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Investigating the Visual Behavior Characteristics of Architectural Heritage Using Eye-Tracking

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Abstract: The visual quality of architectural heritage is crucial to the preservation of architectural features, enhancement of the environmental quality, and conservation of the sustainable development and adaptive use of architectural heritage. Few studies have explored the visual behavior characteristics of rural architectural heritage and which elements influence visual perception. Our study used eye-tracking technology to explore this issue. The results indicate that participants have different visual behavior characteristics for architectural heritage in different scenarios, with five eye movement metrics showing statistical differences. Featured elements attracted more visual attention. The visual behavior characteristics were related to the area, relative area, distance from center, and perimeter. Based on the results, decision-makers can target the sustainable and virtuous development of architectural heritage and enhance environmental quality.

Keywords: architectural heritage; eye tracking; visual behavior characteristics; the Chinese Eastern Railway

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1. Introduction

Since the 1972 Convention concerning the Protection of the World Cultural and Natural Heritage, the protection and conservation of natural and cultural heritage have contributed to sustainable development. In 2002, the Budapest Declaration on World Heritage was referred to as an instrument for the sustainable development of all societies [1]. The sustainable conservation of architectural heritage can create and maintain local identity, cultural diversity, social vitality, and cohesion [2]. In general, people view heritage through visual perception [3]. The visual environment can influence people's perceptions, cognitions, and assessments [4]. Preserving and improving the built environment can benefit the local area socially and economically [5]. However, in the context of urbanization and rural revitalization, the architectural heritage of traditional villages is facing unprecedented changes [6]. On the one hand, the improvement and beautification of architectural heritage have improved its visual quality; on the other hand, the common phenomenon of "All Villages with the Same Features" [7] has affected people's perception of the traditional village experience. Therefore, in the 21st century, it is vital for all stakeholders in architecture, heritage, urban planning, and tourism to understand how architecture affects people's senses [8]. Importantly, new technologies offer new perspectives to explore the issue.

There is a growing interest in the visual quality of architectural heritage [9,10]. Research on the visual quality of architectural heritage includes visual analysis, visual impact, and visual preference [11–14]. Most planning guidelines and policy documents for assessing the visual quality of architectural heritage in China have only provided generalized recommendations [15]. Few studies and policies have focused on the visual perception of architectural heritage. Accordingly, more efforts are warranted to understand how and why we capture architectural heritage elements [16]. Visual research methods can help us discover or amplify neglected or weakened elements [17].

Visual quality research is mainly based on qualitative research and indirect evaluation methods from the subjective perspective of the evaluator, such as the questionnaire method (Scenic Beauty Estimation method and semantic differential method) and interview method. However, some scholars suggest that such research methods are highly subjective and poorly reliable [18]. During the sustainable conservation and development of architectural heritage, architects and planners should understand participant perceptions and preferences, how participants observe architectural heritage, and which elements and information can be captured. Eye-tracking technology offers a new approach to solving this issue. Eye-tracking techniques can visually respond to participants' areas of visual attention [19]. Moreover, it can reflect the internal cognitive processes of individuals to a certain extent [20]. In recent years, eye-tracking techniques have been applied to the visual quality assessment of landscapes and the visual perception of artworks. Studies related to the visual quality of a landscape include analyzing the participant's visual behavior [21–23], assessing the landscape's quality [24] and making inferences about how landscape elements affect visual quality [25,26]. Importantly, eye-tracking technology can be harnessed to grasp the information needs of visitors [27] and analyze the impact of light, colors of artworks, museum exhibition methods, and visual context and individual differences in the perception of artworks [28–31]. Researchers have analyzed and discussed the relationship between scene characteristics and human eye movement patterns. Landscape openness and heterogeneity significantly influence observations [32]. In addition, people's visual observation behavior is also influenced by the scene's complexity; the smaller the proportion of buildings in the scene is, the less intense that the visual exploration is [33]. Eye movement patterns always focus on the overall arrangement of visual centers, major volumes, and areas with contrasting elements rather than the geometric features of buildings [34–36]. Moreover, a balanced architectural facade composition orients the gaze and causes the line of sight to move to the lower left of the composition [37]. High-quality architectural elements and unique spatial elements are more attractive and perceived as aesthetically pleasing factors and observed for longer times by the participants [38,39]. Through a review of the above research, most studies have revolved around rural landscapes or urban architectural heritage. However, it remains unclear how the participants observed rural architectural heritage in different scenes.

We found that many researchers analyzed the impact of scene features on visual behavior. However, few eye movement studies have explored different scenes of architectural heritage, and the elements of architectural heritage are the main media for people to understand and identify heritage characteristics. They are also an important part of architects' transformation and renewal. Therefore, it is particularly essential to explore which architectural elements people pay attention to when viewing architectural heritage and which characteristics of the elements affect their perception. However, there is no clear answer at present. This study explored people's visual behavior characteristics when observing rural architectural heritage to improve the visual quality of the built environment, shape the humanistic and regional characteristics of traditional villages, and provide decision support for local government's protection of the renewal, development, and management of local construction (Figure 1). We sought to explore the differences in the eye movement metrics of people viewing architectural heritage in different scenes and investigate their visual behavior characteristics for different elements. Finally, we explored the reasons behind the differences in visual behavior characteristics.

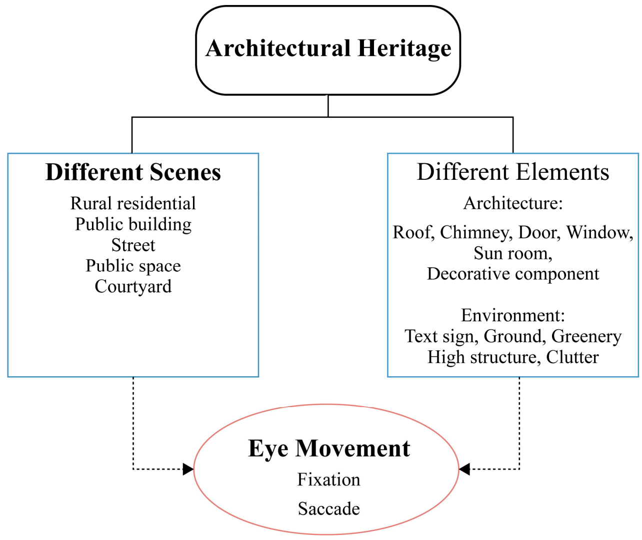


Figure 1. Conceptual framework of the visual behavior characteristics of architectural heritage.

