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Revisiting Virtual Nature Interventions: A Meta-Analytic Review on Positive Emotion and Stress Communication in Academic Contexts

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ABSTRACT

With rising urban stress and limited access to restorative natural environments, scholars have increasingly explored virtual nature as an emerging pathway for emotional recovery and stress communication. This meta-analytic review synthesizes current empirical findings on virtual nature interventions, including virtual reality (VR) forest environments, to evaluate their effectiveness in enhancing positive emotion and alleviating stress in academic and therapeutic contexts. Across the reviewed studies, virtual nature exposure reliably contributes to short-term emotional benefits, such as reduced physiological arousal, lower perceived stress, and improved affective states. Interventions that integrate guided therapeutic elements—such as mindfulness, reflective tasks, or stress-communication prompts—tend to yield stronger and more sustainable psychological outcomes than passive exposure alone. Evidence also suggests that water-enriched landscapes and immersive sensory designs may amplify restorative effects. However, the heterogeneity in intervention design, duration, and measurement tools remains a barrier to cumulative theory-building. Overall, virtual nature represents a promising modality for scalable emotional well-being interventions, and future research should prioritize standardized protocols, long-term impact tracking, and deeper investigation into communication mechanisms that translate virtual experiences into meaningful stress recovery in academic populations.

Keywords: Virtual nature; Virtual reality (VR) intervention; Positive emotion; Stress reduction; Stress communication; Restorative environments

INTRODUCTION

Numerous technologies hold promises for improving the effectiveness and accessibility of mental health therapies in a society where there are a great deal of psychological discomfort and a dearth of resources for mental health care [1]. One kind of technology is to induce calm and attentive states that lessen stress and general symptoms. An additional category of technologies focusses on organised treatments aimed at resolving certain problems (e.g., exposure therapy to treat different phobias and anxieties, and motivational interviewing to decrease addictive behaviour). We could discover no prior study on therapeutic education in a virtual forest, and there has been little research on the integration of calming technology with therapeutic instruction [1, 2]. By examining the effects of applying therapeutic instructions in a virtual forest, with social anxiety as the target mental health concern, we fill this gap in our research.

Travelling and exploring new places, taking a walk in the outdoors, and spending enjoyable times with loved ones. Because they may elicit happy feelings, all of these seemingly little encounters are really good for our wellbeing [2, 3]. Numerous works of literature have shown that happiness and contentment are the cornerstones of human satisfaction and wellbeing. Additionally, life achievement, quality of life, longevity, and cognitive function are all strongly correlated with happy emotions.

In natural environments, urban forest parks are great places for locals to unwind and enjoy their daily free time. Researchers have often examined the connection between these parks and subjective well-being. Reyes Riveros specifically carried out a rigorous bibliometric assessment of 153 publications, emphasising the substantial positive effects of public urban green spaces on people's health and happiness [3]. Using grounded theory as their

analytical tool, conducted qualitative study to examine the therapeutic benefits of urban forests for middle-aged women taking part in forest therapy programs. Their research showed that people's mental states may be positively restored by urban forest parks [3, 4]. In conclusion, urban forest parks are an important area for study since they are essential parts of urban green spaces and greatly improve psychophysiological recovery, which in turn improves people' well-being.

The idea that environments in nature greatly improve subjective well-being is supported by at least three strong arguments. First, there is scientific evidence that experiences in natural environments may affect the neurological system, reduce stress, [3, 4], and help people focus again. There is a reasonable evolutionary explanation for this link, known as biophilia: humans are essentially a part of nature, and our 10,000-year history of dependence on it has generated our innate emotional bond with it.

Exposure to natural surroundings has moderate to substantial impacts on raising pleasant emotions and decreasing negative ones, according to a meta-analysis of the biophilia hypothesis. This supports the idea of nature -based design [3, 4]. Second, social activities, leisure, and physical activity—all of which produce dopamine and improve subjective well-being—may be encouraged and supported by natural settings. More specifically, a meta-analysis of eleven UK research by Barton and Pretty revealed that both men and women's mood and self-esteem were considerably enhanced by green exercise in natural environments [4]. Third, there are often less detrimental factors that affect subjective well-being in natural settings, such as air pollution and noise. Significant sleep difficulties and cardiovascular problems may result from prolonged exposure to urban traffic noise, and air pollution is associated with a number of common respiratory and cardiovascular conditions. The detrimental effects of these variables on health may lower subjective well-being levels, as Welsch noted, even if people are not aware of the causal relationship [4, 5]. In conclusion, research from a variety of angles has shown that exposure to natural settings greatly improves subjective well-being.

