DOCTORAL DISSERTATION

Study of the influence of different architectural features on aesthetic and pleasure value judgments

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DAI ANBANG

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Fukuda Laboratory

Architecture Course

Doctoral Program in Environmental Engineering

Graduate School of Environmental Engineering

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令和 5 年度博士論文

Study of the influence of different architectural features on aesthetic and pleasure value judgments

建築物の特徴の違いが美的・快適価値判断に及ぼす影響に関する研究

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Study of The Influence of Different Architectural Features on The Aesthetic And Pleasure Value Judgments Of Architecture

ABSTRACT

Architectural design used to be a job that relied heavily on the aesthetics of the architect, but nowadays architecture increasingly needs to take into account the feelings of the user. Designs that are aesthetically pleasing to the majority of non-specialist users are more likely to be appreciated by the general public. Architectural designers can use psychology, brain science, and behavioral science to understand the subjective aesthetics of the general public, and through a range of literature we can understand how differences in certain architectural features can affect the emotional and aesthetic judgments of users. We are not sure whether the differences in aesthetic judgments of architectural features are related to the aesthetic education received. Therefore, in addition to comparing the results of experiments in Chinese populations with the results of Western aesthetic judgments of architectural features, we also try to understand whether age causes differences in aesthetic judgments. Therefore, this paper hopes to investigate the effects of ceiling height, openness and silhouette on different populations under various conditions through a series of instruments. In addition to the influence of architectural features on aesthetic judgments, we also try to explore the influence of street features on aesthetic judgments in traditional Chinese ancient villages.

In Chapter 1, RESEARCH BACKGROUND AND PURPOSE OF THE STUDY. In Chapter 1 we present the background of architecture-related aesthetic research, including the current status and bottlenecks of architectural aesthetic research, and the kinds of directions of architectural aesthetic research. These related studies are then presented to help the reviewer understand the purpose and reasons for the research in this paper by presenting how they can contribute to this work on architectural design.

In Chapter 2, LITERATURE REVIEW OF RELATED STUDIES. Focusing on architectural interior features, this chapter examines the influence of relevant architectural features on human aesthetic judgments of architecture that mainstream studies have focused on, as well as the shortcomings of these studies. Based on the previous studies, what improvements will be made in this paper to verify the experimental results in a more rigorous way or to arrive at a different perspective from the previous studies.

In Chapter 3, AESTHETIC JUDGMENT OF ARCHITECTURE FOR CHINESE OBSERVERS. Using previous experiments on architectural interior features conducted in the West, the subjects were replaced with Chinese subjects. Since the subjects in the

Western experiments grew up with Western aesthetic education, while the subjects in this chapter were raised with Chinese aesthetic education, it is possible to compare whether different traditional aesthetic education has an impact on the aesthetic judgment of architectural interior features.

In Chapter 4, THE INFLUENCE OF VIEWING TIME AND COLOR ON ARCHITECTURAL AESTHETIC JUDGMENT. Since prolonged gaze at the pictures may cause more attention to distracting factors other than architectural interior features and may stimulate subjects to recall and reflect on them affecting the accuracy of aesthetic judgments.From the previous literature review, it is known that 200 ms can already trigger subjects' aesthetic judgments. Therefore, the first experiment in this chapter shortened the presentation time of the stimulus pictures from 3 s to 200 ms. In order to exclude the confounding factor of the selection of the experimental stimulus architectural pictures, the second experiment in this chapter decolored the stimulus pictures and tried to investigate the difference between the decolored architectural interior picture stimuli and the colored stimuli on human aesthetic judgments.

In Chapter 5, THE INFLUENCE OF AGE ON THE AESTHETIC JUDGMENT OF ARCHITECTURAL INTERIOR FEATURES. Because the aesthetic education of modern young people is relatively similar, the architecture in the living environment is also more similar. Therefore, in order to more accurately investigate whether receiving different aesthetic education has an impact on the aesthetic judgment of architectural interior features, and the difference in aesthetic judgment between older and younger people for the same architectural interior pictures. This chapter attempts to investigate the effect of age on aesthetic judgments of architectural interiors by limiting the age of the subjects to 65 years or older.

In Chapter 6, CONCLUSION AND FUTURE WORK. This chapter provides a summary of the chapters and the related research to be conducted in the future.

戴　安邦 博士論文の構成

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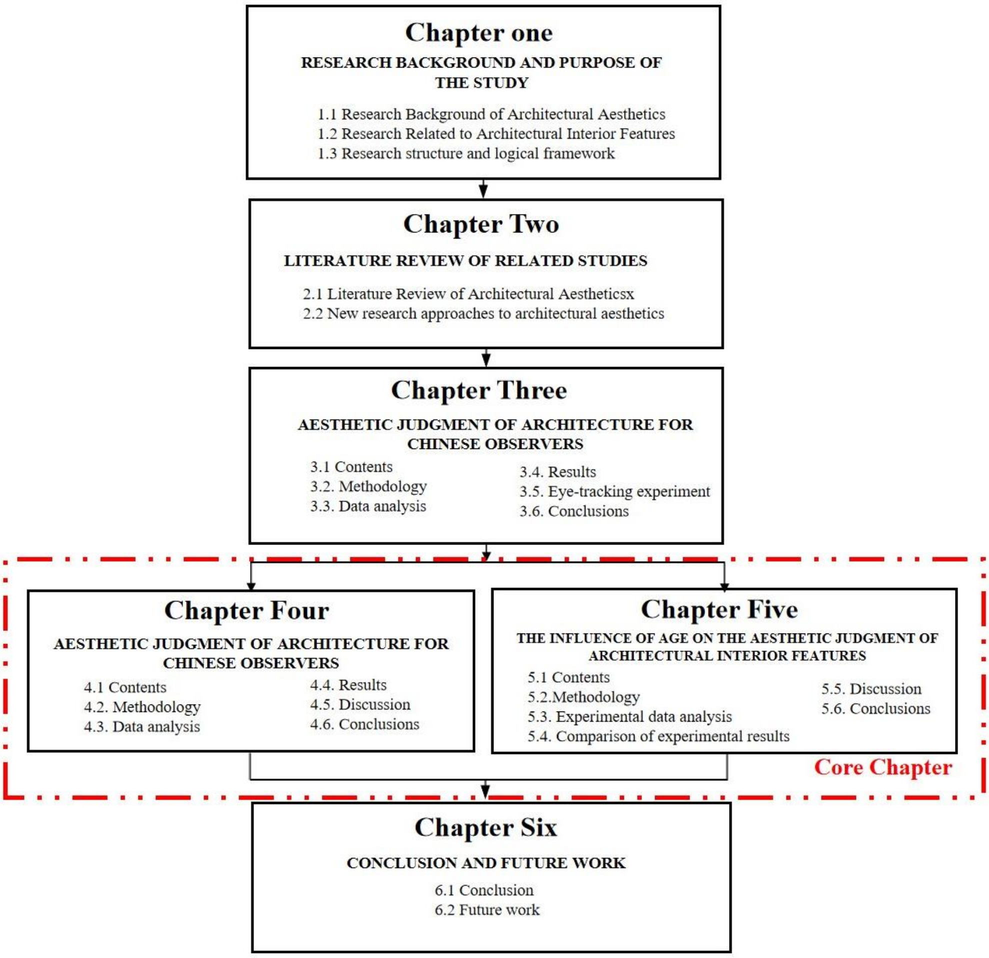

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Chapter 1

RESEARCH BACKGROUND AND PURPOSE OF THE STUDY

CHAPTER ONE: RESEARCH BACKGROUND AND PURPOSE OF THE STUDY

1.1 Research Background of Architectural Aesthetics

Many designs painstakingly created by architects meet with unexpected criticism. As time passes, some works that were originally lauded come to be seen as problematic because of environmental changes, altered user behaviors and other factors. Public comments on architectural designs that question the architect's original intention have become more prominent in the information age. Thus, the task that many architects now face is meeting the public's esthetic preferences by making their designs both functional and pleasing. However, architects' knowledge of design and experience alone are often insufficient to obtain the desired results.

Early studies have shown that around the world, urban residents spend more than 87% of their time in buildings every day**[1]**. Therefore, the indoor environment of a building is of great significance to its occupants. Currently, however, most architectural designs rely on only the architect's own esthetic tastes and knowledge of architecture, ignoring more objective esthetics preferences such as those of the public and the importance of practical architectural functions in building design. Therefore, the author proposes that architects should not only carry out design review but also engage in continuous post-use evaluation so that problems can be identified and thus provide relevant information for future designs**[2]**.

1.1.1 The role of architectural aesthetic research on architectural design

What factors drive our aesthetic experience is a topic that receives a considerable amount of attention. The field of empirical aesthetics emphasizes that aesthetic experience should be empirically studied and experimentally validated. Using the empirical aesthetics approach, it has been shown that the relationship between complexity and novelty, and aesthetic appreciation has an inverted U shape – People generally prefer an intermediate level of complexity and novelty [3]. Empirical aesthetics studies have revealed that the evaluation or production of beauty, ugliness, prettiness, harmony, elegance, shapeliness or charm is governed by a host of factors, such as stimulus symmetry, complexity, novelty, familiarity, artistic style, appeal to social status, and individual preferences [3].

Investigating the preference of architectural features from the perspective of empirical aesthetics allows architects to gather more information about how to design structures that can meet both functional and public aesthetic requirements. Environmental characteristics can trigger neurological and physiological responses in humans, thereby exerting a positive or negative impact on them[5-7]. To a certain extent, a good architectural design enhances users' comfort, cognition and creativity[8]. Architectural aesthetics connects emotion and aesthetics and strikes a balance between the two[9]. Previous studies have demonstrated the reward circuitry in the brain is activated when seeing artwork. Artists who know how to exploit this circuitry can intensify an individual's aesthetic experience[10]. Once a certain architectural element fits in a certain life scene, such as work, study, and rest, it can enhance behavioral effects through positive emotions[11, 12]. Currently, many architects have such ideas but lack the theoretical foundation as well as an understanding of the effect of some architectural factors on subjective experience. In order to increase the understanding the relationship between architectural factors and subjective experience, researchers have done a lot of exploration in western culture.

1.1.2 The relationship between aesthetics and cultural differences

In a comparison experiment between experts and nonexperts, O. Vartaniana et al. found that experts were less attracted to common contour types and more interested in abstract curves and could view buildings more rationally but were also less interested in entering buildings[13]. The experiment showed that people who have studied architecture and people who have not have different reactions to the same architectural features, so we can infer from this that people who have grown up with different experiences and cultures likewise have different responses to the same architectural features.

In a series of experiments, Takahiko Masuda found that Asians pay more attention to background images and the overall relevance of a picture than US Americans do. Asians prefer paintings with scenery, so they create larger scenes. However, due to the complexity of the content in Asian art, the image is often flatter due to the lack of perspective and object relationships. Westerners are better at depicting and perceiving perspective. Compared with the scenes found in Asian art, Western art depicts the actual observed state of objects, and the images are more intuitive and stereoscopic[14].

These differences result from both painting techniques and variations in cultural expression. When a painting is displayed as a scroll, the picture is seen to move and change, being unable to provide a specific focus, and it is difficult to provide much perspective, as the painting is a description more of a state of being than of an object. The overlap of various scenes makes the picture more storylike. In one experiment, Japanese subjects mentioned more information about an object when describing it after having watched a short film, possibly because the East Asian participants were more willing to combine the picture of the object and its context to obtain information. The American subjects, on the other hand, tended to describe the appearance of the object when describing it, which may indicate that Westerners are more focused on the most prominent visible attributes of an object. The study also described the impact that the development of many ancient cultures and religious, ideological and other differences has had on Eastern and Western concerns. A picture reflects the cultural characteristics of the image content, and thus, in this study, we hope to learn more about whether a picture of a given culture will elicit different feelings in people from different cultural backgrounds.

Motti Regev noted that culture has national and regional characteristics and that people who subscribe to national traditional esthetic standards are more suspicious of new art; even so, traditional art is constantly merging with other cultures and artforms and giving birth to new branches of art, thus contributing to a worldwide esthetic perpetuated by the outside world's influence on local things that, in turn, affect the outside world[15]. This blending cycle produces new worldwide criteria for judging beauty. If esthetics judgments become more similar across the world, it may indirectly eliminate the differing judgments of beauty between different cultures. Eastern students studying within the same esthetic education system as those in the West or even new generations of Asian youth who accept the impact of Western esthetics may receive different feedback on their work than that found in previous Western studies in terms of the self-perception and esthetics judgment of their work. This subject requires much research. If different cultural backgrounds produce different esthetic tastes, then the proportion of local esthetic tastes incorporated into building design should be higher than that of universal esthetic tastes.

Culture with different connotations, and caused as a representative of the ancient architecture of the different styles of sacrificial architecture. While the West emphasizes a single building, with a towering upward image, and uses columns or arches to enhance the upward momentum, Chinese ritual architecture is mostly a large group, with a vertical and horizontal plan, and the structure and shape are confined to a strict hierarchy[16]. Due to the constraints of agrarian civilization, the spatial form of a square or an indoor gathering space, which is common in European architecture, is rarely found in traditional Chinese environments. The public outdoor space in traditional architecture is usually linear in shape[17].

1.2 Research Related to Architectural Interior Features

Studies in the Western culture have shown that the aesthetic judgment of architecture is influenced by the response to specific sensory features, such as contour, ceiling height, and openness [1, 9]. Studies have showed that Western observers prefer structures with curvilinear contours, high ceilings, and open space [10–13]. Ceiling height and openness also impact people's perception and emotion [8, 14]. In structures with high ceilings, people tend to have more positive emotional responses, such as "happiness", "comfort" and "fun". Similarly, openness influences judgments of beauty and pleasantness, people tend to experience more positive emotions in spacious environments than in small environments [15, 16]. Although it has been demonstrated that contour, ceiling height, and openness are critical factors that influence the aesthetic judgment of architecture for Western observers, it remains unclear whether the preference to these features is universal. If the preference to architectural features is strongly influenced by daily architectural aesthetic experience, observers living in environments with different building styles may prefer different architectural features [17, 18, 22] .

1.2.1 Introduction to architectural psychology

From the perspective of neuroesthetics, understanding people's preferences regarding architectural features can enable architects to obtain relevant information so that architects can design works that meet both the functional and esthetic needs of the public. Viewing a beautiful work of art produces excitement in the human brain, and a person’s cerebral cortex then activates the neural loop that controls the brain’s "reward" system. As we learn more about this connection, our knowledge can be applied to deepen the pleasure of the esthetic experience **[17]**. Therefore, the relations among perception, emotion, behavior, attention, decision-making and neuroesthetics related to architecture should be studied further. Sternberg EM and colleagues have shown that basic psychological processes play fundamental roles in our responses to architecture, including our visual perception, spatial navigation and memory **[8]**. To some extent, architecture can arouse memories and emotional resonance from the past. When people spontaneously label an architectural work a symbol of culture or a memorial, this adds more significance to the piece. Such buildings resonate with us not only because of historical events, cultural phenomena, national emotions and the memory of past historical figures but also because they may trigger childhood memories or seem familiar.

Michael Arbib proposed that successful architectural neuroscience must link not only action and perception but also emotion and esthetics and find a proper balance between the latter**[9]**. An architectural work can be not only a cultural symbol but also a place for the daily activities of living and working. Sternberg EM noted that environmental characteristics trigger neurological and physiological reactions, which can have positive or negative effects on people, and good architectural design does, to some extent, improve users' cognition, creativity and comfort**[8]**. If a particular built environment can better serve to the needs of a certain daily activity, then regardless of whether that activity is work, study, or rest, better results can be obtained. However, although many architects hope to realize such ideas, they lack the theoretical basis and understanding of some architectural features or the effect of environmental design, and thus their final results are not as expected.

For example, Annu Haapakangas's study of the contrast between the ABW office design favored by so many new companies and the traditional office did not return the expected results, as the ABW office design failed to achieve the goals of having a flexible office location, enhanced collaboration between different departments, and different regions that meet varying needs. In ABW offices, it is difficult to gather the whole team together for a discussion, resulting in lower efficiency in ABW offices than in traditional offices. Furthermore, the sense of belonging felts by employees in ABW offices has declined because they do not have space to themselves**[18]**. Such research results seem to run counter to the original intention of the ABW design.

In light of such results, it appears that the design concept needs to be bolstered by scientific evidence regarding ergonomics and the relationship between humans and architecture from actors throughout the architectural industry and other industries in order to make continuous progress. As the scope of the field has gradually become standardized, the impact of architecture on human psychology has become a new subject that every professional needs to consider. The exploration of relevant psychological concepts relies on psychological experiments, which is why brain science and behavioral science will be frequently consulted in future architectural endeavors.

