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Stress Recovery Effects of Viewing Simulated Urban Parks: Landscape Types, Depressive Symptoms, and Gender Differences

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Abstract: Previous studies may have overstated the restorative benefits of natural environments by comparing them to low-quality urban environments. Few studies have compared the stress recovery effects across various park settings. Moreover, it is unclear how depressive symptoms affect these benefits. Depressive symptoms may lessen or boost the restorative effects of viewing nature. A total of 125 participants engaged in the Trier Social Stress Test (TSST) to induce stress and were then randomly assigned to view one of five 10 min video presentations depicting greened streets, lawns, plazas, forests, or watersides. Depressive symptoms experienced over the last month were measured using the Patient Health Questionnaire (PHQ-9). The analysis revealed that, while greened streets had a physio-psychological stress-relieving effect, they were not as effective as the four park settings. The skin conductance level (SCL) declined significantly in the forest group's first and second halves of the recovery period. However, the difference between the four park settings was insignificant at the end of recovery. Subjects viewing the four park conditions (vs. the greened street) reported that perceived stress remained stable as individual depressive symptoms increased; subjects with higher depressive symptoms reported lower perceived stress under lawn conditions. However, the SCL did not show the same trend. Our findings may support the hypothesis that natural interventions may be especially beneficial for people suffering from subclinical depressive symptoms. We also found gender differences in perceived stress and SCL reduction across all five settings, which may be due to the differences in women's and men's perceptions and use of restorative environments, or their responses to stressors.

Keywords: physio-psychological stress responses; gender different; urban park landscapes; greened street; simulated viewing; depressive symptoms

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1. Introduction

1.1. Background

The urban planning concept of healthy cities has attracted attention from countries worldwide, especially since the outbreak of COVID-19 [1,2]. In addition to meeting basic survival needs, cities also need to be able to protect physical and mental health, as well as a host of other more advanced needs [3]. However, urbanization brings many challenges to human health, both physical and mental. For example, noise [4], air pollution [5], rising temperatures [6], gentrification [7], and lack of natural contact have a negative impact on human mental health. In addition, the COVID-19 epidemic has further increased the psychological pressure on urban residents, causing mental health problems and leading to a surge in depression [8–11]. According to statistics, in 2020, countries worldwide spent less than 2% of their total expenditure on dealing with mental health issues during the COVID-19 pandemic [12]. Access to nature is a basic human need and may be one way to alleviate the mental health problems of urban residents [13]. Previous studies have shown various restorative benefits from exposure to nature. For example, these benefits include countering maladaptive rumination [14], reducing negative emotion [15], relieving stress [16], and improving attentional function [17,18]. However, relevant studies often compare low-quality urban environments (e.g., busy roadways [19], industrial regions [20], streets without greening [21], and viaduct roads [22]) with natural environments, which may overstate the restorative benefits of natural environments. Different natural environments may have different recovery benefits for people [22–27], and few studies have compared the restoration benefits of different landscape types in relevant studies. In addition, these recovery benefits may be influenced by an individual's current mental condition. For example, recent high-stress events (e.g., COVID-19 quarantine, exams, and job interviews) have brought additional psychological stress to people, which leads to negative psychological symptoms. These psychological symptoms may reduce [28–30] or enhance [31–33] the stress recovery benefits people derive from nature. Therefore, it is important to understand the recovery benefits of different virtual landscapes for people and the impact of individual psychological symptoms on recovery effects, especially during the COVID-19 pandemic, when people may not have the opportunity to directly access green spaces.

In this study, we started by reviewing research about stress relief benefits and various settings. Next, we reviewed the influence of individual factors on stress relief benefits, particularly depressive symptoms and gender. We then described the stress-relieving effects of various settings (greened street, lawn, plaza, forest, and waterside) for men and women based on experiments involving 125 individuals. After that, we determined whether depressive symptoms modulated these benefits. Finally, we discussed the implications for urban landscape design, planning, and mental disorder treatment.

1.2. Natural Settings and Stress Relief Benefits

This study focuses on urban park settings. Unlike truly natural settings, restorative settings in the urban context primarily result from human activity. Such settings are ubiquitous in cities and include parks, urban forests, artificial lakes, etc. In terms of restorative benefits, such places that were designed and managed by humans were not inferior to true natural settings [34–36]. Therefore, we focused on natural settings in the urban context, especially urban parks, and asked whether there were differences in the stress relief benefits across park landscapes.

Restorative environment research frequently employs Stress Reduction Theory (SRT) and Attention Restoration Theory (ART) to explain its findings. SRT explains how people relieve stress by interacting with nature [16], whereas ART focuses on the cognitive benefits of interactions with nature [17,37,38]. The present study concentrates on stress reducing effects and consequently builds upon SRT.

Many studies compared natural environments in urban contexts, such as blue spaces, green spaces, and forests. Although most studies found no differences across natural environments [21,39–41], several reported mixed results. Some studies found that open grass space gave the best recovery effect. For example, the increase in positive emotions was more substantial in a courtyard with grass than in trees or no vegetation [23]. Another study found that partially open green spaces had the most significant positive effect on negative emotions, and closed green spaces had the worst positive effect on negative emotions [24]. According to a Norwegian study, participants assessed pocket parks with substantial grassy areas as having a high possibility of restoration [25]. However, two studies suggest that forests may be more suitable for relaxation as a restorative environment. Deng et al. reported that subjects' meditation and attention scores in mountain forests were higher than for lakesides or lawns [26]. Similarly, a field study found that urban forests provided more perceived restorative effects than parks; however, the difference was insignificant [27]. Finally, a study reported that nature-based scenarios (small lake and lawn) were more effective than hardscapes (plaza) in galvanic skin reduction [22]. In general, the differences in recovery benefits across restorative environments do not yield consistent results. When compared to physiological data, self-reported data appear to be more likely to detect differences in stress recovery across settings. This conflict between physiological and self-reported data points to the possibility that various natural settings may lack differences in actual restorative effects. This phenomenon may reflect a common restorative effect inherent to all-natural stimuli and settings. On the other hand, while self-reported data may be influenced by the awareness and experience of the participants [42–45], we cannot simply ignore studies that report differences. Therefore, studies of self-reported and physiological measures are needed to understand the actual stress-reducing effects of various natural settings.

Another debated point concerns whether a greened street environment's stress-reducing capability is equivalent to natural settings. One of the primary criticisms is that some restoration studies, to contrast sharply with the natural environment, choose sites that are least likely to have restorative potential to represent urban settings—for example, busy roadways [19], industrial regions [20], streets without greening [21], and viaduct roads [16]. This bias may lead the literature to overstate a natural environment's restorative effects. Scholars began by adopting ordinary urban settings as control groups; these included streets with greenery [46], quiet residential neighborhoods [40], and pedestrianized settings [47]. The present study used a greened street as a control group, which was in line with previous research. Because the greening rate is a rigid indicator of urban planning, such an environment is pervasive in large cities in China.

1.3. Individual Factors and Stress Relief Benefits

Individual factors, such as depressive symptoms and gender, may influence the health benefits of restorative settings. Depression is a clinical psychological condition that causes depressive symptoms. Depressed mood, diminished interest or pleasure in all activities, feelings of helplessness, and problems with eating, sleep, and concentration are key signs of clinical depression symptoms. Depressive symptoms not only appear in clinically depressed patients but also in physically healthy people who experience recent high-stress events, through a condition known as subclinical depression [48–50]. The restorative benefits of nature could be affected by an individual's depressive symptoms in two opposing ways.

