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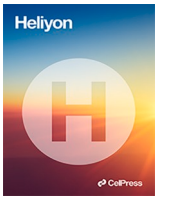

Research article

Correlation research on visual behavior and cognition of impression against localized church facades in China

Menghan Wang [a,b], Xiaoying Geng [c], Zhicheng Zhang [c], Chao Jia [c,d,*], Hiroatsu Fukuda [a]

[a] Faculty of Environmental Engineering, The University of Kitakyushu, Kitakyushu, 808-0135, Japan
[b] Academy of Arts and Communications, Qingdao Binhai University, Qingdao, 26555, China
[c] College of Architecture and Urban Planning, Qingdao University of Technology, Qingdao, 266033, China
[d] Faculty of Design, Kyushu University, Fukuoka, 819-0395, Japan

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ABSTRACT

Churches in China are material witnesses of cultural dissemination, and their architectural forms are in the process of localization. In order to determine the optimal degree of localization of church facades as well as to study the correlation between visual behavior and subjective cognition, five church facades with different degrees of localization were selected in present study, and the questionnaire survey as well as eye-tracking technology were used to collect data from two aspects: subjective cognition (the impression and acceptance levels) and objective eye movement (the first fixation duration, total fixation duration, fixation count, and visit count). The results showed the differences in public perceptions of church facades, and the impression of participants was continuously enhanced with the increasing of localization degree of church facade, while the acceptance level showed a U-shaped change. What's more, the correlation between the impression level and the first fixation duration was found to be 0.910, the Pearson coefficient between the acceptance level and the total fixation duration was found to be 0.928, indicating that eye-tracking indicators could accurately reflect the subjective cognition of the public. Performed analyses demonstrated that eye-tracking technology would provides an important technical mean for the design, conservation, and renewal of building facades.

1. Introduction

1.1. Research background

Cultural dissemination and integration are important issues in global development [1]. Churches in China are important carriers of cultural dissemination and the architectural forms have gradually been localized to promote cultural identity. Eye-tracking technology is a convenient solution for promoting public participation in the design process and defining the value elements of architectural heritage [2,3]. In order to promote the preservation of localized churches and to enhance the cognition of impression, an eye-tracking technique is proposed in this paper to determine the optimal degree of localization of the church facades, as well as to explore the relevance of visual behaviors on the cognitive impression.

* Corresponding author. No.11 Fushun Road, North District, Qingdao City, Shandong Province, China.
E-mail address: jiachao0932@163.com (C. Jia).

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1.2. Literature review

(1) Visual Behavior and Cognition

Visual perception is human's main source of information as well as the basis of cognition [4]. It has been demonstrated that the gaze was naturally drawn towards specific elements such as details, contrasts, and structural aspects that and structures that make overall geometrical sense [5–7]. Which may attribute to the fact that neurons in the initial stages of perception are specialized to detect basic visual attributes like differences in brightness, contrasting colors [8]. Rosas et al. [7] found that the human gaze would fixate first on images of buildings with features of organized complexity, natural scenes as well as face-like features and dwell on these images for longer. Suárez [9] compared the relations between visual attention to a historic train station and the subjective experiences produced during its observation. The results showed that architectural elements identified as examples of high-quality architecture and perceived as aesthetically pleasing by the participants were observed for longer times.

(2) Architectural Aesthetics and Visual Preferences

The aesthetic was regarded to emergent in the process of spatial cognition based on human's visual physiological mechanism [10]. Jennath et al. [11] found that in library buildings, the judgement of aesthetic appeal showed a linear or directly proportional relation between expected reading comfort (or the functionality). Elver Boz et al. investigated architectural spaces variables that affect aesthetic experience. The results showed that factors including the shape of the curvilinear boundaries of architectural spaces as well as their size, light, texture, and color are the key dimensions of aesthetic experience. Carreiro et al. [12] proven that rounded, curvilinear elements are being more pleasant and preferred than sharp, rectilinear ones. In terms of façade design, abstract ones are more favored by the crowd. Cuerda et al. [13] used a questionnaire to study the impression and preference of five sets of single-family residential facades with different levels of complexity. The results showed a U-shaped relationship between complexity and the preference criteria, indicating that simple facades were more favored than complex ones while the facades with the most complex-looking were the most impressive. In cultural-expo architecture, Liu et al. [14] found that people preferred an easy-to-understand architectural appearance design. Which may attribute to the association between the ease of interpreting the stimulus meaning and a positive aesthetic response. In the field of environmental aesthetics, Cold B [15] demonstrated that natural environments and natural elements have a positive effect on well-being as well as on health.

(3) Factors affecting cognitive differences

What's more, studies showed that the differences in the cognition of viewers against things lead to the differences between the acceptance and impression levels [16,17]. Cook et al. [18] studied the influence of personality on aesthetic preferences, and indicated that architectural familiarity was found to be highly predictive of preferences for all styles. Jam et al. [19] confirmed the impact of expertise on preference, visual exploration, and cognitive experience during the aesthetic judgment of designed façades. By comparing the perceptional similarities and differences between designers and users on residential buildings' facades. Ilbeigi et al. [20] found the conflicting viewpoints about aesthetic between them, more specifically, non-architects found 'uniqueness' to be the most effective parameter in selecting the best façade; while architects considered 'pleasantness' as the most crucial factor. Dealing with conservation of monuments, Rusnak et al. [21] analyzed the difference in the attention on the color of historical buildings and logos between architectural professionals and non-professionals. The results suggested that professionals were not representative of the general perception standards of the public. Therefore, public participation should be promoted in the process of urban planning and architectural design, and eye-tracking technology provides technical support for proposing potentially successful solutions.

