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The Use of Virtual Reality in Environment Experiences and the Importance of Realism

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Abstract

Introduction. Virtual reality (VR) can be extremely useful in simulating nature when physical presence is not possible. Additionally, it allows for environments to be customised (e.g., weather, or topography) and facilitates the design of controlled experimental settings. However, VR can involve the use of expensive equipment and complex software to create highly realistic immersive experiences. But is it necessary for experiences to rival the latest Hollywood blockbuster? This paper explores whether such investment can be valuable in research on nature experiences.

Studies. Two studies were conducted to examine how realism of environmental presentations impact affective responses and participant perceptions. Study One (n = 16) explored perceptions of the same lake presented to participants in the real world, in VR and as a video. Study Two (n = 120) compared participant's affective responses to one of four possible virtual environments differing in level of realism (*high* or *low*) and type (*natural* or *built*).

Results. Study One showed that experiences of VR presentations fell between real and video presentations. Study Two found that more realistic VR environments evoked more positive affective and serenity responses, as well as a greater sense of presence. In both studies, participants stressed the importance of naturalistic interaction, sensory immersion, and graphical realism in the experiences, which may help explain these effects.

Conclusion. The level of realism that can be attained with VR does impact affective responses and perceptions. Investment in VR for future research can be highly beneficial.

Keywords

physical environment; simulated environment; environmental quality; restoration; stress; stress reduction.

1.1 The Use of Virtual Reality in Environment Experiences and the Importance of Realism

Environmental experiences in field settings are likely to evoke stronger affective responses than surrogate experiences (e.g., photographs or video). However, it can be difficult to find suitable environments for controlled experimental research.

Virtual reality (VR) can be extremely useful for this type of research as it can be used to simulate environments when physical presence is not possible and allows environments to be customised (e.g., weather, or topography). LaValle defines VR as “inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference” (2019 p. 1). This type of immersive extension to reality can be achieved in numerous ways by using different types of stimuli and equipment. Experiences can take the form of computer-generated environments or pre-recorded videos (see Steuer, 1992), which can be viewed via head-mounted displays (HMD) or projected onto the walls, ceiling and floor of a room (see Cruz-Neira et al., 1992). Additionally, a *virtual reality* could be established solely as a three-dimensional auditory experience (e.g., binaural recordings or ambiophonics) for use in research exploring imagination, emotions, or body awareness. For the purposes of the current work VR will refer to computer-generated environments presented via an immersive head-mounted display.

Unfortunately, the cost of producing realistic experiences using VR can be high. At the very least powerful computers capable of running them can easily costs thousands of pounds. On top of this, buying or building these experiences, either yourself or through a third party, can significantly impact budgets in the form of fees, licences, and training costs. But is it necessary for experiences to rival the latest Hollywood blockbuster? If not, then researchers could save a significant amount of time and money. The following work aims to examine whether research in field of VR (Virtual Reality), nature experiences and psychology should spend more money on the quality of the VR in order to gain more valid and timely results?

It has been well established in the literature that contact with nature provides wellbeing benefits, particularly with regard to affect (Berto, 2014; Bowler et al., 2010; Joye & Bolderdijk, 2015; Meredith et al., 2020; White et al., 2019). Spending time in nature elicits a response that fosters an increase in positive and decrease in negative affect (Korpela et al., 2002; Ulrich et al., 1991). Spending time in built environments typically does not have such restorative effects (Gidlow et al., 2016; Hartig et al., 2003; Ulrich et al., 1991). Although significant evidence has pointed to the restorative benefits of natural environments, there is still a lack of understanding of the environmental factors that influence these benefits. This is partly because experimental control of specific environmental features (e.g., the weather, the presence of people, the density of the woods) in different environmental settings is not easy when trying to maintain a realistic environmental experience. Virtual reality technology can help overcome this problem.

Existing research has demonstrated that restorative experiences can be found using different environment presentation methods of natural environments including real on-site experiences (e.g., Yuen & Jenkins, 2019), photography slideshows (e.g., van Rijswijk et al., 2016), video recordings (e.g., Gatersleben & Andrews, 2013) and as VR presentations of real environments (e.g., Nukarinen et al., 2020)

The use of computer-generated environments is not new to research (e.g., Depledge et al., 2011; Valtchanov et al., 2010). However, in most of this work these environments were still viewed on walls or screens and fell short of a perception of immersive VR propagated through films like The Matrix (Wachowski & Wachowski, 1999). Thankfully, such experiences are no longer relegated to the realms of science fiction and recently studies have begun to use immersive head mounted displays to present the computer-generated environments (e.g., Chirico et al., 2018; Yin et al., 2020), which have been successful in eliciting affective responses from participants (Felnhofer et al., 2015). Being able to place participants directly into an environment that can react to their presence allows us to better study human-environment interactions by doing so within a controlled context. However, further exploration of how to best to use computer-generated environments and immersive interaction technologies (e.g., HMDs) in tandem is needed, particularly within the context of participant perceptions and expectations.

There is no contention that, currently, surrogate nature experiences can or should replace the real thing. Studies that have compared on site experiences with videos or images have found that while both afforded the beneficial effects of natural environments the results were comparatively stronger in the former (Gatersleben & Andrews, 2013; Huang, 2009; Kjellgren & Buhrkall, 2010; Mayer et al., 2009). Real experiences have also been found to be more enjoyable and elicit greater affective responses than more immersive surrogate experiences (i.e., via HMD; Calogiuri et al., 2018). However, this has not invalidated their use within research, as surrogate experiences can enable access to environments when physical presence is not possible. Additionally, computer generated environments can be customised to match research needs; thus, permitting new lines of enquiry within the field.

All surrogates are not created equal, however, as comparison between videos and images found that participants are drawn in more by dynamic displays, wanting to explore the environment further (Heft & Nasar, 2000). Comparison between VR and images of nature found a greater increase in positive affect in the former (Valtchanov et al., 2010). Using VR has been found to be more beneficial than viewing experiences on a 360° video or screen (Nukarinen et al., 2020; Yeo et al., 2020). Clearly, VR provides a surrogate much richer and closer to the real thing.

The computational power needed to maintain a smooth and stable virtual experiences, and thus avoid issues such as cyber-sickness (Epic Games, n.d.; LaViola, 2000), opens the door to producing environments closer to the real thing in terms of both graphical and interaction quality. Striving for visual realism is beneficial because it makes users feel more engaged with the experience and contributes to a sense of immersion (R. P. McMahan et al., 2012). This is important because cultivating a sense of immersion, typically through the use of immersive HMDs, helps to bring an environment to life and strengthen the response to, and effects of the experience (Regenbrecht et al., 1998). Additionally, the more abstract a representation of an environment the more it impacts participants' perception of the environment (Daniel & Meitner, 2001).

In summary, there are a wide variety of presentation options available that are beneficial for researching psychological perceptions and affective responses to different environments. Each method has its own advantages and disadvantages, for example, in terms of the extent to which the experience is immersive for participants or the extent to which researchers can manipulate the environment to which the participants are exposed. However, there has been little experimental research that examines the effect of different presentations on participants' responses and perceptions. Some studies have demonstrated that three-dimensional (3D) VR experiences provide a greater restorative experience than exposure to the same environment in a 360° video (Nukarinen et al., 2020; Yeo et al., 2020). However, research in this field is still scarce. Research comparing environmental experiences in a real environment with a two-dimensional (2D) video of the same environment and a 3D virtual simulation of that environment is rare (e.g., Palanica et al., 2019) and we have found no examples of this type of research within the context of environmental restoration and stress. Additionally, no studies have examined affective responses to 3D virtual simulations of natural and built environments with varying levels of realism. Gaining a better understanding of the importance of graphical realism in VR research on environmental experiences is important to direct investment and training in this research area.

Considering the cost not only to learn the necessary software but also to purchase the appropriate equipment from a long and expensive list, it is understandable why there may be hesitation about adopting this research method when other surrogates have been deemed acceptable. Is it vital that the most cutting-edge technology be used, and the most realistic experiences produced?

This paper presents two studies to address this question. Study One compared perceptions and affective responses to the same natural environment (a lake) experienced in the real world, in 3D VR, and as a 2D video. Study Two examined affective responses to one of four possible virtual environments differing in level of realism (*high* or *low*) and type (*natural* or *built*).

2.1 Study One: Comparing realism across different presentation methods

A hybrid field-laboratory experiment was conducted to examine affective responses and ratings of enjoyment after viewing a lake in the real world, in VR, and as a video. We expect that reported *positive affect* and *serenity,* as well as enjoyment, will be higher and reported *negative affect* will be lower after having experienced the environment in the real world, versus in VR, versus as a video. To further explore how the different presentation methods may have affected perceptions and experiences, participants completed a short survey with open-ended questions at the end of the experiences.

