

Article

Exploring the Impact of Campus Landscape Visual Elements Combination on Short-Term Stress Relief among College Students: A Case from China

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Abstract: Although the effect of campus landscape space on stress relief among college students has been confirmed, few existing studies have considered the impact on stress recovery from the perspective of factor combination, and the key visual elements and the most effective combination of visual elements to relieve stress are still unclear. This study attempts to conduct a natural experiment within Chinese campuses, measuring physiological indicators of stress such as heart rate (HR), frequency domain index of heart rate variability (LF/HF), skin conductance level (SCL), skin temperature (SKT), and respiratory rate (RESP) using physiological instruments. It explored the effects of visual elements and their combinations in campus landscape spaces on short-term stress relief among college students through semantic segmentation, multifactorial analysis of variance, and post hoc multiple comparison methods. Research results demonstrate that the presence of water elements in the field of vision can effectively improve the stress relief effects of landscape spaces. Reasonable combinations of natural landscape elements and artificial landscape elements in the design can also effectively promote stress relief among students. Building facade area and sky area, water area and sky area, and plant species and pavement area are three combinations of factors with the strongest interactive effects. “Natural water scenery” and “exquisite artificial” are two campus landscape design patterns most conducive to short-term stress relief.



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Keywords: campus; landscape; visual elements; stress relief; element combinations

1. Introduction

Studies have shown that the transition from late adolescence to early adulthood is a high-risk period for psychological issues [1,2], coinciding with the stage of university education [3]. Evidence from a study involving 15 countries during the COVID-19 pandemic indicates that 31.2% of college students exhibit symptoms of depression, with a stress morbidity rate of 26.0% [4]. A study in China shows that over 30% of Chinese college students suffer from depression [5,6]. Entering university entails facing multiple pressures, such as social role transitions, changes in the living environment, detachment from previous social relationships, and academic demands [7]. Numerous pieces of evidence indicate that accumulated stress during this period can lead to negative psychological states such as pessimism, anxiety, and depression among adolescents who are sensitive in their psychosocial development [8–11]. This, in turn, affects various aspects of academic success, including academic performance, career development, interpersonal relationships, work efficiency, and academic functioning. Without a timely intervention, it may also lead to the onset of mental illnesses. As college students represent the reserve force for driving future technological development and social progress, a healthy psychological state is the primary prerequisite for fully realizing their own value and potential. This suggests that the mental health status of college students will also, to some extent, influence the future development and health trends of society, necessitating focused attention and

collaborative efforts from all sectors of society [12]. Currently, there are increasing numbers of psychological counseling and intervention methods aimed at helping college students alleviate mental stress. However, due to the hidden nature of psychological stress and feelings of shame associated with mental illness, this measure has not achieved significant results. The psychological pressure within the college student population continues to grow and become more acute, making it a focal point for the prevalence of mental health issues [1,13,14]. As the most direct and frequently used natural spaces for college students, people are beginning to pay attention to the numerous benefits that campus landscape spaces provide to students. Several studies have shown that campus landscape spaces have benefits, such as stress relief, attention restoration, physical activity and social interaction promotion, and academic performance improvement [15–19]. These spaces offer an environmental intervention measure for alleviating stress among college students. How to construct campus landscape environments that promote the mental health of college students and fully utilize the natural healing effects of landscapes has become a topic of interest for many scholars.

2. Literature Review

2.1. Theoretical Basis

The biophilia hypothesis [20], attention restoration theory [21–23], and stress restoration theory [24,25] suggest that the health benefits of stress recovery in most natural environments can also promote improvements in the emotional state of perceivers, restoration of directed attention, and beneficial physiological changes [26–30]. These theories provide a solid theoretical foundation for research. The stress restoration theory posits that stress is the process by which individuals respond to threatening or challenging external stimuli in psychological, physiological, and behavioral forms. When individuals' coping abilities fail to adapt to environmental demands, it can lead to the development of negative emotions and physiological responses and even evoke avoidance behaviors. Visual landscapes can influence individuals' emotional states; observing natural or urban landscapes may affect personal perceptions and have significant positive or negative effects on the body. This theory emphasizes the visual characteristics of the environment and the aesthetic and emotional responses they evoke. In his book *The Hidden Dimension*, Hall analyzed proportion data of the human senses [31], revealing that vision accounts for 78% of the sensory system. Due to the difficulty in capturing attributes such as olfaction, taste, and touch, along with the subjective limitations of the human body [32], vision is considered the most important sensory form for perceiving the objective world. It can simultaneously convey environmental stimuli with good temporal and spatial resolutions [33]. Therefore, investigating the impact of visual landscape elements on the stress recovery of college students is of significant importance.

2.2. Research Progress

Most existing research on landscape and stress recovery primarily focuses on quantitative studies or a combination of quantitative and qualitative research types, with fewer purely qualitative studies. Previous qualitative studies often used descriptive words to express people's perception of landscapes by constructing an evaluation index system. Although it has the advantage of easy operation, it is difficult to summarize accurate conclusions and effectively explain landscape attributes. Consequently, many scholars have attempted to use quantitative experimental methods to explore the impact of visual landscapes on stress recovery, primarily divided into two categories. One category primarily focuses on comparative studies of the differences in stress recovery effects among different landscape spaces, involving various landscape types (plazas, woodlands, flower fields, lake views, etc.) [34,35] and vegetation structures (open, semiopen, enclosed, etc.). For example, Ping Zhan and others selected three types of landscape spaces on university campuses as experimental environments, comparing the differences in physiological indicators, emotional states, and perceptual recovery among them. They found that all three types of

spaces had some impact on relaxing participants' mental states [12]. Mohamed Elsadek and others chose landscapes in Vancouver, Canada, and Japanese and architectural gardens as experimental sites, discovering that the Japanese garden attracted more attention, and the duration of attention varied depending on the garden style [36]. However, these studies mainly explore which types of landscape spaces have better stress recovery effects from the overall perspective of environmental scenes; the duration of the gaze varies depending on the garden style. Another category involves attempting to establish measurable indicators describing the objective features of landscapes and using mathematical methods to explore the mathematical relationships between landscapes and specific health indicators. Some scholars believe that taking a detailed perspective on environmental elements makes it possible to identify which specific landscape elements or features positively impact stress recovery. This approach can better provide scientific evidence for practice. Additionally, advancements in technologies such as computer vision and image processing enable the precise measurement of landscape visual features, promoting the transition of research from traditional qualitative evaluation to technological, quantitative, and scientific development. A few studies have employed the construction of multivariate models to explore the relationships between landscape elements and psychological recovery, whether promoting or inhibiting. These studies involve visual elements such as plant diversity, tree coverage density, and water bodies [37–39]. For example, Huang Q measured the perceived stress differences among three types of courtyards: grass, trees, and concrete [40]. Jaeyoung Ha and others confirmed the relationship between the composition ratio of trees, grass, and water elements in green spaces in Chicago and the reported level of psychological distress in individuals [41].

