A study on visual perception of traditional residential architectural decoration using eye tracking and electroencephalogram (EEG) experiments

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Abstract

Background: Traditional residential architecture often integrates intricate decorative patterns, vital in shaping the overall aesthetic experience. Aim: The purpose of this research is to investigate the visual perception of traditional residential architectural decorations using eye-tracking experiments, focusing on various design elements influence aesthetic appreciation. Methodology: In this study, we used eye-tracking equipment to record participants' gaze patterns and fixation lengths while they viewed images of traditional architectural decorations. 95 participants from diverse demographic backgrounds in the Leizhou Peninsula were involved in the experiments. The eye tracking data was analysed to determine how participants' visual attention varied based on the attractiveness and complexity of the decorative patterns. We examined eye movements to evaluate fixation counts, duration, and pupil dilation using electroencephalogram (EEG). Additionally, subjective feedback was collected through surveys to gauge participants' aesthetic preferences. Result and Conclusion: Findings indicate that more elaborate and visually appealing traditional decorations elicited longer fixation durations and higher levels of engagement compared to simpler designs. This study highlights the significant impact of traditional decorative patterns on visual perception and aesthetic appreciation. These findings can guide the design of modern residential products, ensuring they resonate with cultural aesthetics while enhancing the user experience.

Keywords: Traditional Residential Architectural Decoration, Eye Tracking Experiments, Visual Perception, Leizhou Peninsula.

In traditional Chinese architecture, courtyards are a crucial area that is frequently found in southern China's traditional homes. The courtyard areas with traditional homes are vanishing because of the rapid acceleration of modernization and urbanization [1]. A greater and more satisfactory quality of life is becoming more and more desired as the global economy grows and people's living levels rise. Grayspace ideas, the interaction between buildings and the environment, and others are slowly coming into focus [2]. The sensible organization of functions is no longer the exclusive goal of architecture; instead, spatial quality is becoming increasingly important. Multidisciplinary research is becoming more and more popular as a result of the ongoing, in-depth advancement of study in the field of building studies in recent years [3].

These techniques from psychology, especially environmental psychology, have shown positive outcomes in the subject of architecture. Many have been carried out using psychological experimentation techniques in areas like human subjective spatial perception [4]. These methods rely on a physically created environment, mimic complex, realistic behaviours poorly, need extensive field testing, and present challenges when used during the conceptual design phase. Consequently, one of the main challenges in conventional home design has always been to measure and analyze how human behaviour interacts with the courtyard areas [5]. Virtual eye-tracking investigations are carried out in the lab to collect information on people's visual perceptions of various courtyard environments. Analyze people's subjective experiences and spatial perceptions in courtyard areas using new experimental techniques. Establish groups of experiments with and without courtyards to statistically validate the design theories associated with conventional residential courtyards [6]. Eye-tracking is greater than previous approaches in that it can gauge visual attention, which opens up rich sources of cognitive information and converts raw eye-tracking data into analysing variables [7]. To investigate how courtyard spaces affect people's spatial experiences statistically, gather eye-tracking data from people using these areas. Compare the parallels and contrasts in the spatial characteristics of various types of courtyards by comparing the spatial cognitive differences of persons in traditional home courtyards with three distinct layouts [8]. List the fundamentals of courtyard area design that are appropriate for both contemporary and rustic home designs. Examine how the fundamental concepts of traditional courtyard area design strategies can be incorporated into architectural design. It is highly significant to perform a quantitative study on courtyard spaces with virtual eye-tracking equipment [9]. It broadens the researchers' comprehension of people's real actions and perceptual patterns in courtyards, which makes it possible to assess courtyard designs guide people [10]. This study's main goal is to use eye-tracking tests to examine how traditional home architectural ornamentation in the Leizhou Peninsula is perceived visually. The study intends to comprehend how people visually interact with and interpret the ornamental aspects of traditional Leizhou home architecture by examining eye movement data.

The structure of the article is as follows: Section 2 presents the findings of earlier studies; Section 3 presents the suggested approach to enhance digital media art; and Section 4 summarizes the outcomes. The conclusion of the article is found in Section 5.