One possibility is that depressive symptoms may inhibit people from obtaining benefits from restorative settings. According to the cognitive theory of depression, individuals with depressive symptoms selectively pay attention to negative stimuli (biased attention), have stronger perceptions of negative stimuli (biased processing), and repeatedly recall negative memories (biased memory and rumination) [51]. The rumination state leads to intensified negative emotions in depressed individuals and may impair short-term/working memory [52–54], which exhibits blunted emotional responses [55]. A study confirmed that individuals with significant depressive symptoms did not obtain significant cognitive benefits from a 50 min nature walk [28]. Two other studies showed that interacting with nature did not significantly alleviate depressive symptoms [29,30]. Thus, one might expect that individuals with higher depressive symptoms would recover less from viewing restorative environments.

Conversely, individuals with depressive symptoms might derive more recovery benefits from restorative environments. Individuals experiencing high levels of stress or depressive symptoms have a greater need for recovery [56], which is a motivation that causes individuals experiencing stress or depressive symptoms to be more adaptable to natural environments. Depressive symptoms cause individuals to conserve cognitive resources in the face of complex tasks [57], while natural environments can alleviate cognitive load and negative emotions. Thus, natural environments may produce more substantial cognitive and emotional recovery benefits for individuals with higher recovery needs. A study found that fatigued individuals had higher subjective ratings of attentional recovery and restoration likelihood on a forest simulation walk than non-fatigued individuals [58]. Similarly, other studies documented that nature may provide more significant recovery benefits for people who experience higher emotional stress [59–61]. Recent studies further expand this idea; individuals with higher levels of depression experience higher emotional, stress, and cognitive benefits from nature [31–33]. In short, individuals with depression may be more adapted to natural environments because of their more significant restorative needs, and thus gain more restorative benefits.

Men and women may experience different stress recovery benefits in restorative environments. Several large-scale social surveys revealed gender differences concerning the link between nearby outdoor environments and physical/mental health [62–64]. Other studies reported gender differences in the effects of natural environments on cognitive performance [65], preference [66], and self-reported health [67]. Recent studies reported gender differences in the stress-relieving effects of natural environments [22,68,69]. In addition, the stress and mental health of young people may differ between men and women [70,71]. These gender differences in stress responses may be explained by biological and social differences between men and women [72–74]. Thus, we investigated gender differences in restoration effects across several natural settings in the present study.

1.4. Study Aims

Previous studies compared the stress-relieving benefits of natural settings versus low-quality urban settings. Nevertheless, it remains unclear whether there are differences in stress recovery effects of greened streets versus different park landscapes. Moreover, individual factors, such as depressive symptoms and gender, may influence the restorative effects of environments. Therefore, we included the individual's depressive symptoms and gender as control variables.

We tested whether viewing 10 min videos of various environments would improve physiological stress (skin conductance level, SCL) and psychological stress (perceived stress) measurements and whether individual depressive symptoms modulated these stress-relieving effects. The research questions were as follows:

1. Are there differences in the stress recovery effects (SCL, perceived stress) of different settings (greened street, lawn, plaza, forest, and waterside)?
2. Are there gender differences in these responses?
3. Does the individual's mental health influence the stress recovery effects of the environment?

2. Materials and Methods

Our study used a within-subjects and between-subjects design, in which environmental condition was the between-subjects variable and time was the within-subjects variable. Participants were randomly assigned to one of five environments, with 25 in each group. All participants were not informed ahead of time what kind of video they were about to watch. Perceived stress was recorded at baseline, after the stressor task, and after the simulated viewing. The SCL was recorded throughout the whole experiment.

2.1. Measures

2.1.1. Skin Conductance Level

Previous studies showed that the SCL indicates physiological stress [75], and it is often used in restoration studies [16,23,41,76–78]. We placed silver/silver chloride electrode pads on the participants' index and middle digits of the non-dominant hand. We used the MindWare biofeedback device and its accompanying Biolab software to monitor, measure, and record the SCL in micro Siemens (1000 samples/s). The raw data were processed to remove noise from breathing and body movement using the accompanying analysis software.

2.1.2. Perceived Stress

We measured perceived stress using a visual analog scale (VAS). The VAS was a 10 cm long horizontal line (marked "not at all" on the left and "extremely" on the right). Using the VAS, subjects described their subjective experiences more freely [79]. Previous studies have used many items to measure perceived stress. Two studies used single item questionnaires [76,77]. Others used multiple items. For example, Childs et al. used five items, including anxiety, uneasy, jitteriness, stimulation, and calmness [80]. Jiang et al. used three items, including anxiety, tension, and avoidance [81]. Following these studies, and to balance the accuracy of the questionnaire and the burden of the subjects, we selected four items ("stress," "anxiety," "tension," and "avoidance") to measure perceived stress. At baseline (Cronbach's $\alpha = 0.835$) and after the Trier Social Stress Test (TSST) task (Cronbach's $\alpha = 0.828$) and simulated viewing (Cronbach's $\alpha = 0.868$), the participants were required to complete the VAS. The order of items was shuffled each time.

2.1.3. Control Variables

Before the experiment began, we recorded the following variables, because they may influence the measurements of SCL and perceived stress. We recorded depressive symptom scores using the Patient Health Questionnaire (PHQ-9) (Cronbach's $\alpha = 0.844$), which was proven to be reliable in clinical diagnoses [82]. We also measured perceived physical health, chronic mental fatigue, and chronic stress using 7-point, single item scales (e.g., what do you consider your chronic mental fatigue level to be in the last month?)

2.2. Inducing Stress

The TSST is used in restoration studies to induce mental stress in laboratory settings [68,76,81,83]. The TSST program consists of a 5 min English speech and a 5 min mental arithmetic task. First, participants have 3 min to prepare and select five questions from a list to introduce themselves. To increase stress levels, all questions and instructions were presented in English, and participants could only answer questions in English. Research has shown that non-native speakers often experience anxiety when speaking English or other foreign languages [84,85], and previous research successfully induced stress using spoken English exams [22]. The interviewer would remind the participant if he paused for more than 30 s during his speech. Next, participants completed a 5 min serial subtraction task using mental arithmetic. Participants were asked to continue subtracting 13 from a four digit number until the 5 min timer ran out. All tasks were completed in front of two interviewers and a video camera. Participants were informed that their performance would be videotaped and used for evaluation. However, no video was captured. No pens or paper were permitted during the task.

2.3. Environmental Stimulus

Inspired by simulated walking (which is often employed in restoration studies [21,47,58,86–88]), we developed a standardized observation procedure—simulated viewing. Simulated viewing refers to the simulated human observing environment by swinging a virtual camera showing approximately 270° of a panoramic picture. The horizon line was always in the center of the screen while recording; the camera swung at a constant pace (4.5°/S) to decrease the potential for dizziness. Each panoramic picture was recorded as a 2 min video with 1920 × 1080 resolution at 60 feet per second. The initial camera position was aimed at the main viewpoint of most interest in the panoramic picture; for example, the main viewpoint in the waterside condition was facing the lake. First, the camera panned 90° to the left at a constant speed (20 s) and displayed the left landscape for 10 s. The camera then panned back to the central perspective at the same speed and remained there for 10 s. Next, the camera repeated the movement pattern to the right. A standardized observation procedure was employed to ensure that all participants would view the environment the same way and avoid boredom generated by static images.