2.1.1 Design

All participants experienced the environment surrounding the lake at the university in the real world, in VR, and as a video recording projected onto a wall. The order of the experiences was randomised for each participant.

2.1.2 Participants

A total of 16 student and non-student participants from the south of England (n_{female} = 8, M_{age} = 43, SD = 17) were recruited via posters and email. Participation was voluntary and permitted entry into a draw to win a gift voucher worth £20.

Three quarters of the participants had previously been to the study site. Half had regularly visited natural parks and almost all (n = 15) said they derived a lot of pleasure from doing so regardless of the frequency of their visits. All the participants reported regularly being sat in front of a computer screen. More than half regularly used a computer for leisure (n = 10), but rarely or never played video games (n = 9). Most (n = 13) had hardly any or no experience using head mounted virtual reality displays.

2.1.3 The environments

2.1.3.1 Real experience

Participants sat for 10 minutes on a bench by the lake (Figure 1) on a dry, clear summer day during a period of low pedestrian activity (i.e., mid-morning or mid-afternoon).

Point of view from the bench The bench's location

Imagery ©2018 Google, Map data ©2018 Google.

Figure 1. The university lake.

2.1.3.2 Video

Participants sat on a wooden chair, analogous to the real bench, in a laboratory (Figure 2). The video was projected onto a screen (approx. 6.5-by-3.5 feet) flanked by two speakers used to play the recording's audio. All lights in the laboratory were switched off during playback to focus on the recording. The ten-minute recording was filmed from the same bench as the real experience and contained no people. It consisted of three equal length shots to the left, straight on, and right from the point of view of the bench.

Figure 2. The lab setup

2.1.3.3 VR

Participants sat in the same laboratory as the video experience (Figure 2). The virtual environment was developed using the Unreal Engine (Version 4.19; 2017). Care was taken to create a near as identical graphical representation of the lake environment as possible. The virtual environment was presented via the lenses and in-ear headphones of a VIVE head mounted display (Figure 3; HTC, 2016). An Aurora R7 gaming desktop computer (Alienware, 2017) was used to run the software. The computer included an Intel Core i7K 8700K processor, NVIDIA GeForce GTX 1080 Ti video card, and 16GB of DDR4 RAM. All lights in the laboratory were switched off during experience to prevent light entering through the headset's nose-arch. The experience consisted of an acclimatisation area followed by the virtual replica of the lake, viewed from as if seated at the same position as the bench in other experiences. The acclimatisation area was used to instruct the participant on how to use the equipment safely and give them time to get used to the feel of being in virtual reality (Figure 4). Participants spent a couple of minutes in the acclimatisation area and 10 minutes at the virtual lake.

Figure 3. Head mounted display and controllers.

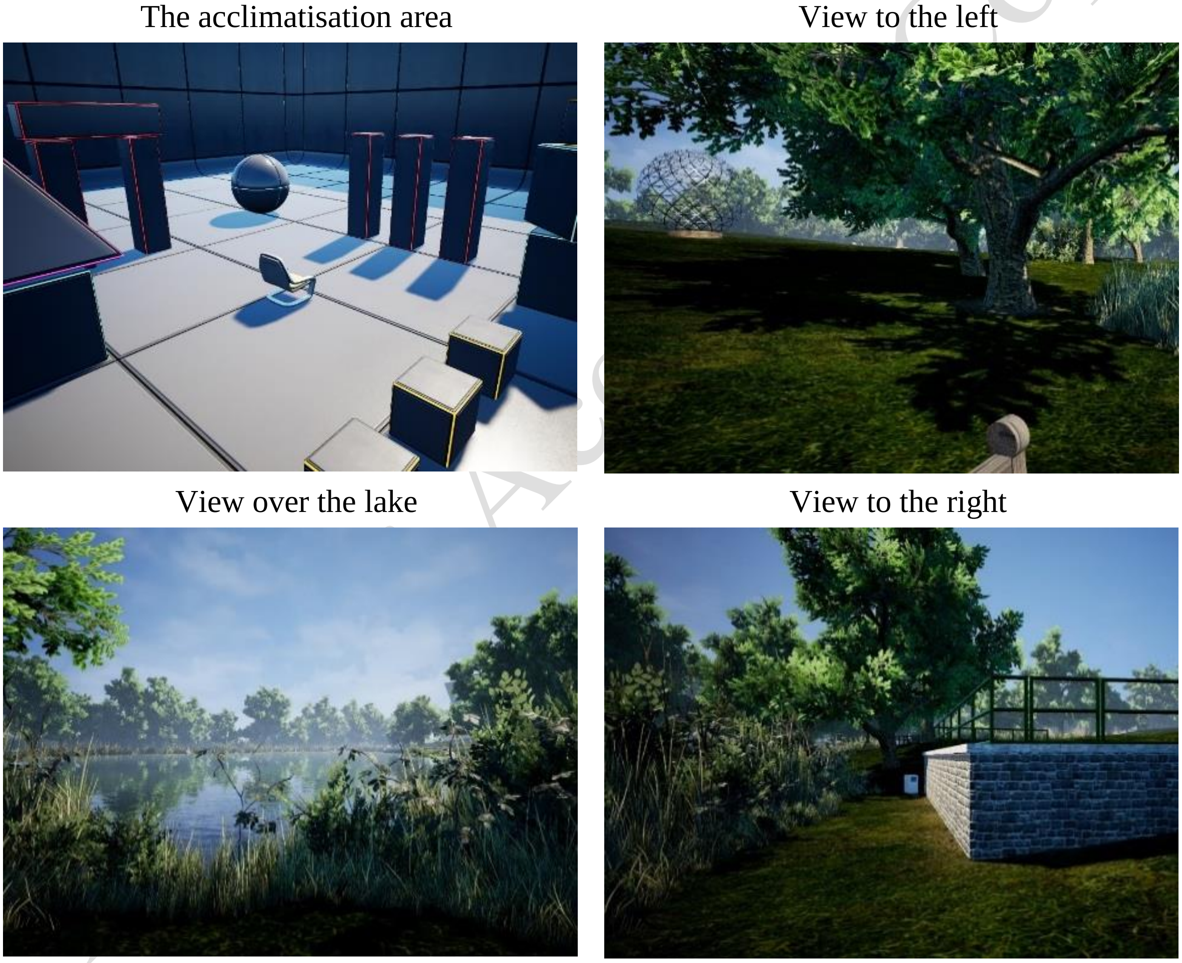

Figure 4. The computer-generated environments

2.1.4 Measures

2.1.4.1 Self-reported mood

The PANAS-X (Watson & Clark, 1994; n_{terms} = 27) was used to measure affect. Participants were asked to indicate the extent to which they felt a series of different feelings and emotions "at the present moment" (1 = *very slightly or not at all*, 5 = *extremely*). The higher order scales of *positive* (n_{terms} = 10; Cronbach's α = .88) and *negative* (n_{terms} = 10; α = .85) affect and the lower order scale of *serenity* (n_{terms} = 3; α = .74) were included. The latter was included to capture low arousal positive mood (i.e., feeling relaxed rather than stressed), which is relevant for understanding environmental restoration (Ulrich, 1991) but not specifically captured by the positive and negative affect scales. The order of the terms in the scale were randomised each time the participant completed it, that is, baseline and after each of the three experiences.

2.1.4.2 Relationship with nature and technology

Participants were asked if they had previously visited the university lake. Additionally, they were asked a series of questions to ascertain their relationship with natural parks (n_{items} = 2; e.g. How frequently do you visit natural parks, similar to the one you went to today?; 1 = *not at all*, 7 = *regularly*) and technological prowess (n_{items} = 5; e.g., How much experience do you have using head mounted virtual reality systems?; 1 = *none at all*, 7 = *a lot*). Both the nature (Cronbach's α = .77) and technology (α = .67) scales have an acceptable level of internal consistency.

2.1.4.3 Review of experiences

After each experience, participants were asked how much enjoyment they got (1 = *none at all*, 7 = *a lot*) and to briefly describe what they liked and disliked. At the end of the experiment, they were asked to compare VR to the real and video experiences separately, describing what was similar and different.

2.1.5 Procedure

At the start of the experiment participants completed the PANAS-X and then were either escorted to the lake (real experience) or remained in the laboratory (VR and video). Once on site they were instructed to spend some time sitting on the bench observing the natural surroundings and letting their mind wander. For the laboratory-based conditions these instructions included asking them to imagine they were at the lake. The VR experience was preceded by putting the equipment onto the participant and running them through a safety briefing in the acclimatisation area. After each experience participants completed the PANAS-X again. This was done before returning to the laboratory from lake. At the end of the experiment participants completed a short questionnaire and review of the experiences. The experiment lasted approximately 75 minutes and was approved without necessity for ethical review in line with the university's self-assessment governance and ethics procedure.

