect levels ($F$ (1, 39) = 1.55, $p$ = 0.220, $\eta_p^2$ = 0.038).

**2.** *Negative affect levels will be lower after the exposure to the virtual environment in each condition.*

The 5-minute exposure to the 3D-VR environment elicited a statistically significantly negative change in negative affect levels in university students ($Z = -3.725$, $p < 0.001$, see Table 1).

The 5-minute exposure to the 360-VR environment elicited a statistically significantly negative change in negative affect levels in university students ($Z = -2.634$, $p = 0.008$, see Table 1). This means that on average, participants had lower negative affect levels after the exposure to each environment. Thus, this hypothesis is accepted.

**2.1.** *Negative affect levels will be the same across conditions.*

There was a statistically significant main effect of time on negative affect levels ($F$ (1, 39) = 40.85, $p < 0.001$, $\eta_p^2 = 0.512$). This means that affect levels were lower post-exposure than pre-exposure, with a mean of 14.51 ($SD = 0.761$) pre-exposure, and a mean of 12.44 ($SD = 0.626$) post-exposure ($M_{Dif} = 2.060$, $SD = 0.322$, $p < 0.001$).

There was no significant main effect of condition on negative affect levels ($F$ (1, 39) = 0.1, $p = 0.748$, $\eta_p^2 = 0.003$). This means that negative affect levels were not statistically significantly different across conditions. Thus, this hypothesis is accepted.

There was no significant time by condition interaction on negative affect levels ($F$ (1, 39) = 3.02, $p = 0.090$, $\eta_p^2 = 0.072$).

**3.** *Nature connectedness will be higher after the exposure to the virtual environment in each condition.*

The 5-minute exposure to the 3D-VR environment elicited a statistically significant positive change in nature connectedness in university students ($Z = -3.947$, $p < 0.001$, see Table 1).

5-minute exposure to the 360-VR environment elicited a statistically significant positive change in nature connectedness in university students ($Z = -3.508$, $p < 0.001$, see Table 1). This means that on average, participants had higher levels of nature connectedness after the exposure to each environment. Thus, this hypothesis is accepted.

**3.1.** *Nature connectedness will be higher in the 3D-VR condition than in the 360-VR condition.*

Since the assumption of equality of covariances was violated, the following results were taken from the Pillai's Trace test statistic. There was a statistically significant main effect of time on nature connectedness ($F$ (1, 39) = 25.33, $p < 0.001$, $\eta_p^2 = 0.39$). This means that nature connectedness was higher post-exposure than pre-exposure, with a mean of 4.15 ($SD$ = 0.239) pre-exposure, and a mean of 5.22 ($SD$ = 0.178) post-exposure ($M_{Dif}$ = -1.074, $SD$ = 0.213, $p <$ 0.001).

There was no significant main effect of condition on nature connectedness ($F$ (1, 39) = 0.13, $p$ = 0.720, $\eta_p^2$ = 0.003). This means that nature connectedness was not statistically significantly different across conditions. Thus, this hypothesis is rejected.

There was no significant time by condition interaction on nature connectedness scores ($F$ (1, 39) = 0.015, $p$ = 0.903, $\eta_p^2 = 0.000$).

**4.** *Sense of presence will be higher in the 3D-VR condition than in the 360-VR condition*.

Since the different scores were found to have differently shaped distributions in the two groups, mean ranks were used for comparison.

The general item G1 was found to be statistically significantly higher in the 3D-VR group than in the 360-VR group ($U$ = 60, $p < 0.001$, $r$ = 0.629). This shows that participants had a higher "sense of being there" in the 3D-VR environment than in the 360-VR video environment.

The mean score of spatial presence was statistically significantly higher in the 3D-VR group than in the 360-VR group ($U$ = 60.5, $p < 0.001$, $r$ = 0.611). This shows that participants had a higher sense of being physically present in the 3D-VR environment than in the 360-VR environment.

There was no statistically significant difference found between conditions concerning the involvement mean score ($U$ = 145, $p$ = 0.088, $r$ = 0.266). This means that there is no difference in the attention devoted to the virtual environment and the involvement experienced between the two groups.

