

Article

Seasonal Associations Between Park Environments and User Emotions: Evidence from Six Spaces in Jiefang Park, Wuhan, China

Luyao Cheng ^{1,†}, Xiaotian Yang ^{2,†}, Weiqian Zhang ¹ and Li Zhang ^{1,3,4,*}

¹ College of Horticulture and Forestry Sciences, Huazhong Agricultural University, No.1 Shizishan Street, Wuhan 430070, China; c7ly@webmail.hzau.edu.cn (L.C.); zhangweiqian@webmail.hzau.edu.cn (W.Z.)

² Wuhan Jianghua Urban Development Consulting Co., Ltd., Wuhan 430070, China; 13667218776@163.com

³ International Science and Technology Cooperation Base for Urban and Rural Human Settlements and Environmental Sciences, Wuhan 430070, China

⁴ Key Laboratory of Urban Agriculture in Central China, Ministry of Agriculture and Rural Affairs, Wuhan 430070, China

* Correspondence: zhangli09@mail.hzau.edu.cn

† These authors contributed equally to the work.

Abstract

Urban parks contribute to emotional well-being, yet the relationship among park environments, users' perceptions, recreational activities, and emotions across seasons remains insufficiently understood. Using Jiefang Park in Wuhan, China, as a case study, this study analyzed 2233 valid questionnaires from four-season field surveys across six surveyed spaces, together with measured spatial environmental data. Partial least squares structural equation modeling (PLS-SEM) was used to examine the associations and interaction effects of landscape perception, thermal perception, recreational activities, and positive and negative emotions. Hierarchical linear modeling (HLM) was used to account for respondents nested within 24 space-season units and examine cross-level statistical indirect associations. Emotional responses varied across seasons and among the six surveyed locations. The surveyed lawn space showed the highest positive-emotion and lowest negative-emotion scores, whereas the surveyed fitness activity space had the highest negative-emotion score. The surveyed fitness activity and waterfront spaces displayed smaller seasonal fluctuations. Thermal and visual perceptions were consistently associated with emotional responses in the season-specific models. Measurement invariance was not established, so path coefficients were not formally compared. Spatial environmental characteristics showed significant indirect associations with emotions mainly through perceptual variables, whereas indirect associations through recreational activities were not significant. Vegetation color richness showed favorable indirect associations, while green view, pavement visibility, and fitness facility quantity showed adverse indirect associations at the surveyed locations. These findings suggest that seasonally responsive park design should emphasize perceptual quality, thermal adaptability, and context-sensitive spatial configuration.

Keywords: urban park; emotional responses; seasonal variation; landscape perception; thermal perception; recreational activities; Wuhan; China

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1. Introduction

1.1. *Urban Parks and Emotional Well-Being*

As urbanization continues to advance, changes in urban environments and lifestyles have posed increasing challenges to public health, particularly mental health. As essential components of sustainable urban environments, urban parks and green spaces play an important role in promoting residents' physical and psychological well-being [1,2]. Previous studies have shown that exposure to urban natural environments can alleviate psychological stress, improve mood, and promote positive emotional responses. Compared with many other built-environment settings, parks may offer stronger restorative benefits [3–5].

Urban parks can support emotional well-being through multiple pathways. They provide opportunities for walking, jogging, social interaction, and other forms of recreation, which are associated with reducing negative emotions (NEs) and enhancing positive emotions (PEs) [6]. Parks may also improve users' emotional experiences by reducing exposure to noise, air pollution, and heat stress, restoring attention, relieving psychological stress, and promoting health-related behaviors such as physical activity and social interaction [7]. In addition, vegetation, water bodies and spatial configurations can modify local microclimatic conditions. Favorable outdoor thermal conditions can encourage park users to engage in recreational activities, thereby increasing the vitality of urban public spaces and strengthening their emotional benefits [8–11]. Understanding how park environments shape positive and negative emotions is therefore an important issue in healthy urban planning and landscape design.

1.2. *Seasonal Variations in Park Environments and Emotional Responses.*

The environmental and emotional benefits of urban parks may vary across seasons. Seasonal changes in vegetation, thermal conditions, and the suitability of outdoor spaces can alter users' environmental exposure and experiences. Consequently, the same park space may provide different emotional benefits under different seasonal conditions.

Previous studies have demonstrated that emotional responses vary according to the spatial and environmental characteristics of urban parks. Natural open spaces, such as lawns, have been associated with stronger PE and restorative experiences, whereas plaza spaces tend to show weaker restorative effects [12]. Water areas are positively associated with PE, while impervious surfaces show the opposite relationship [13]. The green view index and the degree of spatial enclosure may also significantly influence psychological restoration, particularly among older adults [14]. Moreover, the green view index within a 200 m buffer zone has been found to be negatively associated with NE [15]. Pavement materials and the quality of fitness facilities can further affect users' emotional states [16].

Outdoor thermal conditions represent another important source of seasonal variation. Thermal perception plays an important role in shaping emotional and restorative experiences, with thermal comfort exerting a stronger positive effect on PE than on NE [17,18]. In hot and humid regions, thermal perception may also substantially influence the restorative benefits derived from exposure to green space [19]. Seasonal differences in temperature, solar radiation, vegetation cover, and shade may therefore alter users' emotional responses to different park spaces. However, most previous studies have focused on individual environmental factors or observations conducted during a single season, and four-season comparisons among multiple settings within the same comprehensive park remain limited.

1.3. *Perception and Recreational Activities in Park–Emotion Relationships*

The emotional associations of park environments depend not only on objective spatial characteristics but also on how users perceive and use these environments. Landscape

perception, thermal perception, and recreational activities may be directly associated with emotional responses and may also form statistical indirect associative pathways between spatial environmental characteristics and emotions.

Users' perceptions and recreational activities are closely related to their emotional responses in urban parks. Landscape features such as spatial openness, water visibility, and plant community richness can enhance perceived restoration, while visual and auditory perceptions may jointly contribute to positive emotional experiences [20,21]. Multi-sensory comfort also contributes to emotional restoration, and visual comfort may become particularly important when conflicts occur among sensory experiences [22,23]. Visual, auditory, and olfactory perceptions may further be associated with emotions through thermal comfort [24], while perceived biodiversity has been identified as an important predictor of psychological restoration [25].

Recreational activities may be directly associated with users' emotional states and may also contribute to statistical indirect associations between park environments and emotions. Longer park stays are generally associated with stronger PE [26], while social interaction within parks can provide positive experiences [27]. Adequate shade and well-developed activity facilities may increase activity frequency and duration [28], and walking has been shown to provide public health benefits [29]. Park accessibility, aesthetic quality, and facility configuration may also be associated with mental health through physical activity [30]. Different activity patterns may play different roles: sedentary activities may link natural features to psychological restoration, whereas active activities may link recreational facilities to attention restoration [31].

Landscape perception, thermal perception, and recreational activities may also be interrelated. Users' perceptions of landscape and thermal conditions may affect the frequency, intensity, type, and duration of their activities, while participation in recreational activities may be associated with their perceptions and emotional experiences [32]. Nevertheless, whether these associations and interactions are consistent across seasons and whether perception and recreational activities form indirect associative pathways between spatial environmental characteristics and emotions remain insufficiently understood.

1.4. Research Gaps, Objectives, and Conceptual Framework

Despite increasing attention to the emotional benefits of urban parks, several research gaps remain. First, relatively few studies have conducted field surveys across all four seasons, limiting understanding of seasonal patterns in park environment–emotion relationships. Second, systematic comparisons among multiple spatial settings within the same comprehensive urban park remain scarce. Third, objective spatial environmental characteristics, landscape perception, thermal perception, recreational activities, and positive and negative emotions have rarely been incorporated into a unified analytical framework. Fourth, the nesting of individual responses within different space–season contexts has not always been adequately considered, potentially obscuring the distinction between individual-level experiences and upper-level environmental characteristics.

To address these gaps, this study investigates users' emotional responses across six surveyed spaces in Jiefang Park, Wuhan, using field data collected in spring, summer, autumn, and winter. Specifically, the study aims to: (1) identify the spatial and seasonal patterns in users' positive and negative emotions; (2) examine the associations of spatial environmental characteristics, landscape perception, thermal perception, and recreational activities with emotional responses; (3) examine interactions among landscape perception, thermal perception, and recreational activities within each seasonal sample; and (4) assess statistical indirect associations between spatial environmental characteristics and emo-

tions via perception and recreational activities. The findings are expected to provide evidence for seasonally adaptive park planning, design and management strategies that enhance users' emotional well-being.