2.2 Results

2.2.1 Manipulation check

A baseline affective measurement showed that generally participants felt moderate levels of *positive affect* (M = 31.63, SD = 5.21), as well as very slight or no *negative affect* (M = 11.56, SD = 2.28), and *serenity* (M = 12.94, SD = 2.41).

2.2.2 Post experience affective responses

To explore the experiences' impact on affect, a repeated-measures analysis of variance (ANOVA) was run comparing affective responses recorded directly after each of the three experiences.

While the data for *positive affect* were normally distributed, the assumption of normality was violated in some cases for *negative affect* (Z_{skew}: 2.15 to 3.47; $Z_{kurtosis}$: 4.11 to 12.59) and *serenity* (Z_{skew}: −1.15 to 0.00; $Z_{kurtosis}$: −0.60 to 3.58). Several tests, including ANOVA, have been found to be robust to assumptions of normality (see Blanca et al., 2017; Vickers, 2005), thus could be argued to be appropriate to use for all three measures. However, to ensure the conclusions are robust and not to inflate the risk of a Type I error, both parametric (repeated ANOVA) and non-parametric (Friedman) tests were run. As the conclusions were consistent, this further supported the appropriateness to report the former.

The assumption of sphericity was violated for *negative affect* (Table 1) and in this instance results are reported with the Greenhouse-Geisser correction.

Positive affect (F(2, 30) = 0.925, p = .408, η_p^2 = .058) and *negative affect* (F(1.358, 20.372) = 0.513, p = .537, η_p^2 = .033) were not significantly different between each of the experiences. However, there was a significant difference between *serenity* scores, F(2, 30) = 4.241, p = .024, η_p^2 = .220.

Table 1

Mean and standard deviation results for PANAS-X scales after each experience.

Scale	*M* for Real (*SD*)	*M* for VR (*SD*)	*M* for Video (*SD*)
Positive affect	29.75 (7.77)	28.13 (7.40)	28.00 (7.73)
Negative affect	10.44 (0.89)	10.63 (1.41)	10.63 (1.78)
Serenity	12.94 (2.41)	11.88 (2.13)	11.00 (3.03)

Note. PANAS Scores range from 10 to 50 for *positive* and *negative* affect, and 3 to 15 for *serenity*.

Post-hoc tests with the Bonferroni correction applied revealed that *serenity* scores were significantly higher after the real experience than the video (p = .005; Table 1). However, the differences were not significant between the real experience and VR (p = .549) or the VR and video (p = .692).

2.2.3 Experience appraisals

A repeated-measures ANOVA was run to compare ratings of enjoyment recorded after each experience. The data were normally distributed. Mauchly's test of sphericity indicated that the assumption was not violated, $\chi^2(2)$ = 3.40, p = .183. Enjoyment ratings differed significantly between experiences, F(2, 30) = 20.89, p < .001, η_p^2 = .58, with enjoyment highest for the real experience, followed by VR and then the video (Figure 5).

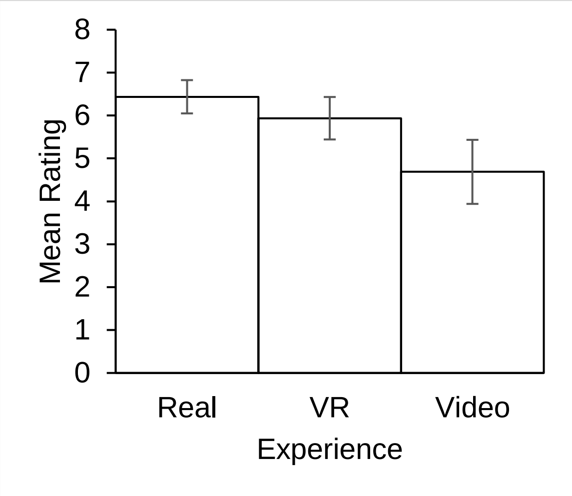

Figure 5. Mean ratings and standard deviation of enjoyment for the three experiences (Error bars: 95% CI).

Post-hoc tests with the Bonferroni correction applied revealed that the differences between ratings for the real experience and VR were not significant (p = .081). However, the video was rated significantly lower than both the VR (p = .003) and the real experience (p < .001).

2.2.4 Themes within appraisals

Using a thematical approach, open-response questions about what participants liked, disliked, and how the experiences compared were examined by searching for reoccurring topics that multiple participants referred to within the responses (see Braun & Clarke, 2006). Identified themes related to *presence*, *immersion*, *variety and disturbances*, and *safety and comfort*. To avoid the common confusion between *presence* and *immersion* they are defined here in accordance with Slater's interpretations (2003). *Immersion* refers to the sensory fidelity of an experience, for example, are users able to move around in the experience as they would in the real world? *Presence* refers to the users' response to immersion, that is, do they feel like they are in the environment?

2.2.4.1 Presence

References to *presence* served to differentiate between the real experience and VR, as participants cited computer-generated, rather than realistic graphics, lack of a body and unrealistic movement of flora as detracting from the experience; “I did notice how elements of the virtual experience were clearly virtual (e.g., the plants moved in a formulaic fashion). Also I had no legs” (Participant #12). However, a general feeling that it was “realistic enough to make me feel like I was really there” (#11) and a sense of fascination in the novelty of the experience prevailed; “I was amazed by what can be simulated in VR” (#12). The video experience was also criticised as participants cited being able to see the rest of the room, despite the cinema-dark environment, as distracting; “The artificial ‘room’ was also annoying, we were clearly indoors watching a video”.

2.2.4.2 Immersion

A key theme was the importance of being able to feel the breeze and smell the scents typically associated with nature. Their absence from VR and the video was repeatedly noted; “Being able to smell, feel, hear & see all of the environment is invaluable” (#08). References to *immersion* also served to differentiate between VR and the video as the ability to freely inspect elements of the scene that pique one’s interest was said to improve the experience; “The virtual experience is so much more real and involving. In VR are you are there – in simulated [video] you are merely a spectator” (#06).

2.2.4.3 Variety and disturbances

Participants expressed a desire for a greater *variety* (e.g., more people, animals, and sounds) so that there was more to explore and absorb within the scene; “The virtual experience was a good substitute for being outside, outside just made me feel more engaged” (#10). However, this was not without issue as the natural variety of the real world also brings with it the potential for *disturbances*; “the virtual experience had less distractions taking away from the experience (like noisy people)” (#04).

2.2.4.4 Safety and comfort

When evaluating the real experience participants noted the heat, sun in their eyes and risk of sunburn when out of the shade as a concern. It should be noted that the UK experienced severe heatwaves in the summer of 2018. Additionally, the weight of the device for the VR experience took some getting used to and was not easily ignored; "[my] enjoyment was slightly hindered by having something on my head / face" (#01).

2.2.5 Conclusion

Study One highlighted a preference for real and virtual experiences over watching a video, in terms of feelings of serenity, ratings of enjoyment, a sense of presence, and a sense of immersion. However, real and virtual experiences were not found to be particularly different to one another, except for comments regarding graphical realism. It is interesting that the perceived loss of realism did not have a greater impact and calls into question the cost-benefit of producing hyper-realistic experiences. Study Two will explore this further.

3.1 Study Two: Testing the importance of realism within VR

A laboratory experiment was conducted to examine whether the level of realism of a virtual environment impacts recovery from a state of negative affect (stress). In Study Two, stress was induced via a writing task before participants experienced either a *high* or *low* realism version of a *natural* or *built* environment. We expect that improvement in affect will be greater in the *high realism* compared to the *low realism environments* and greater in the *natural* compared to the *built* environments. To further understand their experiences participants were asked open-ended questions at the end of the study.

3.1.1 Design

Study 2 compared how recovery from stress is affected when the level of realism of a natural or built VR scene is altered. Here the level of realism referred to the extent each environment represented its real-world counterpart; that is, the quantity and complexity of the models and the detail of the textures (Figure 6).

