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# Visual Quality Analysis of Urban Park Landscapes Based on Eye Tracking: A Case Study of Nanjing Xiaohong Stone Carving Park

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**Abstract** The landscape quality of urban parks is an important aspect of tourists' landscape experience. A full understanding of their relationship is beneficial to the park design, construction and management. In this paper, Xiaohong Stone Carving Park in Nanjing was selected as a case study. Firstly, the subjective landscape visual quality evaluation of tourists was obtained through the scenic beauty evaluation, and the objective landscape visual preference of users was obtained through eye movement experiment and analysis. Secondly, the values of various park landscape elements were measured respectively. And then the correlation between the subjective and objective evaluation and the values of park landscape elements was analyzed. The results showed that: (1) The visual preference of plant cluster landscape with beautiful shape, distinct layers and significant color contrast is high; (2) The preference for waterfront scenes with significant terrain differences, rich background vegetation levels, and clear and vivid water side reflections is high; (3) The designed artificial structures often become the focus of attention in the whole scene, which can improve the beauty of the scene; (4) The overall landscape composition is very important for the beauty of the scene. Finally, through the comprehensive analysis with the design expectation, the optimization strategy was proposed.

**Keywords** Urban park, Landscape visual evaluation, Eye tracking

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Urban parks are important places for urban residents' daily outdoor leisure and recreation activities. The landscape quality and facility conditions can directly reflect the level of park design, construction and management. The research on the visual quality evaluation of urban park landscape based on public tourists' perception is of great significance to improve the landscape quality of urban parks[1-2].

The visual quality evaluation of park landscape is an important index for tourists' landscape experience and the evaluation of landscape quality. The existing landscape visual quality evaluation model is mainly from the subjective point of view, but there are still shortcomings in the objective evaluation. Traditional psychophysical methods such as scenic beauty evaluation (SBE), semantic difference, and psychological scale are widely used. Combined with SPSS and other statistical analysis software, they can objectively reflect the subjective cognition of the subjects[3-5]. With the development of computer simulation and surveying and mapping technology and the iterative updating of practical tools, the research methods and technical means of landscape visual evaluation have been greatly developed. In recent years, virtual reality, remote sensing and 3D modeling have gradually become the trend of landscape vision research at home and abroad[6]. Qi Jinda et al.[7] used geographic data and GIS to evaluate the selected factors quantitatively; Zhu Yan et al.[8] updated the traditional SBE method by using the capability of VR panoramic technology in simulating the spaces and scenes, and evaluated on the basis of observational experiment. Shan et al.[6] explored the methods of 3D scene modeling, dynamic simulation and real-time rendering, on this basis, built the comprehensive evaluation index system based on visual elements and landscape visual sensitivity; Yu Furong et al.[9-10] combined street view map with image attributes and geographical attributes, collected information using the image processing algorithm of electronic interactive map, then further quantitatively analyze and evaluate the landscape visual elements.

Participation of multiple technologies and tools pushes the landscape visual evaluation to the digitization, precision and intellectualization, improves the precision of evaluation, and to some extent overcomes the spatial limitation, and enhances public participation of landscape planning[11]. Eye tracking technology can objectively reflect the visual preferences, supplement and improve the subjective evaluation model, and effectively enhance the rationality and reliability of the evaluation model. Li Xin et al.[12] combined subjective evaluation and eye tracking technology, conducted empirical analysis of the realistic spatial visual quality in riverfront areas of Hankou, and explored the key spatial design elements that influenced the visual quality of urban spaces. Zhou Xiang et al.[13] took Yongqingfang in Guangzhou for example, used eye tracking and subjective questionnaire survey to evaluate the visual experience of historic block landscapes, and established the experience evaluation mathematical model highlighting the quantitative features. Zhang Ting et al.[14] applied both questionnaire survey and eye tracking on the basis of SOR model, verified the different experience and responses of observers brought by different types of terraced landscapes from the perspective of aesthetic experience. Qiu Yao[15] took urban spaces in Fujian Province for example, used landscape photos of these cities, eye movement analysis and aesthetic preference test for the quantitative analysis of the testees' visual attention and aesthetic preferences, and explored the relationship between the attention and the preference among landscape visual elements.

In conclusion, research on the landscape visual quality evaluation based on public perception is an important approach of improving landscape quality of urban parks. The combination of conventional psychophysical methods and modern technologies makes the visual quality evaluation of landscapes more digitalized, precise and smart, and the application of eye tracking technology works as an essential supplement for the subjective evaluation model, so it can objectively reflect the visual preference characteristics of the testees, and make the evaluation model more reasonable and reliable.

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Based on the above researches, this paper took Xiaohong Stone Carving Park in Nanjing City as an example, analyzed the visual quality of park landscapes through the subjective evaluation of landscape characteristic elements and objective eye tracking technology, so as to explore visitors' preferences on the visual landscapes of urban parks, and proposed corresponding strategies for the landscape improvement.