Overall, a large body of research demonstrates that happiness is influenced by mental recovery and that psychological healing and subjective well-being are significantly enhanced by natural settings. The whole "natural environment—mental recovery—subjective well-being" effect route, however, has not been thoroughly investigated [4, 5]. By assessing the subjective restorative qualities of urban forest parks, this paper seeks to empirically examine the impact of environments that are natural on subjective well-being. It focusses on the ways in which these environments impact residents' subjective well-being and the moderating function of personal evaluations.

METHODOLOGY

54 students, aged 18 to 25 (34 women and 20 men), were selected from a first-year psychologist program at the University of China to take part in the research. In exchange for their involvement, the students were given course credit [29]. There was no pre-screening for baseline anxiety levels or VR familiarity before participants were randomly allocated to three situations [27, 38]. Three conditions existed: Conditions A (only the VR forest), Conditions B (both the VR forest and therapeutic activities), and Conditions Non-VR (non-VR, that is, just therapy activities). Based on Table 1, 9 out of the 40 learners under the two pertinent circumstances remained to participate in a second session (18–19 years old; women = 5, men = 4; B = 5, non-VR = 4).

TABLE 1 Number of participants for each session and condition.

Session	A	B	Non-VR
1	17	21	17
2		7	3

Materials and Supplies

The supplies and equipment used in this investigation included;

Self-reported surveys measuring immersive Ness, [28, 30], usefulness, restorative effects, and social anxiety;

Virtual reality headsets for Meta Oculus Quest 2 and applications for virtual forests; and

Therapy instructions.

Psychological Assessments

The 20-item Social Interaction Anxiety Scale (SIAS) is a self-report survey that assesses the level of stress encountered during social interactions using a Likert scale with five points.

Measures of VR Usability

Our evaluation of VR software's quality in terms of user interface, in-game support, [24, 29], and VR-induced signs and consequences was conducted using the Virtual Reality Neuroscience Questionnaires (VRNQ).

VR Software and Headset

Participants used the Meta Oculus Quest 2 VR headset to interact with the virtual woodland. A group of programmers from the Interaction Media Lab at the Chinese Academy of Sciences of China created and built the

virtual forest program using Unity (2020.3.26f1) [20, 31]. Unity's Asset Store was used to purchase assets such as the woodland environment (Nature Manufacture's woodland Nature), wildlife (WDALLGRAPHICS and PROTOFACTOR INC.), and architectural structures (Star Gaming Studios) [21, 28].

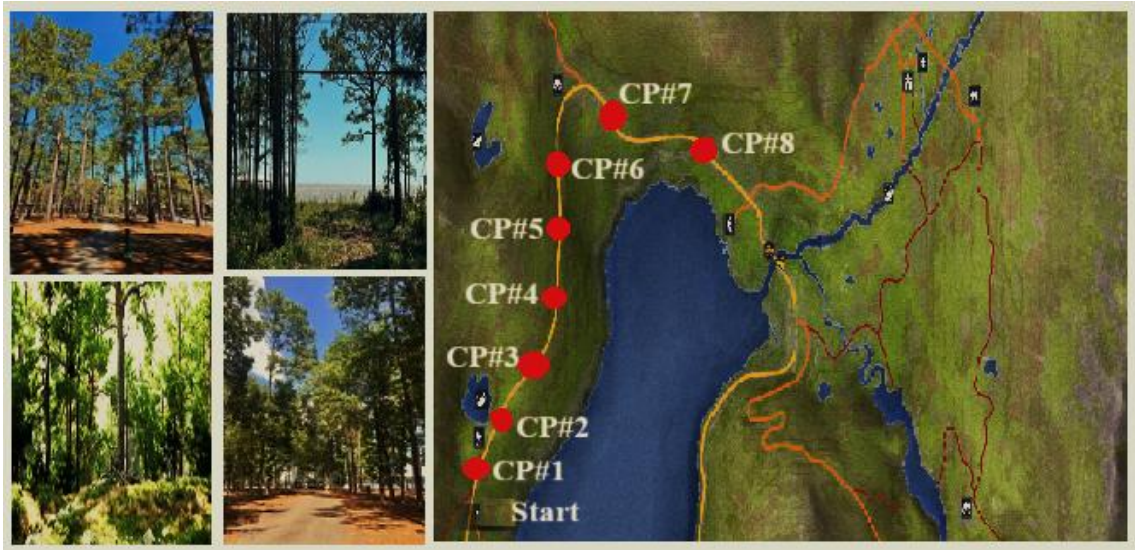

FIG. 1 Participants must follow the red trail on the virtual forest map, which also has 8 checkpoints indicated in yellow; (b) images of the forest modelling.