2. Materials and Methods

2.1. Study Area

This study was conducted in Yimianpo, Shangzhi city, Heilongjiang province, China (Figure 2). Yimianpo is a historical town along the Chinese Eastern Railway and is a traditional Chinese village. The Chinese Eastern Railway, a "T" broad-gauge railroad built by Russia in northeast China in the late nineteenth and early twentieth centuries, is a well-known area on the map of China and an essential historical point in the development of the northeast region. Numerous historical villages and Russian historical buildings remain along the railroad line. There are 105 Russian-style buildings in Yimianpo town, of which 56 are architectural heritage. Many of the buildings were built between 1903 and 1904 along with the opening of the Chinese Eastern Railway, and the main buildings remain intact.

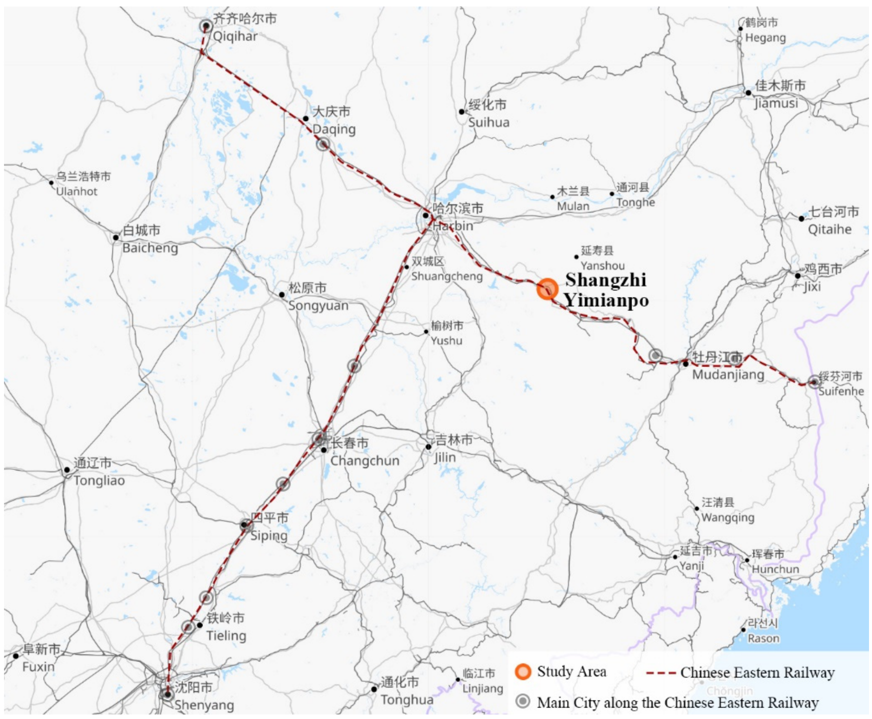


Figure 2. Location of the study area.

Yimianpo's architectural heritage is distinctive and unique. The Russian architecture is divided into public buildings with services and residential buildings for railroad construction and operation, according to their functions. The space is divided into courtyards, streets, and public spaces, according to the degree of openness. The architectural styles include Classicism, Art Nouveau, traditional Russian architectural styles, and styles specific to railroad architecture. Some of the public buildings have a Russian Classicism style. The building plan and facade are symmetrical in the central axis, using the classic "horizontal three vertical five" facade composition form. The facade has many classical architectural elements, such as columns, pediments, and surbases. The Art Nouveau style is reflected in residences. The typical symbols of Art Nouveau and short linear surbases appear on the facade. Wooden houses are the main expression of the traditional Russian architectural style. There is a mature practice and formal language of standardized design principles, including standardization of the plan, facade composition, and components. Their decorative elements contribute to the multifaceted formal beauty of the heritage, including point-type decorations, surbases, columns, pediments, roofs, etc. Masonry architecture is a form that emerged with railroad construction. The facade forms a rich visual effect through the arrangement and staggering of masonry blocks.

2.2. Experiment Preparation

2.2.1. Photograph Selection

Under the same imaging technique and weather conditions, we took 200 images of similar quality of the architectural landscape of Yimianpo town. Four experts selected sixteen images, including four traditional dwellings, three public buildings, three streets, three public spaces, and three courtyards. The resolution of the sample images was 2560 × 1600 pixels at 300 dpi, with a height–width ratio of 1:1.6.

2.2.2. Participants

We selected 56 undergraduate and graduate students (26 males and 30 females), aged 17 to 30, who were enrolled at the Harbin Institute of Technology, as participants. The majors of the participants were architecture-related (n = 31) and non-architecture-related (n = 25), with professional backgrounds in physics, chemistry, computer science, sociology, economics and management, accounting, etc. Previous studies showed no significant difference in aesthetics among different groups. Because experts and professional students have the best discriminative ability and consistency, they are still the best people to involve in landscape evaluation, but the public's judgment should also be considered [40]. College students have definite aesthetic-judging abilities based on relevant eye-tracking studies [22,38,39]. All participants saw the samples for the first time and had an uncorrected or corrected visual acuity of 1.0 or higher and normal color acuity.

2.3. Procedure

Given that light can cause serious interference in eye-tracking experiments [41], our experiment was conducted in a room without an outdoor light source. The only light illumination was the internal lights in the Harbin Institute of Technology library, to make sure that the experimental environment was well-controlled. Currently developed eye trackers are camera-based P-CRs. The P of P–CR eye trackers refers to the pupil's center in the camera image and the CR to one or more reflection center(s) in the cornea from infrared illuminators in the eye tracker. P–CR eye trackers are well-established to estimate gaze direction as a function of the relative positions of the P and CR coordinates in the pixel coordinate system of the video image [42]. The Tobii Pro Fusion 250, a screen-based eye tracker, was used to record participants' eye movement data while observing photographs of architectural heritage. The data were sampled at 250 Hz. The pictures were displayed on a 16-inch (2560 × 1600 dpi) computer screen.

