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Does Social Distancing Affect the Stress Reduction and Attention Restoration of College Students in Different Natural Settings?

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Abstract: The restorative benefits of the natural environment are crucial for human well-being and sustainable development. Although stress reduction and attention restoration through natural exposure have been quantified through physiological and psychological pathways, numerous studies have intentionally constructed idealized natural settings devoid of individuals to minimize interference. This deliberate approach has raised concerns about the accuracy of these restorative results, as real-world settings invariably involve other people. To address this issue, we designed and executed a randomized controlled experiment. By measuring physiological and psychological indicators and utilizing a two-way ANOVA and Tukey post-hoc comparison, we explored the restorative potential of natural settings within seven distinct social distances across five landscape types in virtual reality environments. The results revealed that beyond a social distance of 3.8 m, the presence of people had minimal impact on stress reduction, with attention restoration effects remaining consistently positive. Optimal physiological and psychological restoration is achieved when the social distance exceeded 20 m. Further exploration is warranted to elucidate the influence of landscape types on the restoration of natural environments. The findings provide valuable insights for the planning and design of restorative natural settings, supporting research endeavors aimed at improving human health and well-being and allowing for sustainable management.

Keywords: social distancing; restorative effects; natural settings; virtual reality; landscape types; physiological and psychological indicators

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1. Introduction

According to the Global Burden of Disease study, nearly 11% of the global population experienced impaired mental health [1,2]. Any measures that can improve mental health are of significant importance to human well-being and sustainable development [2–4]. A growing body of empirical research indicates that exposure to nature positively influences human mental health and well-being via both psychological and physiological pathway [5,6]. Following the guidance of the World Mental Heath Report, contact with nature is crucial, allowing for restorative experiences and improving physical and mental well-being [7]. However, with the continuous growth of the global population, the available natural settings are not an inexhaustible resource. As people flock to the limited natural spaces, and as the social distances decrease, questions emerge about potential fluctuations in the restorative benefits provided by natural environments. How do these benefits change, and to what extent, when individuals are in closer proximity to each other within these natural settings? The answers to these questions have implications for human well-being and the sustainable management and utilization of natural environments.

1.1. Stress Reduction and Attention Restoration

In the field of environmental psychology, the benefits of natural settings on well-being primarily stem from the Stress Reduction Theory (SRT) and Attention Restoration Theory (ART) [8–10]. SRT, proposed by Ulrich, claims that natural environments can support reductions in psycho-physiological stress and enhance positive emotional states [11–13]. As changes in perceived stress levels prompt a cascade of physiological responses, numerous empirical studies have explored the restorative effects of various natural environments, including virtual reality natural settings, by monitoring shifts in physiological indicators [11,14–16]. ART focuses on recovery from attention fatigue [17,18]. Four specific components are introduced in ART: being away (psychological distancing from the routines and resting one's directed attention), fascination (holding one's attention in an undramatic fashion), extent (a sense of coherence and connection), and compatibility (the relationship between a natural setting and human inclinations) [5,17,19–21]. The rating scales embedded within a questionnaire encompassing these four components are utilized to evaluate attention restoration due to being in natural environments [22–26]. Both SRT and ART quantify the restorative potential of the natural environment by tracking changes in psychological and physiological data before and after individuals' exposure to natural settings [11,12,14,17,19,21,27].

1.2. The Restorative Natural Settings without Human Presence

Building upon the SRT and ART, the exploration of how natural environments influence human well-being is experiencing a continual upsurge. However, existing research often does not consider the presence of people, neglecting factors such as the perception of crowding, the sense of safety, visitor interactions, and social distancing, which can influence individuals' restorative experience and well-being [28–31]. Given that the presence of others may be perceived as a source of stress to individuals, differing social distances from others may alter people's behavioral patterns in public spaces [8,18], and this may affect the restorative benefits of the natural environment. Therefore, it is critical to account for the restorative effects in environments with 'someone' rather than disregard the presence of individuals in natural settings.

Previous research has demonstrated that heavy traffic and pedestrians can induce stress in urban environments, and consequently diminish the restorative benefits, with the level of stress increasing proportionally with the number of people [11]. Based on this, the following question arises: Do pedestrians in natural environments elicit the same stress-inducing effect? Ulrich indicated that the spacing between visitors significantly influences perceptual evaluations of natural settings, particularly in densely populated areas, hindering visitors' cognitive engagement with the natural landscape [32]. The presence of other people may divert individuals' attention from the physical environment, as they become preoccupied with the potential dangers posed by others, compromising the quality of the restorative experience [17,30].

Following on from this, if an individual's presence serves as a potential stressor, does this imply that a natural environment devoid of any human presence is the most restorative? While natural environments are generally more restorative than built ones, a setting entirely devoid of people requires individuals to independently navigate challenging and potentially hazardous terrains, leading to feelings of insecurity due to lack of orientation [17,24,33]. This may discourage people from accessing attractive natural environments, even for restorative purposes [30]. From this standpoint, the presence of someone else may manifest as a positive factor in terms of restoration. Thus, the presence or absence of people in a natural scene, as well as their position and distance from the observer, can significantly influence the restorative experience of the environment. The following question then arises: What is the distance between individuals that maximizes the restorative effect? Addressing this requires the implementation of a controlled experiment, designed according to varying social distancing scenarios and ideally conducted in a laboratory setting due to the challenges associated with controlling the number of people and the duration of their

presence in a real-world environment. Despite the infrequent inclusion of individuals in restoration environments, studies on the perception of crowding provide a basis for simulating scenarios with people. Kim et al. employed simulated photographs in a Korean park representing encounter levels from 1 to 15 to measure perceptions of crowding [34]. Nevertheless, previous studies on crowding perception primarily focus on the number of people appearing in a photograph, without specifically addressing the distances between individuals. The use of VR technology can facilitate the quantification and manipulation of the number of individuals, as well as their positions and the distance between them.

1.3. Landscape Types and the Restoration

There is, at present, no consensus on what types of natural settings can deliver optimal restorative benefits. In an empirical study, Zhang revealed that forests characterized by serene ambiance and rich biodiversity significantly reduce stress levels and alleviate symptoms of anxiety and depression, acting as essential sanctuaries for mental recuperation [35]. Dan et al. suggested that desert landscapes devoid of the stressful elements of urban life can evoke a sense of quietness and calmness, fostering positive emotional states [36]. However, without comparing different natural environments, determining whether all types of natural settings provide the same level of restorative benefits proves to be a challenging task. To address this gap, Van den Berg et al. analyzed the restorative benefits of urban public spaces with varying levels of naturalness (e.g., a parkland, tended woodland, and wild woods), revealing no significant differences in stress recovery [37]. Arnberger et al. found that mountain rivers and remote alpine meadows provided similar health benefit ratings [38]. However, the consensus of there being no significant differences in the restoration results across different natural settings is not universal, with several studies ranking the restorative effects of different landscape types. In particular, research has identified water features as the most restorative landscapes [39]. Li et al. revealed that lakesides and forests performed best in reducing negative emotions and enhancing positive emotions in young adults [40]. Therefore, it seems that there is still controversy regarding whether different natural settings yield similar restorative effects.

