



Article Do All Types of Restorative Environments in the Urban Park Provide the Same Level of Benefits for Young Adults? A Field Experiment in Nanjing, China

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Abstract: Previous research has consistently shown that exposure to natural environments provides a variety of health benefits. The purpose of this study is to investigate the restorative benefits of nonvirtual environments in field experiments as well as the differences in physiological and psychological effects between different types of restorative sites for stressed young adults. This controlled study design used the Positive and Negative Affect Schedule (PANAS), electroencephalogram (EEG), and heart rate variability (HRV) as psychophysiological indicators of individual affect and stress. We used a "stress imposition-greenspace recovery" pre- and post-test mode to simulate the most realistic shortterm recovery experience in the park (Grassplots, Square, Forest, and Lakeside) under relatively free conditions. The experimental results show that all four natural spaces in the park have some degree of recovery. However, there were discernible differences in the restorative effects of four selected natural sites. Lakeside and Forest demonstrated the most robust restorative properties in terms of both negative emotion reduction and positive emotion enhancement. In contrast, Square showed the weakest facilitation of recovery, while Grassplots promoted moderate resilience. Physiologically, we found that the EEG- α % of the Square was significantly lower than the EEG- α % of the Forest (t = -3.56, p = 0.015). This means that stressed young adults were much more relaxed in the forest than in the paved square. The study answers which types of natural spaces, when considered together, would provide greater restorative benefits to stressed young people participating in natural therapies in urban parks. The study's policy implications include the need to create more green natural spaces, especially forests with multiple plant levels, as well as to improve the restorative nature of urban parks through appropriate landscape space design.

Keywords: restorative benefits; nature therapy; forest therapy; urban park; physiological effects; greenspaces

1. Introduction

With urbanization, populations are growing and cities are becoming denser. Highdensity cities are crowded with gray land, so access to greenspace is becoming more limited. Environmental pollution and car-dependent lifestyles have become important factors in the changing spectrum of human health and illness [1]. Increases in chronic conditions such as respiratory diseases, cardiovascular diseases, and obesity have occurred [2,3]. In addition, the city dwellers' fast-paced lifestyle has increased stress and mental health problems. The balance between adapting to modern city life and staying healthy has become critical. Especially post-pandemic, people have become more aware of the importance of health. Research has consistently confirmed that exposure to natural environments generates various dimensions of health benefits [4,5]. Specifically, urban greenspaces (UGS), such as parks, are essential public resources for improving human health [6,7]. Researchers have continued to demonstrate the benefits of greenspaces for human wellbeing, including



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Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). improving psychological state and mental health [8,9], reducing stress [10], increasing positive emotions [11], and eliminating anxiety [12,13]. In addition, greenspace enhances young people's cognitive functioning and wellbeing [14,15]. Therefore, such exposure can be regarded as a nature-based solution for promoting urban resilience and public health. Some studies identified three potential relationships between green space and health: harm reduction, restoring capacities, and capacity building [16] (e.g., encouraging physical activity and promoting social cohesion).

Previous research on the short-term health effects of nature exposure was mostly based on Stress Recovery Theory (SRT) and Attention Restoration Theory (ART). SRT states that the natural environment significantly impacts people's recovery from mental fatigue. Through contact with nature, release of beneficial neurotransmitters helps diminish harmful thoughts and emotions, reducing the stress response [4,17,18]. ART emphasizes how plants and other natural features restore effective attention, allowing the remaining neurological and cognitive mechanisms to function [5,19]. Based on SRT and ART, researchers have investigated the emotional and state restoration effects of greenspace or environments with natural features under specific conditions. A series of studies have compared the restorative effects of natural and urban environments on psycho-physiological functioning. The research suggests that exposure to natural environments with greenspace and water (instead of urban ones) can improve positive mood by reducing stress and restoring attention [20]. Studies have found that natural environments are more beneficial for physiology than urban ones for reducing stress, and improving emotional valence and cognitive abilities [21]. Forest visits have health advantages that lower the risk of stress-related illnesses and diseases linked to a sedentary lifestyle and are linked to better mental and physical health [22]. Physical activity in such green environments is better for physical and mental health than under other conditions [23,24]. Such studies are not limited to "in-person experience". Some studies showed how natural environments are beneficial, even indirectly through observation from windows or rooftops [25,26]. Furthermore, virtual nature contact benefits have been observed. Virtual research has evolved from still photographs to video and, finally, virtual reality (VR). Several studies have compared VR with live nature exposure and found that both had a restorative effect. However, only the outdoor environment measurably increased pleasant emotions [27].

Evaluating the potential of various environmental factors to bring restoration is essential for evidence-based health design [28]. "Natural versus urban" may gloss over meaningful within-category variability regarding the restorative potential of different physical environments [29]. Some scholars have conducted studies on the restorative nature of indoor and outdoor environments [30]. Additionally, the greenspace's type, quality, and context should be considered in assessing its relationship with wellbeing [31]. Studies have investigated the relationship between greenspace characteristics and restorative effects. These characteristic elements include the type of greenspace [32,33], general quality [34,35], biodiversity [36,37], landscape appearance [38,39], and composition of the internal environment [40,41]. Some researchers believe that the greatest influence on psychological recovery is the greenspace's vegetation and biodiversity. Its facilities and topography also have an affect [42]. Additional studies have demonstrated that park type and size, impermeable ground areas, and water bodies have varying degrees of association with favorable visitor effects [43]. In addition to this, the differential effects of forest ages and types on recovery have been demonstrated in other experiments [44]. Overall, several studies examined largescale correlations between green environmental exposures and population health and their action pathways. Other studies used relatively small-scale physiological-psychological experiments in different natural settings. Most of these studies used psychological measures (e.g., Perceived Restorative Scale [PRS], Profile of Mood States [POMS], Positive and Negative Affect Schedule [PANAS]) based on self-report supplemented by physiological activity measures (e.g., electrodermal activity [EDA], electroencephalography [EEG], blood pulse [BP], heart rate [HR], and heart rate variability [HRV]) to validate the results in different scenarios [45]. It contains only a small number of field experiments on the spatial differences

in the recovery of different natural features, which may have quite a lot of confounding factors. In contrast, it is easier to control variables in virtual indoor experiments.

However, natural restoration is a dynamic integrated process with visual and auditory [46,47], tactile [48], olfactory [49], and other multifaceted perceptual pathways. The population directly perceives the restoration benefits of greenspaces through various senses [50]. Other types of perception other than audio-visual are difficult to mimic and reproduce in virtual experiments. For example, a correlation exists between psychological recovery and bird diversity and insects (butterflies and bees) [51,52]. Measuring these types of perceptions requires live experiences in nature rather than virtual environments. Research has examined the effects of different landscape types on population health. However, few studies discuss the differing restorative effects of various landscape components, especially in non-virtual settings. We therefore need to design a controlled experiment that can accurately measure the physiological and psychological indicators of visitors, that meets the need for visitors to personally interact with nature in terms of perception and experience while controlling variables as much as possible in a non-laboratory setting.

This study aims to investigate the restorative benefits of non-virtual environments in field experiments as well as the differences in physiological and psychological effects between different types of restorative sites for stressed young adults. We hypothesize that natural spaces made up of various components have a restorative effect on participants and the benefits of different scenes differ significantly. Furthermore, we presume Forests have the best restorative properties in comparison, and the psychological scale data correlate strongly with each physiological index. This study adopts a control experiment design to obtain more accurate physiological–psychological data in real scenarios. It combines the PANAS scale and physiological indicators (EEG and HRV) obtained by wearing wireless devices to experiment in four similarly sized different landscape spaces through the preand post-test mode of "stress imposition greenspace recovery". This experimental model recording the initial state allows for clarification of the differences in restorative benefits between scenarios. In addition, the physiological equipment uses wireless sensors that guarantee the real-time transmission of outdoor data. This capability collects participants' physiological indicators in a natural setting more accurately.

2. Materials and Methods

2.1. Participants

According to recent studies, intense social competition and involution have resulted in an increase in stress among today's youth, particularly among new young workers and soon-to-be-employed college students. As a result, there is a critical need for research on this young adult population [53,54]. We pre-computed the required sample size using G*Power software (version 3.1.9.7) and analyzed the effect sizes of existing restorative environmental studies. ANOVO: Repeated measures (within-between interaction) and means (difference between two dependent means (matched pairs)) were selected based on the analytical approach of the experiment. Based on the results of the two tests described above, the total sample size required for one site was 32 individuals. We recruited volunteers for the experiment by means of posters and social media. Participants were required to meet specific conditions, including having no psychiatric disorders (such as depression, schizophrenia, or mood disorders) and no visual, hearing, or cognitive impairments. Furthermore, the age range is restricted to young adults over the age of 18, and no more than two years of work experience if they have work experience. Finally, 39 young adults (19 males and 20 females) aged 18 to 28 (mean 24.5) were chosen to participate in this study. These include college students, young company workers, and civil servants. All participants underwent a brief training session and were asked to avoid alcohol and psychotropic drug use during the experiment. Before giving written consent, they were fully informed about the experiment.