Instructions for Therapy

As previously mentioned, at every checkpoint, participants from Conditions B and Non-VR were required to pay attention to the directions given by the virtual therapist [29]. Psychoeducation, meditation techniques, and tests that evaluated students' learning were all included into the therapeutic instruction.

Procedure

The research was uploaded on the University of China's first-year psychology course's participant pool system during the winter semester of 2024 [22, 28]. In order to be eligible for registration, individuals had to be a minimum of 18 years old and free of a social anxiety disorder diagnosis. At the University of China's Interaction Multimedia Laboratory, the studies were conducted in person.

Data Analysis

To evaluate the impact of different conditions of experimentation on users' social anxiety, quiz effectiveness, user interface, and restoration results, [30, 37], data analyses were conducted using R (Version 4.2.1), R Studio (Version 2023.06.0+421), and Python (Version 3.12).

Results and Application

Measuring Social Anxiety

Analysis of Factors and Reliability

We used a factor analysis to determine the underlying constructs of the Social Interaction Anxiety Scale (SIAS), which comprises 20 items [24, 26]. With a KMO value of 0.87, the sample was deemed adequate. Bartlett's test of sphericity revealed that the relationship matrix was factorable, with $\chi 2(187) = 549.89$, $p < 0.001$. Figure 2 is the sole factor that the scree plot indicated. The structure was made apparent by using Varimax rotation. With a loading of 0.184, Item 14, "I have difficulty talking to people I am attracted to," had the lowest loading among the 20 items in Table 2, [25, 26], indicating a weak contribution to the factor. The other loads were all more than 0.3.

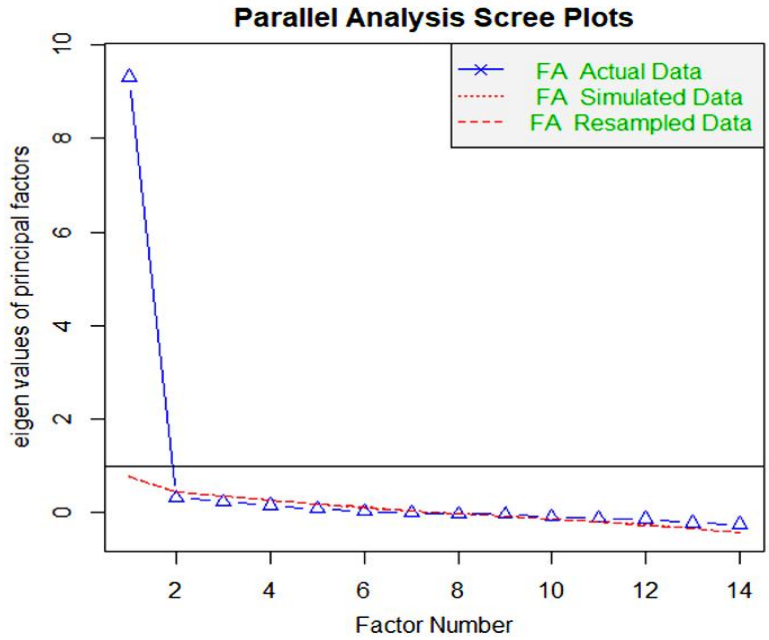

FIG. 2 Factor analysis of the 20 Social Interaction Anxiety Scale (SIAS) sections in a visualisation plot.

TABLE 2 Social Interaction Anxiety Scale (SIAS) 20 component loadings of factors.