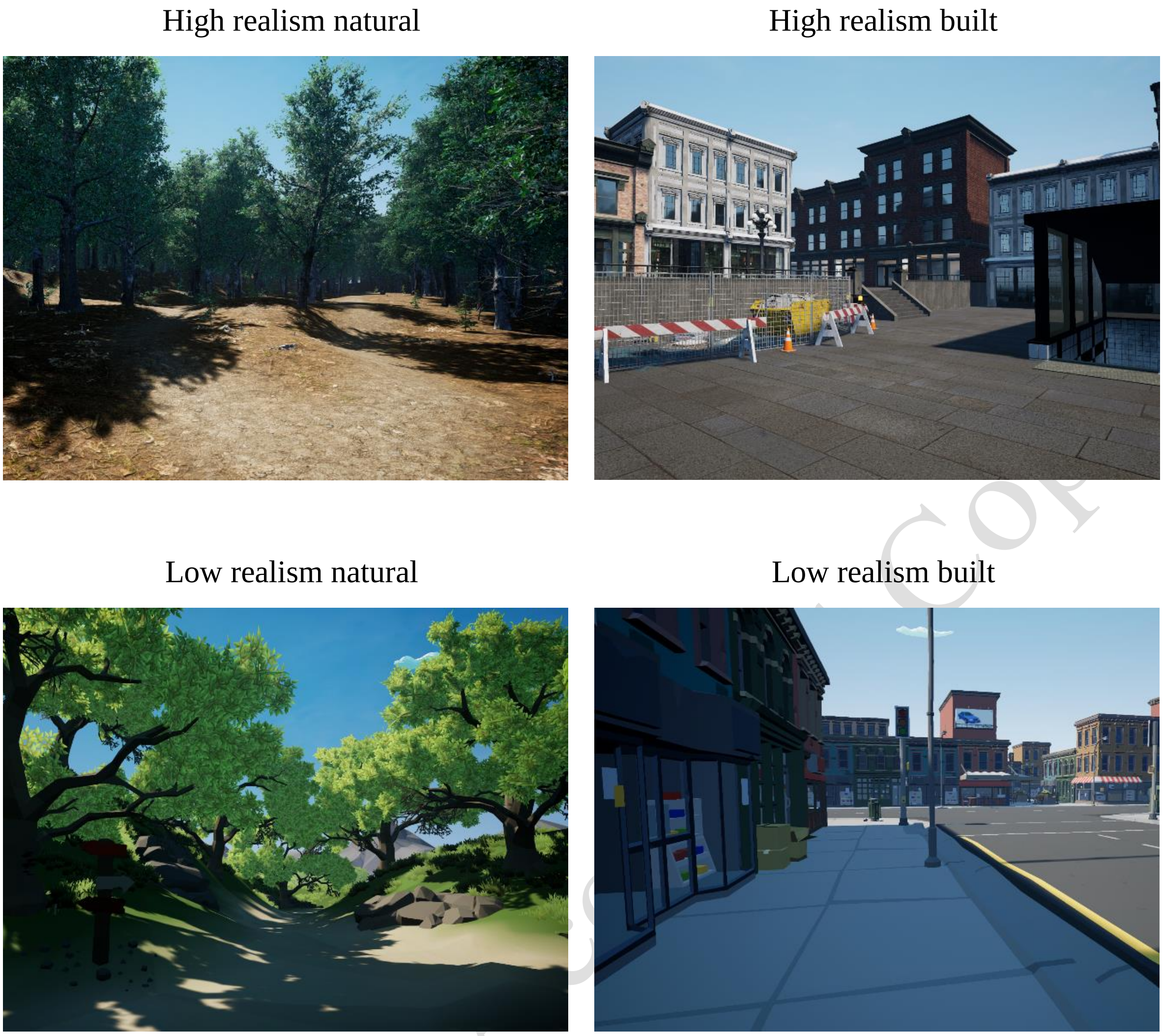

Figure 6. Sample images of different high and low realism scenes.

Participants were presented with a scenario designed to prime stress and then viewed one of four possible environments differing in realism (*high* or *low*) and type (*natural* or *built*).

3.1.2 Participants

An a priori power analysis was conducted using G*Power (see Faul et al., 2007, 2009) using effect size estimates for positive (0.31) and negative (−0.12) affect provided by McMahan and Estes (2015). This suggested a sample size of 30 and 182 respectively. A total of 120 participants (Table 2) were recruited via the university's online research recruitment system and email. Three respondents chose to not reveal their gender and four their age.

Participation was voluntary and could be compensated as part of a token-based study participation incentive scheme.

Table 2

Age and gender distributions among the conditions.

Condition	M_{age}	*SD*	n_{female}	n_{male}	n_{not_say}
High realism natural	20	3	24	4	2
Low realism natural	20	2	25	5	0
High realism built	20	2	27	3	0
Low realism built	20	3	25	4	1

Computer use was high amongst the participants with 93% frequently being sat in front of a computer screen and 68% regularly having used a computer for leisure. Video game time was not as high with 63% saying they had played rarely or never. Additionally, 78% had hardly any or no experience using head mounted virtual reality displays.

3.1.3 Materials

3.1.3.1 Laboratory

The entire study took place in a specially designed eXtended Reality lab (Figure 7). The lab contained a safe area for participants to move around in during the VR experience, a desk and computer for experimental tasks, and an adjoining room so the researcher would not disturb the participant but could assist if needed.

Figure 7. The eXtended Reality Lab.

3.1.3.2 Stress task

Previous research has induced desired affective states in participants by asking them to write about previous experiences with the requisite valence (Baker & Guttfreund, 1993; Mills & D'Mello, 2014). Drawing inspiration from these, participants were given ten minutes to write by hand in detail about a stressful time (Appendix A); defined in accordance with Ulrich's (1991) interpretation of the emotion, that is, feelings of anxiousness, irritability, fatigue, or being overwhelmed. They were instructed to avoid traumatic events and focus on more common place experiences (e.g., assignment deadlines). If they finished before the allotted time, they were asked to read over what they had written.

3.1.3.3 VR environments

The virtual environment was presented using the same equipment as in Study One, although the experience was developed using a newer version of the Unreal Engine (Version 4.22; 2019). Again, all lights in the laboratory were switched off during the experience, which consisted of a different training area to the first study (Figure 8) and one of the four possible environments. The training area was used to instruct the participant on how to use the equipment safely and give them time to get used to being in VR.

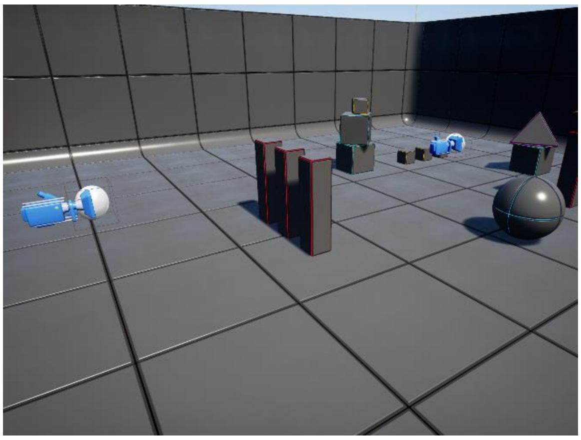

Figure 8. The training area. The two blue cameras represent the points participants were teleported between to demonstrate movement for the experience.

Each of the four environment experiences consisted of five individual scenes for participants to explore. While the scenes within an experience were different from one another they were all appropriate to the theme of that experience to make it feel like a realistic and logical walk through the environment (e.g., a forest pathway led to an open field). Participants spent two minutes exploring each scene before being automatically teleported to the next; a soft transition was used where the screen briefly faded to black, akin to blinking. When participants walked around within the safe area in the laboratory their movement was mapped into the VR experience, creating the illusion of moving around the virtual environment. If they reached the edge of the safe area a light mesh appeared briefly to indicate they should not move any further. There were no people in the *natural* environments, but there were light crowds and signs of human presence in the *built* environments (e.g., cars driving past; see Bratman et al., 2015; Hartig et al., 2003; Laumann et al., 2003; Staats et al., 2003; Takayama et al., 2014; Tyrvaeinen et al., 2014).

Structurally the *high* and *low* realism versions of environments were identical, sharing the same lighting, camera positions and physical layout. The only differences are in the reduced number of elements in the environment that come from the decreased level of detail in the low realism environments (e.g., less foliage on the ground, fewer and simpler shop interiors; Figure 6). Although the *natural* and *built* environments do differ in theme and content, they are structurally similar; for example, the long path through a forest in the *natural* environment became a long stretch of shops down a high-street in the *built* environment.

3.1.4 Measures

3.1.4.1 Self-reported mood

The PANAS-X (Watson & Clark, 1994; n_{terms} = 27) was used in the same way as Study One to measure restoration from stress. These scales were calculated for baseline (Time 1; T_1), after the stressor task (T_2), and after the VR experience (T_3).

3.1.4.2 Presence

Items relating to *realism, sensory, and control (*n_{items} *= 16)* from the questionnaire developed by Witmer and Singer (1998) were used to measure presence in virtual environments. Due to overlapping items, a new refined scale (n_{items} = 8) was created. Participants were asked to respond to questions based on their experience of the virtual environment (e.g., How completely were all of your senses engaged; 1 = *not at all*, 5 = *very*). The scale had good internal consistency (Cronbach's α = .78). The order of the items was randomised for each participant.