(4) Applications of eye-tracking technology

By applying eye-tracking technology, Spanjar et al. [22] measured inhabitants' visual experiences of the city and suggest that a coherent design of streetscapes in high-rise environments may contribute to a human scale at eye-level. Li et al. [3] explored the visual behavior characteristics of rural architectural heritage and found that relative area, distance from center, and perimeter were elements that influence visual perception. Ergan et al. [23] defined the set of architectural design features that people notice immediately in a space, and found that certain features such as the openness of space, presence of windows and daylighting are powerful enough to change human experience. De la Fuente Suárez [9] used the eye-tracking technology to study the relationship between visual attention and subjective experience in the process of architectural experience. This research pointed out that there was a correlation between gaze duration and subjective experience and proposed high-quality and pleasant architecture elements for longer gaze. While the specific interpretation between eye movement indicators (the first fixation duration, fixation count, etc.) and subjective feelings in the process of architectural experience is still a research gap.

1.3. Problem statement and objectives

In summary, differences in the cognition of viewers have been confirmed, eye movement indicators such as the first fixation duration, the total fixation duration and the visit count can all be interpreted as target attractiveness and information coding difficulty [19]. But there is a lack of a clear definition of eye movement indicators on public perceptions such as impression and acceptance. In

present study, localized churches were selected as research object, and the research purposes are to (1) study the differences in the impression and acceptance levels against churches with different localization degrees through questionnaires; (2) analyze the eye movement behavior characteristics of youth groups against churches with different localization degrees by eye movement experiments; (3) explore the relationship between eye movement indicators and subjective impression and acceptance by the correlation analysis.

2. Research methods

In order to obtain data on public acceptance, impression and eye movement behavior of church facades, we selected five church facades with different localization degrees, and asked participants to conduct eye tracking experiments in a closed laboratory and fill in the questionnaire.

2.1. Study samples

In present study, facades of five churches with different localization degrees were selected. They are St.Paul's Arch (SPA), Xi'an Five Star Street Catholic Church (FSSCC), Mosey Catholic Church (MCC), Guiyang North Catholic Church (GNCC), and Ancient City Catholic Church (ACCC). In order to avoid the influence of urban cultural background on participants, all of selected churches were seen by the subjects for the first time, with no information about the building's history or current function was given to them.

Through the digital analysis of the elevation map, the digitally derived geometric proportional relationship of the church facade could be obtained [24]. Fig. 1 shows the quantitative analysis of the localization of five church facades based on the proportion of Chinese and Western elements in decoration, doors, windows, and roofs. As shown, the localization degrees of the facades are 0%, 25%, 50%, 75%, and 100%, respectively. Five images of church facades were resized to have the same proportions on the computer screen to ensure that the attention of participants was evenly distributed on the screen.

2.2. Questionnaire survey

The questionnaire (seen in Table 1) included personal information and subjective evaluation of the church facades of the