Social Interaction Anxiety Scale (SIAS)	Factor Loading
Speaking with a teacher, employer, or other authoritative figure makes me anxious.	0.695
I have trouble looking people in the eye.	0.508
Talking about myself or my emotions makes me nervous.	0.418
I have trouble getting along with the folks I work with.	0.809
Making pals my own age is hard for me.	0.395
If I run into someone I know on the street, I become anxious.	0.648
I feel uneasy in social situations.	0.795
If there is just one other person around, I become nervous.	0.359
Meeting people at events like parties is hard for me.	0.348
I find it hard to communicate with other people.	0.798
I have a hard time coming up with topics to discuss.	0.548
I'm afraid I'll come out as odd if I explain myself.	0.418
I have a hard time disagreeing with other people's opinions.	0.528
Talking to someone I'm attracted to is hard for me.	0.988
I fear that I won't know how to respond in social settings.	0.488
Mixing with folks I don't know well makes me anxious.	0.364
I'm afraid I'll say something awkward when I speak.	0.418
I fear that I will be overlooked when I mingle with other people in a group.	0.982
In a group setting, I am tense.	0.147
I'm not sure whether I should greet someone I know just a little.	0.689

Five additional items were added as a result (7, 12, 15, 17, and 19). Strong internal consistency was shown by this 5-item scale, [27, 28], as shown by Cronbach's alpha values of 0.87 for pre-session data and 0.93 for post-session statistics Table 3.

TABLE 3 Five-item Scale Retained Following Analysis of Item Reliability.

Phase and Alpha Cronbach's	Social Interaction Anxiety Scale (SIAS) Items
S1 Pre =0.89	I feel uneasy in social situations.

S2 Post= 0.98	I fear that if I express myself, I may come out as uncomfortable.
	I fear that I won't know how to respond in social settings.
	I'm afraid I'll say something awkward when I speak.
	In a group setting, I am tense.

Changes in Social Anxiety Under Three Conditions

The five categories from Section were averaged to create a social anxiety score [29, 30]. The variations in social anxiety among the three situations in Session 1 are then shown in the Cumming plot in Figure 3 after we deducted the post-session social anxiety from the pre-session social anxiety.

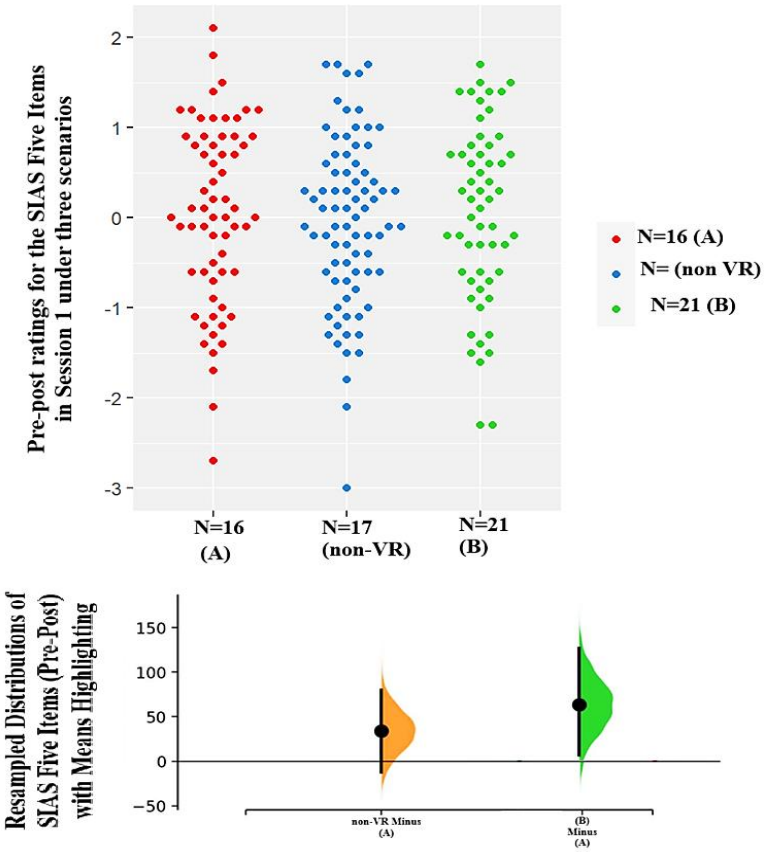

FIG. 3 Cumming plot on the decrease in social anxiety (pre-post) in three circumstances (a): virtual forest alone as a control condition; non-VR (Green): therapies solely; and b): therapy and virtual forest together) in Session 1.

Performance on the Checkpoint Quiz

We used Fisher's exact test to compare the performance of participants in Condition B with the Non-VR condition at the three checkpoints in the first sessions (Table 4) [30, 31]. The first two checkpoints demonstrated no disparity in the results between the two circumstances (Checkpoint 1: p = 1; Checkpoint 2: p = 1).

TABLE 4 Participate Accuracy Contingency Table for the Three Checkpoints.