2.3. Insufficient Research

Existing research has produced relatively rich research results but has focused mainly on the relationship between the effects of individual landscape elements and stress recovery. In fact, landscape spaces are not formed and presented in isolation by individual landscape elements alone. Instead, they are composed of combinations of multiple landscape elements, which evoke physiological and psychological responses in individuals through the overall picture presented by the objective environment. Solely focusing on the positive or negative effects of a single element often overlooks the interaction and combination relationships among elements, making it difficult to grasp the general principles of how landscape spaces function fully. This limitation restricts the application scenarios and effectiveness of research conclusions. Considering the comprehensive benefits of visual element combinations on stress recovery is more practically meaningful in the design and management processes. However, current research rarely considers the interaction of multiple landscape elements or examines the impact of stress recovery from the perspective of element combinations. Therefore, we need more examples to increase the detailed understanding of visual landscape elements for stress recovery.

Exploring the impact of campus visual landscape element combinations on short-term stress relief in college students is important in providing scientific evidence for creating psychologically healthy university campus environments. This paper takes the Huazhong University of Science and Technology campus as the research area. Physiological experiments are conducted by recruiting experimental subjects, measuring psychological indicators, and designing experimental procedures. Multiple factor analysis and other methods are employed to explore the key visual elements and combinations of elements that are most effective in relieving student stress, supplementing research on the impact of stress recovery from the perspective of visual element combinations. This paper aims to achieve three main objectives: First, explore the most beneficial visual elements in campus landscapes for promoting stress relief in college students. Second, introduce interaction terms to investigate the effects of element combinations. Finally, explore the most effective landscape design patterns for alleviating stress in college students. The research hopes to enrich theoretical studies related to restorative environments while providing landscape

designers with scientific evidence and design guidance for updating campus landscape spaces, thereby providing more directions for efforts to maintain the physical and mental health development of college students.

3. Materials and Methods

3.1. Landscape Space Selection

The Huazhong University of Science and Technology has two campuses, old and new, and its diverse built environment enables it to cover most types of campus landscapes. The campus covers an area of about 470 hectares, with a green coverage rate of up to 72%, earning it the nickname “Forest University”, and it boasts a considerable amount of natural space. Moreover, as a well-known high-level university in China, the Huazhong University of Science and Technology has more than 50,000 undergraduate and graduate students, who face heavy academic pressure and need more campus landscapes for relaxation. Whether from the campus environment or student needs, selecting this campus for research is highly representative.

In order to make the research results have authenticity and practical application value, this paper carefully combed through the existing scholars’ methods of dividing typical campus landscape types in China [42]. Taking 20% of the total number of each landscape space type as standard, 45 landscape spaces with different scales, forms, and design features were selected as samples, which comprehensively covered various landscape types of the campus (Figure 1).



Figure 1. Distribution of landscape space samples.

3.2. Participant Recruitment

Participants were recruited voluntarily for landscape experience both online and offline in the university. A total of 54 participants from different majors and grades were recruited. Personal information surveys were conducted, which included gender, age, academic stage, major, and initial stress levels. The initial stress level was assessed using the College Student Stress Scale developed by Li Hong in 2002 [43]. Group consistency tests were performed when assigning participants to each experimental site to eliminate potential group differences that could impact the study results. This was performed to mitigate external factors and enhance the internal validity of the experiment. The number of participants at each experimental site ranged from 4 to 5 individuals, and the same student could participate in multiple experiments. In total, 228 independent experimental

participants were involved. Detailed descriptive statistics of participant attributes for all experimental sessions are presented in Table 1.

Table 1. Recruitment of students' sociodemographic characteristics.

Indicator	Quantity
Gender	Male (1) = 78; Female (2) = 150
Age	Mean = 23; Median = 23; Minimum = 16; Maximum = 26; Standard Deviation = 2.53
Academic Stage	Undergraduate (1) = 75; Master's (2) = 143; Ph.D. (3) = 10
Major	Humanities (1) = 40; Science (2) = 10; Engineering (3) = 178
Initial Stress Level	Mean = 28; Median = 25; Minimum = 2; Maximum = 65; Standard Deviation = 14.72

Source: this study (own contribution).

3.3. Experimental Procedure Design

The experiment was scheduled from 27 October to 3 November 2022, during early autumn, with pleasant weather and rich vegetation displaying diverse color changes. The average temperature and wind speed during the experiment were 22 to 29 °C and 2 to 3 levels, respectively, maintaining stable external weather conditions.

We conducted 45 repeated experiments over 9 consecutive days, with five experimental locations each day. The duration at each location was controlled to be approximately 50 min, avoiding exposure to harsh midday sunlight and insufficient evening light. The basic experimental procedure is as follows (Figure 2): First, we arranged participants to sit indoors to calm their emotions and measure the baseline physiological stress level. Next, following a predetermined route, participants were led to various landscape spaces, where they engaged in short periods of sitting, while simultaneous measurements of their momentary physiological stress indicators were taken. To mitigate the cumulative effects of landscape exposure and emotional influences during the journey, participants were given sufficient time to adjust their emotions before entering the next testing point. Once the physiological indicators stabilized, data collection was conducted. During the experiment, a staff member was responsible for capturing five on-site photos from the participant's perspective (top, front, rear, left, and right). These photos would be used to calculate visual environment indicators (refer to Figure 3). This design facilitated a comprehensive understanding of participants' physiological responses in different landscape environments, ensuring the accuracy and reliability of experimental data.