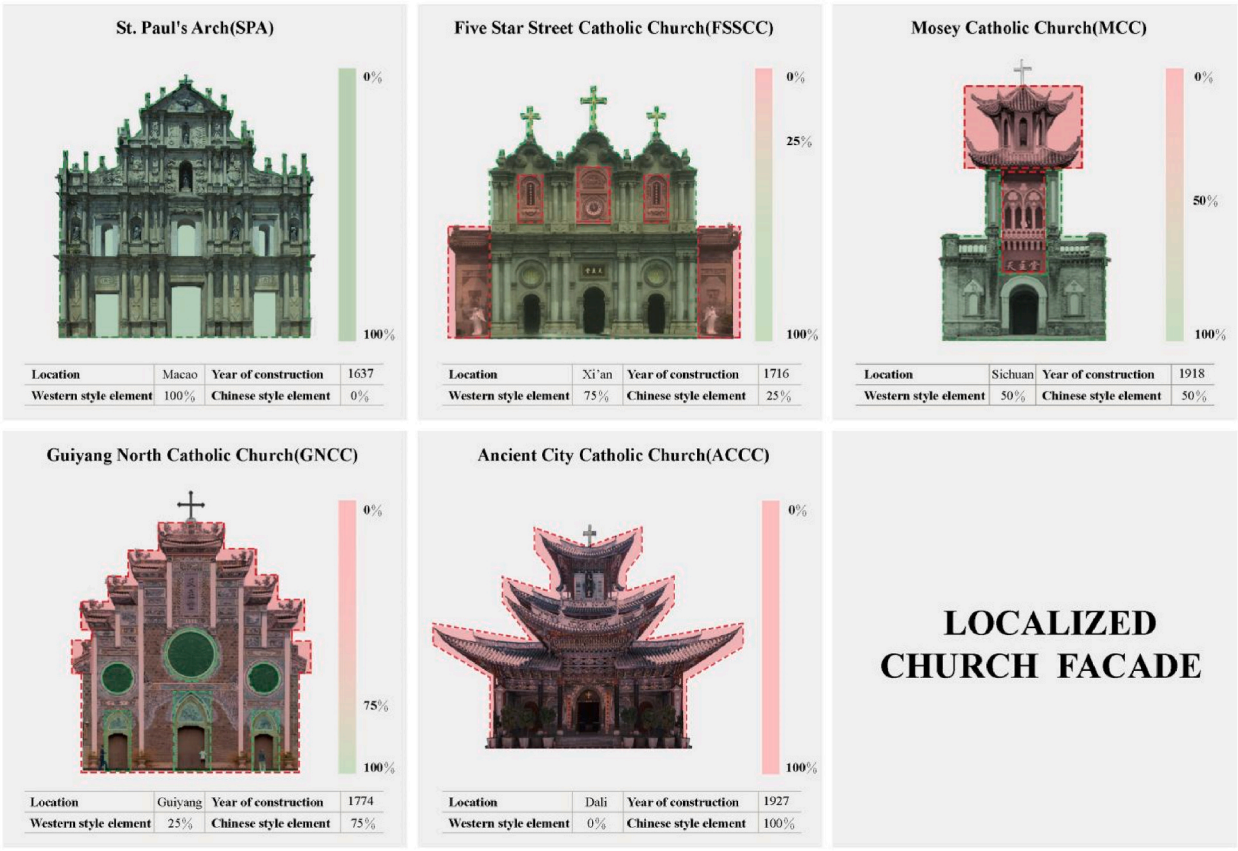

Fig. 1. Quantitative analysis of the localization of the facades of five churches.

participants. It was designed based on a psychometric scale, which suggested that elements such as Knowledge, Learning, and Emotional and Spiritual Experience could measure the degree of meaningful experiences for visitors that a church provided [25,26]. In order to verify the quantitative analysis of selected church facades with cognitive subjective judgment, all of the participants should rank church facades in descending order of localization according to their awareness and understanding. Then the participants rated impression and acceptance on a Likert 7-point scale based on their personal Emotional and Spiritual Experiences.

2.3. Experimental study

The experiment was conducted from April 10 to 12, 2022 at the laboratory of the Binhai Academic Center of Qingdao University of Technology. Fig. 2 shows the experimental procedure. Before the experiment, the height of the computer screen and the seat position were adjusted to conduct the calibration of the eye-tracking, between which, the experimental procedure and precautions were informed to participants. Then the experiment began. Five images were shown in random order to ensure that the order did not affect the cognitive evaluations of the participants. The participants viewed each image for 30 s and then rested for 10 s to reduce visual

Table 1
Questionnaire on impression and acceptance of indigenous churches.

I**. Personal information**

1.**Gender:** ☐Male ☐Female

2.**Age:**☐18-20 ☐21-23 ☐24-26

3.**Education level:**☐Bachelor's degree ☐Master's degree

4. **Native place:**☐South ☐North (the border is between Qinling Mountains and Huaihe River)

II. Personal evaluation

5. Please rank the localization of the five church, facades observed in the experiment

	0%	25%	50%	75%	100%
Fig 1	☐	☐	☐	☐	☐
Fig 2	☐	☐	☐	☐	☐
Fig 3	☐	☐	☐	☐	☐
Fig 4	☐	☐	☐	☐	☐
Fig 5	☐	☐	☐	☐	☐

6. Please rate the impression of the five church facades observed in the experiment (-3 points means very unimpressive, 3 points means very impressive)

	Very unimpressive (-3)	Unimpressive (-2)	Slightly unimpressive (-1)	Neutral (0)	Slightly impressive (1)	Impressive (2)	Very impressive (3)
Fig 1	☐	☐	☐	☐	☐	☐	☐
Fig 2	☐	☐	☐	☐	☐	☐	☐
Fig 3	☐	☐	☐	☐	☐	☐	☐
Fig 4	☐	☐	☐	☐	☐	☐	☐
Fig 5	☐	☐	☐	☐	☐	☐	☐

7. Please rate the acceptance of the five church facades observed in the experiment (-3 points means very unacceptable, 3 points means very acceptable)

	Very unacceptable (-3)	Unacceptable (-2)	Slightly unacceptable (-1)	Neutral (0)	Slightly acceptable (1)	Acceptable (2)	Very acceptable (3)
Fig 1	☐	☐	☐	☐	☐	☐	☐
Fig 2	☐	☐	☐	☐	☐	☐	☐
Fig 3	☐	☐	☐	☐	☐	☐	☐
Fig 4	☐	☐	☐	☐	☐	☐	☐
Fig 5	☐	☐	☐	☐	☐	☐	☐

fatigue caused by prolonged viewing [27]. After watching the five images, the participants filled out a questionnaire. Fig. 3(a and b) shows the eye-tracking equipment and the experimental photo. Eye movements and indicators including first fixation duration, total fixation duration, fixation count and visit count were recorded automatically by eye-tracking equipment in the process of gazing.

2.4. Evaluation indicators and statistical analysis

In this study, church facade images were the analysis unit. Evaluation indicators included subjective preference and objective preference. Subjective preference (impression and acceptance) was measured by the average of the ratings of the participants for each image in the questionnaire. Objective preference was measured by the weighted average of eye movement indicators including the first fixation duration, total fixation duration, fixation count, and visit count (Table 2). A correlation analysis was conducted by employing SPSS22.0 to identify the eye movement indicators that were most correlated with subjective preference.