Currently, with the continuous development of psychology and neuroscience, a series of interdisciplinary research methods have emerged that enable architects to improve their work and provide a more scientific basis for their understanding of design.

Numerous studies involving functional magnetic resonance imaging (fMRI) show that more people find curvilinear contours to be more beautiful than rectilinear contours and that using the former to construct an environment can affect human behavior, emotion, and brain function[19]. Many studies have also found that people prefer curved objects, and curves can cause pleasant emotions[20-22]. Logically, the brain's response to architectural features also affects a person's judgment of esthetics. architectural features have an influence on people's subconscious that may not even be perceived by the people themselves. People's likes, dislikes and physiological reactions to a space they have entered cannot always be clearly described; therefore, we need to conduct multiple experiments to show how these features affect which parts of a person's judgment and whether different people experience different effects.

1.2.2 Aesthetic differences due to age

With the growing problem of aging in the world, we need to pay more attention to the importance of the elderly in our research. In recent years, there has been a growing number of studies on architecture in which older adults are the subject of study. Several studies on the built environment have concluded that older adults are more familiar and comfortable with the natural environment and less familiar and comfortable with the built environment and urban street environment than adolescents and adults**[23]**. This is consistent with the need to design for the physical and cognitive health of older adults to meet the demands of an active and less stressful environment. More interdisciplinary collaboration between medical researchers and architects could also lead to greater well-being and health security for older adults in their everyday environments**[24]**. In addition to health considerations, promoting a sense of familiarity and security can also help improve the residential satisfaction of older adults**[25]**.

Due to the diminished vision and reduced color sensitivity of older adults, a large number of studies have been proposed on architectural color preferences of different age groups. There are studies on the color preferences of the elderly in housing**[26]**. There are also attempts to explore color design criteria for bathrooms in elderly living environments**[27]**. Or studies that have experimented with specific differences in color perception between older and younger people**[28]**. There are also studies on the design of illuminated spatial patterns in elderly facilities that have explored the impact of vision on the elderly in addition to color**[29]**. All of these suggest that visual influences may alter older adults' observations of architectural interior features and further influence their aesthetic judgments of architectural interiors.

Shepley did not obtain meaningful results in his experiment to understand the changes in perceptual responses and preferences of people of different ages to specific categories of built environments**[30]**, perhaps due to too many confounding factors in the experimental design. The experiments in this chapter were conducted with older adults in the same manner as in Chapter 3 to make the results of older and younger adults as comparable and meaningful as possible.

In Mura's study, the age of the building can be considered as a variable that can influence people's preferences, with some historic and traditional buildings being more popular**[31]**. Traditional architecture may influence people's preference for architectural aesthetics. However, due to the convergence of modern aesthetic education and the gradual lack of national boundaries in architectural design styles in most parts of the world, the architectural environment that older people are accustomed to may lead them to have different preferences for architectural interior features than younger people. The cognitive age of older adults influences the interior design characteristics of their homes. The younger the cognitive age of seniors, the more they live in modern style bedrooms or living rooms. In addition, the older their cognitive age, the more they lived in bedrooms or living rooms with traditional Korean styles **[31]**. This also proves that age can have an impact on the preference and choice of living environment.

1.3 Research structure and logical framework

1.3.1 Research purpose and core content

In the context of previous architectural designs that mostly relied on the aesthetics of architects, understanding the feelings of users is the new trend. This paper conducts a study on the aesthetic preference of architectural interior features for the general population to understand what effect different architectural interior features have on people's subjective aesthetics and to give architects a reference of certain architectural features before designing buildings. In addition, this paper also explores what different aesthetic needs the elderly have for architectural interior features, which provides inspiration for the design of age-appropriate buildings in an increasingly aging country and brings positive emotional support to the elderly who live there.

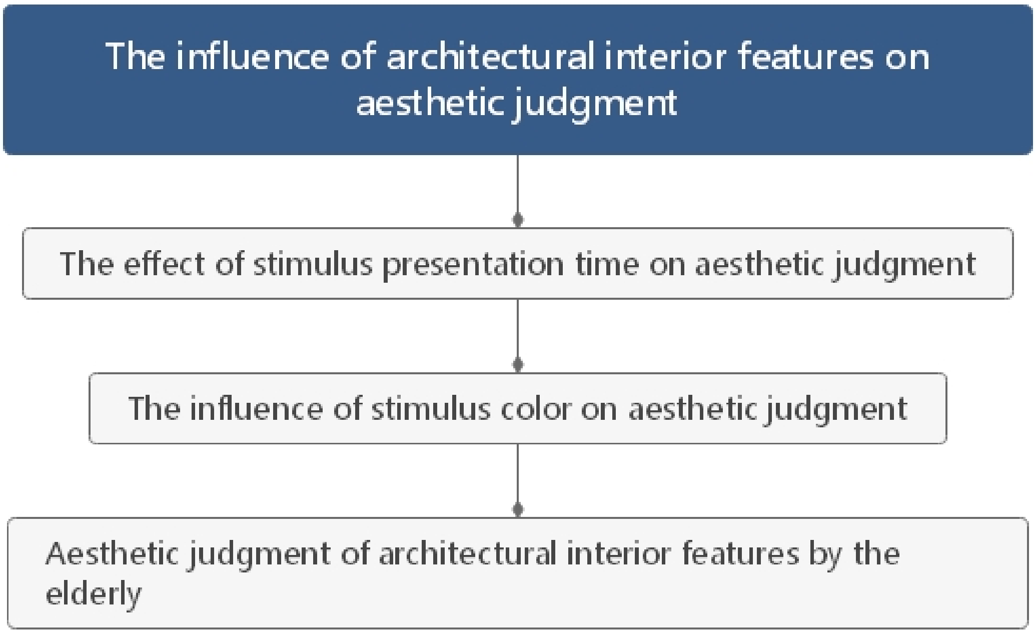

Fig 1-1 Research logic of the article

1.3.2 Chapter content overview and related instructions

The chapter names and basic structure of this paper are shown in Fig 1-2. Besides, the brief introduction of chapters schematic is shown in Fig 1-3.

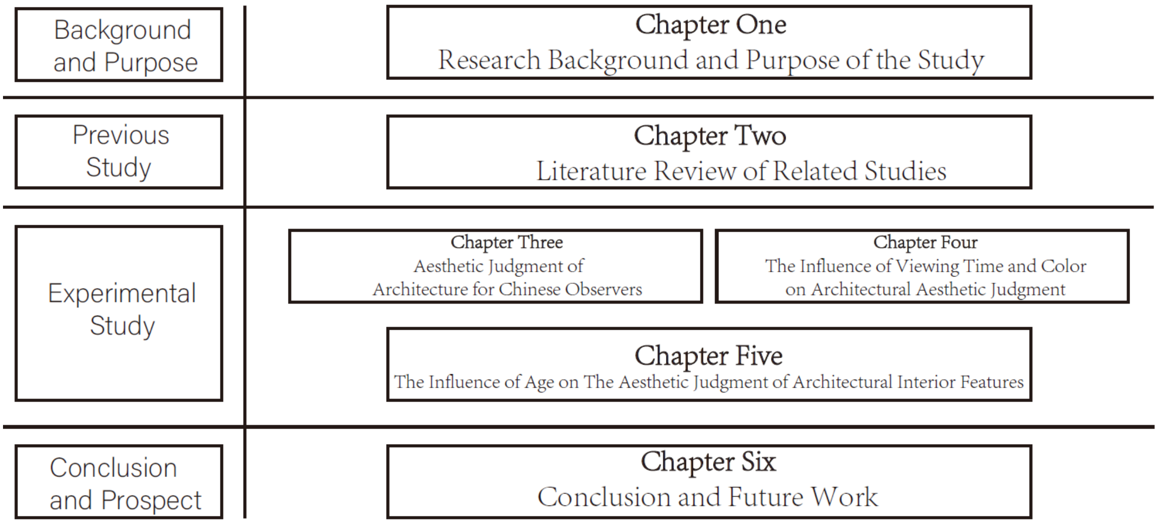

Fig 1-2 Chapter name and basic structure

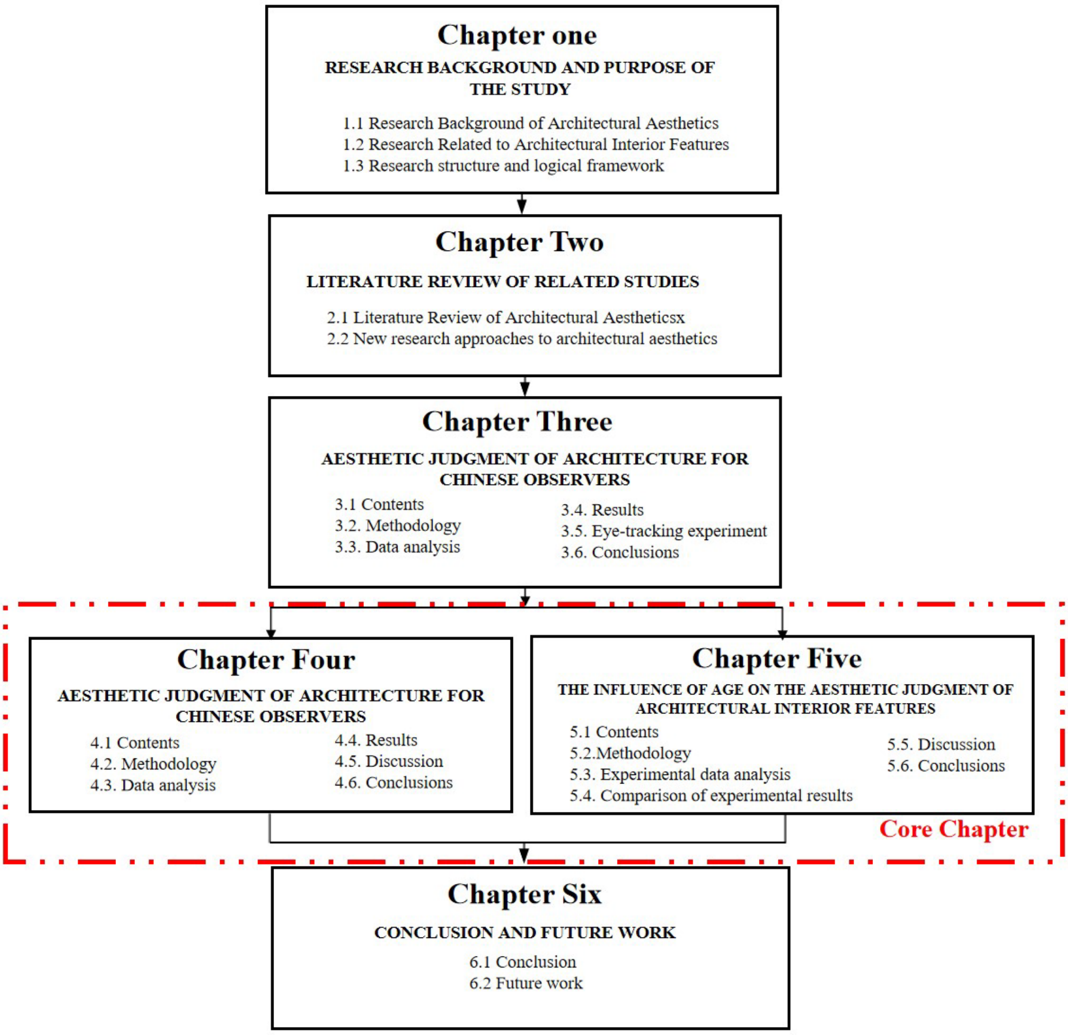

Fig 1-8 Brief chapter introduction

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Chapter 2

LITERATURE REVIEW OF RELATED STUDIES

CHAPTER TWO: LITERATURE REVIEW OF RELATED STUDIES

2.1 Literature Review of Architectural Aesthetics

2.1.1. The study of aesthetics in architectural psychology

From a neuroaesthetic perspective, understanding people's preferences for architectural features can provide architects with relevant information that will enable them to design works that meet both the functional and aesthetic needs of the public. Viewing a beautiful work of art creates a sense of arousal in the human brain, and a person's cerebral cortex then activates the neural circuits that control the brain's "reward" system. As we learn more about this connection, our knowledge can be applied to deepen the pleasure of aesthetic experience[1]. Therefore, the relationship between perception, emotion, behavior, attention, decision-making, and neuroaesthetics related to architecture should be further investigated. sternberg EM and colleagues have shown that fundamental mental processes play a fundamental role in our responses to architecture, including our visual perception, spatial navigation, and memory[2]. To some extent, architecture can evoke memories and emotional resonance with the past. When people spontaneously label architectural works as symbols of culture or monuments, this adds more meaning to the work. Such buildings resonate with us not only because of historical events, cultural phenomena, national emotions and memories of historical figures from the past, but also because they may trigger childhood memories or seem familiar.

Michael Abib suggests that a successful architectural neuroscience must link not only action and perception, but also emotion and aesthetics, and find the right balance between the latter[3]. An architectural work can be not only a cultural symbol, but also a place for daily activities of living and working. Sternberg EM points out that environmental features trigger neurological and physiological responses that affect people positively or negatively, and that good architectural design does, to a certain extent, improve users' perception, creativity and comfort[2]. If a particular built environment can better meet the needs of a certain daily activity, then better results can be obtained, whether that activity is work, study or rest. However, although many architects wish to realize such ideas, they lack the theoretical basis and understanding of some architectural features or environmental design effects, so their final results are not as satisfactory as they could be.

For example, Annu Haapakangas' study of the comparison between ABW office design, favored by many new companies, and traditional offices did not yield the expected results because ABW office design failed to achieve the goals of having flexible office locations, enhanced collaboration between different departments, and different areas to meet different needs. In ABW offices, it is difficult to bring the whole team together for discussions, resulting in ABW offices being less efficient than traditional offices. In addition, employees' sense of belonging in ABW offices is reduced due to the lack of their own space[4]. Such findings seem to contradict the original intent of the ABW design.

Given such results, it appears that design concepts need to be supported by scientific evidence from across the building industry and beyond regarding ergonomics and the relationship between humans and buildings in order to make continued progress. As the scope of the field has become more standardized, the impact of architecture on the human psyche has become a new topic for every professional to consider. The exploration of relevant psychological concepts relies on psychological experiments, which is why brain science and behavioral science will be frequently referenced in future architectural work.

Currently, as psychology and neuroscience continue to evolve, a range of interdisciplinary research methods have emerged that enable architects to improve their work and provide a more scientific basis for their understanding of design.

Numerous studies involving functional magnetic resonance imaging (fMRI) have shown that more people find curved contours more aesthetically pleasing than straight ones, and that using the former to construct environments can influence human behavior, emotion, and brain function[5]. Many studies have also found that people prefer curved objects and that curves can elicit pleasant emotions[6-8] . Logically, the brain's response to architectural features can also influence a person's judgment of aesthetics.

There is evidence that the ceiling height and openness of buildings can influence cognition and emotion in the built environment[9-11] .

Thus, architectural features have an impact on people's subconscious, and may not even be perceived by people themselves. People's likes, dislikes, and physiological reactions to the spaces they enter cannot always be clearly described; therefore, we need to conduct multiple experiments to show how these features affect which parts of a person's judgment, and whether different people experience different effects.

In a comparative experiment between experts and non-experts, O. Vartaniana et al. found that experts were less interested in common types of contour lines and more interested in abstract curves and could view buildings more rationally, but were also less interested in entering them[12]. The experiment showed that people who had studied architecture and those who had not reacted differently to the same architectural features, so we can infer from this that people who have grown up in different experiences and cultures likewise react differently to the same architectural features.

What factors drive our aesthetic experience is a topic that receives a considerable amount of attention. The field of empirical aesthetics emphasizes that aesthetic experience should be empirically studied and experimentally validated. Using the empirical aesthetics approach, it has been shown that the relationship between complexity and novelty, and aesthetic appreciation has an inverted U shape – People generally prefer an intermediate level of complexity and novelty[13]. Empirical aesthetics studies have revealed that the evaluation or production of beauty, ugliness, prettiness, harmony, elegance, shapeliness or charm is governed by a host of factors, such as stimulus symmetry, complexity, novelty, familiarity, artistic style, appeal to social status, and individual preferences[14].

