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A Study on the Aesthetic Preference of Bamboo Weaving Patterns Based on Eye Movement Experiments

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Abstract: Bamboo weaving is an intangible cultural heritage in China. Exploring people's aesthetic preferences for bamboo weaving patterns to better serve the design of bamboo architectural decoration can help promote the upgrading of traditional crafts. This study explored the differences between genders in the oculomotor indicators in different bamboo weaving patterns through an eye-movement experimental study combined with a subjective questionnaire to explore whether different genders have aesthetic preferences for people's pictures of bamboo weaving patterns. The results showed that both males and females preferred less visually striking and softer corrugated patterns, with males paying more attention to the more 'angular' hexagonal and triangular patterns, while females were more interested in the more regular and uniform brickwork and diagonal patterns.

Keywords: eye-movement experiments; bamboo weaving patterns; architectural decoration; innovative designs

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1. Introduction

With the development of society and the economy, the deterioration of the environment and the shortage of resources attract more attention to the topics of environmental protection and low carbon. As an environmentally friendly green material, bamboo grows quickly and is able to fill the shortage of wood resources effectively, which meets the needs of the times. It is used as a raw material for a series of processes that have wood-like properties, and because the fibers are longer than wood, they are more flexible and are used as a substitute for wood in earthquake-resistant construction materials [1]. Among bamboo products, bamboo weaving is one of the most important decorative techniques. Due to their excellent physical and mechanical properties, bamboo slivers can be woven to form various patterns with a natural decorative aesthetic and are often used as an important form of expression in the application of decoration on furniture as well as in household products and architectural decoration. The study is not about interior decoration but about essential architectural components. According to these characteristics, this study is not only aimed at interior decoration but also at essential architectural components.

As a traditional intangible cultural heritage of China, bamboo weaving has a long history of development, carries the distinctive culture of different regions, and can fully satisfy people's demand for cultural connotations. However, in modern times, China's bamboo weaving industry is still at the stage of handicraft, not to mention the lack of objective research into the aesthetics of the bamboo weaving process. Unlike developed countries, China's information revolution took place before industrialization was completed. Therefore, traditional industries need to undergo transformation and upgrading within a short period of time. The bamboo weaving process is caught in the dilemma of self-sufficiency and is increasingly marginalized by the mass-produced industry. The main technical difficulties of bamboo weaving are the inability to achieve mass production to meet market demand and the high cost; the complexity of various bamboo weaving patterns for different architectural decoration occasions; and the difficulty of standardization. Due to the dry shrinkage and wet expansion characteristics of bamboo itself, the finished product is extremely susceptible to cracking and bending [2]. Due to these problems, the development of bamboo weaving for decoration in architecture is still in its infancy.

Exploring the aesthetic differences between men and women helps enrich the human aesthetic experience. Men and women often have different aesthetic evaluations of the same thing, which means that there are different aesthetic perceptions and preferences between men and women. When the aesthetic differences between men and women are fully recognized and understood, we can also gain a better understanding of the aesthetic preferences and directions of development of different cultures and social groups, thus promoting the development of artistic and cultural diversity.

The aim of this study was to examine the visual and cognitive characteristics of consumers through physiological measurements and subjective evaluations. An eye-tracking device was applied to track the eye movements of gender-specific participants, and semantic differences were examined to identify participants' subjective cognitive evaluations. The bamboo patterns of common bamboo decorations were selected as the study object to clarify the aesthetic preferences of different gender consumers for bamboo patterns and to provide a reference for the design of bamboo decorative patterns in architecture.

2. Research Background

The weaving techniques for bamboo can be divided into irregular weaving techniques and regular weaving techniques. The irregular weaving technique is difficult, time-consuming, and unsuitable for mass production, while the regular weaving technique is a constant repetition of a certain geometric pattern that can be realized by machine and is more suitable for systematic application to large areas of large-scale bamboo and rattan furniture as well as in architectural decoration [3]. With the acceleration of urbanization, people are putting forward higher demands on the spiritual and cultural level; architecture as a product of the development of modern cultural ideology is receiving more and more attention, and the need for philosophy and art in the decoration of architectural spaces is becoming more and more urgent. Bamboo weaving, as a representative of traditional Chinese skills, is the result of thousands of years of the accumulated wisdom of the Chinese working people and contains the excellent aesthetic culture of the Chinese nation. A scientific and objective study of the aesthetics of bamboo weaving patterns will not only further enhance the artistic value of China's traditional culture but also meet the needs of modern people for the cultural connotations of architecture. For example, in previous studies of bamboo woven lamps, it was found that participants preferred bamboo woven patterns with simple textures and regular holes, which constitute a pattern with simple beauty and can bring a more relaxed psychological feeling to the user, in line with the user's preference and aesthetic concept [4]. However, there is a distinct lack of research into the application of bamboo weaving patterns in architecture, with traditional research on bamboo weaving focusing on the craft characteristics of bamboo weaving and little attention paid to people's preferences for bamboo weaving patterns. According to the findings of Suhaimi and Kuys on architectural joints, visual complexity and appeal (aesthetics) are often more important than the performance of the product (functionality) [5].

