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Effects of Urban Greenway Environmental Types and Landscape Characteristics on Physical and Mental Health Restoration

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Abstract: As important linear public spaces, urban greenways are highly important for improving public health. Many studies have proven the benefits of urban greenways for human well-being, but fewer studies have focused on the impact of their specific environmental types and characteristics on physical and mental health. In this study, 100 subjects participated in a comparative experiment on three types of urban greenways (urban roads, urban parks, and urban rivers), and corresponding physiological indicator (systolic blood pressure [SBP], diastolic blood pressure [DBP], and pulse) and psychological indicator (perceived restorativeness scale [PRS] and positive and negative affect schedule [PANAS]) data were collected. The results indicated that (1) different greenway environment types lead to different physiological and psychological states; (2) urban park-type greenways (SBP [t = 2.37, p = 0.020], DBP [t = 2.06, p = 0.042], PANAS = 2.80, PRS = 5.39) have the greatest physical and mental recovery benefits, followed by urban river-type greenways (SBP [t = 2.84, p = 0.006], DBP [t = 1.29, p = 0.200], PANAS = 2.30, PRS= 5.02) and urban road-type greenways (SBP [t = 0.78, p = 0.440], DBP [t = 0.37, p = 0.716], PANAS = 2.00, PRS = 4.15); (3) plant color and layer diversity have a significant positive impact on the mental health benefits of the three greenway types; (4) the aesthetics of waterscapes and ornaments can significantly improve the perceived restoration ability of urban river-type greenways; and (5) the comfort of pathways and facilities can effectively promote the psychological recovery potential of urban road-type greenways. These findings systematically demonstrate for the first time the differences in restoration potential among urban greenways of different environmental types and summarize the key landscape characteristic predictors influencing the restoration potential of various types of urban greenways. Our research provides new ideas for proactive greenway interventions for physical and mental health and for enriching the restorative environmental science system.

Keywords: urban greenway; restorative environment; environmental types; landscape characteristics; urban green spaces; public health

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1. Introduction

Rapid urbanization has led to an increasing proportion of the global population residing in urban areas. As of 2021, the urban population worldwide constituted 56% of the total population, a figure projected to increase to 68% by 2050 [1]. High-density urban living environments and fast-paced urban lifestyles have resulted in widespread mental fatigue and psychological issues among residents, posing significant health challenges worldwide [2]. As an important place for residents to get close to and feel nature, urban green spaces (UGSs) have been shown to be an important means of addressing adverse health conditions [3,4]. These environments have demonstrated positive effects on fostering positive emotions [5], alleviating anxiety and stress [6], enhancing cognitive abilities [7], and reducing the incidence and mortality rates of cardiovascular and respiratory diseases [8,9].

Urban greenways connect urban natural habitats and communities because of their linear characteristics. While protecting biodiversity, they help crowded cities improve opportunities for positive interactions between people and nature, becoming an important part of UGSs. Serving as nearby natural settings for urban residents, urban greenways offer the surrounding population opportunities for commuting and physical activities [10], spaces for relaxation and leisure [11], and spaces that foster physical and mental health restoration [12]. In addition to providing a physical environment that supports outdoor activities, urban greenways also provide social capital and enhance social cohesion, which together benefit residents' physical and mental health [13]. Therefore, urban greenways might possess different capabilities than those offered by other UGSs, enabling them to integrate natural resources while promoting the restoration of public health. Researching the restorativeness of urban greenways could help provide nature-based solutions for high-quality urbanization [14].

Currently, two mainstream theories suggest that exposure to nature has restorative effects on human health: attention recovery theory (ART) and stress reduction theory (SRT). ART, proposed by Kaplan [15], suggests that the restorativeness of the natural environment is mainly reflected in the restoration of attention. Nondirected attention activities (observing nature) that do not require energy consumption will have a recovery effect on directed attention (work and study). SRT, introduced by Ulrich [16], suggests that natural environments can relieve stress and help calm excitement, thereby allowing rapid recovery from short-term stress. The two theories basically matured in the early 1990s. Because they were produced at the same time, they also supplemented and improved their respective views during mutual debates. In line with the restorativeness theory, Hartig defines restorative environments as spaces where individuals can disengage and relax, fostering positive recovery effects, and that provide a means of escape from everyday life [17]. Based on restorative theory, many scholars have explored the relationship between UGSs and public health. Research has revealed that the environmental types [18], environmental elements [19], and spatial characteristics [20] of UGSs are significant factors influencing the restoration of physical and mental health. Natural environments better enable health recovery than urban environments; however, not all natural environments exhibit the same level of restorativeness [21], and there are differences in the restorative properties of the various elements of natural environments. Topographic landscapes with natural mountain forests have a strong restorative effect [18]. Enhancing the quality of elements such as trees, lawns, flowers, and water bodies is a reliable method for increasing the restoration benefits of UGSs [22,23]. In conclusion, UGSs exhibit diverse restorative benefits, and different types of green environments possess varying restoration potentials due to differences in environmental characteristics. Landscapes with various natural elements may offer better restoration because they are more likely to meet different needs and provide resources for various restorative experiences.

As a special type of UGSs, urban greenways stimulate more physical activity and are better at predicting health than traditional urban parks due to their linear characteristics [24]. Natural elements, recreational facilities, road quality, and cleanliness have been proven to be important factors affecting the use and well-being of urban greenways [13,25,26]. The attributes of greenways may affect the use of greenways through place attachment [26], place preference [27], environmental perception [28], cultural value [29], the promotion of sports activities [30], and social interaction [31], thereby improving the health and well-being of residents. In summary, there is a close connection between the environmental quality of urban greenways and health and well-being. However, as an emerging green space type, research on urban greenways and public health has focused only on the use and overall impact of greenways. In this research, two comparative studies on large-scale, multifunctional urban greenway interventions attracted our interest: Hunter et al. [32] evaluated the physical activity, quality of life, and mental health of residents before and after the Connswater Community Greenway (CCG) intervention in Northern Ireland in approximately 2010 and 2017. This study was one of the first to assess the multifunctionality of urban greenway interventions. The results indicated that, at the current stage, the CCG did not significantly improve physical activity behavior or mental health in the population. Xie et al. [30] studied the impact of large-scale urban greenway interventions on public health for the first time in China. Two rounds of survey data (before and after the intervention in 2016 and 2019, respectively) showed that the Wuhan East Lake Greenway intervention significantly improved residents' physical activity and physical health. The two seemingly contradictory conclusions from two similar studies conducted during the same period prompted us to conduct a further comparison. The CCG is an urban greenway constructed along three rivers, while the Donghu Greenway mainly relies on urban parks and lakes. Numerous studies have demonstrated that the environmental type and elements of UGSs are crucial factors influencing health recovery. Therefore, we propose the following hypothesis: Differences in the environmental types of urban greenways affect health recovery potential. This suggests that the impact of urban greenways on public health may require more nuanced and specific assessments rather than investigating their effects on health at an abstract, general level.