We used a repeated measures approach. Each participant (numbered 1–39) was involved in four different experimental settings. This method yields a larger sample

size for the experiment with fewer participants. To control order effects, the participants were divided into four groups (10, 10, 10, and 9). Each group participated in these four restorative experiments in a different order during the experimental days. The specific experimental arrangement and the order of participation are shown in the Supplementary Materials (Table S1). This study was approved by the Ethics Committee of Nanjing Forestry University.

2.2. Experimental Sites

Xuanwu Park in Nanjing was selected as the experimental site. It is the largest comprehensive park in central Nanjing, covering a total area of 5.13 km². It is a wellequipped scenic spot with a diverse landscapes and rich biodiversity. Setting the research in large city parks is beneficial. Urban parks, as inclusive, open spaces, can include a variety of greenspace types with varying characteristics while reducing experimental error due to site location, climate, elevation, and inconvenient transportation of equipment and people. The authors selected four natural environments of similar size within the park (see Figure 1 and Table 1): Grassplot (site A), Square (site B), Forest (site C), and Lakeside (site D). Site A is a large lawn with an open, gentle topography where visitors can relax. Site B is a sculpture square with ample seating and prominent markers. Site C is a dense forest with more shadiness and a complex plant hierarchy. Site D is a ribbon corridor consisting of a chain of wooden boardwalks and a few lakefront platforms with wide views of the distant skyline. The experiment was conducted from 11 October to 5 November 2021. With bad weather (heavy rain and wind) and non-working days excluded, there were a total of 16 measured days. The Supplementary Materials (Table S1) provide specific time and location information for the measurement.



Figure 1. Photos of the four experimental sites. (a) Grassplot; (b) Square; (c) Grassplot; (d) Lakeside.

Site	Α		В		С		D	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Area (hm ²)	0.82		0.76		1.03		0.91	
Temperature (°C)	16.99	1.54	16.90	1.68	16.19	2.39	17.12	2.35
Relative humidity (%)	25.41	5.69	20.36	3.96	24.74	6.10	33.21	4.01
Wind speed (m/s)	3.15	2.09	2.73	1.90	2.28	1.81	3.61	2.12

Table 1. Average temperature and humidity on experiment days.

2.3. Stress Induction

We elicited a suboptimal state before the restorative experiment to ensure that an initially pleasant one did not obscure the recovery difference. This phase was conducted using two simultaneous approaches. Firstly, we used stimulating audio to induce unpleasant emotions and mental fatigue. The stimulating audio, created using Adobe Audition (CS6, Adobe Systems Incorporated, Mountain View, CA, USA), can be found in the Supplementary Documents Audio S1. It consisted of gradually accelerating heartbeats, street traffic noise, and sharp, harsh sounds. Secondly, as the participants were students, we induced mental stress with a timed (3 min) math test. Previous studies have used exams and calculations to induce stress [55,56]. We printed four math test question sets with comparable difficulty coefficients to avoid the stressful effects of repeating questions in other scenarios. Participants were administered a different five-question test in each experimental setting.

2.4. Measurements

The assessment used subjective mood scales and objective device measures. The benefits of assessing resilience using self-report combined with objective measures have been previously supported by research [45].

2.4.1. Psychological Measurements

The PANAS Scale was developed by Watson, Clark, and Tellegen (1988). The scale is designed to measure positive and negative feelings in a person's current state. The final score is derived from the sum of ten items for each of the positive and negative dimensions. These twenty items describe emotions, stress, and mental states. They can reflect changes in the subject's affect to some extent [57]. Using the PANAS scale to describe the restorative quality of natural environments has shown high consistency (89%) with physiological indicators in previous analyses [45]. The PANAS has been translated into Chinese so that native Chinese speakers can have a more accurate measure of their psychological state. The content of this version of the PANAS is shown in Supplementary Materials (Table S2). The PANAS uses a 5-point Likert scale, with scores from 1–5 representing very slightly/not at all, a little, moderately, quite a bit, and extremely. We used a pre- and post-test model to study changes in participants' psychological states. The pre-test asked participants to complete the PANAS based on their current psychological state immediately after stress administration. The post-test asked participants to complete it based on their condition after spending time in experimental spaces. As Watson stated, "When used with short-term time frame instructions (i.e., moment or today), the PANAS scales are sensitive to changing internal or external circumstances [57]". This sensitivity is well-suited to describing changes in participants' measured mood before and after the restorative experiment. The Positive Mood Scale total ranges from 10 to 50. It is the sum of items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19, with higher total scores representing higher levels of positive mood. Similarly, the total score of the Negative Emotion Scale ranges from 10 to 50 and is the sum of items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20, with higher scores representing greater emotional distress. The difference between the post-test and pre-test scores, ΔD , is used to indicate recovery. ΔDP = total post-test positive emotion score – total pre-test positive emotion score. $\Delta DP > 0$ means that the post-test positive emotional level is higher than the pre-test, while $\Delta DP < 0$ signifies that the post-test positive emotion is lower than the pre-test level. ΔDN = total score of post-test negative emotion – total score of pre-test negative emotion. $\Delta DN > 0$ means the post-test negative emotion level is higher than the pre-test level, while $\Delta DN < 0$ means the post-test negative affect score is lower than the pre-test negative affect score. Thus, unpleasant emotion was somewhat reduced.

2.4.2. Physiological Measurements

Electroencephalogram (EEG) is a powerful tool for assessing the emotional impact of various landscapes and architectural environments [58]. The EEG power spectrum components consist of five common frequency bands (waves): δ (1–4 Hz), θ (4–8 Hz), α (8–13 Hz), β (13–30 Hz), and γ (>30 Hz) [59]. Alpha waves (α) indicate that the person is relaxed and less susceptible to external interference [60]. Earlier studies confirmed that α power is elevated under more restorative and natural environmental conditions [17]. Lower frequency EEG bands might characterize comfortable or restorative environments and associated pleasant emotions [61]. Beta waves (β) are associated with higher arousal and alertness levels. Previous studies have concluded that natural window-scape produced more beta waves than urban ones [25]. In addition, β waves were associated with greater mental tension and in-depth thinking [62]. Significantly higher β waves are produced in stressful than in calm conditions.

The EEG data were continuously recorded using a semi-dry wireless EEG instrument (Kingfar Technology Co., Ltd., Beijing, China). The instrument records raw EEG signals from parietal (P3, P4), frontal (F3, F4), occipital (O1, O2), and frontal midline (FpZ, Fz) electrodes and transmits them to a wirelessly connected laptop. All electrodes were referenced to the linked earlobe (A1, A2) and grounded at the midpoint between Fpz and Fz [63,64]. Semi-dry electrodes and fewer EEG channels save time and reduce the adverse impact on participants. Pre-processing can reduce EEG channel numbers without reducing accuracy [65]. The experimental sampling rate was 256 Hz, and the bandpass filter was set between 0.5 Hz and 100 Hz. A 50 Hz band-stop filter was used to filter the I.F. signal.

HRV has been widely used as a reliable indicator with high temporal resolution in previous recovery experiments [56,66]. The low/high frequency (LF/HF) ratio is an HRV frequency domain parameter indicating sympathetic and parasympathetic activity [67]. It is suitable for objective measures of stress, with higher LF/HF values indicating an overactive sympathetic nervous system associated with increased stress and anxiety [68]. The HRV data were recorded with a wearable Human Factors Logger (Kingfar Technology Co., Ltd., Beijing, China). The data were pre-processed using the HRV module of ErgoLAB V3.0.

2.5. Experimental Procedure

Before the experiment, all participants completed a personal basic information questionnaire, including age and gender, via WeChat and email. Each participant was informed that they could withdraw if they experienced any discomfort during the experiment. Upon arrival at the site, participants will be guided through the day's experimental site by our staff and informed of the site boundaries. Figure 2 shows the five experimental steps: preparation (T0), baseline (T1), pressure application (T2), restoration (T3), and post-test interview (T4), over approximately 44 min. Physiological measurements were taken during baseline (T1), pressure application (T2), and restoration (T3). Psychological measurements were taken before and after the restoration stage.