Related works

Previous studies in architectural perception have focused mainly on the two-dimensional perception of Architectural spaces, facades, and architectural features. Nevertheless, more investigation still needs to be into the traditional residential architectural decoration vision in terms of aesthetic culture and the Leizhou Peninsula. The previous research has provided the foundation for exploring visual perception and stressed the roles of cultural and contextual factors in appreciating visual experiences in architectural environments. However, more research needs to be done to focus on traditional residential architectural decoration in terms of visual perception, and this study aims to fill this gap using eye-tracking experiments. Moreover, prior studies have employed eye tracking and EEG experiments to understand participants' fixation on, time spent gazing at, and brain activity when encountering conventional ornamental architectural elements.

Human dining experiences and behaviours can be significantly influenced by sound. The term "sonic seasoning," which originates from cross-modal messages, refers to the potential for sound capes that have similar taste and flavour characteristics to change people's opinions of food [11]. The importance of hotels' website

visuals play is the main topic of the paper. Using this methodology, the study examined the primary image of a hotel website, which is thought to be a topic of great interest [12]. The goal of the research is to ascertain if the types of understanding and levels of participation that students have in the virtual museum (VM) [13] throughout their Sciences and Humanities course impact their academic performance. The research presents and evaluates a system that can track these kinds of fast eye movements, with operating frequencies well over 500 Hz [14]. The effect that signals had on learning outcomes and processes in brief instructional movies was investigated in the study. One of four conditions was randomly allocated to one hundred and twenty college students to watch brief movies. Study [15] addressed how some buildings in Cologne, Germany's historic center, which were created by renowned architects, were seen visually. It includes eye-catching studies on the possible applications of eye-tracking technology in several sectors, including architecture, urban planning, administration, psychology, and business [16]. Using a technique known as mispronunciation correction, children can connect words from their oral vocabulary to new printed word forms, allowing them to compensate for phonological errors in decoding [17]. Using views from embodied cognition and the theory of cognitive load, the present research investigated the effects of gesturing and tracing actions on the surface of multimedia instruction [18]. It devised studies where participants imitate actions that could lead a mobile eye tracker move to examine how the eye-tracker slippage impacts data quality [19]. The virtual reality (VR) tool WayR, which is presented in the work, is intended to study how pedestrians navigate a multi-story structure in both regular and emergency circumstances. In addition to collecting head motions, gaze points, and pedestrian walking trajectories automatically, WayR facilitates free navigation [20]. The purpose of the work is to advance its knowledge of people perceive spatial design in VR settings. Human psychological reactions to architectural settings are evaluated using biometrics [21]. New avenues for intelligent cityscape management and observation have been made possible by the quick development of new digital technologies, including VR [22], artificial intelligence (AI), and human-computer interaction. In a prior research, 50 university students were used to objectively capture the eye-tracking data on the perception of traditional village scenes. It was essential to find out that mountains and landscape structures received more attention, which goes against subjective impressions from the questionnaires. Reaction time, depending on the further or deeper observation of landscape elements, informs subjective preference, meaning that data obtained using eye-tracking technology could help determine observer preferences of rural landscapes and the formation of landscape design and construction plans [23]. The recent study centers on three types of courtyards in “Kong House” to examine the spatial perceptual qualities. Using data collection, literature review, questionnaires, and eye-tracking experiments, the research confirms the design theory of the courtyard area. It analyzes the spatial difference between the overall courtyard, landscaped courtyard, and functional courtyard. The findings presented in the study reveal that courtyard spaces affect people’s behavior and decisions, with extensive courtyards providing stimuli for increased movement and loitering. Virtual reality and eye-tracking experiments help understand human reactions and assess the effectiveness of converting the approach used in traditional residential design [24].

The previous studies have also provided the foundation for this research by pointing out the importance of complex geometric and arabesque designs in the perception of the arts. These studies have highlighted that previous work has focused on how visual perception is affected by different design aspects in site-built, single-family homes. Earlier studies on traditional residential architectural decoration in the

Leizhou Peninsula have prepared the ground for this study by stressing the importance of diverse and complex decorative patterns in the general conception of architectural ornamentation. These studies have focused on the sociability of visual perception concerning different facets of architectural design in conventional dwelling units.

Methodology

Eye tracking tests are being conducted for this study on subjects who have been exposed to traditional Leizhou Peninsula house architectural decorations. To evaluate visual attention and perception of ornamental aspects, eye-tracking equipment will record and analyze gaze patterns. Key visual characteristics and their effects on the enjoyment of aesthetics and spatial comprehension will be determined by evaluating the data.