3.1.4.3 Connectedness to nature

To evaluate (and if needed control for) participants' connectedness to nature, the NR-6 (Nisbet & Zelenski, 2013; n_{terms} = 6) was used. Participants were asked to indicate their agreement with a series of statements (e.g., I feel very connected to all living things and the earth; 1 = *disagree strongly*, 5 = *agree strongly*). The scale had good internal consistency (Cronbach's α = .82). The order of the items was randomised for each participant.

3.1.4.4 Connectedness to built environments

A new scale was created to measure affinity with built environments (n_{terms} = 4; BR-4) by modifying elements from the NR-6 (Nisbet & Zelenski, 2013) where it was appropriate or possible. Participants were asked to indicate their agreement with the new statements (e.g., I feel very connected to cities and city life; 1 = *disagree strongly*; 5 = *agree strongly*). Similarly, this scale was found to have a good level of internal consistency (Cronbach's α = .77). The order of the items was randomised for each participant.

3.1.4.5 Review

Participants were asked to briefly describe what they liked and disliked about the experience, any memories evoked by the environment, and the severity of any sickness symptoms.

3.1.5 Procedure

Participants completed the PANAS-X both before (baseline) and after (manipulation check) the stressor task. The participant was then helped into the VR equipment and run through a safety briefing in the training area. Prior to starting the allocated virtual experience (e.g., high realism nature) they were given the following briefing scenario.

> On a calm Wednesday afternoon, you have decided to visit a [*local natural area / town*]. You have parked nearby and are about walk around. You will spend a couple of minutes stopped at five points of interest along your walk. During this time, you can move around and inspect the scene, observing your surroundings and letting your mind wander.

At the end of the experience the participant completed another PANAS-X. They were then asked to complete the presence measure, connectedness to environment scales, and the questionnaire. Except for the stressor task all written aspects of the procedure (e.g., PANAS-X) were completed at the computer (Figure 7). The experiment lasted approximately 45 minutes and was approved without necessity for ethical review in line with the university's self-assessment governance and ethics procedure.

3.2 Results

3.2.1 Manipulation checks

3.2.1.1 Cyber-sickness

Most participants did not experience any cyber-sickness symptoms (73%), with a total of 32 instances of sickness symptoms being reported, 27 of which were very slight or of little effect and five of moderate effect. For those instances, participants reported experiencing *headaches*, *sweating*, *eye fatigue*, *nausea*, *dizziness*, and *disorientation*. All symptoms were no longer present at the end of the experiment.

3.2.1.2 Presence

An independent samples t-test was run to see if there was any difference in presence scores for the high and low realism environments. The score was significantly higher in the high realism environments (M = 3.41, SD = 0.66) compared to the low realism environments (M = 3.16, SD = 0.60), $t(118) = 2.12$, $p = .036$, $d = .37$. Considering that higher levels of realism are linked to a greater sense of presence (Hvass et al., 2017) then the environments were significantly different in terms of graphical realism.

3.2.1.3 Connectedness to environment

A paired samples t-test was run to see if there was a significant difference in participants' connectedness to natural or built environments. There was no significant difference between participants' NR-6 (M = 3.39, SD = 0.84) and BR-4 (M = 3.28, SD = 0.87) scores, $t(119) = 0.936$, $p = .351$, $d = .13$. This shows that participants were not significantly connected to one type of environment and were generally indifferent to either.

3.2.1.4 Stressor task

A series of repeated-measures ANOVAs were run for each of the affect outcomes to see whether there was a significant difference in emotional state before and after the stressor task (within-subjects: T_1; T_2), and to check this was similar across all four of the conditions (between-subjects: *high* or *low* realism; *natural* or *built* environment).

While the data for *positive affect* and *serenity* were normally distributed, the assumption of normality was violated in some cases for he data for *negative affect* before (Z_{skew}: 1.66 to 2.36; $Z_{kurtosis}$: 2.40 to 6.58) and after (Z_{skew}: 0.53 to 1.73; $Z_{kurtosis}$: −0.32 to 3.87) the stressor task. As the other measures were normally distributed, ANOVAs are argued to be robust to assumptions of normality (see Blanca et al., 2017; Vickers, 2005), and that non-parametric equivalents would not allow us to consider all factors together (i.e., time, level of realism and environment type), ANOVAs are consequently reported for all measures. However, to ensure the findings are not sensitive to Type I error, a series of non-parametric tests were run, and the conclusions were replicated. *Positive affect* and *serenity* were significantly lower after the stressor task (Table 3). *Negative affect* was significantly higher after the stressor task. There was no significant interaction with type of experience for any of the subscales suggesting that the task induced a similar emotional state conducive to restoration in each condition.

Table 3

Repeated-measures ANOVA results for before and after the stressor task.

	Before stressor (T_1)		After stressor (T_2)		Change over time			Time x Condition interaction		
Scale	*M*	*SD*	*M*	*SD*	*F* (1,116)	*p*	η_p^2	*F* (3,116)	*p*	η_p^2
Positive affect	28.47	6.52	22.93	8.24	162.70	<.001	.584	1.07	.367	.027
Negative affect	14.03	4.47	17.98	6.07	102.34	<.001	.469	2.11	.103	.052
Serenity	9.23	2.52	7.27	2.46	84.70	<.001	.422	2.61	.055	.063

Note. PANAS Scores range from 10 to 50 for *positive* and *negative* affect, and 3 to 15 for *serenity*.

3.2.2 Affective responses

A 2x2x2 mixed ANOVA was run to see whether level of realism (*high* vs *low*) or type of environment (*nature* vs *built*) had an impact on positive affect, negative affect, and serenity before and after the VR experience (T_2 to T_3). Pre-stressor task (T_1) measurements were included as a co-variate in the analyses.

3.2.2.1 Positive Affect

There was a significant main effect of time $F(1, 115) = 21.78$, $p < .001$, $\eta_p^2 = .16$, with positive affect higher after ($M = 28.32$, $SD = 8.17$) the VR than before it ($M = 22.93$, $SD = 8.24$). There was no significant main effect of level of realism, $F(1, 115) = 1.03$, $p = .313$, $\eta_p^2 = .01$. There was a significant main effect of type of environment, $F(1, 115) = 5.72$, $p = .018$, $\eta_p^2 = .05$. In this instance, positive affect was significantly higher for natural ($M = 26.61$) compared to built ($M = 24.64$) environments.

There was a significant interaction between time and level of realism, $F(1, 115) = 5.24$, $p = .024$, $\eta_p^2 = .04$. In high realism environments positive affect was greater after the VR ($M = 29.35$, $SD = 9.02$) compared to before ($M = 22.57$, $SD = 8.95$). Similarly, in low realism environments it was greater after the VR ($M = 27.28$, $SD = 7.34$) than before ($M = 23.30$, $SD = 3.98$). Follow up within-subjects t-tests showed that these increases were significant for both the high ($t(59) = -7.39$, $p < .001$, $d = 0.76$) and low realism ($t(59) = -4.88$, $p < .001$, $d = 0.53$) environments. Additionally, a between-subjects t-test using change scores showed a significantly greater change in high ($M_{High} = 6.78$, $SD = 7.11$) compared to low ($M_{Low} = 3.98$, $SD = 6.32$) realism environments, $t(118) = 2.28$, $p = .024$, $d = 0.39$. There were no significant interactions between time and type of environment ($F(1, 115) = 0.80$, $p = .374$, $\eta_p^2 = .01$) and level of realism and type of environment ($F(1, 115) = 0.03$, $p = .856$, $\eta_p^2 = .00$).

There was no significant three-way interaction between time, level of realism and type of environment, $F(1, 115) = 0.17$, $p = .685$, $\eta_p^2 = .00$ (Figure 9).