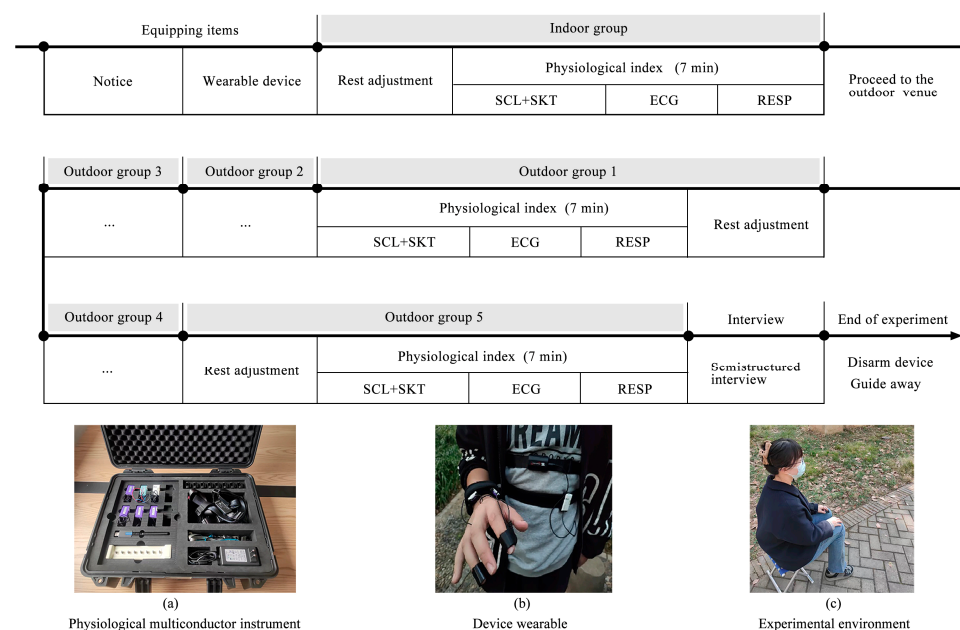


Figure 2. Experimental process.

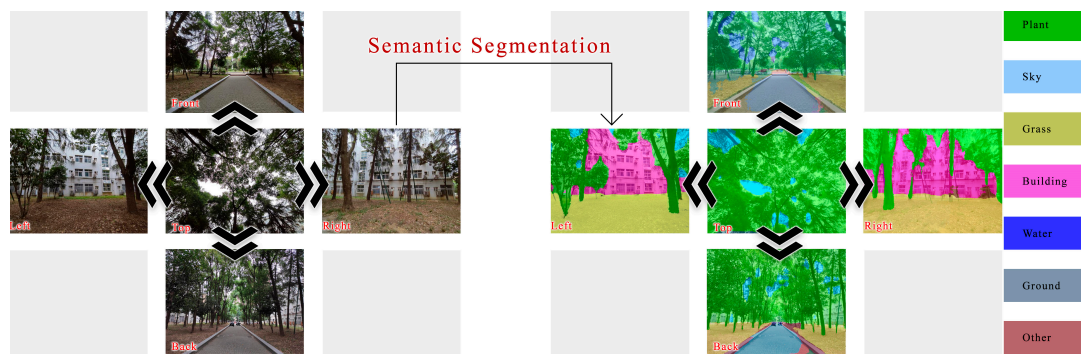


Figure 3. Semantic segmentation of on-site captured photos.

3.4. Measurement of Experimental Indicators

(1) Physiological Indicator Measurement

Subtle physiological changes induced by the environment can also be accurately and rapidly recorded and measured through physiological sensors, facilitating the objective recording of subconscious cognition and experiences that are challenging to measure directly. Electrocardiographic (ECG) signals represent the periodicity within a certain range of cardiac excitation and conduction, with the electrophysiological depolarization and repolarization of cardiac cells facilitating normal heart function. Stress induces changes in the autonomic nervous system, leading to an acceleration of the heart rate, an increase in blood pressure, and accelerated respiration. In a stressed state, the excitability of the heart is enhanced. Heart rate variability has been confirmed to reflect individual psychological stress changes in different situations and is a key indicator characterizing psychological stress [44,45]. The LF/HF frequency domain index of heart rate variability is commonly used to reflect the balance between the sympathetic and parasympathetic nervous systems [46]. Skin temperature is used to reflect changes in skin surface temperature in response to environmental stimuli. Some studies suggest that the sympathetic nervous system is activated in tense situations, leading to an increased metabolic rate and elevated body temperature. After reducing tension and anxiety, the body temperature naturally returns to normal. Respiration refers to the process of gas exchange between the human body and the external environment, and to some extent, it can reveal individual emotions, tension, and other psychological states. Deep, fast breathing and increased oxygen supply to the body to improve gas exchange in the lungs also occurs when there is emotional excitement or psychological stress. The integration of physiological parameters for psychological stress assessment is a developing trend based on evaluating stress through physiological parameters. Karthikeyan et al. utilized various physiological parameters, including ECG, EEG, skin conductance, and blood pressure, measured using stimuli such as colored cards, public speaking, and games [47]. They demonstrated that the integration of these physiological parameters is more effective in assessing stress. Healey et al. demonstrated that, compared with electromyography (EMG) and respiration, ECG and skin conductance more effectively reflect the psychological stress status of drivers [48]. Costin et al. collected two physiological signals, EEG and ECG, and confirmed that the morphological variability of heart rate variability and EEG signals effectively detects psychological stress status [49]. The comprehensive measurement of various physiological indicators provides a more comprehensive understanding of participants' physiological responses in different environments, offering crucial objective data support for the field of environmental psychology.