2. Materials and Methods

2.1. Study Area

This study was conducted in Jiefang Park, Wuhan, China. Located in the central part of Wuhan, Jiefang Park was established in 1952 and covers an area of approximately 46 ha (Figure 1). It is a large comprehensive urban park in Wuhan's main urban area and serves as an important ecological "green lung" for the city. Wuhan has a humid subtropical monsoon climate, with four distinct seasons and concurrent rainy and hot periods.

Six spaces within the park were selected as survey sites: a shaded space with deciduous trees (DTS), a shaded space with evergreen trees (ETS), a waterfront space (WS), a lawn space (LS), a fitness activity space (FAS), and a plaza space (PS) (Figure 2). Each surveyed space was represented by one specific physical location. The selected spaces provided contrasting environmental and recreational conditions for comparing users' emotional responses.

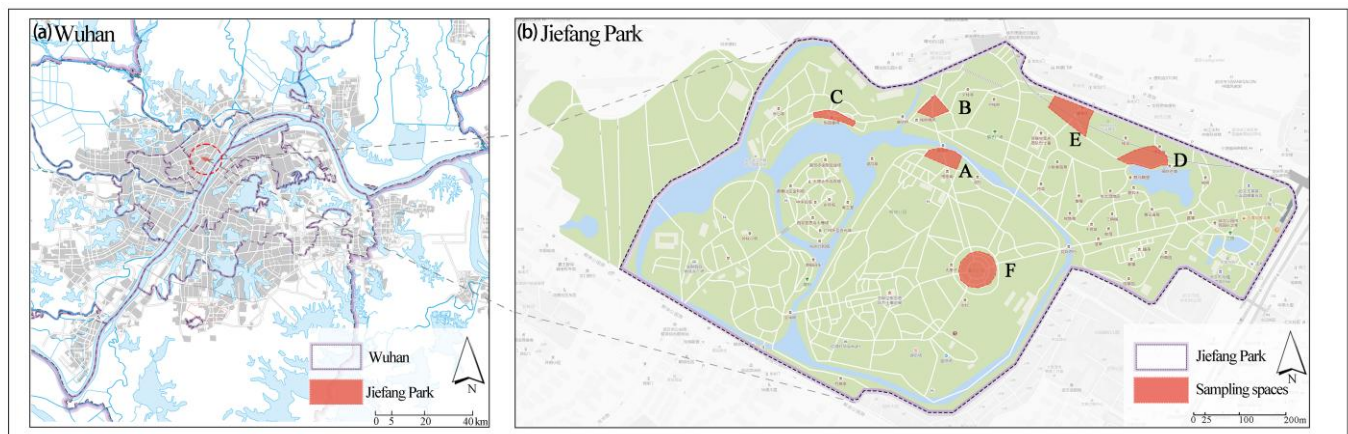


Figure 1. Location of the Jiefang Pak in Wuhan (a) and six sampling spaces in Jiefang Park (b).

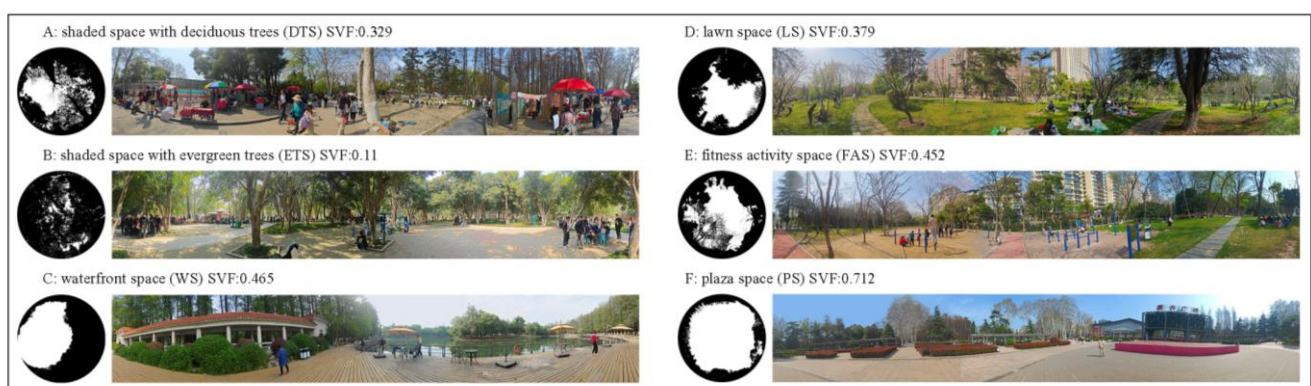


Figure 2. Panoramic views of the six surveyed spaces in summer.

2.2. Data Collection

Field surveys were conducted in spring, summer, autumn, and winter. In each season, surveys were carried out on two weekdays and two weekend days. Data were collected during two fixed periods, from 08:00 to 11:00 and from 14:00 to 17:00, under clear and calm weather conditions to ensure comparability across survey days.

An on-site intercept questionnaire survey was conducted simultaneously with the field investigation. The questionnaire covered users' emotional states, landscape perception, thermal perception, and recreational activities. A pilot survey was conducted before the formal investigation to test and refine the questionnaire. A total of 2312 questionnaires were collected, of which 2233 were valid, yielding a valid response rate of 96.6%.

Microclimatic conditions were measured across the six surveyed spaces at a height of 1.5 m above the ground. HOBO temperature and humidity data loggers and a TESTO portable weather station equipped with an anemometer and a globe thermometer were used to continuously record air temperature (T_a), relative humidity (RH), wind velocity (V_a), and globe temperature (T_g) at 1 min intervals.

Spatial environmental data were also collected in the six surveyed spaces. Equirectangular panoramic images were captured at a height of 1.5 m and used to derive visual and spatial indicators. Field observations were conducted in each surveyed space to record plant species and facility characteristics. For the multilevel analyses, the spatial environmental and microclimatic data were summarized for each of the 24 space–season survey units. Each respondent was assigned the environmental values corresponding to the space and season in which the questionnaire was completed.

2.3. Variables

Users' emotions were measured using the Positive and Negative Affect Schedule (PANAS). Following exploratory factor analysis, items with cross-loadings were removed. The final scale retained nine positive-emotion items, including "determined", "attentive", and "active", and five negative-emotion items, including "guilty", "scared", and "hostile". All items were rated on a 5-point Likert scale from 1 = very slightly or not at all to 5 = extremely. Mean scores were used for descriptive analyses, while standardized latent scores from the full-sample measurement model were used in HLM.

Perception was divided into landscape and thermal perception. Landscape perception comprised visual, usability, safety, and spatial dimensions. Visual perception (VP) included landscape view, tree shade, vegetation richness, satisfaction with vegetation color, water features, and topography. Usability perception (UP) included facility density, comfort, and facility completeness. Safety perception (SA) included barrier-free design, pavement material, and facility maintenance. Spatial perception (SP) included perceived openness, olfactory comfort, and acoustic comfort. Thermal perception (TP) included thermal comfort, satisfaction, and acceptability. All items used a 5-point Likert scale from very poor or uncomfortable to very good or comfortable.

Recreational activities (RAs) were conceptualized as the overall level of recreational participation, reflected in three complementary dimensions: habitual park use, represented by activity frequency; time investment, represented by activity duration; and activity intensity. Although these indicators capture different aspects of recreational behavior, they were specified as a single latent construct and subsequently evaluated using exploratory factor analysis and the PLS-SEM measurement model. Activity intensity was classified according to Ainsworth's Compendium of Physical Activities, including sedentary behavior (1–1.5 METs), light activity (1.6–2.9 METs), moderate activity (3.0–5.9 METs), vigorous activity (6.0–8.9 METs), and very vigorous activity (≥ 9.0 METs). Activity duration was divided into five categories at 0.5 h intervals: <0.5 h, 0.5–1 h, 1–1.5 h, 1.5–2 h, and >2 h. Activity frequency was divided into five categories: 1–2 times per year, 1–2 times per month, once per week, several times per week, and daily.

Spatial environmental characteristics were measured using indicators related to spatial openness, vegetation composition, facility function, and microclimatic characteristics. Spatial openness was represented by the sky view factor. Vegetation composition was

measured using the green view index, plant species richness, and vegetation color richness. Facility function was measured using the pavement view index, number of leisure facilities, number of fitness facilities, and number of facility types. Microclimatic characteristics included air temperature (T_a), relative humidity (RH), wind velocity (V_a), globe temperature (T_g), and physiological equivalent temperature (PET). The measurement methods and descriptions of these indicators are summarized in Table 1.

