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ORIGINAL ARTICLE

Phone-based virtual exploration of green space increases positive affect in students with test anxiety: a pre-post experimental study with qualitative insights

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Abstract
Nature confers a host of benefits including recovering from stress, replenishing attentional resources, improving mood, and decreasing negative thinking. Virtual nature, i.e. exposure to natural environments through technological means, has proven to also be efficacious in producing benefits, although more limitedly. Previous studies with immersive virtual reality with university students have shown that one bout of virtual nature can reduce negative affect in students with high test anxiety and can reduce feeling of worry and panic after several weeks of daily exposure. The present study aimed at replicating the effect of one bout of virtual nature on affect and extend it to cognition in a sample of university students with different levels of test anxiety. An inexpensive goggle + phone apparatus was utilized and the one bout of virtual nature was self-administered. 48 university students took part in the study, randomized between viewing a 360 degrees video of nature or of an urban environment. They completed the Positive and Negative Affect Schedule and the Cognitive Reflection Test before and after the exposure to the virtual environments and responded to open-ended questions about their experience of the intervention. Results showed improvements in positive affect in students with higher anxiety were obtained in the nature condition, no other effects were found. Qualitative appraisal indicated that participants in the nature condition felt more relaxed and focused, however the technical issues were detrimental to the benefits. In conclusion one bout of virtual nature could support students with higher test anxiety when confronted with examinations.

Keywords Nature benefits · Virtual reality · Test anxiety · Affect · Attention restoration · Stress recovery

1 Introduction

A growing body of evidence shows that green environments, either experienced in real or virtual scenarios, can help to alleviate stress, overcome cognitive overload, and recover from attentional fatigue due to their restorative properties (Litleskare et al. 2020; Setti & MacIntyre 2023; Sumner et al. 2022). Green environments include any vegetated areas of nature such as open landscapes, parks and forests (Berto 2014).

The demands of daily life require constant attentional engagement, leading to eventual mental fatigue (Kaplan 2001; Kaplan and Kaplan 1989a). Attention Restoration Theory (ART) suggests that spending time in green environments evokes a type of effortless attention known as 'soft fascination', that is, the undemanding exploration of an engaging but not attentionally draining setting (Kaplan 2001). ART also asserts that green environments elicit feelings of 'extent' (existing in a vast enough world where 'scope' and coherence can be perceived) and 'being away' from attentional demands (Hartig et al. 1991). In agreement with ART, green environment exposure has been shown to yield improvements in attention, executive functions, and memory-related tasks, suggesting that exposure to nature can have a positive impact on cognitive performance (Bratman et al. 2012). Complementarily, Stress reduction theory

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(SRT) contends that spending time in green environments yields cognitive benefits due to their significance for human evolution (Ulrich et al. 1991). More specifically, because of the intrinsic ties we hold with the natural world, spending time in green environments can positively stimulate our parasympathetic nervous system, which, in turn, reduces stress levels (Ulrich et al. 1991). In support of SRT, for example, going for a walk in a natural environment e.g. a forest has been significantly associated with decreased cortisol levels (Yao et al. 2021).

In an increasingly urbanised world, opportunities for exposure to nature may be limited and, in certain circumstances, virtual nature may help compensate for that, through its ability to mimic the restorative properties of its 'real' counterpart, although not to the same extent (Calogiuri et al. 2018). Virtual reality technology has enabled the creation of immersive virtual environments (IVE) (Calogiuri et al. 2018), in which synthesised sensory information is manipulated to produce a continuous flow of surrounding stimuli (Calogiuri et al. 2018). IVEs have been shown to successfully reproduce, to a certain extent, the restorative properties of 'real' green environments (De Kort et al. 2006; Ulrich et al. 1991). For example, research by Calogiuri et al. (2018) found that the use of commercial IVE technology simulating interaction with green environments yielded adequate levels of "being there" and "sense of reality" within participants. Several studies have also demonstrated virtual nature via IVE to be a valid tool for promoting relaxation and managing stress (Anderson et al. 2017; Annerstedt et al. 2013; Valtchanov et al. 2010; Villani et al. 2007). Together these findings highlight IVE as a useful technology for green environment research and practice.