The Ergolab wearable physiological multichannel recorder produced by Jinfa Technology was used to collect participants' physiological indicators. The selected modules include EDA, PPG, RESP, and SKT. Apart from the respiratory belt dedicated to testing breathing waves and the temperature probe for measuring body surface temperature, all other physiological indicators were measured using standard (Ag/AgCl) skin electrodes. The

collection of physiological signals was analyzed using Ergolab 3.0 software. The selected physiological indicators included HR, LF/HF, SCL, SKT, and RESP. Due to individual variations in physiological responses, a relative percentage change was used for standardization to compare the observed physiological responses in the natural environment (baseline) and the original data. The formula is as follows:

$$((\text{Raw value} - \text{Baseline value}) / \text{Baseline value}) \times 100.$$

(2) Measurement of Visual Element Indicators

The quantity and area ratio of various elements in the field of view are considered important factors affecting visual perception and are also the focus of landscape space design. Drawing from existing research on landscape visual elements and specific methods of landscape construction, we determined 10 key visual elements of interest in this study from the dimensions of “quantity” and “proportion” (Table 2). The measurement of quantity-based elements was conducted by on-site audits by staff. The measurement of proportion-based elements was conducted using semantic segmentation, which divides landscape photos taken from the perspective of the subjects into seven types: vegetation, grassland, pavement, water bodies, sky, buildings, and others. The proportions of different visual elements in the field of view were calculated. The specific process is illustrated in Figure 3. The semantic segmentation task was completed by an open program provided by the High-Performance Computing Laboratory (CUG.HPSCIL). The program is based on a deep learning fully convolutional network (FCN) and was trained on the ADE_20K dataset, demonstrating the ability to segment 150 object labels. During testing, the program achieved a pixelwise accuracy of 0.81 on the training dataset and an accuracy of 0.67 on the testing dataset, indicating that the program exhibits high accuracy when performing image segmentation tasks, while also demonstrating good applicability and generalization capabilities.

Table 2. Composition indicators of visual elements in campus landscape space.

Type	Visual Element	Measurement Method	Content	Mean	Variance
Quantity element	Number of facilities	Manual audit	Number of furniture items, such as tables, chairs, pavilions, fountains, pools, flower beds, sculptures, landscape walls, etc.	7.91	41.95
	Number of plant species		Number of visible plant species in the field of view	6.33	17.95
Proportion element	Percentage of vegetation area	Semantic segmentation of on-site captured images	$\frac{\sum_{i=1}^4 \text{Vegetation pixels}_i}{\sum_{i=1}^4 \text{Total pixels}_i}$	0.58	0.04
	Percentage of paving area		$\frac{\sum_{i=1}^4 \text{Pavement pixels}_i}{\sum_{i=1}^4 \text{Total pixels}_i}$	0.23	0.03
	Percentage of water body area		$\frac{\sum_{i=1}^4 \text{Water pixels}_i}{\sum_{i=1}^4 \text{Total pixels}_i}$	0.11	0.04
	Percentage of sky area		$\frac{\sum_{i=1}^4 \text{Sky pixels}_i}{\sum_{i=1}^4 \text{Total pixels}_i}$	0.16	0.02
	Percentage of building facade area		$\frac{\sum_{i=1}^4 \text{Building pixels}_i}{\sum_{i=1}^4 \text{Total pixels}_i}$	0.10	0.01

Source: this study (own contribution).

3.5. Experimental Data Analysis

(1) Descriptive Statistics

Descriptive statistics were derived on the changes in stress physiological indicators before and after the experiment for all participants (Table 3). It can be observed that, except for SCL, the changes in the other four stress physiological indicators are all negative, indicating a trend of stress relief during short periods of sitting in campus landscape spaces.

This reflects the potential positive impact of campus landscapes on students' psychological well-being. However, there may be individual differences in increasing SCL.

Table 3. Changes in stress physiological indicators (postexperiment–pre-experiment).

Physiological Indicators	Maximum	Minimum	Mean	Median	Metric
HR	10.482	−51.758	−10.677	−9.256	92.251
LF/HF	1.919	−6.488	−0.967	−0.728	1.209
RESP	2.536	−8.746	−1.642	−1.381	2.425
SCL	45.073	−11.252	1.799	1.616	24.89
SKT	8.932	−42.708	−8.411	−7.35	57.241

Source: this study (own contribution).

(2) Data Processing

First, the environmental indicators were categorized. The natural breakpoint method was employed to classify elements into three levels: high, medium, and low (Table 4). This approach enables a more accurate assessment of different levels of environmental indicators.

Table 4. Results of visual element reclassification.

Type	ID	Visual Element	Type 1	Type 2	Type 3
Quantity element	X1	Number of Facilities	1 (0~5)	2 (6~13)	3 (14~26)
	X2	Number of plant species	1 (1~5)	2 (6~13)	3 (14~17)
Proportion element	X3	Percentage of vegetation area	1 (0.051~0.440)	2 (0.441~0.656)	3 (0.656~0.868)
	X4	Percentage of paving area	1 (0~0.209)	2 (0.210~0.418)	3 (0.419~0.781)
	X5	Percentage of water body area	1 (0~0.077)	2 (0.078~0.364)	3 (0.365~0.766)
	X6	Percentage of sky area	1 (0.003~0.123)	2 (0.124~0.280)	3 (0.281~0.470)
	X7	Percentage of building facade area	1 (0~0.116)	2 (0.117~0.388)	3 (0.389~0.736)

Source: this study (own contribution).

Second, physiological indicators were selected. Using the “bidirectional selection/random consistency” method, the intraclass correlation coefficient (ICC) was calculated to test the consistency. The results indicated that the changes in various physiological indicators of the participants were not entirely consistent within the same scene. Specifically, the consistency between HR and RESP was good ($ICC > 0.75$), while the consistency between HR and SKT, RESP and SCL, and LF/HF and RESP was at a moderate level ($ICC > 0.50$). There was considerable inconsistency among other indicators. Based on the consistency of physiological indicators reflecting stress (such as the highly consistent changes between HR and RESP) and considering data collection quality issues (such as sensors measuring SCL being significantly affected by external temperature), one of these factors was chosen for analysis. Ultimately, HR and LF/HF, two indicators that are both representative and of good data quality, were selected for further analysis.