Figure 3 shows the experimental procedure. After the participants became familiar with the experimental environment and agreed to the experiment, they were guided to sit 60–65 cm in front of the screen. The experimenter explained the experiment's purpose, procedure, and requirements to the participants. After the participants understood the experiment, the experimenter calibrated the eye tracker. Next, 16 samples were automatically played. Each sample was played for 10 s, with a 2 s blank interval between pictures to relieve eye fatigue and focus attention.

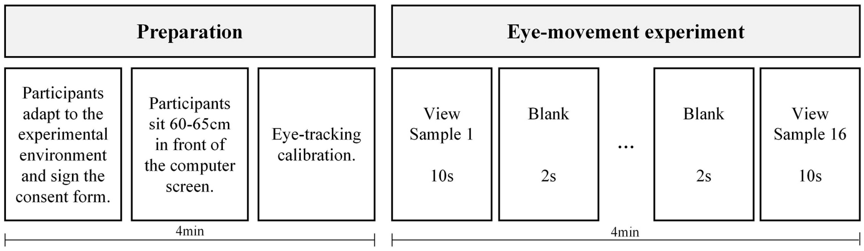


Figure 3. Experimental procedure.

2.4. Data Analysis

The eye movement data were processed by Tobii Pro Lab software to extract the required indicators. The eye movement data and questionnaire results were imported into SPSS25.0 for statistical analysis. Only the data with a sampling rate higher than 80% and calibration accuracy and precision below 0.65 degrees were selected. Two males were excluded because their sampling rate did not meet the requirements. In total, 54 valid eye movement data were included in our study.

2.4.1. Eye-Tracking Metrics Selection

Henderson and Hollingworth argued that eye movement behavior during scene browsing could be divided into two relatively independent phases: fixation and saccade [43]. Therefore, we analyzed the characteristics of the visual behavior of those viewing the architectural heritage from the perspectives of fixation and saccade and selected six fixation metrics, three saccade metrics, and the average pupil diameter (APD). Table 1 shows their specific meanings.

Table 1. The meaning of eye movement metrics.

Metrics		Abbreviation	Basic Significance
Fixation metrics	Total fixation duration (s)	TFD	The longer the TFD was, the more the participants paid attention to the area and the more they had difficulty in processing the corresponding information.
	Average fixation duration (s)	AFD	The longer the AFD was, the harder it was to perceive the picture.
	Fixation count (no. of fixation)	FC	FC reflected the participants' ability to process the scene, the difficulty of the scene, and the participants' interest in the content they looked at. The areas with more fixations were generally the parts that participants were more interested in.
	Time to first fixation (s)	TFF	It took time for the eyes to move to the area of interest (AOI). If the TFF was short, it was easier to notice an element. TFF was used to measure visual saliency.
	First fixation duration (s)	FFD	The longer FFD was, the more challenging it was to recognize the AOI or find it more attractive.
	Fixation duration per area (s/1000 m^2)	FDPA	The proportion of the TFD relative to each AOI

Table 1. *Cont.*

Metrics		Abbreviation	Basic Significance
Saccade metrics	Average saccades amplitude (degree)	ASA	Referred to the average distance between saccades, usually measured as a viewing angle. Reflected the range of visual information searched. A larger ASA had a more distinct picture feature, and the participant could reach the target area directly.
	Saccade count (no. of saccades)	SC	SC referred to the number of eye movements between fixations. Viewers in the no-disturbance stimulus condition had more saccades than those in the with-disturbance stimulus condition.
	Average saccades peak velocity (degree/second)	ASPV	ASPV was an index that evaluated the size of the range of information acquired by the participants and reflected the distinctive features of the picture's information.
Average pupil diameter (mm)		APD	APD correlated with the interest value of the visual stimulus.

2.4.2. Defining AOI

Areas of interest (AOIs) were applied to explore the relationship between eye movement behavior and the visual world. AOI is a segment of stimulus space that identifies a portion of the stimulus and is of interest in the experimental design of studies. AOIs are usually defined by screen-pixel boundaries during monitor-based eye tracking [42]. In our study, we divided the elements in the scenes into architectural and environmental elements (Figure 4). Architectural elements are the constituents of the building on the façade, including roofs, chimneys, hopper doors and doors, windows, sunrooms, and decorative components, while environment elements are other elements seen in the scene, including text signs, grounds, greenery, high structures, and clutter. The AOIs were defined by the Tobii Pro Lab software. Due to deviations in the eye tracker, when defining AOIs, the drawn boundaries were usually slightly larger than the area to be analyzed. A certain distance between AOIs was considered. The software used an algorithm to assign gaze points to AOIs [44].

Figure 4. *Cont.*

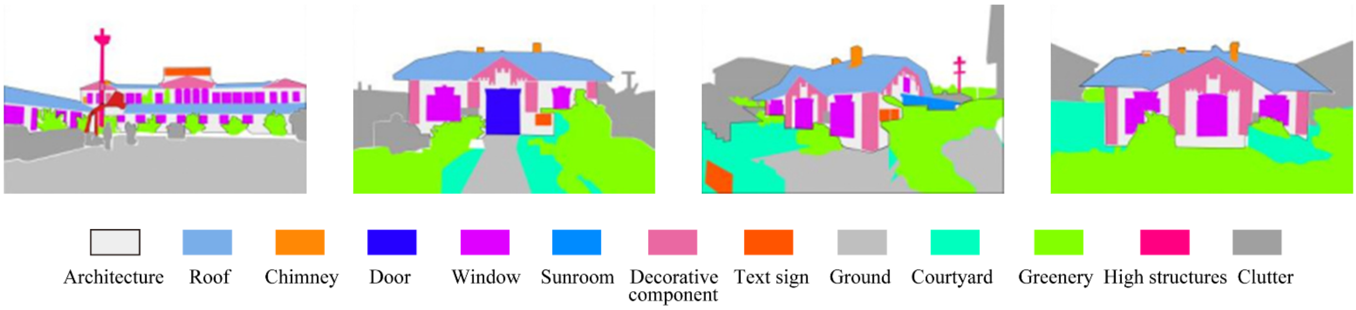


Figure 4. AOI of elements.