Currently, visual cognition research is primarily conducted through subjective evaluations and physiological measures, each of which has its own strengths. Subjective evaluations include in-depth interviews, questionnaires, user observations, and focus groups [6,7], enabling researchers to identify problems, clarify phenomena, summarize research participants' subjective cognitive information, and access a wealth of research data and a rich explanatory space. However, subjective evaluation relies on the researcher's research competence and familiarity with the particular field. The process is labor-intensive and may be influenced by the researcher's own subjective emotions [8]. As research theories and techniques have evolved, methods of physiological measurement have become increasingly diverse. Physiological measurements involve instruments that combine infrared imaging, virtual reality, EEG, and eye-tracking technologies to detect changes in participants' heart rate, neural arousal, respiration, expression, and other physiological indicators, thereby identifying their underlying, intuitive physiological feedback. This research method allows objective observation of participants' immediate emotions and intuition but requires complex operational procedures and the elimination of extraneous factors in the measurement of indicators.

Among the advanced technologies that can monitor consumers' physiological metrics, eye tracking is the most promising method for analyzing information that captures consumers' attention [9]. The study of human mental activity by examining human eye movements has been carried out as early as the end of the 19th century, and Alfred Yarbus completed landmark and pioneering work on eye tracking by conducting extensive research [10]. In 1879, Javal attempted to explore eye movement patterns by observing participants' eye movement characteristics through a mirror [11]. Pfiffelmann, J et al. explored the impact of personalized recruitment advertisements on job seekers' visual attention, attitude towards advertisements and final job intention through eye movement experiments. [12]. As eye movement technology has been refined, it has been widely used in medicine, human-computer interaction, sports psychology, transportation psychology, aerospace science, advertising, and consumer psychology. In recent years, several scholars have introduced eye-movement analysis into architectural design-related research [13–15], with Ann Sussman as a representative researcher who has better provided architects with a new understanding of design with the aid of 3M-VAS [16–18]. These studies provide scientific, objective, and quantitative references to promote the wider application of eye-movement technology in the academic field. In addition, as consumer demand for products has increased, some researchers have begun to use eye-tracking technology to analyze people's preferences for products. It has been found that most of the sensations induced by a product come from the initial visual perception. In addition, consumers' visual perception is the most important sensation during the purchase of a product [19]. With the help of eye-tracking technology, it is therefore possible to objectively analyze consumers' aesthetic preferences for products through experimental studies. Few studies have focused on bamboo weave patterns. Therefore, this article explores the aesthetic preferences of different gender groups for bamboo weave patterns through eye-tracking technology and applies them to architectural design. This research can provide a more objective and scientific basis for the design of bamboo weave decoration in architecture, helping the architectural decoration industry carry out customer segmentation and enabling designers to consider how to integrate the aesthetic preferences of different genders to create a more unique and attractive bamboo weaving pattern design.

3. Materials and Methods

3.1. Participants

A total of 20 participants from China, including ten males and ten females, aged between 18 and 45 (M = 27.20, SD = 8.258), were recruited to participate in the experiment. All participants were in good health. Color blindness (both partial and total color blindness), abnormal trichromacy, astigmatism, limitations, or night blindness were not detected. The visual acuity, or corrected visual acuity, was at least 1.0, and all had adequate sleep and a good diet prior to the experiment. A post hoc statistical power analysis using G*Power software(3.1.9.2) indicated that at a 0.25 effect size and a 5% significance level, the number of participants was sufficient to reach a statistical power of 90%. The Institutional Review Board of Beijing Forestry University approved the study. Each of the participants provided an informed consent agreement.

3.2. Apparatus

Experiments are carried out in a quiet, comfortable, well-lit, well-ventilated space with a suitable temperature. Participants were seated in a comfortable position to avoid moving and reduce interference. The equipment is a Dikablis glass with a data sampling frequency of 30 Hz and infra-red compensated illumination technology, which allows the experiment to be carried out under any lighting conditions and ensures the accuracy and stability of the test. The experiments were computer-controlled (Figure 1).

Figure 1. Eye movement instrument Tobii Pro X2-30.