Preparation: The staff reviewed the main procedures and precautions with the participants. Next, they assisted participants with wearing the semi-dry wireless EEG instrument and Human Factors Logger. Ten minutes, on average, were needed to achieve good skin-electrode contact quality.

Baseline: Participants relaxed with their eyes closed. Wireless noise-canceling headphones (1MORE ComfoBuds Z) measured their physiological index for three minutes without visual and auditory interference [56].



Figure 2. Steps of the restorative experiment.

Pressure application: Stimulating audio was played during a three-minute cognitive (math) test, inducing unpleasant emotions and mental stress through auditory stimuli and deep thinking. The math test questions were not scored but induced mental fatigue. At the end of the pressure induction stage, participants completed a modified Positive/Negative Affect Scale (PANAS) as a pre-test.

Restoration: In previous studies, it usually lasted from 3–15 min [69,70]. We controlled for the effects of physical activity, social cohesion, and other pathways as much as possible through prior training of participants [14]. Participants were asked to walk slowly or sit within a pre-defined field area for twelve minutes and observe the park scenery casually. They were instructed not to eat, drink, or talk to others. Physiological data were continuously measured and recorded in real-time. Throughout the restoration period, an experimental assistant with a laptop computer monitored the participant closely but non-intrusively to ensure their safety and comfort, while ensuring that the wireless data signal from the physiological sensors was transmitted intact. After the restoration stage, the Positive/Negative Affect Scale (PANAS) was administered again.

Post-test interview: Some participants agreed to a semi-structured in-depth interview to better explain and understand the experiment. They were asked if contingencies such as weather and other visitors impacted their affective changes. All field interviews were audio-recorded and later transcribed for statistical analysis.

2.6. Statistical Analysis

The paired-samples *t*-test analyzed whether each landscape space had a restorative psychological effect. The mood scores before and after each site's recovery stage were paired to verify whether the difference between positive/negative mood recovery before and after was significant. The independent variable type was a within-subjects variable. Each participant underwent the restorative trials of the four sites in their entirety to investigate further whether the difference in restorative of each site was significant. Therefore, the difference before and after the positive/negative mood restoration (ΔD) was used as the independent variable, and a repeated-measures ANOVA tested whether the four scenes' restorative effects differed. Then, multiple comparisons compared the difference between each site's ΔD . Normality tests were conducted on the before-and-after ΔDP and ΔDN . The Shapiro–Wilk method test showed the difference between the before-and-after positive and negative sentiment scores for each site followed normal distribution, allowing for the repeated-measures ANOVA. First, we performed Mauchly's test of sphericity. If

the sphericity hypothesis was satisfied, dependent variable data for repeated measures exhibited equal variance–covariance matrices. Thus, the Greenhouse–Geisser analysis results for within-subject effects could be used. Otherwise, the results of Roy's Largest Root in Multivariate Tests was used.

The total percentages of alpha and beta wave bands (EEG- α , EEG- β) and the low-/high-frequency ratio (LF/HF) were used as physiological indicators of participants' stress and mental status. The change in EEG is a process. Thus, we chose the proportion of α and β and LF/HF throughout the stage rather than at a point or during a segment. Two-way repeated-measures ANOVAs verified each landscape space's physiological restoration effects and whether they significantly differed. Additional algorithms were performed to analyze the interaction effects of site*time and can be found in the Supplementary Materials (Equation S1). Pearson correlation was used to analyze the associations between various parameters.

The statistical analysis was performed using SPSS 22.0 (IBM Corp, Armonk, NY, USA). Data analysis graphs were performed using GraphPad Prism 9 (GraphPad Software Inc., La Jolla, CA, USA). *p*-Values < 0.05 (*) were considered significant, *p*-values < 0.01 (**) were considered highly significant, and *p*-values < 0.001 (***) were considered extremely significant.

3. Results

3.1. Descriptive Statistics

Table 2 shows the mean total scores and standard deviations of our calculated psychological and physiological measures.

Site	A (N =	39)	B (N =	39)	C (N =	39)	D (N =	39)
Measures	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PANAS-POS								
Pre	24.35	5.08	23.71	4.94	23.28	3.59	23.18	4.56
Post	28.41	4.94	27.41	3.88	28.44	4.62	29.44	5.27
PANAS-NEG								
Pre	31.54	4.73	30.97	6.15	30.82	5.70	31.05	5.53
Post	27.33	3.37	26.62	5.52	25.79	5.36	24.15	2.81
EEG-α (%)								
T1	54.24	11.13	56.58	10.33	61.07	12.46	53.80	7.88
T2	22.42	2.39	23.44	3.57	23.52	4.13	22.53	3.10
Т3	26.74	3.77	25.14	2.22	27.59	3.22	27.99	2.90
EEG-β (%)								
T1	20.16	5.71	21.05	5.30	19.24	4.97	22.38	4.65
T2	30.31	4.48	33.07	4.53	31.41	3.04	31.40	4.66
Т3	25.71	3.71	28.78	5.98	25.86	5.76	24.93	4.28
LF/HF								
T1	1.11	0.33	0.99	0.27	1.01	0.21	1.00	0.27
T2	3.87	1.59	3.53	1.64	3.80	1.49	4.13	1.55
T3	3.03	1.73	2.90	1.51	2.89	1.70	3.25	1.95

Table 2. Descriptive statistics for relevant variables at the experimental sites.

3.2. Psychological and Physiological Restorative Effects

3.2.1. Psychological Restorative Effects

The Cronbach's alpha for the Chinese version of the full PANAS was 0.863. The positive and negative PANAS scales were 0.855 and 0.881, respectively, indicating good reliability. The Shapiro–Wilk normality test showed each landscape space's positive and negative psychological scores were normally distributed.

Table 3 indicates that the *p*-values for the PANAS-P and PANAS-N paired-sample *t*-tests were below 0.001 (***), the post- to pre-test positive affect difference was $\Delta DP > 0$, and the negative difference was $\Delta DN < 0$. This discrepancy indicates that the PANAS-P

score was significantly elevated. The PANAS-N score was reduced for all four scenarios after the restoration stage. Figure 3 displays trends in psychological indicator changes.

Table 3. Pairwise comparisons of post- to pre-tests at the experimental sites.

	Mean	SD	95%CI of	the Difference	t	p
PANAS-P			Lower	Upper		
Site A	4.05	4.24	2.68	5.43	5.96	< 0.001 ***
Site B	3.69	2.91	2.75	4.64	7.92	< 0.001 ***
Site C	5.15	3.62	3.98	6.33	8.88	< 0.001 ***
Site D	6.26	4.56	4.78	7.74	8.56	< 0.001 ***
PANAS-N						
Site A	-4.21	3.44	-5.32	-3.09	-7.63	< 0.001 ***
Site B	-4.36	4.27	-5.74	-2.97	-6.38	< 0.001 ***
Site C	-5.03	4.11	-6.36	-3.69	-7.64	< 0.001 ***
Site D	-6.90	4.62	-8.39	-5.40	-9.33	< 0.001 ***



Figure 3. Trends in psychological indicators changes. (**a**) Pre- and post-affect score changes in positive scale. (**b**) Pre- and post-affect score changes in negative scale.

3.2.2. Physiological Restorative Effects

Two-way repeated-measures ANOVAs were performed for each EEG- α , EEG- β , and LF/HF at baseline (T1), stress (T2), and restoration (T3) stages for the four sites. Table S3 in the Supplementary Materials presents the results. EEG- α (F = 340.27, p < 0.001 ***, Partial $\eta^2 = 0.98$), EEG- β (F = 53.15, *p* < 0.001 ***, Partial $\eta^2 = 0.76$), and LF/HF (F = 140.54, $p < 0.001^{***}$, Partial $\eta^2 = 0.88$) were highly significant for the time effect. However, neither EEG-α (F = 2.12, p = 0.13, Partial η² = 0.52), EEG-β (F = 1.62, p = 0.175, Partial η² = 0.09), nor LF/HF (F = 0.21, p = 0.943, Partial η^2 = 0.01) were significant in terms of interaction effects, and further pairwise comparisons are needed. Further pairwise comparisons were made between the baseline (T1), stress (T2), and restoration stages (T3). The results showed extremely significant differences between the baseline stage (T1) and the pressure application (T2) for all data. This result indicates that applying pressure had a marked intervention effect. The pressure application (T2) was compared to the restoration stage (T3), showing significant differences in EEG for all sites except B. Restoration- α was distinctly greater than Stress- α , and Restoration- β was distinctly less than Stress- β for sites A, C, and D, as shown in Table 4. Figure 4 shows the EEG trends from the pressure application to restoration. Only the LF/HF of Site A changed significantly during the pressure application (T2) compared to restoration (T3), while no significant differences were seen for the remaining sites.