A rapidly evolving field of IVE research concerns the impact of virtual immersion in nature on psychological mood states (Frost et al. 2022), with a particular focus on outcomes of positive and negative affect. A recent systematic review by Spano et al. (2022) showed consistent evidence that exposure to virtual nature results in decreased feelings of negative affect (Mattila et al. 2020; Yu et al. 2018, 2020). Results for positive affect are mixed, with some studies finding no changes in positive effect (Anderson et al. 2017; Gao et al. 2019; O'Meara et al. 2020) and others finding increases in positive affect, post-nature exposure (Browning et al. 2020; Huang et al. 2020; Mattila et al. 2020; Schutte et al. 2017). Interestingly, two studies observed increases in positive affect following exposure to both virtual and in-person nature, with no significant difference found between the two 'realities' (Chirico and Gaggioli 2019; Rockstroh et al. 2019). However, there was considerable variability in the type of virtual reality equipment used across research; several studies used high-quality technology such as head-mounted display (HMD) or cave automatic virtual environment systems, while others opted for less immersive, but more affordable and portable technology such as three-dimensional panoramic photos (Spano et al. 2022). Few studies compared the efficacy of different VR modalities in conveying the beneficial effects of nature. Liszio et al. (2018), examined the use of virtual nature in the context of acute stress. Participants underwent a stress-inducing task, after which they were exposed to a natural environment via a desktop screen (2D) or via an HMD. The group that was assigned the HMD showed significantly greater levels of positive affect and lower levels of stress (as indicated by cortisol and heart-rate variability) compared to those who were assigned to the desktop or control group (Liszio et al. 2018). Similarly, in Yeo et al.'s (2020) study, participants were randomly assigned to view virtual nature via a 2D-screen, a 360-degree video or an HMD system following a boredom-induction task. Significant increases in positive affect were found across all VR modalities; however, participants who experienced nature via the most immersive form of VR (i.e. HMD) exhibited the greatest changes in positive affect. These findings highlight a need for further research into whether less immersive VR modalities, that are cheaper to use and easier to implement, can still effectively deliver the restorative benefits of virtual nature. For example, a more recent study by Cadogan et al. (2023) found that viewing a 6-minute nature video led to reduced feelings of negative affect and rumination in individuals with high levels of sensory processing sensitivity.

One applied field in which virtual nature could be particularly useful is to alleviate the burden of stressful situations in the workplace or educational contexts. Test-taking is an inextricable part of academic life, therefore it is unsurprising that test anxiety is experienced by an increasing number of students each year (Duraku 2017). Test anxiety can be defined as the fear, worry and dread of failure before or during an exam scenario (Trifoni and Shahini 2011) that is accompanied by tension, physiological over-arousal, dips in positive affect and surges in negative affect, all of which typically result in poor concentration and detrimental cognitive appraisals (Chin et al. 2017; Putwain et al. 2016). Studies have found associations between poor academic performance and overall negative experiences of exam situations (Abulghasemi 2008; Chin et al.,2017; Trifoni and Shahini 2011). Test-taking demands require high-levels of working memory and attention-related resources in order to achieve a good performance; this can be impaired when these resources become compromised by ruminative, task-irrelevant thoughts (Beilock & De Caro, 2007). This is also referred to as 'choking' under pressure (Krawietz 2013). The majority of individuals who have test anxiety 'choke' immediately before or during the test (e.g. in an exam hall, where nature is not readily available) (Beilock & De Caro,

2007). Even when choking does not occur, the experience of being tested is particularly stressful for some individuals, therefore there is potential in this context to capitalise on the positive effects of nature to improve the exam experience. Students may not always have nature spaces to visit in the proximity of testing environments or places of study, therefore a VR solution could prove to be useful in this context.

In our previous study (O'Meara et al. 2020) we found that exposure to a green environment may help reduce the negative impact of the testing situation on mood. We selected twenty high- and twenty low-test anxiety college students utilising the Pasco Hernando Community College Test Anxiety Questionnaire (Nist and Diehl, 1990) who underwent a pseudo exam and were asked to report their mood before and after being exposed to either a green or urban virtual environment via a head mounted display system. We also assessed positive and negative affect before and after the pseudo exam as they have both been shown to relate to test anxiety (Chin et al. 2017). Participants were asked to attend the session in the Immersive Virtual Reality (IVR) IVR laboratory where they explored a 360 degrees video of either a woodland or an urban industrial area. Results showed that only those with high anxiety who experienced the nature VR intervention displayed significant decreases in negative affect, supporting the hypothesis that time in nature, even if virtual, can have a positive impact on an individual's experience of taking an exam, however no impact on the test itself was found, possibly due to ceiling effects as the positive affect scores were high; alternatively nature exposure through virtual nature could mainly modulate negative affect, although an a-priori reason for it remains unclear. Along those lines, in a recent study by Browning et al. (2023), 40 university students were assigned to either a virtual nature intervention or a control condition. In the virtual nature condition, participants were provided with IVR glasses and asked to watch one 4-minutes, 360 degree video once a day, Monday to Saturday for 3–4 weeks. Questionnaires were administered before and after the intervention, measuring worry, rumination, panic (anxious arousal) and depressive symptoms. Results showed that worry and panic decreased after exposure to the nature condition.

IVR is still an expensive tool if we consider regular use by students, therefore the present study aims at assessing the efficacy of a cheaper off-the-shelf IVR technology, to improve mood in one bout of nature exposure. Although inexpensive, phone-mounted VR are less immersive than the head mounted display system used in our original study (and in Browning et al. 2023), they are an inexpensive, more portable form of VR, and thus more accessible to the general public. Therefore, if the VR headset yield significant benefits, it would be a more accessible and easy to use tool in the context of an exam setting where nature is not available. As with the previous study (O'Meara et al. 2020), we anticipated that the restorative properties of a green, as opposed to an urban environment (Kaplan 2001; Kaplan & Kaplan, 1981; Hartig et al. 1991; Ulrich et al. 1991), delivered via VR, would help to reduce negative affect associated with test anxiety and increase positive affect, particularly in those with higher test anxiety, as they are more likely to be those in need to replenish their mental resources. We also hypothesised a beneficial effect of virtual nature on performance in the cognitive test, particularly for those with higher test anxiety. It is likely that the original cognitive task (O'Meara et al. 2020) used did not pose a sufficient level of difficulty to participants, and so this study opted for a more sensitive test that still focused on reasoning and problem solving, which are required in a real-exam situation. Brief post-experiment qualitative questions were presented to participants to gain further insight into their experience with the virtual intervention and how they felt after having engaged with it, as only informal comments were gathered in the previous study.