In summary, to date, studies on the influence of individuals' presence in natural scenes on their physiological and psychological responses, particularly across various natural landscape settings, are limited. To address this gap, we conducted a controlled experiment to compare the restorative effects of five distinct natural landscapes (mountain, forest, ocean, wetland, and desert), incorporating individuals at seven social distances. This study aims to pinpoint the restorative potential by addressing three key research questions:

1. Does the presence of individuals in natural scenes affect the inherent restorative benefits of the natural environment?
2. Does the presence of individuals at different social distances within natural environments yield varying impacts on restoration?
3. Does the presence of individuals at different social distances in natural environments exclusively influence the restorative effects of specific natural conditions, or does it generate diverse effects due to varying natural conditions (i.e., mountain, forest, ocean, wetland, and desert)?

2. Methods

2.1. Social Distancing

Social distancing refers to maintaining a specific physical distance from others during interpersonal interactions and is also indicative of how individuals interact with the natural environment [18,41,42]. Restorative environment theory emphasizes the pivotal role of natural settings in enhancing both physiological and psychological well-being. However, the restorative effects of these settings may be modulated by social distancing [43]. Hall categorized social distances as intimate (0–45 cm), personal (0.45–1.30 m), social (1.30–3.75 m), and public (over 3.75 m) [44]. Building upon this framework, Gehl in 'Life Between Buildings', further investigates social distancing at 40 cm, 2 m, 7.5 m, 20 m, 50 m, and 80 m [44].

Drawing from these scholarly insights, our study explores seven distinct model settings for social distances, namely, '0–0.5 m', '0.5–1.3 m', '1.3–3.8 m', '3.8–7.5 m', '7.5–20 m', '>20 m', and 'nobody'.

2.2. Virtual Reality Natural Settings

Virtual reality (VR) has been validated as an effective tool for studying the restorative effects of natural settings [15,16,45]. To examine the physiological and psychological responses to the presence of individuals in different natural environments, we designed and constructed five VR environments, including mountain, forest, ocean, wetland, and desert. Leveraging VR technology, we successfully simulated the distinctive characteristics of each environment, delivering a sensory experience comparable to real natural settings. The construction of the virtual scenes involved three steps. In step 1, we established the fundamental framework of each environment using the SketchUp 2021 modeling software. Step 2 involved in-depth rendering to enhance scene details, which was accomplished using Lumin 10.0. This process included the precise mapping of complex material textures, the dynamic simulation of environmental lighting, and the accurate projection of shadows. In Step 3, we imported the rendered scenes into the 720 Cloud Platform (https://vr.justeasy.cn/, accessed on 11 September 2023) to generate high-definition panoramic views, seamlessly stitching together a 360-degree navigable scene. This ensured that the rendered scenes could be fully displayed within a VR environment while maintaining visual coherence and an immersive experience from any observational angle. Following the scene construction, we introduced varying numbers of individuals in these five virtual environments based on the seven social distance settings ('0–0.5 m', '0.5–1.3 m', '1.3–3.8 m', '3.8–7.5 m', '7.5–20 m', '>20 m', and 'nobody'). This resulted in the generation of 35 virtual scenes, organized in a 5 × 7 matrix (Table 1). The VR scenes for the seven social distances were played randomly during the experimental process.

In the post-experiment interviews, participants were asked to evaluate the quality of the VR environments. Since each group of participants only viewed virtual scenes of one landscape type during the experiment, we randomly presented all five types of landscape scene (all scenes devoid of people) during the interview phase. The majority of participants (80.63%) expressed that their experiences in the virtual scenes were similar to those in real-world environments, stating phrases such as 'similar to the real environment', 'more real than I expected', 'I felt like I was among the crowd', and 'able to perceive the main characteristics of this landscape type'. Additionally, most participants (75.63%) believed that the quality of the scenes for the five landscape types was similar, mentioning phrases like 'the quality feels very similar', 'I don't notice significant differences in quality', and 'the scene models might have been created by the same person'. Some additional feedback included concerns about feeling slightly overheated when wearing VR headsets for an extended period, suggestions that naked-eye 3D be used, and recommendations to incorporate other sensory experiences.

Table 1. Five VR natural settings with seven social distances.

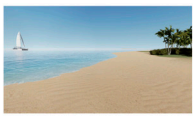
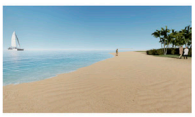
Social Distancing Landscape Type	Mountain	Forest	Ocean	Wetland	Desert
Nobody					
>20 m					

Table 1. *Cont.*

Social Distancing Landscape Type	Mountain	Forest	Ocean	Wetland	Desert
7.5–20 m					
3.8–7.5 m					
1.3–3.8 m					
0.5–1.3 m					
0–0.5 m					

2.3. Measurements

2.3.1. Physiological Measurements

The ErgoLAB human-environment synchronization test cloud platform (Beijing Jinfa Technology Instrument Co., Ltd., Beijing, China), and its accompanying Electrodermal Activity (EDA) module, were employed to monitor, measure, and record the galvanic skin response (GSR). GSR has been demonstrated as an effective indicator of physiological stress in previous restoration studies, as heightened emotions (e.g., tension and excitement) enhance sweat gland secretion activity, resulting in higher skin conductance values [46]. GSR data were collected with silver–silver chloride (Ag-AgCl) electrode pads that were attached to the index and middle digits of the non-dominant hands of the participants [16,46,47]. Blood pressure (BP) and pulse rate (PR), also reflective of stress levels [35], were recorded using a Yuwell arm-type electronic blood pressure monitor (Yuwell YE660A, Jiangsu Yuyue Medical Equipment and Supply Co., Ltd., Nanjing, China). The blood pressure indicators included systolic blood pressure (SBP) and diastolic blood pressure (DBP).

The participants' physiological restoration was quantified by calculating the changes in physiological indicators between the stress and recovery stages and dividing by the data from the stress phase. Taking pulse rate as an example, we calculated the restorative pulse rate (ΦΔPR) as follows:

$$\Phi\Delta PR = \Delta PR / PRa \times 100\%,$$

where ΔPR denotes the difference between the PR measured during the stress phase (PRa) and the recovery phase (PRb), respectively. The rates of change for systolic blood pressure (ΦΔSBP), diastolic blood pressure (ΦΔDBP), and galvanic skin response (ΦΔGSR) were calculated in the same manner. A positive change in the physiological indicators indicates that the natural settings offered restorative physiological benefits, with a larger absolute value corresponding to a more pronounced restorative effect. Conversely, a negative change in physiological indicators suggests that the natural setting not only lacked restorative physiological benefits but also led to adverse effects, with a larger absolute value denoting a greater negative impact.

2.3.2. Psychological Measurements

The Restorative Component Scale (RCS), conceptualized by Laumann et al., was employed to assess psychological restoration [21,22,48]. Based on previous studies and practical applicability, a revised version of the RCS, with 15 items grouped into the indicators 'being away', 'extent', 'fascination', and 'compatibility', was utilized to evaluate the restorative experiences of natural settings (Table 2) [5,21–23,48]. Participants were asked to respond to each of the 15 items using the seven-point Likert scale by rating the restorative impact of the given scenarios from 1 (strongly disagree) to 7 (strongly agree). Higher scores correlate with an environment's heightened potential for psychological restoration.

Table 2. RCS questionnaire.