	Stage	Mean Difference	Std. Error	р	t
EEG-α (%)					
Site A	T2-T1	-31.82	2.67	< 0.001 ***	-11.91
	T3-T1	-27.49	2.91	< 0.001 ***	-9.44
	T3-T2	4.33	1.12	0.004 **	3.88
Site B	T2-T1	-33.13	2.57	< 0.001 ***	-12.87
	T3-T1	-31.43	2.44	< 0.001 ***	-12.87
	T3-T2	1.70	1.02	0.345	1.66
Site C	T2-T1	-37.56	2.98	< 0.001 ***	-12.61
	T3-T1	-33.48	2.86	< 0.001 ***	-11.70
	T3-T2	4.08	1.33	0.021 *	3.07
Site D	T2-T1	-31.27	1.98	< 0.001 ***	-15.76
	T3-T1	-25.82	1.92	< 0.001 ***	-13.44
	T3-T2	5.46	0.92	< 0.001 ***	5.94
EEG-β (%)					
Site A	T2-T1	10.16	1.72	< 0.001 ***	5.89
	T3-T1	5.56	1.70	0.014 *	3.27
	T3-T2	-4.60	1.33	0.009 **	-3.47
Site B	T2-T1	10.25	1.12	< 0.001 ***	9.17
	T3-T1	7.68	1.65	< 0.001 ***	4.67
	T3-T2	-2.57	1.30	0.193	-1.98
Site C	T2-T1	12.18	1.48	< 0.001 ***	8.26
	T3-T1	6.63	1.93	0.009 **	3.44
	T3-T2	-5.55	1.83	0.023 *	-3.03
Site D	T2-T1	9.02	1.48	< 0.001 ***	6.11
	T3-T1	2.55	1.77	0.506	1.44
	T3-T2	-6.47	1.35	< 0.001 ***	-4.80
LF/HF					
Site A	T2-T1	2.71	0.35	< 0.001 ***	7.68
	T3-T1	1.87	0.38	< 0.001 ***	4.92
	T3-T2	-0.84	0.26	0.012 *	-3.28
Site B	T2-T1	2.60	0.37	< 0.001 ***	7.04
	T3-T1	1.96	0.33	< 0.001 ***	5.98
	T3-T2	-0.64	0.43	0.451	-1.50
Site C	T2-T1	2.77	0.33	< 0.001 ***	8.53
	T3-T1	1.87	0.38	< 0.001 ***	4.91
	T3-T2	-0.90	0.51	0.270	-1.79
Site D	T2-T1	3.15	0.34	< 0.001 ***	9.35
	T3-T1	2.27	0.42	< 0.001 ***	5.46
	T3-T2	-0.88	0.55	0.368	-1.62

Table 4. Pairwise comparisons of EEG- α , EEG- β and LF/HF in T1-T3 stages.

Adjustment for multiple comparisons: Bonferroni. * p < 0.05, ** p < 0.01, *** p < 0.001.



Figure 4. Trends in EEG changes from pressure application to restoration. (a) Trends in EEG- α (%) changes from T2 to T3. (b) Trends in EEG- β (%) changes from T2 to T3.

3.3. Variability in Recovery Benefits

3.3.1. Differences in Psychological Recovery Benefits

We analyzed the differences in the change of PANAS scores (ΔD) for each site with a repeated-measures ANOVA tested. Table 5 shows the results of the 2 × 2 comparison.

Table 5. The 2 \times 2 comparison of ΔD results for the experimental sites.

	Mean Difference	Std. Error	р	95% CI for Difference		t
ΔDP				Lower	Upper	
A-B	0.36	0.78	0.99	-1.82	2.54	0.46
A-C	-1.10	0.76	0.92	-3.21	1.01	-1.45
A-D	-2.21	0.81	0.06	-4.46	0.05	-2.73
B-C	-1.46	0.48	0.025 *	-2.79	-0.13	-3.04
B-D	-2.56	0.69	0.004 **	-4.48	-0.65	-3.71
C-D	-1.10	0.64	0.55	-2.88	0.67	-1.72
$\Delta \mathbf{DN}$						
A-B	0.15	0.76	0.99	-1.96	2.26	0.20
A-C	0.82	0.77	0.99	-1.31	2.95	1.07
A-D	2.69	0.72	0.004 **	0.69	4.70	3.74
B-C	0.67	0.57	0.99	-0.92	2.25	1.17
B-D	2.54	0.64	0.002 **	0.76	4.32	3.98
C-D	1.87	0.73	0.088	-0.17	3.91	2.56

Adjustment for multiple comparisons: Bonferroni. * p < 0.05, ** p < 0.01.

PANAS-POS: Sig. of ΔDP (Greenhouse–Geisser) = 0.002 < 0.05, F (3.00, 36.00) = 5.84, Partial η^2 = 0.33. A significant difference was detected in the change in positive mood measured before and after the four sites. It was concluded that the Square significantly differed from the Forest and Lakeside spaces for increased positive affect. The change in the positive affect scores of Site B was significantly less than Site C (t = -3.04, *p* < 0.05) and Site D (t = -3.71, *p* < 0.01).

PANAS-NEG: Sig. of Δ DN (Greenhouse–Geisser) = 0.001 < 0.05, F (2.73, 103.64) = 6.23, Partial η^2 = 0.14. The negative affect score difference for the Lakeside was significantly lower than the Square Δ DN (t = 3.98, *p* < 0.01) and Grassplot spaces Δ DN (t = 3.74, *p* < 0.01). Figure 5 illustrates the differences in psychological affect change across sites.



Figure 5. Differences in the amount of ΔD in the experimental sites. * p < 0.05, ** p < 0.01.

3.3.2. Variability of Physiological Indicators during the Restoration

The multivariate simple effects analysis results for the sites showed that the EEG- α and EEG- β of the groups differed significantly during the restoration stage: EEG- α (F = 4.82, p = 0.015 < 0.05, Partial $\eta^2 = 0.49$); EEG- β (F = 4.80, p = 0.015 < 0.05, Partial $\eta^2 = 0.49$). Otherwise, no significant differences in EEG- α and EEG- β were detected between the groups during the baseline stage and pressure application. This suggests that the groups' initial states were uniform and the restorative experiments' outcomes were comparable.

For LF/HF, the results of the multivariate tests showed no significant differences in LF/HF among scenarios during the restoration stage (F = 0.19, p = 0.903 > 0.05, Partial $\eta^2 = 0.03$) (Table S4 in Supplementary Materials).

The changes of EEG in the restoration stage were further explored through pairwise comparisons for each site. Square's EEG- α was significantly lower than Forest's EEG- α (t = -3.56, *p* = 0.015 < 0.05). Square's EEG- β was significantly higher than Lakeside's EEG- β (t = 3.79, *p* = 0.009 < 0.01). No significant differences were detected between the other sites, and Table S5 in Supplementary Materials shows these results. Figure 6 illustrates the differences in EEG indicators between sites in the restoration stage.



Figure 6. Differences in EEG between the experimental sites at restoration (T3). * p < 0.05, ** p < 0.01.

3.4. Index Correlation

Pearson correlation was used to analyze the associations between self-reported and objective measures of recovery effects. The results showed a significant (p < 0.05) inverse relationship between EEG- β and the amount of positive mood change during the restoration stage, with a strength of r = -0.223 *. This is consistent with our hypothesis. No significant correlations were detected between PANAS indicators for other physiological indicators. In addition, we found a significant inverse correlation (p < 0.01) between EEG- α and heart rate variability index LF/HF in the restoration stage, with a correlation strength of r = -0.342 **. As in previous studies, a highly significant negative correlation was found between EEG- α and EEG- β . However, we found a non-significant association between the amount of positive and negative affect change. Figure 7 shows the correlation coefficients among restorative indicators.



Figure 7. Correlation coefficients among restorative indicators. * p < 0.05, ** p < 0.01, *** p < 0.001.