The focus of urban greenways is to connect and enhance existing green spaces, and their typological differences are largely influenced by the land use types in the surrounding areas. In previous studies, urban greenways were categorized into three types based on the resources they used: (1) urban road-type greenways established along city roads, (2) urban park-type greenways integrated within city parks, and (3) urban river-type greenways developed along urban river systems [33,34]. Although this classification distinguishes differences in the types and characteristics of urban greenways, no research has yet conducted a more in-depth investigation into whether these differences affect the realization of benefits related to urban greenways (such as health restoration benefits). Therefore, this study investigates these three types of urban greenways to record the physical and mental recovery experiences of the population to explore the following two scientific questions: (1) Are there variations in physical and mental health recovery capabilities across environmental types of urban greenways? and (2) Which landscape characteristics in various types of urban greenways influence the restorative effects? Through this research, we aim to provide a theoretical foundation for more rational planning and configuration of environmental types and characteristics of urban greenways. This endeavor will enable more targeted construction of restorative environments along greenways, enhancing the quality of residents' restorative experiences and providing evidence-based practices towards achieving human-centered habitat construction goals.

2. Materials and Methods

2.1. Participants

This study included a total of 100 participants, with ages ranging from 18 to 30 years (mean age = 23.15 years, SD = 2.32, maximum age = 30 years, minimum age = 18 years). According to the central limit theorem, when the sample size exceeds 30, the sampling distribution of the mean tends to approach a normal distribution. Hence, a sample size of 100 individuals met the requirements for subsequent statistical analyses. The gender distribution among the 100 participants was equal, with 50 males and 50 females, with the aim of minimizing interference and bias resulting from gender imbalance. To expand the sample size and enhance representativeness, we recruited volunteers by posting posters on university campuses and in communities around the greenways in the Chengdu urban area and utilized online social platforms (WeChat group chats) to disseminate advertisements. All volunteers were healthy residents with Chinese as their native language. They entered the online registration system (WPS online form) to register voluntarily by scanning the QR code on online and offline posters. Once the number of male and female participants reached 50 each, the registration system automatically closed. Apart from controlling for sex, no other specific criteria were applied during the participant selection process to avoid potential biases. All participants were informed of the experimental procedures and associated risks and signed an informed consent form before the trial. Participants were instructed to refrain from smoking, drinking alcohol, and engaging in strenuous physical activities throughout the entire study period. Although we had to exclude a small number of participants from the data analysis due to incomplete data or technical issues, we believe that the overall sample size (n = 93, men = 47) is still sufficient to support this study. The study was conducted in accordance with the Declaration of Helsinki. The study was conducted with the approval of the Academic Ethics Committee of the College of Landscape Architecture, Sichuan Agricultural University, China (project identification code: 20220017).

2.2. Study Sites and Materials

As visual replicas of real landscapes, images are widely used in research because this method is time-saving and cost-effective while allowing better control of external interfering variables during experiments. Therefore, as the stimulus source material of this study, the shooting and selection of greenway photos were particularly important.

Chengdu has the world's largest greenway system, the Tianfu Greenway. The total length of the Tianfu Greenway is 16,900 km, with excellent ecological background and wide coverage of landscape features, enabling it to effectively represent the development status of China's greenways. We first conducted an on-site investigation of three types of urban greenways in Chengdu city. The following criteria had to be met when selecting greenway sections: (1) the entire section is located within the urban area of Chengdu and meets the requirements of urban greenways; (2) the sections are located in different areas of Chengdu to ensure the representativeness and universality of the sample; (3) the landscape features are obvious and can better reflect the characteristics of various urban greenways; and (4) the flow of people is large and the frequency of use is high. Finally, a total of six sections of three types of urban greenways were selected (Figure 1). These surveys covered seven urban districts, Jinjiang, Qingyang, Jinniu, Wuhou, Chenghua, Wenjiang, and Shuangliu, for a total surveyed greenway distance of 23 km. Specifically, the Jinjiang Greenway (Huoshui Park to Hejiang Pavilion section) in Jinjiang District, the Panda Greenway (Jiaozi Interchange to Chengyu Interchange section) spanning Jinjiang and Chenghua Districts, the Jincheng Greenway (Jincheng Lake to Guixi Ecological Park section) in Wuhou District, the Panda Greenway (Supo Interchange to Yangxi Interchange section) crossing Qingyang and Jinniu Districts, the Jincheng Greenway (Intangible Heritage Park to Shuxian Scenic Area section) spanning Qingyang and Shuangliu Districts, and the Nancheng Greenway (Binjiang Bridge to Biluo Lake Park section) located in Wenjiang District were included.

After the investigation, we opted to capture real scenes of the greenways in autumn (15 November–30 November 2022), when the landscape undergoes obvious seasonal changes and is highly ornamental. The photography of the greenways followed specific standards: (1) photographs were taken under good weather conditions, either clear or partly cloudy skies, between 9 a.m. and 4 p.m.; (2) a Sony A7M2 camera equipped with a Sony 28–70 mm full-frame standard zoom lens (FE 28–70 mm f/3.5–5.6) was used; (3) a tripod was utilized to position the camera at a height of 1.5 m, maintaining a horizontal field of view while minimizing nonlandscape elements within the frame; and (4) images were captured at observation points along the main scenic pathways, with shots taken every 20 m. A total of 1132 landscape photographs of the six sampled greenway segments were taken in compliance with these criteria.