## 1 Research framework and method

### 1.1 Research framework

Measuring the subjective landscape evaluation and objective landscape elements is the two main parts of the research framework. The first part is the subjective landscape evaluation. Combining the questionnaire survey and semantic difference scale, the subjective landscape evaluation information was obtained, eye movement experiment and analysis were applied to get the users' preferences on objective landscape visual behavior, analyzed the correlation between subjective and objective evaluation, verified the feasibility of eye tracking technology in the evaluation of landscape visual quality, selected corresponding indexes on the basis of feasibility, obtained the visual preferences on the overall spatial landscapes according to the classification analysis of eye movement views, and proposed the strategies for optimization. The second part is the objective landscape elements including terrain and vegetation landscape (terrain fluctuation, vegetation form and layer design), waterscape (water and related artificial or ecological revetment), artificial construction landscape (building, stone carving, sacred way, bridge and plank road) and tourist trail landscape (trail and square).

### 1.2 Research method

**1.2.1** Eye tracking technology. Human beings perceive visual scenes by moving eyes, thus capturing, expressing and storing the eye movement information can dynamically reflect people's perception of neighboring visual environment. Eye tracking is a technique of capturing and analyzing visual attention, eye tracking equipment can be used to detect the pupils so as to obtain information such as the fixation point of the testee at a certain time, the fixation duration, the fixation frequency, and tracks of eye movement[16], then the data processing used to digitalize the eye movement information and demonstrate the spatial-temporal characteristics of the fixation behavior. The technique has been widely applied in multiple fields, already played an important role in visual search[17], pattern recognition[18], scene perception[12] etc.. In landscape vision research, eye tracking technology helps analyze the users' visual experience and aesthetic preferences objectively, particularly some hidden experience that can hardly be described.

Considering the influence of multiple factors limiting the landscape evaluation, such as labor, materials, and site, the research took photos as the media, Tobii Glasses 2.0 as the main experimental instrument, photo observation as the tool, to collect the eye movement data using Tobii Pro Glasses Controller. Thirty landscape photos were played in computer automatically, 7 s for each, and 1-s black screen set between each 2 photos to avoid the influence among photos. After ensuring the testees understand the experimental procedures, they were required to stare at the calibration card to calibrate the eye tracker, and then the experiment started after the calibration. After playing all photos, the data were primarily screened, the eye movement data with a sampling frequency above 60% was considered as the valid data.

Tobii Pro Lab was used to process the eye movement data primarily. Thirty photos were input into the software, and classified according to AOI based on the landscape characteristic elements, and corresponded to the testees' eye movement data, so as to quantitatively classify the observation and fixation behaviors of the testees, obtain the AOI-based metrics data and eye movement views under different indexes.

**1.2.2** Semantic differential method. Data in eye tracking experiment were obtained from the eye movement of the testees. But emotional preferences of the testees behind the fixation could not be distinguished, and there is no simple way to demonstrate the brain activity during the certain visual fixation[20]. Therefore, landscape characteristic element evaluation scales based on semantic differential method could be applied to get the subjective evaluation of landscape visual quality[19], and through the correlation analysis between the subjective evaluation scale data and the objective eye movement data, the relationship between different eye movement indexes and subjective preferences in the landscape visual evaluation could be verified. In this way, the feasibility of the indexes in reflecting the landscape visual preferences can be further verified[21-22]. On the basis of feasibility analysis, suitable indexes could be chosen for the visualization analysis, for the comprehensive evaluation and analysis of landscape visual quality. The overall tour route is shown as Fig.1.

After the eye movement experiment, subjective evaluation data should be collected immediately to ensure the consistency between the testees' perception and eye movement experiment data. First, questionnaire survey was used to evaluate the overall beauty of the above photos, and the testees were required to finish the evaluation scale of landscape characteristic elements in Xiaohong Stone Carving Park (Table 1), and evaluate the elements in the photos according to the type and evaluation criterion.

## 2 Landscape visual evaluation of Xiaohong Stone Carving Park

### 2.1 Feasibility of eye movement experiment in landscape visual evaluation

Tobii Pro Lab was used for the primary processing of the eye movement data. Thirty landscape photos were input into the software to correspond to the testees' eye movement data. The visualized analysis of the eye movement data of the 30 photos were conducted, then the heat map of fixation duration and frequency and eye movement path map were output. According to the basic eye movement data, landscape characteristic elements were used to classify the AOI of the 30 photos, then output the AOI-based metrics data, and conducted the correlation analysis of eye movement indexes based on the subjective evaluation scale. The correlation between gaze behavior characteristics and subjective preference was evaluated to verify the feasibility of eye movement experiment results in the evaluation of landscape visual quality.

**2.1.1** Total duration of fixations. Total duration of fixations indicates the total duration of fixations in AOI, and is perhaps the most applied measuring method in eye tracking researches[17-18]. Most researchers thought that total duration of fixations reflects the testees' absorption and processing of information, i.e. the functional connection between the watched objects and the perception processing of these things, the longer the duration of fixation is, the higher the processed "depth" is. Pearson correlation coefficients were used to indicate the strong and weak relationship, the correlation between the eye movement data (total duration of fixations in AOI) and 12 landscape characteristic elements was explored, to correspond to the landscape characteristic elements represented by the AOI.