4. Discussion

4.1. Restorative Effect of Landscape Sites

Psychologically, the pre- and post-test data of the restoration stage in all types of selected environments showed significant differences, with a considerable increase in positive mood scores and a substantial reduction in negative mood scores. All four sites were restorative for participants' emotions, consistent with the results of previous relevant studies [71,72]. Some researchers found that changes in positive emotions before and after the restoration stage were not significant [73]. Their outcome may have been due to the participants' initial emotional state. In contrast, the stress administration before the restoration stage of the present experiment was crucial.

Regarding physiological indicators, EEG measurements showed generally high beta in the stress stage. These measurements were associated with brain activity induced by the cognitive test and harsh noises. The baseline alpha was significantly higher at all four sites than in the stress or restoration stages, probably because the participants were asked to relax with their eyes closed. Alpha waves were more pronounced when the participants were in this state. Barry, Clarke, Johnstone, Magee, and Rushby noted that two conditions, eyes closed and open, produced differing EEG measurements [74]. Therefore, the baseline stage only served to calm and standardize the participants' emotions. It was not used as baseline data in restorative trials. The interaction effect analysis results showed that the Square's alpha and beta did not vary significantly in the restoration and stress stages. However, the interaction effect analysis results showed that the alpha and beta of the Square did not change significantly in the restoration and pressure application stages. Moreover, all other sites' restoration stages differed significantly during stress. This finding suggests that the Grassplot, Forest, and Lakesides spaces also promoted psychological recovery, with a significantly higher proportion of participants in the restoration stage being relaxed and significantly decreasing tension and stress. The Square's recovery effect was not significant, this may be because the square has relatively few natural factors and more artificial factors [17].

Compared to the EEG measurement results, only the LF/HF data from Grassplot showed significant differences compared to the pre-restoration phase. HRV data are more sensitive to environmental changes at the physical level than EEG metrics, and it has been suggested that there may be greater fluctuations in LF/HF may occur during non-stationary conditions [75]. During the experiment, the baseline and pressure application phases were stationary conditions. Participants had more freedom of movement during the restoration phase. We specified that participants could only walk slowly and sit still during recovery. However, errors in ear-tip pulse measurements may have occurred due to excessive or rapid head movements. Participants spent more time sitting quietly in the Grassplot than in other sites, which may explain the significant reduction in LF/HF for only Grassplot. Some studies suggested that a trend toward higher LF/HF than before exercise was found only after moderate and high-intensity exercise [76]. In conclusion, for outdoor experiments, EEG may be more reliable than HRV.

4.2. Variability in Restorative Benefits

Sections 3.2 and 3.3 showed no significant differences in LF/HF across sites. Therefore, this section discusses the trend characteristics of PANAS and EEG indicators. A repeated-measures ANOVA was conducted on the change in mood to explore whether the difference between the four sites was statistically significant. The results showed that the change in positive emotions was significantly greater in Sites 3 and 4 than in 2, indicating that Square was significantly less effective than Forest and Lakeside in enhancing them. Researchers have shown that environments with natural components have a better restorative effect on PANAS-POS than concrete ones [33]. Additionally, the difference between the pre- and post-measures of negative emotion in Site 4 is significantly different from Sites 1 and 2, indicating that Lakeside, an interwoven green and blue space, has a stronger ability to moderate unpleasant emotions compared to Grassplot and Square sites. This finding is

consistent with White et al.'s [77]. They state that "adding some water to a green scene leads to significantly higher resilience" while arguing that the optimal restorative environment may be the interface between land and large bodies of water.

For indicators with a large degree of subjectivity and significant differences, the discrepancy in change is a more accurate choice [78,79]. Since Square's EEG metrics did not change substantially between the Restoration and Stress stages, the difference was not significant when comparing them. The EEG index analysis of different scenes in the three phases by two-way repeated-measures ANOVA showed that the interaction effect was non-significant. However, the baseline and pressure application phases were included.

The results of the multivariate simple effects analysis of the baseline and the pressure application phases showed that all p-values of these two phases were greater than 0.05. It means that the four sites had the same initial state before the restoration phase, confirming the comparability between the data. The restoration stage results showed significant differences in EEG data between the four groups. This outcome demonstrates differences in the physiological effects of the various restorative environments in the park. The results showed that Site 2's α was significantly lower than Site 3's, indicating that stressed young adults were much more relaxed in the forest than in the paved square. This is consistent with the results of some previous studies related to forest therapy [80,81]. The study also confirmed that Square's ability to reduce mental fatigue was significantly less than Lakeside's. The Square condition showed weaker recovery on the EEG compared to the other sites. This might be because it has a more mixed environment and less greenness. Brain waves can be relatively "calmed" whenever the human body is stimulated by green visual scenes [82]. In contrast, Square, a landscape space with more artificial sites and less green environment, showed weaker performance in restorative ability. No other significant differences in physiological restorative properties were found between the experimental sites.

In general, the natural park habitats of Forest, Grassplot, and Lakeside have strong psychological and psychological restorative effects, while Square has only significant psychological but minor physiological restorative effects. When comparing the restorative effects of various scenes, no significant differences were found between Forest and Lakeside in terms of statistical significance and both induced better recovery, which aligns with previous studies [16]. The higher resilience induced by waterfront space may relate to its higher biodiversity. Many participants reported more birds and insects in the waterfront area due to the Lakeside's more pronounced edge effect. The edge effect is the increased population density and diversity of species where two adjacent ecosystems overlap [83]. The forest's restorative nature may be due to its greater plant variety and density [84]. More surrounding vegetation can create a visually stimulating environment, enhancing recovery [14]. This suggests that not only natural forests in the wild but also forest scenes in urban parks can provide restorative benefits for stressed young people. This also brings the convenience of forest therapy to city dwellers. Grassplot's resilience was intermediate, while Square's was relatively poor.

Furthermore, in exploring the degree of consistency between psychological and physiological indicators, we found a significant inverse correlation between EEG- β and the enhancement of positive affect. Other psycho-physiological indicators were somewhat correlated with each other. However, no significant correlation was found. This may be explained by the fact that both PANAS, EEG, and HRV data are comprehensive indicators which may be correlated at some sub-levels, but the correlation is not significant in a combined statistical analysis. Further investigation is required. We also found a correlation between the two physiological indicators, with EEG- α and LF/HF being significantly negatively correlated.

4.3. Limitations and Future Research

In outdoor field experiments, seasonal changes at the same site at different times of the year can affect mood. For example, changes in plant leaf color may increase feelings of wellbeing, calmness, and recovery potential [53]. Some researchers found that the lake area did not have a significant restorative effect [38]. They hypothesized that this was partly due to a lack of shady places for rest. By contrast, the present experiment was conducted in autumn on a day with a suitable temperature, and the Lakeside was highly restorative. In addition to seasonal and temperature limitations, some limitations exist concerning the study region. We only explored larger urban parks. Smaller sites such as community and street gardens were not included. In this study, to control for variables, participants were prohibited from engaging in free-flowing physiological activities such as eating and talking. And they were also asked to walk slowly and sit quietly to control for physiological effects due to exercise pathways. However, improvement of health problems in high-stress populations requires not only restorative mechanisms but also other active pathways. This requires a larger number of subjects and more complex and comprehensive studies. Furthermore, this study only conducted a restorative experiment on young adults and did not make a consistent comparison with other groups such as children and older adults. More groups will be included in the study in the future, which will help to investigate the differences in the restorative nature of different types of groups. Individual differences may result in a bias in the results. For example, differences in an individual's ability and sensitivity to resist stress can make it difficult to achieve consistent standards during the pressure application phase. Similarly, differences in measurement time can affect the results. The total experimental time will be shortened by simultaneous measurements at multiple sites, but this will increase the need for laboratory staff and equipment, which we will address in future research.

Through semi-structured, in-depth interviews, we found that unexpected events affected participants' emotions, for example, flying birds, streaming clouds, and sudden music. These elements were not included in the planned scenario. However, they affected the participants' emotions through attention shifting. Furthermore, we could explore how "attractors" affect recovery and how they work. We will also consider the strength of attractors and construct a structural equation model of restorative influences.

5. Conclusions

This study analyzed the relationship between different environments and their restorative and recovery effects using a field experiment. We used pre- and post-measured PANAS and real-time transmitted EEG data as psychological and physiological indicators to confirm the restorative effect of different types of natural immersion for stressed young adults. The experimental results showed that exposure to various types of restorative environments in the park can significantly reduce negative emotions and increase positive emotions in stressed young adults. Physiologically, we found that all sites except the square had a significant positive effect on relaxation. When comparing different types of spaces, the Forest and Lakeside sites together showed the most robust restorative properties. Forest can make stressed people feel more relaxed and less susceptible to external disturbances, while Lakeside tends to reduce brain fatigue and deep thinking. Grassland also shows a lower level of restorative capacity than the Forest and Lakeside but a significantly higher level than the Square. Furthermore, this study demonstrated the correlation between various physiological and psychological indicators. EEG- β indicators in the restoration stage were significantly and inversely correlated with positive affect enhancement.