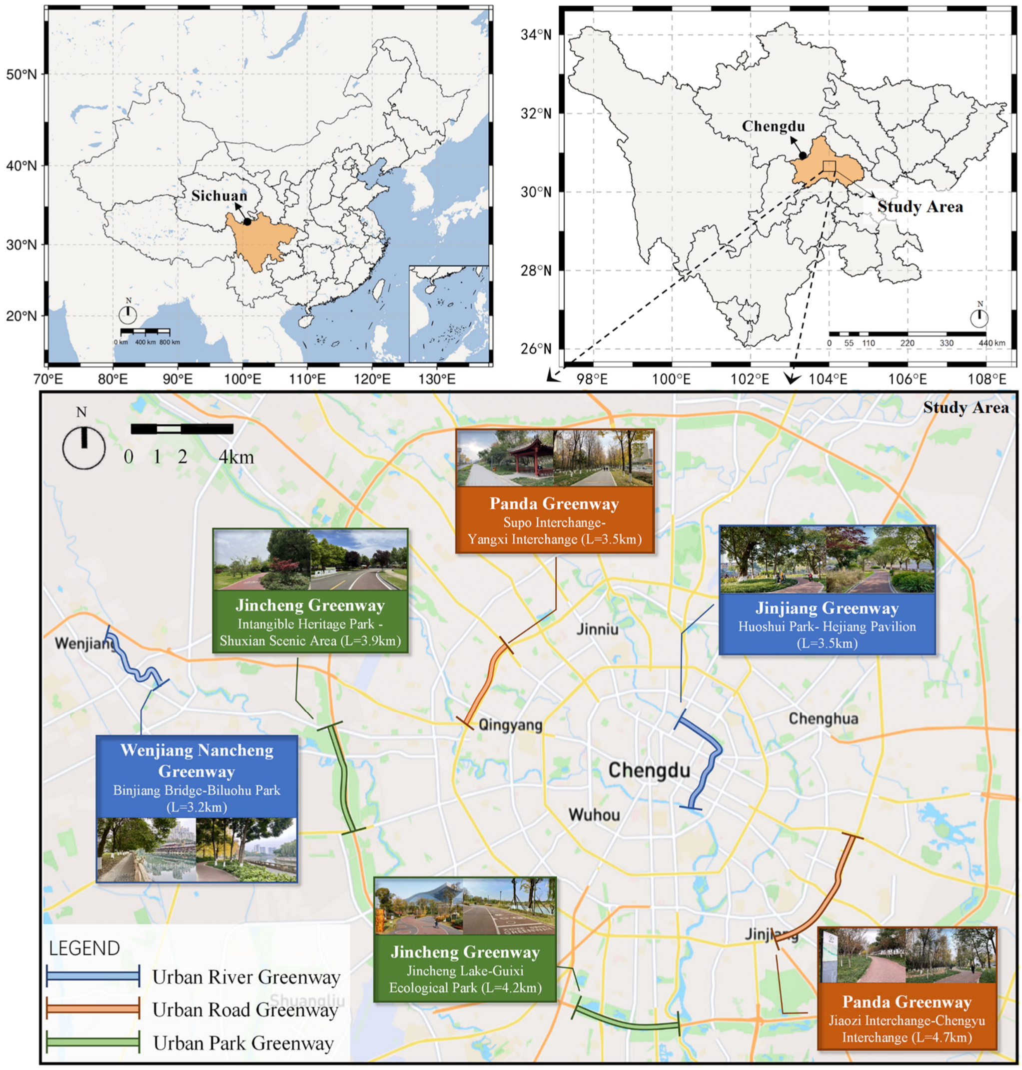

Figure 1. Location of the research site.

After the images were taken, we further refined the images to ensure that the results were robust. The specific criteria for evaluation were as follows: (1) photos with dim lighting or blur were excluded; (2) photos with unnatural compositions that made it difficult to focus on the greenway environment were excluded; (3) photos with similar environmental characteristics were decreased to selected photos that reflected the specificity of the landscape features; and (4) photos with poor landscape effects, such as obvious garbage, serious damage to facilities, and poor vegetation, were excluded. Finally, 10 landscape architecture experts selected a total of 60 photos that could fully and truly reflect the environmental characteristics of the three types of urban greenways (20 photos for each of the three types of greenways) as stimulus materials for subsequent experiments. For details, see the Supplementary Materials (Figure S1).

2.3. Procedure

Before the experiment, the 100 participants were asked to avoid smoking, drinking, and undertaking strenuous physical activity. In this study, the experiments were conducted simultaneously in two laboratories. Each experiment lasted 45 min. Two subjects in each laboratory participated in the experiment at the same time. Each laboratory could handle 25 subjects per day, and the experiment was completed in two days.

Each subject experienced three types of greenway stimulation through five steps: experimental preparation, stress tests, pretests, greenway stimulation, and post-tests (Figure 2).

Before entering the laboratory, participants first completed a demographic characteristics scale to report their basic information and signed an informed consent form. After entering the laboratory, the experimenter put the experimental equipment on the participants and explained the experimental procedures. According to previous studies, 1–5 min of rest can make people relaxed and calm [35,36]; therefore, after putting on the instrument, the subjects closed their eyes for 1.5 min to reach a calm and relaxed state before starting the experiment. Participants were initially exposed to a 1.5 min stress video (traffic noise video, construction noise video, or noisy rock live video) to simulate daily high-pressure and mentally tense situations. Previous research has effectively used similar scenarios to induce physical and mental stress [37–39]. The experimenter closely monitored the participants' emotional states throughout the entire process and ensured that they had the right to withdraw from the stress video at any time. During the two-day experiment, two participants questioned slightly elevated sound levels, and the experimenter promptly addressed their concerns. Subsequently, pretest data for physiological and psychological measures (blood pressure, pulse, and positive and negative affect schedule [PANAS]) were collected. Ulrich's research has shown that immersion in a natural environment for 3–5 min yields significant physical and mental restoration effects [40]. Hence, after the pretest, participants viewed photos of the first greenway for 5 min (comprising 20 images, each displayed for 15 s). Following this, they completed various questionnaires (Perceived Restorativeness Scale [PRS], PANAS, and Environmental Characteristics Perception Scale) and underwent physiological data measurements, totaling 5 min for the post-test. When completing the questionnaire, a combination of photos of the current greenway landscape (involving all landscape features; see Supplementary Materials Figure S1 for details) was provided to help the participants perceive the overall environment of this type of greenway. After the post-test, the first section of the greenway experiment ended, totaling 15 min.

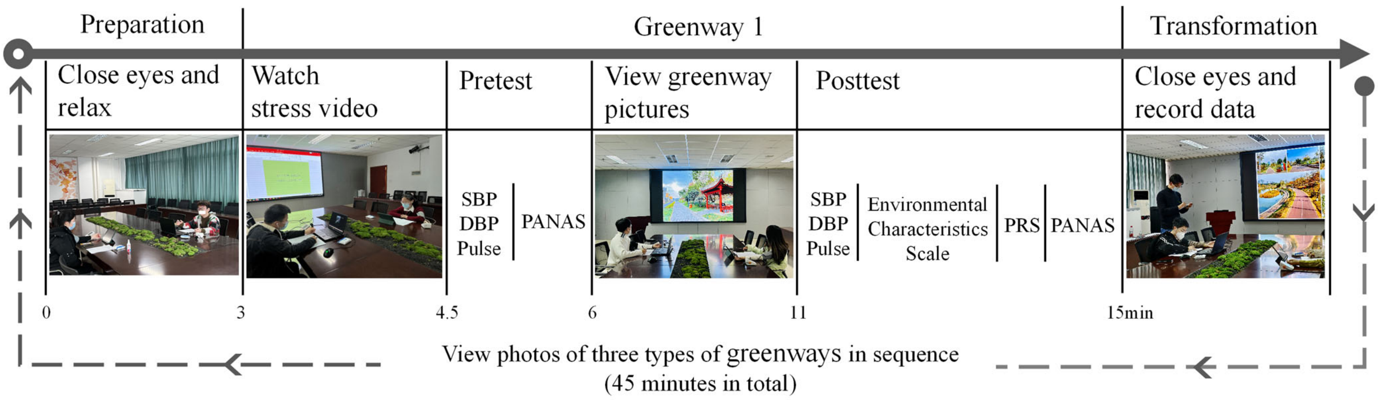

Figure 2. Experiment flow chart. SBP: systolic blood pressure; DBP: diastolic blood pressure; PANAS: positive and negative affect schedule; PRS: perceived restorativeness scale.

After viewing a greenway, the subjects sat quietly with their eyes closed for 1.5 min before viewing another type of greenway to eliminate the legacy effect. After the three greenway tests were completed, the subjects received their remuneration, and the experiment ended. The total experimental time for each participant was approximately 45 min. Notably, the experimenters simultaneously adjusted the viewing sequence of the greenways within each experimental group to eliminate order effects. For instance, there were six possible playback sequences, such as 1-2-3 (Group 1), 1-3-2 (Group 2), and 2-3-1 (Group 3). The total number of groups for morning or afternoon sessions was also six, completing a full cycle.