According to the specific analysis, there is a positive correlation between area of B water and b-1 water surface; there is a positive correlation between C water quality and b-1 water surface. The correlation coefficient

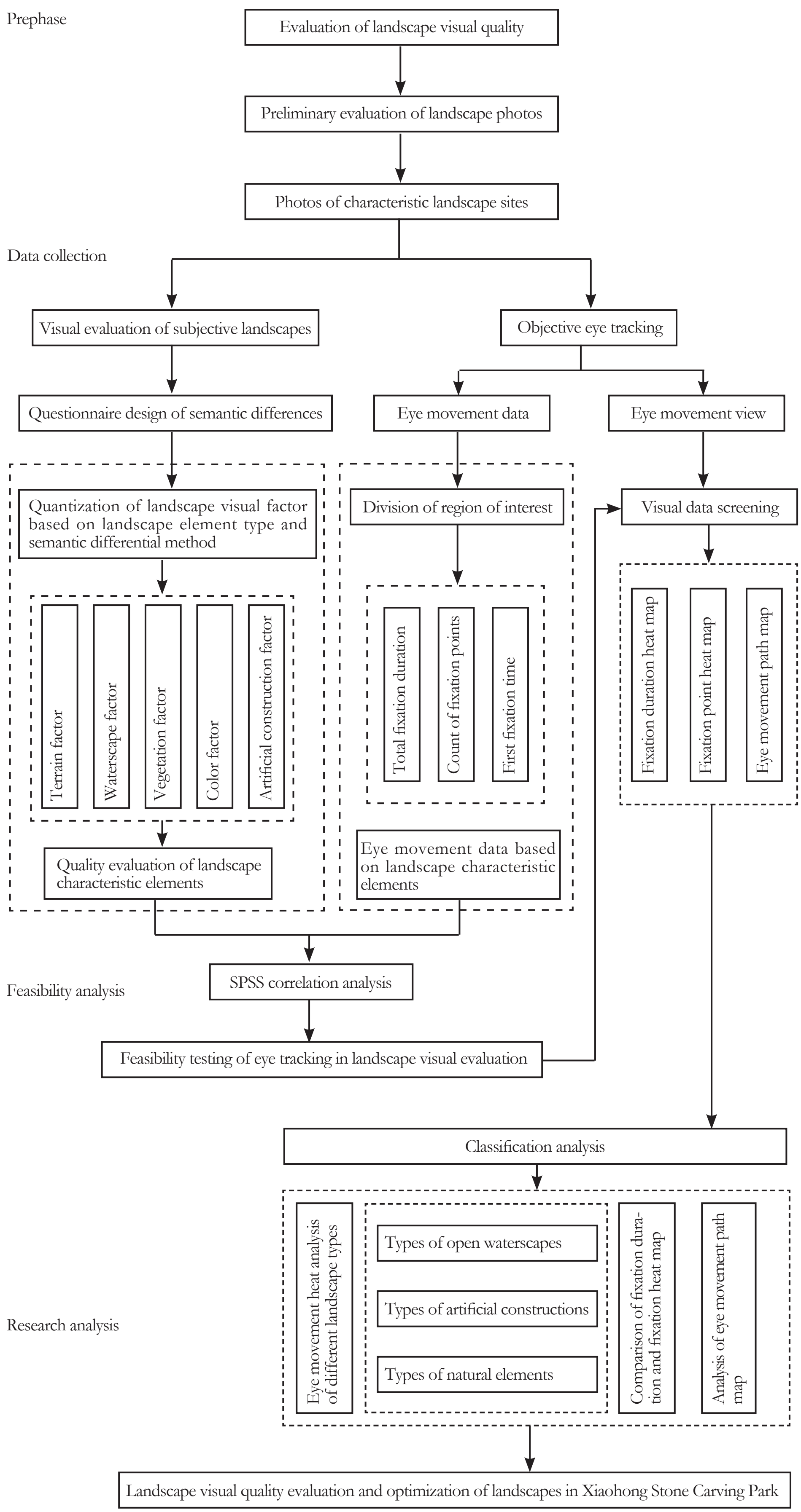



**Fig.1 Technical routes**

value between D revetment b-1 water surface and b-2 ecological revetment is significant; the correlation coefficient value among E vegetation rate, c-1 foreground vegetation and c-2 distant-view vegetation is significant; the correlation coefficient value between G landscape color contrast and c-3 color vegetation is significant; the correlation coefficient value between H favorable artificial constructions and a-3 landscape path, a-4 construction and landscape wall is significant; the correlation coefficient value between I unfavorable artificial constructions and d-3 dustbin is significant.

According to the correlation analysis (Table 2), "total duration of fixations" shows high consistency with the corresponding subjective visual preference evaluation. In terms of the landscape elements such as water, revetment, vegetation and favorable artificial constructions, higher total duration of fixations indicates higher evaluation of the AOI; in addition, subjective preferences on unfavorable artificial construction is negatively correlated with the total duration of fixations, and it is supposed that the remarkable visual characteristics obtain longer duration of fixations.

**2.1.2** Fixation counts. Fixation counts indicate the quantity of fixation points in AOI, i.e. the frequency of fixation behaviors in AOI, similar to the total duration of fixations, so it can also reflect the testees' processing of information and perception. Moreover, it was also reported that fixation counts showed a certain degree of positive correlation with the testees' excitement degree[17].

Pearson correlation coefficients were used to indicate the strong and weak relationship, the correlation between the eye movement data (total fixation counts in AOI) and 12 landscape characteristic elements was explored, to correspond to the landscape characteristic elements represented by the AOI.