The visual stimuli were a greened street, lawn, plaza, forest, and waterside. Each condition required participants to watch five similar environmental videos for a total of 10 min (5 × 2 min). The videos were played in random order. Based on the following principles, one author selected 442 sites from parks and streets in Wuhan, China; the goal was to identify environments with similar physical properties for each condition. Chosen criteria for the images included the following points:

- Exclusion of special features that could impact environmental restoration (e.g., billboards, construction sites, fences, holiday decorations, animals and people, and historical features).
- The vegetation color was limited to green, because different vegetation colors may impact restorative potentials [89,90].
- Exclusion of woodlands with too many shrubs or that were very dense; people may perceive inaccessibility or a lack of safety due to dense vegetation [91].
- Open spaces with flat terrain and good visibility.
- Panoramic photos taken at noon on a cloudy or sunny day.
- To minimize differences in street greening and building characteristics, we chose streets with moderate traffic and pedestrian flow between Wuhan's second and third ring roads.

Two landscape experts then assessed all sites, and each provided a list of unsuitable scenarios. The sites with two votes were eliminated from the sample pool, and the sites with one vote were considered again. We ended up with 25 scenarios (5 for each condition) (Figure 1). The soundscape for the street environment was a moderate traffic sound; for the four park settings, the sound was the rustling of leaves and birds chirping.

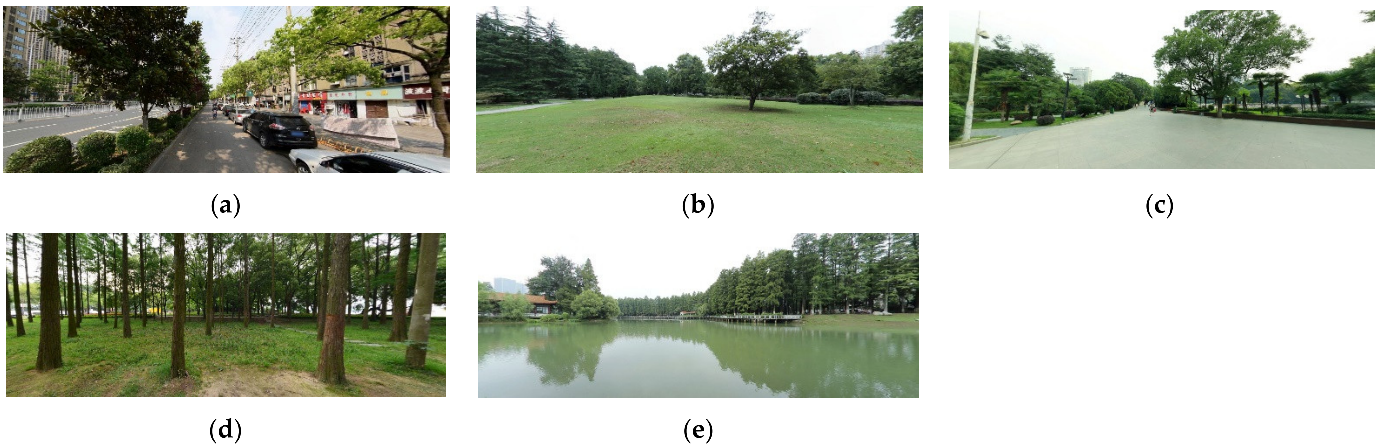


Figure 1. Example screenshots of five environment conditions: greened street (**a**), lawn (**b**), plaza (**c**), forest (**d**), and waterside (**e**).

2.4. Participants

We calculated that a partial *eta* square of 0.06 (small = 0.01, medium = 0.06, large = 0.14) with $\alpha = 0.05$ and power = 0.95 would require 125 samples with five groups and three measures using a two-way repeated-measures analysis of variance (RM-ANOVA). All participants (N = 125; 62 men and 63 women) were physically non-disabled native Chinese-speaking college students. They were non-English majors of various grades. Their ages ranged from 18 to 32 (Mean = 22, SD = 2.3). SCL data from three participants and the perceived stress data from one participant were missing. Finally, we included 123 SCL data and 124 perceived stress data in the statistical analysis. For each participant, we recorded demographic and basic health information.

We recruited participants in June, because Chinese college students generally experience high-stress events at this time (e.g., job search, dissertation defense, and final exams). Although these participants were physically healthy, they could show different subclinical depressive symptoms due to the high-stress events. We provided a panoramic picture to determine whether the participant felt dizzy while watching, and this possibility was double-checked when they arrived at the laboratory. We excluded those who self-reported dizziness and those who smoked, drank alcohol, drank coffee, drank tea, or exercised vigorously during the 6 h before the experiment. All potential participants were informed about experimental procedures, associated risks, and confidentiality issues and provided written informed consent before the experiment.

2.5. Procedure

Figure 2 depicts the experimental procedure. First, we briefed participants on the experiment and obtained consent. We thoroughly explained the questionnaire and scale to ensure that participants understood the meaning of all items. Before the experiment began, participants completed questionnaires regarding demographic information and health status in a separate room, and they were then taken to a 24 °C constant temperature laboratory. We placed silver/silver chloride electrode pads on the participants' index and middle digits of the non-dominant hand. Their SCL was recorded throughout the whole experiment. First, the respondents relaxed for 5 min before filling out the VAS to assess their baseline score of perceived stress (T0: baseline). Participants were then asked to complete an English interview and a mental arithmetic task to induce acute stress, followed by another VAS (T1: stressed). Finally, participants viewed a 10 min video before completing the VAS for the third time (T2: minute 5 of recovery, T3: minute 10 of recovery). The experiment was carried out individually for each respondent. After the experiment, we asked the participants if they had any problems, and each participant was compensated with 40 RMB.

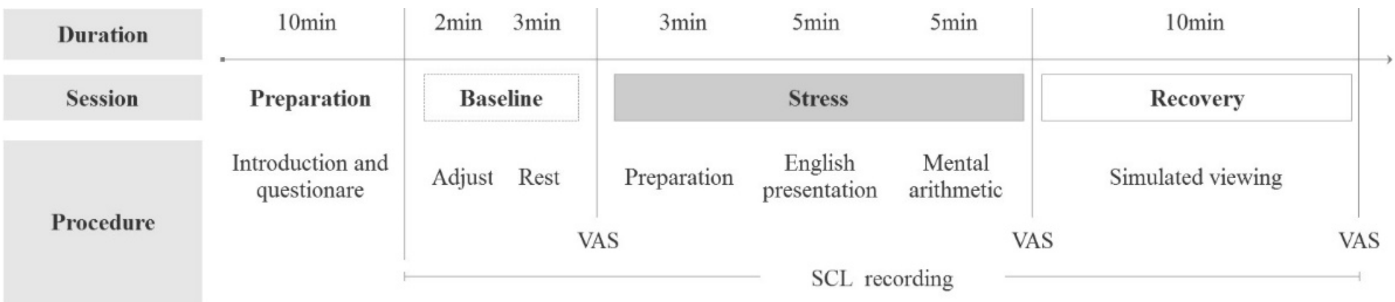


Figure 2. Experimental procedure.

2.6. Data Analysis

Because the first two minutes of the baseline served as an adaptation period, we used the mean SCL of the final three minutes to represent the baseline (T0) physiological stress level. The mean SCL of the 10 min TSST task represented the physiological stress level of the stress phase (T1). We included each minute of simulated viewing (1–10 min) to capture the minute-by-minute SCL changes during the recovery period. Because the SCL data were right-skewed, we used a logarithmic transformation for original measures of the SCL to reduce kurtosis. After transformation, the assumptions of normality and homoscedasticity were met. A summary perceived stress score was created by averaging the four component scores (stress, anxiety, tension, and avoidance). Stress reduction was calculated by subtracting the stress level after the simulated viewing (T3) from the stress level of the stressor task (T1).