3. Results and discussion

3.1. Analysis of questionnaire survey

The participants were the youth group aged from 18 to 26. They were different from other age groups. They were in the establishment stage of cultural cognition and were more willing to explore things [28]. Also, the youth group is the main object of cultural communication and the leader and backbone of cultural communication in the future. A total of 30 students (15 males and 15 females) participated in the experiment. Table 3 shows the information of the participants.

3.1.1. Subjective and objective evaluation of localization

Fig. 4 shows the degree of consistency between the ranking of the participants and the digital quantitative analysis for the localization of church facades. The judgment of the participants for SPA and ACCC was completely consistent with the quantitative results, while there were some deviations in the judgment for FSSCC, MCC, and GNCC. The consistency degree was over 90% and the error was within the acceptable range.

3.1.2. Impression and acceptance levels

From the statistical graph of the impression level of the participants against five church facades shown in Fig. 5(*a*), it can be seen that the impression level increased with an increase in the localization degree of the church facades. The impression level was the lowest at the 0% localization degree and was the highest at the 100% localization degree, indicating that highly localized churches gave the most profound impact on the participants. When the localization degree increased from 50% to 75%, the impression level of the participants showed the largest increase indicating that the interest points of the participants had changed greatly by this change in the localization degree.

The impression level indicated the first feeling of the participants against the church facades. However, it did not represent their acceptance level. Fig. 5(*b*) shows a statistical graph of the acceptance level of the participants for the five church facades. There was a U-shaped relationship between the acceptance level and the localization degree of the church facade. The acceptance levels at the 0% and 100% localization degrees were higher which were 5.25 and 4.85, respectively (close to ''Slightly acceptable''). The acceptance level at the 50% localization degree was the lowest of 3.70 (below ''Neutral''). These results indicated that the participants were highly receptive to purely local churches, especially pure Western churches (0% localization degree), and were less receptive to churches with the 50% localization degree.

Studies have shown that people's memory of things depends on their interest cognition [29]. The varied architectural facade style is easy to arouse the interest and impression of observers. The public's preference for things depends on the complexity of the observed objects [30,31]. Therefore, the simpler the building facade is, the easier it is to be accepted.

3.1.3. Population differences in the impression and acceptance levels

To investigate the influence of the difference in the impression level of the participants, this study analyzed the impression level of the participants with different genders, ages, educational levels, and native places. After the analysis, it was found that there was no significant difference in regards to age and native place. Fig. 6 shows the impression level of the participants with different genders and educational levels. As seen in Fig. 6(*a*), males showed higher impression levels than females. Which may be attribute to the fact that

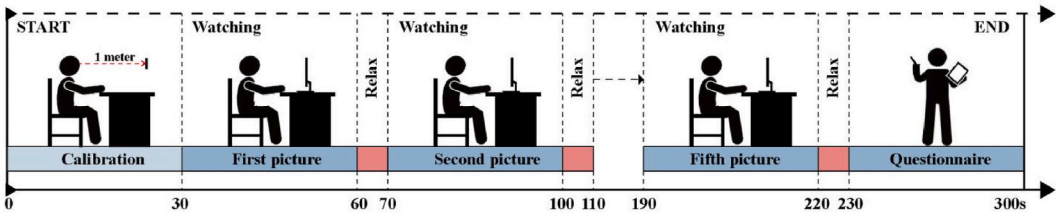

Fig. 2. Experimental procedure.

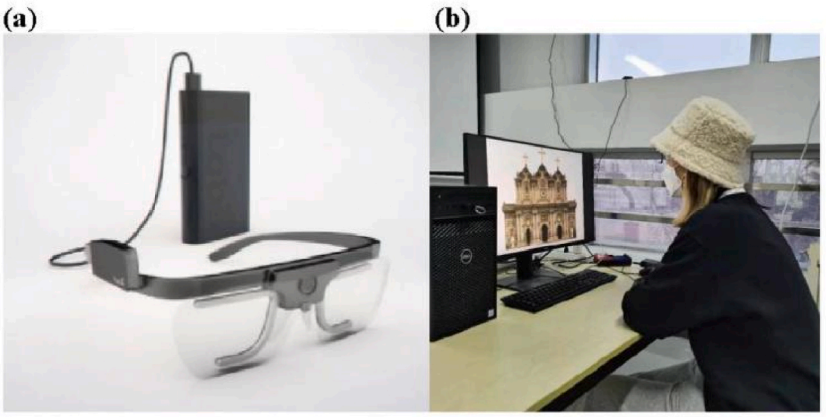

Fig. 3. (*a*) Eye-tracking equipment and (*b*) Experimental photo.

Table 2
Evaluation indicators and test methods.

Indicators	Test methods	Content
Impression	Questionnaire	The impression degree was cast on a 7-point scale.
Acceptance	Questionnaire	The acceptance degree was cast on a 7-point scale.
First fixation duration	Eye-tracking	The duration of the first attention of the participant to a certain area of interest
Total fixation duration	Eye-tracking	The sum of all the time the participant looked at a certain area of interest.
Fixation count	Eye-tracking	The number of participants who looked at a certain area of interest since they looked at this area.
Visit count	Eye-tracking	The number of times the participant started looking back at a certain area of interest.