3.3. Stimuli

Eight representative bamboo weaving patterns were selected through the internet, including crosse, return, hexagonal hole pattern, triangular hole pattern, jumble pattern, brickwork pattern, herringbone pattern, and wave pattern. The base color of each image is white, and the pixel size is the same (1600 × 900). Processed by Adobe Photoshop CC as a grayscale image to remove the effect of color on cognitive judgment (Figure 2).

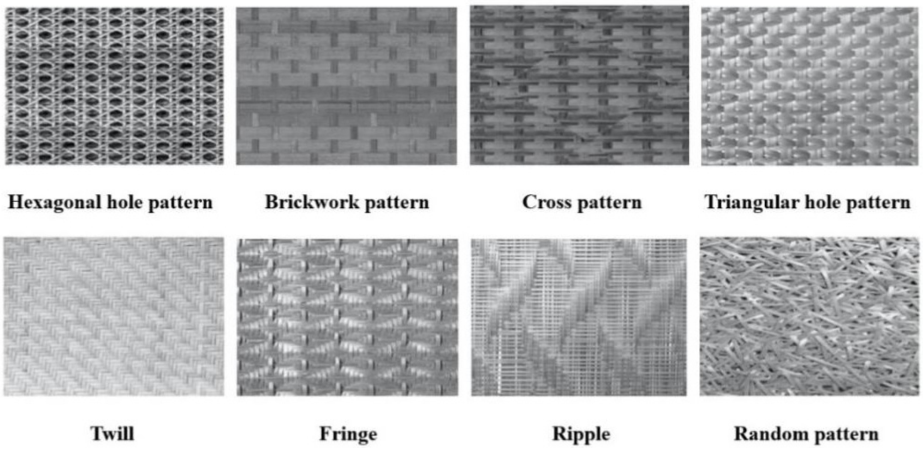

Figure 2. Eight types of bamboo weaving patterns.

3.4. Procedure

To eliminate the position generated by the position of the picture display, a Latin square arrangement was used for the eye movement experiment. According to the definition of a Latin square arrangement, when the number of treatments is even, the horizontal rows are: 1, 2, n, 3, $n-1$, 4, $n-2$, … … ("n" represents the number of quantities to be sorted); the subsequent order is to add "1" to the number of the first order until a Latin square. Then there should be one pattern per picture, with each pattern picture appearing only once in each column and each row. The pattern of arrangement is shown in the following table (Table 1).

Table 1. Arrangement of pattern images.

A	1	2	8	3	7	4	6	5
B	2	3	1	4	8	5	7	6
C	3	4	2	5	1	6	8	7
D	4	5	3	6	2	7	1	8
E	5	6	4	7	3	8	2	1
F	6	7	5	8	4	1	3	2
G	7	8	6	1	5	2	4	3
H	8	1	7	2	6	3	5	4

Throughout the experiment, eight images appeared in each chart and were arranged in a circular pattern figure as below, with one legend dividing the eight zones of interest (Figure 3).

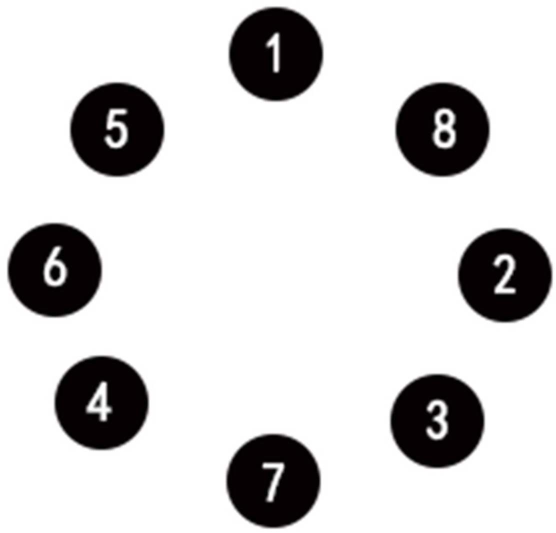

Figure 3. Ring arrangement of images.

3.5. Pattern

The experiment was divided into two parts, with the eye-movement experiment being conducted first, followed by the preference questionnaire. In the oculomotor experiment, participants were first seated in the laboratory so that the instrument could capture the binocular data. The participant was guided through the eye calibration at five points on the display while sitting in a stable and comfortable position; before the experiment began, the experimenter conveyed precise information about the experiment to the participant, and the experiment began after participants understood the introduction of the experiment. The experiment was randomized with the order in which the pictures were presented, with each picture being viewed for 10,000 ms and a blank page with a "*" symbol displayed for 30,000 ms before each picture appeared in the center of the computer screen. The images then appeared randomly and remained there for 10,000 ms, with each experiment taking an average of 2 min. The flow of the eye movement experiment is shown in the diagram below (Figure 4).