Checkpoints	Conditions	Correct	Incorrect
1	B	44	1
	Non-VR	36	1
2	B	18	2
	Non-VR	16	1
3	B	39	2
	Non-VR	14	17

Survey for User Experience

User experience ratings were greater among respondents in the VR conditions, indicating that VR circumstances were favoured over the non-VR condition [33]. The user experience overall quality assessment had a significant impact by condition, according to the one-way ANOVA for the Session 1 data ($F(2, 56) = 5.48$, $p <$

0.01, η2 = 0.16) [32]. As demonstrated in Figure 5a, post hoc Tukey tests showed that Condition Non-VR (M = 4.98, SD = 1.48) had significantly lower overall satisfaction ratings than Conditions A (M = 5.95, SD = 1.49, p < 0.05, Cohen's d = 0.79, 95% CI [0.79, 1.49]) and B (M = 6.00, SD = 1.08, p < 0.05, Cohen's d = 0.86, 95% CI [0.26, 1.78]). In Session 1, there were no variations in the evaluations of sound, visuals, immersion, and pleasure among the three circumstances [34, 35].

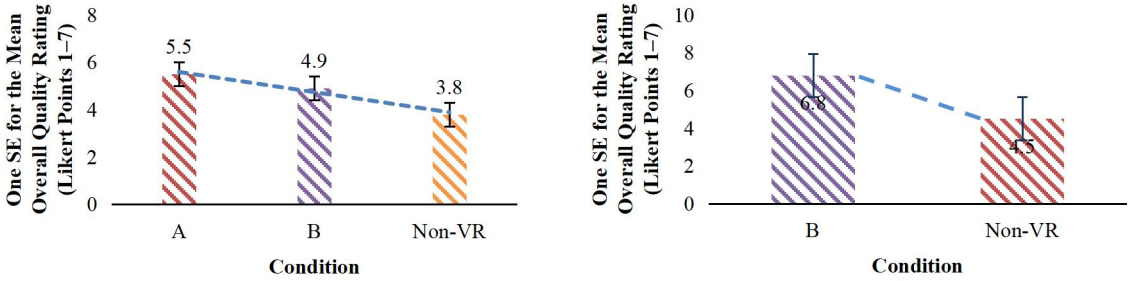

FIG. 4 (A) Average Ratings for overall quality in session 1 under three situations; (B) average ratings for pleasure in session 2 under two conditions.

Open-ended Remarks

We were curious to see whether emotion changed when VR was present [36]. Would the VR forest be more appealing to people? To find out how VR and non-VR groups affected the sentiment score of the respondents' remarks in the first examination, we used an independent samples t-test.

It's possible that respondents thought the experience was more engaging, captivating, or fulfilling than Condition Non-VR. Figure 6 and Table 5 demonstrate that participants' positive sentiment ratings were marginally higher in the VR conditions than in the non-VR condition [18, 33].

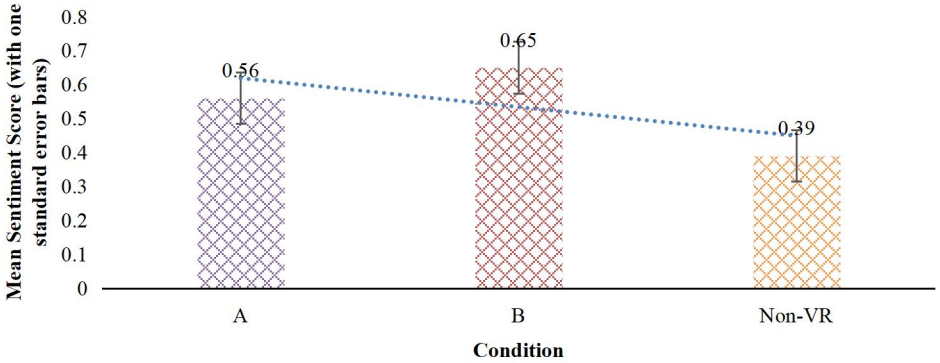

FIG. 5 A bar graph representing the average sentiment rating with one standard error for participant remarks in session 1 under three different settings. Condition A: SD=0.78, M=0.75. Conditions Non-VR: M=0.38, SD=0.47; Condition B: M=0.67, SD=0.34.

TABLE 5 Comments on the top and worst sentiment scores.