2.4. Measurements

2.4.1. Environmental Characteristics Measurement

The Greenway Environmental Characteristics Perception Scale reflects the overall environmental characteristics of urban greenways. The "Sichuan Province Urban and

Rural Greenway Planning and Design Standards (DBJ51/T097-2018)" divides greenway environmental elements into four categories: greenway trails, greenway vegetation, rest stations, and facility systems [41]. Liao divided the components of urban greenways into paths, plants, water systems, facilities, and signs [34]. Chang et al. roughly divided the construction characteristics of urban greenways into five categories: trails, nature, water bodies, facilities, and surrounding landscapes, and each characteristic is evaluated through the two dimensions of component type and construction quality [13,25].

Based on previous relevant research and combined with field surveys of urban greenways, we noticed that among the many environmental elements of greenways, pathways, vegetation, facilities, water bodies, and ornaments are most often mentioned and appear most frequently. Therefore, we initially divided greenway environmental characteristics into the above five environmental dimensions. Each dimension is evaluated mainly based on measurement indicators such as aesthetics, comfort, and richness. From the perspective of intuitive visual perception, aesthetics and richness are easier-to-perceive features of the landscape environment, while from the perspective of recreational experience, comfort is a more important influencing factor. In the end, there were approximately 3 items under each environmental dimension, using a 5-point Likert scale. The entire Greenway Environmental Characteristics Perception Scale measured a total of 5 environmental dimensions and 18 environmental characteristics. The scale subsequently passed reliability (Cronbach's alpha = 0.921) and validity (KMO = 0.907, Bartlett's test $p < 0.05$) tests. Each respondent completed the greenway characteristics scale after viewing each greenway landscape. The complete scale is shown in the Supplementary Materials (Table S1).

2.4.2. Physiological Measures

This experiment utilized a portable electronic blood pressure monitor (YUWELL, YE660C, Danyang, Jiangsu, China) placed on each participant's left arm to measure systolic pressure (mmHg), diastolic pressure (mmHg), and pulse rate (bpm). Each participant had their physiological data measured twice—once after the stress test and again after observing the greenway pictures. Blood pressure and pulse rate reflect the state of physiological arousal or relaxation in the human body [42,43].

2.4.3. Psychological Measures

According to ART and SRT, the relationship between UGSs and mental health is mainly based on perceptual recovery and emotional recovery. This study used the Perceived Restorativeness Scale (PRS) to measure the perceived restorativeness of greenways. This scale was developed by Hartig based on the ART proposed by Kaplan and evaluates the perceived restorative quality of an environment in terms of being away, fascination, compatibility, and extent [44,45]. To avoid respondent fatigue, this study adopted Huang et al.'s revised short version of the scale, which consists of a total of 18 items and passes reliability, validity, and confirmatory factor analysis tests [46]. Each respondent completed the PRS after viewing a section of the greenway landscape. The complete scale is shown in the Supplementary Materials (Table S2).

This study employed the Positive and Negative Affect Schedule (PANAS) to measure emotional recovery. The PANAS, developed by Watson et al. in 1988, is a well-established and widely recognized scale for assessing emotions. It consists of 20 items (10 for positive affect [PA] and 10 for negative affect [NA], arranged in random order) to gauge both positive and negative emotions [47,48]. Each participant completed the PANAS questionnaire twice—once after the stress test and again after viewing the greenway landscapes. The complete scale can be found in the Supplementary Materials (Table S3).

2.5. Statistical Analysis

This study utilized SPSS 26.0 (IBM Corp. Armonk, NY, USA) to first describe the participants' demographic characteristics and analyze their impact on physical and mental recovery. Subsequently, the data were tested for reliability and validity. Once validated, paired t-tests, one-way ANOVA, Wilcoxon signed-rank tests, and Kruskal-Wallis tests were employed to examine the influence of the type of urban greenway environment on physiological and psychological restoration benefits. Next, stepwise regression analysis was conducted to explore the relationships between various landscape characteristics of urban greenways and mental recovery.

3. Results

3.1. Urban Greenways and Physiological Recovery

The results of paired t-tests analyzing systolic and diastolic blood pressure as well as pulse data before and after viewing are presented in Figure 3. After observing the urban park-type greenways, participants exhibited significant decreases in systolic pressure (104.8 ± 14.7 and 103.0 ± 13.42, t = 2.367, p = 0.020) and diastolic pressure (68.2 ± 11.1 and 66.8 ± 12.0, t = 2.061, p = 0.042), while pulse did not significantly change (77.6 ± 10.2 and 77.4 ± 10.7, t = 0.216, p = 0.829). After observing urban river-type greenways, participants showed highly significant decreases in systolic pressure (104.5 ± 14.1 and 102.4 ± 14.6, t = 2.838, p = 0.006), whereas diastolic pressure (67.83 ± 11.8 and 67.10 ± 11.1, t = 1.290, p = 0.200) and pulse (77.16 ± 10.9 and 76.33 ± 10.3, t = 1.370, p = 0.174) exhibited no significant changes. Following the observation of urban road-type greenways, participants showed no significant changes in their physiological parameters (systolic pressure [103.9 ± 13.0 and 103.2 ± 12.5, t = 0.776, p = 0.440], diastolic pressure [67.5 ± 11.1 and 67.3 ± 12.3, t = 0.366, p = 0.716], or pulse [77.6 ± 10.6 and 77.2 ± 10.8, t = 0.583, p = 0.561]).

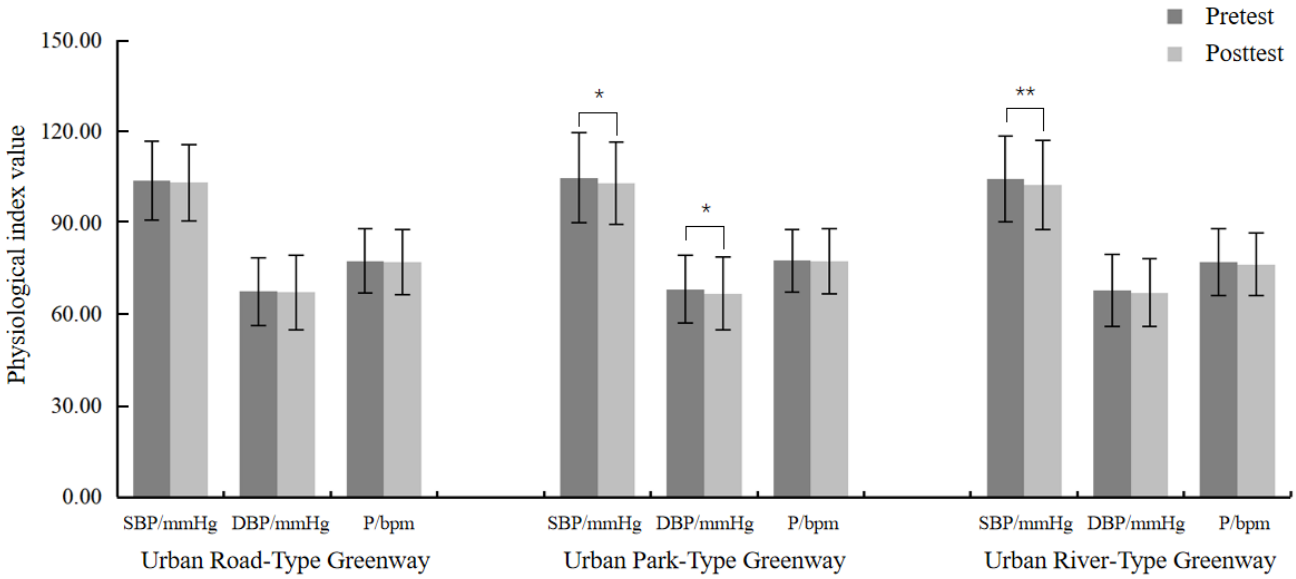

Figure 3. Blood pressure and pulse changes before and after participants viewed the three types of greenways. n = 93; means ± SDs; * $p < 0.05$, ** $p < 0.01$; validated by paired t-tests.

