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Visual Evaluation of Park Landscape Based on SBE and Eye Tracking

Qiang Wang[1, 3, †], Mingyuan Zhao[2, †], Lanyong Zhao[2, *]

[1]College of Horticultural Science and Engineering, Shandong Agricultural University, Taian, China

[2]College of Forestry, Shandong Agricultural University, Taian, China

[3]School of Architecture and Landscape Design, Shandong University of Art & Design, Ji'nan, China

Email address:

sdzly369@163.com (Lanyong Zhao)

[*]Corresponding author

† Qiang Wang and Mingyuan Zhao are co-first authors.

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Abstract: In the field of landscape visual aesthetic evaluation, the SBE (Scenic Beauty Estimation) method is the main way for researchers of the psychophysical school. It obtains evaluation results by having evaluators observe photographs and rate landscape objects using uniform evaluation criteria, and is currently recognized as one of the better methods for landscape evaluation. Meanwhile, eye-tracking technique is another experimental technique that has been applied to landscape evaluation by researchers in recent years with many results. In this study, we take photos of environmental spaces taken in Jinan city park in China as landscape aesthetic evaluation objects, and use SBE method and eye tracking analysis method to conduct experiments respectively. On the one hand, we explore the SBE value of various environmental spaces in Jinan city park, and on the other hand, we conduct eye tracking experiments for the same subject scenes and obtain data (AOI area ratio, Fixation count, Fixation and Saccade duration). The correlation between SBE values and eye-tracking data and the analysis of eye-tracking heat maps were then carried out to investigate the relationship between the subjective aesthetic evaluation and the objective eye-tracking data. The following conclusions were reached: SBE values were significantly and positively correlated with the main indicators of eye-tracking; Naturalness, Spatiality and Visual interest points were the three key factors in the visual evaluation of the park landscape.

Keywords: Visual Evaluation, Urban Park, SBE, Eye Tracking

1. Introduction

In the 1960s, western countries, represented by the United States, introduced a series of laws to protect natural landscape resources on the basis of landscape visual assessment studies, for example, the Wildlands Act (1964), The National Environmental Policy Act (1969), Coastal Zone Management Act (CZMA, 1972), etc. were enacted and implemented in the United States [1], In the UK, the Countryside Act (1968) authorized the establishment of 'Countryside Commissions' and country parks [2], extending the protection of the landscape from national parks to the wider countryside, to protect and enhance the natural beauty of the countryside and to meet the needs of ordinary people for recreation in the countryside. These laws signify that the conservation and study of landscape aesthetic resources is increasingly valued by governments and is beginning to take on significant legal status. Later, based on the studies of Zube, Taylor, Daniel, Vining and others, two camps of landscape aesthetic evaluation ("professional/design-based" and "public perception-based") and four major schools of thought emerged: psychophysical paradigm, expert paradigm, cognitive paradigm and empirical paradigm. Psychophysics, a branch of psychology, is a discipline that studies the theories and means of establishing relationships between environmental stimuli and people's sensations, perceptions and judgments [3]. The most common method of evaluating landscape aesthetics in the psychophysical school of thought is the method of evaluating the degree of beauty proposed by Daniel and Boster [4], which uses photographs or slides as the evaluation medium and allows the evaluator to rate them according to evaluation criteria, establishing a mathematical quantification of the relationship between objective scenery and subjective evaluation. However, the use of the SBE method alone can be influenced to a large extent by differences in the evaluator, such as personal preferences, cultural background, age, etc. Eye-tracking is a technique developed since the late 19th century, which is used to track the eye movements of an observer in order to explore the interest points and areas of interest of the observer in a scene or image. In this paper, the SBE method and eye-tracking method are combined to study and analyse the evaluation of a group of park landscapes, and to investigate the correlation between the SBE value and eye-tracking data of park landscapes through experimental data.

2. Methodology

2.1. SBE Method

Scenic Beauty Estimation (SBE) is considered to be an ideal representation of a landscape that is not influenced by the criteria and scoring system, and the result of the evaluator's judgement of the landscape should be a combination of both the evaluator's perception of the landscape and the criteria [4-6].

2.1.1. Evaluation Material Collection

The main mode of landscape aesthetic evaluation is the use of photographs or slides as evaluation media under laboratory conditions, and studies have concluded that there is no significant difference between the effectiveness of evaluation with slides (photographs) and real landscape environments [7-9]. Therefore, in this study, a Sony α6000 micro-single camera was used to collect photographs of the Jinan urban park landscape, and the height of the human point of view was used to take photographs.