Components of Attention Restoration Theory	Item
Being away	1. Here I feel free from work and daily routines. 2. Here I feel free from other people's demands and expectations. 3. Here I do not need to think of my responsibilities and obligations.
Extent	4. The elements here are interconnected. 5. Everything here harmoniously blends into the environment. 6. The surroundings here are coherent.
Fascination	7. There is plenty to discover here. 8. This setting has many things that I am curious about. 9. There are many objects here that attract my attention. 10. There are many things in this setting that make me want to stay longer. 11. I am absorbed by these surroundings.
Compatibility	12. The environment provides me with the opportunity to carry out activities that I like. 13. I can handle the types of problems that arise here. 14. I can adapt rapidly to this setting. 15. There is an agreement between what I like to do and this environment.

2.3.3. Two-Way Analysis of Variance and Tukey Post-Hoc Comparison

We initially employed a Levene's test for homogeneity of variances to verify the equality of variance across all experimental groups. Once the condition of homogeneity of variances was satisfied (p-value > 0.05), a Two-Way Analysis of Variance (two-way ANOVA) was conducted to assess the impact of two independent variables, namely social distancing and landscape type, on the changes in physiological and psychological indicators (Figure 1). Upon identifying significant effects through the two-way ANOVA (p-value < 0.05), Tukey's post-hoc comparison was applied to pinpoint specific experimental groups with significant differences exist (p-value < 0.05). Conducting a pairwise comparisons across multiple sample groups is pivotal to identify the sources of these differences. This step is essential for discerning which social distancing and landscape types significantly influence physiological and psychological restoration.

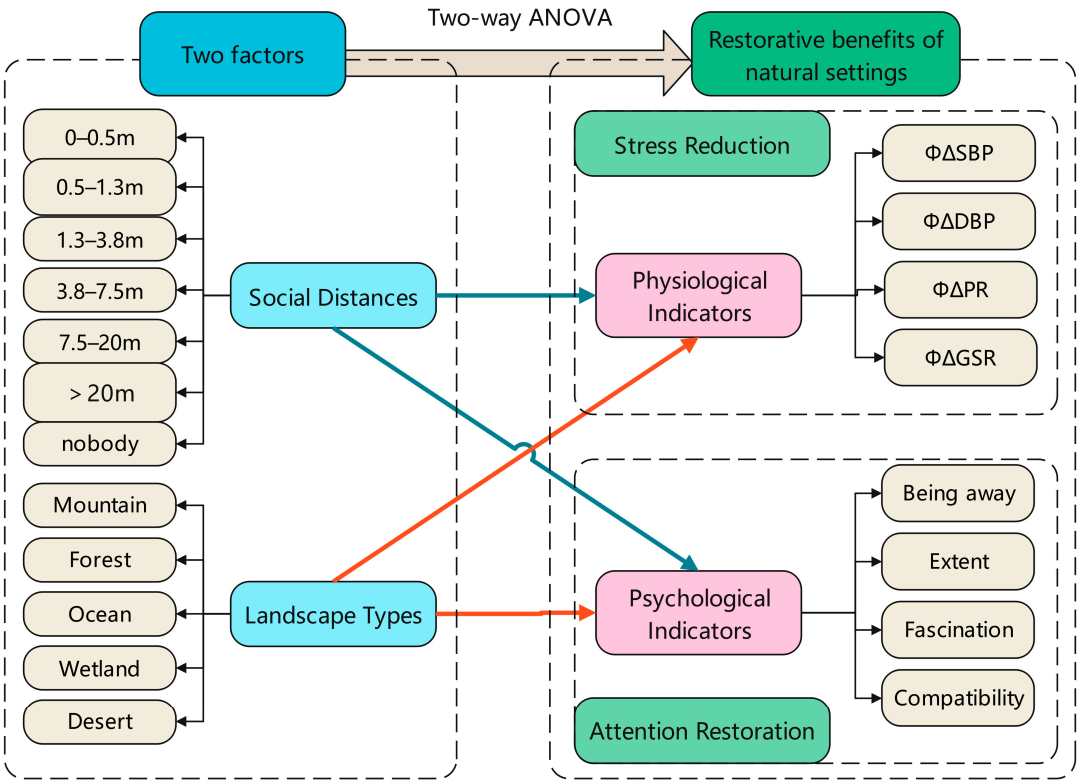


Figure 1. The framework assessing the effects of social distances and landscapes on the restoration of natural settings.

2.3.4. Participants

We recruited experimental participants through posters, emails, and social media platforms at Fujian Agriculture and Forestry University in China. Eligible participants were required to be between 18 and 35 years of age, to be in good physical and mental health, and to possess normal or corrected-to-normal vision and hearing. Additionally, they should have no significant medical history such as hypertension or heart disease, nor any major psychological trauma. Demographic information, including gender, age, and academic discipline, was collected through questionnaires. After screening the data, a total of 160 college students were selected to participate in the experiment (71 males and 89 females), with ages ranging from 18 to 29 (M = 22.8, SD = 2.75). We ensured an equal representation of students from landscape architecture and other fields. The participants were randomly assigned to one of five equal-sized groups (N = 32), each paired with five landscape types of VR natural settings. Informed consent was obtained from all participants before the experiment, and the order of the experiments was randomly determined.

To ensure the equivalence of the five experimental groups at baseline, we conducted Levene's Test for equality of variance. The results showed that the *p*-values for systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse rate (PR), and galvanic skin response (GSR) were all above 0.05 ($p = 0.793$, $p = 0.933$, $p = 0.863$, and $p = 0.132$, respectively), indicating homogeneity of variance across groups. Further ANOVA analysis revealed that the differences between groups in terms of the aforementioned indicators were not significant: SBP ($p = 0.828$), DBP ($p = 0.847$), PR ($p = 0.915$), and GSR ($p = 0.723$). These results confirm that, prior to the commencement of the experiment, there were no significant differences in physiological responses among the experimental groups.

2.3.5. Experimental Procedure

The experimental procedure and duration for each group were designed by drawing from previous research on restoration [5,16,35,40,49]. At the outset of the experiment, participants were equipped with physiological monitoring devices. After ensuring correct sensor

placement and stable data transmission, a 3 min baseline monitoring period commenced, during which baseline physiological data were collected to establish the calm-state reference. A 2 min stress induction phase involving math tests followed, with the simultaneous recording of physiological responses. Participants then entered the restoration phase, in which they wore VR headsets to expose themselves to 360° panoramic VR immersive experimental scenes for 3 min. Continuous monitoring of participants' physiological indicators (SBP, DBP, PR, and GSR) occurred throughout the VR exposure. Following this, participants filled out the RCS questionnaire to subjectively assess their restorative experience. Short rest periods were incorporated between each VR-scene exposure to minimize carry-over effects and allow participants to return to a baseline state. Throughout the experiment, participants were exposed to seven VR scenes representing the seven social distances in a randomized order; thus, the measurement process was repeated seven times. Following the measurement phase, a post-experiment interview was conducted. The participants were questioned about the authenticity of the scene, whether they felt dizzy or experienced other physiological discomforts, and their opinions and suggestions regarding the experiment. Upon completion of the experiment, the participants were escorted to the laboratory exit (Figure 2).