3.2. Urban Greenways and Psychological Restoration

3.2.1. Emotional Recovery

As shown in Figure 4, after observing the three urban greenway types, participants demonstrated significant increases in PA scores and significant decreases in NA scores, albeit with varying degrees of change. Wilcoxon signed-rank tests revealed that after observing urban road-type greenways, participants exhibited significant increases in PA (1.80 and 2.60, Z = 7.424, $p < 0.01$) and significant decreases in NA (2.80 and 1.10, Z = −8.296, $p < 0.01$). Following the observation of urban park-type greenways, participants showed significant increases in PA (1.80 and 3.20, Z = 8.088, $p < 0.01$) and significant decreases in NA (2.80 and 1.10, Z = −8.377, $p < 0.01$). Similarly, after observing urban river-type greenways, participants displayed significant increases in PA (1.80 and 3.00, Z = 8.009, $p < 0.01$) and significant decreases in NA (2.50 and 1.10, Z = −8.187, $p < 0.01$). The results also indicated that after observing the three types of greenways, the urban park-type greenways yielded the highest PA scores and the lowest NA scores.

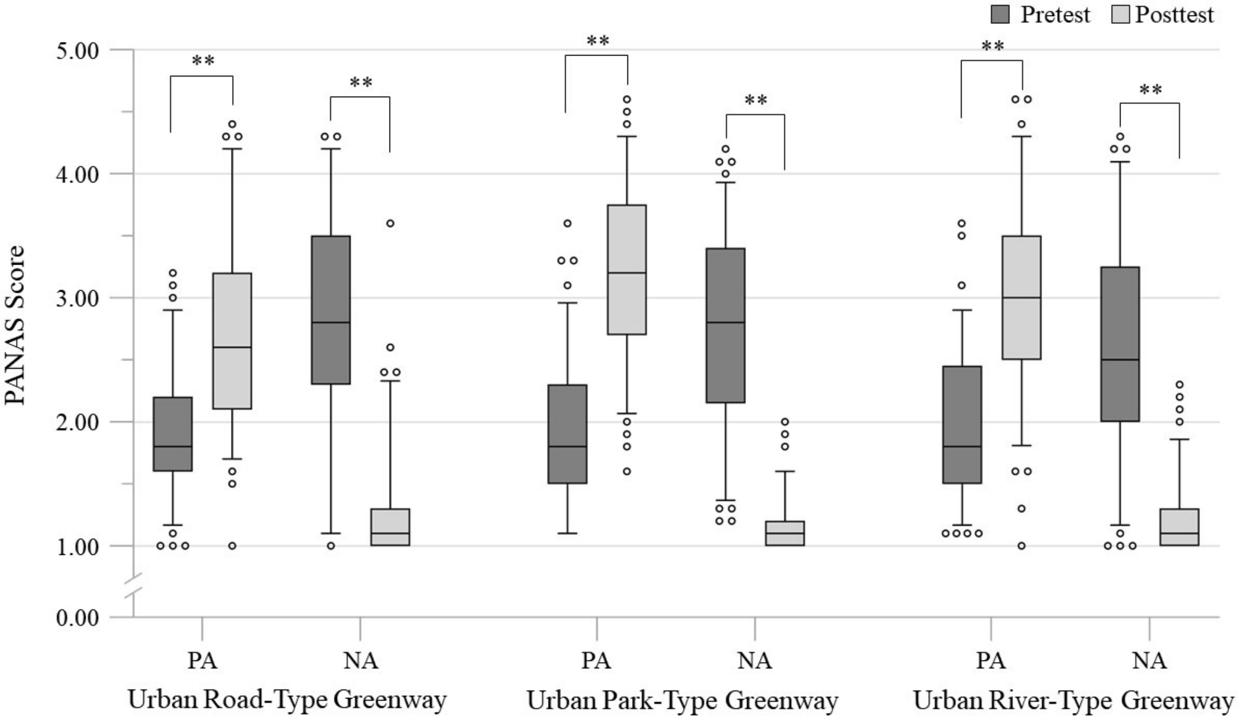

Figure 4. Changes in the PANAS scores before and after participants viewed the three greenway types. PA: positive affect; NA: negative affect. $n = 93$; the data shown are medians (central lines), interquartile ranges (box margins), adjacent values (whiskers), and outliers (dots); ** $p < 0.01$; validated by paired Wilcoxon tests.

After further comparing the increases in PA, decreases in NA, and total emotional changes (the sum of the former two), for the three types of greenways (Figure 5), the Kruskal-Wallis test revealed significant intergroup differences in the increases in PA (H = 22.832, d.f. = 2, $p < 0.01$) and total emotional changes (H = 10.041, d.f. = 2, $p < 0.01$) among participants after visiting different greenways. However, there was no significant intergroup difference in the decrease in NA (H = 2.972, d.f. = 2, $p = 0.226$). Bonferroni post hoc correction was used for pairwise comparisons among groups that showed significant intergroup differences. The increases in PA in urban park-type greenways were significantly greater than those in urban road-type (1.30 and 0.60, adjusted $p < 0.01$) and urban river-type greenways (1.30 and 1.00, adjusted $p < 0.05$). Additionally, the increases in PA in urban river-type greenways were significantly greater than those in urban road-type greenways (1.00 and 0.60, adjusted $p < 0.05$). In terms of total emotional change, the urban park-type greenways exhibited significantly greater changes than did the urban road-type (2.80 and 2.00, adjusted $p < 0.01$) and urban river-type greenways (median: 2.80 and 2.30, $p < 0.05$).

A stepwise linear regression analysis was performed on the emotional recovery ability of urban greenways and various environmental characteristics (Table 1). The results showed that the environmental characteristics of the three types of urban greenways explained 32.8%, 21.9%, and 8.8% of the emotional recovery benefits. For urban road-type greenways, suitable pathway width (β = 0.273, t = 3.025, $p = 0.003$), an abundance of landscape ornaments (β = 0.234, t = 2.361, $p = 0.020$), and well-maintained pathway paving (β = 0.211, t = 2.194, $p = 0.031$) emerged as crucial environmental factors enhancing emotional recovery capacity. Interestingly, a negative correlation was found between good water affinity (β = −0.531, t = −3.456, $p = 0.001$) and the emotional recovery potential of urban road-type greenways. Within urban park-type greenways, rich plant colors (β = 0.253, t = 2.540, $p = 0.013$), good vegetation shading effects (β = 0.246, t = 2.641, $p = 0.010$), and suitable pathway widths (β = 0.228, t = 2.269, p = 0.026) were identified as key environmental features that enhance emotional recovery capacity. Rich plant layers (β = 0.313, t = 3.141, p = 0.002) emerged as a key feature in boosting the emotional recovery capacity of urban river-type greenways.