Lastly, there was no statistically significant difference found between conditions concerning the experienced realism mean score ($U$ = 205, $p$ = 0.896, $r$ = 0.020). This means that there is no difference in the subjective experience of realism in the virtual environment

between the two groups. Thus, sense of presence is partially higher in the 3D-VR condition and the hypothesis is partially accepted.

All descriptive statistics are reported in Table 1.

**Table 1**

*Descriptive statistics of each dependent variable in both conditions*

| Dependent variable | 360-VR | | | | 3D-VR | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-VR | | Post-VR | | Pre-VR | | Post-VR | |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Positive Affect | 29.30 | 7.66 | 29.40 | 9.44 | 29.48 | 6.52 | 31.24 | 7.50 |
| Negative Affect | 14.45 | 5.37 | 12.95 | 4.52 | 14.57 | 4.35 | 11.95 | 3.44 |
| Nature Connectedness | 4.20 | 1.70 | 5.30 | 1.17 | 4.10 | 1.34 | 5.14 | 1.11 |
| Sense of Presence | | | | | | | | |
| General Item | | | 2.55 | 1.05 | | | 4.38 | 1.28 |
| Spatial Presence | | | 3.08 | 0.85 | | | 4.43 | 0.88 |
| Involvement | | | 2.9 | 1.01 | | | 3.64 | 1.10 |
| Experienced Realism | | | 3.28 | 0.81 | | | 3.20 | 1.12 |

*Note.* Sense of presence was only measured post-exposure.

**Discussion**

This study aimed to explore how two different virtual nature environments – one a 3D model of a forest and one a 360° video of a real forest – influence positive and negative affect levels, sense of presence, and nature connectedness.

There are three key findings of the present study. Firstly, it can be concluded that the two conditions did not have a significant difference between each other in terms of how they influenced affect levels, involvement, experienced realism as well as nature connectedness. There was, however, a significant difference in sense of presence between the conditions concerning spatial presence and the general sense of being there with the participants in the 3D-VR condition reporting higher levels. This implies that both conditions affected the participants' nature connectedness and affect levels in similar ways, while the 3D model of the

virtual forest elicited a higher sense of being there and spatial presence in the participants compared to the 360° video of the real forest.

Secondly, in either condition nature connectedness was higher after the 5-minute exposure to the VR environment. This implies that both environments effectively elicited higher nature connectedness in university students.

Thirdly, in either condition negative affect levels were decreased after the 5-minute exposure to the VR environment, while positive affect levels did not significantly change. This implies that, while spending time in the virtual nature environment does alleviate mood, only one aspect – negative affect levels – is being affected in a significant manner.

*Sense of Presence*

The hypothesis concerning the differences in sense of presence was partially accepted, as the general sense of being there and spatial presence were significantly higher in the 3D-VR condition than in the 360-VR condition, whereas involvement and experienced realism did not differ significantly. Concerning involvement, an interpretation of the findings is that this aspect of sense of presence did not differ much between conditions since the participants were asked to stay seated and look around in both conditions, thus they were simply "observers" and had the same role of involvement in the environments. Concerning experienced realism, an interpretation could be that the level of realism displayed in the 3D model was high enough so that the participants can accept it as "real". It is important to note, however, that many participants did criticise the 3D environment in contrast to the 360° video. They reported that the environment was a bit pixelated, that the field of view blurs too quickly and that one could see blinking in the bushes upon closer examination. But, while these criticisms were pointed out, they did not seem to affect experienced realism significantly. An explanation for this could be that the game-like nature of the 3D environment made criticism feel more appropriate since this environment could be improved upon with more refined skills, whereas the 360° video shows a part of actual nature, similar to a TV. Thus, expectations might have been higher for the 3D environment, since it is something malleable, not concrete like a pre-recorded video. Concerning the sense of being there as well as spatial presence, there may be a similar explanation. It could be that the 360° video was too "flat" since it was recorded on an incline, thus being in an odd position that feels less natural to the observer. Perhaps the 3D environment had more depth since it was a more open field with more distinctive things to look at, thus the participants in the 3D-VR condition reported a higher sense of being there and spatial presence.