According to the correlation analysis (Table 3), "total fixation counts" shows high consistency with the corresponding subjective visual preference evaluation. In terms of the landscape elements such as water, revetment, vegetation and favorable artificial constructions, more total fixation counts indicates higher evaluation of the AOI; in addition, subjective preferences on unfavorable artificial construction is negatively correlated with total fixation counts, and it is supposed that their remarkable visual characteristics obtain more fixation counts.

**2.1.3** First time of fixation. First time of fixation in AOI, i.e. when the testees first stare at the AOI after the stimulation, is usually interpreted as the time of fast-speed processes such as reflecting the recognition and recognizing. The index can reflect the identifiability, vividness and attraction of this landscape element in the visual level.

In terms of waterscape elements and vegetation color elements, eye movement data and landscape characteristic element evaluation showed significant positive correlation, no significant correlation with other corresponding elements (Table 4).

Considering the data analysis of 3 indexes, except the first time of fixation, the other 2 indexes showed significant correlation with landscape visual quality, i.e. under these 2 indexes, objective eye movement fixations can directly reflect the testees' spatial visual preferences.

## 2.2 Eye movement view analysis

Heat map of visualized analysis could manifest the results of the testees' fixation directly, color gradation from red to green was used to show the fixation distribution in a scene, and to some extent show the extent of the testees' concern on different regions. This visualization result was the comprehensive analysis result of all testees, the fixation duration degraded from red to green.

**2.2.1** Eye movement hotspot analysis of different landscape types in Xiaohong Stone Carving Park. According to the heat map of open water classification (Fig.2), for the landscape photos including open waters, most fixation points centered on the borders between waters and revetments, and compared to the revetments, more fixation points were on the reflections along the revetments. Plants with beautiful figures and artificial elements such as constructions became the central visual attention with water as the foil, and even their reflections in water also won more attention, particularly these landscape elements in the central area could easily become the visual focuses. In the photos, plants with bright colors got higher attention, it showed that regions with strong color contrast could attract more attention.

According to the heat map of artificial constructions (Fig.3), favorable constructions could attract more attention, including Stone Carving Pavilion, sacred way, bridge and landscape wall. As a scene included many artificial constructions, landscape points (such as Stone Carving Pavilion) could become the visual focus of the photo more easily than the linear landscapes (such as sacred way, landscape way) and landscape surfaces (such as square).

According to Fig.4, compared to the single plant formation, the testees paid more attention to those plants or plant clusters with distinct layers, rich colors and beautiful figures; plants with bright colors and flowering plants were also visual focuses.

Through analyzing the landscape heat maps, it could be found that fixation points mostly centered on the photo centers; for the scenes with roads, the visual attention was often on the road ends; as the scenes showed strong sense of perspective, the vanishing points of the configuration were always the centers of fixation.

**2.2.2** Contrastive analysis between fixation duration heat map and fixation point heat map. According to Fig.5, ranges of visual focus on

**Table 1 Evaluation of landscape characteristic elements in Xiaohong Stone Carving Park**

| No. | Landscape factor | Category and evaluation criterion | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| A | Terrain | Basically flat | – | Slightly fluctuating | – | Fluctuating/Landscapes |
| B | Water area | No water | Small | Moderate | Large | Very large |
| C | Water quality | No water | Poor | Moderate | Good | Very good |
| D | Revetment | No revetment | Poor | Relatively good | Relatively ecological natural revetment | Ecological natural revetment |
| E | Vegetation rate | Lower | – | Moderate | – | Higher |
| F | Plant configuration mode | No vegetation | Tree/shrub | Tree/shrub/grass (water plants) | Tree/shrub/flower/grass | Tree/shrub/green hedge/flower/grass |
| G | Landscape color contrast ratio | Weak | – | Relatively clear | – | Clear |
| H | Favorable artificial constructions (path, sculpture, landscape wall, plank road, construction) | No | 1 | 2 | 3 | 4 |
| I | Unfavorable artificial constructions (sign, railing, power facilities) | No | 1 | 2 | 3 | 4 |

**Table 2 Correlation analysis of eye movement data (total fixation duration) and subjective evaluation of landscape characteristic elements**

| | A Terrain | B Water area | C Water quality | D Revetment | E Vegetation rate | F Plant configuration mode | G Landscape color contrast ratio | H Favorable artificial constructions | I Unfavorable artificial constructions |
|---|---|---|---|---|---|---|---|---|---|
| a-1 Road | 0.182 | −0.730** | −0.686** | −0.672** | 0.345 | 0.200 | 0.352 | −0.302 | 0.093 |
| a-2 Plank road and bridge | −0.161 | 0.331 | 0.337 | 0.403* | 0.180 | 0.019 | 0.027 | 0.151 | 0.032 |
| a-3 Landscape path | 0.033 | 0.328 | 0.292 | 0.118 | −0.448* | −0.493** | −0.392* | 0.397* | 0.204 |
| a-4 Construction and landscape wall | 0.312 | −0.076 | −0.142 | −0.203 | −0.600** | −0.474** | −0.349 | 0.521** | −0.114 |
| b-1 Water | −0.276 | 0.857** | 0.736** | 0.767** | 0.031 | 0.318 | 0.051 | 0.074 | −0.137 |
| b-2 Ecological revetment | −0.078 | 0.450* | 0.422* | 0.491** | 0.121 | 0.141 | −0.198 | −0.228 | −0.059 |
| c-1 Foreground vegetation (plants with special figures) | −0.037 | −0.547** | −0.548** | −0.494** | 0.377* | 0.120 | 0.135 | −0.299 | 0.196 |
| c-2 Distant-view vegetation | 0.059 | −0.350 | −0.354 | −0.285 | 0.473** | 0.190 | 0.189 | −0.387* | −0.217 |
| c-3 Color vegetation (color leaf and flower) | 0.033 | −0.230 | −0.169 | −0.146 | 0.332 | 0.602** | 0.615** | −0.522** | −0.091 |
| d-1 Sign | 0.158 | −0.085 | −0.060 | −0.005 | 0.150 | 0.130 | 0.007 | 0.014 | 0.328 |
| d-2 Lamp | 0.024 | −0.362* | −0.369* | −0.336 | 0.355 | −0.004 | 0.008 | −0.373* | −0.034 |
| d-3 Dustbin | 0.048 | −0.252 | −0.288 | −0.282 | 0.185 | 0.308 | 0.291 | −0.280 | 0.412* |