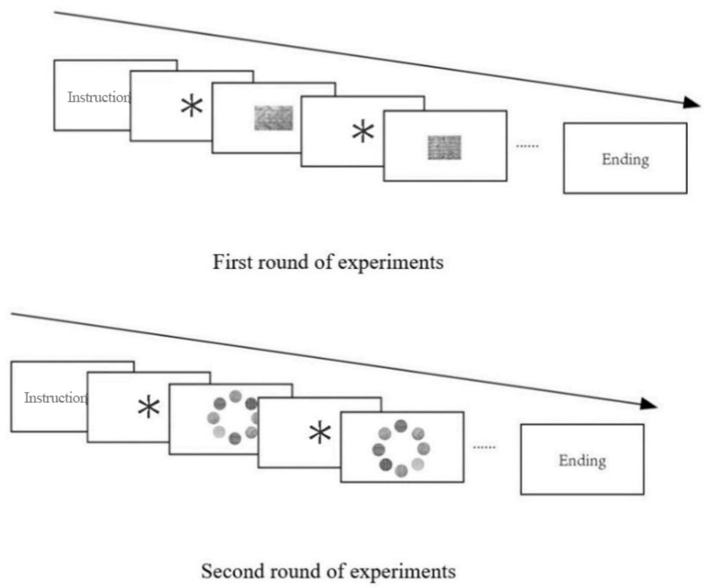

Figure 4. Experiment process.

After the eye-movement experiment, a questionnaire was used to ask the participants to subjectively rate their preferences for the different pictures of bamboo weaving patterns just presented, using a 7-point Likert scale, with higher (highest 3) ratings indicating stronger preferences [20]. There were 7 ratings for preference, as shown in Table 2.

Table 2. Preference ratings.

Dislike	→					**Like**
1	2	3	4	5	6	7
− − −	− −	−	neutral	+	++	+++

3.6. Data Processing and Statistical Methods

Eye movement data were recorded in real time by a Dikablis glass coulometer. The dependent variables were divided into two groups, psychological and physiological, with the psychological group being the statistical means of the subjective scales and the physiological group being the oculomotor data (including mean gaze duration, the mean number of gaze movements, gaze point movement order, and pupil size), and the data were collated using Excel and analyzed using SPSS26 for relevant mathematical and statistical knowledge. A multi-factor ANOVA was used to analyze the independent and dependent variables, corrected using the Greenhouse-Geisser correction, and the alpha value was set to 0.05 when performing the statistical tests. The means were analyzed for multiple comparisons in Tukey's post-test.

4. Results

4.1. Results of Heat Map

A gaze hotspot map is a statistically generated image based on a participant's eye movement data that reflects the participant's duration and overall eye movement on the screen. It uses a chromatogram to indicate where and for how long the participants focus their attention, as shown in Figures 5 and 6 [21].

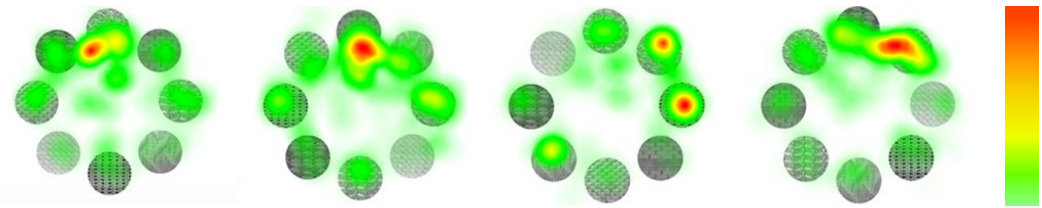

Figure 5. Heatmap of the female test.

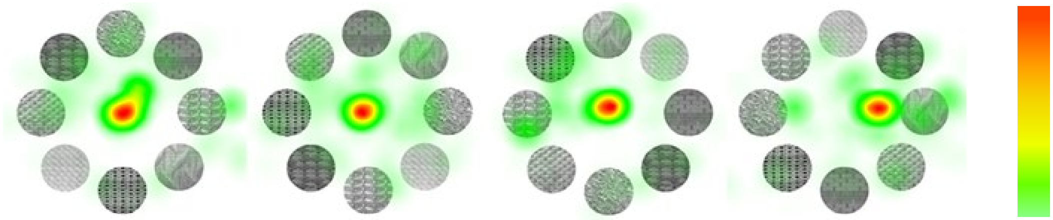

Figure 6. Heatmap of the male test.