The study meets the practical need for "hands-on" outdoor experience while reducing the uncertainty of field experiments through a rigorous experimental design and scientific statistical approach. These included (1) rigorous training of participants; (2) rationalization of the experimental procedure for participants; (3) use of appropriate measurement equipment; (4) joint reasoning from physiological and psychological data; (5) establishment of a baseline measurement phase to unify the initial data; (6) imposing stress and mental strain in two ways; (7) discussing the correlation between psychological and physiological indicators; and (8) using repeated-measures analysis of variance. The research methodology adopted in this study can be used in providing an idea to be considered for similar field experiments. For designers and decision-makers, each park landscape space's composition should reasonably match. The artificial square space could be appropriately reduced under the condition that enough activity space is available. Creating more natural greenspaces, especially forests, can help enhance the park's restorative nature. Creating appropriate landscape space along the water's edge can also help enhance restorative quality, especially in areas where blue and green spaces are interwoven and biodiversity is high. Moreover, short-term restorative effects may be influenced by attractors. Therefore, this element should be considered in future recovery mechanism studies.

Supplementary Materials: The following supporting information can be downloaded at: https://www. mdpi.com/article/10.3390/f14071400/s1, Table S1: The order of subjects' participation; Audio S1: Stimulating audio; Table S2: Positive and Negative Affect Scale (English & Chinese versions); Equation S1: The interaction effects of site*time; Table S3: EEG results of two-way repeated-measure ANOVAs; Table S4: The multivariate simple effects of physiological indicators; Table S5: Pairwise comparisons of EEG in the restoration stage.

Author Contributions: Y.L.: conceptualization, methodology, data curation, writing—original draft, writing—review & editing. J.Z.: supervision, methodology, writing—review & editing. B.J.: software, visualization. H.L.: investigation. B.Z.: project administration, conceptualization, supervision. All authors have read and agreed to the published version of the manuscript.

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References

- Le Roux, D.M.; Zar, H.J. Community-Acquired Pneumonia in Children—A Changing Spectrum of Disease. *Pediatr. Radiol.* 2017, 47, 1392–1398. [CrossRef]
- Cosselman, K.E.; Navas-Acien, A.; Kaufman, J.D. Environmental Factors in Cardiovascular Disease. Nat. Rev. Cardiol. 2015, 12, 627–642. [CrossRef]
- 3. Frank, L.D.; Saelens, B.E.; Powell, K.E.; Chapman, J.E. Stepping towards Causation: Do Built Environments or Neighborhood and Travel Preferences Explain Physical Activity, Driving, and Obesity? *Soc. Sci. Med.* **2007**, *65*, 1898–1914. [CrossRef] [PubMed]
- Ulrich, R.S. Aesthetic and Affective Response to Natural Environment. In *Behavior & the Natural Environment;* Springer: Boston, MA, USA, 1983.
- 5. Kaplan, R.; Kaplan, S. *The Experience of Nature: A Psychological Perspective*; Cambridge University Press: Cambridge, UK, 1989; ISBN 0-521-34939-7.
- Bedimo-Rung, A.L.; Mowen, A.J.; Cohen, D.A. The Significance of Parks to Physical Activity and Public Health—A Conceptual Model. Am. J. Prev. Med. 2005, 28, 159–168. [CrossRef] [PubMed]
- Zhang, J.; Yu, Z.; Zhao, B.; Sun, R.; Vejre, H. Links between Green Space and Public Health: A Bibliometric Review of Global Research Trends and Future Prospects from 1901 to 2019. *Environ. Res. Lett.* 2020, 15, 063001. [CrossRef]
- Barton, J.; Pretty, J. What Is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis. Environ. Sci. Technol. 2010, 44, 3947–3955. [CrossRef] [PubMed]
- 9. Young, C.; Hofmann, M.; Frey, D.; Moretti, M.; Bauer, N. Psychological Restoration in Urban Gardens Related to Garden Type, Biodiversity and Garden-Related Stress. *Landsc. Urban Plan.* **2020**, *198*, 12. [CrossRef]
- Hazer, M.; Formica, M.K.; Dieterlen, S.; Morley, C.P. The Relationship between Self-Reported Exposure to Greenspace and Human Stress in Baltimore, MD. *Landsc. Urban Plan.* 2018, 169, 47–56. [CrossRef]
- 11. Hartig, T.; Johansson, G.; Kylin, C. Residence in the Social Ecology of Stress and Restoration. J. Soc. Issues 2003, 59, 611–636. [CrossRef]