*Note*: * indicates $p<0.05$, ** $p<0.01$.

some landscape characteristic elements varied between fixation count and fixation duration visualized heat map. Fixation count heap map had more visual focuses than fixation duration heat map in such places as plant clusters with rich colors, reflections on water surfaces, and pedestrians in the scenes. These elements could attract attention possibly because of their stronger visual impact, but could hardly attract longer fixation because of the less landscape information they contained. However, in both heap maps, bridges, pavilions, stone carving ruins and the affiliated buildings attracted more attention, thus these well-designed artificial constructions with positive visual effect showed prominent advantages in both degree of distinctness and visual attraction, the information in visual level could induce longer "appreciation" activities.

**2.2.3** Analysis of eye movement path map. Path map generally is used to analyze the tracks and routes of eye movement, circles are used to indicate fixation points, straight lines indicate one twitching of the eyelid, bigger circles indicate longer fixation duration on this point. The visualized analysis result can be used to describe the sequence and location of the testee's fixation, and compared to the heat map, it gave more concrete feedback about the testees' eye movement.

Eye movement path was greatly influenced by personal preferences, the data were relatively scattered, thus only vague rules could be obtained from the overall analysis.

According to Fig.6, the first fixation point always appeared in the high-quality artificial construction or vegetation area with rich color layers; as they paid attention to water and revetment, their fixations focused on the revetment and clear reflections in water.

## 3 Conclusions and discussion

### 3.1 Landscape evaluation of Xiaohong Stone Carving Park

**3.1.1** Vegetation configuration. There are lush vegetation and various plant types in Xiaohong Stone Carving Park. In terms of single vegetation species, those species with beautiful and special figures won more attention, such as maple (*Acer palmatum* Thunb.) and pear tree (*Pyrus calleryana*). Visitors showed strong preferences on those plants with color leaves and flowers. In terms of overall plant configuration, plant clusters with distinct layers and strong color contrast had higher visual quality, while those with simple species configurations and layers failed to attract more visual attention, such as metasequoia and weeping willow woods.

**3.1.2** Waterfront landscape. For the park centering on an open water, the water and waterfront landscape were the core elements in the whole

**Table 3 Correlation analysis of eye movement data (average count of fixation points) and subjective evaluation of landscape characteristic elements**

| | A Terrain | B Water area | C Water quality | D Revetment | E Vegetation rate | F Plant configuration mode | G Landscape color contrast ratio | H Favorable artificial constructions | I Unfavorable artificial constructions |
|---|---|---|---|---|---|---|---|---|---|
| a-1 Road | 0.157 | −0.696** | −0.631** | −0.609** | 0.299 | 0.133 | 0.242 | −0.296 | 0.083 |
| a-2 Plank road and bridge | −0.149 | 0.347 | 0.345 | 0.415* | 0.139 | 0.012 | 0.026 | 0.180 | 0.061 |
| a-3 Landscape path | 0.035 | 0.289 | 0.240 | 0.068 | −0.448* | −0.462* | −0.314 | 0.398* | 0.115 |
| a-4 Construction and landscape wall | 0.185 | −0.081 | −0.116 | −0.174 | −0.489** | −0.416* | −0.400* | 0.474** | −0.050 |
| b-1 Water | −0.252 | 0.873** | 0.754** | 0.787** | 0.003 | 0.251 | 0.005 | 0.124 | −0.058 |
| b-2 Ecological revetment | −0.058 | 0.445* | 0.422* | 0.480** | 0.127 | 0.030 | −0.269 | −0.108 | −0.009 |
| c-1 Foreground vegetation (plants with special figures) | −0.086 | −0.493** | −0.487** | −0.443* | 0.405* | 0.137 | 0.187 | −0.374* | 0.217 |
| c-2 Distant-view vegetation | 0.147 | −0.418* | −0.328 | −0.258 | 0.376* | 0.207 | 0.332 | −0.434* | −0.118 |
| c-3 Color vegetation (color leaf and flower) | 0.045 | −0.194 | −0.143 | −0.113 | 0.284 | 0.569** | 0.568** | −0.501** | −0.126 |
| d-1 Sign | 0.153 | −0.131 | −0.108 | −0.066 | 0.084 | 0.012 | −0.058 | 0.144 | 0.376* |
| d-2 Lamp | 0.058 | −0.346 | −0.364* | −0.336 | 0.343 | 0.032 | 0.062 | −0.375* | 0.053 |
| d-3 Dustbin | 0.055 | −0.252 | −0.290 | −0.283 | 0.186 | 0.310 | 0.286 | −0.282 | 0.403* |

*Note*: * indicates $p<0.05$, ** $p<0.01$.