Table 3
Information of the participants.

Variables	Parameters	Participants	
		Number	Percentage (%)
Gender	Male	15	50
	Female	15	50
Age	18–20years old	9	30
	21–23years old	9	30
	24–26years old	12	40
Education	Undergraduate	15	50
	Graduate	15	50
Region	North (north of the Qinling-Huaihe dividing line in China)	21	70
	South (south of the Qinling-Huaihe dividing line in China)	9	30

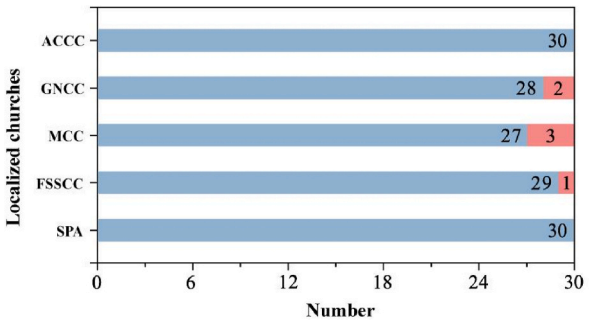

Fig. 4. Degree of consistency between the ranking of participants and the digital quantitative analysis for the localization of church facades.

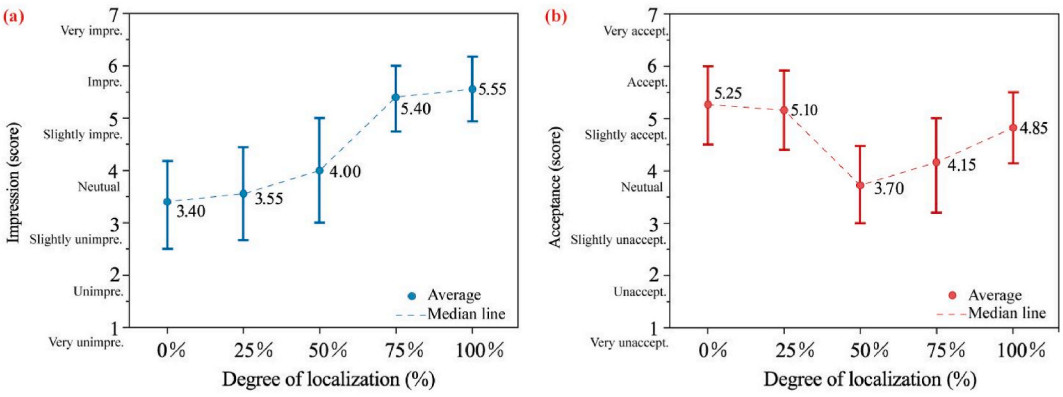

Fig. 5. Distribution of (*a*) impression level and (*b*) acceptance level.

men and women have different emphases on the evaluation of artworks, and men pay more attention to the background of the art while women pay more attention to the work itself [28]. Fig. 6(*b*) shows that the impression levels of undergraduates were higher than those of graduates. This difference decreased gradually as the localization degree increased, and was negligible at the 50% localization degree.

Fig. 7 shows the acceptance level of the participants with different genders and educational levels. As can be seen from Fig. 7(*a*), the acceptance level of males was the highest at the 0% localization degree with a score of 1.40 (between ''Slightly acceptable'' and ''Acceptable'') and was the lowest at the 75% localization degree with a score of −0.20 (between ''Slightly unacceptable'' and ''Neutral''). The acceptance level of females was the highest at the 100% localization degree with a score of 1.30 (between ''Slightly acceptable'' and ''Acceptable'') and was the lowest at the 50% localization degree with a score of −0.60 (between ''Slightly unacceptable'' and ''Neutral''). Also, the acceptance level of males was higher than that of females at the 0%, 25%, and 50% localization degrees while the results were opposite at the 75% and 100% localization degrees. As shown in Fig. 7(*b*), the acceptance level of graduates was higher than that of undergraduates at the 0% and 25% localization degrees while the results were opposite at the 50%, 75%, and 100% localization degrees. The change in the acceptance level with the change in the localization degree for undergraduates was smaller than that for graduates.

3.2. Analysis of eye movement indicators

To compare the differences between eye movement indicators, Fig. 8 shows the first fixation duration, total fixation duration, fixation count, and visit count of the participants.

3.2.1. Eye movement indicators

Fig. 8(*a*) shows that the first fixation duration increased with an increase in the localization degree. The first fixation duration was the longest (0.69 s) at the 100% localization degree and was the shortest (0.49 s) at the 0% localization degree. The change curve showed that an increase in the first fixation duration was small when the localization degree increased from 0% to 50% (0.05 s) and