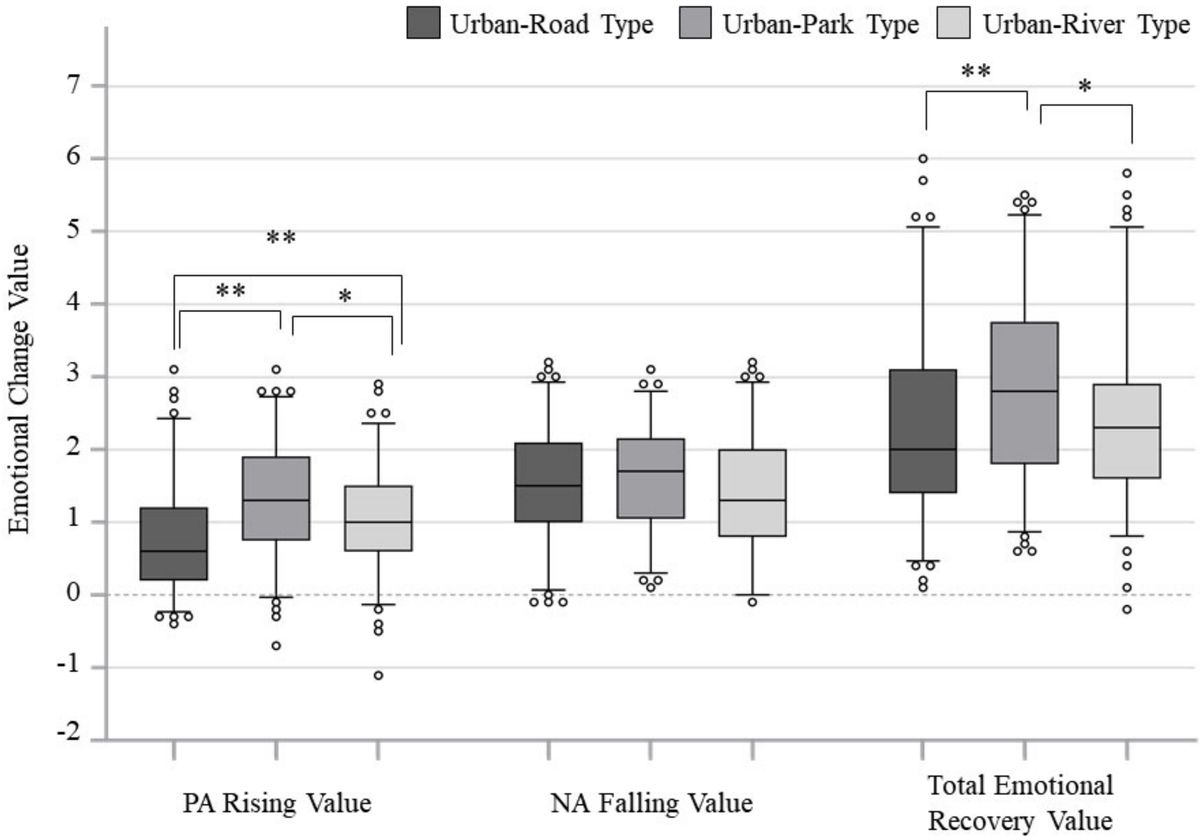

Figure 5. Differences in PA, NA, and total emotional recovery values among the three greenway types. n = 93; the data shown are the medians (central lines), interquartile ranges (box margins), adjacent values (whiskers), and outliers (dots); * $p < 0.05$, ** $p < 0.01$; validated by the Kruskal-Wallis test.

Table 1. Key landscape characteristics for emotional recovery.

Dependent and Independent	Standardized Beta	t	p	Collinearity Statistics	
				Tolerance	VIF
Urban Road Type (Adj. R^2 = 0.328; p < 0.001)					
Suitable pathway width	0.273	3.025	0.003	0.895	1.117
Good water affinity	−0.531	−3.456	0.001	0.310	3.226
Abundance of landscape ornaments	0.234	2.361	0.020	0.743	1.346
Well-maintained pathway paving	0.211	2.194	0.031	0.788	1.269
Urban Park Type (Adj. R^2 = 0.219; p < 0.001)					
Suitable pathway width	0.228	2.269	0.026	0.840	1.190
Good vegetation shading effect	0.246	2.641	0.010	0.978	1.023
Rich plant colors	0.253	2.540	0.013	0.856	1.169
Urban River Type (Adj. R^2 = 0.088; p < 0.005)					
Rich plant layers	0.313	3.141	0.002	1.000	1.000

Note: The dependent variable is the mean emotional recovery. Correlations were considered significant at the $p < 0.05$ level.

3.2.2. Perceived Restoration

Table 2 shows the differences in scores among the three types of greenways across PRS dimensions. The PRS total score was analyzed using one-way ANOVA, while the other four dimensions were assessed using the Kruskal-Wallis rank-sum test. The results indicate significant intergroup differences between the three greenway types across all PRS dimensions: being away [d.f. = 2, H = 47.908, $p < 0.01$]; extent [d.f. = 2, H = 41.489, $p < 0.01$]; fascination [d.f. = 2, H = 59.207, $p < 0.01$]; compatibility [d.f. = 2, H = 50.938, $p < 0.01$]; and PRS total score [d.f. = 2, F = 36.69, $p < 0.01$]. Except for the being away dimension, urban park-type greenways scored significantly higher than did urban road-type and urban river-type greenways across all PRS dimensions. Urban river-type greenways also scored significantly higher than did urban road-type greenways across all PRS dimensions. There was no significant difference in the scores of urban park-type greenways and urban river-type greenways in the being away category, but they were both higher than the scores of urban road-type greenways.

Table 2. Differences in PRS scores among the three greenway types (n = 93).

	Being Away	Extent	Fascination	Compatibility	Overall Restoration
Urban road type	4.00 [b]	4.00 [c]	4.25 [c]	4.20 [c]	4.15 [c]
Urban park type	5.60 [a]	5.50 [a]	5.50 [a]	5.60 [a]	5.39 [a]
Urban river type	5.00 [a]	5.00 [b]	5.25 [b]	5.00 [b]	5.02 [b]

Note: Verified by the Kruskal-Wallis test and one-way ANOVA. Different lowercase letters indicate that the PRS scores are significantly different among the different greenway types at $p < 0.05$ according to the Bonferroni correction.

A comparison of the scores across various PRS dimensions for the three types of greenways is presented in Table 3. For urban roadway greenways, there were higher scores for extent and compatibility, while being away and fascination scored lower. For urban park-type greenways, there were higher scores for fascination and compatibility and slightly lower scores for being away and extent. For urban river-type greenways, the scores were greater for fascination and extent but lower for compatibility and being away.

Table 3. PRS score differences for each greenway type (n = 93).