**Table 4 Correlation analysis of eye movement data (first fixation time) and subjective evaluation of landscape characteristic elements**

| | A Terrain | B Water area | C Water quality | D Revetment | E Vegetation rate | F Plant configuration mode | G Landscape color contrast ratio | H Favorable artificial constructions | I Unfavorable artificial constructions |
|---|---|---|---|---|---|---|---|---|---|
| a-1 Road | 0.288 | −0.366* | −0.324 | −0.298 | 0.050 | 0.083 | 0.193 | −0.156 | 0.276 |
| a-2 Plank road and bridge | −0.271 | 0.121 | 0.222 | 0.248 | 0.248 | 0.208 | 0.263 | 0.003 | −0.428* |
| a-3 Landscape path | −0.097 | 0.359 | 0.303 | 0.275 | −0.222 | −0.163 | -0.276 | 0.583** | 0.300 |
| a-4 Construction and landscape wall | −0.331 | 0.230 | 0.283 | 0.297 | 0.103 | −0.081 | -0.138 | 0.127 | 0.152 |
| b-1 Water | −0.416* | 0.411* | 0.660** | 0.590** | −0.125 | −0.143 | -0.232 | 0.222 | 0.034 |
| b-2 Ecological revetment | −0.181 | 0.371* | 0.390* | 0.494** | 0.013 | −0.206 | -0.533** | 0.037 | 0.174 |
| c-1 Foreground vegetation (plants with special figures) | 0.203 | 0.176 | 0.107 | 0.018 | −0.220 | −0.350 | -0.346 | 0.235 | 0.235 |
| c-2 Distant-view vegetation | 0.379* | −0.020 | −0.132 | −0.081 | −0.226 | −0.106 | -0.066 | 0.058 | 0.059 |
| c-3 Color vegetation (color leaf and flower) | 0.111 | −0.026 | −0.109 | −0.044 | 0.186 | 0.368* | 0.456* | −0.236 | 0.103 |
| d-1 Sign | −0.201 | 0.220 | 0.190 | 0.251 | 0.299 | 0.273 | 0.108 | −0.052 | 0.028 |
| d-2 Lamp | −0.287 | −0.103 | −0.081 | −0.039 | 0.333 | 0.013 | -0.060 | −0.278 | 0.026 |

*Note*: * indicates $p<0.05$, ** $p<0.01$.