Condition	Comments	Sentiment Score
	Remarks that received the greatest sentiment ratings under each of the three scenarios.	
A	The soothing visuals and music were a huge stress reliever for me. It was also simple for me to lose myself in it and have a deep feeling of peace. Because they were all unique and evoked awe and curiosity, the constructions were pleasant. I had a great time with it.	0.97
B	Although I appreciate that there are adorable animals there, it would be preferable if they could all be pushed (I'm not sure why pushing animals is so pleasant). I'm also a little disappointed since I was hoping to see anything under the surface of the river, like fish, but there isn't any. However, the forest is lovely, the sound effect is really genuine, and the experience is nice altogether. If I have time, I'll return. I appreciate the experiment.	0.85
Non-VR	The courses were enjoyable and extremely beneficial. Thank you.	0.84

	Among the three situations, the comments with the lowest sentiment scores	
A	I like the atmosphere the headset generated and was completely absorbed in the virtual reality world; however, the one thing that bothered me and made me dislike the experience was the nausea I had.	-0.49
B	Although I like some of the pictures, such as the flowers, river, and clouds, I also thought they were a little distracting since I felt like I was in a fake virtual world. Additionally, it made me sick, which interfered with my ability to focus.	0.89
Non-VR	Excellent experience, although I think I may have lost concentration on Module 4 since I found it to be quite lengthy and dull.	-0.76

In Session 1, a one-way ANOVA showed substantial variations in word occurrences between circumstances ($F(2,69) = 7.65$, $p < 0.05$, $\eta 2 = 0.75$; see Figure 7) [24, 29]. In comparison to Condition Non-VR ($M = 0.19$, $SD = 0.69$), Condition A ($M = 0.67$, $SD = 0.84$) had much more immersive Ness linguistics, according to post hoc Chinese tests ($p < 0.05$, Cohen's $d = 0.87$, 95% CI). [0.87, 1.87].

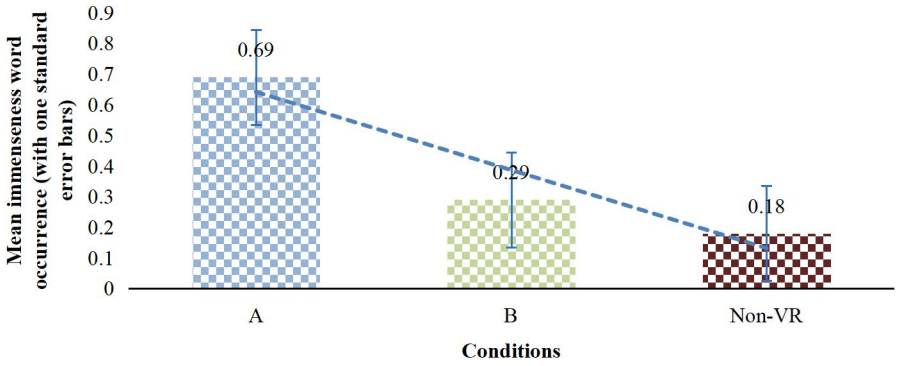

FIG. 6 Bar Plot shows the mean incidence of the phrase "incredibleness" (with one standard error bar) on the remarks of participants in session 1 under three scenarios.

Restoration Outcome Measurement

In Session 1, we used combined ANOVA to investigate how circumstances and stages affected restoration rating [22, 37]. The main impact of phases was significant, with $F(1, 108) = 27.49$, $p < 0.0001$, and $\eta 2 = 0.67$ Figure 8.

Participants from all three conditions showed a significant increase in restoration rating from pre-experiment ($M = 3.54$, $SD = 0.41$) to post-experiment ($M = 4.59$, $SD = 1.39$), Cohen's $d = 0.95$, 95% CI [0.85, 1.37] [38, 39]. This suggested both the virtual forest shown in the two VR conditions, as well as the forest sounds and forest picture in the background in Condition Non-VR, [40], can invoke similar levels of increased restoration.