Investigating the preference of architectural features from the perspective of empirical aesthetics allows architects to gather more information about how to design structures that can meet both functional and public aesthetic requirements. Environmental characteristics can trigger neurological and physiological responses in humans, thereby exerting a positive or negative impact on them[15-17]. To a certain extent, a good architectural design enhances users' comfort, cognition and creativity[2]. Architectural aesthetics connects emotion and aesthetics and strikes a balance between the two[3]. Previous studies have demonstrated the reward circuitry in the brain is activated when seeing artwork. Artists who know how to exploit this circuitry can intensify an individual's aesthetic experience[1]. Once a certain architectural element fits in a certain life scene, such as work, study, and rest, it can enhance behavioral effects through positive emotions[11, 18]. Currently, many architects have such ideas but lack the theoretical foundation as well as an understanding of the effect of some architectural factors on subjective experience. In order to increase the understanding the relationship between architectural factors and subjective experience, researchers have done a lot of exploration in western culture.

2.1.2. Application of Aesthetics to Architecture

In a series of experiments, Takahiko Masuda found that Asians pay more attention to background images and the overall relevance of the picture than Americans do. Asians prefer paintings with landscapes, so they create larger scenes. However, due to the complexity of content in Asian art, the images tend to be flatter due to the lack of perspective and object relationships. Westerners were better at depicting and perceiving perspective. In contrast to scenes in Asian art, Western art depicts objects in their actual observed state and the images are more visual and three-dimensional[19].

These differences are caused by changes in painting techniques and cultural expressions. When a painting is displayed in the form of a scroll, one sees the picture moving and changing, unable to provide a specific focus and hardly offering many perspectives, because the painting is more a description of a state of being than a description of an object. The overlap of various scenes makes the picture more story-like. In one experiment, Japanese subjects mentioned more information when describing an object after watching a short film, probably because East Asian subjects were more willing to combine the picture of an object with its context to obtain information. On the other hand, American subjects tended to describe the appearance of the object when describing it, which may indicate that Westerners focus more on the most salient visible attributes of the object. The study also describes the development of many ancient cultures and the impact of religious, ideological and other differences on Eastern and Western concerns. A picture reflects the cultural characteristics of its content, so in this study we wanted to learn more about whether a culturally specific picture evokes different feelings in people from different cultural backgrounds.

Motti Regev points out that cultures are national and regional in nature, and that people who identify with traditional national aesthetic standards are more skeptical of new art; even so, traditional art is constantly merging with other cultures and art forms and giving birth to new branches of art, thus contributing to a cosmopolitan aesthetic that is perpetuated by the influence of the outside world on local things, which in turn (influencing the outside world[20]. This mixed cycle generates a new worldwide standard of aesthetic judgment. If aesthetic judgments become more similar throughout the world, it may indirectly eliminate different judgments of beauty between cultures. Eastern students studying in the same aesthetic education system as in the West, or even a new generation of Asian youth influenced by Western aesthetics, may receive different feedback on their sense of self and aesthetic judgments of their works than they have in previous Western studies. This topic requires a great deal of research. If different cultural backgrounds produce different aesthetic interests, then the proportion of local aesthetic interests incorporated into architectural design should be higher than the proportion of universal aesthetic interests.

2.2 New research approaches to architectural aesthetics

2.2.1. Research on Color and Architecture

In one experiment, Gegenfurtner used color image stimuli for 30-50 ms to compare different levels of image luminance, and the results showed that color images can provide better memory guidance in both man-made and natural scenes**[21]**. For example, color stimuli may increase the perception of aesthetic value when architectural scenes trigger emotions and memories.

In Oliva and Schyns' experiment, 160 images were divided into three groups with different characteristics (normal shading, abnormal shading, and grayscale) and each image was displayed for 120 ms, asking the subjects to quickly identify and describe the images. The results showed that the recognition of normal color images was faster than the recognition of grayscale versions of the same images**[22]**. Normal colors play an important role in simulating the visual experience of real-life scenes. Color contributes to the recognition of the cognitive system**[21, 23]**. Spence found that color has an advantage in visual scene recognition memory in the early stages of visual processing**[24]**. His experiments also confirmed our previous suspicions. Graf and Landwehr proposed the pleasure-interest model, which argues that judgments of the pleasure value of aesthetic objects are stimulus-driven and share features with automatic processing**[25]**. In an experiment, John W. Mullennix and colleagues examined subjects' preferences for black-and-white or color art photography. The procedure was as follows: 29 subjects (4 men and 25 women) in the experiment viewed 32 color photographs in sequence, followed by corresponding black-and-white photographs taken two weeks after the color photographs. The results showed that in the seven photographs where there was a significant difference between the color and black-and-white versions, the former always scored higher than the latter.

However, the semantic difference scores of the six black-and-white photos showed that they were perceived as more unexpected, obvious, vibrant, concrete, expressionless, quiet, or realistic than their color counterparts**[26]**. The current experiments suggest that although grayscale stimuli were recognized at a lower rate and may have scored lower than color stimuli for pleasurable and aesthetic value, the former scored higher for semantic descriptors that may indicate positive associations with architectural image stimuli.

Examples of warm colors tend to elicit more active sensations, while examples of cool colors tend to be associated with calming sensations in response[27]. For example, warm colors are perceived as stimulating, highly arousing, and exciting, whereas cool colors are associated with spaciousness, tranquility, and calmness. This result supports the observations of[28, 29] [30, 31] [32, 33], who all concluded that cool colors relax people, make interior spaces more peaceful, and add a feeling of spaciousness, while warm colors are more stimulating and make interior spaces seem less spacious. For the achromatic scheme, the response was rather negative compared to the warm and cool colors. As previously demonstrated[34], people respond more positively to brighter colors (white, pink, red, yellow, blue, purple, and green) and more negatively to darker colors (brown, black, and gray).

2.2.2. Time of Observation and Aesthetics

Feifei Li et al. argue that humans can quickly and accurately understand real-world scenes and complete multiple scans per second in complex scenes. Some experiments used rapid picture changes as stimuli, and some experiments provided multiple choice responses to judge after a brief display of pictures. However, in short-stimulus experiments (27-40 ms), subjects' perception of the pleasurable and aesthetic value of the architecture was evident**[35]**. Thus, it was hypothesized that people could judge architectural pictures very quickly, even if the exposure time was short, and that changes in architectural features would have an impact on such judgments. Because the complexity of the pictures used for stimuli may vary, the characteristics of the pictures may influence the aesthetic judgments of the subjects in the experiment.

Caitlin Mullin's study showed that people prefer a location in a restaurant where they can observe the restaurant as a whole or look outward, and that aesthetic judgments can be made by implicit testing 50 ms**[36]**. In an experiment involving complex image stimuli, people tended to choose simple outdoor scenes, but no significant relationship was found between the complexity of the indoor scenes and the aesthetic judgments of the scenes. This suggests that even if architectural images are complex and confusing, such features may not affect the aesthetic judgments of the images. Therefore, the differences in aesthetic value judgments obtained in the current experiment are more likely to be influenced by the architectural features themselves.

2.2.3. Aesthetic Research on Architecture for the Elderly

With the growing problem of aging in the world, we need to pay more attention to the importance of the elderly in our research. In recent years, there has been a growing number of studies on architecture in which older adults are the subject of study. Several studies on the built environment have concluded that older adults are more familiar and comfortable with the natural environment and less familiar and comfortable with the built environment and urban street environment than adolescents and adults[37]. This is consistent with the need to design for the physical and cognitive health of older adults to meet the demands of an active and less stressful environment. More interdisciplinary collaboration between medical researchers and architects could also lead to greater well-being and health security for older adults in their everyday environments[38]. In addition to health considerations, promoting a sense of familiarity and security can also help improve the residential satisfaction of older adults[39].

Due to the diminished vision and reduced color sensitivity of older adults, a large number of studies have been proposed on architectural color preferences of different age groups. There are studies on the color preferences of the elderly in housing[40]. There are also attempts to explore color design criteria for bathrooms in elderly living environments[41]. Or studies that have experimented with specific differences in color perception between older and younger people[42]. There are also studies on the design of illuminated spatial patterns in elderly facilities that have explored the impact of vision on the elderly in addition to color[43]. All of these suggest that visual influences may alter older adults' observations of architectural interior features and further influence their aesthetic judgments of architectural interiors.

Shepley did not obtain meaningful results in his experiment to understand the changes in perceptual responses and preferences of people of different ages to specific categories of built environments[43], perhaps due to too many confounding factors in the experimental design. The experiments in this chapter were conducted with older adults in the same manner as in Chapter 3 to make the results of older and younger adults as comparable and meaningful as possible.

In Mura's study, the age of the building can be considered as a variable that can influence people's preferences, with some historic and traditional buildings being more popular [45]. Traditional architecture may influence people's preference for architectural aesthetics. One of the reasons for using older people as a research subject in this chapter is the difference between the built environment of the era in which older people grew up and the built environment of the era in which younger people grew up. In the experiments in Chapter 3, we attempted to explore whether people who grew up in different cultural backgrounds and aesthetic education would have different aesthetic preferences for the same architectural interior features. However, due to the convergence of modern aesthetic education and the gradual lack of national boundaries in architectural design styles in most parts of the world, the architectural environment that older people are accustomed to may lead them to have different preferences for architectural interior features than younger people. The cognitive age of older adults influences the interior design characteristics of their homes. The younger the cognitive age of seniors, the more they live in modern style bedrooms or living rooms. In addition, the older their cognitive age, the more they lived in bedrooms or living rooms with traditional Korean styles[46]. This also proves that age can have an impact on the preference and choice of living environment.

2.2.4. Aesthetic Research on Architecture for the Elderly

Machine learning is a subset of artificial intelligence (AI) that allows computer systems to automatically improve their performance over time by learning from data. It involves the use of algorithms that can analyze and find patterns in large data sets to make predictions or decisions. Machine learning can be supervised, unsupervised, or semi-supervised. In supervised learning, the algorithm is trained using labeled data. In unsupervised learning, the algorithm is trained using unlabeled data, while in semi-supervised learning, the algorithm is trained using both labeled and unlabeled data.

Natural language processing (NLP) is a branch of AI that deals with the interaction between computers and humans in natural language. It involves the use of algorithms to analyze, understand, and generate human language. NLP has many applications, including sentiment analysis, text classification, and machine translation. NLP technologies include natural language understanding (NLU) and natural language generation (NLG).

Computer vision is another branch of AI that involves teaching machines to interpret and understand visual data from the world around them. It involves the use of algorithms to analyze and recognize images and videos. Computer vision has many applications, including object detection, image segmentation, and facial recognition.

Robotics involves the design, construction, and operation of robots to perform various tasks in the physical world. Robotics can incorporate other technologies like machine learning, NLP, and computer vision to make robots more intelligent and capable of performing complex tasks. Robots can be used in various industries such as manufacturing, healthcare, and logistics.

In conclusion, machine learning, natural language processing, computer vision, and robotics are all important technologies that are transforming the world around us. Each of these technologies has its own unique capabilities and applications, but they can also be combined to create even more powerful and intelligent systems. As these technologies continue to advance and evolve, we can expect to see even more exciting and innovative applications emerge in the future.

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Chapter 3

AESTHETIC JUDGMENT OF ARCHITECTURE FOR CHINESE OBSERVERS

CHAPTER THREE: AESTHETIC JUDGMENT OF ARCHITECTURE FOR CHINESE OBSERVERS

3.1 Contents

With today's flow of transportation and information, people can quickly understand and adapt to new information, esthetic educations in the East and West are becoming more similar, and there is no major difference in terms of the esthetic environment in which young people grow up. This holds true for the architectural environment as well. Relatively prosperous cities have a lack of traditional Asian architecture. As traditional living and working patterns, such as traditional unsanitary kitchen facilities, ambiance-defining habits, dressing habits and production methods, declined, architectural styles around the world became increasingly similar. This chapter aims to explore whether certain architectural features have different effects on different cultural groups, and whether architectural images displaying specific features elicit a sense of alienation or closeness among different cultural groups in the experiment, as these factors may lead to different evaluations of the pleasure value and aesthetic value of architecture.

It is hoped that the experiment will explore the effects of architectural features such as ceiling height, openness and contour on people's aesthetic judgments about architecture and its perceived pleasure value, and attempt to compare aesthetic differences between people from different cultural backgrounds.

3.2. Methodology

3.2.1. Participants and Exclusion criteria

The participants in this study were college students who were all right-handed, had no visual impairments and color blindness, had normal or corrected vision, and had no history of psychosis or neuropathy. The experimental protocol for this study was approved by the Research Ethics Committee of Zhejiang University School of Medicine (2019–047). Before the experiment, all participants signed a written informed consent form, and after completing the experiment, each participant received 40 RMB monetary reward. A total of 29 participants were included in this study, including 19 males (age: 23.05±1.99 years) and 10 females (age: 23.00 ±2.00 years).

3.2.2. Stimulus material

The stimuli for this study consisted of 200 photographs of architectural spaces. The stimuli were culled from larger architectural image databases available from the L.B.F. at the Department of Architecture, Design, and Media Technology at the University of Aalborg, Denmark and to N.R. at The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, School of Architecture [1]

Figure 3-1 A total of 200 pictures were divided into 8 groups of 25 pictures each. Each picture contained 3 notable aspects: ceiling height, degree of openness and contour type [2]

.

3.2.3. Laboratory and equipment setup

The experiment was conducted in a soundproof room used for professional psychological experiments. There was a display screen on the table, an eye tracker, a laptop, and a keyboard. The display screen was used to display the questions and pictures for the eye tracker experiment. The eye tracker was used to record the experimental data; the laptop, on which the eye tracker driver software was installed, was used to calibrate the eye tracker instrument. The subjects used the keyboard to initiate the experiment and record their answers. The keys for numbers 1 through 5 (on the left-hand side of the keyboard) were used to indicate the subject's answer, and the 0 key (on the right-hand side) was used to initiate the experiment. Rubber tape was affixed to the keys used for the experiment so that they could be distinguished by touch.

There was a chin rest placed on the edge of the table, and the seat was adjusted so that the subject's chin rested on top of the chin rest and the line of sight was approximately 1/4" above the center of the display screen.

The subjects were relaxed and had their hands are on the correct keys of the keyboard, but they were required to maintain the a posture without moving their chin or chair and without looking down at the keys. Next, the eye tracker was tested and calibrated. First, the right eye of the subject was selected as the test object using the software program, and the subject was asked to look at the four corners of the display screen, which helped determine whether the subject's pupil was properly captured and could be tracked across the entire display screen in the experiment.

Next, the accuracy of the eyeball fixation was assessed. At this stage, a black circle appeared in the center of the screen, and the subject was instructed to keep watching the center of the circle. When the test started, the circle randomly appeared at nine various points distributed across the screen. Then, the participants were asked to not attempt to anticipate where the circle would appear. If the test was accurate, the eye tracker would capture each the fixation points is a standard rectangular profile; the test was a failure if there were significant deviations from the rectangular profile. If the test results were satisfactory, further calibration was needed. During the calibration, the subject was asked to follow the movement of the center of the circle. The software showed the distance between the fixation point of the subject and the actual center of the circle. Subjects pressed 0 to start the test after the staff member left the soundproof room. The software was an experimental program prepared for MATLAB 2018.