3.1. Study area

The Leizhou Peninsula, which is renowned for its distinctive decorative themes and rich cultural legacy, is the subject of the study's traditional residential architecture and design. Intricate architectural features and decorative accents that honour historical and cultural values define this area. The study attempts to gain insights into the architectural decoration impacts the viewer's involvement and enjoyment by examining how these classic design elements affect visual perception and aesthetic enjoyment. Figures 1 and 2 show the variety of patterns and fixed architecture.

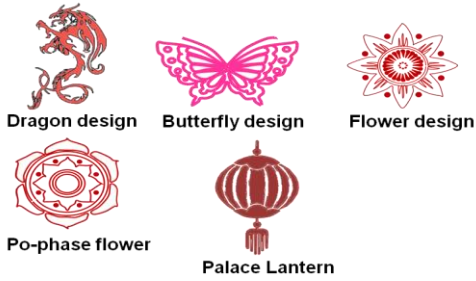

Figure 1: Variety of patterns

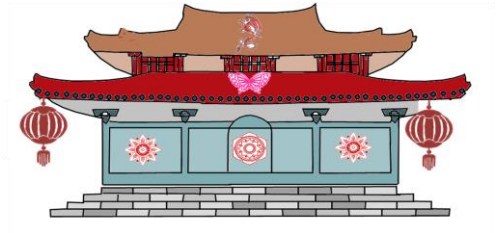

Figure 2: Variety patterns fixed traditional architecture

3.2. Study participants

The research comprised 95 Leizhou Peninsula residents with a range of demographic backgrounds. A NeurOne system with an electrode cap containing 35 electrodes was used to provide an EEG signal that was continuously recorded. A modified version of the National 10-20 Electrode Placement System was used to locate the electrodes. EEGs were digitally filtered using a low-pass filter that was set to 40 Hz and re-referenced to the left and right mastoids to eliminate artifacts during segment trials and independent component analysis. The electrode's impedance was maintained at or below 5 KΩ during the investigation. To gain a better understanding of the distribution of the scalp, attractiveness correlate potential (ACP) testing employs four sets of electrode locations: frontal, central, parietal, and occipital. Figure 3 shows the basic setup for the testing procedure and experimental methods.

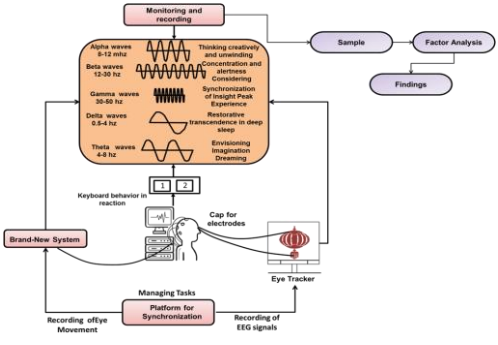

Figure 3: Procedure equipment of testing method

3.3. Factor analysis based on the EEG signal

Decomposing the complicated data into underlying factors or components that characterize the basic patterns of brain activity is known as factor analysis, and it is applied to EEG signals. Through the examination of EEG recordings, scientists can pinpoint important elements that account for differences in electrical activity in various brain areas. Through a better knowledge of the cognitive processes linked to certain mental states or tasks, this strategy makes it possible to interpret EEG data in a focused and intelligent manner. Table 1 depicts the values of wavelengths.

- Alpha Waves (8 - 12 Hz): Linked to relaxed wakefulness and reduced visual attention. Changes in alpha waves can indicate cognitive and emotional responses to stimuli.
- Beta Waves (12 - 30 Hz): Associated with active thinking, attention, and cognitive processing. Beta wave activity can be analyzed to study responses to facial expressions and attractiveness.
- Gamma Waves (30 - 50 Hz): Linked to high-level cognitive processing, perception, and conscious awareness. Gamma activity is associated with processing complex visual stimuli and emotional responses.
- Delta Waves (0.5 - 4 Hz): Typically associated with deep sleep and not used for examining facial expressions, eye movements, or attractiveness.
- Theta Waves (4 - 8 Hz): Associated with relaxation and light sleep. Sometimes relevant in studies of emotional processing.