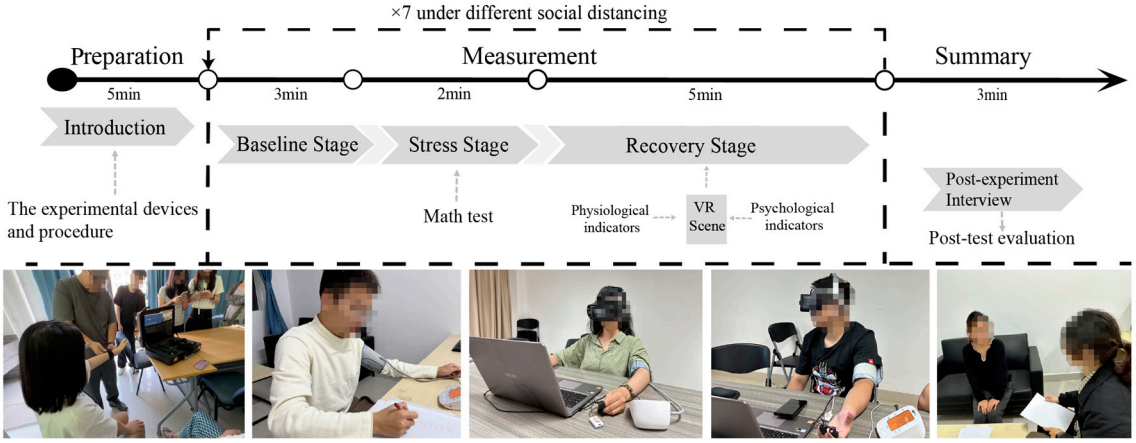


Figure 2. Experimental procedure in each landscape-type group.

3. Results

3.1. Physiological Restoration

The trends of the physiological indicators (ΦΔPR, ΦΔSBP, ΦΔDBP, and ΦΔGSR) illustrate changes in participants' stress levels following their engagement with the VR natural settings compared to the baseline physiological measurements (Figure 3). The values of ΦΔSBP for the social distance groups 'nobody', '>20 m', and '7.5–20 m' were closely aligned and positive, indicating effective physiological restoration. A trend of increasing negative values was observed as social distances decreased to less than 7.5 m, suggesting that closer distances between individuals correlated with diminished physiological restoration. This held true across all five landscape types. Similar trends were observed for ΦΔDBP, where wetlands exhibited a pronounced shift from positive to negative restorative effects compared to other landscape types. The trend of ΦΔPR generally mirrored that of ΦΔSBP and ΦΔDBP. After reaching a peak at '7.5–20 m', the restorative effects for all landscape types, with the exception of oceans, gradually declined with further reductions in distance. The overall trend of ΦΔGSR was similar; the optimal restorative effect occurred at '7.5–20 m' across landscapes, with the exception of wetlands, and subsequently decreased as the distance diminished.

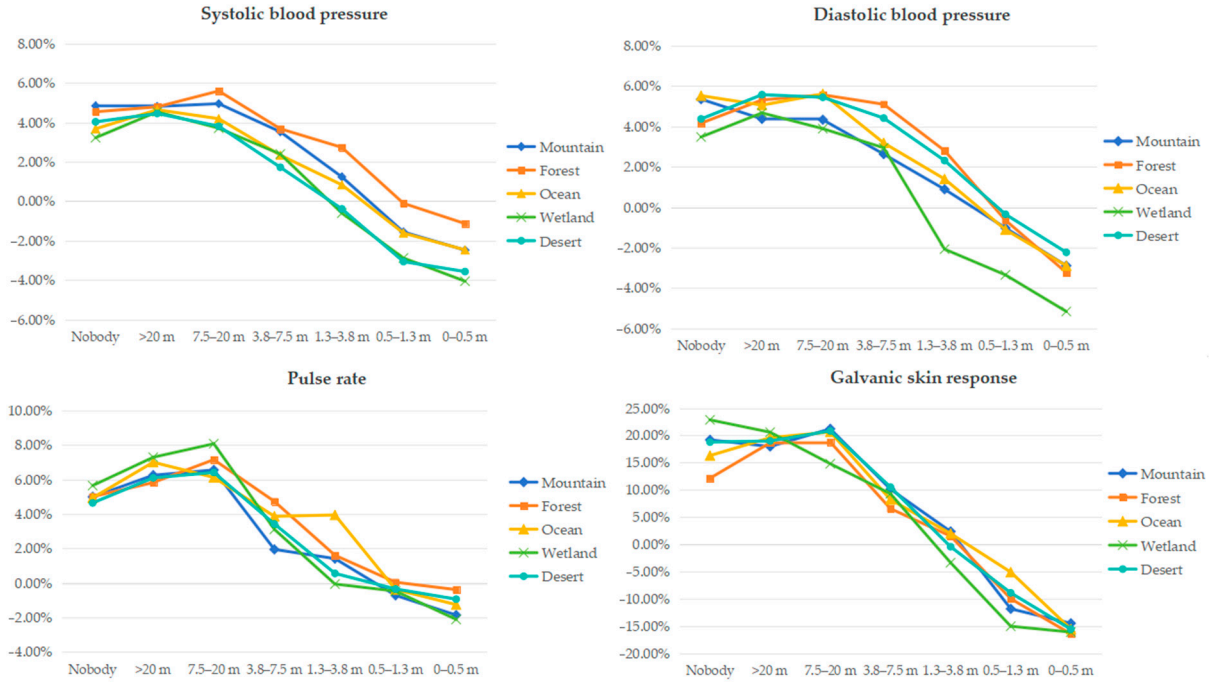


Figure 3. Trends of physiological indicators across landscape types.

The results of Levene's test for homogeneity of variance for ΦΔPR (p = 0.546), ΦΔSBP (p = 0.060), ΦΔDBP (p = 0.220), and ΦΔGSR (p = 0.313) indicated homogeneity of variance, suggesting statistically significant differences in the physiological indicators among the experimental groups. Based on the results of the two-way ANOVA (Table 3), it is evident that social distance significantly influences all physiological indicators (ΦΔSBP, ΦΔDBP, ΦΔPR, ΦΔGSR).

Table 3. The impact of social distances and landscape types on physiological indicators.

Physiological Indicators	Social Distances			Landscape Types			Social Distance × Landscape Types		
	F	p	η^2	F	p	η^2	F	p	η^2
ΦΔSBP	81.794	0.000 **	0.311	8.344	0.000 **	0.030	0.463	0.988	0.010
ΦΔDBP	47.104	0.000 **	0.207	3.166	0.013 *	0.012	0.481	0.984	0.011
ΦΔPR	36.441	0.000 **	0.168	1.210	0.035 *	0.004	0.550	0.962	0.012
ΦΔGSR	41.674	0.000 **	0.187	3.203	0.013 *	0.012	1.028	0.425	0.022

* and ** denote $p < 0.05$ and $p < 0.01$, respectively.

Conversely, the effect sizes of landscape types on all physiological indicators (η^2 = 0.030, η^2 = 0.012, η^2 = 0.004, and η^2 = 0.012, respectively), indicate their relatively weak impact on physiological restoration, despite their statistical significance.

Moreover, the interaction between social distance and landscape types does not significantly affect physiological indicators. Across all physiological indicators, the p-values for interaction are higher than the significance level, suggesting that the influence of social distance and landscape types on physiological indicators is not affected by their interaction.