(3) Analysis Process

We employed a multifactorial analysis of variance to investigate the impact of visual elements on stress relief, following the steps below: first, a unifactorial analysis was conducted; second, interaction terms were introduced to explore the effects of element combinations; and third, we sought the optimal combination of visual elements for stress recovery. To avoid the complexity and interpretational challenges associated with too many interaction terms, this analysis considered interactions involving up to three elements (Figure 4).

In the process of exploring element combinations, we listed all possible combinations of two and three elements, constructing n analysis of variance models (where n is the total number of possible combinations). Each model included seven individual visual elements

and an interaction term to be explored. Additionally, five personal attribute indicators were introduced as covariates to enhance the accuracy and interpretability of research effects by controlling for other variables that might influence the results. Significant ($p < 0.05$) element combinations were selected, and the constituent features of these significant combinations were analyzed. Finally, through post hoc multiple comparisons, we identified landscape visual element combinations that exhibited the most effective stress relief. The entire analysis process was conducted using the Python programming language and the Statsmodels statistical analysis module.

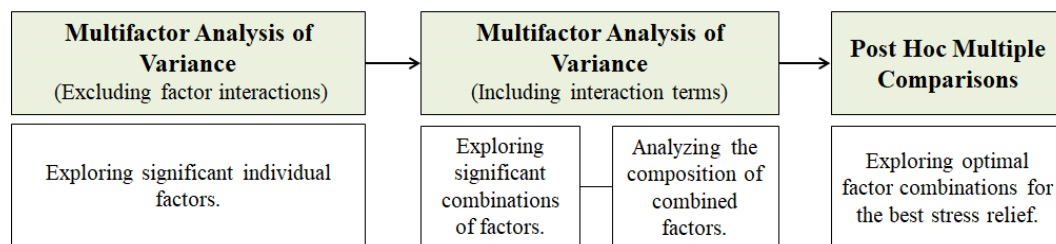


Figure 4. Data analysis process.

4. Results

4.1. Stress Relief at Different Experimental Locations

The locations exhibiting the most effective stress relief were primarily situated near water bodies (e.g., Figure 5(a_4,e_5)) and expansive campus green areas (e.g., Figure 5(e_1)). Additionally, some carefully designed landscape spaces, such as the campus entrance (e.g., Figure 5(b_5)) and the academic exchange center (e.g., Figure 5(d_5)), also demonstrated notable stress reduction effects. In comparison, the stress relief effects in less artificially intervened mountainous and forested areas (e.g., Figure 5(e_2,e_3)) were relatively limited. Small green spaces (e.g., Figure 5(h_2,i_1)) and courtyards between teaching buildings or dormitories (e.g., Figure 5(f_1,h_4)) displayed the least effective stress recovery outcomes (Figure 5).

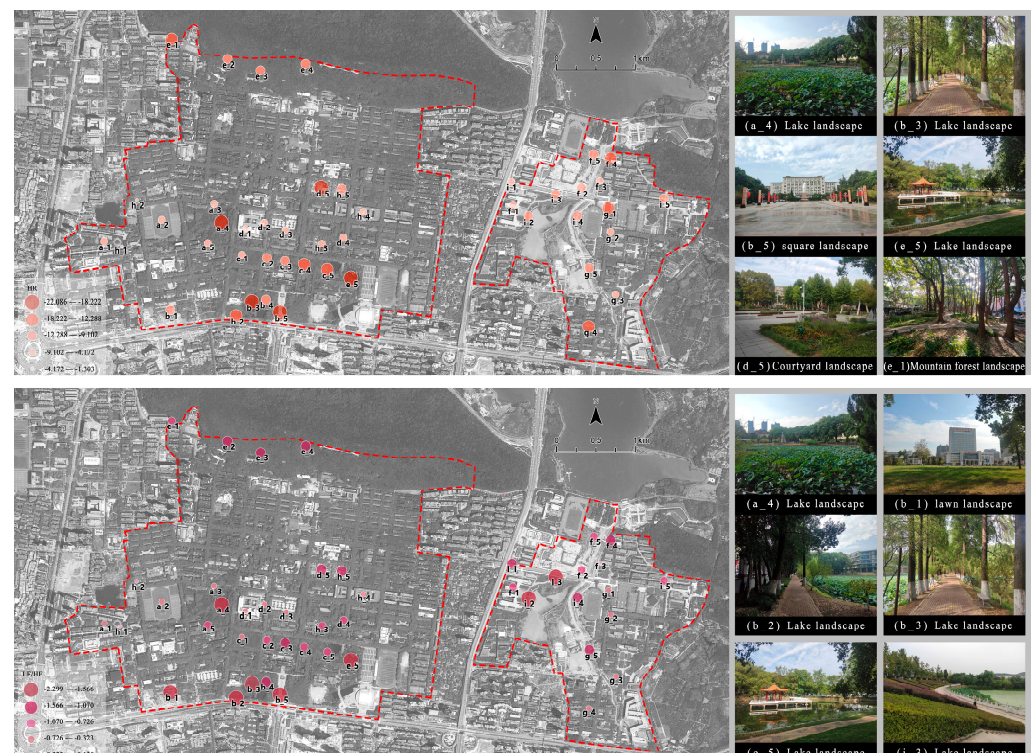


Figure 5. Multifactorial analysis results for HR and LF/HF indicators.

4.2. Influence of Single Factors on Stress Relief

According to the results in Table 5, it was found that only the water feature among all landscape visual elements had a significant impact on the changes in HR and LF/HF stress physiological indicators ($p < 0.05$). As depicted in Figure 6, it is evident that, with an increase in the area of water elements in the field of view, university students experience better stress relief effects in the landscape space.