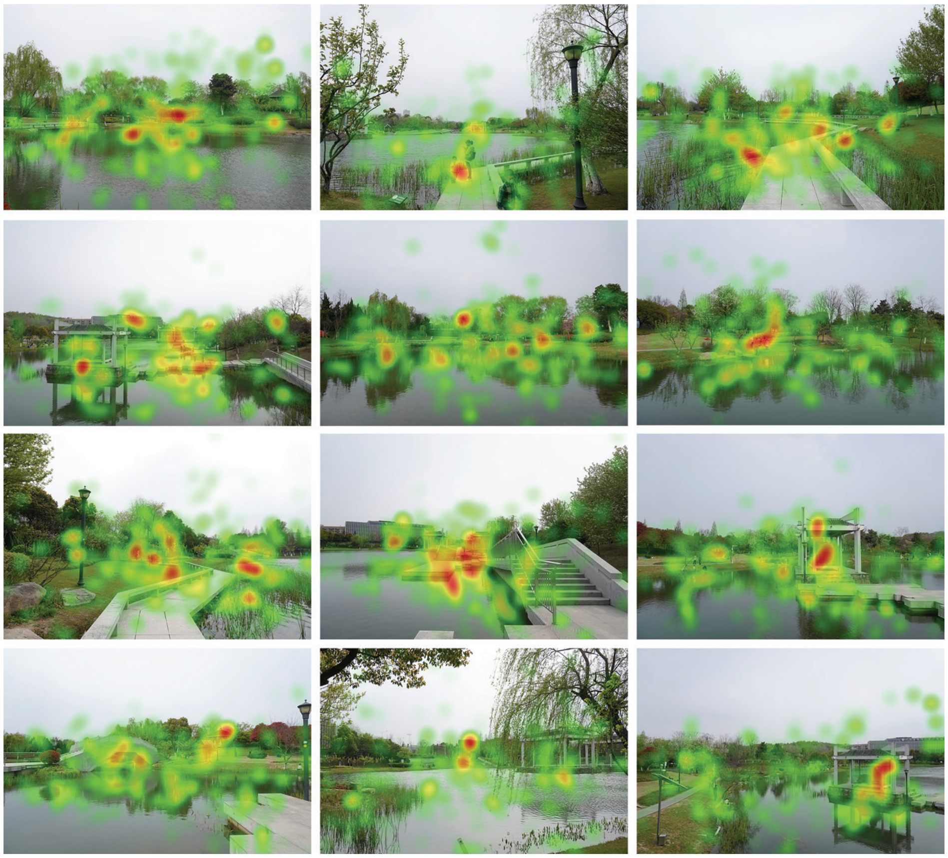


**Fig.2 Eye movement heat map of open waters**

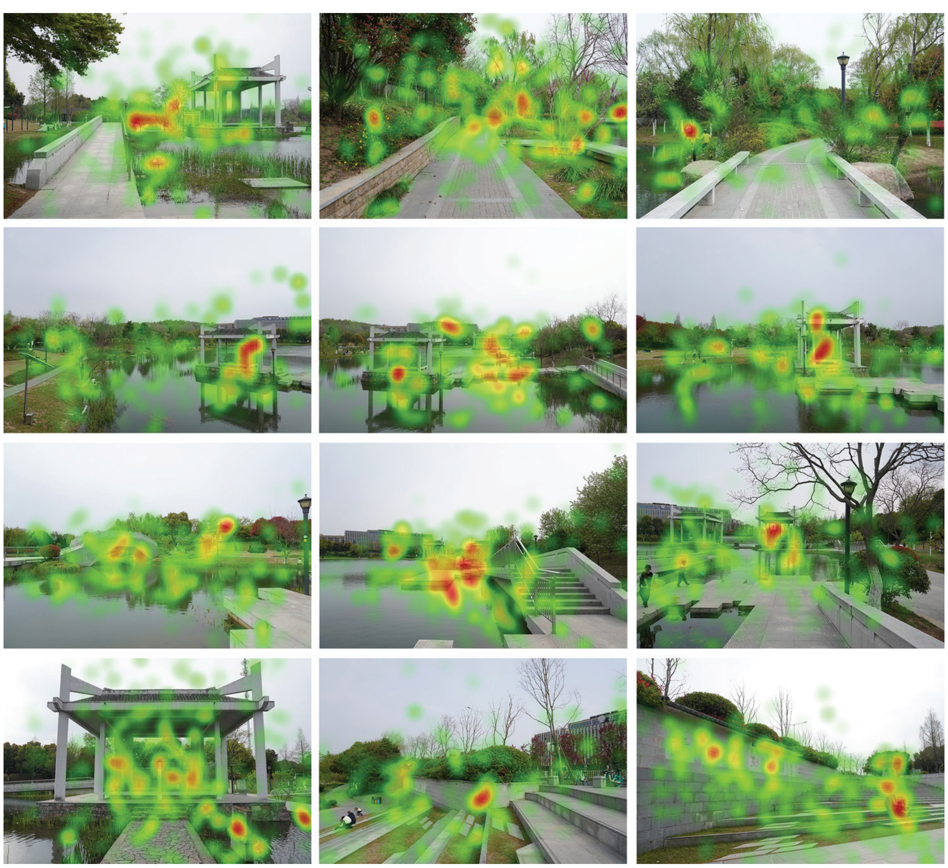


**Fig.3 Eye movement heat map of artificial constructions**

visual landscape system, attracting the most attention of visitors. In particular, the region with strong terrain contrast, rich vegetation layers, beautiful colors and clear water reflections had extremely high visual quality.

**3.1.3** Artificial constructions. Large artificial constructions such as protecting pavilions, stone carvings and sacred ways always were the visual focuses, playing a positive role in improving the quality of visual landscapes. In a landscape scene, visitors prefer the landscape with a higher percentage of natural landscape rather than artificial structures. Moreover, lamps, dustbins and power facilities could easily attract visitors' attention, but failed to provide better visual landscapes, thus they had negative impact on the overall landscape quality.

**3.1.4** Overall configuration. Winding paths and sacred ways with strong depth perception could bring visitors strong sense of extension, thus quality of landscape elements at the end of road and vanishing point of the sight, and the overall landscape configuration was crucial for visual beauty.

### 3.2 Improvement strategies

**3.2.1** Highlighting the vegetation focuses, building plant landscape clusters with diversified styles. Diversity of vegetation types for the regions centering on pear tree(Pyrus calleryana) should be enhanced to build a more dynamic plant landscape belt with distinct layers and various colors. Through enriching the vegetation spaces, the serenity of metasequoia woods and the elegance of weeping willow woods could be further enhanced, as a result, vegetation landscapes along the tour route can be more reasonably designed. Moreover, color-leaf plants, flowering plants and grasses with different seasonal features can be properly combined to enrich the overall color and texture of the park, and enhance visual experience of tourists.

**3.2.2** Enhancing the layer of revetment waterscapes, and highlighting the location of appreciating reflections. Central water and neighboring waterscapes should be further optimized, protection and restoration of waterscapes should be enhanced to keep the water clarity, design of vegetation, stone arrangement, landscape settings can help build revetment spaces with richer layers and higher landscape quality. In the design of tour routes, road pavement and space design can be used to highlight the reflection appreciation area, and the reflections can be used to improve the vividness of the central cultural landscape—Stone Carving Pavilion, and attract visual attention of visitors.