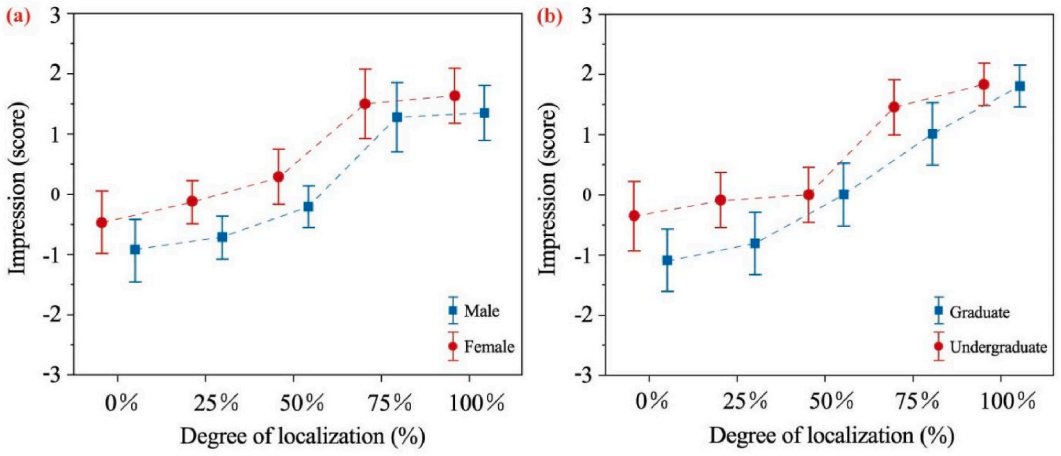

Fig. 6. Impression level voting of the participants (*a*) with different genders and (*b*) with different educational levels.

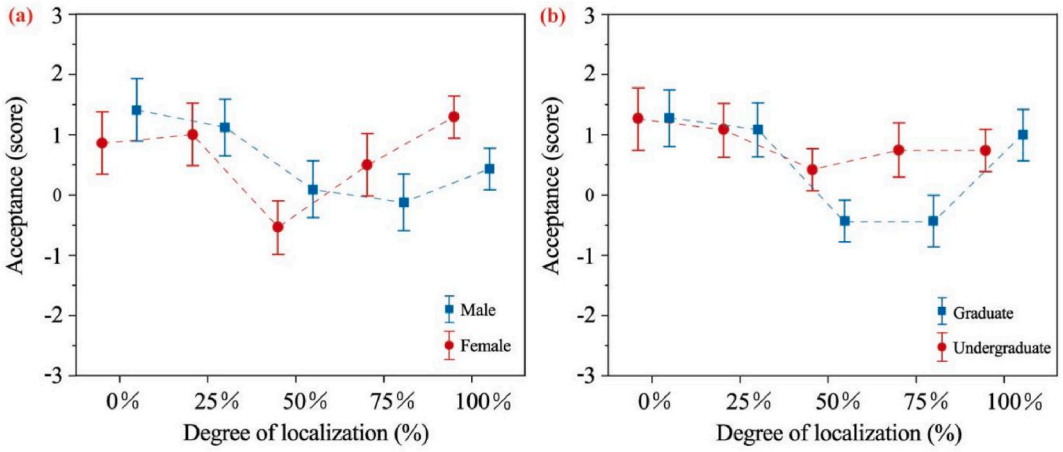

Fig. 7. Acceptance level voting of the participants (*a*) with different genders and (*b*) with different educational levels.

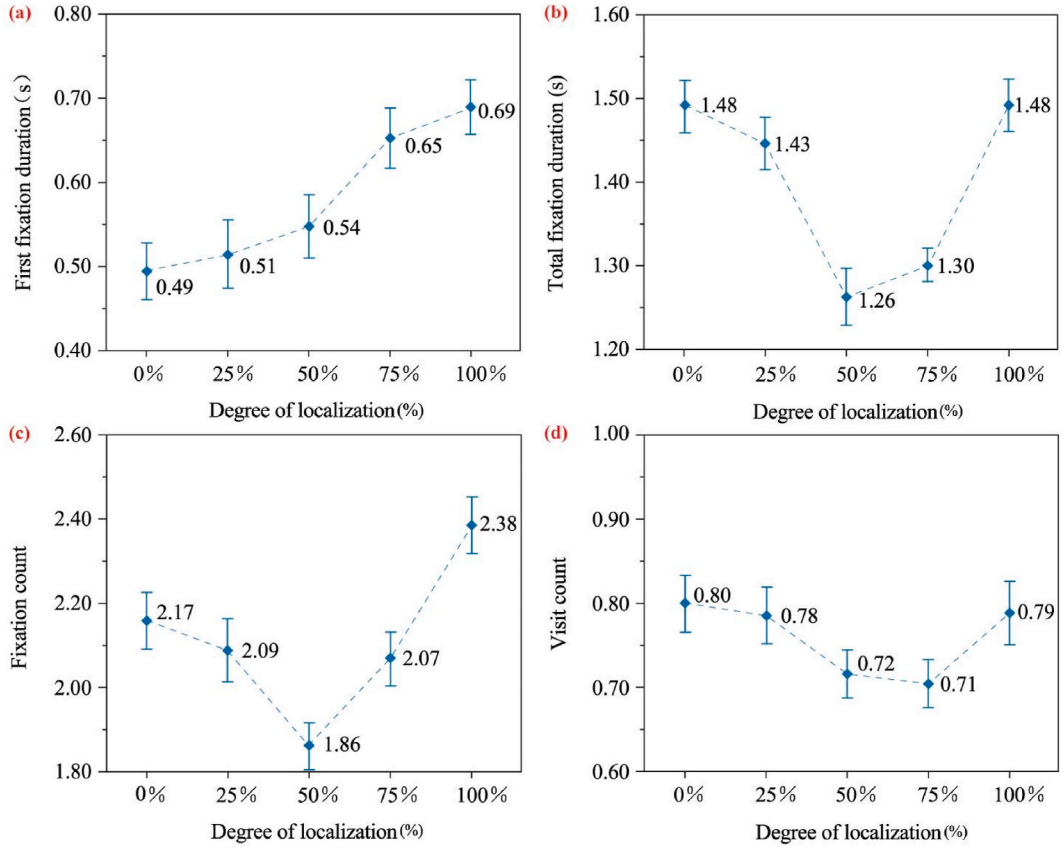

Fig. 8. Line chart of (*a*)first fixation duration, (*b*) total fixation duration, (*c*) fixation count, and (*d*) visit count.

from 75% to 100% (0.04 s) while it was larger when the localization degree increased from 50% to 75% (0.11 s).