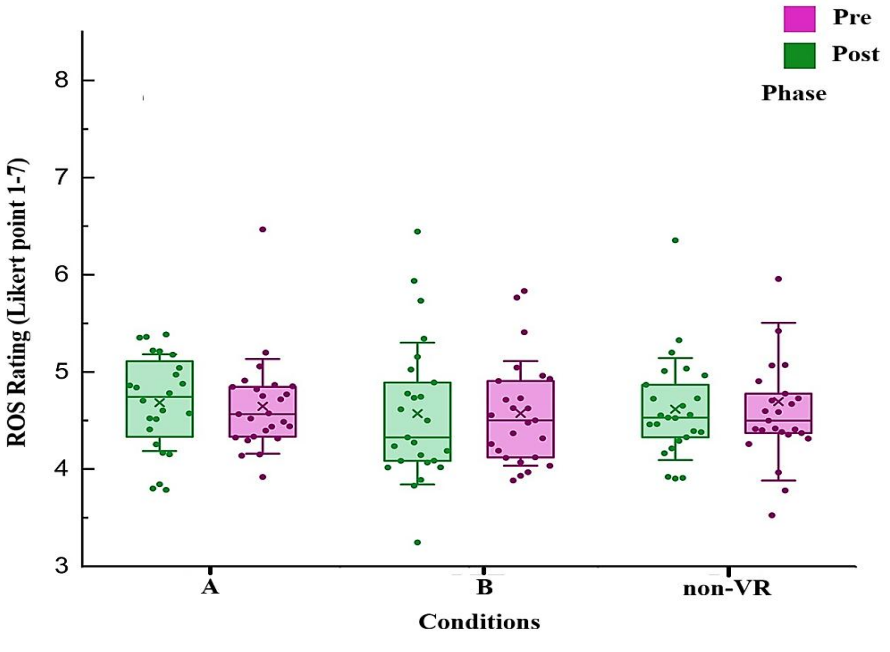

FIG. 7 Boxplot of ROS rating for three circumstances in Session 1 before (purple) and after (light green) phases.

Discussion

According to this research, going to a natural setting may greatly improve one's subjective sense of wellbeing. For a number of reasons, we refrained from explicitly stating that natural settings had a favourable impact on subjective wellbeing in our proposed model [11, 17]. First, a large body of research has previously shown that exposure to natural settings greatly improves subjective well-being. Second, many park visitors reported feeling more subjectively well while they were there, [19], and they were more inclined to interact positively with life afterwards, according to feedback they provided throughout the survey procedure [22].

These results are consistent with studies by researchers who propose that the natural setting of urban forest parks might have a healing impact on the psychological health of locals. For instance, Tsunetsugu compared four urban forest regions with urban areas in central and western Japan. The results showed that participants in the forest areas had significantly lower heart rates, higher parasympathetic nervous activity, [40, 41], and lower diastolic blood pressures. The importance of urban forest habitats in fostering human well-being is shown by this evidence.

This overall goal closely matched our original goal of offering a cost-effective therapy alternative for those with mental health conditions. Additionally, [4], the whole chain of natural environment perception → mental healing → subjective well-being supports the idea that being in natural settings is an essential tactic for mental recovery, [28], which in turn improves subjective well-being.

This connection could show itself as guests at the urban forest park first feeling comforted and rejuvenated after coming into contact with the green areas of the natural setting, which then causes their subjective well-being to improve [29]. Prior research has often ignored this mediating effect, despite the fact that it is consistent with the stimulus-mental-behavior impact route in cognitive psychology.

While most of the included investigations showed that virtual natural surroundings had a good effect on eliciting emotions, it is important to emphasise that there is still conflicting data and that further research is necessary [42]. In particular, although the majority of studies indicated that VR experiences had a favourable influence on emotional states by reducing negative emotions, not all of the study found that the VR experience significantly increased positive affect. For instance, a decrease in negative valence emotions was recorded, but no discernible changes in positive valence emotions were evaluated [42]. In a similar vein, negative emotions declined while pleasant ones remained same.

Some research, however, claimed a non-significant decrease or an increase in arousal. Methodological difficulties might be the cause of these surprising findings. Participants in the experiment alternated between sitting and walking, [14], which would have stimulated their bodies. In a similar vein, engaging players in the VR experience might activate processes that increased arousal instead of decreasing it [29].

There is a Possibility that the non-VR (therapy only) Condition Might Lessen Social Anxiety

The only treatment that seemed to have a propensity to lower social anxiety levels was the non-VR one [27, 29]. Unlike the single-session intervention that the majority of participants in this research received, social anxiety usually needs numerous sessions over a longer length of time since it is often firmly embedded in people. Therefore, the lack of statistically significant decreases in social anxiety is not unexpected [28]. In contrast, all three settings for experiments showed a substantial rise in ROS scores after the intervention.

VR Therapy Improves Learning of Therapeutic Information and Long-Term Engagement

According to the quiz performance statistics, participants in Condition B outperformed those in Condition Non-VR in terms of accuracy at Checkpoint 3, [24, 26], which evaluates understanding of the therapeutic material. After around fifteen minutes of the interaction assignment, Checkpoint 3 was reached.