3. Results

3.1. Visual Behavior Characteristics of Participants When Viewing Architectural Heritage in Different Scenes

3.1.1. Differences in the Eye Movement Metrics of Architectural Heritage in Different Scenes

A one-way ANOVA was conducted on the eye movement metrics of the five scenes (Table 2). The post hoc test was performed using the LSD test. The architectural heritage in different scenes exhibited variability in five metrics: total fixation duration, average fixation duration, saccade count, average saccade peak velocity, and average pupil diameter. It indicates significant differences in the participants' observations when viewing the architectural heritage in different scenes.

Table 2. Differences in eye movement metrics of architectural heritage in different scenes.

Metrics	TFD(s)	AFD(s)	FC (No. of Fixation)	TFF(s)	FFD(s)	SC (No. of Saccades)	ASPV (Degree/Second)	ASA (Degree)	APD (mm)
Overall difference (Sig.)	**0.008 ****	**0.005 ****	0.164	0.776	0.384	**0.048 ***	**0.014 ***	0.150	**0.009 ****
Differences among architectural heritage in different scenes									
Traditional dwelling (a)	7.65 [de]	0.27 [c]	30.17	0.08	0.17	22.00 [cde]	171.22 [d]	4.70 [d]	2.89 [cd]
Public building (b)	7.45 [e]	0.26 [c]	30.38	0.07	0.16	21.17 [c]	164.58 [d]	4.59	2.82 [d]
Street (c)	7.49 [e]	0.33 [abde]	27.93	0.09	0.19	18.76 [ab]	167.20 [d]	4.60	2.76 [a]
Public space (d)	7.39 [a]	0.27 [c]	29.20	0.08	0.16	19.64 [a]	150.92 [abce]	4.18 [a]	2.68 [abe]
Courtyard (e)	7.18 [abc]	0.25 [c]	30.16	0.09	0.17	19.56 [a]	167.91 [d]	4.57	2.79 [d]

* Significant difference with $p < 0.05$. ** Significant difference with $p < 0.01$. [a]: Traditional dwelling, [b]: Public building, [c]: Street, [d]: Public space, [e]: Courtyard. 7.65 [de] in the traditional dwellings, 7.65 refers to the mean value of the total fixation duration in the traditional dwellings. [de] indicates that the traditional dwelling is significantly different from the public space and the courtyard. The other values are interpreted in the same way as this.

In terms of fixation metrics, the TFD of traditional dwellings was significantly different from that of public spaces and courtyards. The longest and shortest TFD were found for the traditional dwellings and courtyards, indicating that traditional dwellings were more likely to attract participants' attention. The average fixation duration of the street was significantly different compared with the other scenes. Streets had the longest AFD (0.33) and FC (27.93), revealing that participants experienced the most difficulty extracting information from streets and experienced a peak cognitive load. The APD was the largest for traditional dwellings (2.89) and the smallest for public spaces (2.68). The architectural features of the traditional dwellings were more pronounced, and participants were more interested in this type of architectural heritage. Moreover, participants were concerned with understanding the detailed information in public spaces.

In terms of saccade metrics, participants had the highest saccade count, average saccade peak velocity, and average saccade amplitude when viewing traditional dwellings (4.70, 22.00, and 171.22, respectively). Eye movement metrics were smaller for public spaces. Participants preferred to seek information in large areas of traditional dwellings. In contrast, public spaces were less distinctively characterized, and participants were not interested in exploring new areas or locations.

3.1.2. Fixation Characteristics of Architectural Heritage in Different Scenes

Table 3 shows the heatmap of architectural heritage and the total fixation duration of different elements. Red in the heat map indicates a long fixation duration, the green indicates a short fixation duration, and the areas that failed to attract participants' attention are transparent. In the front facade of the traditional dwellings (samples 1 and 2), the fixation points were distributed along the horizontal direction, and the fixation duration was longer. The fixation points were more distributed on the gable (samples 3 and 4).

The participants spent more time viewing architectural elements such as windows, roofs, and sunrooms. In sample 1, two text plaques introducing architectural information held participants' attention. They helped participants understand the history and characteristics of the heritage, which is a momentous element in traditional village conservation.

Table 3. Fixation characteristics of architectural heritage in different scenes.

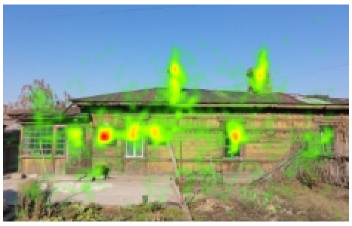
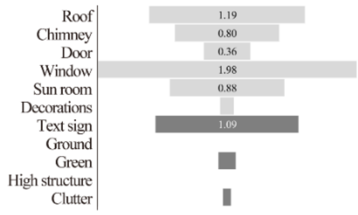
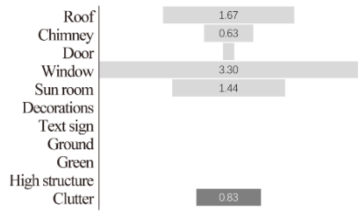
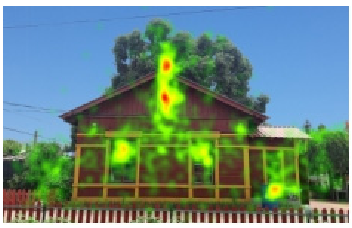
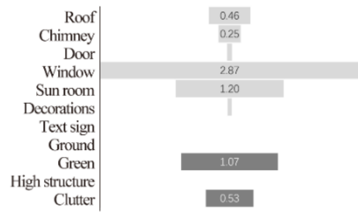
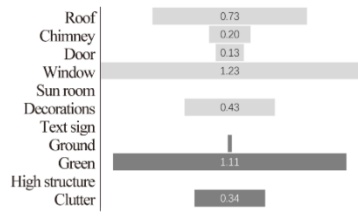
Scene		Heat Map	TFD of Elements
Traditional dwelling	Sample 1		
	Sample 2		
	Sample 3		
	Sample 4		