This finding is somewhat in line with previous research, as Yeo and colleagues (2020) found that their 3D-VR condition also elicited greater experienced presence than their 360-VR condition. This study contradicts the findings of Brivio and colleagues (2020), who had a similar study set-up to this one, since the participants had a passive observational role, too. In their study, they found that after exposing their participants to either the 360-VR or the 3D-VR condition, sense of presence did not differ significantly. This could potentially be attributed to the different measurement scale used – or the fact that their exposure lasted 3 minutes as opposed to 5 in this study. Thus, duration of the exposure could be a factor to consider as well.

*Positive and Negative Affect Levels*

Here, the hypotheses concerning positive affect levels were both rejected, as positive affect levels were not significantly influenced by the exposure to either condition and did not differ between condition. The hypotheses concerning negative affect levels were both accepted, as negative affect levels decreased significantly after the exposure to either condition and did not differ between condition, similarly to the study by Yeo and colleagues (2020). When asked what their experience was, many participants reported having a "relaxing" time, which is something that is not covered by the PANAS scale. Moreover, participants reported in the brief talk after the experiment that during those 5 minutes they got taken out of their daily worries for a bit, which could explain the change observed in negative affect. Indeed, low negative affect is associated with calmness and serenity (Watson et al., 1988). One participant mentioned that the 360° video was a bit "under-stimulating", which could have added to the fact that positive affect levels did not change as well. This is in line with previous research, e.g., in the study by Browning and colleagues (2020), where positive affect levels stayed the same in the virtual nature condition, whereas negative affect decreased, which they attributed to the possibility of boredom. This is contrary to the findings in the study by Yeo and colleagues (2020), where the 3D environment could be interacted with; participants were free to move around and interact with the sea animals as well as corals – here, the 3D-VR condition did elicit a significantly positive change in positive affect levels. Of interest here is that the 3D-VR environment elicited a greater sense of presence than the 360° video did. While a different sense of presence scale was used, it is possible that all components of sense of presence must be significantly elicited to observe a significant change in positive affect levels. In this study only sense of being there and spatial presence were different between conditions, but involvement and experienced realism were not. Another reason for the unaffected positive affect levels could be due to age. In the study by Chan and colleagues (2021), the findings showed that while only

negative affect levels were decreased in the study with young adults, positive affect levels were increased in the study with senior citizens, which the authors contribute to higher state nature connectedness. Thus, age is a potential moderator of the beneficial effects of exposure to nature, with higher age being associated with higher positive affect levels (Chan et al., 2021). Since only university students between the ages of 18 to 28 took part in the study, this could be an explanation as to why negative affect levels were significantly changed, but not positive affect levels.

*Nature Connectedness*

The hypothesis that nature connectedness would be higher after the exposure to either environment was accepted, whereas the hypothesis that nature connectedness would be higher in the 3D-VR environment than in the 360-VR environment was rejected. Similar to the findings in the previous section, nature connectedness was significantly increased by the same amount in both conditions, thus being equally effective at eliciting nature connectedness in university students after a 5-minute exposure to each virtual nature environment. This is in line with previous research, e.g., the second study of Leung and colleagues (2022), who found that immersive virtual nature increases nature connectedness in people with low nature affinity. Additionally, it is important to mention that the campus of the university the participants are enrolled in offers much nature, thus participants might have been more easily influenced by the virtual nature environment as it looked similar to the nature surrounding them on campus – or on the contrary, a bigger increase would have been possible with participants who have less nature available to them. Moreover, the results are in line with Yeo and colleagues' (2020) findings as well, as the participants in their study had higher connectedness to nature post-exposure, though in their study nature connectedness was marginally significantly greater in the 3D-VR condition than in the 360-VR condition, which is not the case in the current study. As previously mentioned, in their study, the 3D-VR environment could be interacted with, which may be a reason as to why there was a difference between the two conditions. In the current study, both environments were observed by the participants, but not interacted with. Thus, being able to interact with the nature environment in VR may increase nature connectedness further and enhance the differences between the mediums, as 360-VR is not interactable, whereas 3D-VR is.