It can be seen that there was a U-shaped relationship between the total fixation duration, fixation count, visit count and the localization degree in Fig. 8(*b*), (*c*), and (*d*). In Fig. 8(*b*), the total fixation duration was the longest (1.48 s) at the 0% and 100% localization degrees and the shortest (1.26 s) at the 50% localization degree. Also, the total fixation duration of the participants varied significantly as the localization degree increased from 25% to 50% and from 75% to 100%. In Fig. 8(*c*), the maximum value of the fixation count was 2.38 when the localization degree was 100% while the minimum was 1.86 when the localization degree was 50%. The overall change in the fixation count was large. In Fig. 8(*d*), the maximum value of the visit count was 0.80 at the 0% localization

degree and the second-highest value of the visit count was 0.79 at the 100% localization degree. Its minimum value was 0.71 at the 75% localization degree. The overall change in the visit count was small.

Studies have shown that the first fixation duration during the eye movement process can reflect the interest pull of the target information [32]. The total fixation duration, fixation count, and visit count can reflect the difficulty of extracting target information [30]. Buildings with a single style (the localization degree was 0% and 100%) paid more attention to the integrity of the facade style, the information was less prominent and might result in a high extraction difficulty. While buildings with a mixture of Chinese and Western styles (the localization degree was 25%, 50%, and 75%) paid more attention to the uniqueness of the facade elements, which could result in a low extraction difficulty.

3.2.2. Population differences in eye movement indicators

The questionnaire results showed that there were differences in the impression and acceptance levels among the participants with different genders and educational levels. Therefore, the eye movement behaviors of different groups were analyzed. Table 4 shows the eye movement indicators of the participants of different genders. Females showed a higher first fixation duration than males. The total fixation duration of males was higher than that of females at the 0%, 25%, and 50% localization degrees. Males gazed more frequently than females in the item of the fixation count and visit count.

Table 5 shows the eye movement indicators of the participants with different educational levels. The undergraduates showed a longer first fixation duration than graduates. The total fixation duration differed greatly between undergraduates and graduates when the localization degree was 50% and 75%. In terms of the fixation count and visit count, undergraduates showed higher values than graduates.

3.3. Correlation analysis between subjective preference and eye movement indicators

As defined by statistics, correlation analysis is a method of statistical analysis that examines the correlation between two or more random variables that are on equal footing. In present study, the pearson correlation coefficient method was applied to prove the relationship between eye movement indicators and public impression and acceptance, which is commonly used to measure the degree of linear correlation between two variables. Pearson correlation coefficient ranges from 1 to −1, the larger the absolute value of the coefficient represents the greater the degree of correlation.

From the correlation analysis chart between the eye movement data and the impression level shown in Fig. 9(*a*), it can be seen that the first fixation duration showed the highest correlation with the impression level with the absolute value of the Pearson coefficient of 0.910 ($P < 0.05$). This indicated that the data were valid. In the correlation analysis of the total fixation duration, fixation count, and visit count, the P values were larger than 0.05 and the data were invalid. The results showed that there was a significant and positive correlation between the first fixation duration and the impression level of the participants.

From the correlation analysis chart between the eye movement data and the acceptance level shown in Fig. 9(*b*), it can be seen that the total fixation duration, fixation count, and visit count were highly correlated with the acceptance level. Among them, the correlation between the total fixation duration and the acceptance level was the largest and the absolute value of the Pearson coefficient was 0.928 ($P < 0.01$). Thus the data were valid. The correlation of the visit count was the second largest with the Pearson coefficient of 0.891. In the correlation analysis for the fixation count and first fixation duration, the P-values were larger than 0.05 showing that the data were invalid. The results showed that there was a significant and positive correlation between the total fixation duration, visit count and the acceptance level of the participants where the correlation was larger for the total fixation duration.

The first fixation duration in the eye movement behavior was correlated with the impression level. Studies have shown that the first fixation duration can reflect the level of interest in the brain. A building facade with a higher degree of variation is more likely to arouse the interest of visitors [33,34]. Therefore, in the design and renovation of a building facade, unconventional expressions can be used to improve the attractiveness of the architectural form and leave a deeper impression on visitors.

The total fixation duration and visit count in the eye movement behavior were correlated with the acceptance level. Studies have shown that the total fixation duration is positively correlated with the cognitive load and the visit count is negatively correlated with the information salience [35,36]. For understanding the object, a lower degree of the information salience and shorter process are likely to give a higher acceptance level. Therefore, compared with highlighting the expression of elements, emphasizing the integrity of the facade design can more effectively improve the affinity of the architectural language and gain wider audience acceptance.