Table 3. *Cont.*

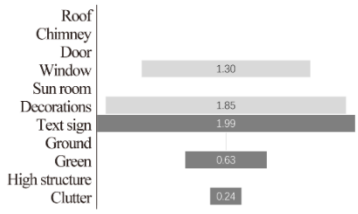
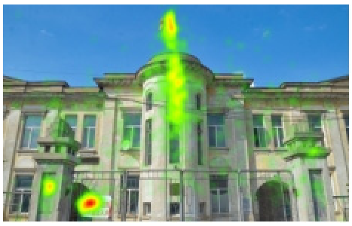
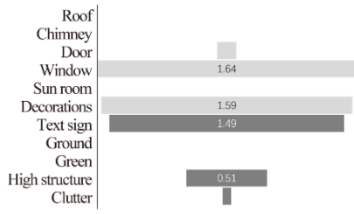
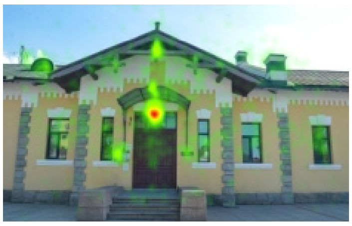
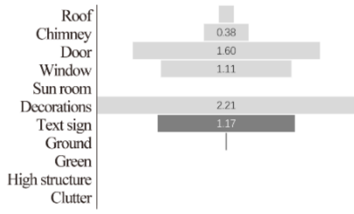
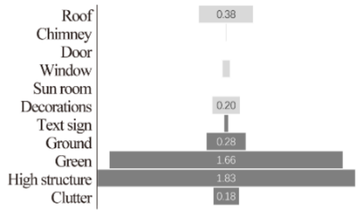
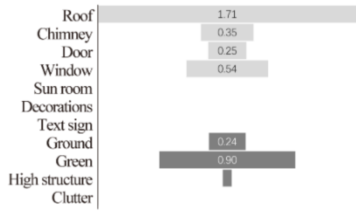
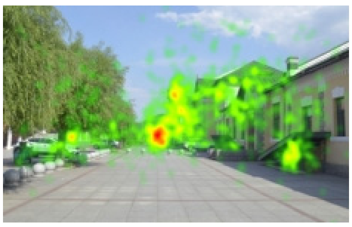
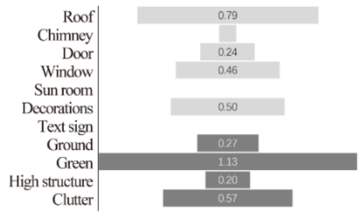
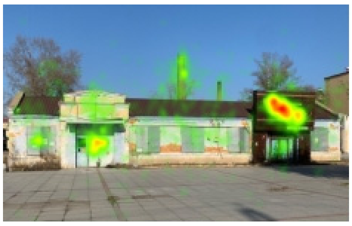
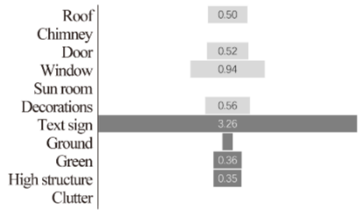
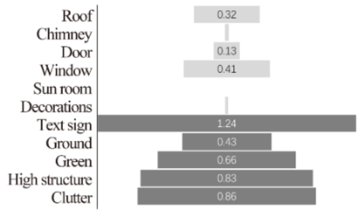
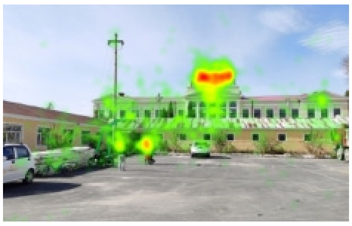
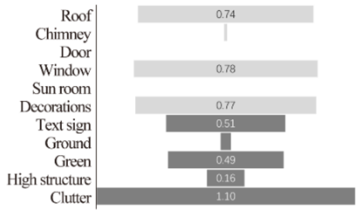
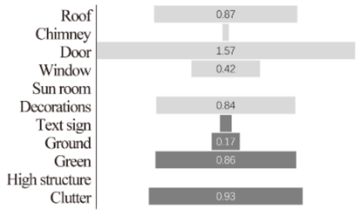
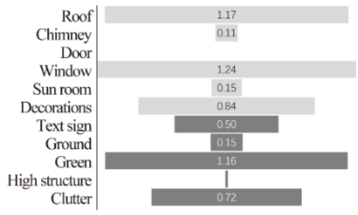
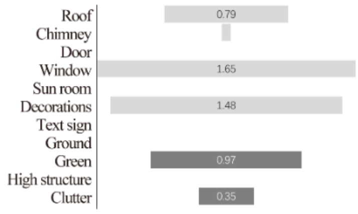
Scene		Heat Map	TFD of Elements
Public building	Sample 5		
	Sample 6		
	Sample 7		
Street	Sample 8		
	Sample 9		
	Sample 10		

Table 3. *Cont.*

Scene		Heat Map	TFD of Elements
Public space	Sample 11		
	Sample 12		
	Sample 13		
Courtyard	Sample 14		
	Sample 15		
	Sample 16		
Legend		Short fixation Long fixation	Architectural elements Environmental elements

The visual range of public buildings was much more focused, with the fixation points mainly concentrated on the central area. Participants' observation of the Russian text on the building in sample 5 lasted longer. Furthermore, the textual content in samples 6 and 7 also captured participants' attention. The visual fixation on the street was concentrated at the vanishing point. The high structure (water tower) fixation at the end of the street in samples 8 and 10 was longer. Participants also paid attention to buildings on both sides of the street when they were of good quality (sample 10). Fixation in public spaces exhibited a relatively scattered distribution with a short duration. The miscellaneous objects and text signs in public spaces had the longest fixation duration. The participants' visual attention was focused on the roofs, windows, decorative elements, and greenery of courtyards.

The participants' visual attention was also focused on the upper and middle parts of the scene and at the vanishing points. Doors, windows, decorative details in the building, unique elements (e.g., text), prominent elements (high structures), and clutter in the environment held the participants' attention.