Figure 4 presents the Tukey post-hoc comparison matrices for the four physiological indicators against social distance. Greater social distances tend to yield better stress reductions across ΦΔDBP, ΦΔSBP, ΦΔPR, and ΦΔGSR, with no significant differences observed among 'nobody', '>20 m', and '7.5–20 m'. The two closest social distances, '0.5–1.3 m' and '0–0.5 m', showed no significant differences in ΦΔDBP, ΦΔSBP, and ΦΔGSR, with both providing the most negative restorative effects. Additionally, when comparing '3.8–7.5 m' with 'nobody', no significant differences were observed across all four physiological indicators. However, significant differences were found between '3.8–7.5 m' and '>20 m'

concerning ΦΔDBP, ΦΔPR, and ΦΔGSR. This could be attributed to the fact that while stress reductions at '3.8–7.5 m' are not significantly different from those observed for 'nobody', they are notably inferior to those observed for '>20 m'. Significant differences were noted among all other groups of social distances, with restorative effects diminishing as the distance decreases.

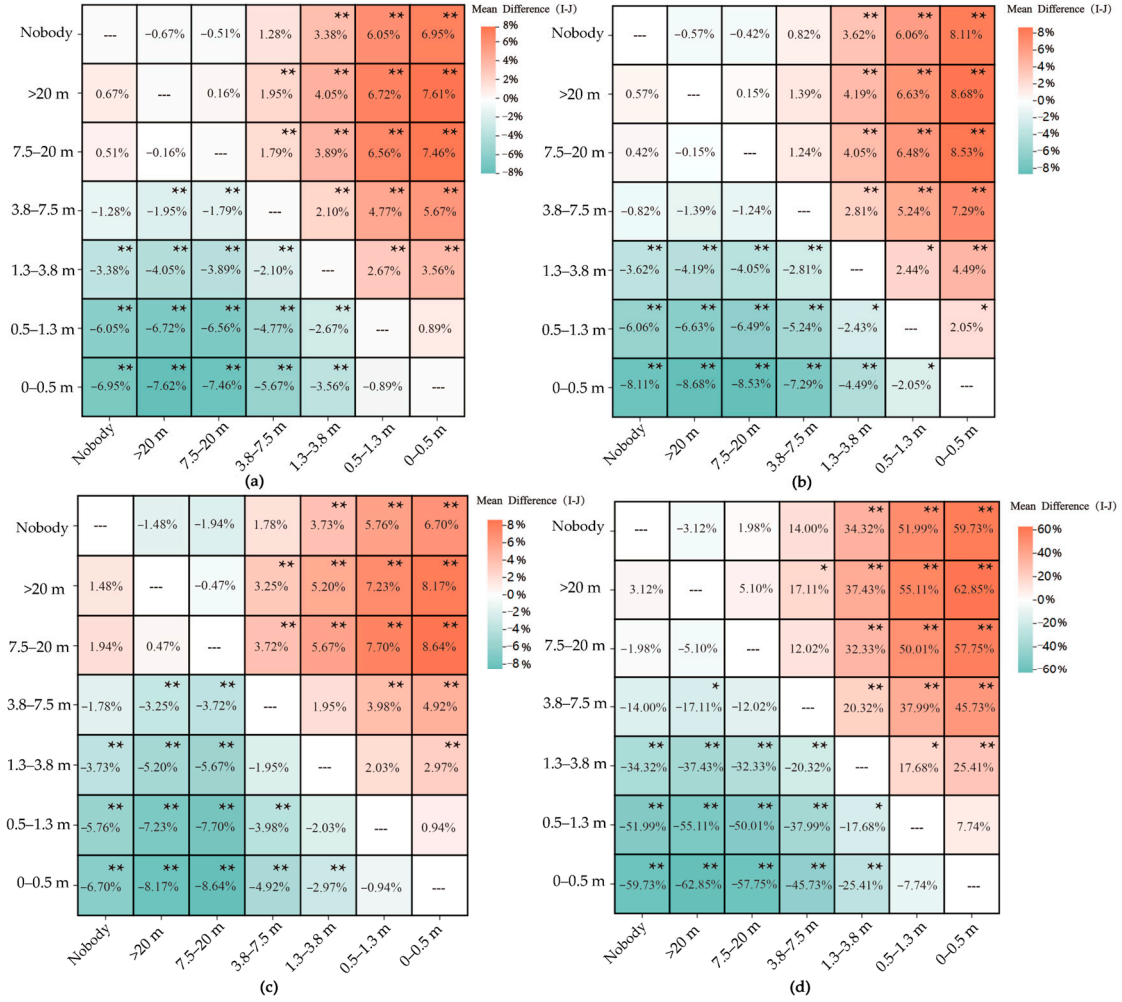


Figure 4. Tukey post-hoc comparison matrices for physiological indicators and social distances. (**a**) ΦΔDBP; (**b**) ΦΔSBP; (**c**) ΦΔPR; (**d**) ΦΔGSR. * and ** denote $p < 0.05$ and $p < 0.01$, respectively.

Figure 5 depicts the Tukey post-hoc comparison matrices for the four physiological indicators against landscape type. The results indicate that no significant differences were observed in ΦΔPR among all five landscape types. Regarding ΦΔSBP, significant differences were observed between 'ocean', 'wetland', and 'desert'. For ΦΔGSR, significant differences were only noted between 'mountain', 'forest', and 'desert', while the other landscape types showed no significant differences. In terms of ΦΔDBP, significant differences were found between 'mountain' and 'wetland', 'mountain' and 'desert', 'forest' and 'ocean', 'ocean' and 'wetland', and 'ocean' and 'desert'.