2 Method

2.1 Participants

A total of 48 participants (female = 33, male = 10, remaining participants did not indicate), aged 18 to 53 (mean = 22.67, SD = 5.97) completed an online experiment and survey. An a priori sample size calculation, utilising GPower, indicated a minimum sample size of 74 for each linear regression model. Despite great recruitment efforts, only 48 participants could be included (see Fig. 1). All participants were enrolled in either undergraduate or postgraduate study at the time of recruitment in University College Cork, Ireland. Participants were recruited mid-semester, at a time when exams do not take place to avoid potential interference with exams performance.

Participants were recruited by distributing an invitation to partake in the survey to University College Cork's student mailing list, or in person. Ethical approval for the study was obtained from UCC School of Applied Psychology's Ethics Committee. Participants were given the option to enter a raffle for a €15 One4All voucher upon completion of the study. Participants were fully informed about the scope of the study, and informed consent was obtained before participation by ticking the corresponding box in the online survey linked to the experiment.

Participants were recruited in two phase (Fig. 1). Participants were recruited online, in recruitment phase 1, and were presented with the Pasco Hernando Community College Test Anxiety Questionnaire (PHCC TAQ) (Nist and

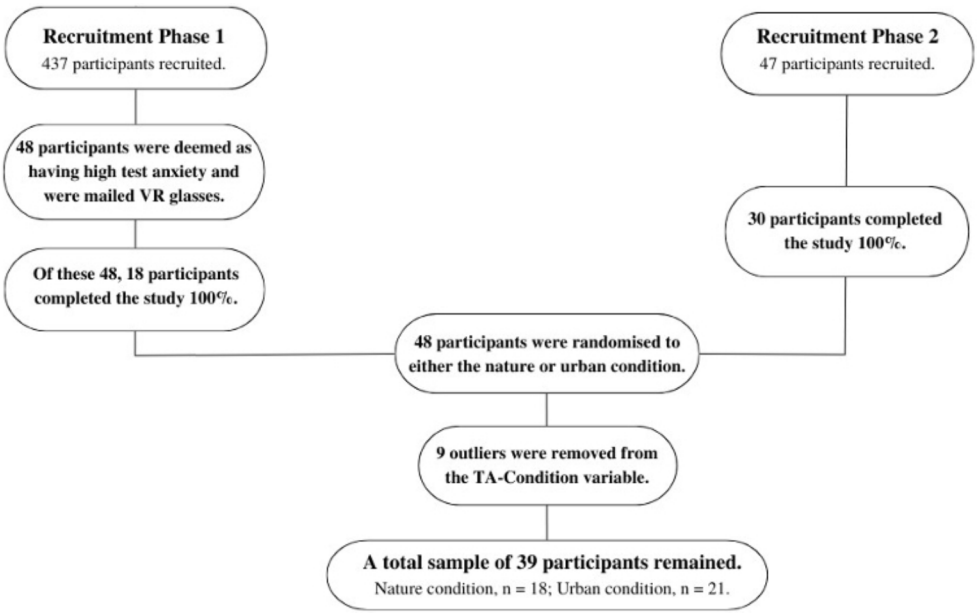

Fig. 1 Participant recruitment and screening process. TA, test anxiety

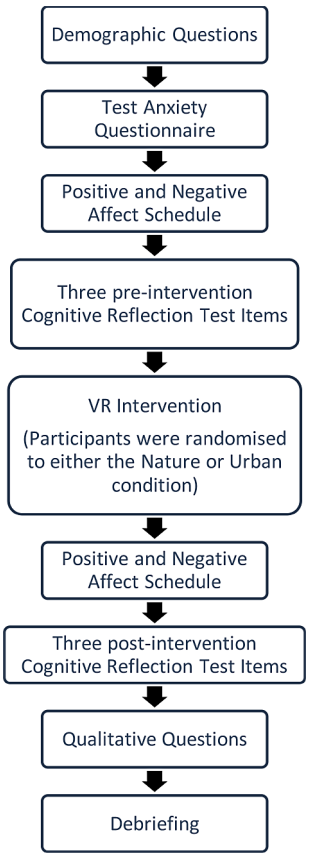

Fig. 2 Flowchart outlining the survey's order

Diehl, 1990). Only those who scored high in TAQ and provided a postal address were sent a VR headset by post so that they could complete the study. This was to ensure to have participants with high test anxiety in our sample. In recruitment phase 2, participants were recruited in-person. This cohort was not screened based on TA scores, the test was administered but all those who completed the task were included.