3.2. Visual Behavior Characteristics of Elements

3.2.1. Differences in the Eye Movement Metrics of Different Elements

The eye movement metrics of the elements were statistically analyzed (Table 4, Figure 5). The TFD, AFD, and FC were higher for architectural elements such as windows, decorations, and roofs. Environmental elements such as greenery, clutter, and text signs could catch participants' attention but were also harder to be perceived.

Table 4. Eye movement metrics of different elements.

Metrics	TFD (s)	AFD (s)	FC (No. of Fixation)	TFF (s)	FFD (s)	FDPA (s/1000 m^2)	SC (No. of Saccades)
Architectural elements							
Roof	0.72	0.94	3.84	1.55	0.13	0.41	0.81
Chimney	0.22	0.60	0.84	0.95	0.06	1.27	0.13
Door	0.44	0.50	1.63	1.31	0.12	0.88	0.35
Window	1.24	2.14	4.88	1.42	0.10	0.74	0.61
Sunroom	0.91	0.28	3.33	2.69	0.22	0.54	1.36
Decorations	0.87	1.60	3.72	1.21	0.08	0.76	0.57
Environmental elements							
Text sign	1.13	0.80	4.02	1.06	0.11	4.76	1.60
Ground	0.15	0.29	0.60	1.29	0.08	0.04	0.13
Greenery	0.85	1.20	3.32	1.77	0.12	0.22	0.65
High structure	0.49	0.36	1.90	1.53	0.14	1.77	0.36
Clutter	0.60	0.93	1.87	1.67	0.10	0.97	0.35

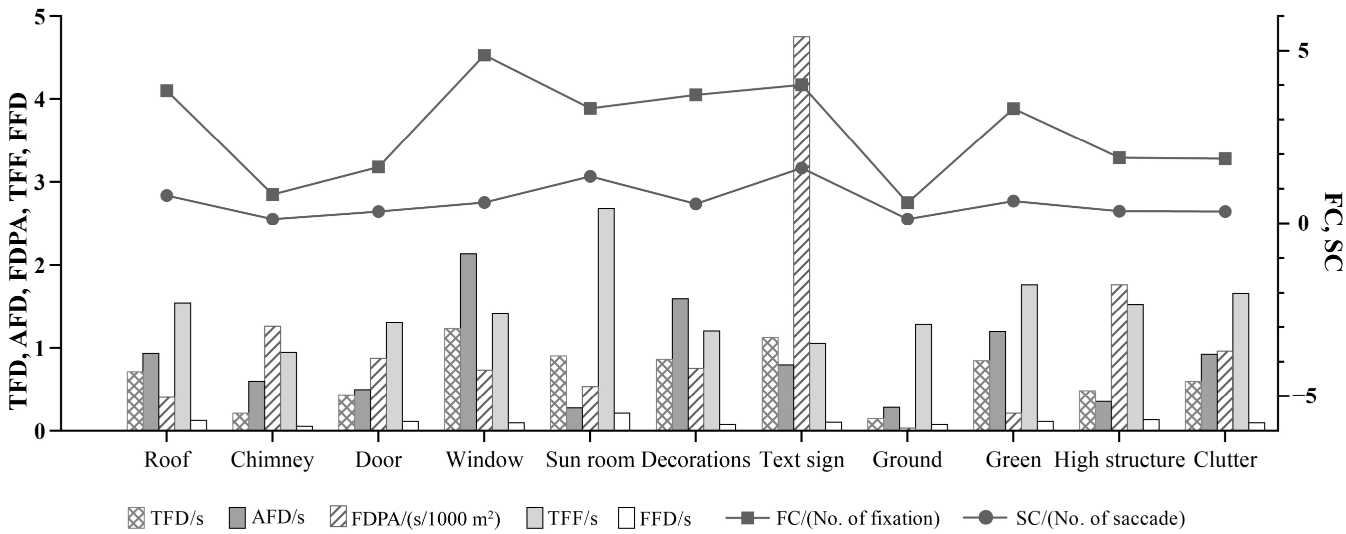


Figure 5. Eye movement data of different elements.

The roofs of the Chinese Eastern Railway houses differ from other villages in that the decorative and detailed elements attracted more attention. Chimneys and text signs had the shortest TFF and caught the most attention. Considering the first-time interest appeal and the difficulty of cognitive process, the chimney had the shortest FFD. The sunroom had a longer TFF and a longer FFD, revealing that participants were curious and took a long time to cognize the sunroom, a unique element in the context of the Chinese Eastern Railway and an indoor activity space used to regulate the climate. Since the area and location strongly influence the eye movement data, the fixation duration per area (FDPA) was a more objective response to the participants' visual perception. The FDPA of text signs was higher than other elements, indicating their attractiveness. Importantly, the higher SC of the sunrooms and the text signs engaged more exploration.

In summary, the AFD of the architectural elements was higher than that of the environmental elements, meaning that the cognitive load of the buildings was greater than that of the surrounding environment. However, the higher FDPA for the environmental elements indicated that the environmental elements represented an essential part of the visual perception of the architectural heritage, especially the text signs. The visual salience of architectural and environmental elements showed no significant difference, although the sunroom had the highest first-interest appeal. As a unique element, the sunroom played an important and influential role in the visual perception of the heritage.