4. Conclusions

This study investigated the differences in impressions and acceptance of churches with different degrees of localization among youth groups, and analyzed the correlation between eye behavioral indicators and subjective perceptions based on eye-tracking techniques. The specific findings are as follows：

(1) The impression level of the participants increased with an increase in the localization degree. The impression level was the highest at the 100% localization degree and was the lowest at the 0% localization degree. Females showed higher impression levels than males and undergraduates showed higher impression levels than graduates.
(2) The relationship between the acceptance level and the localization degree showed a U-shaped change with a turning point at the localization degree of 50%. Also, the acceptance level of the participants with different genders and educational levels was consistent with the overall acceptance level trend.

Table 4
First fixation duration, total fixation duration, fixation count, and visit count of the participants with different genders.

Items	First fixation duration (s)		Total fixation duration (s)		Fixation count		Visit count	
	Males	Females	Males	Females	Males	Females	Males	Females
SPA(0%)	0.35	0.57	1.58	1.34	2.29	1.55	0.65	0.55
FSSCC(25%)	0.40	0.62	1.37	1.29	2.27	1.69	0.90	0.65
MCC(50%)	0.53	0.78	1.28	1.01	2.29	1.42	0.90	0.83
GNCC(75%)	0.68	0.74	1.17	1.23	2.04	1.86	0.78	0.63
ACCC(100%)	0.77	0.81	1.34	1.63	2.55	2.19	0.85	0.71

Table 5
First fixation duration, total fixation duration, fixation count, and visit count of the participants with different educational levels.

Items	First fixation duration (s)		Total fixation duration (s)		Fixation count		Visit count	
	Undergraduate	Graduate	Undergraduate	Graduate	Undergraduate	Graduate	Undergraduate	Graduate
SPA(0%)	0.49	0.35	1.61	1.51	2.05	1.63	0.76	0.56
FSSCC(25%)	0.51	0.50	1.30	1.36	2.26	1.91	0.82	0.72
MCC(50%)	0.69	0.65	1.19	1.11	1.90	1.82	0.91	0.83
GNCC(75%)	0.75	0.72	1.43	1.17	2.29	1.84	0.76	0.65
ACCC(100%)	0.77	0.77	1.36	1.46	2.47	1.89	0.96	0.59

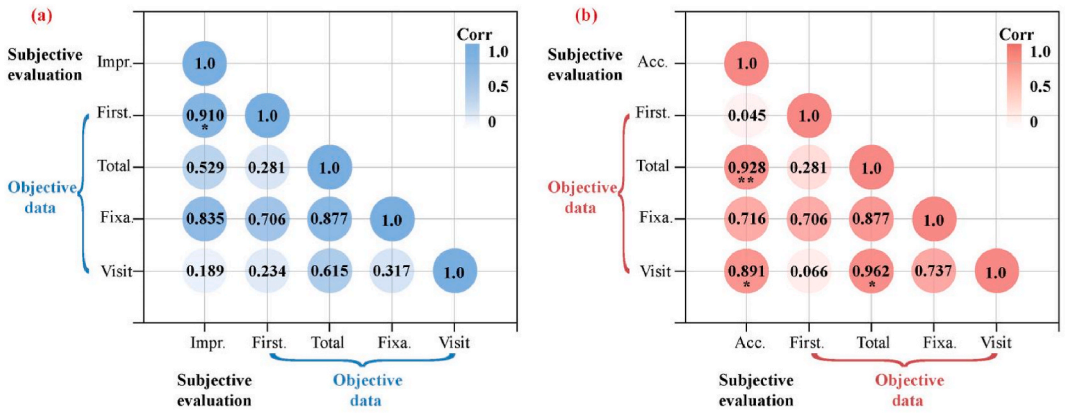

Fig. 9. Correlation analysis between the eye movement index and (*a*) the impression level and (*b*) the acceptance level (* indicates $P < 0.05$ and ** indicates $P < 0.01$).

(3) The first fixation duration could reflect the impression level. The longer the participants' first fixation duration during the observation process, the higher the impression of the church facade. While the total fixation duration and the visit count could reflect the acceptance level, and the longer the participants' total fixation duration during the observation process, the higher the acceptance of the church facade.

Generally speaking, the degree of subjective cognition was defined by eye movement indicators and a new method to study the relationship between architectural form and subjective cognition was proposed from the perspective of visual perception, which will help to promote the application of eye-tracking technology in public participation in urban development, architectural design and heritage conservation. However, subjective cognition is inevitably affected by building materials and scale, future research in this part will be supplemented. What's more, future experiments will be conducted in a wider population and in more related fields.

Data availability statement

All relevant data are included in the paper.References.

CRediT authorship contribution statement

Menghan Wang: Writing – review & editing, Writing – original draft, Investigation, Data curation, Conceptualization. **Xiaoying Geng:** Writing – review & editing, Writing – original draft, Resources, Investigation, Data curation, Conceptualization. **Zhicheng Zhang:** Writing – review & editing, Writing – original draft, Software, Resources, Methodology, Data curation, Conceptualization.

Chao Jia: Writing – review & editing, Writing – original draft, Visualization, Investigation, Funding acquisition, Data curation, Conceptualization. **Hiroatsu Fukuda:** Writing – review & editing, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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