	Urban Road Type		Urban Park Type		Urban River Type	
	Mean Rank	**Ranking**	**Mean Rank**	**Ranking**	**Mean rank**	**Ranking**
Being away	182.69	3	183.20	3	179.00	4
Extent	194.30	1	179.80	4	188.10	2
Fascination	178.61	4	195.44	1	195.28	1
Compatibility	190.40	2	187.56	2	183.62	3

Note: Verified by the Kruskal-Wallis test. A rank was awarded to each PRS dimension based on the mean rank.

Stepwise linear regression analysis of the perceived restoration ability and environmental elements of urban greenways (Table 4) revealed that the environmental characteristics explained 64.2%, 46.2%, and 49.0% of the perceived restoration benefits for the three types of urban greenways, respectively. Rich plant layers (β = 0.287, t = 3.620, $p < 0.001$) and well-maintained service facilities (β = 0.236, t = 3.309, p = 0.001) emerged as key environmental factors for enhancing the perceived restoration ability of urban road-type greenways. Rich plant layers (β = 0.441, t = 5.295, $p < 0.001$), good water affinity (β = 0.242, t = 2.881, p = 0.005), and suitable pathway slopes (β = 0.238, t = 2.907, p = 0.005) were pivotal environmental features for enhancing the perceived restoration ability of urban park-type greenways. For urban river-type greenways, rich plant layers (β = 0.254, t = 2.626, p = 0.010), high aesthetic quality of the water body (β = 0.387, t = 4.725, $p < 0.001$), and high aesthetic value of landscape ornaments (β = 0.241, t = 2.874, p = 0.005) were key environmental elements for increasing restoration ability.

Table 4. Key landscape characteristics affecting perceived restoration.

Dependent and Independent	Standardized Beta	t	*p*	Collinearity Statistics	
				Tolerance	VIF
Urban Road Type (Adj. R^2 = 0.642; $p < 0.001$)					
Rich plant layers	0.287	3.620	0.000	0.619	1.617
Well-maintained service facilities	0.236	3.309	0.001	0.765	1.307
Good vegetation shading effect	0.163	2.337	0.022	0.805	1.243
High pathway comfort	0.160	2.055	0.043	0.642	1.557
Urban Park Type (Adj. R^2 = 0.462; $p < 0.001$)					
Rich plant layers	0.441	5.295	0.000	0.841	1.190
Suitable pathway slope	0.238	2.907	0.005	0.874	1.144
Good water affinity	0.242	2.881	0.005	0.827	1.209
Urban River Type (Adj. R^2 = 0.490; $p < 0.001$)					
Rich plant layers	0.254	2.626	0.010	0.591	1.691
High aesthetic quality of the water body	0.387	4.725	0.000	0.827	1.210
High aesthetic value of landscape ornaments	0.241	2.874	0.005	0.785	1.273
Rich plant colors	0.211	2.320	0.023	0.668	1.496
Adequate service facilities	−0.186	−2.264	0.026	0.823	1.214

Note: The dependent variable is the perceived restoration mean. Correlations were considered significant at the $p < 0.05$ level.

4. Discussion

4.1. Greenway Environment Types and Psychophysiological Recovery

This study explored the psychophysiological recovery effects of individuals exposed to various types of greenway environments. The results indicate that participants experienced varying degrees of psychophysiological restoration after observing the three types of greenways. However, significant differences were observed between the levels of physical relaxation, emotional states, and perceptual recovery abilities associated with these types of greenway environments. This confirms that distinct environmental types have varied effects on the psychophysiological recovery of individuals [22,38], further emphasizing the crucial role of specific environmental characteristics in the restoration experience [18].

Compared to the other two types of greenways, urban park-type greenways demonstrate superior psychophysiological recovery potential. From the perspective of the resources it relies on, urban park-type greenways built on city parks have richer plant communities, which can create a shaded environment and improve the comfort of the microclimate, which is helpful for physiological relaxation [49,50]. Over the last decade, numerous studies have indicated the substantial role of the perceived sensory dimensions (PSDs) of green spaces in facilitating restoration experiences and psychological well-being [51–53]. Most urban park-type greenways have wide lawns on both sides. Natural environments with abundant activity venues and wide views may have extended the space and prospects of urban park-type greenways, increasing the possibility of restoration and generation, and the higher sky openness also improved the physiological and psychological recovery capabilities [54,55]. Therefore, the natural park landscape and open green space environment may jointly improve the fascination and compatibility of urban park-type greenways (Table 3) and promote the healthy restoration benefits of this type of greenway environment. Previous studies have shown that an optimal restorative environment requires a balance of dense vegetation and open views [52,56], and our results support this view. It also aligns with the refuge–prospect theory proposed by Appleton, suggesting that both refuge and prospect landscape qualities are crucial for human survival [57]. The rich trees and shrubs flanking urban park-type greenways might create a refuge for visitors by forming sheltered spaces, while interspersed open grasslands provide a prospect. Such environments with clear views and hiding locations significantly enhance individuals' capacity for health recovery [58].

Urban river-type greenways also possess strong restoration potential. Evidence suggests that exposure to blue spaces can trigger positive physiological and psychological responses [59,60]. Our results further confirm that urban river greenways can not only reduce cortisol levels [24] but also effectively reduce systolic blood pressure. In further detail, urban rivers serve as crucial "air lanes", providing not only cooling but also fresh air to citizens [61–63], collectively increasing physical comfort. On the other hand, certain visual (reflection of light) and auditory (sound of running water) properties of rivers are also potentially attractive and restorative, helping to trigger positive associations and promote psychological recovery [19,64]. From an evolutionary perspective, urban river-type greenways are located at the interface between land and water bodies. Such habitat intersections tend to have stronger biodiversity and are more likely to meet human life needs [65], which has evolutionary significance [19,66,67], and this may cause a positive reaction in the human body. Notably, this experiment occurred in the dry seasons of autumn and winter in Sichuan Province, when the river water level was low and the water body and riverside landscape were boring. Previous studies have shown a strong positive correlation between aesthetic preferences and restoration potential [23,37], and the aesthetic quality of water bodies and riverside plants is an important restoration attribute [68,69]. Therefore, the restorativeness of urban river greenways in this study may have been affected by seasonal deviation.

Urban road-type greenways exhibit weaker environmental restorative characteristics than do other types of greenways. The findings indicate that after experiencing the urban road-type greenways, participants exhibited weaker perceived restoration capabilities in terms of the dimensions of being away and fascination (Table 3). Being away provides a strong contrast between the environment and daily life, as well as an escape from mundane concerns and worries. Fascination occurs when the environment is sufficiently interesting to effortlessly capture people's attention, and both are crucial predictive factors affecting psychological health restoration [70,71]. Hartig suggested that the motivation for visiting green spaces may stem from a desire to escape the stress of urban environments [72]. Research by Macaulay et al. demonstrated that mind wandering in nature may be more effective in improving mood and relieving stress than other forms of experiences, possibly influenced by "a sense of psychological distance from work" [73,74]. These findings align with our observations. Urban road-type greenways are generally constructed between urban roads and buildings along streets. In comparison to the other two types of greenways, these greenways are narrower and more susceptible to external traffic disturbances. After seeing the urban roads and unnatural artificial elements beside such greenways, subjects may associate them with heavier traffic flow and artificial noise and are more likely to think of trivial matters of daily study and work, thereby reducing the remoteness of the environment. A narrower width also makes it more difficult for urban road-type greenways to carry rich landscape structures, thus affecting the generation of fascination and further weakening the recovery benefits of urban road-type greenways. Therefore, when planning urban road-type greenways in the future, it is possible to enhance their restoration benefits by integrating multiple vertical levels of natural vegetation to reduce traffic noise, enhance the sense of "being away", and simultaneously increase their fascination.