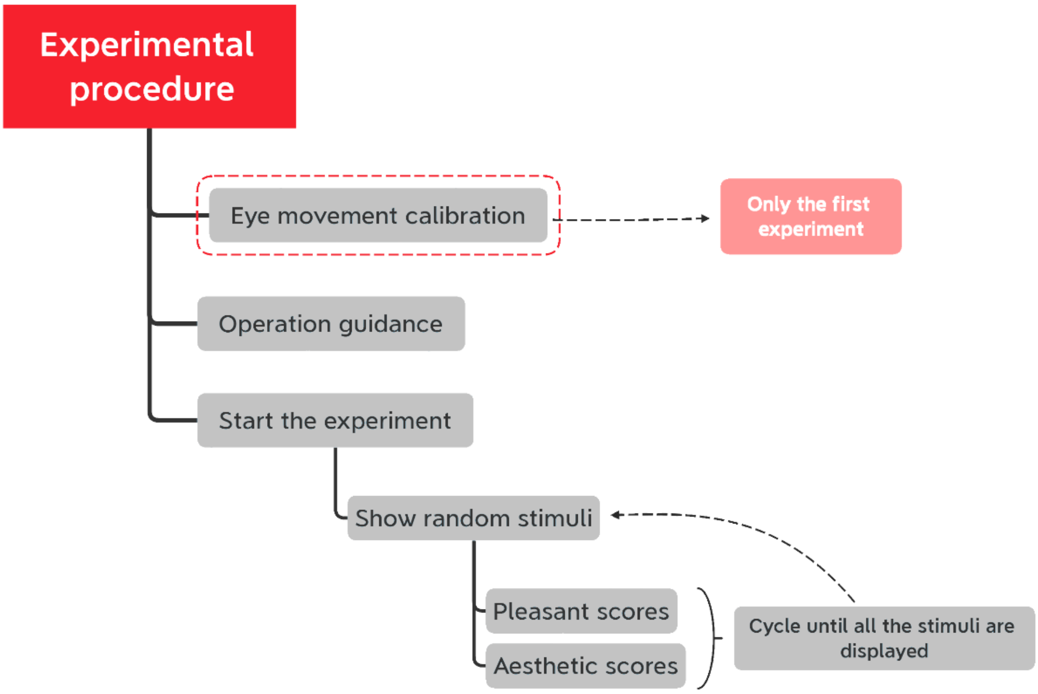


Figure 3-2 Experimental procedure

Figure 3-3 Soundproof room

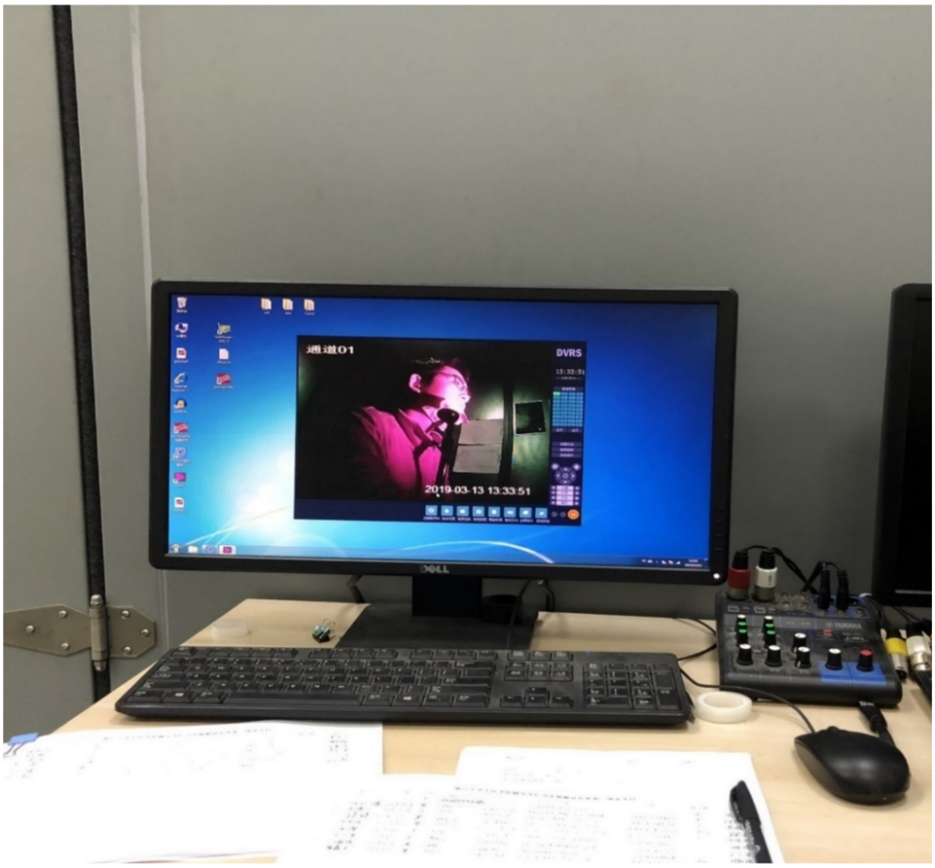


Figure 3-4 Experimental observation

3.2.4. Experimental procedure

The subjects in the experiment comprised 29 students from Zhejiang University, including 19 males (23.05 ±1.99) and 10 females (23.00 ±2.00) pursuing undergraduate (9), master's (13), and doctorate (7) degrees. The first experiment used a total of 200 architectural pictures in eight groups, each with three distinct properties (1-ceiling height; 2-degree of openness; 3-contour type).

Before the experiment began, we guided the subjects through the eye tracker setup and a series of calibrations to ensure the technology's smooth functioning. The subjects looked at the "×" symbol in the center of the screen for 1000 ms, and then a random stimulus picture was displayed for 3000 ms. When the stimulus disappeared, two scoring questions in the subject's mother tongue regarding the perceived pleasure value and esthetic value of the image were displayed, with responses ranging from 1, meaning very unpleasant (unaesthetic), to 5, meaning very pleasant (beautiful).

The 200 stimuli in the experiment were divided into four groups. There were breaks between each group of images, and the eye tracker was recalibrated after each break. The total duration of the experiment was approximately 35-75 minutes.

The code used for the experiment is as follows:

```
%*****************************************************************************************

% can parse the asc file obtained by eyelink 1000

% Unresolvable values and values to be ignored are filled with nan


% result: matrix

% First dimension: data sampling points

% second dimension: time; x-axis coordinates; y-axis coordinates; pupil size; data marker 1 (1: FIXATION 2: SACCADE 0: OTHERS); data marker 2 (3: BLINK 0: OTHERS)


%trial_record:need to add Eyelink('Message', 'TRIALID %d',ind) to the experimental program

%*****************************************************************************************

clear;clc
```

```
%%

%/~~~~~~~~ read the contents of the ASC file ~~~~~~~/

% FileName = 'subject1';



for sub = [28:32] %Tried

% for blo = [1 2] %Block1, 2, 3


    fid = fopen(['. \' num2str(sub) '_TEST.asc'],'r'); % get file handle


    %/``````` reads the entire text content of `````/

    contents = {};

    ct = 1;


    tline = fgetl(fid);

    while ischar(tline)


        contents{ct} = tline;

        ct = ct+1;

        tline = fgetl(fid);

    end

    fclose(fid);


    %%
```

```
len = length(contents); %total number of lines of text
pat = '\s+'; %Split a line into strings according to spaces
ct = 1;
trial_record = []; %Total number of trials recorded, and when they occurred
trial_record_ct = 1;
percentage = 10;
EyeType = 0; % data type marker: 0: no type data specified 1: FIXATION 2: SACCADE
BlinkNo = 0; %DataType flag: 0: data of unspecified type 3: BLINK
Start = 0; %0: data not between TRIAL, consider data invalid, do not record 1: data between TRIAL, consider data valid, need to record
for line_idx = 1:len
  %/``````` shows processing progress `````/
  if(line_idx==floor(len*percentage/100))
    fprintf('sub%d-completed %%%d\n',sub,percentage);
    percentage =percentage+10;
  end
  line = contents{line_idx}; %read one line at a time and process it until the entire data is traversed
  line_strs = regexp(line,pat,'split'); % split each line into strings according to spaces
  %/``````` the line is empty, then ignore the new line `````/
  if(isempty(line_strs{1}))
    continue;
  end
  %/``````` mark TRIALID, ignore reline after completion `````/
  if(length(line_strs)==5 && strcmp(line_strs{3},'TRIALID')==1)
    trial_record(trial_record_ct,1)=str2double(line_strs{2});
```

```
    trial_record(trial_record_ct,2)=str2double(line_strs{4});
    trial_record_ct = trial_record_ct+1;
    Start = 1; % detect the beginning of TRIAl, allow to record data
    continue;
end
if(length(line_strs)==4 && strcmp(line_strs{3},'TRIAL_RESULT')==1)
    Start = 0; %TRIAl end detected, disable data logging
    continue
end
%/``````` mark FIXATION as 1, ignore change line `````/ after completion
if(strcmp(line_strs{1},'SFIX') == 1)
    EyeType = 1;
    continue;
end
if(strcmp(line_strs{1},'EFIX')==1)
    EyeType = 0;
    continue;
end
%/``````` mark SACCADE as 2, ignore change line `````/ when done
if(strcmp(line_strs{1},'SSACC')==1)
    EyeType = 2;
    continue;
end
if(strcmp(line_strs{1},'ESACC')==1)
    EyeType = 0;
```

```
    continue;
end
%/``````` mark BLINK as 3, ignore change line `````/ when done
if(strcmp(line_strs{1},'SBLINK') == 1)
    BlinkNo = 3;
    continue;
end
if(strcmp(line_strs{1},'EBLINK')==1)
    BlinkNo = 0;
    continue;
end
%/``````` the line is not composed of all numbers, then ignore to change the line `````/
if(~isempty(find(isstrprop(line_strs{1},'digit') == 0)))
    continue;
end


%/``````` the line consists entirely of numbers, for eye data, need to record `````/
if Start == 1
    for s_idx = 1:4 % data format is: time x-axis y-axis pupil size
        result(ct,s_idx) = str2double(line_strs{s_idx}); %record time
        if(isnan(result(ct,s_idx))) %When data is blink, x-axis, y-axis, pupil data is none, use
nan instead
            result(ct,2:4) = NaN(1,3);
            break;
        end
    end
```

```
            result(ct,5) = EyeType; % mark the type of data as 1:FXATION 2:SACCADE 0:other
            result(ct,6) = BlinkNo; % mark data of type 3:BLINK 0:Other

            ct = ct+1;
        end

    end

    %%
    out.fs = 1e3/(result(2,1)-result(1,1));
    out.trial = trial_record;
    out.samples = result;

    save(['. \yandong\' num2str(sub) '_TEST'],'out');

    clear result trial_record contents
% end
end
% ****************************************************************
%
% Ignore Eyelink's marking of the data, average the trial directly, and find the frequency spectrum
%
% 1. Since BLINK data do not have coordinates with pupil diameter, use nanmean
% 2, will directly use the position coordinates, converted to degrees
%
```

```
% 2017.09.22
% ************************************************************

clc;clear;

ScreenYPixel = 1024;
ScreenXPixel = 1280;

%%

ct = 1;

for sub = [1:5,7:19,21:23,25:32]

    cctt = 1;

        clear y1 TrialPos

        load(['. \yandong\' num2str(sub) '_TEST.mat']); % read in eye movement data
        % data : matrix
        % first dimension : data sampling points
        % second dimension: time; x-axis coordinates; y-axis coordinates; pupil size; data marker 1
(1: FIXATION 2: SACCADE 0: OTHERS); data marker 2 (3: BLINK 0: OTHERS)
        fs = out.fs;
```

```
data = out.samples;
trialHead = out.trial;
trialHead(:,1) = ceil(trialHead(:,1)/2)*2; % is constant for even numbers, plus 1 for odd numbers, indicating the starting position of each trial
clear out

%Get the starting position of each trial in the matrix
for ind = 1:length(trialHead)
    TrialPos(ind) = find(data(:,1) == trialHead(ind,1)); % store the starting position of trial in the matrix
end
TrialPos(length(trialHead)+1) = size(data,1);


for trial = 1:size(trialHead,1)

    clear EyeMoveTrial
    EyeMoveTrial = data(TrialPos(trial):TrialPos(trial+1)-1,:);
    yy(1:size(EyeMoveTrial,1),:,trial) = EyeMoveTrial;
    TriLen(trial) = size(EyeMoveTrial,1);
end
% load(['... \... \data\OrientData\behaviorResults\CA' num2str(sub) BlockName{blo}]);
% Pois = find(correct_response(:,2-mod(blo,2)) == 0);
%
% yem(:,::,:,cctt,ct) = yy(1:500*24,:,Pois);
% cctt = cctt+1;
```

```
% ct = ct+1;
    eye_data = yy(1:1501,:,2:3:end-1);
    save(['. \eye_result\sub' num2str(sub) '_EYEDATA'],'eye_data','fs');
    disp(sub);
end
for sub=[2:5,7:12,14:19,21:23,25:32];


load(['.\eye_result\sub' num2str(sub) '_EYEDATA'],'eye_data','fs');
load(['.\' num2str(sub) '_TEST.mat'])


x=squeeze(eye_data(:,2,:));
y=squeeze(eye_data(:,3,:));



for index=1:200
    condi1(index)=result(index).condition1;
    condi2(index)=result(index).condition2;
    condi3(index)=result(index).condition3;
    Num(index,:)=result(index).Num;
end


for index=1:200


    number(index,:)=condi3(index)*1+condi2(index)*2+condi1(index)*4+1;
```

```
end

for index=1:200
    eyedata(:,1,Num(index),number(index))=x(:,index);
    eyedata(:,2,Num(index),number(index))=y(:,index);
end

save(['.\performance\' num2str(sub) '_eyedata.mat'],'eyedata');

end
clear;
clc;

sub=31;
load(['.\performance\' num2str(sub) '_eyedata']);



pic_blk=ones(1080,1920,3,'uint8');

xz=1920/2;
yz=1080/2;

for ind1=3
    for ind2=1
```

```
file=dec2bin(ind1-1,3);
picpath=['.\pic\' file '\'];
pic_all = dir(fullfile(picpath,'*.jpg'));
pic = imread([picpath, pic_all(ind2).name]);
pic_blk(yz-size(pic,1)/2+1:yz+size(pic,1)/2,xz-size(pic,2)/2+1:xz+size(pic,2)/2,:)=pic;


figure;
imagesc(pic_blk);
hold on;


for index=1:1500
   x=eyedata(index,1,ind2,ind1);
   y=eyedata(index,2,ind2,ind1);
   plot(x,y,'r*')


end
```

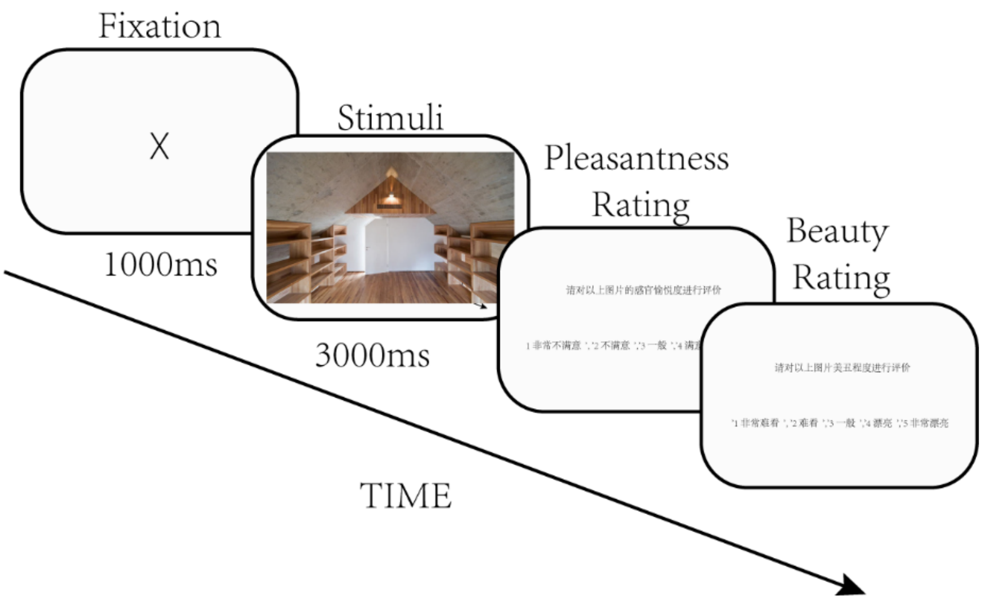


Figure 3-5 Experimental procedure.

3.2.5. Introduction to eye tracker

An eye tracker is a device that tracks and measures information on eye position and movement. It has been widely used in research on visual systems, psychology and cognitive linguistics.

The eye tracker works by directing near-infrared light towards the center of the eye (the pupil), causing detectable reflections in the pupil and cornea (the outermost optical element of the eye). These reflections—vectors between the cornea and pupil—are tracked by an infrared camera. This is an optical tracking of the corneal reflex called the pupil-centered corneal reflex (PCCR). Light from the visible spectrum can produce uncontrolled mirror reflections, while infrared light allows for a precise distinction between the pupil and iris—when light enters the pupil directly, it "bounces" off the iris. Another advantage of using this technique is that tracking the eyes does not cause a distraction because infrared light is invisible to humans.

The eye tracker uses a near-infrared light source to create a reflective image of the eye's cornea and pupil, which is then captured using two image sensors. The position of the eye in space and its line of sight are accurately calculated by an image processing algorithm and a 3-D eyeball model. Different indicators have been used in eye movement tracking studies:

Gaze Point: The gaze point is a basic unit of measurement corresponding to a raw sample captured by the eye tracker[3]. Fixation: Fixation occurs when the eye lingers on a particular object for relatively long a period of time. AOI (area of interest): An AOI may be used to help focus the analysis on a specific area of the stimulus. An AOI can be compared with other AOI if needed.

Heatmaps: Heatmaps are visualizations of fixed locations over time as a superposition of specific stimuli.Fixation sequences: Through detailed fixation sequences and direction tracing, researchers can track the subject first that draws the participant's attention and check the AOIs of the stimulus. TTFF (time to first fixation): The TTFF is the time between the appearance of the stimulus and the first fixation on an AOI within a limited area[3].