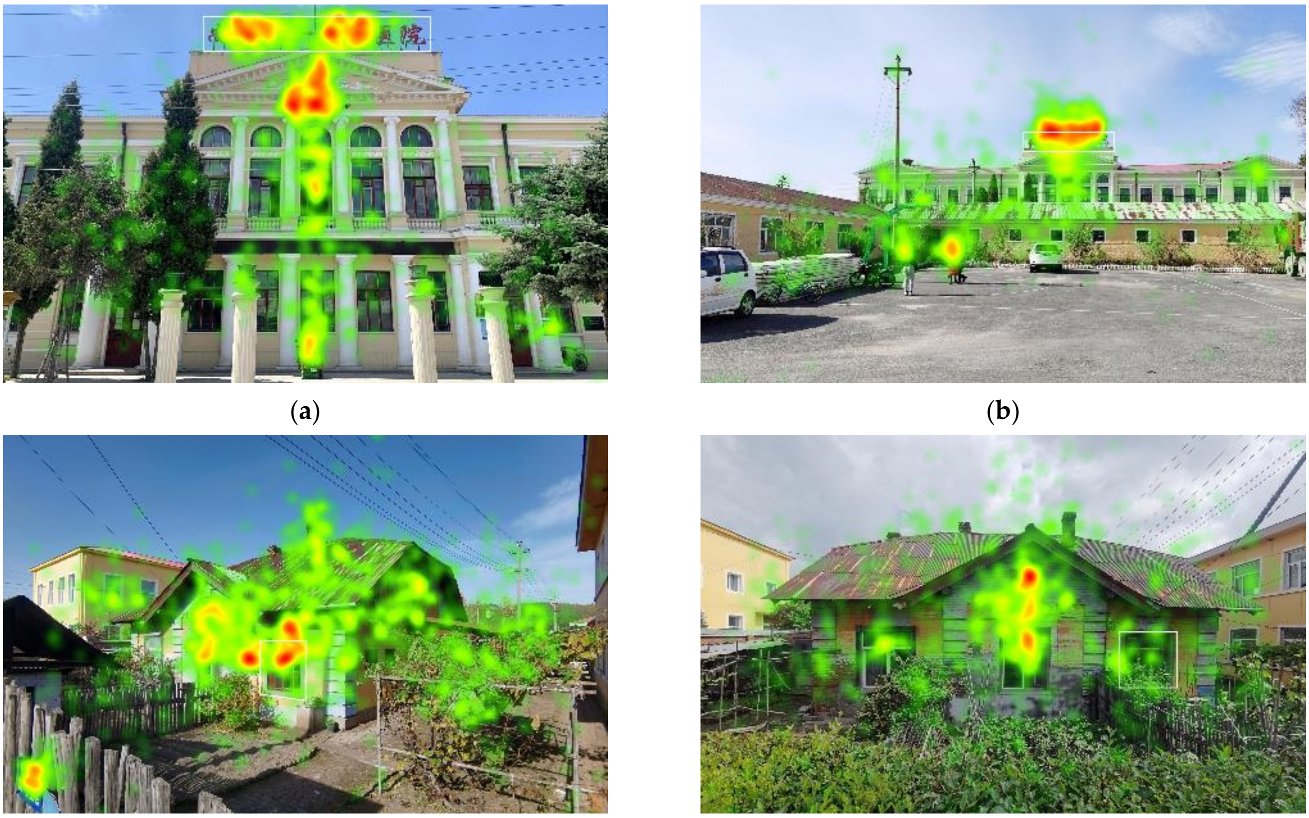
3.2.2. Differences in Fixation Characteristics of the Same Elements in Different Scenes

Table 5 shows a one-way ANOVA on the total fixation duration of elements in different scenes. Figure 6a,b show the heat maps of the same text logo in different scenes but with different positions and proportions in the picture. The text in the center of the picture in Figure 6b was associated with a longer fixation duration. Figure 6c,d show the heat maps of the window in different views. The fixation duration of the window in Figure 6c is longer. The difference in fixation duration of the same element in different scenes refers to participants paying attention to different elements in different scenes, which could contribute to the variation of the proportion of the feature in the photo and the angle of the display.

Table 5. Differences in total fixation duration for the same elements in different scenes.

	Traditional Dwelling (a)	Public Building (b)	Street (c)	Public Space (d)	Courtyard (e)
			Architectural elements		
Roof	1.015 ^{bd}	0.043 ^{acde}	0.961 ^{bd}	0.521 ^{abce}	0.943 ^{bd}
Chimney	0.468 ^{bcde}	0.127 ^{ad}	0.143 ^{ade}	0.011 ^{abce}	0.068 ^{acd}
Door	0.172 ^{ae}	0.573 ^{acd}	0.165 ^{be}	0.216 ^{be}	0.517 ^{acd}
Window	2.346 ^{bcde}	1.350 ^{acd}	0.350 ^{abde}	0.711 ^{abce}	1.108 ^{acd}
Sunroom	0.878 ^{e}	-	-	-	0.049 ^{a}
Decorations	0.145 ^{bde}	1.882 ^{acde}	0.233 ^{bde}	0.449 ^{abce}	1.058 ^{abcd}
			Environmental elements		
Text sign	0.273 ^{bcd}	1.549 ^{ace}	0.009 ^{abde}	1.671 ^{ace}	0.191 ^{bcd}
Ground	-	-	0.265 ^{be}	0.203 ^{b}	0.108 ^{bc}
Greenery	0.578 ^{bce}	0.210 ^{acde}	1.229 ^{abd}	0.504 ^{bce}	0.995 ^{abd}
High structure	-	0.171 ^{cd}	0.693 ^{b}	0.448 ^{b}	-
Clutter	0.440 ^{bcde}	0.099 ^{acde}	0.252 ^{abde}	0.652 ^{abc}	0.666 ^{abc}

^{a}: Traditional dwelling, ^{b}: Public building, ^{c}: Street, ^{d}: Public space, ^{e}: Courtyard. 1.015 ^{bd} in the roof, 1.015 refers to the mean value of the total fixation duration of roofs. ^{bd} indicates a significant difference between the total fixation duration of roofs in traditional dwellings and public buildings and public spaces.



(**a**) (**b**) (**c**) (**d**)

Figure 6. Heat maps of the same element in different scenes. (**a**) Text in public building, (**b**) Text in public space, (**c**) Window in perspective, (**d**) Window in façade.

3.3. Reasons for Differences in Visual Perception

It is well-established that visual attribute indicators may influence eye movement metrics (Table 6). Indeed, roofs and windows occupied the largest area; roofs were closest to the center, and doors were furthest away. The circumference of windows, decorative elements, and greenery were larger than other elements. Pearson correlation analysis was conducted to assess the relationship between visual attribute indicators and the eye movement metrics of each element (Table 7). We found that the area and relative area were significantly and positively correlated with TFD, FC, and SC and negatively correlated with FDPA, suggesting that the larger the area, the more likely the fixation and saccade behaviors can happen. The distance from the center was negatively correlated with TFD, FC, and SC, with a significant positive correlation with TFF, implying that elements occupying the center attracted the first attention. Circumference was significantly negatively correlated with FDPA and significantly positively correlated with other indices.