Table 1. Measurement of spatial environmental characteristics.

Category	Indicator	Measurement	Description
Spatial openness	Sky view factor (SVF)	Calculated using RayMan based on 1.5 m equirectangular panoramic images	Represents spatial openness; values range from 0 to 1, with higher values indicating greater sky exposure.
	Green view index (GVI)	$GVI_i = A_{veg,i} / A_{total,i}$	Proportion of natural vegetation pixels in the panoramic image.
Vegetation composition	Plant species richness (SR)	$SR_i = N_{species,i}$	Number of plant species recorded within a 50 m radius of each sampling point.
	Vegetation color richness (VCR)	$VCR_i = - \sum_{k=1}^n p_k \ln(p_k)$	Diversity of vegetation colors in the panoramic image, calculated using the Shannon–Wiener entropy index.
	Pavement view index (PVI)	$PVI_i = A_{pave,i} / A_{total,i}$	Proportion of hard-paving pixels in the panoramic image.
Facility function	Number of leisure facilities (NLF)	$NLF_i = N_{leisure,i}$	Number of leisure facilities recorded within a 50 m radius of each sampling point.
	Number of fitness facilities (NFF)	$NFF_i = N_{fitness,i}$	Number of fitness facilities recorded within a 50 m radius of each sampling point.
	Number of facility types (NFT)	$NFT_i = N_{type,i}$	Number of facility categories recorded within a 50 m radius of each sampling point.
Microclimatic	Air temperature (T_a)	Field measurement at 1.5 m height	Ambient air temperature recorded at 1 min intervals.
	Relative humidity (RH)	Field measurement at 1.5 m height	Ambient relative humidity recorded at 1 min intervals.
	Wind velocity (V_a)	Field measurement at 1.5 m height	Wind velocity recorded at 1 min intervals.
	Globe temperature (T_g)	Field measurement at 1.5 m height	Globe temperature recorded at 1 min intervals.
	Physiological equivalent temperature (PET)	$PET = f(T_a, RH, V_a, T_{mrt})$	Outdoor thermal comfort index calculated using RayMan

Note: PET was calculated using the measured microclimatic variables together with the latitude and longitude of each measurement point, the specific date and time of measurement, and standardized human-body parameters: height 1.75 m, weight 75 kg, metabolic rate 80 W, and clothing insulation 0.9 clo.

2.4. Research Hypotheses

The hypotheses addressed three sets of relationships. H1–H3 proposed positive associations of landscape perception, thermal perception, and recreational activities with positive emotions. H4–H6 proposed negative associations of these variables with negative

emotions. H7 proposed that the relationships would differ by season. H8–H13 proposed indirect associations of vegetation composition, facility function, and microclimatic characteristics with emotions through perception or recreational activities (Figure 3, Table 2).

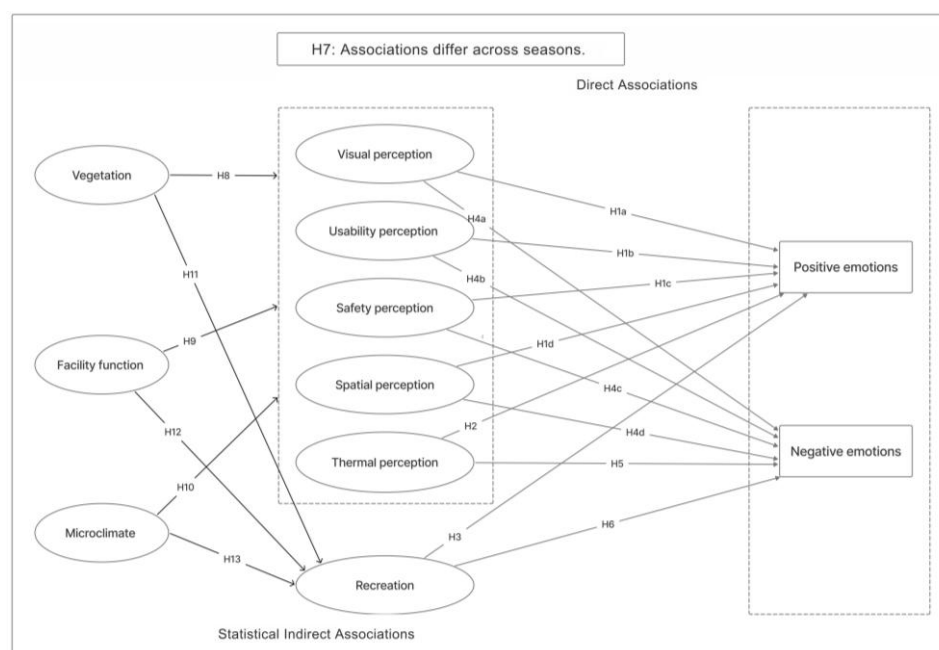


Figure 3. Hypothesized relationships among environmental characteristics, perception, recreational activities, and emotions.

Table 2. Summary of research hypotheses.

Path Type	Hypothesis	Path Relationship	Theoretical Assumption
Positive emotions (PE)	H1a	VP → PE	VP is significantly positively associated with PE
	H1b	UP → PE	UP is significantly positively associated with PE
	H1c	SA → PE	SA is significantly positively associated with PE
	H1d	SP → PE	SP is significantly positively associated with PE
	H2	TP → PE	TP is significantly positively associated with PE
	H3	RA → PE	RA is significantly positively associated with PE
Negative emotions (NE)	H4a	VP → NE	VP is significantly negatively associated with NE
	H4b	UP → NE	UP is significantly negatively associated with NE
	H4c	SA → NE	SA is significantly negatively associated with NE
	H4d	SP → NE	SP is significantly negatively associated with NE
	H5	TP → NE	TP is significantly negatively associated with NE
	H6	RA → NE	RA is significantly negatively associated with NE
Season as moderator	H7	—	The associations of landscape perception, thermal perception, and recreational activities with emotions differ across seasons.
Statistical indirect associations	H8	Vegetation composition → perception → emotion	Vegetation composition is indirectly associated with emotions through perception.
	H9	Facility function → perception → emotion	Facility function is indirectly associated with emotions through perception.
	H10	Microclimate → perception → emotion	Microclimatic characteristics are indirectly associated with emotions through perception.
	H11	Vegetation composition → RA → emotion	Vegetation composition is indirectly associated with emotions through recreational activities.
	H12	Facility function → RA → emotion	Facility function is indirectly associated with emotions through recreational activities.
	H13	Microclimate → RA → emotion	Microclimatic characteristics are indirectly associated with emotions through recreational activities.

Note: VP = visual perception, UP = usability perception, SA = safety perception, SP = spatial perception, TP = thermal perception, RA = recreational activities.

2.5. Statistical Analysis

Descriptive statistics summarized respondent characteristics and study variables. Scale reliability was assessed using Cronbach's α . Construct validity was evaluated using exploratory factor analysis and the PLS-SEM measurement model, including the Kaiser–Meyer–Olkin (KMO) test, Bartlett's test of sphericity, outer loadings, composite reliability (CR), and average variance extracted (AVE). Discriminant validity was assessed using the Fornell–Larcker criterion. Multicollinearity among the spatial environmental variables was examined using variance inflation factors (VIFs). PET and PET squared were included simultaneously to represent potential nonlinear associations, and continuous environmental variables were standardized before model estimation.

PLS-SEM and HLM served complementary analytical purposes. PLS-SEM examined relationships among individual-level latent constructs, whereas HLM accounted for the nested data structure and examined cross-level associations involving space–season environmental characteristics.

PLS-SEM was conducted using SmartPLS 4.0. A full-sample model was first estimated to evaluate the overall associations among the latent constructs and the explanatory power of the structural model. Separate models were then estimated for spring, summer, autumn, and winter. Pairwise interaction models were used to examine landscape–thermal, landscape–recreational, and thermal–recreational interactions. Path significance was assessed using two-tailed bootstrapping with 5000 resamples. Effect sizes were evaluated using f^2 , with values of 0.02, 0.15, and 0.35 indicating small, medium, and large effects, respectively. Out-of-sample predictive relevance was assessed using the PLSpredict procedure. Positive Q^2_{predict} values indicate predictive relevance relative to the naïve benchmark, and RMSE and MAE were also reported. Measurement invariance across the four seasonal groups was assessed using the measurement invariance of composite models (MICOM) procedure before any cross-season comparison.