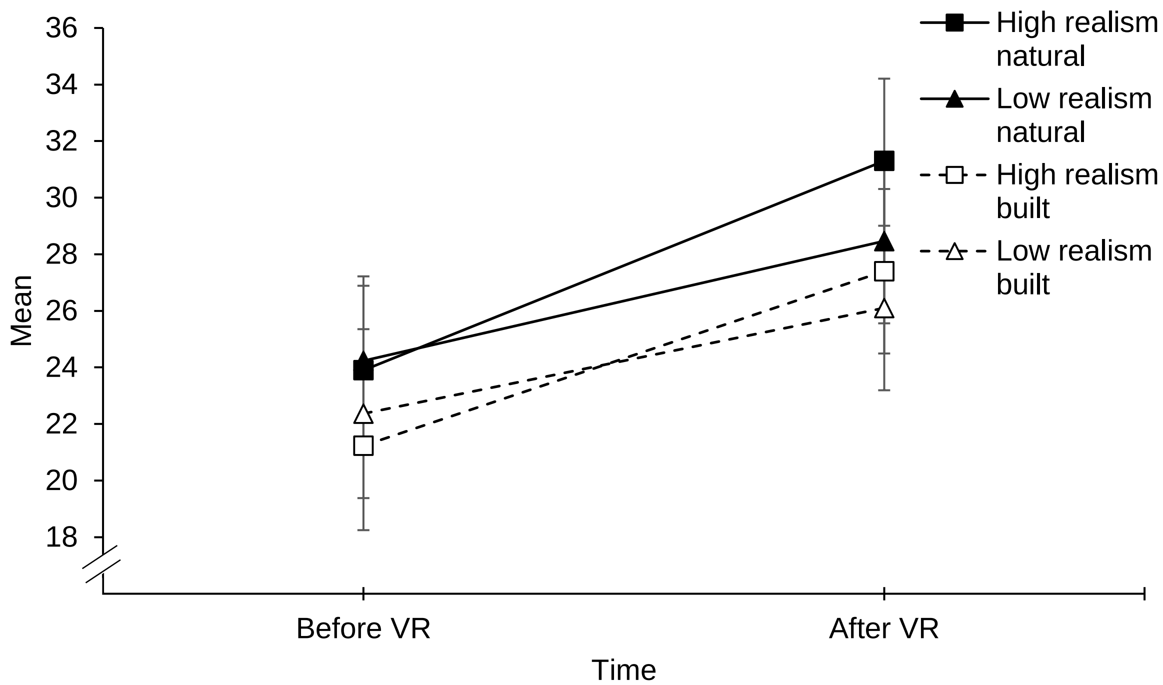

Figure 9. Three-way interaction between time, the level of realism and the type of environment for positive affect (Error bars: 95% CI).

3.2.2.2 Negative Affect

There were no significant main effects of time ($F(1, 115) = 1.21$, $p = .273$, $\eta_p^2 = .01$), level of realism ($F(1, 115) = 2.67$, $p = .105$, $\eta_p^2 = .02$), or type of environment ($F(1, 115) = 0.29$, $p = .590$, $\eta_p^2 = .00$).

There were no significant interactions between time and level of realism ($F(1, 115) = 1.99$, $p = .161$, $\eta_p^2 = .02$), time and type of environment ($F(1, 115) = 0.05$, $p = .818$, $\eta_p^2 = .00$), and level of realism and type of environment ($F(1, 115) = 0.72$, $p = .397$, $\eta_p^2 = .01$).

There was a significant three-way interaction between time, level of realism, and type of environment, $F(1, 115) = 4.83$, $p = .030$, $\eta_p^2 = .04$ (Figure 10).

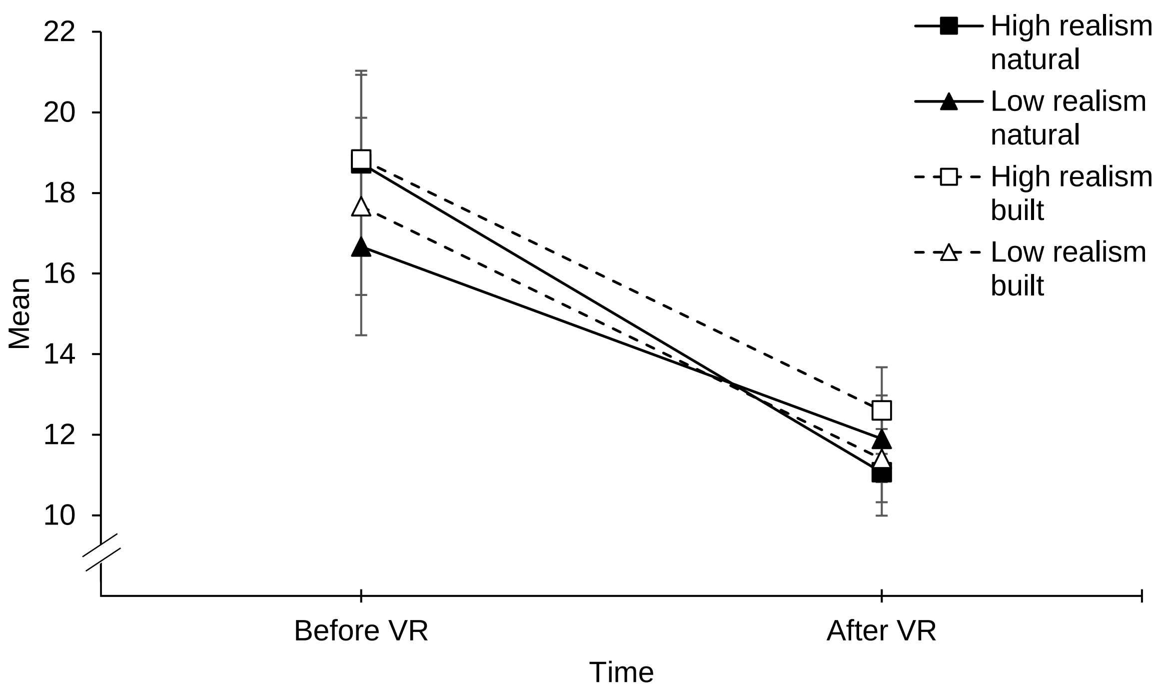

Figure 10. Three-way interaction between time, the level of realism and the type of environment for negative affect (Error bars: 95% CI).

Follow up within-subjects t-tests showed that negative affect was significantly lower after the VR compared to before for each condition (Table 4).

Table 4

Mean and standard deviation

Condition	*M* (*SD*) Before VR	*M* (*SD*) After VR	*t* (*df* = 29)	*p*	*d*
High realism natural	18.73 (6.68)	11.07 (1.93)	7.09	< .001	1.15
High realism built	18.83 (7.52)	12.60 (3.44)	5.11	< .001	0.83
Low realism natural	16.67 (3.53)	11.90 (3.60)	6.93	< .001	1.35
Low realism built	17.67 (5.86)	11.40 (2.62)	6.25	< .001	1.07

Additionally, a follow up one-way between-subjects ANOVA using change scores showed no significant difference between the conditions, F (3, 116) = 1.36, p = .260, η_p^2 = .03.

3.2.2.3 Serenity

There was a significant main effect of time ($F(1, 115) = 18.81$, $p < .001$, $\eta_p^2 = .14$) with serenity higher after ($M = 10.78$, $SD = 2.74$) the VR than before it ($M = 7.28$, $SD = 2.46$). There was no significant main effect of level of realism ($F(1, 115) = 0.13$, $p = .723$, $\eta_p^2 = .00$) or type of environment ($F(1, 115) = 1.51$, $p = .221$, $\eta_p^2 = .01$).

There was no significant interaction between time and level of realism, $F(1, 115) = 2.62$, $p = .108$, $\eta_p^2 = .02$.

There was a significant interaction between time and type of environment, $F(1, 115) = 17.11$, $p < .001$, $\eta_p^2 = .13$. In natural environments serenity was greater after the VR ($M = 11.65$, $SD = 2.68$) compared to before ($M = 7.07$, $SD = 2.43$). Similarly, in built environments it was greater after the VR ($M = 9.90$, $SD = 2.52$) than before ($M = 7.48$, $SD = 2.49$). Follow up within-subjects t-tests showed that these increases were significant for both the natural ($t = −11.82$, $df = 59$, $p < .001$, $d = 1.89$) and built ($t = −6.25$, $df = 59$, $p < .001$, $d = 0.97$) environments. Additionally, a between-subjects t-test using change scores showed a significantly greater change in natural ($M = 4.58$, $SD = 3.00$) compared to built ($M = 2.42$, $SD = 2.99$) environments, $t(118) = 3.96$, $p < .001$, $d = 0.72$. There was a significant interaction between level of realism and type of environment, $F(1, 115) = 5.42$, $p = .022$, $\eta_p^2 = .05$.

There was a significant three-way interaction between time, level of realism, and type of environment, $F(1, 115) = 5.04$, $p = .027$, $\eta_p^2 = .04$ (Figure 11).