All statistical analyses were performed using SPSS 24. ANOVA was used to determine differences in the SCL, perceived stress, and health status between groups at baseline. The paired t-test was performed to determine whether the TSST task successfully induced acute stress responses. We used an independent t-test to see any gender differences in stress reduction. RM-ANOVA was used to investigate changes over the condition and the time within groups. If the sphericity assumptions were violated, Greenhouse–

Geisser corrections (epsilon < 0.75) or Huynh–Feldt corrections (epsilon > 0.75) were applied. Post hoc comparisons were performed using the Bonferroni correction.

We used regression analysis to determine whether individual depressive symptoms modulated stress levels after environmental exposures. All predictor variables were centered according to guidelines for regression analysis [92]. The hierarchical regression analysis included measurements (SCL, perceived stress) after the recovery period (T3) as dependent variables. Measures after the stressor task (T1) were added to correct for differences in stress levels before simulated viewing. In the subsequent block, the condition was entered as the independent variable. The PHQ-9 sum score was added; finally, the interaction item between condition and the PHQ-9 sum score was added. We used an alpha of 0.05 as the threshold for determining statistical significance.

3. Results

3.1. Randomization and Manipulation Checks

We found that 29.6% of the participants showed moderate-or-above (≥10) depressive symptoms in the previous month (0–4 minimal, 5–9 mild, 10–14 moderate, 15–19 moderately severe, 20–27 severe [82]); 22.4% of the participants thought their physical health (1 = very unhealthy 7 = very healthy) level was below normal (<4), and 40.8% believed their chronic stress level (1 = not at all, 7 = severe) was more than moderate (>4).

We used the ANOVA to investigate between-group differences in baseline stress levels and health conditions. There were no significant between-group differences for the SCL ($\mathrm{F} = 1.68, p = 0.160$), perceived stress ($\mathrm{F} = 0.82, p = 0.512$), chronic stress level ($\mathrm{F} = 0.16, p = 0.956$), physical health ($\mathrm{F} = 2.04, p = 0.092$), and depressive symptoms ($\mathrm{F} = 0.54, p = 0.703$). The difference in English and mental arithmetic skill of the participants may have affected the change in stress generated by the stress induction task. Therefore, we ran an ANOVA to examine between-group differences in stress changes, and the results showed no between-group differences in SCL changes ($F = 1.215, p = 0.308$) or perceived stress changes ($F = 0.60, p = 0.666$) after the induction task. The SCL change was calculated by subtracting the mean of 10 min of SCL during the stress period from the mean of 3 min of SCL at baseline. See Table S1 in the Supplementary Materials for a more detailed overview.

We performed a paired t test on the measured variables of the baseline and stress period and found significant differences in SCL ($\mathrm{t} = -19.33, p < .001$) and perceived stress ($\mathrm{t} = -25.62, p < .001$) (Table 1), which suggested that the stressor successfully induced stress in the subjects.

Table 1. Paired t test results and mean values in skin conductance level (SCL) and perceived stress (PS) before and immediately after exposure to the stressor.

Variable	Time	N	Mean	SD	t	*p*	Cohen's d
SCL	Baseline (T0)	122.00	0.03	0.39	−19.33	<0.001 ***	1.82
	Post-stressor (T1)	122.00	0.60	0.22			
PS	Baseline (T0)	124.00	1.12	1.07	−25.62	<0.001 ***	2.81
	Post-stressor (T1)	124.00	5.31	1.82			

*** $p < 0.001$.

3.2. Should Women and Men Be Analyzed Separately?

Previous studies reported gender differences in the effects of natural environments on cognitive performance [65], preferences [66], self-reported health [67], and stress [22,68,69]. We performed an independent t test to examine gender differences in stress reduction and found no significant gender differences in the mean SCL or perceived stress after the stressor task (T1); however, we found significant gender differences in stress reduction after simulated viewing ($\Delta\mathrm{SCL}, \mathrm{t} = 3.70, p < 0.001; \Delta\mathrm{PS}, \mathrm{t} = 2.20, p = 0.027$) (Table

2). It appeared that, in any of those five settings, women had more SCL declines than men. Therefore, we believe it was reasonable to analyze stress responses for each gender separately.

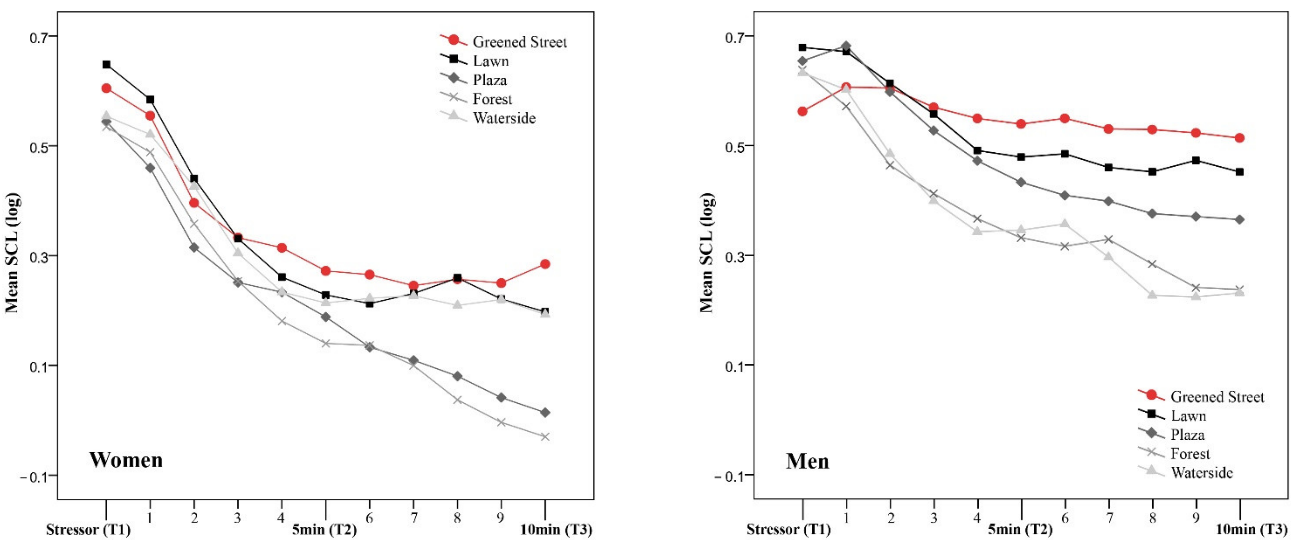
Table 2. Gender difference in skin conductance level (SCL) and perceived stress (PS) reduction after participants were exposed to the same set of environment conditions.

Variable	M(SD)		t	*p*	Cohen's d
	Female	Male			
SCL_{T1}	0.69 (0.21)	0.71 (0.21)	−1.29	0.598	0.096
ΔSCL [1]	0.45 (0.29)	0.27 (0.25)	3.70	<0.001 ***	0.663
PS_{T1}	5.55 (1.93)	5.07 (1.68)	1.29	0.143	0.265
ΔPS [2]	3.88 (1.99)	3.09 (1.92)	2.20	<0.027 *	0.403

[1] $\Delta SCL = -(SCL_{T3} - SCL_{T1})$, [2] $\Delta PS = -(PS_{T3} - PS_{T1})$. * $p < 0.05$, *** $p < 0.001$.