HLM was conducted in R Studio-2026.01.1-403. Individual respondents constituted Level 1 and were nested within 24 space–season survey units at Level 2. Standardized latent-variable scores extracted from the full-sample PLS-SEM measurement model were entered into the HLM as observed Level 1 variables. These scores were treated as fixed observed values; consequently, uncertainty associated with their estimation was not propagated into the HLM standard errors. A unified multilevel SEM was not estimated because the dataset contained only 24 Level 2 space–season units, which was insufficient for reliable estimation of the full latent-variable and cross-level structure. Level 1 variables included individual socio-demographic and landscape perception, thermal perception, recreational activities, and emotional responses. Level 2 variables comprised the spatial environmental and microclimatic characteristics of the corresponding space–season units. Random-intercept null models were first estimated, and intraclass correlation coefficients were calculated to assess the proportion of variance attributable to differences between Level 2 units. Three nested HLMs were then constructed: Model 1 included individual-level controls; Model 2 added environmental variables; and Model 3 added perception and recreational activities. Statistical significance was assessed using Monte Carlo simulation with 20,000 repetitions and 95% confidence intervals.

3. Results

3.1. Sample Characteristics

The sample covered six surveyed spaces and four seasons, with relatively more responses collected in spring and autumn. Weekend responses slightly outnumbered weekday responses, and the gender distribution was generally balanced. Respondents aged 18–69 years accounted for 78.0% of the sample, while 80.7% had educational attainment ranging from high school to undergraduate levels.

Walking and public transport were the main modes of park access, together accounting for 74.8% of all trips. Park use was characterized by frequent visits and relatively short stays: 63.3% of respondents visited the park several times per week or daily, and 91.0% stayed for no more than 2 h per visit. Detailed socio-demographic and behavioral characteristics are provided in Appendix B Table A1.

3.2. Temporal and Spatial Differences in Emotional Responses

Park users reported relatively high PE and low NE. The mean PE score was 3.77, with a median of 3.89, indicating that positive-emotion scores were concentrated in the upper range. By contrast, the mean NE score was 1.19, indicating generally low levels of NE (Figure 4). Among the positive-emotion items, “Excited” (3.84), “active” (3.82), and “strong” (3.80) received the highest scores, whereas the mean scores of the negative-emotion items ranged from 1.13 to 1.26.

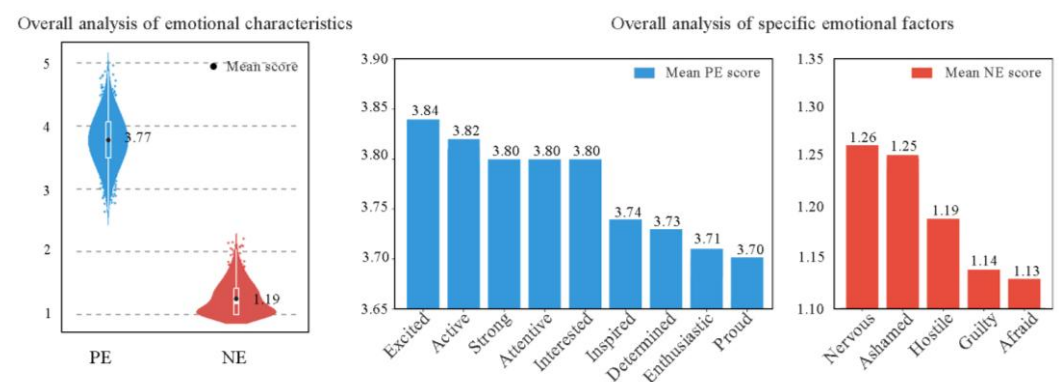


Figure 4. Distribution of positive and negative emotions.

Emotional responses also varied across seasons (Figure 5). PE was highest in spring (3.92), lowest in summer (3.57), and intermediate in autumn (3.81) and winter (3.70). NE showed the opposite pattern, reaching the highest in summer (1.30) and its lowest in winter (1.13). The largest seasonal contrast therefore occurred in summer. Vitality-related positive-emotion items showed the strongest seasonal variation, while “hostile”, “nervous”, and “ashamed” reached their highest values in summer (1.34), suggesting greater emotional discomfort under hot and humid conditions.

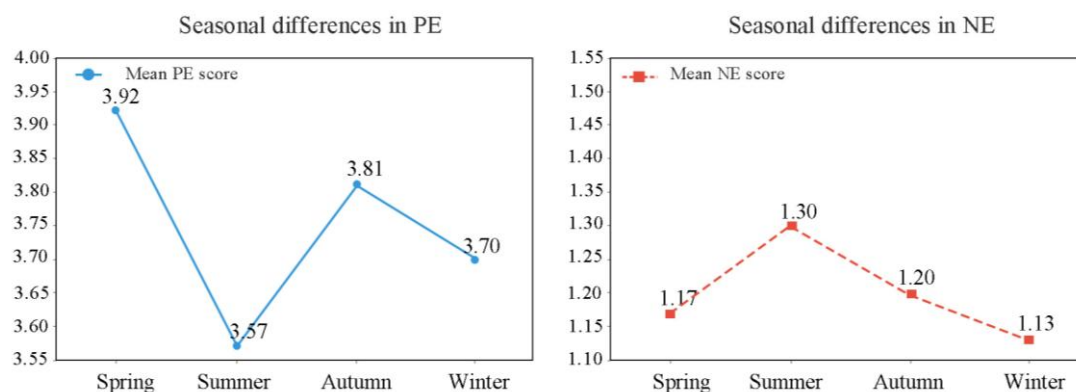


Figure 5. Seasonal patterns in positive and negative emotions.

Differences were also observed among the six surveyed spaces (Figure 6). The surveyed lawn space had the highest PE score (3.86) and the lowest NE score (1.12). The surveyed plaza space and waterfront space also showed relatively high PE scores, whereas

the surveyed fitness activity space had the highest NE score (1.25) and a relatively low PE score (3.73). The surveyed evergreen-shaded space showed a slightly higher PE score (3.75) and lower NE score (1.18) than the surveyed deciduous-shaded space.

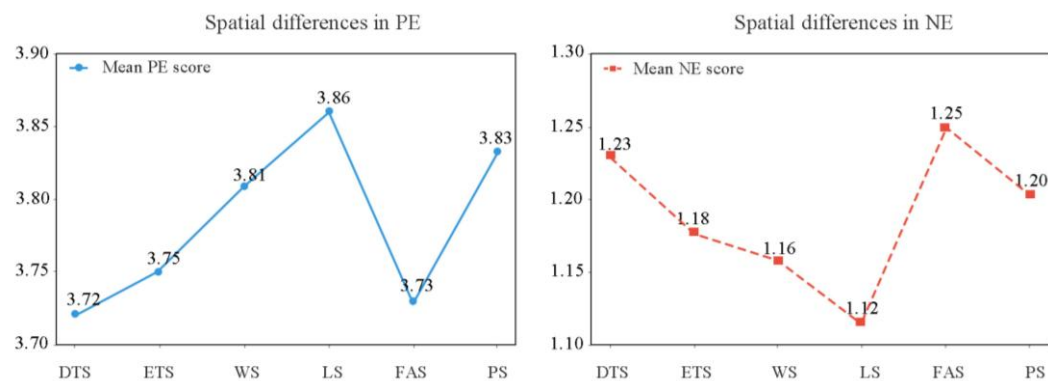


Figure 6. Emotional responses across the six surveyed spaces.

Emotions further varied across combinations of surveyed space and season (Figure 7). The surveyed lawn space showed the largest seasonal fluctuation in PE, decreasing from 4.08 in spring to 3.26 in summer. This pattern suggests that the surveyed lawn space may promote stronger PE under mild climatic conditions but become more sensitive to solar exposure and heat stress in summer. By contrast, the surveyed fitness activity space and waterfront space showed smaller seasonal ranges of 0.23 and 0.29, respectively. NE increased at all six surveyed spaces in summer, with the highest values observed at the surveyed lawn and deciduous-shaded space. In winter, NE generally declined, with the lowest scores observed in the surveyed lawn space (1.07) and evergreen-shaded space (1.10).