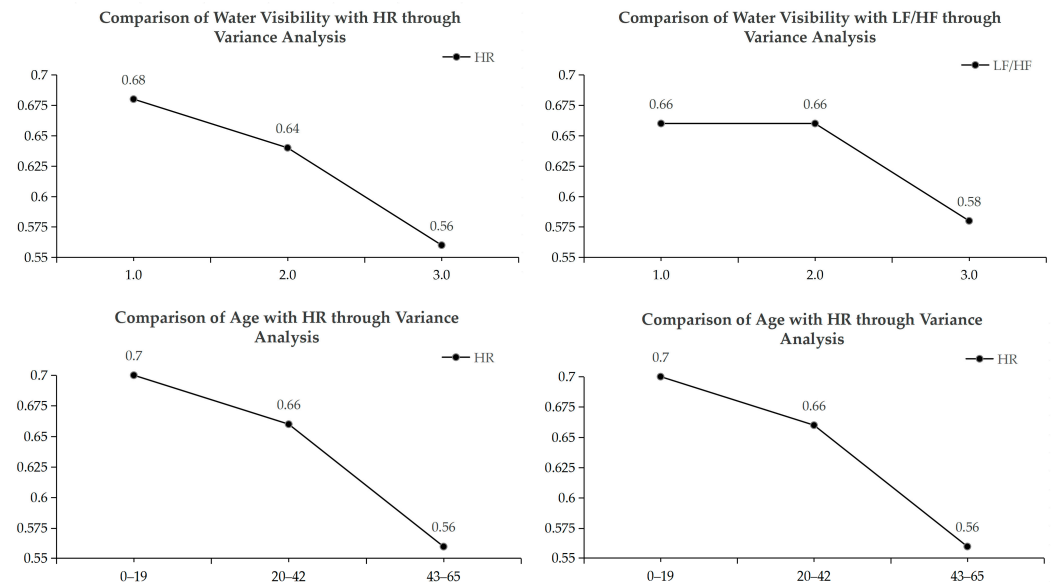


Figure 6. Single-factor analysis of significant indicators.

Regarding personal attributes, the initial stress level significantly influenced HR ($p < 0.001$), while age significantly affected LF/HF ($p < 0.05$). A higher initial stress level in individuals resulted in better stress relief effects. Compared with individuals aged 16–20, the landscape space had a better stress relief effect on those aged 21–26.

Table 5. Stress relief in landscape spaces.

Source	HR					LF/HF				
	Sum of Squares	Degrees of Freedom	Mean Square	F	p	Sum of Squares	Degrees of Freedom	Mean Square	F	p
Corrected model	1.077 a	19	0.057	2.723	0.000 ***	0.413 a	19	0.022	1.302	0.185
Intercept	1.413	1	1.413	67.916	0.000 ***	1.163	1	1.163	69.715	0.000 ***
Number of facilities	0.036	2	0.018	0.857	0.426	0.025	2	0.012	0.736	0.48
Number of plant species	0.004	2	0.002	0.093	0.911	0.001	2	0.000	0.021	0.98
Percentage of vegetation area	0.093	2	0.046	2.226	0.111	0.050	2	0.025	1.502	0.225
Percentage of paving area	0.113	2	0.056	2.709	0.069	0.063	2	0.031	1.879	0.155
Percentage of water area	0.135	2	0.068	3.244	0.041 *	0.114	2	0.057	3.415	0.035 *
Percentage of sky area	0.003	2	0.001	0.067	0.936	0.016	2	0.008	0.484	0.617
Percentage of building facade area	0.027	2	0.013	0.642	0.527	0.029	2	0.014	0.869	0.421
Gender	0.002	1	0.002	0.105	0.746	0.015	1	0.015	0.881	0.349
Age	0.006	1	0.006	0.274	0.601	0.070	1	0.070	4.185	0.042 *
Education level	0.007	1	0.007	0.351	0.554	0.026	1	0.026	1.530	0.218
Major	0.053	1	0.053	2.525	0.114	0.001	1	0.001	0.076	0.782
Level of stress	0.375	1	0.375	18.040	0.000 ***	0.006	1	0.006	0.384	0.536
Error	4.329	208	0.021			3.470	208	0.017		
Total	104.738	228				102.195	228			
Corrected total	5.406	227				3.882	227			
					a. R square = 0.199 (adjusted R square = 0.126)					
					a. R square = 0.106 (adjusted R square = 0.025)					

4.3. Influence of Element Combinations on Stress Relief

In the variance analysis model with 112 included interaction terms, 33 element combinations significantly affected the HR physiological indicator, and 11 element combinations significantly affected the LF/HF physiological indicator. This phenomenon demonstrates the significant importance of artificially designing and combining landscape visual elements, in addition to the natural element of water, for stress relief among university students.

Analyzing the frequency of occurrence of individual elements in the interaction terms, the results (Figure 7) indicate that all visual elements exhibit certain interaction effects. Among them, building facade (X7) and sky area (X6) are the two elements that participate in the most interactions. Additionally, plant species (X2), paving area (X4), and water area (X5) also show some interaction effects with other elements. From the frequency of occurrence of each element in the combinations, it can be observed that combinations involving building facade (X7) and sky area (X6), water area (X5) and sky area (X6), and plant species (X2) and paving area (X4) consistently occur together. This suggests that these elements are more inclined to collectively contribute to stress relief. Through post hoc multiple comparison analysis of the model, five landscape visual element combinations were selected from the models related to the HR index and LF/HF index, respectively, which effectively maintained the stress physiological indicators at lower levels. In theory, these combinations of elements are expected to have the best stress relief effects for university students.

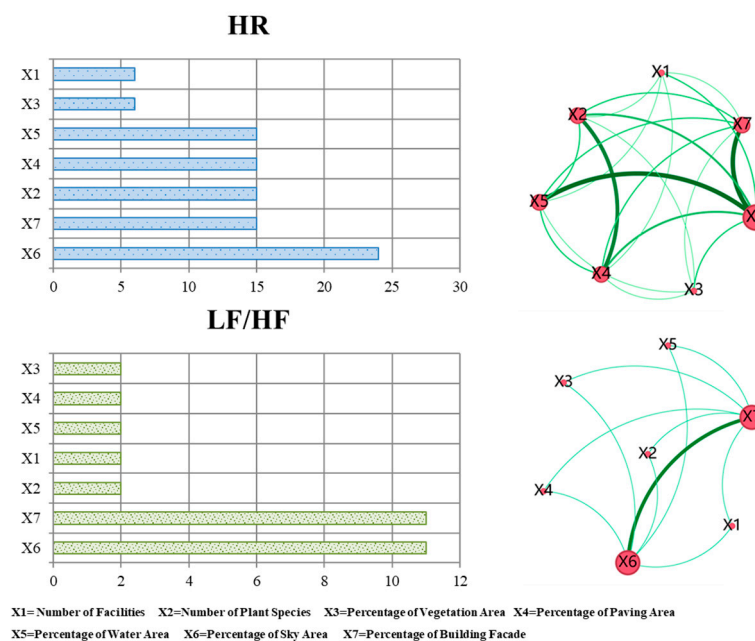


Figure 7. Significant interactive elements and their connections.