3.3. Skin Conductance Level

Figure 3 shows the decline in SCL over time in women (Figure 3a) and men (Figure 3b) in different environments. Although the SCL decreased in all groups at the initial stage of recovery, minute 5 could be regarded as a turning point. For female subjects, the reduction in SCL in the street, lawn, and waterside groups tended to be slow, while the SCL in the plaza and forest groups continued to decrease. For male subjects, the reduction in SCL in all groups showed a slowing trend after minute 5 of recovery. Therefore, we ran a mixed-model 5 × 3 RM-ANOVA for the SCL, in which the environment condition was the between-subjects variable and time (T1: stressed, T2: minute 5 of the recovery, and T3: minute 10 of the recovery) was the within-subjects variable. Considering differences in baseline stress levels for each subject, we used the mean SCL of the baseline (T0) as a covariate. Table 3 displays the results of the RM-ANOVA. A Huynh–Feldt correction was applied (ε = 0.97). After controlling for gender and the baseline level, we found that the interaction effect of time × environment was significant ($F = 3.74, p < 0.001, \eta_p^2 = 0.119$). In addition, a significant interaction effect on the SCL was also detected between time and gender ($F = 6.98, p = 0.001, \eta_p^2 = 0.059$). Hence, we performed RM-ANOVA separately for men and women.



(**a**) (**b**)

Figure 3. Minute-by-minute skin conductance level (SCL) changes of women (**a**) and men (**b**) in different environments during the recovery phase.

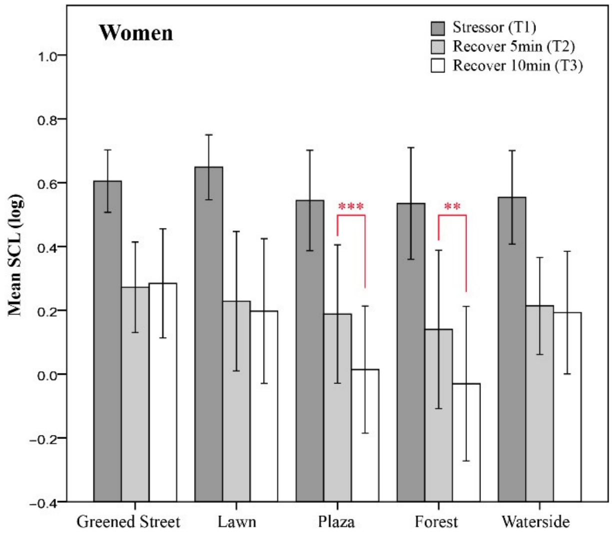
Table 3. Results of RM-ANOVA for skin conductance level (SCL) and perceived stress (PS).

Variable	SCL [1]			PS [2]		
	F	p	η_p^2	F	p	η_p^2
Time (T)	223.36	<0.001 ***	0.668	194.40	<0.001 ***	0.632
Setting (S)	2.06	0.092	0.069	0.46	0.763	0.016
Gender (G)	7.29	0.008 **	0.062	0.70	0.406	0.006
Baseline level [3]	129.12	<0.001 ***	0.538	19.76	<0.001 ***	0.149
T × S	3.74	<0.001 ***	0.119	5.89	<0.001 ***	0.173
T × G	6.98	0.001 **	0.059	6.01	0.016 *	0.051
S × G	0.72	0.577	0.025	1.10	0.362	0.037

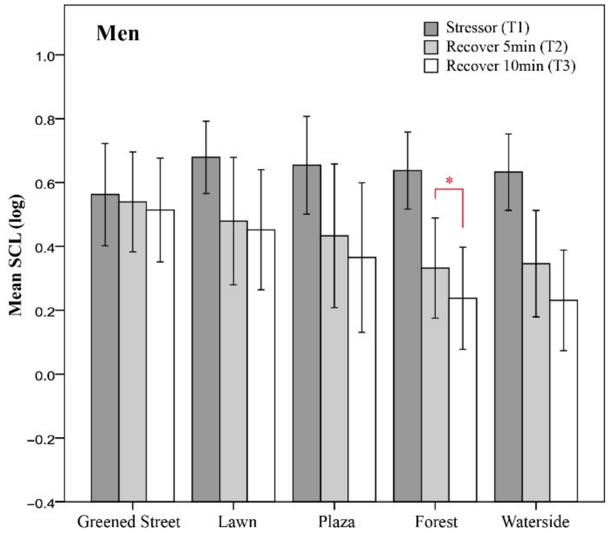
[1] In RM-ANOVA of SCL, we used T1, T2, and T3 as the within-subjects variables. [2] In RM-ANOVA of PS, we used T1 and T3 as the within-subjects variables. [3] We used the SCL and PS of the baseline (T0) as a covariate for each analysis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The results of the RM-ANOVA for women revealed no main effect of the environment. However, the subjects' SCLs changed significantly during the stress period (T1), the middle of recovery (T2), and the end of recovery (T3) ($F(1.75, 97.87) = 134.37, p < 0.001, \eta_p^2 = 0.71$). There was a time × environment interaction effect, though the effect was small and only marginally significant ($F(6.99, 97.87) = 1.89, p = 0.079, \eta_p^2 = 0.12$). A Huynh–Feldt correction was applied ($\varepsilon = 0.87$). To compare the SCL at various times, we examined the time effect of each condition individually. Female subjects in all environments showed significant SCL recovery at T2 compared to T1 ($ps < 0.01$). These significant differences suggest that, like park environments, a greened street may also have some stress-relieving benefits for women. Only male subjects in the plaza ($p < 0.001$) and forest ($p = 0.001$) conditions showed significantly more SCL recovery at T3 than T2 (Figure 4a). We then performed ANOVA separately for each time point to identify significant differences in the SCL between groups. There were no significant between-group differences at T1 and T2. However, there were significant differences between groups at T3 ($F = 4.11, p = 0.005, \eta_p^2 = 0.23$). The pairwise comparison revealed that the SCL of the greened street condition was significantly larger than that of the plaza ($p = 0.007$) and the forest ($p = 0.026$) condition, and the other pairwise comparisons were not significant. The means are presented in Table S2 of the Supplementary Materials. These findings suggest that, although women in the plaza and forest conditions experienced significant reductions in physiological stress during the two 5 min recovery periods, there were no significant differences in stress levels between the four park settings after the recovery period.

The RM-ANOVA of the SCL for men yielded no main effect of environment but did yield a significant main effect of time ($F(2, 108) = 71.99, p < 0.001, \eta_p^2 = 0.57$) and time × environment interaction ($F(8, 108) = 3.64, p = 0.001, \eta_p^2 = 0.21$). We used the same analytical procedures as with the women, and examined the time effects for each condition separately. Male subjects in four park conditions ($ps < 0.05$) showed significant SCL recovery at T2 compared to T1; however, subjects in the greened street condition did not show significant SCL recovery. These findings indicate that the park environment can relieve men's physiological stress, whereas the stress-relieving effect of the greened street appears to be less significant. Only male subjects in the forest conditions ($p = 0.013$) showed significantly higher SCL recovery at T3 than T2 (Figure 4b). We then performed ANOVA separately for each time point. There were no significant between-group differences at T1 and T2. However, there were significant differences between groups at T3 ($F = 2.85, p = 0.032, \eta_p^2 = 0.17$). The pairwise comparison revealed that the SCL of the greened street condition was significantly larger than that of the waterside condition ($p = 0.023$), and the other pairwise comparisons were not significant. Just as with the women, men in the forest condition experienced significant SCL reductions during the two 5 min recovery periods. However, there were no significant differences in stress levels between the four park settings after the recovery period.