- 12. Beyer, K.M.; Kaltenbach, A.; Szabo, A.; Bogar, S.; Nieto, F.J.; Malecki, K.M. Exposure to Neighborhood Green Space and Mental Health: Evidence from the Survey of the Health of Wisconsin. *Int. J. Environ. Res. Public Health* **2014**, *11*, 3453–3472. [CrossRef]
- Peschardt, K.K.; Stigsdotter, U.K. Associations between Park Characteristics and Perceived Restorativeness of Small Public Urban Green Spaces. *Landsc. Urban Plan.* 2013, 112, 26–39. [CrossRef]
- 14. Akpinar, A. How Perceived Sensory Dimensions of Urban Green Spaces Are Associated with Teenagers' Perceived Restoration, Stress, and Mental Health? *Landsc. Urban Plan.* **2021**, *214*, 14. [CrossRef]
- 15. Vella-Brodrick, D.A.; Gilowska, K. Effects of Nature (Greenspace) on Cognitive Functioning in School Children and Adolescents: A Systematic Review. *Educ. Psychol. Rev.* 2022, 34, 1217–1254. [CrossRef]
- Markevych, I.; Schoierer, J.; Hartig, T.; Chudnovsky, A.; Hystad, P.; Dzhambov, A.M.; de Vries, S.; Triguero-Mas, M.; Brauer, M.; Nieuwenhuijsen, M.J.; et al. Exploring Pathways Linking Greenspace to Health: Theoretical and Methodological Guidance. *Environ. Res.* 2017, 158, 301–317. [CrossRef]
- 17. Ulrich, R.S. Human Responses to Vegetation and Landscapes. Landsc. Urban Plan. 1986, 13, 29–44. [CrossRef]
- 18. Ulrich, R.S. Natural versus Urban Scenes: Some Psychophysiological Effects. Environ. Behav. 1981, 13, 523–556. [CrossRef]
- 19. Kaplan, S. The Restorative Benefits of Nature: Toward an Integrative Framework. J. Environ. Psychol. 1995, 15, 169–182. [CrossRef]
- Ulrich, R.S.; Simons, R.F.; Losito, B.D.; Fiorito, E.; Miles, M.A.; Zelson, M. Stress Recovery during Exposure to Natural and Urban Environments. J. Environ. Psychol. 1991, 11, 201–230. [CrossRef]
- Hartig, T.; Evans, G.W.; Jamner, L.D.; Davis, D.S.; Gärling, T. Tracking Restoration in Natural and Urban Field Settings. J. Environ. Psychol. 2003, 23, 109–123. [CrossRef]
- Shim, S.R.; Chang, J.; Lee, J.; Byeon, W.; Lee, J.; Lee, K.J. Perspectives on the Psychological and Physiological Effects of Forest Therapy: A Systematic Review with a Meta-Analysis and Meta-Regression. *Forests* 2022, 13, 2029. [CrossRef]
- Marselle, M.R.; Irvine, K.N.; Warber, S.L. Walking for Well-Being: Are Group Walks in Certain Types of Natural Environments Better for Well-Being than Group Walks in Urban Environments? *Int. J. Environ. Res. Public Health* 2013, 10, 5603–5628. [CrossRef] [PubMed]
- Mitchell, R. Is Physical Activity in Natural Environments Better for Mental Health than Physical Activity in Other Environments? Soc. Sci. Med. 2013, 91, 130–134. [CrossRef] [PubMed]
- 25. Chang, C.-Y.; Chen, P.-K. Human Response to Window Views and Indoor Plants in the Workplace. *HortSci* **2005**, *40*, 1354–1359. [CrossRef]
- Lee, K.E.; Williams, K.J.; Sargent, L.D.; Williams, N.S.; Johnson, K.A. 40-Second Green Roof Views Sustain Attention: The Role of Micro-Breaks in Attention Restoration. J. Environ. Psychol. 2015, 42, 182–189. [CrossRef]
- Browning, M.; Mimnaugh, K.J.; van Riper, C.J.; Laurent, H.K.; LaValle, S.M. Can Simulated Nature Support Mental Health? Comparing Short, Single-Doses of 360-Degree Nature Videos in Virtual Reality With the Outdoors. *Front. Psychol.* 2020, 10, 2667. [CrossRef]
- Memari, S.; Pazhouhanfar, M.; Grahn, P. Perceived Sensory Dimensions of Green Areas: An Experimental Study on Stress Recovery. *Sustainability* 2021, 13, 19. [CrossRef]
- Brancato, G.; Van Hedger, K.; Berman, M.G.; Van Hedger, S.C. Simulated Nature Walks Improve Psychological Well-Being along a Natural to Urban Continuum. J. Environ. Psychol. 2022, 81, 101779. [CrossRef]
- Subiza-Perez, M.; Pasanen, T.; Ratcliffe, E.; Lee, K.; Bornioli, A.; de Bloom, J.; Korpela, K. Exploring Psychological Restoration in Favorite Indoor and Outdoor Urban Places Using a Top-down Perspective. J. Environ. Psychol. 2021, 78, 10. [CrossRef]
- Wheeler, B.W.; Lovell, R.; Higgins, S.L.; White, M.P.; Alcock, I.; Osborne, N.J.; Husk, K.; Sabel, C.E.; Depledge, M.H. Beyond Greenspace: An Ecological Study of Population General Health and Indicators of Natural Environment Type and Quality. *Int. J. Health Geogr.* 2015, 14, 17. [CrossRef]
- 32. de Vries, S.; Verheij, R.A.; Groenewegen, P.P.; Spreeuwenberg, P. Natural Environments . . . healthy Environments? An Exploratory Analysis of the Relationship between Greenspace and Health. *Environ. Plan. A* 2003, *35*, 1717–1731. [CrossRef]
- Huang, Q.; Yang, M.; Jane, H.; Li, S.; Bauer, N. Trees, Grass, or Concrete? The Effects of Different Types of Environments on Stress Reduction. *Landsc. Urban Plan.* 2020, 193, 103654. [CrossRef]
- Knobel, P.; Dadvand, P.; Alonso, L.; Costa, L.; Espanol, M.; Maneja, R. Development of the Urban Green Space Quality Assessment Tool (RECITAL). Urban For. Urban Green. 2021, 57, 126895. [CrossRef]
- 35. Van Dillen, S.M.; de Vries, S.; Groenewegen, P.P.; Spreeuwenberg, P. Greenspace in Urban Neighbourhoods and Residents' Health: Adding Quality to Quantity. *J. Epidemiol. Community Health* **2012**, *66*, e8. [CrossRef]
- Ha, J.; Kim, H.J. The Restorative Effects of Campus Landscape Biodiversity: Assessing Visual and Auditory Perceptions among University Students. Urban For. Urban Green. 2021, 64, 127259. [CrossRef]
- Southon, G.E.; Jorgensen, A.; Dunnett, N.; Hoyle, H.; Evans, K.L. Perceived Species-Richness in Urban Green Spaces: Cues, Accuracy and Well-Being Impacts. *Landsc. Urban Plan.* 2018, 172, 1–10. [CrossRef]
- Deng, L.; Li, X.; Luo, H.; Fu, E.K.; Ma, J.; Sun, L.X.; Huang, Z.; Cai, S.Z.; Jia, Y. Empirical Study of Landscape Types, Landscape Elements and Landscape Components of the Urban Park Promoting Physiological and Psychological Restoration. *Urban For. Urban Green.* 2020, 48, 126488. [CrossRef]
- Liu, Q.Y.; Wu, Y.; Xiao, Y.H.; Fu, W.C.; Zhuo, Z.X.; van den Bosch, C.C.K.; Huang, Q.T.; Lan, S.R. More Meaningful, More Restorative? Linking Local Landscape Characteristics and Place Attachment to Restorative Perceptions of Urban Park Visitors. *Landsc. Urban Plan.* 2020, 197, 11. [CrossRef]

- 40. Li, H.; Xie, H.; Woodward, G. Soundscape Components, Perceptions, and EEG Reactions in Typical Mountainous Urban Parks. *Urban For. Urban Green.* **2021**, *64*, 10. [CrossRef]
- 41. Luo, S.X.; Shi, J.Y.; Lu, T.Y.; Furuya, K. Sit down and Rest: Use of Virtual Reality to Evaluate Preferences and Mental Restoration in Urban Park Pavilions. *Landsc. Urban Plan.* **2022**, 220, 104336. [CrossRef]
- 42. Feng, X.Q.; Astell-Burt, T. Residential Green Space Quantity and Quality and Symptoms of Psychological Distress: A 15-Year Longitudinal Study of 3897 Women in Postpartum. *BMC Psychiatry* **2018**, *18*, 348. [CrossRef]
- 43. Kong, L.Q.; Liu, Z.F.; Pan, X.H.; Wang, Y.H.; Guo, X.; Wu, J.G. How Do Different Types and Landscape Attributes of Urban Parks Affect Visitors? Positive Emotions? *Landsc. Urban Plan.* **2022**, 226, 13. [CrossRef]
- 44. Simkin, J.; Ojala, A.; Tyrvainen, L. Restorative Effects of Mature and Young Commercial Forests, Pristine Old-Growth Forest and Urban Recreation Forest—A Field Experiment. *Urban For. Urban Green.* **2020**, *48*, 12. [CrossRef]
- 45. Bolouki, A. Exploring the Association between Self-Reported and Objective Measures in Search of the Restorative Quality of Natural Environments: A Systematic Review. *Int. J. Environ. Health Res.* 2019, *online ahead of print.* [CrossRef] [PubMed]
- Aletta, F.; Oberman, T.; Kang, J. Associations between Positive Health-Related Effects and Soundscapes Perceptual Constructs: A Systematic Review. Int. J. Environ. Res. Public Health 2018, 15, 2392. [CrossRef] [PubMed]
- 47. Evensen, K.H.; Raanaas, R.K.; Fyhri, A. Soundscape and Perceived Suitability for Recreation in an Urban Designated Quiet Zone. *Urban For. Urban Green.* 2016, 20, 243–248. [CrossRef]
- Ikei, H.; Song, C.R.; Miyazaki, Y. Physiological Effects of Touching Coated Wood. Int. J. Environ. Res. Public Health 2017, 14, 773. [CrossRef]
- 49. van den Berg, A.E.; Koole, S.L.; van der Wulp, N.Y. Environmental Preference and Restoration: (How) Are They Related? *J. Environ. Psychol.* **2003**, *23*, 135–146. [CrossRef]
- 50. Francis, J.; Wood, L.J.; Knuiman, M.; Giles-Corti, B. Quality or Quantity? Exploring the Relationship between Public Open Space Attributes and Mental Health in Perth, Western Australia. *Soc. Sci. Med.* **2012**, *74*, 1570–1577. [CrossRef]
- 51. Wood, E.; Harsant, A.; Dallimer, M.; de Chavez, A.C.; McEachan, R.R.C.; Hassall, C. Not All Green Space Is Created Equal: Biodiversity Predicts Psychological Restorative Benefits From Urban Green Space. *Front. Psychol.* **2018**, *9*, 2320. [CrossRef]
- Hoyle, H.; Hitchmough, J.; Jorgensen, A. All about the "Wow Factor"? The Relationships between Aesthetics, Restorative Effect and Perceived Biodiversity in Designed Urban Planting. *Landsc. Urban Plan.* 2017, 164, 109–123. [CrossRef]
- 53. Fang, Y.; Ji, B.; Liu, Y.; Zhang, J.; Liu, Q.; Ge, Y.; Xie, Y.; Liu, C. The Prevalence of Psychological Stress in Student Populations during the COVID-19 Epidemic: A Systematic Review and Meta-Analysis. *Sci. Rep.* **2022**, *12*, 12118. [CrossRef]
- Chen, Q.; Zhang, Y. Development of Questionnaire on the Sense of Workplace Involution for Newly Recruited Employees and Its Relationship with Turnover Intention. *Int. J. Environ. Res. Public Health* 2022, 19, 11218. [CrossRef] [PubMed]
- 55. Guo, L.N.; Zhao, R.L.; Ren, A.H.; Niu, L.X.; Zhang, Y.L. Stress Recovery of Campus Street Trees as Visual Stimuli on Graduate Students in Autumn. *Int. J. Environ. Res. Public Health* **2020**, *17*, 13. [CrossRef] [PubMed]
- 56. Wang, X.; Rodiek, S.; Wu, C.; Chen, Y.; Li, Y. Stress Recovery and Restorative Effects of Viewing Different Urban Park Scenes in Shanghai, China. *Urban For. Urban Green.* **2016**, *15*, 112–122. [CrossRef]
- 57. Watson, D.; Clark, L.A.; Tellegen, A. Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. J. Personal. Soc. Psychol. **1988**, 54, 1063–1070. [CrossRef] [PubMed]
- 58. Kim, M.; Cheon, S.; Kang, Y. Use of Electroencephalography (EEG) for the Analysis of Emotional Perception and Fear to Nightscapes. *Sustainability* **2019**, *11*, 233. [CrossRef]
- 59. Pivik, R.T.; Broughton, R.J.; Coppola, R.; Davidson, R.J.; Fox, N.; Nuwer, M.R. Guidelines for the Recording and Quantitative Analysis of Electroencephalographic Activity in Research Contexts. *Psychophysiology* **1993**, *30*, 547–558. [CrossRef]
- Murugappan, M.; Nagarajan, R.; Yaacob, S. Combining Spatial Filtering and Wavelet Transform for Classifying Human Emotions Using EEG Signals. J. Med. Biol. Eng. 2011, 31, 45–51. [CrossRef]
- 61. Norwood, M.F.; Lakhani, A.; Maujean, A.; Zeeman, H.; Creux, O.; Kendall, E. Brain Activity, Underlying Mood and the Environment: A Systematic Review. *J. Environ. Psychol.* **2019**, *65*, 101321. [CrossRef]
- 62. Campisi, P.; La Rocca, D. Brain Waves for Automatic Biometric-Based User Recognition. *IEEE Trans. Inf. Forensics Secur.* 2014, 9, 782–800. [CrossRef]
- 63. Yao, Y.; Du, F.; Wang, C.; Liu, Y.; Weng, J.; Chen, F. Numerical Processing Efficiency Improved in Children Using Mental Abacus: ERP Evidence Utilizing a Numerical Stroop Task. *Front. Hum. Neurosci.* **2015**, *9*, 245. [CrossRef]
- 64. Wagner, W. Scalp, Earlobe and Nasopharyngeal Recordings of the Median Nerve Somatosensory Evoked P14 Potential in Coma and Brain Death: Detailed Latency and Amplitude Analysis in 181 Patients. *Brain* **1996**, *119*, 1507–1521. [CrossRef]
- 65. Soler, A.; Munoz-Gutierrez, P.A.; Bueno-Lopez, M.; Giraldo, E.; Molinas, M. Low-Density EEG for Neural Activity Reconstruction Using Multivariate Empirical Mode Decomposition. *Front. Neurosci.* **2020**, *14*, 17. [CrossRef] [PubMed]
- 66. Lee, J.; Park, B.-J.; Tsunetsugu, Y.; Kagawa, T.; Miyazaki, Y. Restorative Effects of Viewing Real Forest Landscapes, Based on a Comparison with Urban Landscapes. *Scand. J. For. Res.* **2009**, *24*, 227–234. [CrossRef]
- 67. Cai, C.; Xu, Y.; Wang, Y.; Wang, Q.; Liu, L. Experimental Study on the Effect of Urban Road Traffic Noise on Heart Rate Variability of Noise-Sensitive People. *Front. Psychol.* **2022**, *12*, 749224. [CrossRef]
- Malik, M. Heart Rate Variability: Standards of Measurement, Physiological Interpretation, and Clinical Use: Task Force of the European Society of Cardiology and the North American Society for Pacing and Electrophysiology. *Ann. Noninvasive Electrocardiol.* 1996, 1, 151–181. [CrossRef]