Table 1: Wavelength values

Architecture Factors	Art Design	Alpha	Beta	Gamma	Delta	Theta
Window	Flower Design	0.7	1.1	1.0	0.1	0.3
Ceiling	Butterfly Design	0.5	1.2	1.1	0.2	0.3
Door	Po-Phase Flower	0.6	1.3	0.9	0.2	0.4
Roof	Dragon Design	0.4	1.0	0.8	0.3	0.5
Wall	Palace Lantern	0.6	1.3	1.2	0.2	0.4

A sample frequency of 50 Hz was used for eye tracking. The eye-fixation patterns that account for the most variance is chosen using principal component analysis (PCA) using a data-driven methodology. It is not necessary to do time-consuming manual tracing of specific facial areas because all fixations are incorporated in the PCA computation. The digital vision literature refers to this analysis as "eigenfaces" and when it comes to eye movements, it is called "eigengaze". Eigenvectors are used to identify common attractive factors in Chinese architecture that capture visual attention.

3.4. Statistical Analysis

Differences can be inferred visually by using differences in the medians of different characteristics at the same point. It is important to recognize that mistakes can occur in these visual discrepancies. Therefore, to give any detected distinctions more solid and trustworthy evidence, more statistical analysis is required. For PCA analysis, we used 3-mer current features to see if it could handle different patterns of distribution among the two groups on the target location, which is our main concern. Next, to ascertain the significant difference between each site in the native sample and the negative control, multivariate analysis of variance, or MANOVA, is utilized. The use of 3-mer characteristics, leads to the conclusion that two nearby bases differ significantly from one another. Therefore, for continuous regions with high significant values, it is crucial to manually select the core locations. The statistical program Statistical Product and Service Solutions SPSS 22 was used to process all of the data. Using a paired t-test, the response time and eye-tracking metrics were first examined.

Results

4.1. The reaction time's outcomes

The study showed no visible change in response times when people observed both beautiful and ugly patterns of traditional residential architectural decoration (TRAD). This implied that participants' attention was split evenly between deeming TRADs attractive or unattractive. The experiment's key press data revealed that 96% of the subjects' TRADs were right for appealing questions, while 93% of them were correct for unattractive ones. A substantial impact was evident in the TRAD preference ratings. This leads to differing subjective scores for the two categories of beauty, which is in line with the restudies findings. Figure 4 depicts the patterns. The finding of the TRAD attractiveness was analysed using the EEG signal and adopted using the standard and difference of the Oddball paradigm.

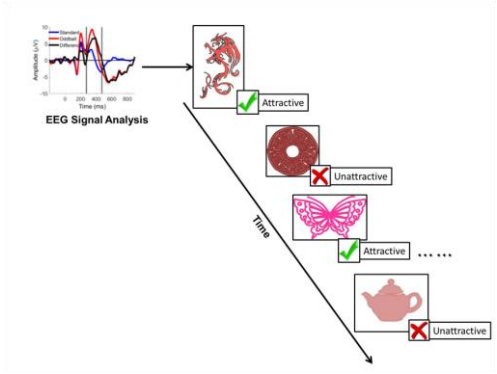

Figure 4: Attractive and unattractive patterns

4.2. Results of eye tracking evaluations

Table 2 presents a comparison between the appealing and unattractive designs in terms of pupil diameters, second fixation length, and fixation counts. The results showed that fixation counts for the attractive TRADs were greater than those for the repelling TRADs. When compared to unattractive TRADs, the second fixation duration was much longer in beautiful TRADs. Furthermore, compared to watching ugly TRADs, people's mean pupil widths were much lower when they viewed attractive TRADs.

Table 2: Attractive and unattractive values

Traditional Pattern	Attractive Fixation Count (n)	Unattractive Fixation Count (n)	Attractive Second Fixation Time (s)	Unattractive Second Fixation Time (s)	Attractive Pupil Size (mm)	Unattractive Pupil Size (mm)
Flower Design	15.23 (3.146)	12.85 (2.912)	3.512 (0.489)	3.278 (0.543)	2.900 (0.312)	2.850 (0.307)
Butterfly Design	14.12 (2.978)	13.12 (2.802)	3.410 (0.453)	3.322 (0.569)	2.845 (0.305)	2.870 (0.299)
Po-Phase Flower	13.89 (2.866)	12.92 (2.764)	3.437 (0.472)	3.355 (0.589)	2.820 (0.300)	2.880 (0.303)
Dragon Design	12.75 (2.912)	13.25 (2.834)	3.398 (0.460)	3.302 (0.577)	2.830 (0.307)	2.875 (0.308)
Palace Lantern	13.55 (2.945)	13.10 (2.756)	3.415 (0.481)	3.340 (0.560)	2.835 (0.306)	2.860 (0.299)

4.3. Attractiveness correlate potential (ACP)

TRADs that are beautiful or unpleasant can generate ACP waveforms and maps of terrain. The average waveform chart showed that the N2 and P300 time frames ranged from 290 to 320 ms and from 480 to 510 ms, respectively. Using repeated-measures MANOVAs, the amplitude and duration of ACP were examined, taking into consideration the effects of location (frontal, central, parietal, and occipital) and attractiveness levels (attractive and unattractive).