2.2 Design

This is a pre-post experiment with affect and problem solving as dependent variables and type of environment (nature vs. urban) as between participants manipulation, with test anxiety as covariate.

2.3 Procedure

A survey was distributed via Qualtrics XM, containing the PHCC Test Anxiety Questionnaire (PHCC TAQ) (Nist & Diehl, 1990), the Positive and Negative Affect Schedule (PANAS) (Watson et al. 1988), an adapted version of the Extended Cognitive Reflection Test (CRT, Toplak et al. 2014) and demographic questions assessing participants' age, gender, education level, year of study in university, the university in which they study and whether they have nature available in the neighbourhoods. The survey presented the PANAS and three CRT items at t1 (pre-exposure to the video) and three different items at t2 (post-exposure to the video), the demographic questions and TAQ were only asked at t1 and the qualitative questions were only presented at t2. Participants were informed that the purpose of the study was to examine how exposure to different VR environments affects cognition. They were unaware of the type of environment that would be presented to them and also of the nature of the pre- and post-intervention survey items. Participants were randomly assigned to the VR conditions;

randomization was obtained with the Randomizer function in Qualtrics.

2.4 Measures

2.4.1 Test anxiety

The PHCC TAQ (Nist and Diehl, 1990) is a 10-item scale which measures the extent to which participants experience test anxiety (TA) – a feeling of fear or anxiety induced by examinations or examination settings. Reponses are presented on a five-point Likert scale, ranging from 1 – Never to 5 – Always, by which participants indicate how often each statement describes them. Scores ranging from 10 to 19 indicate low to negligible TA. Those between 20 and 35 indicate moderate, healthy levels of TA and those exceeding 35 suggests debilitating TA (Nist & Diehl, 1990). Cronbach's alpha for the current study was 0.84. Example items include "I have visible signs of nervousness such as sweaty palms, shaky hands, and so on right before a test" and "I feel nauseated before a test."

2.4.2 Positive and negative affect

The Positive and Negative Affect Schedule (PANAS) is a 20-item scale that measures levels of both individuals' Positive Affect (PA) and Negative Affect (NA) (Watson et al. 1988). It encapsulates the former as the extent to which individuals experience enthusiasm, activeness, alertness, high energy, full concentration and pleasurable engagement with the world around them. The latter is conceptualised as a state in which individuals experience sadness, lethargy, subjective distress, anger, contempt, disgust, guilt, fear and nervousness. PANAS presents twenty items to which participants were instructed to "indicate to what extent you feel this way right now, that is, at the present moment OR indicate the extent you have felt this way over the past week" on a Likert scale from 1 (Very Slightly or Not at All) to 5 (Extremely). Scores from each respective subscale are summed to determine scores to represent participants' PA and NA. The pre-intervention PA and NA subscales had Cronbach's alpha values of 0.88 and 0.90 respectively. The post-intervention PA and NA subscales had Cronbach's alpha values of 0.93 and 0.92 respectively.

2.4.3 Cognitive reflection

The expanded Cognitive Reflection Test (CRT) (Toplak et al. 2014) assesses individuals' tendencies to override an obvious, incorrect response and to engage in cognitive reflection (CR) that results in selecting a correct response. It presents seven items, however, only six of these were presented in the study, to ensure even numbers of pre-intervention and post-intervention items. These items are presented in Online Resource 1 and include "A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost? ____ cents" and "Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class? _____ students." On average, 33% of participants answer all items incorrectly, 27% answer one item correctly, 23% answer two items correctly and 17% answer all items correctly (Frederick 2005). Three items were presented pre-intervention and a different three were presented post-intervention. All participants received the same six items in the same order. The items were not repeated between pre- and post-test. Participants received a score of 1 for each correct answer. Pre- and post-intervention scores were summed to give a total measure of pre- and post-intervention CR respectively.

2.5 Qualitative questions

Two qualitative questions asked the participant to describe how they felt after they finished the virtual reality experience and how the virtual reality experience was for them, to gain a deeper insight into participants' subjective experience of the nature condition, in comparison to the urban one, as well as their experience of the intervention. By posing these questions, it was hoped to assess how immersive or realistic the intervention was, what, if any, emotions participants felt in response to the intervention and how accessible they felt the technology was.

2.6 Virtual reality footage

Participants were presented with a 360-degree Youtube video of either a virtually simulated green environment (Fig. 3) or urban environment (Fig. 4). Each video lasted four minutes. Each condition was presented randomly to participants. Footage for the nature condition was taken in Coombaune Woods, Kenmare, Co. Kerry, Ireland https://www.youtube.com/watch?v=kfIw215c-oM. This location was selected as it contains both a dense population of trees and a segment of open green space; there was also a small stream that added a restorative audio element. The urban intervention depicted an alleyway of an urban area, mainly consisting of the back of buildings and a parked car. This footage was shot in Killorglin, Co. Kerry, Ireland https://www.youtube.com/watch?v=rmwtWz05WKQ. We deliberately chose an urban area that did not have a lot of pedestrian or vehicle traffic in order to match the secluded nature location. Both videos were recorded using a GoPro Fusion 360-degree camera by the first author. The accompanying sounds generated by both environments were also recorded.