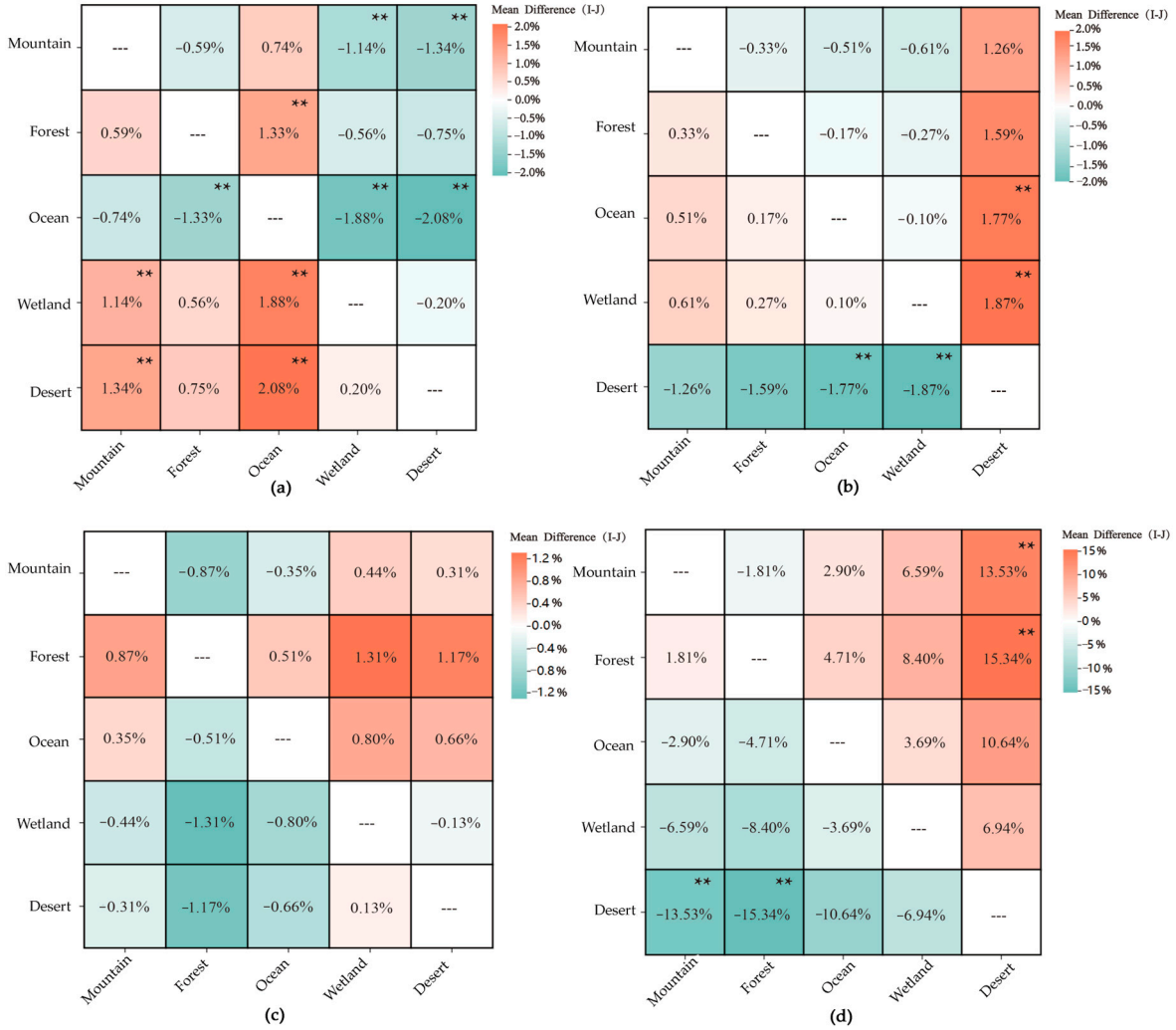


Figure 5. Tukey post-hoc comparison matrices for physiological indicators and landscape types. (**a**) ΦΔDBP; (**b**) ΦΔSBP; (**c**) ΦΔPR; (**d**) ΦΔGSR. ** denotes $p < 0.01$.

3.2. Psychological Restoration

A total of 1120 questionnaires (32 × 7 × 5 = 1120) were distributed using the Restorative Component Scale (RCS) [21–24,48] to evaluate the psychologically restorative effects of seven social distances across five landscape types (Figure 6). The reliability of the questionnaire was assessed using Cronbach's α coefficient, whereby a Cronbach's α value of 0.920 indicates high internal consistency.

The results indicate the social distances contributing positively to restoration for the 'mountain' landscape type to be 'nobody', '>20 m', '7.5–20 m', and '3.8–7.5 m'. Among these, the restoration ranking for 'being away' and 'extent' was as follows: '>20 m' > 'nobody' > '7.5–20 m' > '3.8–7.5 m'. The restoration rankings for 'fascination' and 'compatibility' were also consistent, with '>20 m' > '7.5–20 m' > 'nobody' > '3.8–7.5 m'. In the 'forest' landscape type, 'being away', 'compatibility', and 'fascination' exhibited the same restoration ranking, namely, '>20 m' > 'nobody' > '7.5–20 m' > '3.8–7.5 m'. Positive restorative effects were also observed for 'ocean', 'being away', and 'fascination' at '1.3–3.8 m', while 'extent' and 'compatibility' shifted to negative effects within this social distance range. In terms of the restorative results, 'extent', 'fascination', and 'compatibility' shared the same ranking, with '>20 m' > '7.5–20 m' > 'nobody' > '3.8–7.5 m'. A slight difference was observed for 'being away', with '7.5–20 m' > '>20 m' > 'nobody' > '3.8–7.5 m'. The restoration rankings for 'wetland' were consistent with that for 'ocean', while for the 'desert' landscape type, 'being away', 'extent', 'fascination', and 'compatibility' exhibited the same ranking of '>20 m' >

'7.5–20 m' > 'nobody' > '3.8–7.5 m'. Furthermore, '1.3–3.8 m', '0.5–1.3 m', and '0–0.5 m' were observed to only provide negative restorative effects, and the negative impact increased as the distance decreased. In general, the results identify '>20 m' as the optimal social distance across various landscape types for psychological restoration.

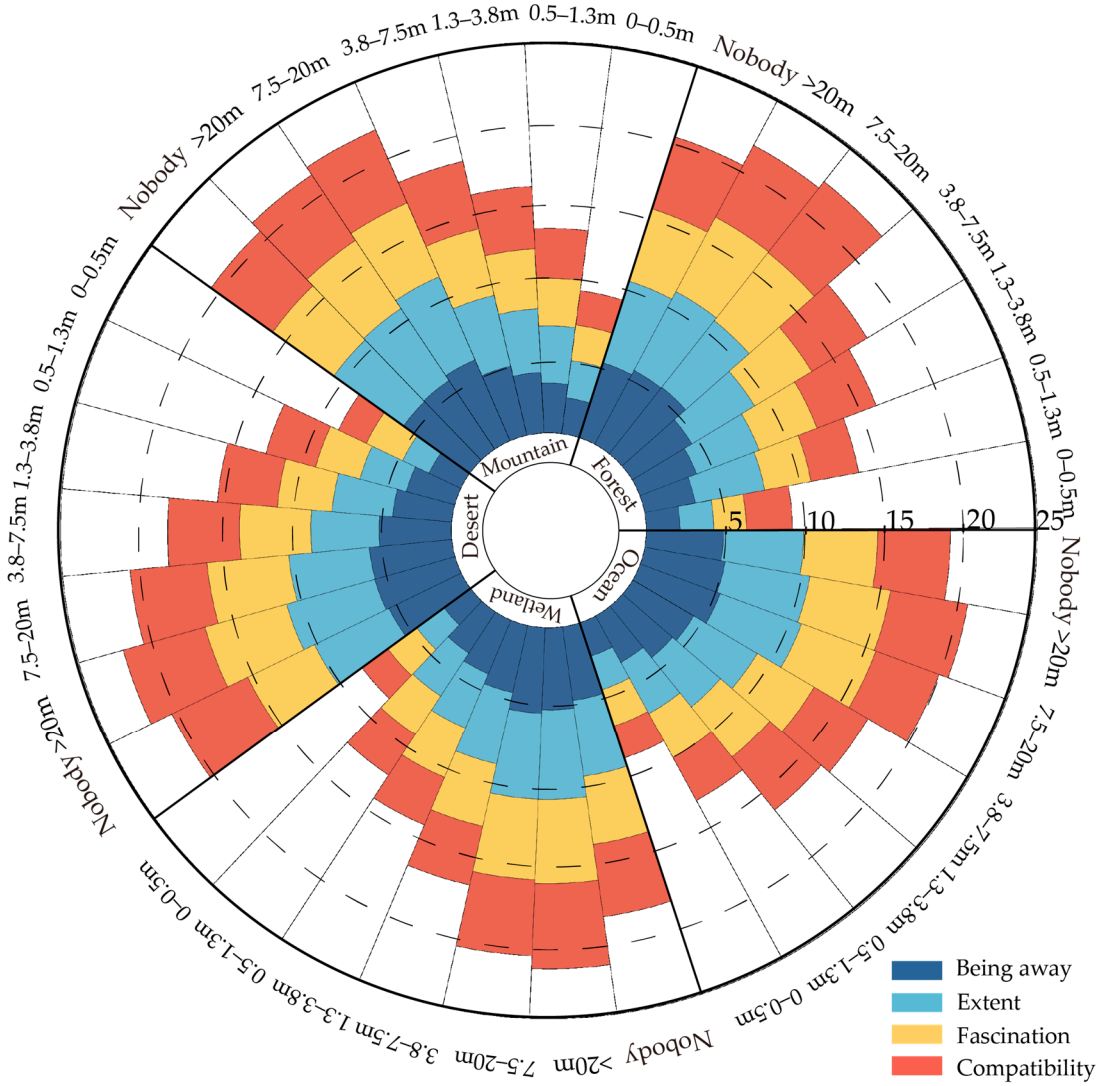


Figure 6. RCS scores at seven social distances in five landscape types.