However, compared to treatment alone, sentiment in the VR conditions tended to be more favourable, according to sentiment analysis of text comments left after the session ($p = 0.067$) [30]. Even though this impact was hardly noticeable, the pattern indicates that participants may have had a more favourable opinion of the virtual forest experience, [32], which might have major effects on treatment adherence and long-term involvement.

Enhancing Restoration Through the Use of Forest Sound

According to the mixed ANOVA, self-reported ROS rose after each of the three experimental conditions. The same background audio—forest noises, such as birds singing, a river running, and wind rustling—was used in all three scenarios [36]. Numerous participants said that the sound of the forest improved their experience's vividness and tranquilly Table 6 [14, 18].

TABLE 6 Comments about forest noises are made by participants.

Conditions	Comments
A	"The sound was really soothing."
	"I thought the graphics and sounds were fantastic."
	"I felt at ease because the sound and visuals gave me the impression that I was truly in the forest."
	"I think my experience was close to a real-life experience because the sounds and images were realistic enough."
	"I thought the setting it created was really lovely, but what really brought it to life was the soundtrack."
B	"The sound quality—both the checkpoint narrator's voice and the background noises from the forest—was one element that really caught my attention."
	The sound quality was the feature of the program that caught my attention. The noises of the forest were quite vivid, and the male narrator's voice had excellent sound quality. It seemed to be simultaneously emanating from everywhere and nowhere.
	"The sound effect is very realistic, and the forest is lovely."
Non-VR	"I was able to picture myself in a forest thanks to the soothing background noises."
	"The sound effects were very realistic, which aided in rapid immersion."

In Condition Non-VR, participants were shown a screenshot of the virtual forest as the backdrop picture on the interface and asked to visualise themselves in a forest [24, 28]. A restorative impact similar to that seen in the VR conditions was generated by combining the sounds of the forest with the virtual forest setting. One Condition Non-VR participant employed phrases like "vibrant" and "immersive" in Table 6 [27].

Conclusion

The usefulness and efficacy of integrating therapeutic activities with a virtual forest to treat social anxiety in young people were investigated in our research. In comparison to the other conditions, Condition Non-VR exhibited a propensity to decrease social anxiety, addressing both our initial research concern in the negative (for a short-term study) and our second research question in the positive. This implies that a straightforward application that concentrates on therapeutic content, free from the distractions of a rich virtual environment, may be more effective at reducing social anxiety, at least temporarily.

The analysis of research on virtual natural settings provides important new information about their efficacy and differences in evoking emotions. The efficacy of virtual nature encounters was significantly influenced by several treatments, such as exposure time and interaction techniques.

Condition B, which combined therapeutic activities with a virtual forest, showed advantages in improving learning and long-term interest. In addition to reporting more favourable experiences, participants in this group performed better on quizzes, suggesting that they understood the treatment material better. The potential for the virtual forest to retain participant interest and engagement with therapeutic training raises the possibility that the combined method may be more successful in sustaining focus and promoting a deeper understanding of the treatment material over time.

The significance of the delivery mechanism in therapeutic treatments is underscored by these results. While the immersive and captivating experience provided by the virtual forest may improve long-term learning and engagement, more immediate social anxiety reduction may be possible using conventional, non-immersive techniques. Future studies should balance characteristics that assist the participant in concentrating on therapeutic information with immersive aspects of the virtual world in order to maximise VR treatment.

Delivering therapeutic information in a virtual woodland setting is a viable approach. In order to prevent the technology from becoming distracting or interfering with the receipt and comprehension of therapeutic information, proper design is necessary. One of the main concerns is how to provide therapeutic information gradually.

There are significant real-world uses for virtual forest technology outside of conventional therapeutic contexts. The elderly who are confined to their homes or reside in nursing homes, people with disabilities who are unable to physically visit a forest, leukaemia patients receiving treatment who are unable to interact with the outside world due to immune deficiencies, or patients in closed institutions like prisons undergoing rehabilitation could all be introduced to these tools. Virtual nature exposure is a safe and efficient way to promote psychological well-being for these individuals, who may not have easy access to natural settings. Even though the difficulties

covered in this study are intricate and will take a lot of work to create virtual forest technologies for therapeutic interventions, the advantages of effectively putting these technologies into practice should much exceed the research necessary to develop products.

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