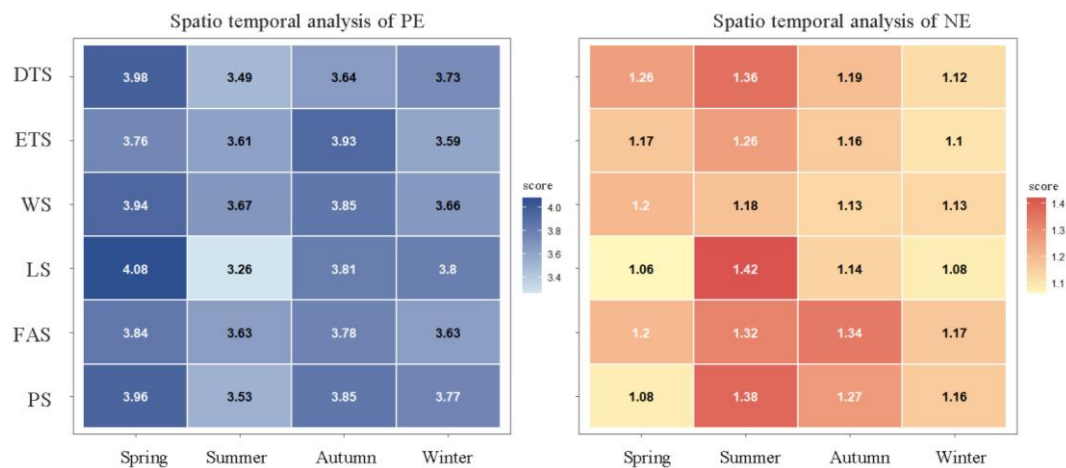


Figure 7. Emotional patterns across surveyed spaces and seasons.

3.3. Measurement Model and Model Diagnostics

The measurement model showed acceptable reliability, convergent validity, and discriminant validity (Appendix B Tables A2 and A3). Cronbach's α values ranged from 0.631 to 0.903, CR values ranged from 0.789 to 0.921, and AVE values ranged from 0.557 to 0.688. Outer loadings generally exceeded 0.60, and the Fornell–Larcker criterion was satisfied for all constructs.

Because activity frequency, duration, and intensity capture different behavioral aspects, the recreational-activities construct was examined separately. Exploratory factor

analysis supported a single-factor structure, with loadings of 0.876, 0.798, and 0.655, respectively, and no substantial cross-loadings. The corresponding PLS-SEM outer loadings were 0.883, 0.824, and 0.639. The construct showed acceptable reliability and convergent validity (Cronbach's $\alpha = 0.690$, CR = 0.829, and AVE = 0.623), and the square root of its AVE (0.789) exceeded its correlations with the other constructs.

The full-sample model explained 44.0% of the variance in PE and 14.1% of the variance in NE. As shown in Table 3, thermal perception had a medium effect on PE, while visual, safety, and usability perceptions and recreational activities had small effects. For NE, thermal and visual perceptions showed small effects, whereas the remaining predictors showed negligible effects. The PLSpredict analysis produced positive Q^2_{predict} values for PE (0.436) and NE (0.140), indicating predictive relevance for both outcomes.

Table 3. Full-sample structural model and predictive diagnostics.

Panel A. Path Coefficients and Effect Sizes					
Path	β	p -Value	f^2	Effect Size	
VP $\rightarrow$ PE	0.251	<0.001	0.085	Small	
UP $\rightarrow$ PE	0.127	<0.001	0.024	Small	
SA $\rightarrow$ PE	0.154	<0.001	0.036	Small	
SP $\rightarrow$ PE	0.070	<0.001	0.008	Negligible	
TP $\rightarrow$ PE	0.337	<0.001	0.162	Medium	
RA $\rightarrow$ PE	0.115	<0.001	0.023	Small	
VP $\rightarrow$ NE	−0.168	<0.001	0.025	Small	
UP $\rightarrow$ NE	−0.082	<0.001	0.006	Negligible	
SA $\rightarrow$ NE	−0.058	<0.05	0.003	Negligible	
SP $\rightarrow$ NE	−0.017	n.s.	0.00	Negligible	
TP $\rightarrow$ NE	−0.179	<0.001	0.030	Small	
RA $\rightarrow$ NE	−0.096	<0.001	0.011	Negligible	
Panel B. Explanatory and Predictive Performance					
Outcome	R ²	Adjust R ²	Q ² _{predict}	RMSE	MAE
Positive emotions	0.440	0.438	0.436	0.752	0.598
Negative emotions	0.141	0.139	0.140	0.932	0.653

Note: For abbreviations, see Tables 1 and 2. f^2 values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively; values below 0.02 were interpreted as negligible. Positive Q^2_{predict} values indicate predictive relevance relative to the naïve benchmark. n.s. = not significant.

All retained environmental variables had VIF values below 10, with the highest value for pavement view index (VIF = 6.10). The null models produced ICCs of 15.54% for positive emotions and 5.86% for negative emotions, supporting multilevel analysis.

3.4. Season-Specific Associations of Perception and Recreational Activities with Emotions

The associations of perception and recreational activities with emotions were examined separately for each season (Table 4). The MICOM procedure did not establish measurement invariance across the four seasonal groups. Consequently, seasonal path coefficients were not formally compared, and H7 was not supported. The following results describe the associations identified within each seasonal model.

Table 4. Season-specific path coefficients from the PLS-SEM models.

Hypothesized Path/Statistic	Spring (β)	Summer (β)	Autumn (β)	Winter (β)
Positive emotions (PE)				
VP $\rightarrow$ PE	0.313 ***	0.245 ***	0.279 ***	0.157 ***
SP $\rightarrow$ PE	0.169 ***	n.s.	0.099 ***	n.s.
UP $\rightarrow$ PE	0.075 *	0.243 ***	0.068 *	0.093 *
SA $\rightarrow$ PE	0.112 ***	0.115 ***	0.243 ***	0.135 ***
TP $\rightarrow$ PE	0.231 ***	0.327 ***	0.271 ***	0.292 ***
RA $\rightarrow$ PE	n.s.	0.100 **	0.115 ***	0.225 ***
Negative emotions (NE)				
VP $\rightarrow$ NE	−0.098 *	−0.300 ***	−0.233 ***	−0.160 ***
SP $\rightarrow$ NE	n.s.	n.s.	n.s.	n.s.
UP $\rightarrow$ NE	n.s.	−0.131 **	n.s.	n.s.
SA $\rightarrow$ NE	n.s.	−0.153 **	n.s.	n.s.
TP $\rightarrow$ NE	−0.148 ***	−0.164 ***	−0.095 *	−0.175 ***
RA $\rightarrow$ NE	−0.210 ***	−0.087 *	n.s.	n.s.
Model explanatory power				
R ² (PE)	0.382	0.586	0.445	0.278
Adjusted R ² (PE)	0.376	0.580	0.440	0.270
R ² (NE)	0.081	0.396	0.116	0.096
Adjusted R ² (NE)	0.072	0.387	0.108	0.086

Note: For other abbreviations, see Table 1. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; n.s. = not significant.

Thermal perception was positively associated with PE and negatively associated with NE in all four seasonal models. Visual perception showed the same consistent pattern. Recreational activities were positively associated with PE in summer, autumn, and winter and negatively associated with NE in spring and summer. Usability and safety perceptions were positively associated with PE in all seasons and negatively associated with NE only in summer. Spatial perception was positively associated with PE in spring and autumn but was not associated with NE in any season.

The R² values ranged from 0.278 to 0.586 for PE and from 0.081 to 0.39 for NE. Because measurement invariance was not established, differences in coefficients and explanatory power are interpreted descriptively.

3.5. Season-Specific Interaction Patterns

Two-way interaction models were estimated separately for each season to examine whether the associations among landscape perception, thermal perception, recreational activities, and emotions were non-additive (Table 5). The results showed that significant interaction effects were identified in different season models.

Table 5. Season-specific interaction effects on emotions.

Interaction Type	Interaction Term	Spring (β)	Summer (β)	Autumn (β)	Winter (β)	ΔR^2 (Maximum)
Landscape–thermal	TP $\times$ VP $\rightarrow$ NE	n.s.	0.158 ***	n.s.	0.093 *	+0.124 (NE, summer)
	TP $\times$ VP $\rightarrow$ PE	n.s.	n.s.	0.109 ***	n.s.	
	TP $\times$ SP $\rightarrow$ PE	n.s.	n.s.	0.062 *	0.102 *	
	TP $\times$ SA $\rightarrow$ PE	n.s.	−0.075 *	−0.112 ***	n.s.	
Landscape–recreational	RA $\times$ VP $\rightarrow$ NE	n.s.	0.121 *	n.s.	n.s.	+0.079 (NE, summer)
	RA $\times$ SP $\rightarrow$ NE	n.s.	n.s.	−0.096 *	−0.098 *	
	RA $\times$ UP $\rightarrow$ PE	0.062 *	n.s.	n.s.	n.s.	
	RA $\times$ SA $\rightarrow$ PE	−0.082 **	−0.072 *	n.s.	n.s.	
Thermal–recreational	TP $\times$ RA $\rightarrow$ NE	n.s.	0.180 ***	n.s.	n.s.	+0.048 (NE, summer)
	TP $\times$ RA $\rightarrow$ PE	n.s.	n.s.	0.075 *	n.s.	