2.1.2. Evaluator Selection

Numerous studies by domestic and international scholars on aesthetic differences between different groups have shown that there is a clear consistency in aesthetic attitudes among different types of judges [5, 10]. Arthur's study concluded that landscape experts, university students and the general public do not differ significantly in their aesthetic attitudes, but compared to the other two groups, landscape experts have a lower and smaller variance in their landscape ratings, implying that landscape experts' evaluations have strict and uniform criteria [6]. Therefore, in this study, two groups of landscape undergraduates were selected as evaluators, one group of SBE evaluation of park landscape images and the other group of students collected Eye Tracking data on the same images.

2.2. Eye Tracking Method

The history of eye movement behaviour can be divided into four stages: observation; mechanical recording; optical recording; and modern eye tracking recording. In 1878, Javal discovered that the eyeballs could beat, and in 1897 he used a mirror to observe the eye-movement behaviour of his subjects and explore the pattern of their eye-movement behavior [11]. In the mid-20th century, instruments based on the structure of the mechanical recording method, which records eye movement trajectories by light reflection, were invented. A representative example of this was the optical oculomotor by Yarbus et al. By the end of the 20th century, as technology developed, more reliable, non-invasive and more accurate oculomotors were developed. Oculomotors can record and analyse the trajectory of the human eye while observing objects, thus exploring human mental activity or perceptual processes. It can record subconscious eye movements and discover underlying patterns of aesthetic appreciation based on eye movement data [12]. For example, Dupont et al. measured subjects' visual behaviour by tracking their eyes as they looked at pictures, using eye-tracking measurements (ETM) to test how people see and observe landscapes and to discover the way people observe panoramic, detailed and other views of pictures [13]. Eye tracking technology can therefore help designers to understand which elements attract the attention of participants, and knowing these results can help designers to design spaces [14].

Research has shown that there are three main types of eye movements: Fixation, Saccade and Smooth pursuit. "Fixation" is the main way in which people pay attention and acquire information, and when the central fossa of the eye is aimed at an object for more than 100 milliseconds, the object being gazed at can be imaged in the central fossa and processed more fully to form a clear image. The "Saccade" refers to a sudden change in the point or direction of gaze, during which it is difficult to form a clearer image for cognitive processing and accurate information acquisition, but temporal and spatial information can be perceived. In contrast, "Smooth pursuit" refers to the movement of the eye after an object in order to keep the eye on the object when the object is in relative motion to the eye. These three eye movements are often mixed together to facilitate the selection of visual objects, which are then clearly imaged in the central fossa to obtain information.

3. Results and Analysis

3.1. SBE Value Calculation

The evaluation was carried out in the laboratory, with each image being played for ten seconds, and the visual evaluation of the landscape was carried out afterwards. A total of 54 university students majoring in landscape architecture were selected as evaluators to evaluate the landscape preference of the 24 park images using a Likert scale, which was divided into five levels: very poor, poor, fair, good and very good. The SBE values were then calculated on the basis of the preference ratings.

Daniel and Boster argue that the traditional standardised approach ($X_{ij}= (R_{ij}-\bar{R}_j) /S_j$) is flawed in that it blurs the differences in scale between individuals and does not distinguish between intra- and inter-landscape score differences. After a series of data processing, the landscape score scale values were converted to SBE values, making them representative of the beauty of the landscape independent of the judging criteria and scoring system.

The SBE values were calculated as follows.

(1) Count the frequency (f) of each grade value in the order of the grade score value and calculate the cumulative frequency (cf).

(2) Divide the cumulative frequency by the number of evaluators to obtain the cumulative probability (cp).

(3) Find the value of the one-sided quantile of the normal distribution (z) based on the cumulative probability (cp).

(4) Calculate the mean value of z (the z value of the lowest grade is not taken into account).

(5) If the cumulative probability (cp) of occurrence of other grade values is 1 or 0, calculate the z value using 1-1/2N or 1/2N (N is the number of evaluators).

(6) Randomly select a landscape photograph as a control, so that its SBE value is 0. The $\bar{z}$ values of other landscape photographs and the control landscape photograph are subtracted and multiplied by 100 to obtain the SBE value of either photograph.

From Table 2 it can be seen that the mean value of SBE calculated for the 24 samples was 7.2, with a maximum value of 101.6 and a minimum value of -151.9, 0.819, which is statistically significant.