(**a**)



(**b**)

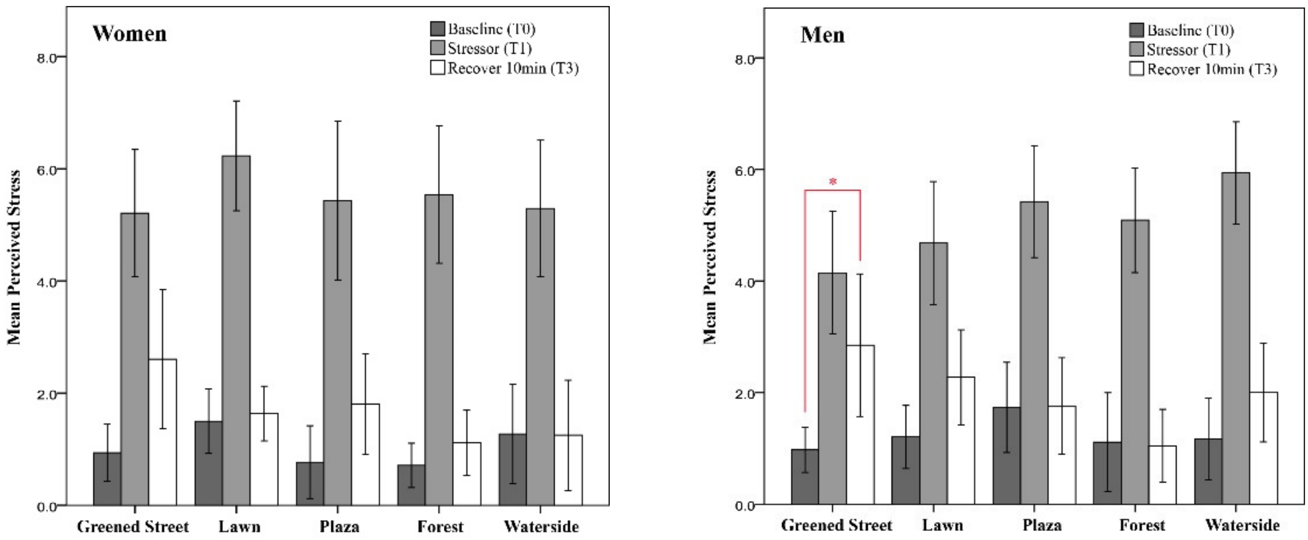
Figure 4. Changes in mean skin conductance level (SCL) of women (**a**) and men (**b**) in different environments during the recovery phase. Pairwise comparisons between minute 5 of recovery (T2) and end of the recovery (T3) in each environmental condition were marked. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.4. Perceived Stress

For perceived stress, we used a mixed-model 5 × 2 RM-ANOVA with environment condition as the between-subjects variable and time (T1: stressed, and T3: minute 10 of the recovery) as the within-subjects variable. To correct for differences in stress levels at baseline, we used the perceived stress of the baseline (T0) as a covariate (Table 3). We discovered that the interaction effect of time × environment was significant after controlling for gender and the baseline stress level ($F = 5.89, p < 0.001, \eta_p^2 = 0.173$). Furthermore, a significant interaction effect on perceived stress was found between time and gender ($F = 6.01, p = 0.016, \eta_p^2 = 0.051$). Therefore, we ran RM-ANOVA separately for men and women for further comparison.

The RM-ANOVA on perceived stress for women yielded no main effect of environment and time × environment interaction but did yield a significant main effect of time ($F(1.87, 108.63) = 244.32, p < 0.001, \eta_p^2 = 0.808$). A Huynh–Feldt correction was applied ($\varepsilon = 0.94$). The change in women's psychological stress was time-dependent; the park and street environments resulted in significantly reduced perceived stress (Figure 5a).

The results of the RM-ANOVA for men revealed no main effect of the condition; however, perceived stress changed significantly during the baseline (T0), the stress period (T1), and the end of recovery (T3) ($F(2, 112) = 189.07, p < 0.001, \eta_p^2 = 0.771$). There was a significant interaction between time and environment ($F(8, 112) = 3.72, p = 0.001, \eta_p^2 = 0.21$). We examined the time effects for each environment separately and found that all environments significantly reduced perceived stress after recovery ($ps < 0.001$). However, the subjects' perceived stress in the greened street remained higher than the baseline ($p = 0.02$) (Figure 5b). Only one significant difference was found in the ANOVA of environment effect on perceived stress at T1 and T3. After the recovery period, the forest condition resulted in lower perceived stress than the greened street condition ($p = 0.041$). These findings suggest that greened streets and parks reduce men's perceived stress; however, streets are less effective. Only forest conditions showed lower perceived stress than street conditions after recovery. There was no significant difference in psychological stress among the four park environments.



(**a**) (**b**)

Figure 5. Changes in mean perceived stress (PS) of women (**a**) and men (**b**) in different environments during the recovery phase. Pairwise comparisons between baseline (T0) and end of the recovery (T3) of men in each environmental condition were marked. * $p < 0.05$.

3.5. Depressive Symptoms as Possible Moderator for Skin Conductance Level and Perceived Stress Restoration

Regression analysis was conducted to predict post-video (T3) SCLs and perceived stress, including condition, depressive symptoms, and the interaction between these variables as predictors while controlling for pre-video stress level (T1) and gender.

For the SCL model (Table 4), the significant main effects of environment indicated that subjects who watched four park videos had lower SCLs than those who watched the greened street video. In other words, park environments had a better effect on the restoration process than the greened street did in the same amount of time. However, neither depressive symptoms (PHQ-9 summed score) nor the interaction between condition and depressive symptoms significantly improved the model. See Table S3 in the Supplementary Materials for a more detailed overview.

For the perceived stress model (Table 4), the results showed that the main effect of environment was significant; this main effect suggests that the perceived stresses of the subjects who watched the natural video were lower than those associated with watching the street scene. We found that depressive symptoms and the interaction between the condition and depressive symptoms significantly improved the model. This finding suggests that individuals with different depressive symptoms have different perceived stress reductions after viewing different environmental videos. After watching a greened street video, subjects with more depressive symptoms reported higher perceived stress. Conversely, the perceived stress reported by participants in the four park conditions remained stable as depressive symptoms increased. In particular, the level of perceived stress reported by subjects in the lawn condition decreased with increasing depressive symptoms (Figure 6). See Table S4 in the Supplementary Materials for a more detailed overview.

Table 4. Results of regression models testing the interaction between environmental condition and depressive symptoms (PHQ-9 sum score) on the outcome measures.

Variable	SCL Model		PS Model	
	B	SE	B	SE
Constant	0.33 ***	0.057	2.496 ***	0.285
Stressor level (centered)	0.869 ***	0.111	0.226 ***	0.066
Male	0.188 ***	0.047	0.437 +	0.229
Condition (Greened street as reference)				
Lawn	−0.144 +	0.073	−0.757 *	0.369
Plaza	−0.234 **	0.072	−0.909 *	0.365
Forest	−0.29 ***	0.074	−1.586 ***	0.367
Waterside	−0.203 **	0.073	−1.128 **	0.368
PHQ (centered)	−0.009	0.009	0.168 **	0.051
Condition × PHQ				
Lawn × PHQ	0.002	0.014	−0.219 **	0.073
Plaza × PHQ	0.002	0.014	−0.079	0.074
Forest × PHQ	0.028	0.015	−0.120	0.076
Waterside × PHQ	0.008	0.013	−0.069	0.070