As can be seen from the heat map, female participants linger longer on a particular sample picture, taking a closer look. Male participants, on the other hand, spend a relatively short time on each pattern picture and basically make sweeping observations.

4.2. Results of Fixation Sequences

The sequence of gaze points is the order formed by the transition of gaze points between areas of interest. Representative pictures of gaze points for different genders were selected, as shown in Figures 7 and 8.

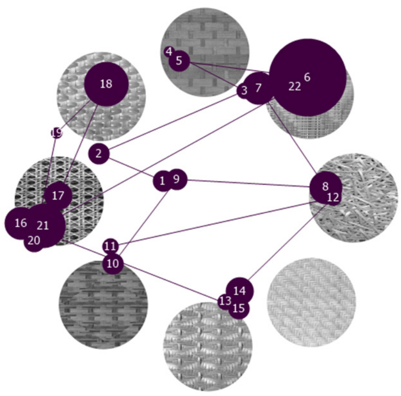

Figure 7. The picture watching the point movement of the male test.

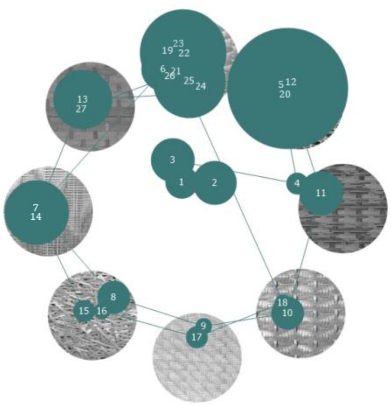

Figure 8. The picture watching the point movement of the female test.

Since the "*" appears in the center of the screen at the beginning, the gaze trajectory starts in the middle. As can be seen from the above diagram, the participants used to start from the top half of the pattern when observing.

4.3. Results of Average Fixation Time

By conducting a univariate multi-factor ANOVA on the full data, as shown in Figure 9 and Table 3, there were significant differences between gender and grain pattern factors on mean gaze time ($p < 0.05$), with females typically having slightly more mean gaze time than males. There was also a significant interaction effect between gender and grain pattern, and a simple effects analysis was conducted, which showed that the mean gaze time for females was significantly different between corrugated and diagonal ($p = 0.005 < 0.05$), corrugated and brickwork ($p = 0.006 < 0.05$), rebate and triangular hole ($p = 0.004 < 0.05$), rebate and cross ($p = 0.006 < 0.05$), and ($p = 0.000 < 0.05$), and back and brickwork ($p = 0.000 < 0.05$), with females showing a greater preference for slant and brickwork.

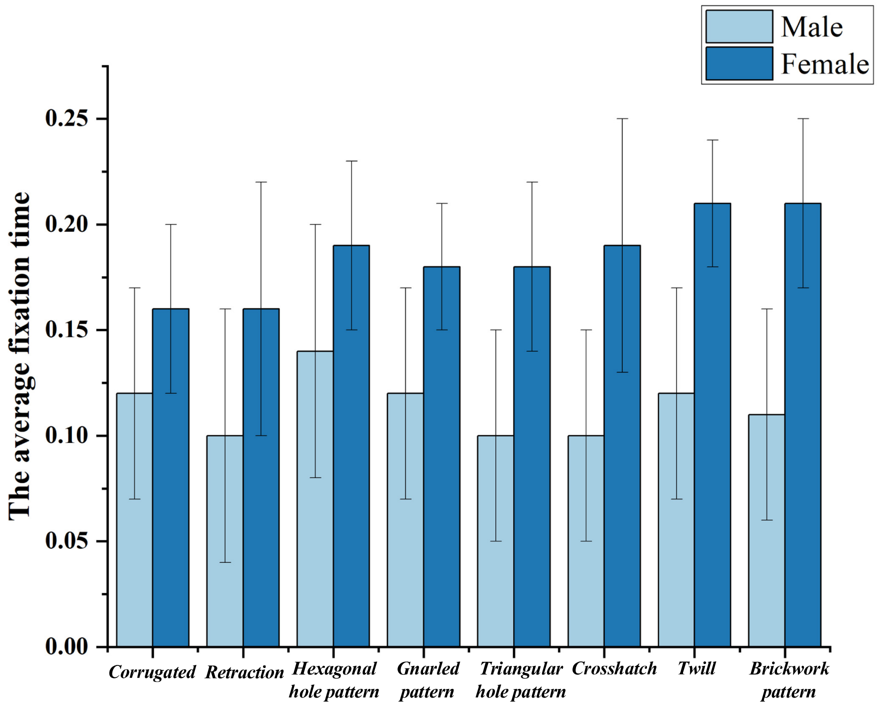

Figure 9. The difference in the average fixation time of the participants under different genders.