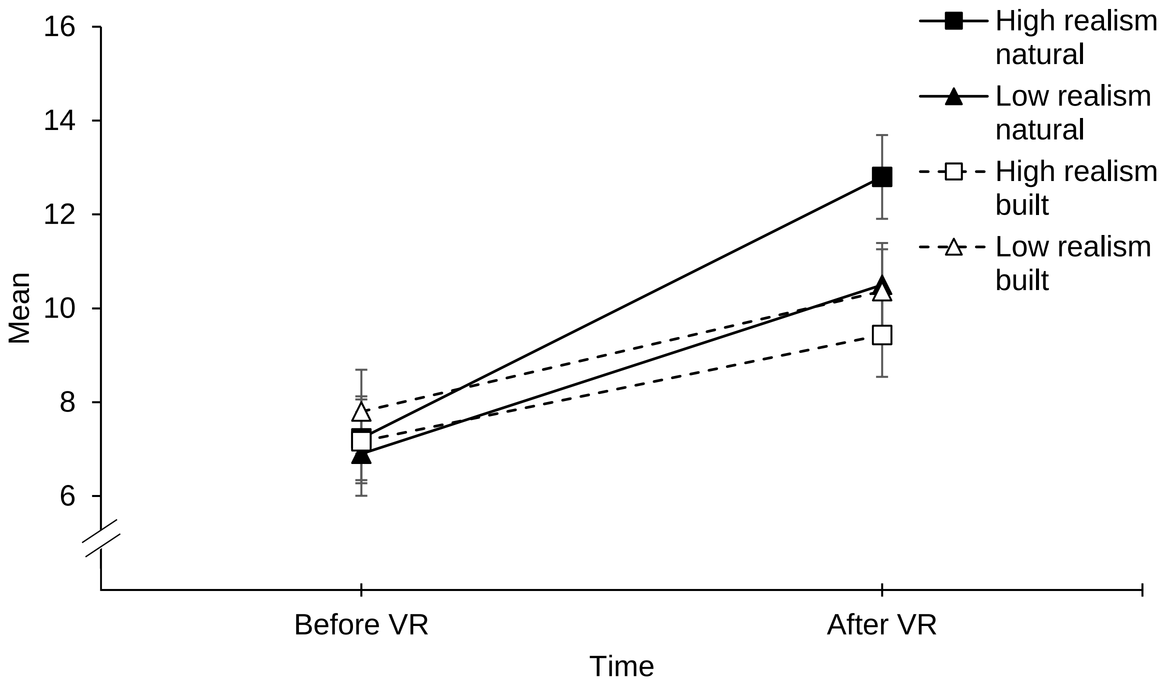

Figure 11. Three-way interaction between time, the level of realism and the type of environment for serenity (Error bars: 95% CI).

Follow up within-subjects t-tests showed that serenity was significantly higher after the VR compared to before for each condition (Table 5).

Table 5

Mean and standard deviation

Condition	*M* (*SD*) Before VR	*M* (*SD*) After VR	*t (df = 29)*	*p*	*d*
High realism natural	7.23 (2.84)	12.80 (2.36)	−9.43	< .001	1.96
High realism built	7.17 (2.49)	9.43 (2.89)	−4.41	< .001	0.91
Low realism natural	6.90 (1.97)	10.50 (2.52)	−4.39	< .001	1.83
Low realism built	7.80 (2.50)	10.37 (2.04)	−8.12	< .001	1.03

Additionally, a follow up one-way between-subjects ANOVA using change scores showed significant differences between the conditions, *F* (3, 116) = 7.73, $p < .001$, $\eta_p^2 = .17$, with serenity changing the most in the *high realism natural* experience (*M* = 5.57, *SD* = 3.23), followed by the *low realism natural* (*M* = 3.60, *SD* = 2.43), *low realism built* (*M* = 2.57, *SD* = 3.20), and then *high realism built* (*M* = 2.27, *SD* = 2.82) experiences. Post-hoc

Bonferroni tests revealed that the change in serenity score was significantly greater in the high realism natural experience than both the low realism built ($p = .001$) and the high realism built ($p < .001$). All other comparisons were not significant ($p > .065$).

3.2.3 Themes within appraisals

Using the same analytical approach as Study One, themes identified from answers to the open response questions related to *presence*, *immersion*, *VR technology*, *reminiscing*, and *atmosphere*.

3.2.3.1 Presence

There was appreciation for realism across all experiences; "…the realism of the trees and the sounds that made it feel like I was really there." (#067; High realism natural); "I liked how realistic the scenario was visually and the audio really helped to make the experience more real." (#074; Low realism natural).

However, there were also those who were aware it was not real in each experience; "Very intreseting [sic] that my brain treated even cartoonish 3D objects as normal. I can see that it is not real but as a mental construction I was pretty sure what is what." (#090; Low realism built); "It reminded me of playing video games when I was younger and films I've seen. I think it was because the scenes looked real but also fake at the same time." (#019; High realism natural).

3.2.3.2 Immersion

While participants appreciated being able to move around in the virtual space, "Very interesting to try a virtual reality experience where you are able to move around in the enviroment [sic]" (#075), there was strong and persistent desire to move beyond the safety boundary to explore; "I would have liked to move around more and get closer to certain places in the setting. The box I was enclosed in was quite small." (#064).

There was also an expectation to interact with the environment or have it react to their presence; “It was really surreal to have no sense of touch - I couldn't feel the wind on the mountaintop, or the cool breeze by the river/pond.” (#010); “I wish I can communicate with the people inside the environment, hence I felt a bit strange and lonely, because no one can see me.” (#009).

3.2.3.3 VR technology

A prominent theme among the responses was the ability for the technology to act as an escape from reality; “I liked how it allowed me to escape from any real-world stresses and free my mind. It also enabled me to view scenes that I've never seen before.” (#007); “It was amazing, so cool to just escape reality, and not think about anything, your worries, the work you have to do. It was like another world. Just escape into the unknown.” (#094).

There was also excitement at getting to experience VR; “it was fun using a VR headset and it was interesting to take part in a different kind of experiment.” (#068); “It is very new to someone who has not used a VR equitpment [sic] before, so it was all very exciting.” (#097).

However, the physical properties of equipment did detract from the experience for some; “The cord got in the way a lot while I walked around.” (#085); “I had a sweaty face from the headset…” (#119); “I disliked the heaviness of the headset that I sometimes became aware of.” (#067).

3.2.3.4 Reminiscing

Regardless of level of realism or environment type the experiences reminded participants of places they had previously lived or visited on holiday; “…I could relate the environment to thew [sic] holidays I have been on. For example Chiang mai [sic] in Thailand where I visited this year. The mountainous areas and the trees is [sic] what reminded me most” (#025); “[It] reminded me of when I first go somewhere new on holiday. Like when I went to Rotterdam [sic], I was always looking around at everything and there were cafes and plazas like in the vr [sic] environment. (#111).

3.2.3.5 Atmosphere

Regardless of the experience participants appeared to find the experience relaxing; "I enjoyed how peaceful the experience was. I love being outdoors, with fresh air and having a view of water makes me feel so calm. I also really liked being able to hear the birds and seeing the grass moving in the breeze was so lovely." (#037).

In the case of the built environments this was related to the amount going on in the scene; "…it reminded me of whenever I go to town on a Sunday - its relatively quiet." (018).; "I liked the quiet and calm of the experience. It was a relaxing environment to be in. There were not too many other people, so my senses were not overwhelmed, as they sometimes can be in town/city environments." (#033).

4.1 Discussion

Virtual reality (VR) is growing in use and has great potential for advancing scientific enquiry by enabling environmental control, manipulation, and accessibility. This paper explored whether the quality of the environment is important. Specifically, by testing different presentation methods (Study One: comparing real vs. 3D VR vs. 2D video) and different levels of detail (Study Two: comparing high vs. low graphical realism in the context of nature and built environments), this paper systematically examined if realism is important for research, in particular within the context of environmental restoration research. Our findings demonstrated that VR can elicit similar positive emotional reactions to experiencing a real natural scene, but that realism - specifically regarding presence and immersion - was somewhat compromised in the VR condition compared to the in-situ real experience. When manipulating realism in the VR context, Study Two found that more realistic VR environments evoked more positive affective and serenity responses, as well as a greater sense of presence. Considering these points, the level of realism that can be attained with VR does impact affective responses and perceptions.

4.1.1 Participant perceptions

Clearly, VR offers a suitable alternative alongside existing surrogate methods, however, participants' expectations of this technology do influence their experiences. In both studies *immersion* was a prominent theme amongst participants. There was a strong desire to be able to engage their somatic and olfactory senses alongside the visual and audio stimuli. Interestingly, criticism at the lack of this extra dimension was typically levied at VR, as opposed to video, which suggests this facet of immersion plays an important role in differentiating participant's expectations and experience of these presentation methods. To address this, researchers could consider adding a quiet fan to simulate the breeze or introduce scents into the environment that match the experience. However, the extra effort should only be made when relevant to the research question, as olfactory stimuli have been found to have no effect on participants' sense of reality or realism, and only affected their sense of presence when unpleasant (Baus & Bouchard, 2017).

Alongside a desire to feel the environment (e.g., a breeze) there were numerous references to wanting to be able to touch elements within it. While it is true that haptic feedback in future technology could provide more realistic two-way interaction (e.g., the sensation of running fingers through long grass) the desire for touch is unusual for these experiences. When walking around a natural area or town centre people rarely want to pick up things off the ground or feel elements of the scenery. On the other hand the dirt and grime of the real world is controlled for in a virtual environment, which may be lowering any inhibition to touch. Additionally, the instructions and structure of the experience may have been driving this desire. On a typical walk people will move through their environment towards a predefined goal (e.g., around the lake, towards a particular shop), whereas here participants were told that they will *stop at points of interest* and can *inspect the scene*. The static environment coupled with these instructions could understandably fuel a desire to closely examine their surroundings through touch; a desire that might not be present in a more ambulatory experience.