Fig. 3 Virtually simulated nature environment. *Note.* Participants were randomly presented with either a Nature or an Urban video, which they viewed using the VR headset. This figure depicts a still taken from the Nature environment 360-degree video

Fig. 4 Virtually Simulated Urban Environment. *Note.* Participants were randomly presented with either a Nature or an Urban video, which they viewed using the VR headset. This figure depicts a still taken from the Urban environment 360-degree video

The literature regarding the time frame of both green environment exposure and VR exposure is mixed (Anderson et al. 2017; Annerstedt et al. 2013; Valtchanov et al. 2010). In our previous study (O'Meara et al. 2020 the same videos of 4 min duration were used, also in line with Browning et al. (2023). Further analysis by Tarrant et al. (2018) found 360-degree videography to significantly reduce anxiety by means of a 360-degree, nature-based, mindfulness VR experience. This study's VR session was of a 5 min and 41 s duration, further supporting the current study's decision to proceed with a four-minute duration for its intervention.

2.7 Virtual reality equipment

Participants were provided with OCULARS Virtual Reality Glasses to use at the time of completing the experiment. They were instructed in writing on how to use the VR headset in conjunction with their smartphones. Participants were either sent the VR headset by post or provided with them in person. Participants were instructed to partake in the study at home or in a quiet location of their choice. Prior to viewing the video, participants were provided with thorough instructions on how to properly configure their smartphone so as to ensure they could experience the VR intervention correctly (See Online Resource 2). They were asked to maximise their screen brightness and phone volume and were instructed on how to set their picture quality to a maximum. Instructions on how to watch a Youtube video using the VR headset were also provided (See Online Resource 2).

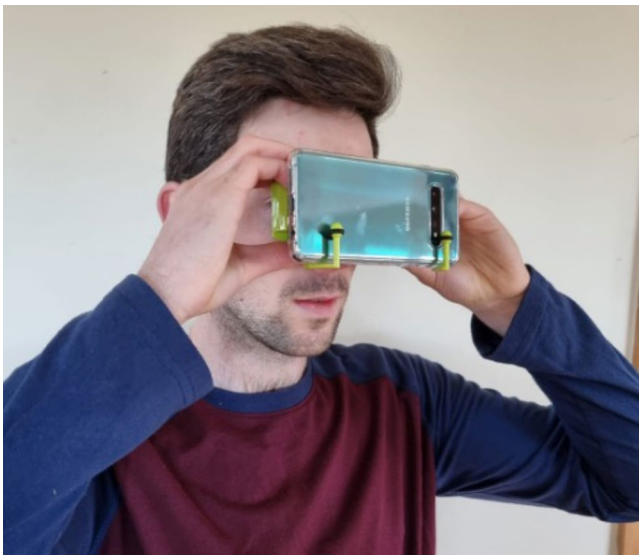

Fig. 5 Demonstration of the OCULARS virtual reality headset in Use. *Note.* Participants were instructed on how to use the OCULARS VR headset. They inserted their smartphone into the headset as shown and were randomly presented with either the nature video or urban video

2.8 Data analysis plan

Scores representing participants' ΔPA and ΔNA were generated by calculating the difference between their pre-intervention and post-intervention PA and NA scores, respectively. ΔCR was calculated by subtracting the number of correct responses to pre-intervention CRT items from the number of correct post-intervention responses. A variable representing the TA x Condition (nature video vs. urban video) interaction effect (henceforth TA x Condition) was computed for inclusion in the multiple regressions. Mean-centring was used to achieve this, to keep the regression model's multicollinearity as low as possible (Iacobucci et al. 2016). TA x Condition represented the extent to which participants from either the nature or urban condition experienced different levels of the dependent variables, based on their TA levels. Descriptive statistics were generated and bivariate analyses determined which variables to include in the main analyses. Three multiple regressions were run to examine associations between TA, Condition (Nature vs. Urban) and TA x Condition as predictors of PA, NA and CR respectively.

The six stages of thematic analysis (Braun and Clarke 2019) were followed with a semantic-inductive approach to analyse participants' responses to the post-intervention qualitative questions. Thematic analysis is a widely-used and robust method of qualitative analysis that allows for the extraction of patterns and themes from verbal data (Braun and Clarke 2021). The data were read and re-read until familiarisation with them was achieved. Codes were generated and assigned to words and phrases in the participants' responses. All data items were coded. These codes generated ideas of the items' meanings. Similar codes were grouped to form overarching themes.