*Implications*

The current study shows that both mediums are valid for improving affect levels and nature connectedness in university students, thus it might be viable as a short-term intervention to take students out of their daily stressors and into a generally relaxing nature experience. While this type of low-interaction VR (either 3D-VR or 360-VR) can be a tool to relax, it may not increase types of emotions associated with the positive affect subscale, such as enthusiasm, activeness, and alertness, whereas negative affect is associated with calmness and serenity in low levels (Watson et al., 1988). Yet, virtual reality provides a tool to overcome hurdles such as inaccessibility to nature environments and can offer benefits to the user (Brivio et al., 2020; Browning et al., 2020). Furthermore, the role of sense of presence and specifically involvement has been emphasised as a possible factor that increases the differences between the virtual reality mediums, especially concerning affect levels (Yeo et al., 2020). It must be pointed out that a 360-VR environment is more cost-efficient and requires less skill than a 3D-VR environment, thus as long as the immersed person is a passive observer, a 360° video in virtual reality is a good, cost-benefit efficient way to alleviate students' mood and increase nature connectedness in a short time. As the only significant difference lied within the variable of sense of presence, a 360° video is easy to record and edit, with less time required to achieve the same effects beneficial to wellbeing.

*Strengths and Limitations*

This study had a few strengths and limitations which should be considered when evaluating the results. One strength of the study is that it is innovative; except for the study by Yeo and colleagues (2020), little research has been done that directly compares VR mediums with a similar nature environment and their effects on the subjects. Thus, this research opens new possibilities for future research which can investigate differences between the mediums further, using this study as a basis. Moreover, a strength of the study was that it was purely quantitative, thus allowing for easy replication and relying on pre-established standardised scales and tests which produce more precise results. A limitation of the study is the generalisability of the results. The generalisability is limited by the fact that a small sample size was available, which can be accredited to the short period of time where data collection was possible. Furthermore, the reliability of these data may be impacted by the fact that random assignment was not possible as there were complications with the set-up of the 360-VR condition, which hindered data collection of this condition in the first two weeks. Additionally, the validity concerning the negative affect analysis in the context of the mixed ANOVA may

have been impacted due to the non-normal distribution in the data. However, since only time effects were significant and non-parametric tests were chosen to compare the pre- and post-exposure data within each condition, this was mostly overcome.

*Future Research*

Further research is needed to explore the effects of sense of presence on nature connectedness and affect levels, as well as to see how it influences the variables between two or more VR mediums. Sense of presence is a key part of VR, but it has not yet been explored much – involvement may be of even greater importance than anticipated, as interaction with the virtual environment has been shown to impact affect levels significantly. Since this type of virtual environment put the participants into an observer role, future research should focus on making an interactive 3D nature environment to further make a distinction between the two mediums as implied by the study of Yeo and colleagues (2020). Moreover, future research should look at different types of nature for the VR environments, such as aquatic or rainforest ones, which might possibly increase positive affect as observers might experience them as novel depending on their background – thus, one might experience self-transcendent emotions which positively impact wellbeing long-term (Neill et al., 2019). Furthermore, comparing different types of 3D-VR environments such as low-realism and high-realism ones to the 360-VR environment can further help in exploring the importance of sense of presence. Additionally, a large sample is recommended ($n > 50$) for future research with participants from different universities with different accessibility to nature, as the campus of the University of Twente has nature parks and thus participants of this university may be more (or less) easily influenced by virtual nature environments – thus looking at differences here could be helpful to understand the role of access to nature on the effectiveness of these mini-interventions. A large sample size could also help to counteract the effect of extraneous factors and see whether demographical differences have an impact on the effectiveness as well.

## Conclusion

This study aimed to explore the differences between a 3D virtual nature environment and a 360° video nature environment in virtual reality on affect levels, nature connectedness and sense of presence.

This research has shown that both types of mediums are effective at decreasing negative affect levels and eliciting nature connectedness, while the 3D environment elicits a higher sense of presence in the virtual environment. Thus, the mediums' effects on affect levels and nature

connectedness are the same, given that both conditions put the subject into a passive observational role. The study provided new insights into the role of sense of presence and indicated that both mediums are effective as a mini-intervention for alleviating mood in university students. Based on these conclusions, further research is needed to establish correlations between the variables and exploring the role of sense of presence as a moderator of differences between the mediums, which could not be done in this study as this would have gone beyond the scope of the study. Considering that 360° videos are more cost-efficient (in terms of time and money) and require less skills, as long as the role of the user is observational and passive, a 360° video is a suitable way to alleviate students' mood and elicit nature connectedness in the short-term with low costs and effort.