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

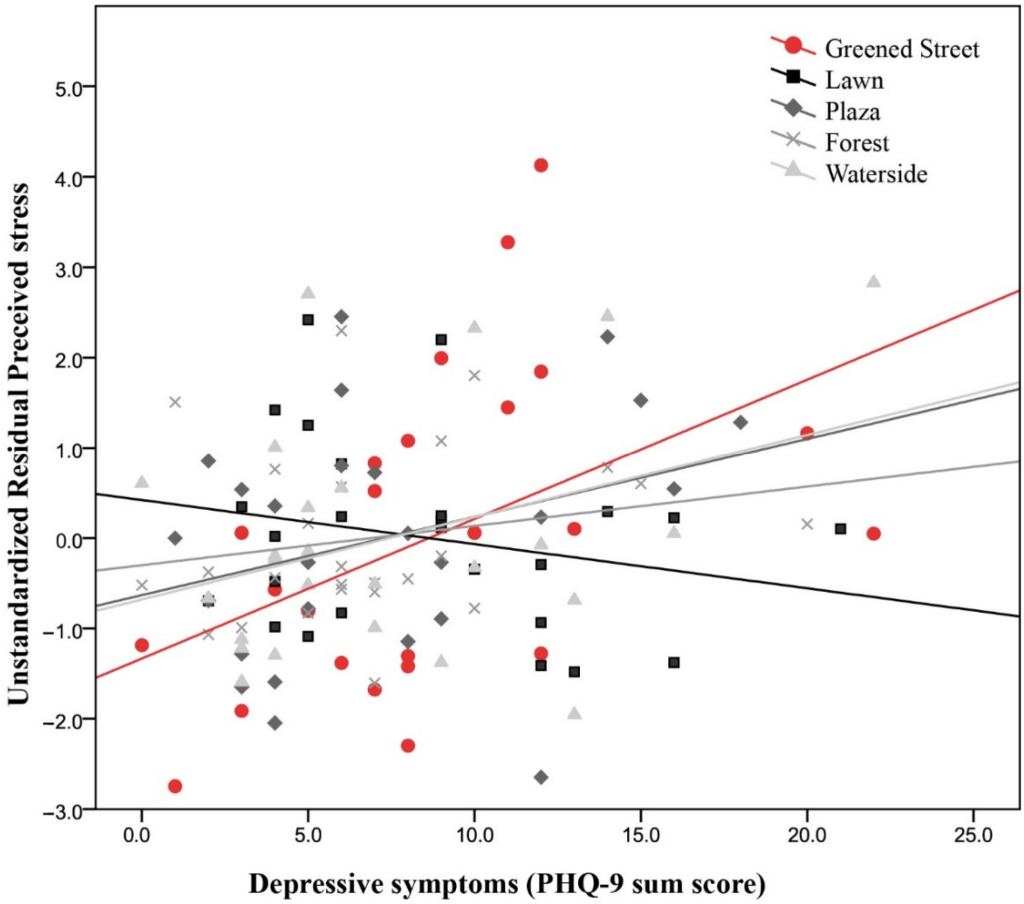


Figure 6. Plotted regression model for perceived stress (T3) corrected for the pre-video (T1) stress level and gender difference.

4. Discussion

4.1. Effects of Setting Types on Stress Reduction Effects

Previous research found that the amount of vegetation on streets positively correlated with stress restoration; therefore, it is not surprising that greened streets can also relieve stress. We found that the restoration effect of greened streets was not as good as park environments. While street greening improves street restoration, bottom-up stimulation unavoidably exists in street contexts. These stimulations capture considerable attention and require directed attention to overcome. (e.g., avoiding traffic and ignoring advertisements). The park environment, by contrast, contains fewer bottom-up stimuli and minimizes the demands of directed attention resources. Park environments contain more "fractal" features, require fewer cognitive processing resources, and are more fluent in processing [20,93]. Fluent processing is correlated with positive affect [94]. Our findings support previous findings that natural elements have powerful physio-psychological stress-relieving benefits [33,95].

Our study found no differences in stress recovery between hardscape (plaza) and other park settings. By contrast, Wang et al. found that nature-based scenarios (lake and lawn) were more effective at reducing stress than hardscapes (plaza) [22]. Some might argue that the relatively low greenness of hardscapes can explain this result, because more vegetation represents more "fractal" features, thereby consuming fewer cognitive resources. This perspective can lead to a bias that landscapes with fewer natural elements (hardscapes or built environments) are less capable of providing restoration potential than natural environments. However, the restoration potential of a place depends on the spatial characteristics (e.g., enclosure) [91], human maintenance [35], historical and cultural meaning [44,96–98], and the activities afforded by that place [99–101]. Therefore, nature-based scenarios are not necessarily better than hardscapes or built environments as restorative environments.

Furthermore, we observed that only the forest provided significant stress recovery for all subjects during the second recovery period, although there was no significant difference in the stress measurement after the recovery period across park settings (Figure 4). This result suggests that the stress restoration effect of forests may be longer lasting. Several studies reported that forests have a more substantial relaxing effect than other restorative environments [26,102]. However, because the recovery period in our experiment was only 10 min, we do not know whether more prolonged exposure to the forest setting might induce even more significant stress recovery effects. Therefore, more research is needed to observe the stress recovery change from prolonged exposure to the forest and compare it with other restorative environments.

Overall, we found that greened streets can also relieve stress; however, the restoration effect of greened streets was not as good as park environments. Planting trees for streets alone will not provide citizens with a sufficiently high-quality restorative environment. We found no differences in stress levels after recovery across four park settings, which suggests that hardscapes have the same potential for restoration as nature-based settings. Only the forest setting produced significant SCL recovery in both men and women during the second half recovery period, which suggests that forests may be more suitable for relaxation.

4.2. Gender Difference

According to physio-psychological stress data, women recovered more than men in all five settings. Viewing greened streets relieved stress for women; however, this stress recovery benefit did not appear to be as effective for men. Men's SCLs did not significantly recover in the greened street condition; moreover, their self-reported stress remained above baseline, despite a significant recovery from stress periods.

One possible explanation is that women are more likely to gain stress recovery benefits from different settings than men. However, major theories about the impacts of exposure to nature on humans make no distinction between men and women [16,37]. Moreover, previous studies did not report gender differences in responses to nature [39,40,103,104]. There appears to be no reason to believe that there are gender differences regarding the benefits of nature. Nevertheless, empirical evidence on gender differences in current restoration studies is mixed. Several studies found that the environment had a more significant impact on women, including being more self-disciplined [65], vitality [105], less prone to obesity [106], and improving emotion [78]. Other studies found significant effects of the environment that were restricted to men, such as decreased cardiovascular and respiratory disease mortality [62], increased stress relief [69], and a decreased risk of hyperactivity/inattention [107]. These findings suggest that men and women may derive different health benefits from the natural environment.

Another explanation that appears more plausible is that gender differences in environmental responses can be explained by differences in women's and men's perceptions and use of urban restorative environments. Several studies reported gender differences in the use of restorative surroundings [108–110]. Thus, women may be more exposed to neighborhood surroundings and more likely to benefit from restorative settings. Furthermore, gender, as a marker of social roles and behavioral norms, may lead to differences in perceptions of the health benefits provided by the restorative environment between genders. For example, gender was a significant determinant of environmental preferences [111,112] and perceived restoration [19,113,114]. Taken together, these findings suggest that those who are more aware of the health advantages of the natural environment and have the habit of visiting natural areas are more likely to visit restorative spaces. People who repeatedly visit restorative settings can recover more quickly from acute stress, because they may gain cumulative benefits to their health from nature [115,116]. Simply put, gender differences in the perception and use of urban restorative environments may lead to different restoration benefits for men and women.

Finally, gender differences in stressor reactions may explain our findings. Numerous studies indicated that men and women have different recovery rates from their physiological responses to stress [74,117–120]. This difference could be attributed to how men and women react to various stressors. Men were more stressed than women when faced with achievement or performance-oriented stressors [121]. Women, by contrast, showed larger stress responses to social rejection or interpersonal stress than men [71,73,122,123]. The TSST used in the present study was more relevant to performance-oriented stressors, because participants were informed that their performance would be evaluated. The effects of such performance-oriented stressors on men may be more persistent, thus resulting in men taking more time to recover from this type of stress.