Table 1 Descriptive statistics for test anxiety and pre-intervention and post-intervention panas and crt scores, by condition

		N	Mean	SD
Nature	TA	18	35.78	2.82
	Pre-Intervention PA	18	26.44	7.71
	Pre-Intervention NA	18	23.78	8.26
	Pre-Intervention CR	18	1.94	1.12
	Post-Intervention PA	18	25.39	9.2
	Post-Intervention NA	18	19.06	9.05
	Post-Intervention CR	18	1.5	0.86
Urban	TA	21	33.86	5.89
	Pre-Intervention PA	21	26.42	7.24
	Pre-Intervention NA	21	22.24	9.3
	Pre-Intervention CR	21	1.76	1.18
	Post-Intervention PA	21	25.24	10.33
	Post-Intervention NA	21	16.82	7.36
	Post-Intervention CR	21	1.33	0.73

Note. See Online Resource 3 for box plots illustrating these scores across conditions (nature vs. urban)

Table 2 Proportion of test anxiety levels, by condition

	Level	*n*	%
Nature	Low	1	6%
	Medium	11	65%
	High	5	29%
Urban	Low	0	0%
	Medium	13	62%
	High	8	38%

Note. Test anxiety levels are characterised using Nist and Diehl's (1990) ranges. A total TAQ score between 10−15 denotes low test anxiety, a score between 10 – 15 denotes medium test anxiety and a score greater than 35 denotes high test anxiety

3 Results

3.1 Quantitative analysis

9 participants were removed as outliers in the TA x -Condition variable. They were removed on account of being greater than the value for 1st quartile + 3IQR or less than the value for 3rd quartile – 3IQR. Due to the randomization process 21 participants were assigned to the urban condition and 18 to the nature condition.

Descriptive statistics are presented in Tables 1, 2 and 3.

3.2 Multiple regression – positive affect

Appropriate assumptions tests were run and suggested the data's suitability for regression analysis.

A multiple regression assessed the roles of TA, Condition (Nature vs. Urban) and TA x Condition in predicting

Table 3 Descriptive statistics for positive, negative affect and crt delta score, by condition

		N	Mean	SD
Nature	ΔPA	18	− 0.83	5.43
	ΔNA	18	-4.72	7.66
	ΔCR	18	− 0.44	0.78
Urban	ΔPA	21	-1.19	5.92
	ΔNA	21	-5.43	7.19
	ΔCR	21	− 0.48	1.08

Note. ΔPA, ΔNA and ΔCR represent the difference between participants' pre− and post−experiment PA, NA and CR respectively. Means represent the difference between mean pre− and post− intervention scores, where pre−intervention values were subtracted from post−intervention ones

the change in PA. A significant regression model which explained 21.8% of the variance in ΔPA was found, F (3, 38) = 4.53, Adjusted $R^2 = 0.22$, $p = .009$, with a 95% confidence interval. ΔPA was associated with both TA (part correlation = − 0.5, $p = .001$) and TA x Condition (part correlation = 0.35, $p = .02$). Thus, for those with higher test anxiety, a higher ΔPA value was observed in participants from the nature condition, compared to those in the urban condition, indicating a greater improvement in PA. The condition alone did not significantly contribute to the overall model (part correlation = − 0.02, $p = .87$).

3.3 Multiple regression – negative affect

A multiple regression assessed the roles of TA, Condition (Nature vs. Urban) and TA x Condition in predicting ΔNA in university students. The model was not statistically significant, F (3, 38) = 0.04, Adjusted $R^2 = -0.08$, $p = .99$, with a 95% confidence interval, and explained 4% of the overall variance in ΔNA. Neither TA (part correlation = − 0.04, $p = .83$), Condition (part correlation = 0.05, $p = .78$) nor TA xCondition (part correlation = 0.01, $p = .95$) made significant contributions to the overall model.

3.4 Multiple regression – cognitive reflection

A multiple regression assessed the roles of TA, Condition (Nature vs. Urban) and TA x Condition in predicting the ΔCR of university students. The model was not significant, F (3, 38) = 0.74, Adjusted $R^2 = -0.02$, $p = .53$, with a 95% confidence interval, accounting for 2% of the overall variance in ΔCR. Neither TA (part correlation = 0.07, $p = .68$), Condition (part correlation = 0.11, $p = .51$) nor TA x Condition (part correlation = − 0.24, $p = .15$) made significant contributions to the overall model.

3.5 Qualitative analysis

Participants responded to two qualitative questions, which aimed to assess their feelings after having engaged with the VR-intervention and their overall experience with using the VR headset.

3.6 How did you feel after you finished the virtual reality experience?

Participants ($n = 26$) reported varied feelings after having engaged with the VR experience. Those in the nature condition seemed to account for a more positive experience than those in the urban condition. Some participants from both conditions reported feelings of nausea, frustration and unease, due to the VR headset. Three themes were identified.