Table 6. Visual attributes indicators.

Indicators	Area/mm^2	Relative Area/%	Distance from Center/mm	Circumference/mm
		Architectural elements		
Roof	1989.03	6.78%	41.89	433.66
Chimney	202.01	0.69%	55.64	80.03
Door	620.87	2.12%	60.62	129.70
Window	1947.17	6.64%	48.39	511.49
Sunroom	1795.30	6.12%	70.06	177.27
Decorations	1673.35	7.55%	46.61	626.59

Table 6. *Cont.*

Indicators	Area/mm^2	Relative Area/%	Distance from Center/mm	Circumference/mm
Environmental elements				
Text sign	313.00	1.07%	45.26	95.68
Ground	4312.32	14.70%	60.31	397.00
Greenery	4333.68	14.77%	65.30	626.66
High structure	1118.17	3.81%	65.92	237.19
Clutter	216.69	0.74%	34.00	100.43

Table 7. Correlation analysis of visual attributes indicators with eye movement metrics.

		TFD	AFD	FC	TFF	FFD	FDPA	SC
Area	Correlation coefficient	**0.743 ****	−0.078	**0.744 ****	−0.055	0.084	**−0.269 ****	**0.756 ****
Relative area	Correlation coefficient	**0.740 ****	−0.079	**0.743 ****	−0.050	0.091	**−0.268 ****	**0.749 ****
Distance from center	Correlation coefficient	**−0.391 ****	0.106	**−0.400 ****	**0.190 ***	0.058	−0.105	**−0.371 ****
Circumference	Correlation coefficient	**0.424 ****	**0.520 ****	**0.448 ****	**0.553 ****	**0.546 ****	**−0.327 ****	**0.314 ****

* Significant difference with $p < 0.05$; ** Significant difference with $p < 0.01$.

4. Discussions

There were significant differences between the eye movement behaviors of architectural heritage in different scenes, confirming previous studies' results [33,45]. We also found that the largest and smallest values for TFD, ASA, SC, ASPV, and APD were observed for traditional dwellings and public spaces (Table 2), respectively, which may be attributed to the spread and horizontal facades of traditional dwellings and rich information. People tend to search for the area of interest in a wide range. Conversely, the design of the public spaces is often straightforward and broad, enabling a better acquisition of general information. Furthermore, we found that streets got the longest average fixation duration, which could be due to the one-point perspective view of this scene. This provides strong visual guidance, causes fixation behavior to occur at the vanishing point, and identifies each person's preferences for bilateral symmetry, curves, and ordered complexity within observed patterns [46] Accordingly, people tend to ignore the buildings on both sides of the street and gaze less often. It should also be noted that the architectural heritage's composition also affected visual behavior characteristics. Given that the configuration of both public buildings and streets is symmetrical, we found that fixation behavior occurred mainly at the center of the scene (Table 3), consistent with findings reported by Hasse and Weber [37]. Importantly, eye-tracking analysis enables the extraction of the language of architectural forms with regional characteristics [47]. People pay more attention to architectural details, symbolic elements [48] and ornaments, expressive architectural elements, and different elements on the facade [49], many of which were found in this study, such as the "transparency" of architectural features such as windows, decorative elements, sunrooms, and textual elements in the scenes (Table 4, Figure 5). The perceptual recognition of landscape elements is affected by the relative area, shape, and relative position of the elements in the photo [50] Urban spaces with a higher cognitive architecture score (edges, facades/patterns, shapes, narrative, and biophilia) will increase one's level of attention [51]. This study found that visual behavior characteristics were related to area and relative to the area, the distance from the center, and the circumference (Table 7).

There are still some limitations and shortcomings in our study. One significant limitation of this study is the use of experimental materials. Indeed, experimental photos cannot completely replace the actual architectural heritage, and the experimental results may be influenced by how the photos are taken. In addition, the differences in the visual perception of architectural heritages in different seasons were not taken into account, especially for the large seasonal variations in northeastern China, where the study site is located. In future studies, we will investigate the visual perception of architectural heritages in winter. Another significant limitation was the selection of college students as the experimental subjects. Although the study has some significance for exploring the visual perception of architectural heritage, more generalized research conclusions cannot be drawn. In future studies, the demographic characteristics of the subjects need to be expanded to include local villagers, government administrators, tourists, and other people to develop a complete strategy for the sustainable development of architectural heritage. Finally, we must consider the relationship between visual behavior characteristics and subjective assessment.

5. Conclusions

This study explored the characteristics of visual behavior toward architectural heritage in different scenes using eye-tracking techniques. Our results are summarized as follows.

(1) There were significant differences in visual behavior when the participants observed architectural heritage in different scenes. More fixation and eye-movement behaviors occurred when viewing traditional dwellings and less frequently when observing public spaces.

(2) A method of identifying architectural features and visual behavior was proposed. We drew the area of interests of architectural and environmental elements and then compared the fixation and saccade metrics.

(3) The area, relative area, distance from the center, and circumference of the elements influenced the visual behavior. The elements with longer total fixation duration generally had the following characteristics: larger area and relative area, closer to the center, and longer circumference.

This research is essential for protecting and improving the visual quality of the architectural heritage of traditional villages along the Chinese Eastern Railway. Eye movement metrics were extracted to characterize the architectural heritage and reflect the conservation status. The results of our study can be combined with subjective perceptions to explore which scenes and elements affect people's experience of architectural heritage. These scenes and elements can be preserved or enhanced to ensure sustainable architectural heritage conservation. It is also possible to refine the priorities of architectural heritage conservation and improvement procedures according to the level of impact. Scenes and elements that negatively affect people's perceptions could be prioritized for improvement. In future research, eye-movement experiments could be applied to real-world scenarios to clarify how people experience architectural heritage.

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