Note: For abbreviations, see Tables 1 and 2. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; n.s. = not significant.

In summer, thermal perception interacted with visual perception in relation to NE ($\beta = 0.158, p < 0.001$), and with safety perception in relation to PE ($\beta = -0.075, p < 0.05$). In autumn, thermal perception interacted with visual perception ($\beta = 0.109, p < 0.001$) and spatial perception ($\beta = 0.062, p < 0.05$) in relation to PE. The thermal-spatial interaction was also associated with PE in winter ($\beta = 0.102, p < 0.05$).

In spring, recreational activities interacted positively with usability perception in relation to PE ($\beta = 0.062, p < 0.05$), and negatively with safety perception ($\beta = -0.082, p < 0.01$); the latter interaction was also significant in summer ($\beta = -0.072, p < 0.05$). Recreational activities interacted with visual perception in relation to NE in summer ($\beta = 0.121, p < 0.05$) and with spatial perception in autumn ($\beta = -0.096, p < 0.05$) and in winter ($\beta = -0.098, p < 0.05$). The thermal-recreational interaction was associated with NE in summer ($\beta = 0.180, p < 0.001$) and with PE in autumn ($\beta = 0.075, p < 0.05$). These results do not constitute formal evidence of differences between seasons.

3.6. Indirect Associations of Perception and Recreational Activities

3.6.1. Nested Model Comparison

Three nested HLMs were constructed to examine the relationships among individual characteristics, spatial environmental variables, perception, recreational activities, and emotions (Table 6).

Table 6. Nested model comparison for positive and negative emotions.

Variable Level and Name	M1 (Control)	M2 (+Environment)	M3 (+Mediators)
Positive emotion model			
Between-group variance (τ_{00})	0.176	0.098	0.031
PET ² (Z)		−0.105 ***	n.s.
Vegetation color richness (Z)		0.197 **	n.s.
Marginal R ² (fixed effects)	0.004	0.107	0.447
Conditional R ² (full model)	0.206	0.201	0.478
Negative emotion model			
Between-group variance (τ_{00})	0.060	n.s.	n.s.
Pavement view index (Z)		0.294 **	n.s.
Fitness facility quantity (Z)		0.185 ***	n.s.
Green view index (Z)		0.192 *	n.s.
PET (Z)		0.113 ***	0.133 ***
PET ² (Z)		0.096 ***	n.s.
Marginal R ² (fixed effects)	0.027	0.069	0.187
Conditional R ² (full model)	0.085	0.097	0.215

Note: Model 3 included all six perceptual and recreational variables. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; n.s. indicates non-significance ($p > 0.05$).

In the positive-emotion model, adding spatial environmental characteristics reduced the between-group variance from 0.176 to 0.098. PET² was negatively associated with PE, while vegetation color richness was positively associated with PE. After perceptual and recreational activities were added in Model 3, these environmental coefficients became non-significant, the between-group variance decreased to 0.031, and marginal R² increased from 0.107 to 0.447.

In the negative-emotion model, pavement view index, the number of fitness facilities, green view index, PET, and PET² were significant in Model 2. After perception and recreational activities were introduced, most environmental coefficients were no longer significant, while PET remained significant. Marginal R² increased from 0.027 to 0.187. These changes are consistent with statistical indirect associations through perceptual variables.

3.6.2. Specific Indirect Associations

Monte Carlo simulations identified indirect effects primarily through perceptual variables, whereas all indirect effects through recreational activities were non-significant. Table 7 therefore reports only the significant perceptual pathways.

Table 7. Significant statistical indirect associations linking environmental characteristics to emotions.

Independent Variable	Mediator	Dependent Variable	Path Coefficient (IV → Med)	Path Coefficient (Med → DV)	Indirect Effect	95% CI
PET ²	VP	PE	−0.150 ***	0.499 ***	−0.075 ***	[−0.099, −0.050]
	SP	PE	−0.125 ***	0.191 ***	−0.024 ***	[−0.034, −0.013]
	UP	PE	−0.096 ***	0.355 ***	−0.034 ***	[−0.052, −0.017]
	SA	PE	−0.085 **	0.325 ***	−0.028 **	[−0.045, −0.011]
	TP	PE	−0.192 ***	0.481 ***	−0.092 ***	[−0.116, −0.068]
	VP	NE	−0.150 ***	−0.320 ***	0.048 ***	[0.031, 0.064]
	SP	NE	−0.125 ***	−0.122 ***	0.015 ***	[0.007, 0.023]
	UP	NE	−0.096 ***	−0.223 ***	0.021 ***	[0.010, 0.033]
	SA	NE	−0.085 **	−0.198 ***	0.017 **	[0.006, 0.028]
	TP	NE	−0.192 ***	−0.273 ***	0.052 ***	[0.037, 0.068]
	TP	PE	0.291 ***	0.481 ***	0.140 ***	[0.067, 0.212]
	UP	PE	0.174 **	0.355 ***	0.062 **	[0.019, 0.104]
Vegetation color richness	SP	PE	0.131 *	0.191 ***	0.025 *	[0.001, 0.049]
	TP	NE	0.291 ***	−0.273 ***	−0.079 ***	[−0.122, −0.037]
	UP	NE	0.174 **	−0.223 ***	−0.039 **	[−0.066, −0.011]
	SP	NE	0.131 *	−0.122 ***	−0.016 *	[−0.032, −0.000]
Green view index	TP	PE	−0.367 **	0.481 ***	−0.177 **	[−0.299, −0.054]
	UP	PE	−0.208 *	0.355 ***	−0.074 *	[−0.145, −0.003]
	TP	NE	−0.367 **	−0.273 ***	0.100 **	[0.029, 0.171]
Pavement view index	UP	NE	−0.208 *	−0.223 ***	0.046 *	[0.001, 0.092]
	TP	PE	−0.559 **	0.481 ***	−0.269 **	[−0.439, −0.099]
	TP	NE	−0.559 **	−0.273 ***	0.153 **	[0.054, 0.251]
Number of fitness facilities	VP	PE	−0.391 **	0.499 ***	−0.195 **	[−0.316, −0.074]
	TP	PE	−0.271 **	0.481 ***	−0.130 **	[−0.224, −0.037]
	SP	PE	−0.205 *	0.191 ***	−0.039 *	[−0.070, −0.008]
	VP	NE	−0.391 **	−0.320 ***	0.125 **	[0.046, 0.204]
	TP	NE	−0.271 **	−0.273 ***	0.074 **	[0.020, 0.128]
Number of facility types	SP	NE	−0.205 *	−0.122 ***	0.025 *	[0.004, 0.046]
	TP	PE	0.316 **	0.481 ***	0.152 **	[0.038, 0.265]
	UP	PE	0.226 *	0.355 ***	0.080 *	[0.015, 0.146]
	TP	NE	0.316 **	−0.273 ***	−0.086 *	[−0.152, −0.021]
	UP	NE	0.226 *	−0.223 ***	−0.050 *	[−0.093, −0.008]
Plant species richness	SP	PE	0.195 *	0.191 ***	0.037 *	[0.005, 0.069]
	SP	NE	0.195 *	−0.122 ***	−0.024 *	[−0.045, −0.002]

Note: For abbreviations PE, NE, VP, SP, UP, SA, TP, see Tables 1 and 2. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Indirect effects and 95% CIs based on Monte Carlo with 20,000 resamples.

PET² showed indirect associations with both PE and NE through visual, spatial, usability, safety, and thermal perception, with thermal perception showing the largest indirect effects. Vegetation color richness was indirectly associated with higher PE and lower NE through thermal, usability, and spatial perception.

The green view index and pavement view index showed adverse indirect associations through thermal and usability perception in the present sample. The number of fitness facilities was also indirectly associated with lower PE and higher NE through visual, thermal, and spatial perception. The number of facility types and plant species richness showed smaller indirect associations through thermal, usability, or spatial perception.

Overall, the HLM results identified significant statistical indirect effects primarily through perceptual variables. Recreational activities were directly associated with emotions in the PLS-SEM models but did not show significant indirect effects between spatial environmental characteristics and emotions.