These points highlight a limitation of both studies, that is, the current condition of VR. As the technology continues to develop, wireless experiences and more naturalistic interaction methods (e.g., to simulate walking) will reduce feelings of being confined to a space and allow participants to explore environments further. Additionally, better quality lenses and lighter headsets will provide more comfortable and clear experiences. Consequently, future research should continue to explore how the latest developments impact experiences.

Across the experiences in both studies, there was a consensus that the environments were at least realistic enough to make the participant feel as though they were really in the environment. While there were those that clearly identified the low realism environments as such, likening them to video games or cartoons, there were also those who unexpectedly described these experiences as realistic. This could be due to a lack of a more representative environment with which to compare it, coupled with the lack of previous exposure to VR. If a participant is unfamiliar with computer-generated environments it is reasonable that the lack of any comparable prototype would qualify these experiences as realistic from their perspective. Future studies should be mindful of participants experience with VR and computer-generated environments to control for the influence of expectations.

Across both studies, there were also participants that mentioned their lack of body or hands in the experience. There was no visual representation of hands as there was nothing in the experience for the participant to interact with and thus no need for them to hold the controllers. No body was included due to the additional overhead of having to match the virtual representation to how a participant perceives their own body. This extends beyond physical properties (e.g., weight) but also to personalisation (e.g., clothing style and tattoos). If this was not accurate it may have adversely impacted results as the type of avatar you embody can impact experience (Ahn et al., 2016; Seinfeld et al., 2018). Future research could explore how allowing the participant to customise their appearance impacts experiences.

The participants' perception of their relative safety was identified as another layer of experimental control afforded by VR. Being away from real life threats removes their influence and thus allows researchers to dissociate confounding factors, such as the concerns regarding the summer heatwave of 2018. While this is also possible with other surrogate experiences, arguably VR offers greater control as reinserting the perception of danger, were it necessary for the research question, would be easier to achieve due to the influence of increased immersion.

Another issue relating to participant safety is that of their wellness during and after the experience. Rarely did responses relating to sickness provide information beyond simply acknowledging the symptom in one or two words (e.g., "slight headache"; #101). Considering that the five who experienced moderate symptoms offered more information, this brevity could be explained by the low severity ratings, suggesting the symptom was fleeting and unimpactful. Those who experienced moderate symptoms all reported feeling a sense of *disorientation*. This could be explained by the participants being teleported between scenes, a veritably unnatural experience. However, this method of transportation is an industry standard for virtual movement. Considering this and not only that 78% of the sample have hardly any or no experience using a head mounted VR display, but that also all the mentions of disorientation came from within this sub-group, it is more likely that the prevalence of disorientation was due to participants not being fully acclimatised to VR experiences.

Steps were taken to ensure that the potential onset of sickness symptoms was minimised, e.g., maintaining a high frame rate with no input lag, and providing a training area. The minimal occurrence of symptoms amongst a sample unfamiliar with VR suggests that these efforts worked, although it would be preferential to have no symptoms occur at all. It is worth noting that disorientation is a standout symptom for new users, and although its presence here was small, future research could consider taking additional steps to mitigate it if its influence is a concern, for example, by adding warm-up sessions to prepare participants (Cobb et al., 1999; LaViola, 2000). Additionally, as cybersickness from VR has been related to numerous individual differences - including motion-sickness susceptibility, gender, and even certain phobias - researchers should add additional screening to ensure consistent participant experiences and safety (Howard & Van Zandt, 2021).

However, while VR remains a novelty and training sessions are necessary, there is the potential for these experiences to impact restoration research by alleviating induced stress prior to the experience.

4.1.2 Effect of realism

The findings demonstrate that the level of graphical realism of a VR experience has an impact on affective responses. The high realism environment did lead to a significant difference in positive affect, with ratings showing a significantly greater increase compared to low realism environments. Additionally, in the first study serenity scores were significantly higher in the real experience compared to watching a video. In the second study the high realism natural condition saw the greatest change in serenity, while the high realism built saw the smallest change; the changes were significantly different from one another. These findings suggest a high level of realism is important when exploring affective response in different types of environments.

The findings that negative affect was reduced by all VR experiences and that were no significant differences between the changes were unexpected, especially considering built environments are well documented as being less or not at all restorative (e.g., Hartig et al., 2003; Takayama et al., 2014; Ulrich et al., 1991; Velarde et al., 2007). Participants cited the absence of activity in the scene as a contributor to a relaxing experience. However, previous research examining built environments has used quiet scenes and found built environments not to be restorative (e.g., Bratman et al., 2015; Gidlow et al., 2016; Hartig et al., 2003; Ulrich et al., 2003; Wilkie & Stavridou, 2013). Alongside acting as a possible confound, the addition of large virtual crowds brings significant overhead, not only in having to provide a range of assets to create a noticeable level of variety, but also to smoothly render a dense amount of people. Alternatively, a street completely devoid of any vehicular or pedestrian activity could be perceived eerie or abandoned. Furthermore, while Artificial Intelligence can create photographs of fabricated faces that appear completely real, even cutting-edge animated virtual renders can lack the level of detail needed to avoid invoking the effects of the uncanny valley, that is an unpleasant reaction to an object whose appearance is similar to that of a human but not completely realistic (Seyama & Nagayama, 2007). Future research could explore how different types of crowds (e.g., density, variety, realism) impact participants' experience of built virtual environments to find an optimum balance.

Considering these points, it is unlikely the level activity in the scene was responsible for these findings. While built environments are often documented as inhibiting restoration there is evidence to suggest they are also capable of being restorative (Weber & Trojan, 2018). The result could be explained by how both types of environment evoked pleasant memories of places that participants had lived or visited on holidays, as supported by the open-response data. However, it is unclear what elements, specifically in the built environments, contributed to this perception. The perception that VR functions as an escape from reality could have set expectations towards relaxation. Additionally, there was a general excitement at simply getting to use the VR technology and take part in a study that was different to the norm. For example, when talking about the real experience participants most frequently used *pleasure* and *contentment* words but used *contentment* and *excitement* words when talking about VR. While, for the latter, these terms may seem antithetical it is likely that while the experience was calming, the fact that most of the participants had hardly any or no experience using VR meant that the novelty of the experience was stimulating. Future research could explore how immersion and different virtual environments work to elicit memories and experiences.

As previously stated real world experiences are optimal for studying human-environment interaction, with results from virtual environments not always completely mirroring their in-situ counterparts (see Browning et al., 2020; Calogiuri et al., 2018). However, the current study adds to a growing body of literature (e.g., Nukarinen et al., 2020; Yeo et al., 2020) that demonstrates valid and timely results can still be achieved with VR.

4.1.3 Conclusion

While real experiences clearly remain the optimum choice for studying any aspect of our relationship with an environment, VR offers a suitable alternative alongside existing surrogate methods. However, it is important that consideration is also given to participants' perceptions of and expectations regarding VR as they can influence the experience. Like any research tool the appropriateness to the method is a key consideration. Other surrogate methods (e.g., videos or photographs) are still valid tools and their comparative simplicity should not be ignored if they can appropriately answer the research question. However, if the additional benefits afforded by VR are relevant then the expenditure is worth the investment.

At the start of the current study, we acknowledged that VR is a broad term and can be implemented in numerous ways. The results presented above are done so within the context of the subset of research where visual and audio stimuli are combined into an immersive computer-generated experience. These findings demonstrate that while low realism environments do yield viable results, stronger effects are produced by higher realism environments. Considering this, future research could continue to explore the impact of different levels of realism and abstraction in different environments (e.g., cartoon graphics, different colour pallets, surreal landscapes).

The current study shows that researchers using VR to explore environment experiences and restoration where a visual component is necessary should endeavour to produce more realistic experiences, both in terms of graphical fidelity and naturalistic interaction.

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Appendix

Stressor Task Instructions

Please try to remember the last time you felt very stressed or in a negative mood. You may have felt **anxious**, **irritable**, **fatigued**, or **overwhelmed**.

We are **NOT** asking you to recall traumatic experiences. Instead we are interested in the types of stressors that may be more common.

Please note *that anything you write will be kept confidentially. You are also welcome to take this sheet with you when you leave. Please refrain from including any information that could be used to identify you (e.g., names, contact information etc.)*

Please try to remember as much as possible from the event and write it down on the sheet: where you were, what you were doing etc. Try to write down in as much detail how you felt: **stressed**, **anxious**, **overwhelmed** etc.

You can write as much as you like, you have 10 minutes. If you finish before the time is up, please read over and think about what you have written.