3.6.1 Calm and restorative nature

Participants from the nature condition ($n = 13$) reported generally positive feelings. The experience seemed to provide participants with calm and a break from their busy everyday lives. Participants felt *"Really chilled out," "Out of it, in a good way"* and *"Calmed and relaxed as [they] got to take a break from life and breathe."* One participant likened the experience to meditation: *"It was very calming and almost meditative."* Participants reported feeling more present and focused after the experience, using words like *"Alert," "Refreshed," "Present," "Intrigued"* and *"Clear-headed"* to describe their post-VR feelings. One participant felt as though their *"mind really slowed down afterwards."* One participant, however, felt as though it was the break from reality that the experience provided, and not the nature condition itself, that provided a small sense of calm. In their opinion, the feelings of calm provided by VR-simulated nature did not compare to that granted by real-world nature: *"My feeling calmer had less to do with the video than it did with focusing on something new for a few minutes, and it definitely hasn't replaced actually touching grass, as far as stress relief goes."*

3.6.2 Urban blues

Some urban participants ($n = 7$) felt impartial to the experience and felt much the same after engaging with the VR experience than they did beforehand: *"No different," "Didn't feel much different."* Others felt more strongly about the urban setting and expressed more pessimistic views about it. The urban setting did not inspire them and left them feeling uneasy: *"Uninspiring. Wouldn't want to hang around there."* The setting seemed to elicit negative feeling in participants, with participant reporting feeling like

a *"nervous alert"* and another stating they *"felt on [their] guard and [that they] wouldn't feel very safe in the area."*

3.6.3 Technology-induced frustration and discomfort

Some participants' dissatisfaction with the VR experience stemmed from issues with the delivery of the study. In some cases, participants ($n=6$) from both conditions felt *"a bit nauseated"* after using the VR headset, stating the experience gave them *"a slight headache."* One participant feeling as though *"the line of vision seemed unnatural, as if my eyes were crossing."* Though some viewed the intervention positively, the VR headset hindered their ability to fully embrace the experience: *"Fascinated with the experience, but my head is dizzy," "I felt very intrigued… but the video was hard for my eyes to focus on."* Such issues with the VR headset and picture quality left some participants feeling *"frustrated"* having engaged with the experience.

3.6.4 How was the virtual reality experience for you?

Generally mixed experiences were accounted for by 29 participants. Some ($n=17$) participants viewed the VR experience positively, citing its novelty and quality as pros. Others found the experience to be uncomfortable and were frustrated by difficulties they experienced with the VR headset and picture quality. Some participants acknowledged both positive and negative elements of the interventions. Finally, while some participants enjoyed the experience, they found it to be somewhat unrealistic ($n=3$). Although the locations depicted in the VR videos were real places, the quality of videos and VR equipment seemed to detract from the intervention's realism for some participants. However, others were impressed by its realism and found the experience to be immersive ($n=2$). Two themes were identified.

3.6.5 Mixed feelings

Mixed feelings towards the experience were observed. Some participants viewed the VR experience positively, describing it as *"good," "great," "pleasant,"* and *"really cool."* For some, it was a new and *"technically interesting"* experience: *"It was a novel experience, but certainly intriguing," "Very interesting. I hadn't done something like this before," "It made me curious about VR."* Others, however, were disappointed with the experience, finding it to be *"underwhelming."*

Some described a *"disconcerting"* and *"uncomfortable"* experience. One participant *"didn't enjoy it at all"* with another reporting a rather uncomfortable experience: *"A little disorienting. The video was really pixelated (I changed the settings as instructed). And my hands holding the phone were really shaky, which lead to the visuals making me feel a bit sick."* Some found the technology hard to navigate: *"It was a bit confusing because of the goggles,"* One participant described the experience unfavourably: *"It was depressing just looking at concrete."*

Some participants acknowledged both positive and negative elements of the VR-experience. While one participant enjoyed the visual and audio elements of the nature condition, it made their eyes feel uncomfortable: *"The movement and sound of the stream was (sic.) relaxing. The quality of the picture, even at its highest on my phone, made it strain (sic.) the eyes a bit."* Another enjoyed the experience, describing it as *"good"* but stated, they *"had to close one eye after a while to stop the unwanted sensation."*

3.6.6 Realism

Views on the experience's realism were mixed. Some participants found the experience to be *"overall positive, but not especially realistic."* Though they seemed to enjoy the experience, they were under no façade that the condition which they were presented was virtually simulated: "*Very good. I knew I wasn't really in a rural area, but it felt like a break away from the real world. It was a nice way to clear my head."* Others, however, found it to be *"immersive"* and were *"impressed by the technology"* and realism of the intervention: *"I… found I to be very immersive. The views and the sounds were very realistic, and it felt as though I was actually in the forest, even though I was only in my kitchen," "It was amazing to see how realistic technology has gotten. As I experienced it, I felt that I had gone into the virtual reality, rather than watching it from (sic.) a screen."*

4 Discussion

4.1 Positive affect

As anticipated, greater increases in positive effect scores were observed in individuals with high anxiety that experienced the nature video, as opposed to those that experienced the urban video. This finding aligns with our hypotheses of a positive impact of nature on PA and adds to our previous study (O'Meara et al. 2020), where no significant change in PA was found. It is possible that this contrast could be due to methodological differences. In our original study, to explain a lack of an effect on negative affect, we reasoned it is possible that only measures of negative affect capture the relationship between affect and TA (Chin et al. 2017). The present findings contradict this explanation by highlighting a significant relationship between TA and PA, which also aligns with existing literature that has found improvements

in positive affect post virtual-nature experience (Browning et al. 2020; Huang et al. 2020; Mattila et al. 2020; Schutte et al. 2017). In addition, participants who engaged in the nature condition reported more positive experiences than those who engaged in the urban condition, using phrases such as calm, relaxed and chilled out to describe their mood post-VR, similar to another study with non-immersive virtual nature (Cadogan et al. 2023). These findings are in agreement with the Stress Recovery Theory (Ulrich et al. 1991).