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# Appendix A

## Informed consent form

**Welcome to our study! Thank you for your interest.**

**Description of the research**

You are invited to participate in a study conducted by Victoria Michelle Link, supervised by Lina Bareisyte at the University of Twente. In the context of this study, you will be in a virtual nature environment using a head-mounted display for around 5 minutes. Before and after the exposure, you will be asked to complete multiple questionnaires. Participation will require approximately 30 minutes in total.

**Potential benefits**

There are no known benefits associated with participation in the study.

**Risks and discomforts**

Some people report headaches, eye strain, dizziness, and nausea after using a VR headset. If you are sensitive to these things, please reconsider participating in this study. No other risks and discomforts are associated with participation in the study.

**Voluntary participation and withdrawal**

Participation in this study is voluntary. Participants have the right to withdraw from the study at any point in time without stating reasons. Withdrawal from the study does not result in any consequences.

**Confidentiality and anonymity**

The data collected in the study is treated confidentially and anonymously. Collected data is only visible to research team but cannot be traced back to the participant. The collected data will be used for analysis purposes and erased after completion of the thesis assignment.

**Contact**

In case of questions, remarks, or other issues, please contact Victoria Michelle Link (v.m.link@student.utwente.nl).

**Taking part in the study**

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 exposure to a simulated nature environment and filling out questionnaires.

○ Yes, I have read and understood the information above and consent to taking part in this study.

## Debriefing form

Thank you for participating in this study.

The aim of this study was to investigate the influence of two different simulated nature environments and their effects on mood, sense of presence and nature connectedness in university students.

You either participated in the group that was exposed to a 360-degree video of a European forest environment or you were in the group that was exposed to a 3D virtual nature environment of a similar forest setting. Both environments are shown to the groups via a head-mounted display. Thus, the only difference is the actual medium you were shown.

The actual conditions of the investigation could not be explained beforehand, as this could have influenced the way participants approached the study. Our data would thus have been more unreliable.

If you have any other questions or remarks, please contact Victoria Michelle Link (v.m.link@student.utwente.nl).

If you wish to withdraw your consent, this is fine and will not have any repercussions. We will simply delete your dataset. If this is not the case, we will use your dataset as anticipated.

○ I **agree** to my data being used.
○ I **withdraw** my consent and **do not** want my data to be used.

**Demographics**

What is your gender identity?

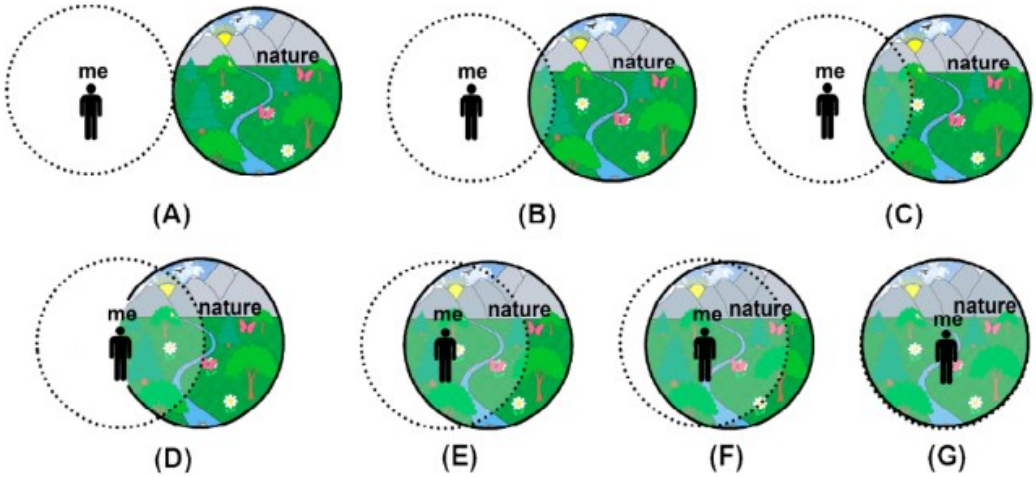
- ○ Male
- ○ Female
- ○ Non-binary / other
- ○ Prefer not to say

What is your age?