Table 3. The effect of the main body of the average fixation time is tested.

	df1	df2	Mean Square	F	Sig.
Gender	1	19	0.106	37.621	0.000 ***
Pattern	7	13	0.009	3.237	0.003 *
Gender × Pattern	7	13	0.010	3.496	0.002 *

* $p < 0.05$, *** $p < 0.001$.

4.4. Results of Average Fixation Number

A univariate multi-factor ANOVA was conducted on the full data, and as shown in Figure 10 and Table 4, the interaction effects of the gender and pattern factors on mean gaze duration and gender and pattern were not significant ($p > 0.05$).

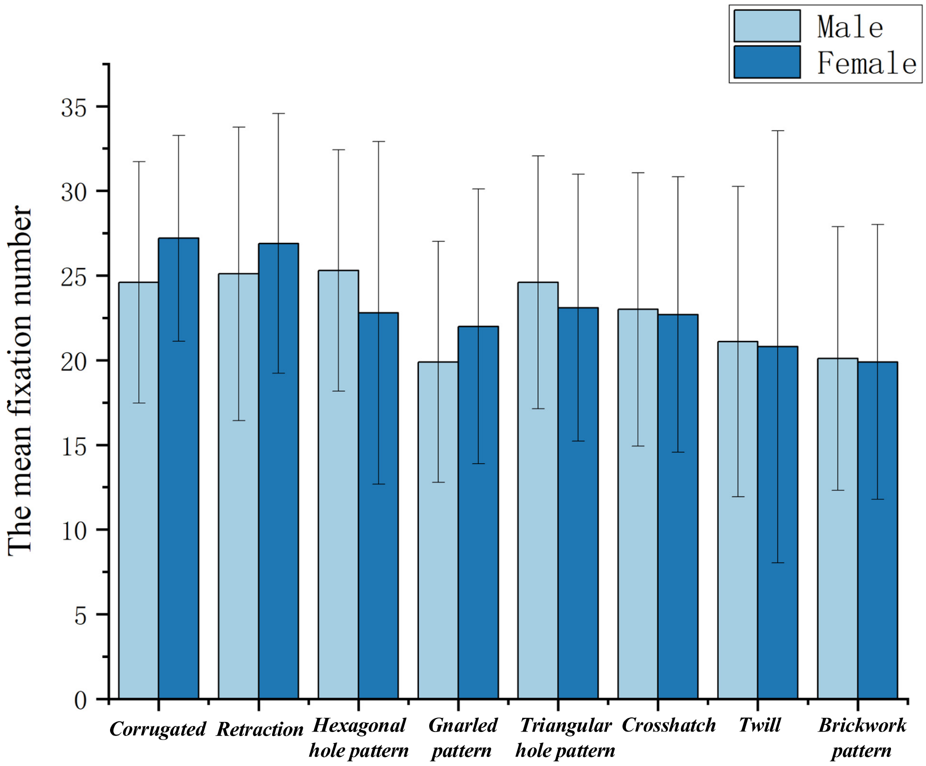

Figure 10. The mean fixation number of the participants under different gender.

Table 4. The test of the effect of the main body of the average fixation number.

	df1	df2	Mean Square	F	Sig.
Gender	1	19	1.056	0.14	0.906
Pattern	7	13	101.992	1.349	0.232
Gender × Pattern	7	13	17.471	0.231	0.977

4.5. Results of Mean Pupil Diameter

By conducting a univariate multi-factor ANOVA on the full data, as shown in Figure 11 and Table 5 There was no significant difference in mean pupil diameter for the gender factor ($p > 0.05$) and a significant difference in mean pupil diameter for the pattern factor ($p < 0.05$), as well as a significant interaction effect between mean pupil diameter for gender and pattern ($p < 0.05$), and a simple effects analysis showed that mean pupil diameter for male was significantly different between hexagonal hole pattern and corrugated pattern ($p = 0.230 < 0.05$), hexagonal hole pattern and rebated pattern ($p = 0.005 < 0.05$), hexagonal hole pattern and jumbled pattern ($p = 0.000 < 0.05$), hexagonal hole pattern and cross pattern ($p = 0.004 < 0.05$), hexagonal hole pattern and oblique pattern ($p = 0.000 < 0.05$), hexagonal hole pattern and brickwork pattern (p= 0.000 < 0.05), triangular aperture stripe and jumbled stripe ($p = 0.00 < 01.05$), and triangular aperture stripe and slanted stripe ($p = 0.008 < 0.05$) were significant, with male observing larger mean pupil diameters for hexagonal and triangular aperture stripe.