**3.2.3** Eliminating the abruptness of infrastructure,

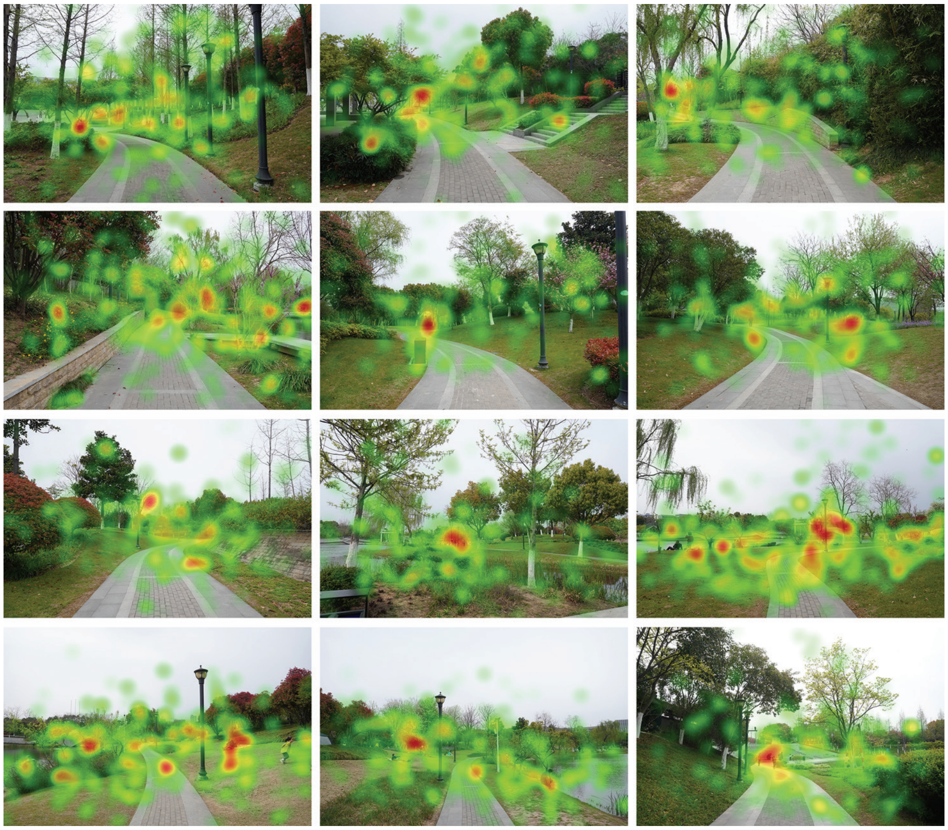
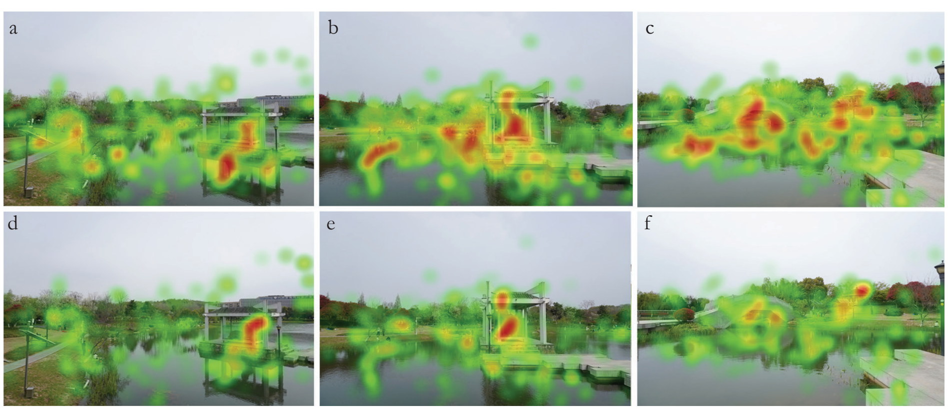


**Fig.4 Eye movement heat map of natural elements**




a–c: visual heat map of fixation count; d–f: visual heat map of fixation time

**Fig.5 Fixation count and visual heat map of fixation time**

**Fig.6 Eye movement paths**

and building the immersive natural experience space. Under the premise of ensuring visitors' convenience, infrastructures and artificial constructions should be planned reasonably, the excessive visual attraction and their destruction to the overall natural configuration should be reduced, shape design or natural elements can be used to eliminate the abruptness.

### 3.3 Further discussion

Eye tracking data of visitors were taken as the feasible objective basis for the visual quality evaluation of urban park landscapes, and could reflect different individuals' perceptions and emotional experience to some extent. However, the application of eye tracking technology showed the confounding of attention and preference, therefore, other supplementary evaluation tools such as subjective and objective evaluation scales should be used to analyze the experience and evaluation of park landscape visual quality more precisely.

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Simultaneously, the urban tree management practices in Oxford are distinguished by sophisticated and intelligent management techniques. These practices involve the utilization of the i-Tree platform to gather data on urban trees and assess their ecological value. Additionally, an information network should be established for the real-time uploading of data to the ArcGIS data analysis platform, thereby facilitating the implementation of efficient urban tree management strategies. The future planning of urban tree management in China can benefit from the overarching principles of Oxford urban tree management, which emphasize high-quality planting and maximizing the benefits for both people and nature. These principles offer a reference for enhancing the comprehensiveness and consistency of urban tree management planning in China. Simultaneously, by drawing upon the sophisticated and intelligent management technology attributes developed by Oxford, platforms such as i-Tree and ArcGIS, along with other online resources, can be utilized in management planning to establish a timely and effective mode of urban tree management.

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