4.2 Negative affect

The lack of a significant decrease in NA scores contradicts the findings of several studies that have shown associations between exposure to virtual nature and decreased feelings of NA (Mattila et al. 2020; Yu et al. 2018, 2020). This includes our previous research (O'Meara et al. 2020), which found that students with high anxiety who experienced immersive virtual nature displayed significant decreases in NA.

The technical issues and feelings of sickness experienced by some participants in both the nature and urban condition may have prevented a fully restorative experience. As emerged in the qualitative interviews, several participants felt a bit nauseated following the VR experience, while one participant stated the experience gave them a slight headache. There was also some frustration element regarding the setup of the VR headset and overall quality of the 360-degree videos. Whether or not such issues can be overcome by practice with VR remains to be established. The advancement of technology may allow in the near future to assess whether these unintended effects of the interventions can be avoided and increase the likelihood of a reduction of negative affect.

4.3 Cognitive reflection test score

No significant associations were found between the problem-solving test (CRT) scores and the VR intervention. This lack of a significant result is in line with our previous study and other research (Spano et al. 2022; Burmeister et al. 2018). For example, Burmeister et al. (2018) found that virtual nature exposure had no significant effect on participant's performance in cognitive tasks that examined accuracy, calculation speed and counting. One potential explanation is that the restorative benefits of virtual green environments, as explained by ART, may only apply to certain aspects of executive functions, such as attention (Spano et al. 2022). It is also possible the task needs to be more similar to a real-life situation. Even though this study used a test that focused on reasoning and problem solving, which are required in a real exam, the contents of the CRT may have been too different to that of the test material that participants would be accustomed to under real-life testing scenarios (e.g. essays, multiple choice, calculations). Given the remote nature of the experiment and its motivation to comply with the University code of professional ethics, it was hard to control for this issue. Piloting this intervention under more realistic settings, more similar to an actual exam situation, may be beneficial in this regard. It should be noted that, subjectively, participants in the nature condition reported feeling more alert and clear-headed following the virtual experience. Such findings convey a general replenishment of cognitive resources, in line with the Attention Restoration Theory (Kaplan et al., 1989), although it was not reflected in the CRT performance. Future research may consider using more complex and lengthy tests where more variability is achieved and there is more at stake, for example a prize based on performance could be introduced.

4.4 Limitations

Limitations included a relatively small sample size and high rate of attrition. While potential participants expressed an interest in the goggles and the study, only few engaged with it. Attitudes towards and experiences with VR technology could play a part, as it is something that few use frequently and is not be considered something to be used in daily life (Hornsey and Hibbard 2024), despite in this study the VR is delivered through low cost and accessible technology. However, recruitment was run partially during Covid-19 and the experiment itself required some time and technical engagement; therefore, the ambitious nature of this study must be taken into account. Although participants were provided with detailed instructions on how to use the VR headset, several individuals struggled with the setup of the VR equipment and quality of the video. Studies conducted in-person with a researcher/VR technician present do not present such issues, however they are less applicable to real-life situations. Future research could consider cybersickness and digital literacy as potential factors to measure systematically (see Calogiuri et al. 2018; Spano et al., 2023). Similarly the relationship between participants and nature, such as frequency of contact with nature (Theodorou, Romano, et al., 2023; Webber et al. 2023) may moderate the effects of the interventions, however due to the time contractarians of this study these were not considered.

The study is also limited in its selection of sceneries. The authors selected the green and urban sceneries informed by the existing literature on attention restoration. However, in future studies, it would be useful to utilise a wider range of landscapes such as in Browning et al. (2023). Given the potential role of positive memories in the restorative effects (see Cadogan et al. 2023 and Yan et al. 2023 for a theoretical

perspective) it is possible that pictures collected by participants themselves could be more effective overall. Nonetheless, the study presents the strength to propose a low cost technological solution for virtual nature, which could be adapted for personal use.

5 Conclusions

This study showed that exposure to a virtual green environment via an affordable VR headset with one's own phone increased feelings of positive affect for student with high TA. The qualitative elements also suggest that inexpensive 'do it at home' VR is feasible, has some positive effects and can convey some of the benefits of nature. Subjectively, the benefits are clear, although the technical difficulties and quality of the experience obtained with this apparatus still present an issue. This indicates that such technology is a potentially useful tool to apply to exam situations in an academic context. However, technical improvements would be necessary before a more effective and seamless experience. It is important point to note, too, is that it is not our intent to demonstrate how virtual nature may replace real nature. Virtual nature should be viewed as an outlet that extends the benefits of nature to those who do not have direct access to it (Frost et al. 2022).

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Declarations

Competing interests The authors declare no competing interests.

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