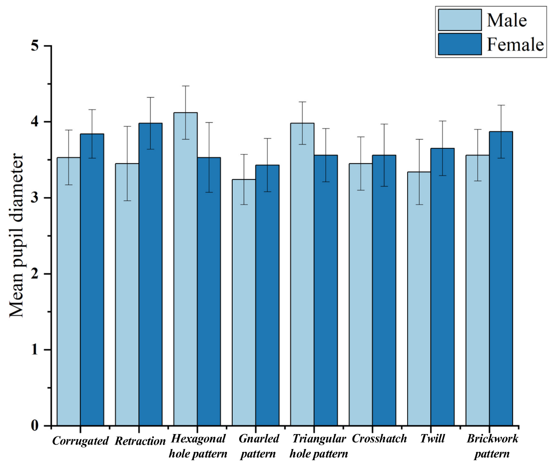

Figure 11. Mean pupil diameter difference under different gender.

Table 5. The inter subject effect test of the image preference values.

	df1	df2	Mean Square	F	Sig.
Gender	1	19	0.361	2.431	0.121
Pattern	7	13	0.559	3.763	0.001 *
Gender × Pattern	7	13	0.762	5.130	0.000 *

* $p < 0.05$.

4.6. Results of the Preference Values

By conducting a univariate multi-factor ANOVA on the full data, as shown in Figure 12 and Table 6, there was no significant difference in mean pupil diameter for the gender factor ($p > 0.05$) and a significant difference in mean pupil diameter for the pattern factor ($p < 0.05$), while the interaction effect of gender and pattern on mean pupil diameter was not significant ($p > 0.05$). The results of pairwise comparisons of grain patterns showed that participants d were significantly different for hexagonal hole pattern and corrugated pattern ($p = 0.0 < 0.05$), corrugated pattern and jumbled pattern ($p = 0.00 < 0.05$), back pattern and jumbled pattern ($p = 0.0 < 0.05$), hexagonal hole pattern and slanted pattern ($p = 0.0 < 0.05$), jumbled pattern and slanted pattern ($p = 0.120 < 0.05$), and the preference values for brickwork and sash ($p = 0.200 < 0.05$) were significant, with participants all showing a lower preference for a sash.

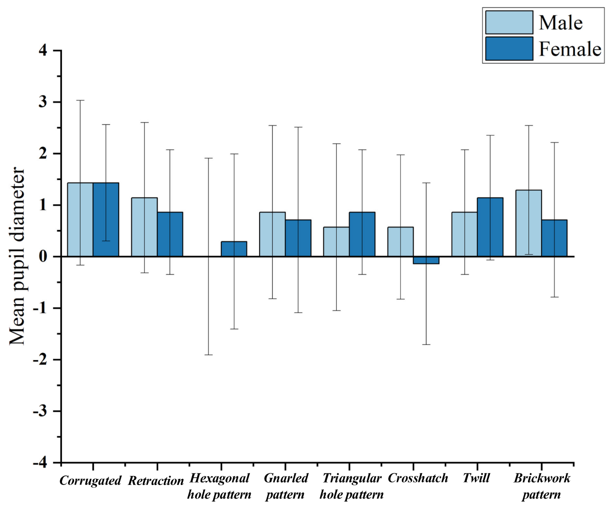

Figure 12. Results of the preference values.

Table 6. The inter participant effect test of the image preference values.

	df1	df2	Mean Square	F	Sig.
Gender	1	19	2.756	1.252	0.265
Pattern	7	13	5.128	2.330	0.028 *
Gender × Pattern	7	13	1.128	0.512	0.824

* $p < 0.05$.

5. Discussion

From the results of the experiment, it can be seen that the average gaze duration of females was slightly longer than that of males, which may be related to the fact that females are more exploratory in their observations [22,23]. The longer the average gaze duration, the longer the participants spent looking at the pictures, and the more likely they were to show interest in them [24]. The results of the analysis show that females are more interested in the diagonal and brickwork patterns, which are more regular and uniform than the jumbled and reversible patterns and, at the same time, softer than the hexagonal and triangular hole patterns. Previous studies have also shown that the total gaze duration is usually longer for patterns with clear textures and bright colors [25].