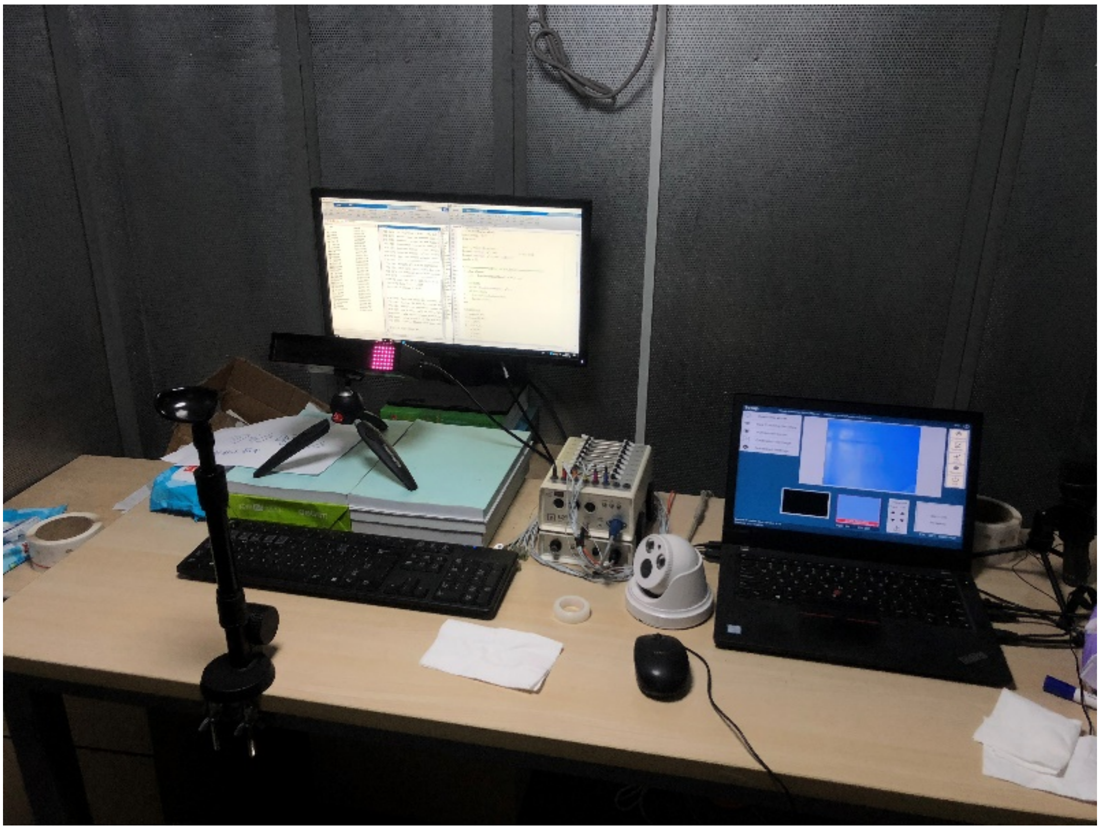


Figure 3-6 Experiments Settings

3.3. Data analysis

Table. 3-1 Three attribute types in each picture

Attribute	Factor	Value
Ceiling height	Low	0
	High	1
Degree of openness	Enclosed	0
	Open	1
Contour type	Rectilinear	0
	Curvilinear	1

To explore the effects of ceiling height, the degree of openness and contour type on the pleasure value and esthetic value, as well as possible interactive effects, a repeated measurement analysis of variance with three intragroup factors was used in this experiment.

First, the response scores from each group of 25 pictures were added up, and the result was an individual "repeated measurement" (the range was 25-125 points). Each individual responded to 8 groups of pictures, so there were 8 "repeated measurement" results. Finally, the scores of all individuals were taken as dependent variables, and the ceiling height, degree of openness and contour type were taken as intragroup factors, which were included in the repeated measurement variance model.

The repeated measurement variance model included three main effect terms: ceiling height, degree of openness and contour type main effect; three second-order interaction terms: ceiling height × degree of openness, degree of openness × contour type and ceiling height × contour type; and a third-order interaction term: ceiling height × degree of openness × contour type.

First, the total variation was decomposed according to the model, and an analysis of variance table was established to test whether the main effects and interaction effects of various factors were re statistically significant. If the third-order interaction term was statistically significant, then we carried out a simple-simple effect test to observe the influence of another factor on the dependent variable under the different experimental treatments of a combination of two factors. In addition, since the analysis of simple-simple effects in this study was part of the overall analysis of variance, there was no need for the additional correction of the p value (as a note, simple-simple effects do not per se need any form of p value adjustment because simple-simple effect analyses are still "omnibus F-tests").

To explore the relevance of the pleasure and esthetic value ratings, we added up the each person's ratings of 200 images (with a range of 200 to 1000 points total for each factor), produced scatter plots, and calculated correlation coefficients r and p values. Then, the responses of all of the subjects in the three trials were combined to create a scatter chart, and the overall correlation coefficients of the r and p values of the pleasure and esthetic value scores were calculated.

To study the influence of picture color and observation time on the final pleasure and esthetic value scores, in the third part of this paper, we take the three experiments as intergroup factors and incorporate them into the variance model of the first part; that is, we use ceiling height, the degree of openness and contour type as intragroup factors, the groups as intergroup factors, and the pleasure and esthetic value scores as response variables to re-establish the repeated measurement variance model.

This paper focuses on the fourth-order interaction of "group × degree of openness × contour type × ceiling height" to see whether the picture color and observation time had any influence on the pleasure and esthetic value scores in the different combinations of degree of openness × contour type × ceiling height.

If the fourth-order interaction term was statistically significant, a simple-simple effect test was carried out.If the difference between the three tests was statistically significant, then the Bonferroni method was used to compare the post hoc pairwise.

The data in this study were analyzed with the bruceR package and tidyverse package of R version 3.6.3, and Cronbach's $\alpha = 0.05$ (two-sided test).

3.4. Results

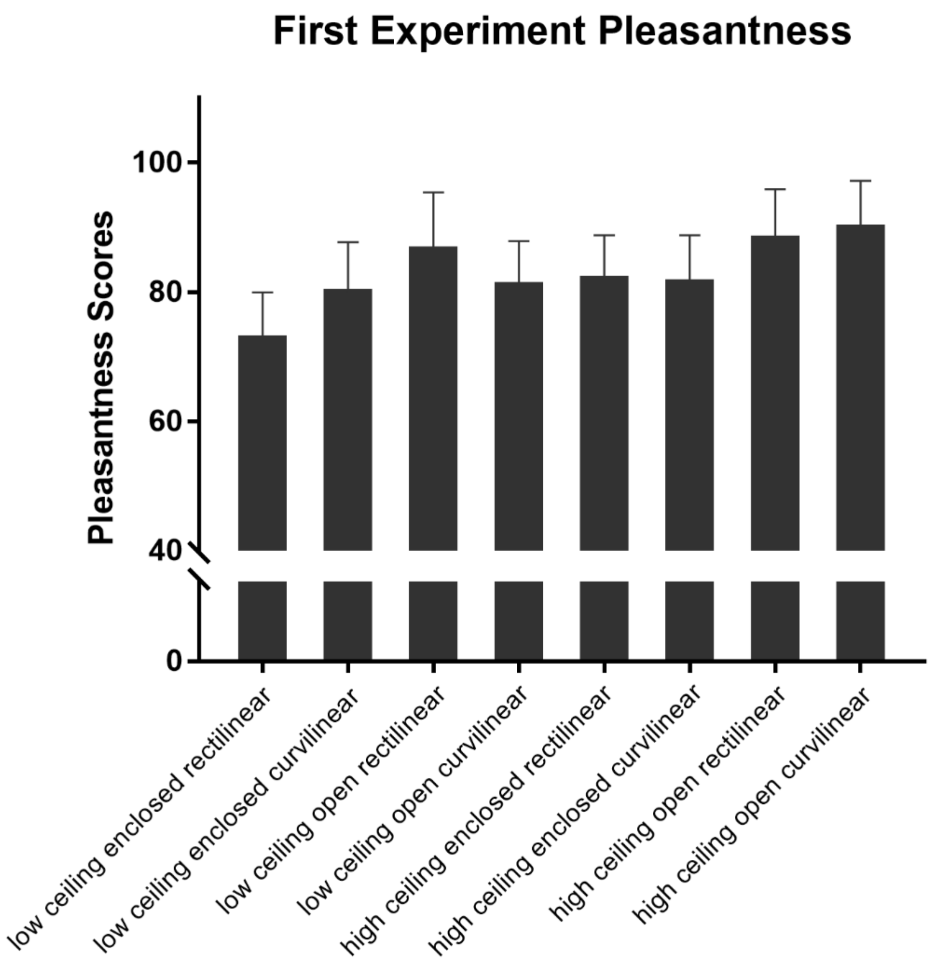


Figure 3-7 shows the pleasure value score given by each group in the first experiment.

The first digit of the abscissa represents the ceiling height, the second digit represents the degree of openness, and the third digit represents the contour type.

The ANOVA table shows that the main effects of the ceiling height and degree of openness were statistically significant, indicating that on the whole, pictures containing high ceilings were more likely to be pleasing ($F_{(1,28)}$=53.38, $p<0.001$), and pictures containing a high degree of openness were more likely to be pleasing ($F_{(1,28)}$=109, $p<0.001$).

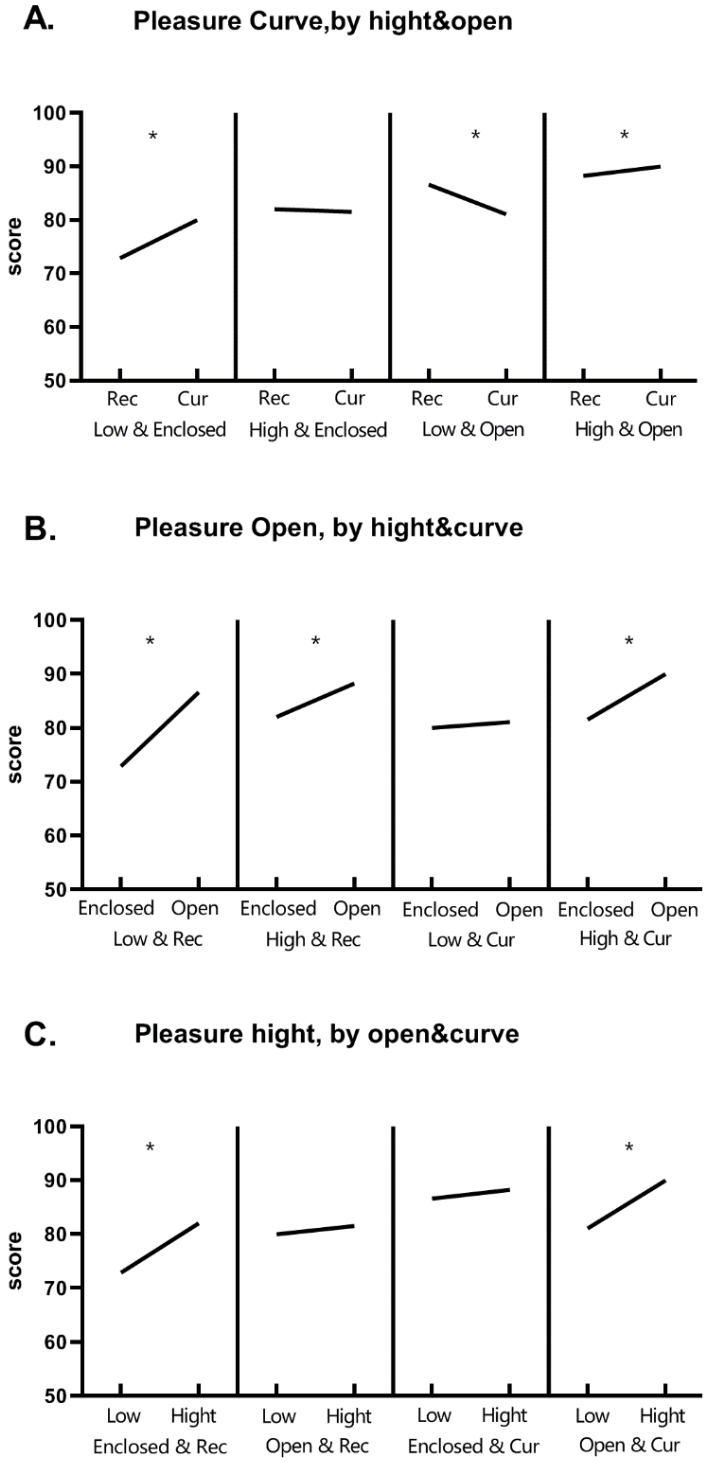
The third-order interaction between ceiling height, degree of openness and contour type was statistically significant, so a simple-simple effect analysis was then conducted.

Table.3-2 η^2p is partial ETA squared (partialη^2), is an effect quantity commonly used in the analysis of variance and represents the variance proportion of the dependent variable explained by a certain independent variable.

Factors	MS	*MSE*	df_1	df_2	*F*	*p*	η^2p	η^2p 90% CI
Ceiling height	1630.28	30.539	1	28	53.38	<0.001*	0.656	0.451～0.753
Degree of openness	3150.97	28.907	1	28	109	<0.001*	0.796	0.656～0.853
Contour type	29.694	12.792	1	28	2.32	0.139	0.077	0～0.253
Ceiling height×Degree of openness	0.108	10.706	1	28	0.01	0.921	0	0～0.03
Ceiling height×Contour type	0.349	13.358	1	28	0.03	0.873	0.001	0～0.059
Degree of openness×Contour type	390.522	17.173	1	28	22.74	<0.001*	0.448	0.205～0.598
Ceiling height×Degree of openness×Contour type	800.694	12.614	1	28	63.48	<0.001*	0.694	0.504～0.78

*$p<0.05$

Some scholars have suggested that the evaluation criteria of η^2p are small effect (≥ 0.01 and < 0.06), medium effect (≥ 0.06 and < 0.14), and large effect (≥ 0.14), but there is no unified evaluation standard at present. Usually, the effect is reported as 90% CI rather than 95% CI.



$p<0.05$

Figure 3-8 The influence of three building factors on the pleasure value score in the first experiment

A shows the main effect of contour type with different combinations of ceiling height and degree of openness.

B shows the main effect of the degree of openness with different combinations of ceiling height and contour type.

C shows the main effect of ceiling height with different combinations of contour type and degree of openness.

A shows that the main effect of contour type is not the same in different combinations of ceiling height and degree of openness. The specific results are as follows: when buildings are enclosed and have low ceilings or are open and have high ceilings, a curvilinear contour is more likely to be pleasing than a rectilinear contour, while in buildings that have low ceilings and a high degree of openness, rectilinear contours are more likely to be pleasing ($p < 0.05$); when buildings are enclosed and have high ceilings, there is no difference in the pleasure value based on contour type.

B shows that the main effect of the degree of openness is not the same with different combinations of ceiling height and contour type. The specific results are as follows: when buildings have low ceilings and rectilinear contours, high ceilings and rectilinear contours, or high ceilings and curvilinear contours, a high degree of openness is more likely to be pleasing than a low degree of openness ($p < 0.05$), but when buildings have low ceilings and curvilinear contours, there is no difference in the pleasure value with different degrees of openness.

C shows that the main effect of ceiling height differs with different combinations of contour type and degree of openness. Although a high ceiling was more likely than a low ceiling to be pleasing with all four combinations, only the enclosed building and rectilinear contour and the open building and curvilinear contour showed a statistically significant effect of ceiling height on pleasure value ($p<0.05$).