4. Discussion

4.1. Spatiotemporal Patterns of Emotional Responses Across the Six Surveyed Spaces

Previous studies have reported seasonal variation in emotional benefits of urban parks, with PE generally being higher in spring and autumn than in summer and winter [33,34], and have identified parks as emotional hotspots [35]. Consistent with this evidence, PE in Jiefang Park was highest in spring, and lowest in summer, while NE was highest in summer and lowest in winter. The hot and humid summer conditions recorded during summer were therefore associated with less favorable emotional response.

The surveyed lawn space showed relatively high PE and low NE but also the largest seasonal fluctuations. The fitness activity and waterfront spaces showed smaller fluctuations. These findings are partly consistent with previous evidence on waterfront and shaded environments [12,13]. The relatively high negative-emotion score at the surveyed fitness activity space may be related to its activity intensity, social environment, or other site-specific characteristics.

4.2. Season-Specific Associations, Interactions, and Indirect Pathways

Thermal and visual perceptions were consistently associated with PE and NE in all four seasonal models. These findings align with studies linking thermal comfort and visual landscape quality to emotional and restorative experiences [9,17,19,36]. Recreational activities were associated with PE in the summer, autumn, and winter models and with lower NE in the spring and summer models, supporting evidence that activity in natural environments is related to psychological well-being [37]. Usability and safety perception were associated with lower NE only in the summer model, suggesting that facility and perceived safety may be particularly relevant to emotional experiences under the environmental conditions observed during summer. Because measurement invariance was not established, these patterns cannot be interpreted as formal seasonal moderation.

The interaction models further identified non-additive relationships among perception and recreational activities within particular seasonal samples. In the summer and winter models, the interaction between visual and thermal perception was associated with NE. Given the negative main associations of both variables, these results suggest a possible compensatory relationship between visual quality and thermal perception under thermally stressful conditions. This interpretation is broadly consistent with studies showing that visual, thermal, and multi-sensory comfort jointly contribute to psychological restoration and emotional experience [22,24]. In the autumn model, interactions involving visual, spatial, and thermal perception were associated with positive emotions, suggesting that multiple favorable perceptions may operate jointly under relatively comfortable conditions [38]. Recreational activities also interacted with landscape or thermal perception in several seasonal models, indicating that activity engagement may alter the relationship between perceived environmental conditions and emotions [32].

The cross-level analysis provided further evidence of statistical indirect associations between spatial environmental characteristics and emotions. Significant indirect effects were mainly identified through perceptual variables, while indirect effects through recreational activities were not significant. Vegetation color richness was indirectly associated with higher PE and lower NE through thermal, usability, and spatial perception. This result is consistent with Hao, who showed that plant richness and color diversity can influence environmental perception, preference, and restoration in urban green spaces [21].

By contrast, the green view index showed adverse indirect associations through thermal and usability perception in this sample. This finding suggests that a higher proportion of visible greenery does not necessarily correspond to more favorable emotional responses when it is accompanied by lower perceived thermal comfort or usability. Dense vegetation may, in some settings, reduce visual permeability, ventilation, or perceived accessibility [14]. The pavement view index and the number of fitness facilities also showed adverse indirect associations through perceptual pathways, indicating that landscape and facility configuration may be more relevant than their quantity alone.

Recreational activities may therefore be more directly related to emotional responses than to the transmission of environmental effects. Users may also adjust their activities in response to environmental conditions, for example by moving to shaded areas, shortening their stays, or reducing activity intensity. Such behavior adaptation may weaken stable indirect relationships between objective environmental characteristics, recreational activities, and immediate emotions.

4.3. Implications for Seasonally Adaptive Park Design

The findings suggest that emotionally supportive park design should prioritize perceptual quality, thermal adaptability, and flexible use. Environmental improvements should consider not only physical attributes but also how users experience visual, thermal, spatial, and facility conditions.

Planting design should consider seasonal variation in vegetation structure and visual composition, rather than overall greenness alone. Flowering or visually distinctive plants may strengthen seasonal landscape experiences during warmer periods, whereas evergreen and structurally distinctive vegetation may help maintain visual interest during colder periods. In enclosed or densely planted locations, selective pruning may improve visual permeability and air circulation, thereby supporting spatial openness and thermal perceptions. Planting design may therefore function as a seasonally dynamic perceptual resource rather than a static measure of vegetation quantity.

The findings related to the pavement visibility and the number of fitness facilities suggest that the spatial organization of hardscape and facilities may be more important than provision quantity alone. Dispersed fitness facilities along shaded edges or semi-natural areas may reduce visual concentration and improve environmental exposure. In highly exposed locations, paving materials and shading should be coordinated to limit heat accumulation. Integrating seating, shade, and resting functions into activity areas may also improve perceived usability and allow users to adjust their activities under different environmental conditions.

Thermal perception was consistently associated with emotional responses, highlighting the importance of coordinating shade, solar access, and ventilation. Open areas may support gathering and active use under moderate thermal conditions, while shaded edge spaces can provide alternatives during hot periods. Vegetation structure and canopy configuration can regulate seasonal solar exposure, whereas waterfront spaces may require both summer cooling and winter wind protection. Thermal design should therefore be integrated with spatial organization and activity planning.

The absence of significant indirect associations through recreational activities does not imply that recreational opportunities are unimportant. Instead, activity-related design may be most effective when it enables users to adapt their behavior. Park environments should accommodate both active and passive use, with shaded and sheltered spaces supporting lower-intensity activities during thermal stress and open spaces supporting more active use under moderate conditions. Flexible elements, including movable seating, multifunctional edges, and adaptable activity areas, may further improve seasonal usability.

4.4. Limitations

This study has several limitations. First, the analysis was based on a single comprehensive urban park in Wuhan, and each of the six surveyed spaces was represented by only one physical location. The designated spatial characteristics were therefore confounded with other site-specific conditions. Moreover, the Level 2 analysis included only 24 space–season units relative to the number of environmental predictors, which may have limited the precision and stability of the cross-level estimates. Standardized latent scores were treated as observed variables in the HLM, so uncertainty associated with their estimation was not propagated into the HLM standard errors. The limited number of Level 2 units also made reliable estimation of a unified multilevel SEM difficult. Future studies should include multiple locations representing each spatial setting and a larger number of upper-level units across different parks and climatic regions.

Second, the study used a cross-sectional design, and different users were surveyed in each seasonal investigation. The relationships represent associations rather than causal effects or within-person seasonal changes. Similarly, the identified indirect pathways should be interpreted as statistical indirect effects rather than confirmed causal mechanisms. Future research could adopt longitudinal or repeated-measures designs to provide stronger evidence regarding seasonal changes and environment–emotion relationships.

Third, measurement invariance was not established across seasonal samples. Consequently, seasonal path coefficients could not be formally compared, and H7 was not supported. Future research should refine the measurement instrument, include multiple comparable locations, and use longitudinal or repeated-measures designs.

5. Conclusions

Using four-season field survey data from six locations in Jiefang Park, Wuhan, this study examined the associations of spatial environmental characteristics, perception, and recreational activities with users' positive and negative emotions. Emotional responses varied across the four survey seasons and among the six surveyed locations. The surveyed lawn space had the highest positive-emotion score and the lowest negative-emotion score, whereas the surveyed fitness activity space had the highest negative-emotion score. The surveyed fitness activity and waterfront spaces showed smaller seasonal fluctuations than the other surveyed locations.

Thermal and visual perception were consistently associated with emotional responses across the season-specific models. Usability, safety, spatial perception and recreational activities showed different patterns of significance within four seasonal samples. However, measurement invariance across seasons was not established; therefore, the seasonal path coefficients could not be formally compared, and H7 was not supported.

The interaction models identified non-additive relationships among landscape perception, thermal perception, and recreational activities within particular seasonal samples. The multilevel analysis showed significant indirect associations mainly through perceptual variables, whereas indirect effects through recreational activities were not significant. Vegetation color richness showed favorable indirect associations, while green view index,

pavement view index, and the number of fitness facilities showed adverse indirect associations at the surveyed locations. Park design and management should therefore coordinate visual quality, thermal adaptability, spatial usability, and flexible recreational opportunities. Multi-site and longitudinal studies are needed to determine whether these associations apply to other parks and climatic contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

Abbreviation	Full form
AVE	average variance extracted
CR	composite reliability
DTS	shaded space with deciduous trees
EFA	exploratory factor analysis
ETS	shaded space with evergreen trees
FAS	fitness activity space
NFF	number of fitness facilities
GVI	green view index
HLM	hierarchical linear modeling
ICC	intraclass correlation coefficient
KMO	Kaiser–Meyer–Olkin
NLF	Number of leisure facilities
LS	lawn space
MET	metabolic equivalent
NE	negative emotions
NFT	number of facility types
PANAS	Positive and Negative Affect Schedule
PE	positive emotions
PET	physiological equivalent temperature
PLS-SEM	partial least squares structural equation modeling
PS	plaza space
PVI	pavement view index
RA	recreational activities
RH	relative humidity
SA	safety perception
SP	spatial perception
SR	plant species richness
SVF	sky view factor

Ta	air temperature
Tg	globe temperature
Tmrt	mean radiant temperature
TP	thermal perception
UP	usability perception
Va	wind velocity
VCR	vegetation color richness
VIF	variance inflation factor
VP	visual perception
WS	waterfront space

Appendix A. Questionnaire

Questionnaire on Emotions, Perception, and Recreational Characteristics in Jiefang Park Green Spaces.