What is your nationality?

- ○ Dutch
- ○ German
- ○ Other, please specify:

**IINS** (pre and post)




Please indicate which diagram best describes how you feel right now about your connection with nature environments.

**PANAS** (pre and post)

This scale consists of a number of words that describe feelings and emotions. Read each item and indicate to what extent you are feeling this way right now.

| | 1 - very slightly or not at all | 2 - a little | 3 - moderately | 4 - quite a bit | 5 - extremely |
|---|---|---|---|---|---|
| Interested | ○ | ○ | ○ | ○ | ○ |
| Distressed | ○ | ○ | ○ | ○ | ○ |
| Excited | ○ | ○ | ○ | ○ | ○ |
| Upset | ○ | ○ | ○ | ○ | ○ |
| Strong | ○ | ○ | ○ | ○ | ○ |
| Guilty | ○ | ○ | ○ | ○ | ○ |
| Scared | ○ | ○ | ○ | ○ | ○ |
| Hostile | ○ | ○ | ○ | ○ | ○ |
| Enthusiastic | ○ | ○ | ○ | ○ | ○ |
| Proud | ○ | ○ | ○ | ○ | ○ |
| Irritable | ○ | ○ | ○ | ○ | ○ |
| Alert | ○ | ○ | ○ | ○ | ○ |
| Ashamed | ○ | ○ | ○ | ○ | ○ |
| Inspired | ○ | ○ | ○ | ○ | ○ |
| Nervous | ○ | ○ | ○ | ○ | ○ |
| Determined | ○ | ○ | ○ | ○ | ○ |
| Attentive | ○ | ○ | ○ | ○ | ○ |
| Jittery | ○ | ○ | ○ | ○ | ○ |
| Active | ○ | ○ | ○ | ○ | ○ |
| Afraid | ○ | ○ | ○ | ○ | ○ |

**IPQ**

In this questionnaire you will see some statements about experiences. Please indicate whether or not each statement applies to your experience. There are no right or wrong answers, only your opinion counts. Please read each statement carefully as not every range of answers is the same. And please remember: answer all these questions only referring to this one experience.

| | -3 - extremely aware | -2 | -1 | 0 - moderately aware | 1 | 2 | 3 - not aware at all |
|---|---|---|---|---|---|---|---|
| How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)? | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

How real did the virtual world seem to you?

| -3 - completely real | -2 | -1 | 0 | 1 | 2 | 3 - not real at all |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

I had a sense of acting in the virtual space, rather than operating something from outside.

| -3 fully disagree | -2 | -1 | 0 | 1 | 2 | 3 - fully agree |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

How much did your experience in the virtual environment seem consistent with your real world experience?

| -3 - not consistent | -2 | -1 | 0 - moderately consistent | 1 | 2 | 3 - very consistent |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

How real did the virtual world seem to you?

| -3 - about as real as an imagined world | -2 | -1 | 0 | 1 | 2 | 3 - indistinguishable from the real world |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

I did not feel present in the virtual space.

| -3 - did not feel | -2 | -1 | 0 | 1 | 2 | 3 - felt present |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

I was not aware of my real environment.

| -3 - fully disagree | -2 | -1 | 0 | 1 | 2 | 3 - fully agree |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

In the computer generated world I had a sense of "being there".

| -3 - not at all | -2 | -1 | 0 | 1 | 2 | 3 - very much |
|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ |

| | -3 - fully disagree | -2 | -1 | 0 | 1 | 2 | 3 - fully agree |
|---|---|---|---|---|---|---|---|
| Somehow I felt that the virtual world surrounded me. | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| I felt present in the virtual space. | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| I still paid attention to the real environment. | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The virtual world seemed more realistic than the real world. | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| I felt like I was just perceiving pictures. | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| I was completely captivated by the virtual world. | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

## Appendix B

Screenshots of the 3D model of a forest environment in Unity

## Appendix C

Screenshot of the 360° video environment