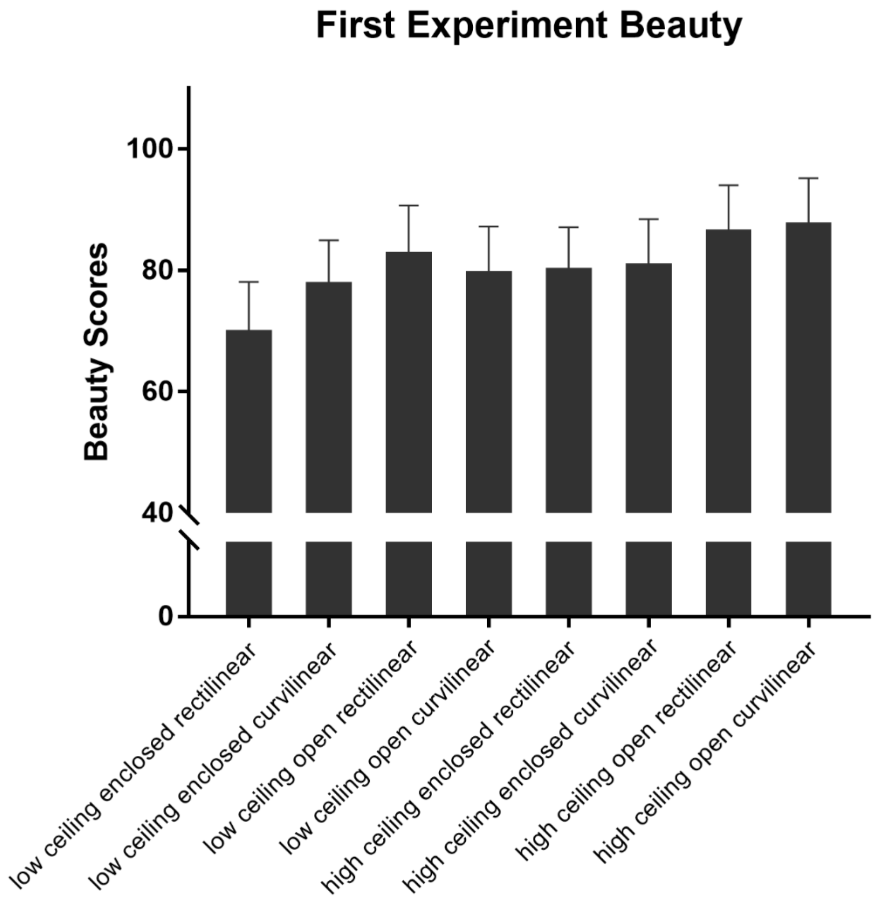


Figure 3-9 shows the pleasure value score given by each group in the first experiment.

The first digit of the abscissa represents the ceiling height , the second digit represents the degree of openness , and the third digit represents the contour type.

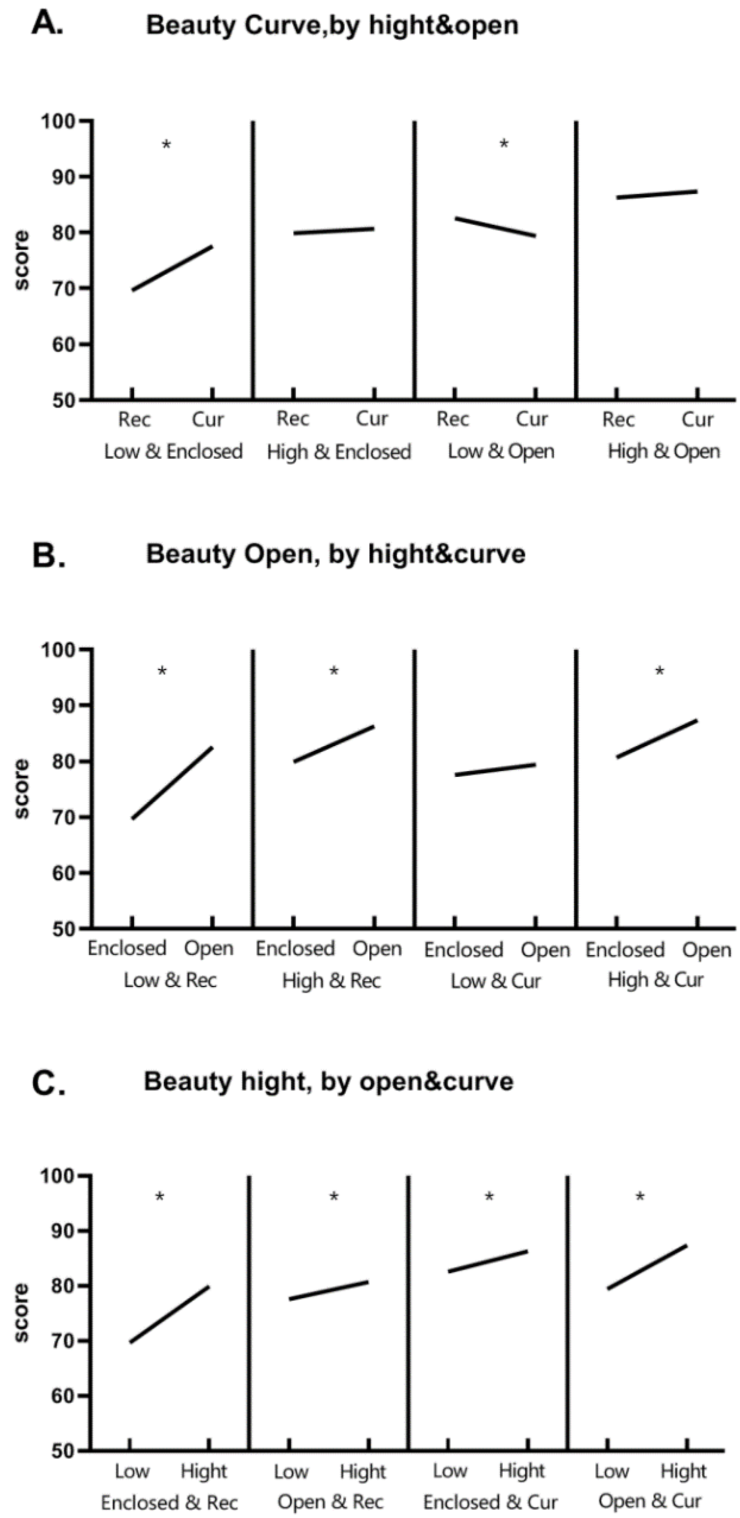
The ANOVA table shows that the main effects of ceiling height, openness and contour are statistically significant, indicating that pictures containing high ceiling are more likely to cause Beauty than pictures containing low ceiling（$F_{(1,28)}=75.05$, $p<0.001$）, Pictures containing open are more likely to cause Beauty than pictures containing enclosed（$F_{(1,28)}=94.3$, $p<0.001$）, Pictures containing curvilinear contour are more likely to cause Beauty than pictures containing rectilinear contour（$F_{(1,28)}=10.56$, $p=0.003<0.05$）. The third-order interaction between ceiling height, degree of openness and contour type was statistically significant, so a simple-simple effect analysis was then conducted.

Table.3-3 η^2p is partial ETA squared (partialη^2), is an effect quantity commonly used in the analysis of variance and represents the variance proportion of the dependent variable explained by a certain independent variable.

Factors	MS	*MSE*	*df1*	*df2*	*F*	*p*	*η^2p*	*η^2p 90% CI*
Ceiling height	2278.142	30.357	1	28	75.05	<.001	0.728	0.554～0.805
Degree of openness	2793.211	29.622	1	28	94.3	<.001	0.771	0.618～0.835
Contour type	157.246	14.889	1	28	10.56	0.003	0.274	0.064～0.456
Ceiling height × Degree of openness	10.349	8.581	1	28	1.21	0.281	0.041	0.000～0.201
Ceiling height × Contour type	29.694	9.158	1	28	3.24	0.083	0.104	0.000～0.287
Degree of openness × Contour type	422.28	11.298	1	28	37.38	<.001	0.572	0.342～0.691
Ceiling height × Degree of openness × Contour type	466.556	14.681	1	28	31.78	<.001	0.532	0.295～0.661

*$p<0.05$

Some scholars have suggested that the evaluation criteria of η^2p are small effect (≥ 0.01 and < 0.06), medium effect (≥ 0.06 and < 0.14), and large effect (≥ 0.14), but there is no unified evaluation standard at present. Usually, the effect is reported as 90% CI rather than 95% CI.



$*p<0.05$

Figure 3-10 The influence of three building factors on the beauty value score in the first experiment.

A shows the main effect of contour type with different combinations of ceiling height and degree of openness.

B shows the main effect of the degree of openness with different combinations of ceiling height and contour type.

C shows the main effect of ceiling height with different combinations of contour type and degree of openness.

A shows that the main effect of contour type differs with different combinations of ceiling height and degree of openness.

The specific results are as follows: when buildings have low ceilings and are enclosed, curvilinear contours are considered more to have higher esthetic value than rectilinear contours, while in buildings that are open and have low ceilings, rectilinear contours are considered to have higher esthetic value ($p < 0.05$); when buildings are enclosed and have high ceilings or open and have high ceilings, there is no difference in esthetic value of the different contour types.

B shows that the main effect of the degree of openness differs with different combinations of ceiling height and contour type.

The specific results are as follows: open buildings that have low ceilings and rectilinear contours, high ceilings and rectilinear contours, or high ceilings and curvilinear contours are considered to have higher esthetic value than enclosed buildings ($p < 0.05$), but when buildings have low ceilings and curvilinear contours, there is no difference in esthetic value with different degrees of openness.

C shows that the main effect of ceiling height differs with different combinations of contour type and degree of openness.

Although high ceilings can increase a building's esthetic value more than low ceilings in each of the four combinations ($p < 0.05$), the amount of that effect differs; that is, compared with that of open buildings with rectilinear contours and enclosed buildings with curvilinear contours, the esthetic value of enclosed buildings with rectilinear contours and open buildings with rectilinear contours is more affected by ceiling height.

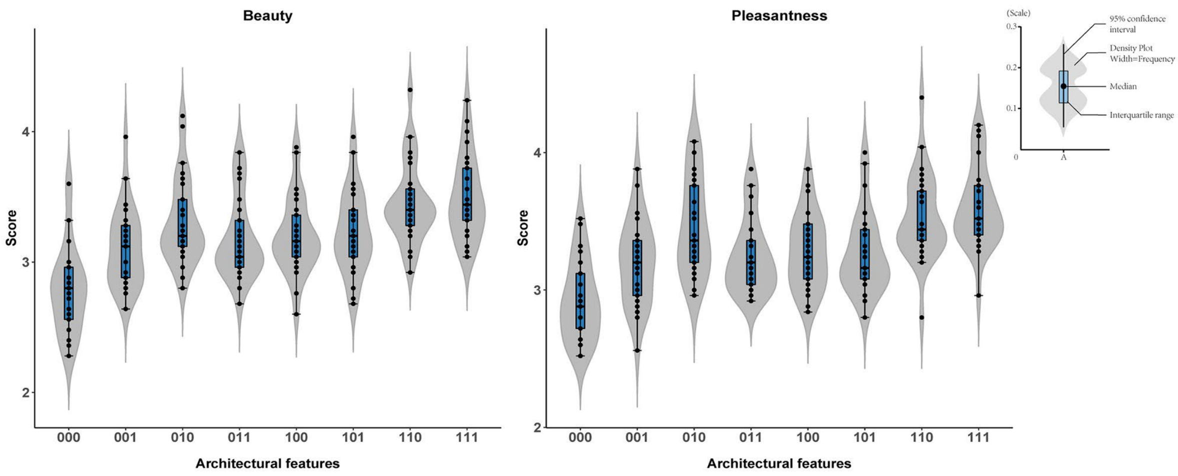


Figure 3-11 Beauty and pleasantness rating. The first digit in the x-axis represents the ceiling height, the second digit represents the degree of openness, and the third digit represents the contour type. In the violin plot, the box in the middle indicates the interquartile range, and the vertical line covers the 95%

3.5. Eye-tracking experiment

In the experiment, we tracked the eye movement path for each stimulus through the eye tracker, and we can clearly see how the subjects observed the architectural scene in the stimulus picture. the eye movement trajectory of two subjects for the same stimulus is shown in Fig. 3-1; we found that both subjects scanned the outline of the building but paid less attention to the rest of the building.

We collected the results of the first group of 29 subjects to make a thermal map of the eye movement data of the same stimulus and found that the subjects' attention was basically distributed along the building's contour. Thus, a very obvious contour within a relatively simple scene may have a certain eye-catching effect.

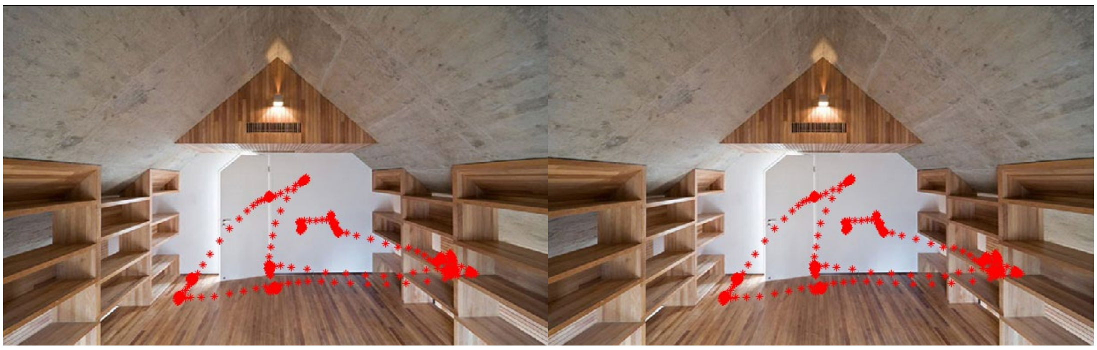


Fig. 3- 1 Eye movement track recording

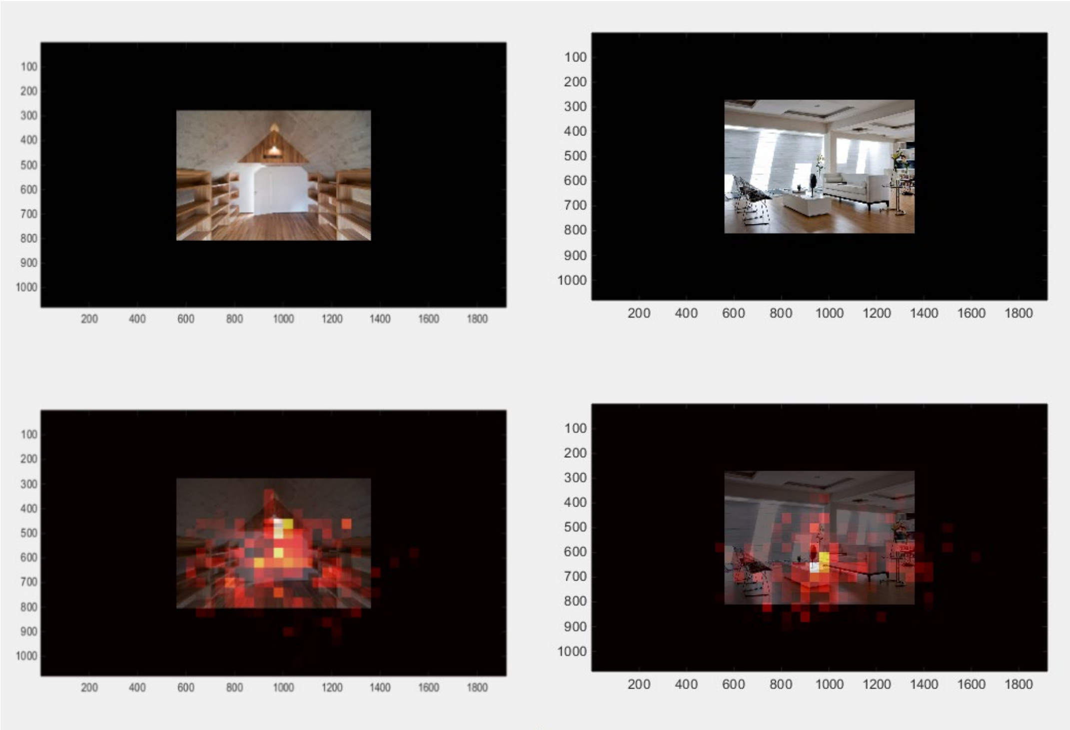


Fig. 3- 2 Eye movement experiment Heat map

Although it is difficult to obtain detailed explanations of the influence of ceiling height, degree of openness and contour type on human observation through eye movement data, we can still infer from the results of this study that a contour can guide one's vision through a limited architectural scene.

However, in a complex scene, there may be interference with the contour so that its line is broken, which will make the viewer pay more attention to identifying the details in the picture. Because the participants did not know the subject and purpose before the experiment, and when the contour line was interrupted or cut off, the focus of their gaze may have been scattered or drawn to the protruding objects in the picture.

Eye tracking devices are often used in Internet design to optimize the user interface because heat maps can analyze the optimal solution of various keys and blocks on a two-dimensional plane. Architectural design, however, is design in a three-dimensional space. In many cases, the importance of designing for the building to be viewed from any perspective or angle inside or outside the building is ignored. The movement of people inside the building is the focus of many designs. As people move from one space to another, the transition will leave people with a specific impression that requires a certain design, and then, they will slowly explore the whole space by moving within it until they stop somewhere. The stop is usually determined by the designer to be a sofa, table, chair, bed, bathing facility, etc. In these "stop" locations, people often remain at a fixed angle for a long time, and the scene they see needs to be optimized.