Table 6 indicates that, in the analysis models related to the HR index, the combination that achieves the best stress relief consists of “fewer building structures + moderate plant species + more paving area.” In the analysis models related to the LF/HF index, several combinations are identified as achieving the best stress relief effects. These combinations include “fewer building structures + moderate sky area + moderate building area”, “less water area + moderate sky area + moderate building area”, “more paving area + moderate sky area + moderate building area”, and “less vegetation area + moderate sky area + moderate building area.” It can be observed that moderate sky area and building area are common elements in all of these combinations.

Table 6. Element combinations achieving the best stress relief effects.

Metric	Combination	Value			Mean
HR	X1 × X2 × X4	X1 = 1 (0~5)	X2 = 2 (6~13)	X4 = 3 (0.42~0.78)	0.48
	X4 × X5 × X6	X4 = 2 (0.21~0.42)	X5 = 2 (0.08~0.36)	X6 = 1 (0.01~0.12)	0.49
	X3 × X5 × X6	X3 = 2 (0.44~0.66)	X5 = 2 (0.08~0.36)	X6 = 1 (0.01~0.12)	0.49
	X5 × X6	X5 = 3 (0.37~0.77)	X6 = 1 (0.01~0.12)		0.50
	X2 × X5 × X6	X2 = 2 (6~13)	X5 = 3 (0.37~0.77)	X6 = 1 (0.01~0.12)	0.50
LF/HF	X1 × X6 × X7	X1 = 1 (0~5)	X6 = 2 (0.12~0.28)	X7 = 2 (0.12~0.39)	0.54
	X5 × X6 × X7	X5 = 1 (0~0.08)	X6 = 2 (0.12~0.28)	X7 = 2 (0.12~0.39)	0.54
	X4 × X6 × X7	X4 = 3 (0.42~0.78)	X6 = 2 (0.12~0.28)	X7 = 2 (0.12~0.39)	0.54
	X3 × X6 × X7	X3 = 1 (0.05~0.44)	X6 = 2 (0.12~0.28)	X7 = 2 (0.12~0.39)	0.54
	X2 × X6 × X7	X2 = 2 (14~26)	X6 = 2 (0.12~0.28)	X7 = 2 (0.12~0.39)	0.55

Source: this study (own contribution). X1 = number of facilities. X2 = number of plant species. X3 = percentage of vegetation area. X4 = percentage of paving area. X5 = percentage of water area. X6 = percentage of sky area. X7 = percentage of building façade.

5. Discussion

5.1. The Impact of Individual Factors on Stress Relief

Our experiment shows that water bodies significantly promote stress relief among university students during periods of sitting, and the stress relief effect is positively correlated with the visibility of water bodies in the field of view. Christopher Alexander made multiple uses of pattern languages associated with water bodies in designing “EISHIN GAKUEN” in Japan, thereby creating a campus environment conducive to stress relief for students [50]. Furthermore, numerous studies have affirmed the significance of water elements in alleviating stress. The importance of the “water” element for stress relief has been confirmed by several studies. For example, White et al. [51] in a restorative experiment comparing natural and built scenes, found that scenes with water, whether natural or built, were preferred, had a greater positive impact, and were perceived as more restorative. Jie Y [34] through on-site experiments with subjects, discovered that urban environments with water induce noticeable physiological and psychological relaxation effects. Yan C’s [52] study on waterfront landscape characteristics and mental health also demonstrated that blue visibility is more likely to evoke positive emotions compared with green visibility or other elements. What sets this analysis apart from other studies is that water bodies are the only element found to have a significant impact. We speculate that this difference may be due to the experimental method commonly used in similar studies, which often involve comparing multiple scenes. This method makes it difficult to discern whether the element alone is causing an effect or if it is combined with other elements. Another important factor may be related to the short duration of time participants spend sitting and observing in the landscape space. When participants suddenly arrive in a landscape space with water, their attention is easily drawn to the water, temporarily overlooking the surrounding environment.

Furthermore, this experiment found significant associations between certain personal attributes and stress relief effects, indicating that individuals with high initial stress levels and older-age students are more susceptible to the influence of landscape elements. This suggests that, for some university students who are under high levels of stress for prolonged periods, taking a brief sit in campus landscape spaces can be an effective way to relax. Generally, older students tend to have better emotional regulation abilities, so they are more likely to use the landscape environment to quickly adjust their negative emotions.

5.2. The Impact of Element Combinations on Stress Relief

The experimental results reveal that, when incorporating interaction terms of landscape elements into the analysis of variance model, the number of elements significantly affecting stress relief increases noticeably. This indicates that when university students sit and observe campus landscapes, most visual elements work together in combination

to alleviate stress. Many studies have demonstrated the beneficial effects of landscape visual elements and scenes on mental health. Our study complements these findings by suggesting that the therapeutic effect of landscape spaces may also result from the combination of several specific elements within the scene. A similar view has been proposed by other studies before; for example, Zhao et al. suggest that audiovisual interactions can have a combined effect on stress relief [53], while Lin et al. emphasize the importance of considering the proportion of landscape elements [54]. The difference between our study and these previous ones is our use of quantitative analysis to identify landscape visual elements that may interact. Among these, the combinations with the strongest interaction effects are building facades and sky area, water area and sky area, and plant species and paving area.