- 69. Brooks, A.M.; Ottley, K.M.; Arbuthnott, K.D.; Sevigny, P. Nature-Related Mood Effects: Season and Type of Nature Contact. *J. Environ. Psychol.* **2017**, *54*, 91–102. [CrossRef]
- Elsadek, M.; Liu, B.; Xie, J. Window View and Relaxation: Viewing Green Space from a High-Rise Estate Improves Urban Dwellers' Wellbeing. Urban For. Urban Green. 2020, 55, 126846. [CrossRef]
- Aziz, N.A.A.; Shian, L.Y.; Mokhtar, M.D.M.; Raman, T.L.; Saikim, F.H.; Chen, W.; Nordin, N.M. Effectiveness of Urban Green Space on Undergraduates' Stress Relief in Tropical City: A Field Experiment in Kuala Lumpur. Urban For. Urban Green. 2021, 63, 9. [CrossRef]
- Tyrvainen, L.; Ojala, A.; Korpela, K.; Lanki, T.; Tsunetsugu, Y.; Kagawa, T. The Influence of Urban Green Environments on Stress Relief Measures: A Field Experiment. J. Environ. Psychol. 2014, 38, 1–9. [CrossRef]
- 73. Gao, T.; Zhang, T.; Zhu, L.; Gao, Y.A.; Qiu, L. Exploring Psychophysiological Restoration and Individual Preference in the Different Environments Based on Virtual Reality. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3102. [CrossRef] [PubMed]
- Barry, R.J.; Clarke, A.R.; Johnstone, S.J.; Magee, C.A.; Rushby, J.A. EEG Differences between Eyes-Closed and Eyes-Open Resting Conditions. *Clin. Neurophysiol.* 2007, 118, 2765–2773. [CrossRef] [PubMed]
- 75. Von Rosenberg, W.; Chanwimalueang, T.; Adjei, T.; Jaffer, U.; Goverdovsky, V.; Mandic, D.P. Resolving Ambiguities in the LF/HF Ratio: LF-HF Scatter Plots for the Categorization of Mental and Physical Stress from HRV. *Front. Physiol.* 2017, 8, 360. [CrossRef]
- Perini, R.; Veicsteinas, A. Heart Rate Variability and Autonomic Activity at Rest and during Exercise in Various Physiological Conditions. *Eur. J. Appl. Physiol.* 2003, 90, 317–325. [CrossRef]
- 77. White, M.; Smith, A.; Humphryes, K.; Pahl, S.; Snelling, D.; Depledge, M. Blue Space: The Importance of Water for Preference, Affect, and Restorativeness Ratings of Natural and Built Scenes. J. Environ. Psychol. 2010, 30, 482–493. [CrossRef]
- Rogosa, D.; Brandt, D.; Zimowski, M. A Growth Curve Approach to the Measurement of Change. *Psychol. Bull.* 1982, 92, 726. [CrossRef]
- Rogosa, D.R.; Willett, J.B. Demonstrating the Reliability of the Difference Score in the Measurement of Change. J. Educ. Meas. 1983, 20, 335–343. [CrossRef]
- 80. Farrow, M.R.; Washburn, K. A Review of Field Experiments on the Effect of Forest Bathing on Anxiety and Heart Rate Variability. *Glob. Adv. Health Med.* **2019**, *8*, 2164956119848654. [CrossRef] [PubMed]
- Song, C.; Ikei, H.; Kobayashi, M.; Miura, T.; Taue, M.; Kagawa, T.; Li, Q.; Kumeda, S.; Imai, M.; Miyazaki, Y. Effect of Forest Walking on Autonomic Nervous System Activity in Middle-Aged Hypertensive Individuals: A Pilot Study. Int. J. Environ. Res. Public Health 2015, 12, 2687–2699. [CrossRef]
- 82. Zhu, H.Z.; Yang, F.; Bao, Z.Y.; Nan, X.G. A Study on the Impact of Visible Green Index and Vegetation Structures on Brain Wave Change in Residential Landscape. *Urban For. Urban Green.* **2021**, *64*, 22. [CrossRef]
- 83. Forman, R.T. Land Mosaics: The Ecology of Landscapes and Regions (1995). In *The Ecological Design and Planning Reader;* Cambridge University Press: Cambridge, UK, 2014; pp. 217–234.
- 84. Tsunetsugu, Y.; Park, B.-J.; Miyazaki, Y. Trends in Research Related to "Shinrin-Yoku" (Taking in the Forest Atmosphere or Forest Bathing) in Japan. *Environ. Health Prev. Med.* **2010**, *15*, 27–37. [CrossRef] [PubMed]

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