Many designers will use large swathes of glass to enhance the openness of the building or increase the ceiling height, and the contours are also determined by the designer. The fixed scene observed from the entrance or “stop” locations can be studied and optimized by eye movement experiments. Based on the judgment of the pleasure and esthetic values, we can synthesize the analysis of eye movement data to obtain an optimal combination of ceiling height, degree of openness and contour type and guide visual attention using design techniques to highlight or blur the contours’ effect. However, because there are many sources of interference in this experiment, not all details of the subjects' observations can be obtained in the pictures with cleaner or more interrupted contour lines. In the next experiment we hope to use a more limited stimulus picture so that the eye movement experiment can analyze the subjects' focus.

3.6. Conclusions

The current results suggest that Chinese observers prefer architectural space with high ceilings and open space. The preference to curvilinear contours interacts with ceiling heights and openness. The preference to high ceilings, open space, and curvilinear contours has also been shown for Western observers **[2, 5, 6]**. Since the current study only employs Chinese observers as the participant, it cannot quantify whether the preference to architectural features varies across cultures. The current study find that the preference to curvilinear contours depends on the ceiling height and openness of the space. Future studies are needed to test whether Western observers also prefer curvilinear contours only when the ceiling is low and the space is enclosed. Although previous studies have not analyzed how the preference to contour relies on ceiling height and space openness, a recent study has shown that experience can strongly modulate preference to curvilinear contours**[6]**. The study shows that, within the Western culture, self-identified architects and designers show stronger preference to curvilinear contours than non-experts. In sum, combing the current results and previous results **[2, 5, 6]**, it is shown that human observers prefer high ceilings and open space, and also prefer curvilinear contours in some conditions.

Reference

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Chapter 4

THE INFLUENCE OF VIEWING TIME AND COLOR ON ARCHITECTURAL AESTHETIC JUDGMENT

CHAPTER FOUR: THE INFLUENCE OF VIEWING TIME AND COLOR ON ARCHITECTURAL AESTHETIC JUDGMENT

4.1 Contents

Humans can quickly and accurately understand real-world scenes and complete multiple scans per second in complex scenes. Some experiments used rapid picture changes as stimuli, while others provided multiple choice responses to judge after a simple display of pictures. However, in the short stimulus experiments (27-40 ms), the subjects' perception of the pleasurable and aesthetic value of the architecture was evident**[1]**. Thus, it was hypothesized that people could judge architectural pictures very quickly, even if the exposure time was short, and that changes in architectural features would have an impact on such judgments. Because the complexity of the pictures used for stimuli may vary, the characteristics of the pictures may influence the aesthetic judgments of the subjects in the experiment. This chapter attempts to explore whether changing the presentation time of architectural pictures affects aesthetic judgments. In addition to this, the use of warm and cool colors in interiors is considered positive, while achromatic colors are considered negative**[1]**, and we use grayscale versions of the same pictures to explore the effect of color on subjects' judgments

4.2. Methodology

4.2.1. Participants and Exclusion criteria

The participants in this study were students at Zhejiang University. They were all right-handed and had no visual impairment or colorblindness. All participants had normal or corrected-to-normal vision and no history of psychosis or neuropathy. The experimental procedure was approved by the Research Ethics Committee of Zhejiang University School of Medicine. All participants signed written informed consent forms before the experiment and received a monetary reward after completing the experiment. A total of 42 participants were recruited. For the condition presenting colorful images, 21 participants were recruited, including 15 males (aged 23.13 $\pm$ 2.00 years) and 6 females (aged 23.33 $\pm$ 2.25 years). For the condition presenting grayscale images, 21 participants were recruited, including 9 males (aged 22.89 $\pm$ 1.90 years) and 12 females (aged 22.25 $\pm$ 1.60 years).

4.2.2. Stimulus material

The stimuli for this study consisted of 200 photographs of architectural spaces. The stimuli were culled from larger architectural image databases available from the L.B.F. at the Department of Architecture, Design, and Media Technology at the University of Aalborg, Denmark and to N.R. at The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, School of Architecture **[3]**.

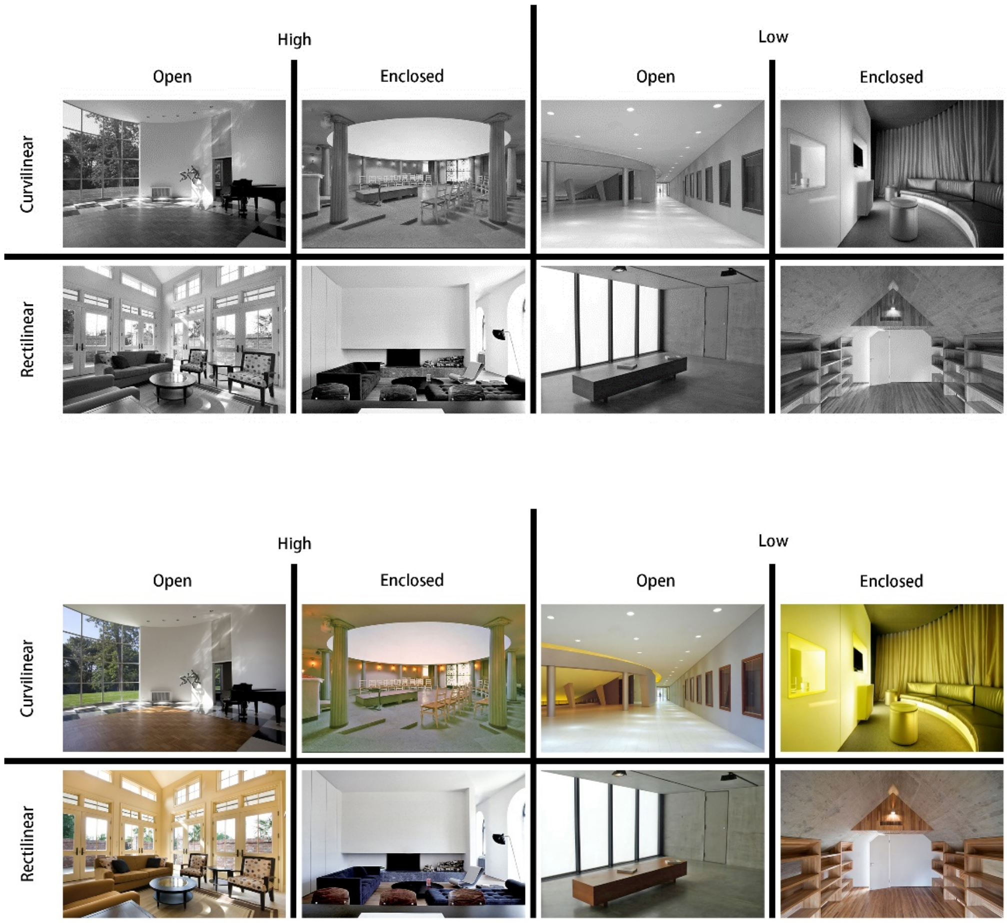


Figure 4-1 A total of 200 pictures were divided into 8 groups of 25 pictures each. Each picture contained 3 notable aspects: ceiling height, degree of openness and contour type

4.2.3. Experimental procedure

Stimulus time and color-gray experiments were conducted in a soundproof room used for professional psychological experiments with a display screen and a keyboard on the table. The display screen was used to show the questions and pictures for the experiment. The keyboard was used to initiate the test and record the responses. The keys for numbers 1 through 5 (on the left-hand side of the keyboard) were used to indicate the subject's answer. The 0 key (on the right-hand side of the keyboard) was used to initiate the test. The subjects pressed 0 to start the test after the staff member left the soundproof room.The software was an experimental program prepared for MATLAB 2018.

The subjects in the Stimulus time experiment comprised 21 students from Zhejiang University, including 15 males (23.13 ±2.00) and 6 females (23.33 ±2.25), pursuing undergraduate (4), master's (10), and doctorate (7) degrees.

The Stimulus time experiment used a total of 200 architectural pictures spread across eight groups, each with three distinct properties (1-ceiling height; 2-degree of openness; 3-contour type).

The subjects looked at the "×" symbol in the center of the screen for 1000 ms, and then a random stimulus picture was displayed for 200 ms. When the stimulus disappeared, two scoring questions in the subject's mother tongue regarding the pleasure and esthetic value of the image were displayed, with responses ranging from 1, meaning very unpleasant (unaesthetic) to 5, meaning very pleasant (beautiful). The total duration of the experiment was approximately 15-25 minutes.

The color-gray experiment had 21 subjects, who were students from Zhejiang University, including 9 males (22.89±1.90) and 12 females (22.25±1.60) pursuing undergraduate (10), master's (7), and doctorate (4) degrees. The color-gray experiment used a total of 200 grayscale architectural pictures arranged in eight groups, each with three distinct properties (1-ceiling height; 2-degree of openness; 3-contour type). The subjects looked at the "×" symbol in the center of the screen for 1000 ms, and then a random stimulus picture was displayed for 200 ms. When the stimulus disappeared, two scoring questions in the subject's mother tongue regarding the pleasure and esthetic value of the image were displayed, with responses ranging from 1, meaning very unpleasant (unaesthetic) to 5, meaning very pleasant (beautiful). The total duration of the experiment was approximately 15-25 minutes.

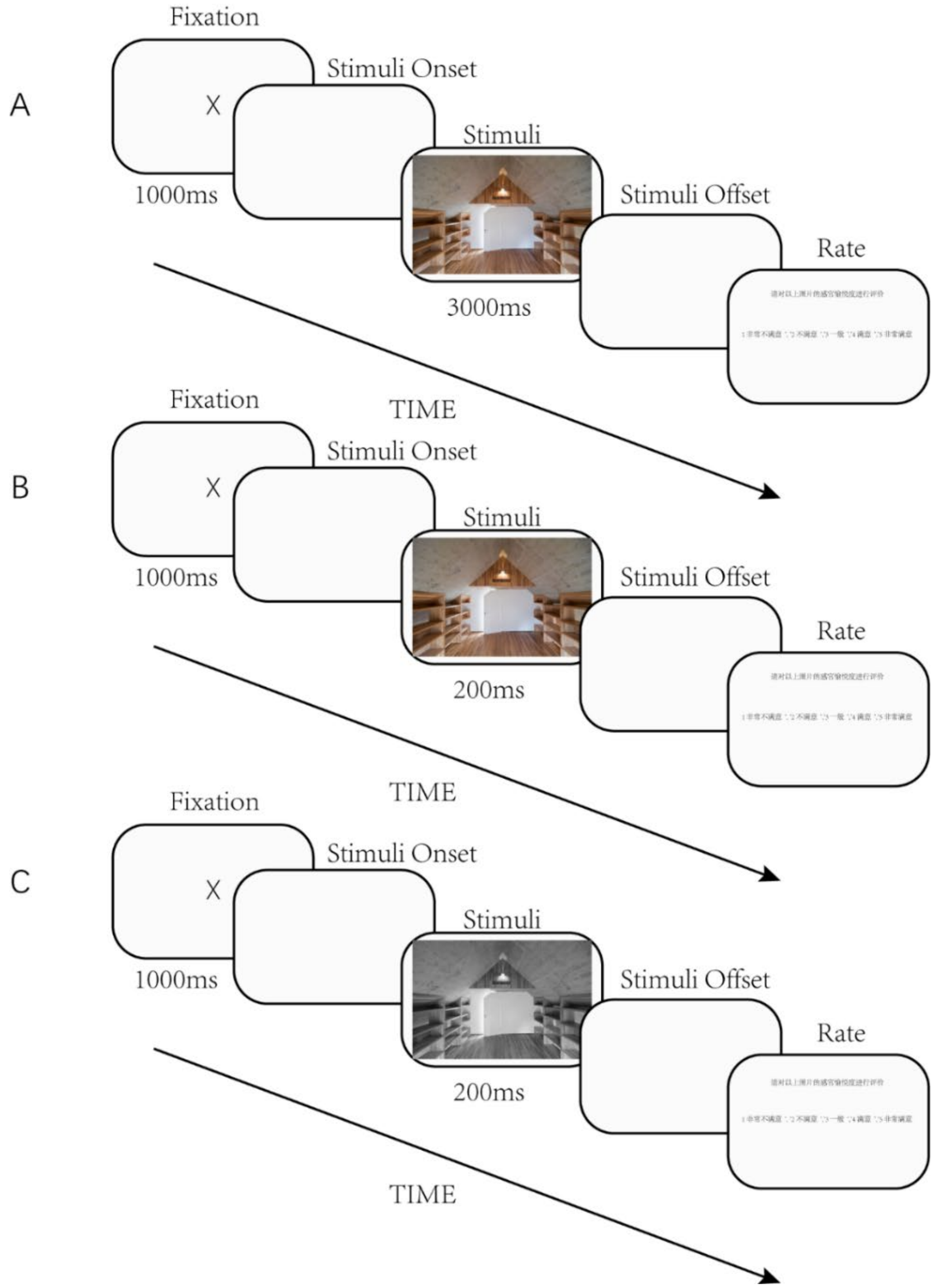


Figure 4-2 Illustration of the experimental procedure.

Table. 4- 1 Three attribute types in each picture

Attribute	Factor	Value
Ceiling height	Low	0
	High	1
Degree of openness	Enclosed	0
	Open	1
Contour type	Rectilinear	0
	Curvilinear	1

To explore the effects of ceiling height, the degree of openness and contour type on the pleasure value and esthetic value, as well as possible interactive effects, a repeated measurement analysis of variance with three intragroup factors was used in this experiment.

First, the response scores from each group of 25 pictures were added up, and the result was an individual "repeated measurement" (the range was 25-125 points). Each individual responded to 8 groups of pictures, so there were 8 "repeated measurement" results. Finally, the scores of all individuals were taken as dependent variables, and the ceiling height, degree of openness and contour type were taken as intragroup factors, which were included in the repeated measurement variance model.

The repeated measurement variance model included three main effect terms: ceiling height, degree of openness and contour type main effect; three second-order interaction terms: ceiling height × degree of openness, degree of openness × contour type and ceiling height × contour type; and a third-order interaction term: ceiling height × degree of openness × contour type.

First, the total variation was decomposed according to the model, and an analysis of variance table was established to test whether the main effects and interaction effects of various factors were re statistically significant. If the third-order interaction term was statistically significant, then we carried out a simple-simple effect test to observe the influence of another factor on the dependent variable under the different experimental treatments of a combination of two factors. In addition, since the analysis of simple-simple effects in this study was part of the overall analysis of variance, there was no need for the additional correction of the p value (as a note, simple-simple effects do not per se need any form of p value adjustment because simple-simple effect analyses are still "omnibus F-tests").

To explore the relevance of the pleasure and esthetic value ratings, we added up the each person's ratings of 200 images (with a range of 200 to 1000 points total for each factor), produced scatter plots, and calculated correlation coefficients r and p values. Then, the responses of all of the subjects in the three trials were combined to create a scatter chart, and the overall correlation coefficients of the r and p values of the pleasure and esthetic value scores were calculated.

To study the influence of picture color and observation time on the final pleasure and esthetic value scores, in the third part of this paper, we take the three experiments as intergroup factors and incorporate them into the variance model of the first part; that is, we use ceiling height, the degree of openness and contour type as intragroup factors, the groups as intergroup factors, and the pleasure and esthetic value scores as response variables to re-establish the repeated measurement variance model.

This paper focuses on the fourth-order interaction of "group × degree of openness × contour type × ceiling height" to see whether the picture color and observation time had any influence on the pleasure and esthetic value scores in the different combinations of degree of openness × contour type × ceiling height.

If the fourth-order interaction term was statistically significant, a simple-simple effect test was carried out.If the difference between the three tests was statistically significant, then the Bonferroni method was used to compare the post hoc pairwise.

The data in this study were analyzed with the bruceR package and tidyverse package of R version 3.6.3, and Cronbach's $\alpha = 0.05$ (two-sided test).