In terms of mean pupil diameter, in general, a larger pupil diameter indicates a higher preference for pictures [26]. In the past, it was thought that there were differences in brain habits between males and females, with males being better at logical analysis and females being more sensitive to images and other visual memories [27]. In past eye-tracking experiments, it was found that females were more active in viewing images than males [28]. In this experiment, it was also found that the average pupil diameter of the female group was larger than that of the male group, and in conjunction with the previous analysis, the average gaze time of the female group was usually slightly longer than that of the male group, further confirming that the female group was more observant than the male group during the experiment, which may also be related to the level of care taken during the experiment. The average pupil diameter of the hexagonal and triangular aperture patterns was larger for the male, and the hexagonal and triangular aperture patterns were more angular than the other patterns, giving them a stronger visual impact.

The comparison of the male and female hotspots shows that the female may have been more careful in their observation of the images, basically looking at each pattern carefully, thus verifying the results obtained from the previous ANOVA. The color range from red to green represents the level of attention, with the redder the color, the more attention the participant pays to that area. It can be inferred from the overall color distribution presented that the female attention to the patterns is less related to the patterns themselves and more related to the location of the patterns, while the male gaze is concentrated in the center of the picture, with each pattern receiving a little attention but no major differences being seen, so it is important to combine this with the specific gaze points. The order of movement is therefore analyzed in relation to the specific point of view.

In the experimental design, a blank page with a "*" symbol is displayed for 30,000 ms before each image appears in the center of the computer screen. Therefore, the first point of view is usually in the center of the screen, and it can be observed that the participant's gaze point usually circles around the pattern. The larger the gaze point in the trajectory diagram, the longer the dwell time and the larger the return gaze point for the pattern of interest. This, combined with the overall image, shows that males are generally less detailed in their observation process than females, which confirms the previous results.

In terms of average gaze points, in general, more average gaze points indicate a higher preference for a picture [29]. The results of the mean gaze points were similar to those of previous studies in terms of gaze duration, with more mean gaze points for patterns with clear textures and bright colors. The fact that the participants in this experiment did not differ significantly in terms of mean gaze points may be related to the pattern images, which are presented in a two-dimensional plane and are more repeatable than the product images.

In terms of subjective preference, there was no significant difference between males and females, and the results of the analysis showed that the participants all showed lower preference values for disordered patterns. Combining the results of the eye-movement data and inferring that the triangular hole pattern, hexagonal hole pattern, and slanted and brickwork patterns were all neater, while the disordered patterns were more disorganized, it can be inferred that the participants showed a lower preference for disordered bamboo patterns.

This study can further broaden our understanding of the aesthetic differences between males and females and improve on the lack of attention to gender in past studies.

6. Conclusions

The introduction of an eye-movement experiment alongside the exploration of consumer preference for bamboo weaving patterns, combined with subjective preference evaluation, allows for both quantitative analyses to obtain an objective, scientific, and valid evaluation as well as a combination of the subjective wishes of the participants, making the conclusions more convincing and more three-dimensional. After the above analysis and discussion, the following conclusions are drawn:

1. There were significant differences in the effects of different gender factors on the participants' aesthetic preferences and visual information processing patterns when viewing the pictures. In terms of average gaze duration, the female spent more time looking at the pictures than the male, had a larger average pupil diameter than the male group, and looked at the pictures more carefully.
2. Females prefer relatively regular and uniform patterns, such as brickwork and bias patterns. Males showed more preference for the more visually striking and sexual brickwork and diagonal patterns.
3. The average gaze duration, average number of gaze points, average pupil diameter, subjective preference, gaze hotspot, and gaze point trajectory maps can be combined to infer that, objectively, males tend to pay more attention to the more angular triangular and hexagonal patterns, while females pay more attention to the regular and uniform brickwork and oblique patterns. The females show a higher interest in the regular and uniform brickwork and twill patterns.
4. The difference in subjective preference for the participants' images by gender was not significant, with both male and female participants more consistently showing lower preference for disordered patterns and disordered patterns being less likely to be favored by consumers in terms of subjective preference.
5. Exploring the influence of different genders on the aesthetic preference of bamboo weaving patterns provides new ideas and new methods for the application of eye-movement research in architectural decoration, and the experimentally derived preferences of different males and females provide a scientifically valid reference for the market application of bamboo weaving in architectural decoration. Selecting appropriate bamboo weave patterns for application in different architectural spaces in order to create a more gender-appropriate aesthetic decorative effect to better meet the needs of gender-specific consumers and provide a more personalized and precise service.

There are still several limitations to this study. Firstly, due to the wide range of bamboo weaving styles, the selection of images of bamboo weaving patterns was limited, and only eight representative images of bamboo weaving patterns were selected for this study. Secondly, the population was only divided by gender, and further discussion of the visual aesthetic preferences of people of different ages and professional backgrounds will be needed in subsequent studies. At the same time, to better apply bamboo weaving patterns to architectural design and to promote their practical application to the market, specific design cases are also analyzed.

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Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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