Levene's test results for homogeneity of variance for 'being away' ($p = 0.064$), 'extent' ($p = 0.609$), 'fascination' ($p = 0.808$), and 'compatibility' ($p = 0.115$) indicated homogeneity of variance, suggesting statistically significant differences in the psychological indicators among experimental groups.

Based on the results of the two-way ANOVA (Table 4), it is evident that social distance significantly influences various psychological indicators (being away, extent, fascination, compatibility). Specifically, the impact of social distance on being away, extent, fascination, and compatibility is highly statistically significant. This indicates that changes in social distance significantly affect the psychological state of the respondents, thereby influencing the attention restoration that can be gained from the natural environments.

In contrast, the influence of landscape type on psychological indicators is relatively minor and non-significant (Table 4). Furthermore, across all psychological indicators, the *p*-values for interaction are higher than the significance level, indicating that the interaction between social distance and landscape type does not have a statistically significant effect on psychological state.

Table 4. The impact of social distances and landscape types on psychological indicators.

Psychological Indicators	Social Distances			Landscape Types			Social Distance × Landscape Types		
	F	*p*	η^2	F	*p*	η^2	F	*p*	η^2
Being away	201.250	0.000 **	0.527	0.513	0.727	0.002	0.420	0.994	0.009
Extent	203.114	0.000 **	0.529	0.691	0.598	0.003	0.503	0.978	0.011
Fascination	151.865	0.000 **	0.456	0.470	0.758	0.002	0.366	0.998	0.008
Compatibility	227.452	0.000 **	0.557	0.780	0.538	0.003	0.412	0.995	0.009

** denotes $p < 0.01$.

Figure 7 presents the Tukey's post-hoc comparison matrices of the four psychological indicators against social distances. Greater distances are associated with better attention restoration, with no significant differences observed between 'being away' and 'nobody', '>20 m', and '7.5–20 m'. For 'extent', '7.5–20 m' did not exhibit any significant differences compared to 'nobody'. The same was observed for 'compatibility' and 'fascination', where '7.5–20 m' did not present any significant differences compared to '>20 m'. Furthermore, comparisons between other social distances revealed significant differences in 'being away', 'extent', 'fascination', and 'compatibility' across all pairwise comparisons, with attention restoration diminishing as the distance decreases.

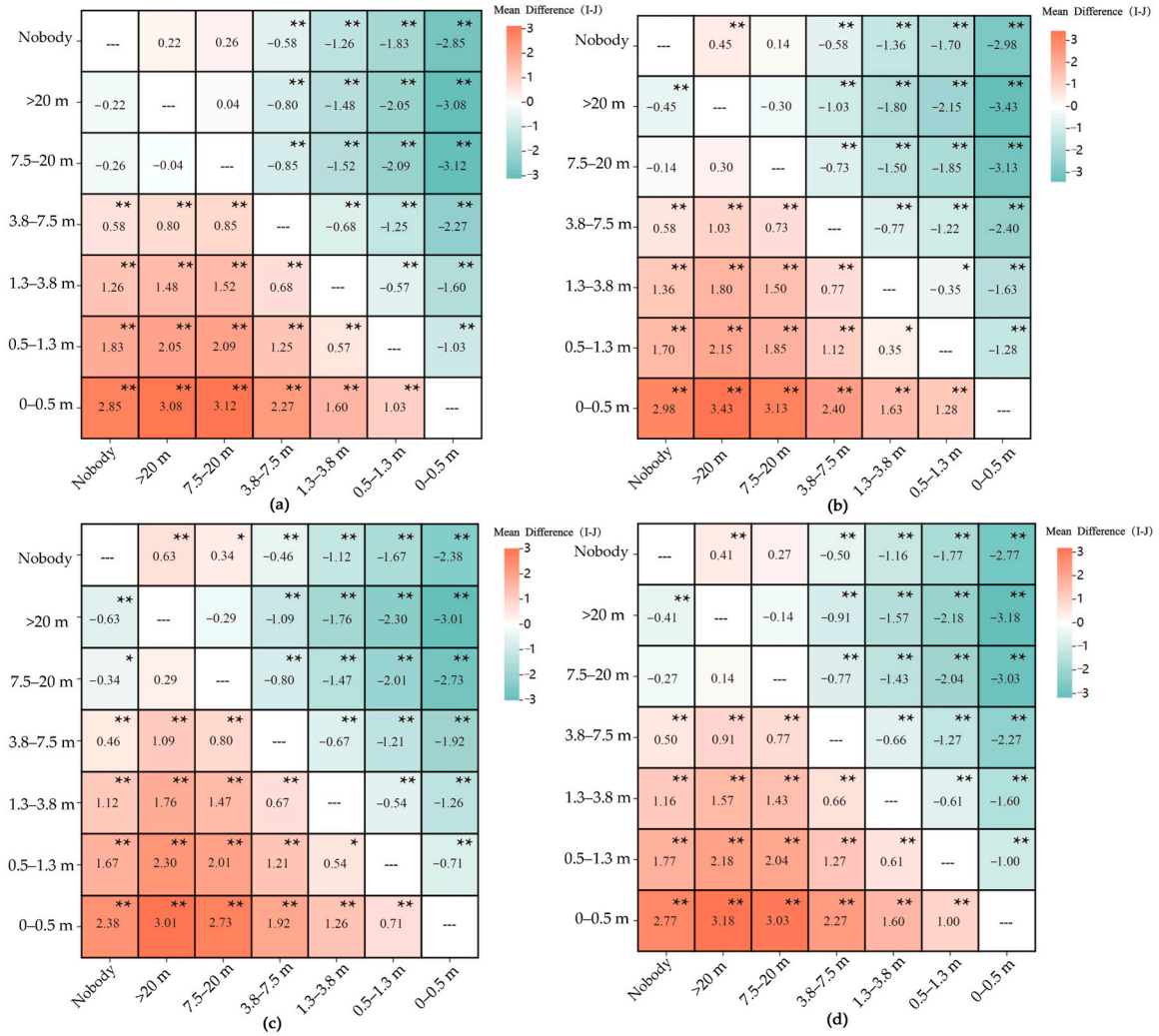


Figure 7. Tukey post-hoc comparison matrices for psychological indicators and social distances. (**a**) being away; (**b**) extent; (**c**) fascination; (**d**) compatibility. * and ** denote $p < 0.05$ and $p < 0.01$, respectively.