4.3.1N2 and P300

The N2 analysis delay revealed that the attraction levels did not vary significantly. Significant differences in the attraction levels were not seen, according to the P300 delay study. There is no appreciable main effect from the location. An analysis of P300 amplitudes revealed that magnetism levels were a significant main factor. It was discovered that the attracting amplitude was significantly larger than the unappealing amplitude. The locations had a notable initial influence. Frontal lobe delay is much smaller than parietal and occipital latency, according to pairwise investigations. Furthermore, the parietal and occipital delays are significantly larger than the central latency. Figure 5 depicts the frontal and central.

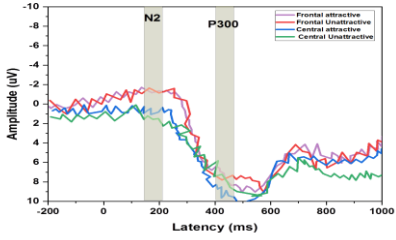

Figure 5: Outcomes of frontal, and central

The places and degrees of attraction showed no evident correlation. The primary effect of attraction levels was not statistically significant, according to N2 frequency and P300 analysis. The locations' main influence was remarkable. The lateral magnitude is much less than the front and central amplitudes, according to pair comparisons. Figure 6 depicts the parietal, and occipital.

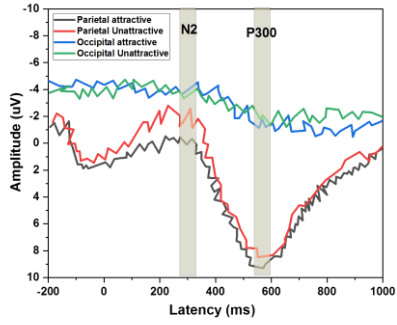

Figure 6: Outcomes of parietal, and occipital

The amplitude of the occipital is notably less than that of the frontal and central. There is a noticeable difference between the frontal and central amplitudes. The sites and attractiveness levels did not exhibit any discernible correlation. Locations had a noteworthy and substantial influence in Table 3.

Table 3: N2 and P300 latencies and Amplitude

Location	N2 of Latency (ms)	N2 of Amplitude	Amplitude of P300
Frontal	295.3 (4.320)	-0.035 (2.243)	6.845 (2.908)
Central	297.6 (6.014)	-1.070 (1.811)	7.390 (3.154)

Parietal	304.5 (6.991)	-2.650 (1.847)	5.872 (2.678)
Occipital	308.2 (5.920)	-2.840 (2.390)	2.145 (1.872)

The occipital amplitude is much less compared to the amplitudes of the frontal, central, and parietal regions, according to comparisons made pairwise. There seems to be no correlation between the level of interest and the location.

Conclusion

The study has offered information about the effects of ornamental patterns on aesthetic sensitivity. To the same extent, it is critical to appreciate conventional ornamental patterns' role in shaping one's perception and appreciation of residential buildings. Due to eye-tracking and EEG data, understanding how these components affect viewer engagement in detail can be helpful when designing modern living spaces that correlate with culture. The study's results reveal that more complex and aesthetically sophisticated TADs garnered longer fixation times and increased attention compared to the less complex designs. This indicates that traditional decorative patterns are crucial in altering how phenomena are perceived. The study can help understand modern residential product design tendencies, especially for those who want to include cultural aesthetics into their products for a better user experience. As a result of the eye-tracking experiments performed and the analysis of comprehensible gaze patterns, this study sheds light on the visual process applied when perceiving traditional architectural ornaments. Furthermore, the research method carried out in this study, which involved using EEG to record pupil size in conjunction with self-reporting questionnaires, provided further depth to the study. The results of this study can be helpful for architects and designers who want to use traditional pattern decorations in modern living spaces to meet the cultural sense and improve the visual stimulation.

Limitations and Future Study

The Leizhou Peninsula's traditional decorations are the main focus of the study, which power restricts the findings application to other areas with distinct architectural and cultural traditions. Examine how historic architectural decoration affects people psychologically and emotionally by combining eye tracking, electroencephalography, and other biometric measurements.

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