We found gender differences in the physio-psychological stress changes for TSST and environmental conditions; these differences could be related to how men and women perceive and use restorative environments. It is also possible that men require more time in restorative environments than women to obtain the same degree of stress relief, as performance-oriented stressors may have more long-term stressful consequences on men. More research on gender differences in environmental restoration is required.

4.3. Depressive Symptoms and Stress Reduction Effects

We found that perceived stress increased in the street condition as depressive symptoms increased. Perceived stress reported by subjects viewing the four park settings (vs. greened street settings) remained stable as individual depressive symptoms increased; especially in lawn conditions, subjects with higher (rather than lower) depressive symptoms reported lower perceived stress. However, the SCL did not appear to be affected by individual depressive symptoms.

In contrast to our findings, depressed individuals may be trapped in a deteriorating negative self-perception loop. They constantly recall negative memories, even in natural environments, and thus fail to gain the natural restorative benefits. One possible reason for this discrepancy is that our results were not based on clinical depression samples.

These subjects' depressive symptoms may have been due to recent experiences of high-stress events (e.g., job search, dissertation defense, or final exams). Therefore, although 29.6% of our subjects self-reported moderate-or-above depressive symptoms, the duration of depressive symptoms may not have been very long. The depressive symptoms caused by high-stress events were insufficient to induce the individuals to form negative self-schemas and generate blunted emotional responses. Furthermore, numerous studies reported increased attentional function and improved mood benefits from nature in clinically depressed patients [18,124,125]. Our results are consistent with these studies that viewing park environments (particularly the lawn setting) can help individuals with more depressive symptoms recover from acute stress.

Our results support the hypothesis that individuals with higher depressive symptoms have more restoration needs, and that nature provides more recovery benefits to people who need it the most [31–33]. Our research provides preliminary practical evidence for natural interventions as a primary care strategy. Viewing nature can help high-stress individuals (who are more prone to depression) avoid being depressed.

4.4. Limitations and Future Research

Our study had some limitations. First, because all our respondents were Chinese and shared a common cultural background, the generalizability of our findings may be limited by ethnicity and culture. Ethnic and cultural backgrounds may influence environmental preferences [126,127]. Preference and environmental restoration are closely related [34,58,87,128–132]. Future research should consider the cultural background as a possible moderator to investigate the physio-psychological recovery benefits of natural environments. The age of our respondents also limited our results, because college students cannot represent the whole population. Additionally, we did not consider individuals who were reluctant to participate in the experiment, which lead to selection bias.

Second, although our sampled participants displayed subclinical depressive symptoms due to recent high-stress events, they may not have been clinically depressed. Their depressive symptoms were collected by self-report rather than being diagnosed by doctors, even though the PHQ-9 is very reliable in clinical diagnosis. We should be cautious about extending the results of this study to clinical individuals. Future studies could explore whether natural interventions are effective in clinically depressed patients with different levels of depression.

Third, the environmental samples we selected may limit the generalizability of our conclusions. This study investigated ordinary street and park scenes in Wuhan, China. We used only one setting per experimental condition. Nevertheless, there are numerous types of restorative settings in the urban context. Future research should extend the investigation to other types of urban environments. Furthermore, we did not include natural features (e.g., color and shape of vegetation) or spatial features (e.g., enclosures) to eliminate sources of variation that could influence the results. Future research should explore factors including the complexity of the natural features, the cultural significance of the vegetation, and the cultural or social character of the place. Understanding more precise restoration mechanisms will assist the government in balancing restoration effects and building costs, thus allowing the government to maximize the benefits of the restorative environment for urban people at the lowest possible cost.

Fourth, our conclusions may be influenced by the type of stress-inducing task, as there may be gender differences in the stress-inducing task for different types of stress. We found that women recovered more than men in the same amount of time, possibly because our stressors caused men to take more time to recover. Future research should consider using a combination of performance-oriented and interpersonal stressors or other types of stressors to balance gender differences, such as workplace accidents [16,33] and horror movies [21].

Finally, we employed simulated environments instead of real ones in our study. It should be emphasized that there is an experiential difference between wandering in a real natural area and seeing nature through a video. The experiences of staying in a real natural environment contain multidimensional stimuli. For example, when people walk through a real urban park, they will feel the temperature and wind on their skin, hear the leaves rustling and birdsongs, smell the fragrance of plants and flowers, and feel the softness of grass and dirt. Although most simulated environmental technologies claim to be sufficiently immersive, they offer a limited analog sensory dimension. Several studies have claimed that the restoration benefits of simulated and real environments are comparable, such as perceived restoration quality [133], attention function [134], emotional changes [135], and psychophysiological responses [136]. In following this literature line, researchers further argue that real natural environments have more benefits than simulated ones, including psychological restorative benefits [137], attentional restorative effects [138], and effects on positive emotions [36]. Virtual nature may not be able to replace real nature now. However, people may benefit from simulated environments when they cannot access real natural environments (e.g., COVID-19 quarantine or lack of physical mobility). They can use nature substitutes (indoor potted plants) or simulations (e.g., pictures, videos, or virtual reality) to obtain restorative effects [87,139]. Furthermore, the advantage of virtual environments is that they make it easy to avoid uncontrollable disturbance factors in the real environment, such as pedestrians, traffic, and climate. These distractions may obstruct the collection process of psychophysiological data. We should be careful when applying our findings to real-world environments. Future studies should integrate multidimensional senses to make the laboratory simulation environment more realistic [41].

5. Conclusions

In general, our study supports previous research showing that the natural environment has powerful benefits for stress recovery. While greened streets can help with stress relief, they are not as good as park environments, which suggests that planting trees for streets alone will not provide citizens with a sufficiently high-quality restorative environment. We also discovered that the hardscapes (which contain fewer natural elements) have the same potential for restoration as nature-based settings. We found significant gender differences in perceived stress and SCL changes, with women recovering more than men. Finally, our research provides preliminary practical evidence for natural interventions as a primary care strategy to alleviate the mental health disorder treatment gap. We found that viewing natural environments can prevent people who are stressed out or have depressive symptoms from progressing further into clinical depression.

Our results have implications. Firstly, due to the lack of space, increasing vegetation in a high-density urban environment is not practical. Our results show that hardscapes can provide restoration benefits that are comparable to nature-based landscapes. The urban environment can be improved by enhancing existing spaces, such as growing greenery around plazas to insulate from traffic noise or creating pocket parks in fragmented spaces. Second, we should improve the greenspace near high-stress locations (e.g., hospitals, schools, and corporate buildings). People in these places can quickly improve their moods and refocus their attention by visiting/viewing greenspace nearby. Third, we can encourage people who cannot access real nature to enjoy the green scenery in different ways (e.g., enjoying the natural scenery through the window, watching videos of natural scenery on their smartphones, spending time with houseplants).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12010022/s1, Table S1: Descriptive statistics and randomization checks; Table S2: Descriptive statistics of the outcome variables; Table S3: Results of regression models testing the interaction between environmental condition and depressive symptoms (PHQ-9 sum score) on the outcome measures; Table S4: Results of regression models testing the interaction between environmental condition and depressive symptoms (PHQ-9 sum score) on the outcome measures.

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Data Availability Statement: We do not provide public access to the dataset due to protection of the privacy of the participants. Regarding the details of the data, please contact the corresponding author.

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

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