Since the main effects of landscape type on the four psychological indicators were not significant, no Tukey's post-hoc comparison was conducted for each psychological indicator against landscape type.

4. Discussion

4.1. Social Distance Threshold for Restoration of Natural Environment

In contrast to the previous research on the restorative effects of natural settings devoid of individuals, our study introduced individuals to the natural scenes using VR, aiming to clarify the impact of the presence of people on the restorative benefits provided by natural environments. The results indicate that the impact of individuals on restoration is markedly dependent on the social distance between them. However, the physiological indicators (ΦΔPR, ΦΔSBP, ΦΔDBP, and ΦΔGSR) at the social distances of '>20 m', '7.5–20 m', and '3.8–7.5 m' did not exhibit any significant differences compared to the baseline environment without the presence of individuals. Therefore, as long as the social distance in the natural settings exceeds the threshold of 3.8 m, the physiological restoration that can be achieved in natural settings with 'someone' are similar to the outcomes of the natural settings with 'no one', inducing no significant increase in stress.

Although 3.8 m is recognized as an appropriate size for 'public' areas, suitable for gatherings and speeches [50], previous research has never confirmed this threshold's impact on environmental restoration through physiological and psychological indicators. Regarding psychological indicators, when social distance exceeds 3.8 m, it positively influences attention restoration across four components ('being away', 'extent', 'fascination', and 'compatibility'). Conversely, negative effects are predominantly observed when the distance falls below this threshold. Given that distances below 3.8 m typically involve ordinary conversation or closer interactions [44,50], this finding aligns with expectations. This threshold can be applied in the spatial design of restorative natural settings, not with the aim of gathering people into 'public' areas, but rather to facilitate restorative experiences, such as through determining the minimum distance that should be maintained between landscape nodes where people are likely to linger.

4.2. Optimal Distance for Restoration of Natural Environment

Previous studies on restoration often deliberately select or construct settings without people, potentially biasing the perception that natural environments devoid of individuals inherently offer the optimal restorative experience. However, the results of physiological indicators reveal no significant differences observed among settings with 'nobody' and people at a distance of '>20 m' and '7.5–20 m'. Concerning psychological indicators, except for 'being away', '>20 m' shows no significant differences compared to 'nobody', whereas, in the other three indicators, '>20 m' significantly surpassed the 'nobody' natural environment. Combining the results regarding both the physiological and psychological aspects, it can be concluded that natural settings with a social distance of greater than 20 m exhibit the optimal restoration performance, offering the optimal opportunity for stress reduction and attention restoration. This result aligns with expectations, as natural environments devoid of people may imply that one could potentially face dangers and uncertainties alone [30,31].

4.3. Impact of Different Landscape Types on Restoration

The impact of landscape type on restoration warrants further investigation. The results indicate that while the influence of landscape types on physiological restoration is significant, the effect size is small. Moreover, the impact of landscape types on psychological restoration is not only weak but also lacks statistical significance. While some studies suggest that water bodies are the most restorative landscape [23,40], followed by mountains and forests [39,40], our study's results align more with the view that there are no significant differences in terms of recovery between various natural conditions, such as parkland,

tended woodland, and wild woods [37], as well as mountain rivers and remote alpine meadow [38].

However, it would be premature to draw simplistic conclusions about the minimal impact of landscape type on restoration effects. Firstly, this inference may depend on the nature of the VR environment. Although existing research supports the efficacy of virtual reality as a tool for studying restorative environments [45] and suggests that VR natural experiences can enhance both physiological and psychological restoration [15,16], there remains a perceptual disjunction between VR scenes and real-world environments concerning landscape intricacies. Secondly, most existing VR restoration studies have focused on singular VR scenarios, such as uniform costal natural settings [15], courtyards [16], or offices [51], where variations in diverse landscape elements are introduced. There is limited research comparing the restorative effects of disparate landscape types within VR settings. While the majority of participants in our study perceived the quality of the experimental scenes of different landscape types to be comparable, potential interference arising from scene quality cannot be discounted. Such interference may also be prevalent in offline restoration studies, encompassing on-site experiments conducted based on prevailing landscape scenes [2,38,39], as well as laboratory-based investigations utilizing photographs and videos capturing diverse landscapes [5,38]. Further investigation is warranted to ensure consistency in scene quality across different landscape types. Moreover, the experimental outcomes might also be influenced by participant characteristics. Notably, the participants in our study comprised young college students, who typically exhibit heightened curiosity and greater tolerance towards VR environments, potentially influencing the ultimate findings. Despite these constraints, the utilization of VR to simulate real-world environments and to construct natural scenes depicting various landscape types represents a meaningful endeavor.

5. Conclusions

In contrast to the idealized scenario of the 'nobody' environment, the inclusion of 'someone' in natural settings better reflects real-life situations. This study established a randomized controlled experiment, employing ΦΔPR, ΦΔSBP, ΦΔDBP, and ΦΔGSR as physiological indicators, and RCS for psychological assessment. By comparing the results from the stress phase with those of the restoration phase, we examined the extent of the impact that seven different social distances had on participants' physiological and psychological responses. To examine whether these effects were influenced by special natural environments, we incorporated five types of natural landscapes: mountain, forest, wetland, ocean, and desert.

While previous studies have demonstrated the stress reduction and attention restoration effects of natural environments, our findings reveal distant physiological and psychological responses to environments containing other individuals at various social distances. Notably, the presence of individuals has minimal impact on stress reduction in natural settings when the social distance exceeds 3.8 m. However, when the social distance is less than 3.8 m, the restorative effects of natural settings progressively diminish, leading to noticeable negative outcomes. Nonetheless, the assumption that closer social distances yield reduced restorative effects does not necessarily indicate that greater social distances lead to superior restorative outcomes. An environment without people, which represents the maximum social distance, may not be the optimal experience, particularly in terms of psychological response. At the social distance of '>20 m', natural settings excel in terms of psychological indicators such as 'extent', 'compatibility', and 'fascination', surpassing the attention restoration observed in the 'nobody' environment. Considering both physiological and psychological results, '>20 m' provided superior restorative benefits. These findings hold true across various landscape types, as alterations in landscape types did not significantly affect the psychological results. Despite the study's limitations, further research is required to comprehensively understand the impact of landscape type on restoration.

This study operated under the assumption that social distances remained relatively constant, overlooking factors such as visitor interaction and scene sounds, both of which can influence the perception of social distance [52]. Additionally, future research could enhance the generalizability of findings by expanding the age range of participants beyond college students, considering the potential influences of age and landscape preferences. Nonetheless, our study marks a significant advancement in the exploration of restorative effects in natural environments, transitioning from an idealized 'no one' setting to a more realistic scenario with the presence of other humans. This shift holds valuable insights for both research and practical applications. Subsequent studies could delve deeper into the correlation between dynamic changes in social distance and the restorative effects of natural environments.

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Institutional Review Board Statement: Given the observational nature of this study and in the absence of any medical treatment, no formal approval of the institutional review board of the local ethics committee was required. Nonetheless, all subjects were informed about the study, and participation was fully on a voluntary basis. Participants were assured of the confidentiality and anonymity of the information associated with the surveys. This study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are available from the authors upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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