4.2. Greenway Environment Characteristics and Psychological Restoration

This study further explored the differences in the restorative capacity of different greenway environmental characteristics. Rich plant colors and layers are identified as crucial environmental features for promoting emotional and perceptual recovery across three types of urban greenways. On the one hand, numerous studies have shown that nature-related environmental features, such as trees, shrubs, and lawns, can enhance subjective well-being (SWB) and positive affect by influencing connectedness to nature (CTN) [75,76], and our study supports these findings. On the other hand, this emphasizes that the complexity and diversity of landscapes not only bring rich perceptual experiences, enhance environmental preferences [77], and provide resources to meet different needs and behavioral goals [24] but can also increase positive affect by enhancing the perceived wildness of urban greenways [78], thus enhancing recovery benefits. At the same time, compared to other grey infrastructures in cities, the rich strip vegetation in urban greenways significantly enhances ecological connectivity and biodiversity by connecting habitat patches [79–81]. It is more likely to inspire the biophilic characteristics of human beings who love nature and desire to be subordinate to nature [82] and thus promote psychological health recovery [83]. This finding aligns with the biophilia hypothesis, suggesting that humans have an inherent tendency and innate impulse to connect with other forms of life in the evolutionary process [84]. Therefore, landscapes rich in natural elements are often more favored by people. In conclusion, when constructing urban greenways, the rich attributes of their natural elements can be appropriately enhanced to enhance overall psychological restorativeness.

The restorative characteristics of urban river-type and urban road-type greenways, beyond requiring natural richness, differ in emphasis. The former emphasizes aesthetics, while the latter emphasizes comfort. The results show that high-aesthetic-value water bodies and landscape ornaments are crucial environmental characteristics influencing the perceptual restoration of urban river-type greenways. Interestingly, this finding aligns with findings in another similar study on urban river-type greenways: urban river greenways with unclean water bodies and no landscaping may reduce the aesthetic quality of the natural landscape and be detrimental to mental health recovery [28]. We tried to analyze the reasons: why the quality of landscape elements will enhance users' participation in outdoor activities and promote health recovery [13,85]. The water body itself is an important predictor of the restoration of UGSs [86], and as the main support of urban river-type greenways, the aesthetic quality of rivers has a self-evident impact on the overall restoration effect of the greenway environment. In more detail, for water bodies, aesthetic quality (good water quality and a natural visual form) is considered the most crucial restorative attribute [87]. An unsightly river environment can make observers think of unpleasant odors and reduce the attractiveness of water [88]. Poorly maintained landscape structures may be associated with criminal activity because of their cluttered appearance [89], reducing perceived safety. Together, these factors may influence the impact of aesthetic quality on the restorativeness of urban river-type greenways.

In urban road-type greenways, higher road comfort, well-maintained pavements and facilities, and appropriate road width are pivotal factors influencing psychological restoration. Related studies indicate that environmental restorativeness is influenced not only by the environmental quality of green spaces but also by the motivations of residents using these areas [90]. According to the theory of planned behavior (TPB), the main variables that affect behavioral intentions include behavioral attitudes, subjective norms, and perceived behavioral control [91,92]. In other words, the more positive a person's attitude before performing a specific behavior and the stronger the influence he feels from others, the less difficult it is to perform the behavior and the more positive the person's behavioral intention will be. Urban road-type greenways are mostly close to urban arterial roads. Compared with other greenways and sidewalks, they have stronger traffic accessibility and a more comfortable walking environment, making it easier for residents to have behavioral intentions for commuting and exercise [31]. Hence, the functionality and experiential comfort of these greenway environments can significantly impact people's emotions and perceptions. Notably, there is a negative correlation between water body affinity and the emotional restoration capability of urban road-type greenways. Combining surveys and analysis, this could be because water bodies in urban road-type greenway environments are often connected to roadside drains, making them prone to human-induced pollution. This results in poor water quality and aesthetics, discouraging people from approaching these areas and thereby reducing their restorative benefits. Overall, while ensuring the richness of natural elements, the aesthetic attributes and comfort of urban river-type and urban road-type greenways must be selectively enhanced. This will ultimately enhance the overall restorative potential of urban greenway environments.

4.3. Limitations and Future Studies

Firstly, the participants in this study were relatively young (mean age = 23.15 ± 2.32 years). Future research should broaden the demographics of participants to include individuals of all age groups and from more diverse social and cultural backgrounds and increase the sample size (to over 300 participants) to enhance the generalizability of conclusions in a more universally objective context. Secondly, the single visual stimulus presented by an image as experimental material may limit the subject's perceptual ability. For example, visual–auditory stimulation has stronger health recovery potential than a single visual stimulus [77]. Therefore, in the future, quantitative research can be conducted in outdoor environments using multisensory and multiple physical and mental measurement methods. This will enable a more comprehensive exploration of the effects of greenway environmental stimuli on health recovery. In addition, further research is needed to determine specific design standards for environmental features that influence recovery (e.g., the optimal visible green index, the width of greenway pathways, and the quantity of facilities). Finally, different seasons will also affect the restorativeness of the environment [93]. This study selected only greenways in autumn in Chengdu as stimulus materials, which may have introduced potential seasonal and regional biases. In the future, longitudinal studies should also be conducted to investigate the effects of regular exposure to various urban greenways across different seasons on both physical and mental health. These issues need to be addressed in a transdisciplinary way also involving psychology or health skills. This will allow for the assessment of the long-term, widespread benefits of greenway exposure on overall well-being.

5. Conclusions

Although many studies have proven that urban greenways have a positive impact on human well-being, to our knowledge, this study is the first to systematically compare the health restoration effects of different environmental types and landscape characteristics of urban greenways. Our research results emphasize the importance of guiding urban greenway planning and design based on different environmental types, providing novel references for policymakers and planners. First, different environmental types of urban greenways have different restorative effects, with urban park-type greenways offering the best restoration experience. Second, rich plant colors and layers are important restorative environmental features for every type of urban greenway. At the same time, for urban river-type greenways, waterscapes and ornaments with high aesthetic value are important restoration attributes; for urban road-type greenways, the comfort of facilities and pathways has a significant impact on promoting restoration. These findings suggest that when designing urban greenways, specific environmental elements and characteristics should be selected and configured for different types of urban greenways to maximize the public's restorative experience. This study provides nature-based solutions for achieving high-quality urbanization by exploring the positive impact of urban greenway environments on physical and mental health.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/f15040679/s1, Figure S1: Three types of urban greenway experiment pictures; Table S1: Greenway Environmental Characteristics Perception Scale; Table S2: Short version of the Revised Perceived Restorativeness Scale (PRS); Table S3: The Positive and Negative Affect Schedule (PANAS).

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