In summary, our study suggests that, in campus spaces, designing a combination of natural elements such as water bodies and plants with artificial elements such as buildings and sculptures can have a better stress-relieving effect on university students. This may be related to the specificity of such urban spatial environments. Universities, as spaces that accommodate a large concentration of higher education communities, have ubiquitous and meaningful artificial elements such as sculptures, patterns, symbols, and buildings, in addition to natural landscapes. These elements can also serve as cultural symbols influencing the emotions and thoughts of university students experiencing stress. Carefully designed landscape forms are more easily perceived and understood by observers with abundant knowledge and rich ideas. Similar findings were observed in studies conducted by Michael W. M. et al., which noted that individuals tend to pay more attention to architectural facades and some artificial architectural decorations when appreciating campus scenery [55]. Xu et al. found in an experiment comparing the recovery capabilities of Chinese cultural and natural landscapes that cultural landscapes have a similar impact on mental recovery as natural landscapes. Moreover, combining humanistic elements with natural environments to create a relaxed and tranquil cultural atmosphere is believed to enhance the environmental recovery capability [56].

5.3. The Best Combination of Elements to Promote Stress Relief

Through post hoc multiple comparisons, we identified the optimal combinations of elements that promote stress relief. Our study found that landscape element combinations related to “a smaller number of facilities + a moderate amount of plant species + more paved area” and “moderate sky area + moderate building facade area” had the greatest promoting effect on stress relief.

Combining the participants’ experiential feedback allows for a reasonable interpretation of these results: When the number of facilities in the participants’ field of view is controlled to within five, carefully designed sculptures, landscape walls, fountains, and seating can effectively serve as visual focal points. The appropriate variety of plant species further enhances spatial depth without causing the participants to feel overwhelmed by clutter. When the paved area in the field of view ranges from 42% to 78%, or the proportion of the building facade area is between 12% and 39%, and the sky area is between 12% and 28%, these indicators suggest that the location where the participants are seated is likely to be a small plaza surrounded by buildings. The artificial environment provides a sense of place and security for observers, ensuring that they can comfortably enjoy the diverse flora, fauna, and beautiful landscape features nearby. This type of landscape space likely allows university students to momentarily forget about their stress through attention diversion. This work complements the findings of Lin W et al. [53], who demonstrated through virtual experiments that the optimal stress relief effect is achieved when the proportion of sky and tree leaves seen in forests is around 33%. Similarly, we demonstrate that when the proportion of building facades to sky in university campuses is similar, a similar effect is observed.

Through further summarization, the landscape element combination patterns that achieve the best stress-relieving effects can be roughly categorized into two types: “natural

water scenes” and “exquisite artificial” modes. The first type is the “natural water scene” mode: primarily focusing on rivers, ponds, and lakes within the campus. By enhancing the surrounding greenery and increasing the variety of plant species to maintain the site’s natural attributes, along with incorporating more water-friendly facilities, students can have a more extensive contact with water bodies, thereby alleviating their stress. This model has been validated through its application in experimental areas, such as the Youth Park and Lake Creek River sites. The second type is the “exquisite artificial” mode: creating a pleasant outdoor space through well-organized architectural layouts. Within the enclosed area of the site, various plants are appropriately planted, and facilities such as sculptures, flower beds, and seats are installed, while architectural facades and pavements are carefully designed to enhance the cultural atmosphere of the location. Campus entrance squares and academic exchange centers, due to their unique characteristics, attract many teachers and students to visit frequently for exchanges, becoming ideal places for relaxation and leisure after class.

5.4. Application

The above research conclusions provide more meaningful assistance for the design of campus landscape spaces.

(1) To construct campus landscape spaces with stress-relieving effects, priority should be given to increasing water features. Encouraging the introduction of water features such as artificial lakes and fountains within or around the campus area is essential to provide the most effective stress-relief effects.

(2) It is important to emphasize the organic integration of natural landscape elements and cultural landscape elements and to strengthen the stress-relief effects of campus landscape spaces through combined designs. For example, cultural elements such as sketches, sculptures, and other artistic installations can be introduced into natural landscapes to enhance the environmental restoration potential. Throughout this process, particular attention should be paid to controlling the proportions of visible architectural facades, sky, and water surfaces and controlling the combination of plant species and paving forms.

(3) Landscape designers can refer to these two design models, “natural water scenery” and “exquisite artificial”, to select certain areas within the campus to create professional healing gardens.

5.5. Limitations

This study has some shortcomings that need to be addressed in future research. First, the recruitment of participants faced practical challenges, such as time constraints, budget limitations, communication difficulties, and participant enthusiasm, leading to a higher proportion of females and graduate students in the sample. Although the study did not find significant effects of gender and education level on stress relief, the uneven distribution of the sample may still lead to some biases in the conclusions. Therefore, it is necessary to control the composition of participants further to enhance the rigor of the research process and ensure the relative fairness of experimental conclusions if conditions permit.

Second, the experiment observed inconsistent changes in the six stress physiological indicators of the human body when facing the same scene. This phenomenon requires the integration of more professional medical knowledge for accurate explanation. In order to make related research more realistic and reasonable, efforts should be made in the future to standardize the effectiveness of various physiological indicators and their ability to explain psychological stress in different usage scenarios. Furthermore, considering personal privacy and student willingness, some personal attribute indicators considered relevant, such as sleep duration, physical activity preferences, and BMI, were not included in the analysis process. In the future, it is necessary to supplement the collection of more prosperous and more scientific personal attribute characteristics to improve the model’s effectiveness further.

Finally, due to limitations in the number of instruments, this study used an experiential route experimental approach. Despite taking necessary measures to avoid the potential effects of cumulative effects, the goodness of fit of the regression analysis model and the significance level of various factors have yet to reach the ideal state. In future research, it is necessary to increase the number of participants and instruments to improve the accuracy and reliability of the model.

6. Conclusions

This study explores the effects of campus landscape visual elements on short-term stress relief among college students using physiological instruments, semantic segmentation techniques, and statistical methods, identifying the most effective elements and combinations for promoting stress relief through experimental analysis. The findings of this study enrich the theory of restorative environments and can be applied to the design of university campus landscapes.

The study hopes to continue adding various experimental cases of university campus landscapes and student psychological stress in the future to verify the reliability of the conclusions. It also calls for continued attention to landscape perceptual elements in related research, especially the role of the combination ratio of elements in mental health, to provide more directions for the maintenance of the physical and mental health development of college students.

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