Table 1. *SBE calculation values.*

No.	SBE value	No.	SBE value	No.	SBE value	No.	SBE value
01	0.00	07	-151.91	13	58.48	19	67.43
02	-54.34	08	32.86	14	-68.92	20	-19.51
03	-34.45	09	23.81	15	14.34	21	61.38
04	29.81	10	-10.10	16	97.82	22	-19.27
05	24.82	11	-107.17	17	9.30	23	-42.77
06	71.79	12	101.55	18	78.40	24	10.42

Table 2. *Descriptive Statistics.*

	N	Minimum	Maximum	Mean	Std. Deviation
SBE value	24	-151.91	101.55	7.2414	63.02072
Valid N (listwise)	24				

Figure 1. *Photos of the top four SBE values.*

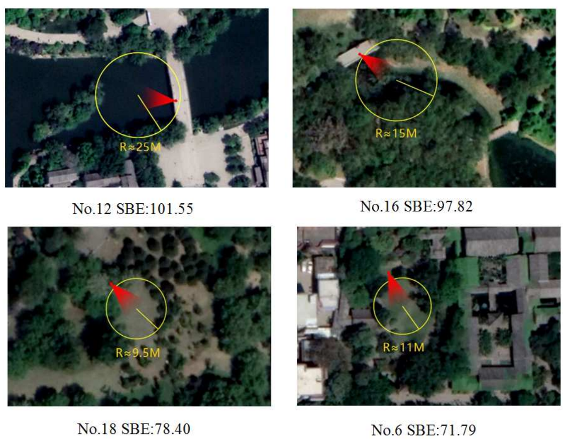

Figure 2. *Spatial analysis of the top four photos of SBE values.*

Figure 3. *Photos of the last four SBE values.*

3.2. Landscape Preference Analysis Based on SBE Values

(1) Visible Green Index (VGI) refers to the proportion of green vegetation in a person's field of vision [15]. Park scenes with a higher VGI have a higher environmental value, with the top four SBE values having a higher VGI (Figure 1) and the last four SBE values having a lower VGI (Figure 3), making VGI one of the key elements in the visual evaluation of park landscapes.

(2) The top four park scenes with a good sense of spatial enclosure have a high environmental value. The horizontal radius of the park scenes with SBE values are about 9.5m, 11m, 15m and 25m respectively, the vertical height of the surrounding vegetation is about

10m, and the ratio of scenic viewing height (H) to sight distance (L) (H/L) is between 1/1 and 1/5, with a comfortable sense of space, which is a popular scale of landscape space (Figure 2).

(3) A park with a rational landscape hierarchy has a higher landscape evaluation value. First, the landscape elevation level is staggered, and the forest canopy line is richly varied, such as the reasonable collocation of trees and shrubs of different forms and textures in Figure 1-No.6, which forms a rich forest canopy line. Secondly, the landscape is rich in the direction of depth, with obvious changes in the near and far scenes, such as Figure 1-No.12, the near scene is the weeping willow, the water, the middle scene is the rocky island and the island's solitary trees, colorful trees and shrubs at the water's edge, etc., and the far scene is the tree thicket. Some scholars also concluded that the near and middle zone contribute 80% of the value of the scenic beauty, and the far zone accounts for 20%[16]. Third, the presence of the focal point of sight can guide the line of sight and create a certain sense of mystery that can arouse the desire for exploration, such as the small bridge located at the far end of the No.12 and No.16 pictures, which is small and inconspicuous, but can arouse strong curiosity in visitors.

(4) Our study shows that parks with rich natural landscape elements have a higher landscape assessment value, i.e. the enhancement of natural-scaled complexity enhances the perceived beauty of the scene [17], for example, there are islands, rocks, solitary trees, water reflections and other natural landscape elements in No.12, and there are gently sloping lawns, trees, streams, bridges and curved banks in No.16.

(5) The density of visitors is an important factor affecting the visual aesthetic evaluation of the park environment. The density of visitors increases the psychological perception of crowding and noise, which greatly reduces the evaluation value (Figure 3).

(6) The evaluation value of park scenes with large paved areas is low, such as plazas and roads with large areas and lack of variation in the environment (Figure 3-No.11, No.14).

3.3. Eye Tracking Data Acquisition

In this experiment, 12 landscape undergraduates, six of each sex, were selected to view 24 images of park landscapes using a Tobii Pro Nano desktop eye-tracking device, with each image played for ten seconds, and the eye-tracking data was recorded and analysed.

Table 3. *Correlations Between SBE and Eye-Tracking Index.*

		AOI (%)	Fixation Count	Fixation Duration(s)	Saccade Duration(s)
SBE (N=24)	Pearson Correlation	0.592**	0.792**	0.838**	0.830**
	Sig.(2-tailed)	0.002	0.000	0.000	0.000

**. Correlation is significant at the 0.01 level (2-tailed).

(1) AOI division: the vegetation landscape area in the picture is divided into Area OF Interest (AOI), which mainly refers to the landscape area with various types of vegetation, but also includes water with vegetation reflection, richly varied terrain, garden buildings or structures, landscape sculptures, etc. The non-vegetation landscape areas include the sky, paved sites or bare ground, road surfaces, crowds, non-landscape buildings or structures, untidy areas, the general water surface, etc., as shown in the red translucent area in Figure 4.