Part I. Basic Information

Your gender:

☐ Male ☐ Female

Your age:

☐ 13–17 ☐ 18–45 ☐ 46–69 ☐ 70 or above

Your education level:

☐ Junior high school or below ☐ Senior high school or technical secondary school
☐ Bachelor's degree/college ☐ Master's degree or higher

Part II. Travel and Visit Characteristics

How do you get to the park?

☐ Walk ☐ Bike ☐ Bus/subway ☐ Car ☐ Taxi/ride-hailing

How long does it take you to reach the park?

☐ Within 15 min ☐ 15–30 min ☐ 30–60 min ☐ 60–90 min ☐ More than 90 min

How long have you stayed in the park?

☐ <1 h ☐ 1–2 h ☐ 2–3 h ☐ 3–4 h ☐ >4 h

How often do you visit this park?

☐ Every day ☐ Several times a week ☐ Once a week ☐ 1–2 times a month
☐ 1–2 times a year

Part III. Recreational Characteristics

Which activities do you do in this space? (Multiple choices allowed)

☐ Chess/cards ☐ Sitting quietly ☐ Reading ☐ Picnic ☐ Taking photos
☐ Walking ☐ Chatting ☐ Dating/matchmaking ☐ Kite flying
☐ Playing musical instruments ☐ Stretching ☐ Jogging/running
☐ Observing nature ☐ Traditional opera ☐ Sword dancing ☐ Tai chi
☐ Fitness training ☐ Basketball ☐ Dancing ☐ Frisbee ☐ Square dancing
☐ Badminton ☐ Table tennis ☐ Football ☐ Roller skating ☐ Skateboarding
☐ Jumping rope ☐ Parent-child activities ☐ Walking dog ☐ Other: _____

How long do you usually spend on these activities in this space?

☐ 0–0.5 h ☐ 0.5–1 h ☐ 1–1.5 h ☐ 1.5–2 h ☐ >2 h

How often do you perform these activities in this space?

☐ Every day ☐ Several times a week ☐ Once a week ☐ 1–2 times a month
☐ 1–2 times a year

Part IV. Thermal Perception

How comfortable do you feel with the current climate (temperature, humidity, wind) in this space?

☐ Very uncomfortable ☐ Uncomfortable ☐ Neutral ☐ Comfortable
☐ Very comfortable

How satisfied are you with the current climate (temperature, humidity, wind) in this space?

☐ Very dissatisfied ☐ Dissatisfied ☐ Neutral ☐ Satisfied ☐ Very satisfied

How acceptable is the current climate (temperature, humidity, wind) in this space to you?

☐ Completely unacceptable ☐ Somewhat unacceptable ☐ Neutral ☐ Somewhat acceptable ☐ Completely acceptable

Part V. Landscape Perception

Please rate the following landscape features of this area.

Perceptual Dimension	1 = Very Poor	2 = Poor	3 = Neutral	4 = Good	5 = Very Good
Visual openness					
Canopy shade					
Vegetation color satisfaction					
Vegetation richness					
Water features					
Topography					
Facility density					
Facility comfort					
Facility maintenance					
Sense of spatial openness					
Acoustic comfort					
Olfactory comfort					
Barrier-free design					
Pavement material					

Part VI. Emotional Characteristics (PANAS)

Please describe your overall feelings in this space. Choose the extent to which you feel each emotion.

Emotion	1 = Very Slightly or Not at All	2 = a Little	3 = Moderately	4 = Quite a Bit	5 = Extremely
Interested					
Distressed					
Excited					
Upset					
Strong					
Guilty					
Scared					
Hostile					
Enthusiastic					
Proud					
Irritable					
Alert					
Ashamed					
Inspired					
Nervous					
Determined					
Attentive					
Jittery					
Active					
Afraid					

Note: The English terms correspond to the PANAS (Positive and Negative Affect Schedule) items used in the study. The order follows the original Chinese questionnaire.

Appendix B

Table A1. Descriptive statistics of respondents' demographic characteristics.

Variable	Category	Frequency (N)	Percentage (%)
	Deciduous understory	451	20.2

	Evergreen understory	350	15.7
	Waterfront	416	18.6
Space type	Lawn	284	12.7
	Fitness	429	19.2
	Plaza	303	13.6
	Spring	639	28.6
Season	Summer	400	17.9
	Autumn	646	28.9
	Winter	548	24.5
Day type	Weekday	957	42.9
	Weekend/holiday	1276	57.1
Gender	Male	1089	48.8
	Female	1144	51.2
Age	13–17 years	37	1.7
	18–45 years	882	39.5
	46–69 years	860	38.5
	70 years or above	454	20.3
Education level	Junior high school or below	328	14.7
	Senior high school or technical secondary school	941	42.1
	Bachelor's degree/college	861	38.6
	Master's degree or above	103	4.6
Travel mode	Walk	833	37.3
	Bike	269	12.0
	Bus/subway	838	37.5
	Car	221	9.9
	Taxi/other	72	3.2
Park stay duration	<1 h	1239	55.5
	1–2 h	794	35.5
	2–3 h	148	6.6
	3–4 h	26	1.2
	>4 h	26	1.2
Visit frequency	1–2 times/year	186	8.3
	1–2 times/month	376	16.8
	Once/week	258	11.5
	Several times/week	763	34.2
	Every day	650	29.1
Total		2233	100.0

Table A2. Reliability and Convergent Validity of the Measurement Model.

Construct	Indicator	Outer Loading	Range	Cronbach's α	CR	AVE
	Topography	0.786				
	Satisfaction with vegetation color	0.773				
Visual perception	Landscape view	0.764		0.841	0.883	0.567
	Vegetation richness	0.753				
	Water features	0.721				
	Tree shade	0.678				
Usability perception	Facility density	0.771		0.739	0.850	0.654
	Facility comfort	0.864				
	Facility completeness	0.788				
	Barrier-free design	0.870				
Safety perception	Pavement material	0.870		0.753	0.856	0.667
	Facility maintenance	0.698				

Spatial perception	Perceived openness	0.803			
	Olfactory comfort	0.835	0.631	0.789	0.560
	Acoustic comfort	0.583			
Thermal perception	Thermal comfort	0.851			
	Thermal satisfaction	0.791	0.773	0.869	0.688
	Thermal acceptability	0.846			
Recreational activities	Activity intensity	0.639			
	Activity frequency	0.883	0.690	0.829	0.623
	Activity duration	0.824			
Positive emotions	Determined	0.838			
	Attentive	0.779			
	Active	0.763			
	Interested	0.759			
	Proud	0.745	0.903	0.921	0.564
	Excited	0.728			
	Enthusiastic	0.724			
	Inspired	0.709			
	Strong	0.702			
	Guilty	0.847			
Negative emotions	Scared	0.824			
	Hostile	0.800	0.853	0.895	0.631
	Ashamed	0.784			
	Nervous	0.710			

Note: CR = composite reliability; AVE = average variance extracted.

Table A3. Discriminant validity based on the Fornell–Larcker criterion.

Construct	1	2	3	4	5	6	7	8
1. Safety perception	0.817							
2. Negative emotions	0.216	0.794						
3. Recreational activities	0.042	0.158	0.789					
4. Thermal perception	0.310	0.353	0.075	0.829				
5. Positive emotions	0.423	0.442	0.203	0.633	0.751			
6. Spatial perception	0.259	0.186	0.034	0.286	0.325	0.748		
7. Visual perception	0.359	0.339	0.078	0.497	0.558	0.385	0.746	
8. Usability perception	0.401	0.248	0.146	0.324	0.419	0.354	0.321	0.809

Note: The bold diagonal values are the square roots of the average variance extracted (AVE), and the off-diagonal values are the correlations between constructs.

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