(2) The subject students were asked to view the aforementioned landscape pictures using the Tobii Pro Nano desktop-side eye-tracking device for ten seconds each, and the eye-tracking data of the 12 students were recorded and analyzed to obtain the percentage of AOI area, Fixation Count, Fixation and Saccade duration (mean value) for each picture. The eye-tracking heat map can also be exported. (Figure 4).

3.4. Eye Tracking Data Analysis

The SBE calculated values and eye tracking data of the experimental images were imported into SPSS software for correlation analysis (Table 3), and it was observed that the SBE calculated values showed significant correlation with the percentage of AOI area and Fixation Count, Fixation Duration(s), and Saccade Duration(s) in the AOI.

3.5. Eye Tracking Heatmap Analysis

The distribution of Fixation points on the landscape picture can be seen visually through the eye tracking heatmap, so as to understand the subject's attention point, as can be seen in Figure 4-No.12, the Fixation points are mainly horizontally distributed along the waterfront and concentrated within the AOI, the hottest point is the combination of rocks and trees on the island in the center of the picture, in addition to the water surface on both sides of the island extending into the distant view also received attention, showing people's exploration preference for environmental space. Figure 4-No.7 shows the crowded visitors around a spring pond, and the evaluator's attention was mainly focused on the observation of the visitors, followed by the flowers on the wall of the old building on the left side of the image and the dark building on the far right side of the image. In addition the attention of this picture was mostly outside the AOI, with the lowest SBE value of low showing a strong correlation with the eye movement index.

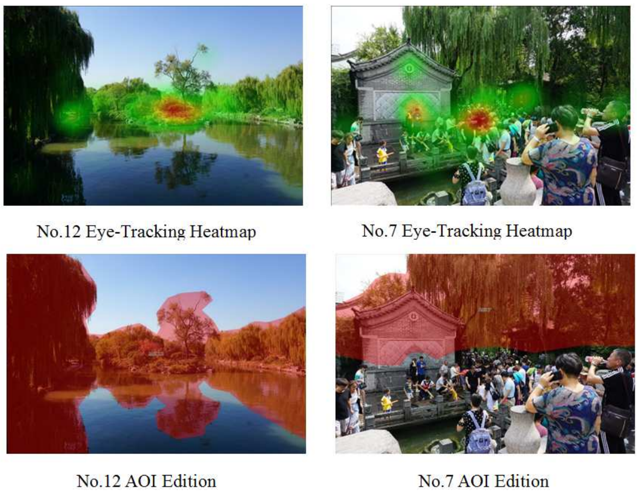

Figure 4. *Eye-Tracking Heatmap & AOI Edition.*

4. Conclusion

Through the SBE calculation and eye-movement data analysis of the park landscape above, it can be concluded that the three aspects of naturalness, spatial sense and visual interest points in the park landscape are the key factors in the visual evaluation of the park landscape.

(1) Naturalness

From the aforementioned analysis, it can be seen that the SBE and the eye movement index of vegetation landscape area show a significant positive correlation (Table 3), so we can use the eye movement index of vegetation landscape area (AOI) to judge the high and low SBE value of the park scene. Research by Gungor et al. shows that naturalness is the most important variable in the quality of landscape aesthetics [18]. The higher the percentage of vegetation landscape area in the park environment, the higher the sense of nature of the scene, in which the sufficient green view rate, reasonable high and low level collocation, good landscape into the depth level and rich combination of landscape elements determine the quality of vegetation landscape area. Conversely, the higher the artificial sense of the scene in the park, the lower the SBE value, such as large paved squares, roads, buildings and a large number of visitors.

(2) Spatiality

A good sense of space in the park environment SBE value is high, the horizontal interface of the park space is generally paving, lawn or water, the vertical interface is mainly trees, scenic walls or buildings, too empty environment, scenery viewing height (H) and sight distance (L) ratio (H/L) is often less than 1/10, will make people feel nothing to rely on, a very low sense of psychological security; and H/L is greater than 2/1, the sense of space is too depression, will also make people feel psychological tension.

(3) Visual interest points

In the park environment, people's visual points of interest mostly focus on direct environmental information first, such as character dynamics, signage, plaque inscriptions, etc.; followed by indirect environmental information, such as when seeing a scene with a strong sense of perspective or line of sight guidance, the observer's interest points tend to focus on the focal point of the line of sight (the end of the road or stream disappears), if there are structures here (bridges, pavilions) is more attractive, which is also in line with the Kaplan's mystery theory [19]; In Addition the contrast between light and dark, vivid colors, artificial buildings, and geometric shapes in the park scenes are also the main visual interest points; also, the visual center point is the main focus when observing landscape pictures. Therefore, too much artificial information in the park environment will affect the viewers' perception of natural scenery and thus reduce the SBE value.

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