The code used for the experiment is as follows：

```
cwd = 'E:\Study_master';

Type=dec2bin(0:7,3);

for type_ind=1:length(Type)
```

```
        picpath_tmp=([cwd '\' Type(type_ind,:) '\']);
        pic_all_tmp = dir(fullfile(picpath_tmp,'*.jpg'));
        for pic_ind=1:length(pic_all_tmp)
            pic{pic_ind,type_ind} = imread([picpath_tmp, pic_all_tmp(pic_ind).name]);
            pic_index(pic_ind,type_ind)=str2double(Type(type_ind,:))*100+pic_ind;
        end
    end
    save Pic_set pic pic_index
    subj_num=1:42;
    for subj_ind=1:length(subj_num)
        load(['./Mat/' num2str(subj_num(subj_ind)) '_' num2str(subj_num(subj_ind)) '.mat'])
        for result_ind=1:length(result)
            HL(result_ind,subj_ind)=result(result_ind).condition1;
            OC(result_ind,subj_ind)=result(result_ind).condition2;
            ER(result_ind,subj_ind)=result(result_ind).condition3;
            Num(result_ind,subj_ind)=result(result_ind).Num;

            Please(result_ind,subj_ind)=result(result_ind).pleasantness;
            Beauty(result_ind,subj_ind)=result(result_ind).beauty;
        end


Pic_Index_tmp=HL(:,subj_ind)*10000+OC(:,subj_ind)*1000+ER(:,subj_ind)*100+Num(:,subj_i
nd)*1;
        Pic_please_tmp=Please(:,subj_ind);
        Pic_beauty_tmp=Beauty(:,subj_ind);
```

```
    [Pic_Index_tmp2,index2]=sort(Pic_Index_tmp,'ascend');
    Pic_please_tmp2=Pic_please_tmp(index2);
    Pic_beauty_tmp2=Pic_beauty_tmp(index2);
    %1, PIC_num; 2, please; 3, beauty;
    Pic(:,1,subj_ind)=Pic_Index_tmp2;
    Pic(:,2,subj_ind)=Pic_please_tmp2;
    Pic(:,3,subj_ind)=Pic_beauty_tmp2;
end
Pic_index_rest=Pic(:,1,1);
Please_H=squeeze(Pic(Pic_index_rest>10000,2,:));
Please_L=squeeze(Pic(Pic_index_rest<10000,2,:));
Please_O=squeeze(Pic(rem(Pic_index_rest,10000)>1000,2,:));
Please_C=squeeze(Pic(rem(Pic_index_rest,10000)<1000,2,:));
Please_E=squeeze(Pic(rem(Pic_index_rest,1000)>100,2,:));
Please_R=squeeze(Pic(rem(Pic_index_rest,1000)<100,2,:));
Beauty_H=squeeze(Pic(Pic_index_rest>10000,3,:));
Beauty_L=squeeze(Pic(Pic_index_rest<10000,3,:));
Beauty_O=squeeze(Pic(rem(Pic_index_rest,10000)>1000,3,:));
Beauty_C=squeeze(Pic(rem(Pic_index_rest,10000)<1000,3,:));
Beauty_E=squeeze(Pic(rem(Pic_index_rest,1000)>100,3,:));
Beauty_R=squeeze(Pic(rem(Pic_index_rest,1000)<100,3,:));
figure(100);
%type_num: 1 color; 0 black;
type_num=2;
```

```
x1=[1 2];
x2=[4 5];
color1=[1 0.4 0.4;0.4 0.4 0.4];
for type_ind=1:type_num
    subplot(231);bar_errorbar_func(x1(type_ind),mean(Please_H(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
    hold on;bar_errorbar_func(x2(type_ind),mean(Please_L(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
    set(gca,'xticklabel',{'high','low'})
    title('ceiling')
    ylabel(' Please ')

    subplot(232);bar_errorbar_func(x1(type_ind),mean(Please_O(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
    hold on;bar_errorbar_func(x2(type_ind),mean(Please_C(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
    set(gca,'xticklabel',{'open','enclosed'})
    title('openness')

    subplot(233);bar_errorbar_func(x1(type_ind),mean(Please_E(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
    hold on;bar_errorbar_func(x2(type_ind),mean(Please_R(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
    set(gca,'xticklabel',{'cur','rec'})
    title('contour')
```

```
subplot(234);bar_errorbar_func(x1(type_ind),mean(Beauty_H(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
hold on;bar_errorbar_func(x2(type_ind),mean(Beauty_L(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
ylabel(' Beauty ')
set(gca,'xticklabel',{'high','low'})
title('ceiling')


subplot(235);bar_errorbar_func(x1(type_ind),mean(Beauty_O(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
hold on;bar_errorbar_func(x2(type_ind),mean(Beauty_C(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
set(gca,'xticklabel',{'open','enclosed'})
title('openness')



subplot(236);h1(type_ind)=bar_errorbar_func(x1(type_ind),mean(Beauty_E(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
hold on;bar_errorbar_func(x2(type_ind),mean(Beauty_R(:,(1:21)+21*(type_ind-1)),1),color1(type_ind,:));
set(gca,'xticklabel',{'Rec','Cur'})
title('contour')
end
legend(h1,{'color','black'})


figure;
subplot(221)
Please=squeeze(Pic(:,2,:));
```

```
Please_cc=corr(Please);

imagesc(Please_cc-Please_cc.*eye(size(Please_cc)));

caxis([0,0.5])

title(' Please ')


for rand_ind=1:1000

    for subj_ind=1:size(Please,2)

        please_rand_tmp(:,subj_ind)=Please(randperm(size(Please,1)),subj_ind);

    end

    Please_cc_rand(:,:,rand_ind)=corr(please_rand_tmp);

end

subplot(223)

Please_cc_rand_mean=mean(Please_cc_rand,3);

imagesc(Please_cc_rand_mean-Please_cc_rand_mean.*eye(size(Please_cc_rand_mean)));

caxis([0,0.5])

title(' Please -shuffle')

subplot(222)

Beauty=squeeze(Pic(:,3,:));

Beauty_cc=corr(Beauty);

imagesc(Beauty_cc-Beauty_cc.*eye(size(Beauty_cc)));

caxis([0,0.5])

title(' Beauty ')

for rand_ind=1:1000

    for subj_ind=1:size(Beauty,2)

        Beauty_rand_tmp(:,subj_ind)=Beauty(randperm(size(Beauty,1)),subj_ind);
```

```
    end
    Beauty_cc_rand(:,:,rand_ind)=corr(Beauty_rand_tmp);
end
subplot(224)
Beauty_cc_rand_mean=mean(Beauty_cc_rand,3);
imagesc(Beauty_cc_rand_mean-Beauty_cc_rand_mean.*eye(size(Beauty_cc_rand_mean)));
caxis([0,0.5])
title(' Beauty -shuffle')
Pic_mean=mean(Pic,3);
[max_value,max_index]=max(Pic_mean,[],1);
[~,please_index]=sort(Pic_mean(:,2),'descend');
Pic_mean_please=Pic_mean(please_index,:);
[~,beauty_index]=sort(Pic_mean(:,3),'descend');
Pic_mean_beauty=Pic_mean(beauty_index,:);
load('Pic_set.mat', 'pic_index', 'pic')
for pic_ind=1:length(Pic_mean_beauty)
    if mod(pic_ind,50)==1
        figure
    end
    pic_index_tmp=Pic_mean_beauty(pic_ind,1);
    score_tmp=Pic_mean_beauty(pic_ind,3);
    plot_index=mod(pic_ind,50);
    if plot_index==0
        plot_index=50;
    end
```

```
        subplot(5,10,plot_index)
        [i_tmp,j_tmp]=find(pic_index==pic_index_tmp);
        pic_tmp=pic{i_tmp,j_tmp};
        imshow(pic_tmp)
        title(pic_index_tmp)
        imwrite(pic_tmp,['./Pic_Score_BeautySort/' num2str(pic_ind) '_' num2str(round(score_tmp*100)) '.jpg'])
    end
    for pic_ind=1:length(Pic_mean_please)
        if mod(pic_ind,50)==1
            figure
        end
        pic_index_tmp=Pic_mean_please(pic_ind,1);
        score_tmp=Pic_mean_please(pic_ind,2);
        plot_index=mod(pic_ind,50);
        if plot_index==0
            plot_index=50;
        end
        subplot(5,10,plot_index)
        [i_tmp,j_tmp]=find(pic_index==pic_index_tmp);
        pic_tmp=pic{i_tmp,j_tmp};
        imshow(pic_tmp)
        title(pic_index_tmp)
        imwrite(pic_tmp,['./Pic_Score_PleaseSort/' num2str(pic_ind) '_' num2str(round(score_tmp*100)) '.jpg'])
    end
```

```
subj_num=1:42;
for subj_ind=1:length(subj_num)
    load(['./Mat/' num2str(subj_num(subj_ind)) '_' num2str(subj_num(subj_ind)) '.mat'])
    for result_ind=1:length(result)
        HL(result_ind,subj_ind)=result(result_ind).condition1;
        OC(result_ind,subj_ind)=result(result_ind).condition2;
        ER(result_ind,subj_ind)=result(result_ind).condition3;
        pleasantness_tmp=result(result_ind).pleasantness;
        Please(result_ind,subj_ind)=pleasantness_tmp(1);
        beauty_tmp=result(result_ind).beauty;
        Beauty(result_ind,subj_ind)=beauty_tmp(1);
    end
    Please_H(:,subj_ind)=Please(HL(:,subj_ind)==1,subj_ind);
    Please_L(:,subj_ind)=Please(HL(:,subj_ind)==0,subj_ind);
    Please_O(:,subj_ind)=Please(OC(:,subj_ind)==1,subj_ind);
    Please_C(:,subj_ind)=Please(OC(:,subj_ind)==0,subj_ind);
    Please_E(:,subj_ind)=Please(ER(:,subj_ind)==1,subj_ind);
    Please_R(:,subj_ind)=Please(ER(:,subj_ind)==0,subj_ind);
    Beauty_H(:,subj_ind)=Beauty(HL(:,subj_ind)==1,subj_ind);
    Beauty_L(:,subj_ind)=Beauty(HL(:,subj_ind)==0,subj_ind);
    Beauty_O(:,subj_ind)=Beauty(OC(:,subj_ind)==1,subj_ind);
    Beauty_C(:,subj_ind)=Beauty(OC(:,subj_ind)==0,subj_ind);
    Beauty_E(:,subj_ind)=Beauty(ER(:,subj_ind)==1,subj_ind);
    Beauty_R(:,subj_ind)=Beauty(ER(:,subj_ind)==0,subj_ind);
end
```

```
figure;
subplot(231);bar_errorbar_func(1,mean(Please_H,1),[0.6 0.2 0.2],0.8);
hold on;bar_errorbar_func(3,mean(Please_L,1),[0.2 0.2 0.2],0.8);
set(gca,'xtick',[1,3])
set(gca,'xticklabel',{'high','low'})
title('ceiling')
ylabel(' Please ')
subplot(232);bar_errorbar_func(1,mean(Please_O,1),[0.6 0.2 0.2],0.8);
hold on;bar_errorbar_func(3,mean(Please_C,1),[0.2 0.2 0.2],0.8);
set(gca,'xticklabel',{'open','enclosed'})
title('openness')
subplot(233);bar_errorbar_func(1,mean(Please_E,1),[0.6 0.2 0.2],0.8);
hold on;bar_errorbar_func(3,mean(Please_R,1),[0.2 0.2 0.2],0.8);
set(gca,'xticklabel',{'cur','rec'})
title('contour')
subplot(234);bar_errorbar_func(1,mean(Beauty_H,1),[0.6 0.2 0.2],0.8);
hold on;bar_errorbar_func(3,mean(Beauty_L,1),[0.2 0.2 0.2],0.8);
ylabel(' Beauty ')
set(gca,'xticklabel',{'high','low'})
title('ceiling')
subplot(235);bar_errorbar_func(1,mean(Beauty_O,1),[0.6 0.2 0.2],0.8);
hold on;bar_errorbar_func(3,mean(Beauty_C,1),[0.2 0.2 0.2],0.8);
set(gca,'xticklabel',{'open','enclosed'})
title('openness')
subplot(236);bar_errorbar_func(1,mean(Beauty_E,1),[0.6 0.2 0.2],0.8);
```

```
hold on;bar_errorbar_func(3,mean(Beauty_R,1),[0.2 0.2 0.2],0.8);
set(gca,'xticklabel',{'cur','rec'})
title('contour')
```

4.3. Data analysis

4.3.1. 200ms picture stimulation experiment data analysis

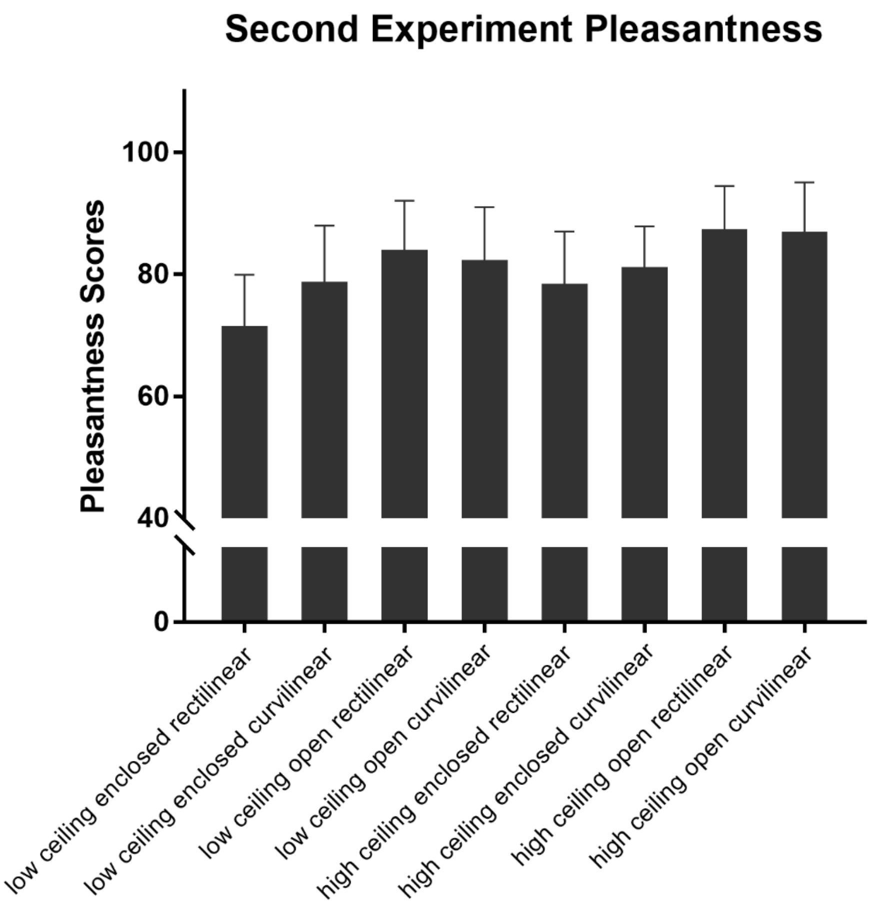


Figure 4-3 shows the pleasure value score given by each group in Stimulus time experiment.

The first digit of the abscissa represents the ceiling height , the second digit represents the degree of openness , and the third digit represents the contour type.

The ANOVA table showed that the main effects of, ceiling height, openness and contour were statistically significant, indicating that on the whole, pictures containing high ceiling were more likely to cause pleasure than pictures containing low ceiling（$F_{(1,20)}=21.39$, $p<0.001$）, and pictures containing open were more likely to cause pleasure than pictures containing closed（$F_{(1,20)}=75.11$, $p<0.001$）。Pictures containing curvilinear are more likely to cause Pleasure than pictures containing rectilinear（$F_{(1,20)}$=8.32, $p=0.009<0.05$）The third-order interaction between ceiling height, degree of openness and contour type was statistically significant, so a simple-simple effect analysis was then conducted.

Table 4-2 η^2p is partial ETA squared (partialη^2), is an effect quantity commonly used in the analysis of variance and represents the variance proportion of the dependent variable explained by a certain independent variable.

Factors	MS	*MSE*	*df1*	*df2*	*F*	*p*	*η^2p*	*η^2p 90% CI*
Ceiling height	733.339	34.289	1	20	21.39	<0.001	0.517	0.228～0.665
Degree of openness	2355.006	31.356	1	20	75.11	<0.001	0.79	0.606～0.855
Contour type	166.006	19.956	1	20	8.32	0.009	0.294	0.047～0.497
Ceiling height × Degree of openness	2.149	9.474	1	20	0.23	0.639	0.011	0.000～0.163
Ceiling height × Contour type	43.006	15.381	1	20	2.8	0.11	0.123	0.000～0.338
Degree of openness × Contour type	363.149	13.374	1	20	27.15	<0.001	0.576	0.295～0.707
Ceiling height ×Degree of openness × Contour type	87.149	16.949	1	20	5.14	0.035	0.205	0.008～0.420

*$p<0.05$

Some scholars have suggested that the evaluation criteria of η^2p are small effect (≥ 0.01 and < 0.06), medium effect (≥ 0.06 and < 0.14), and large effect (≥ 0.14), but there is no unified evaluation standard at present. Usually, the effect is reported as 90% CI rather than 95% CI.

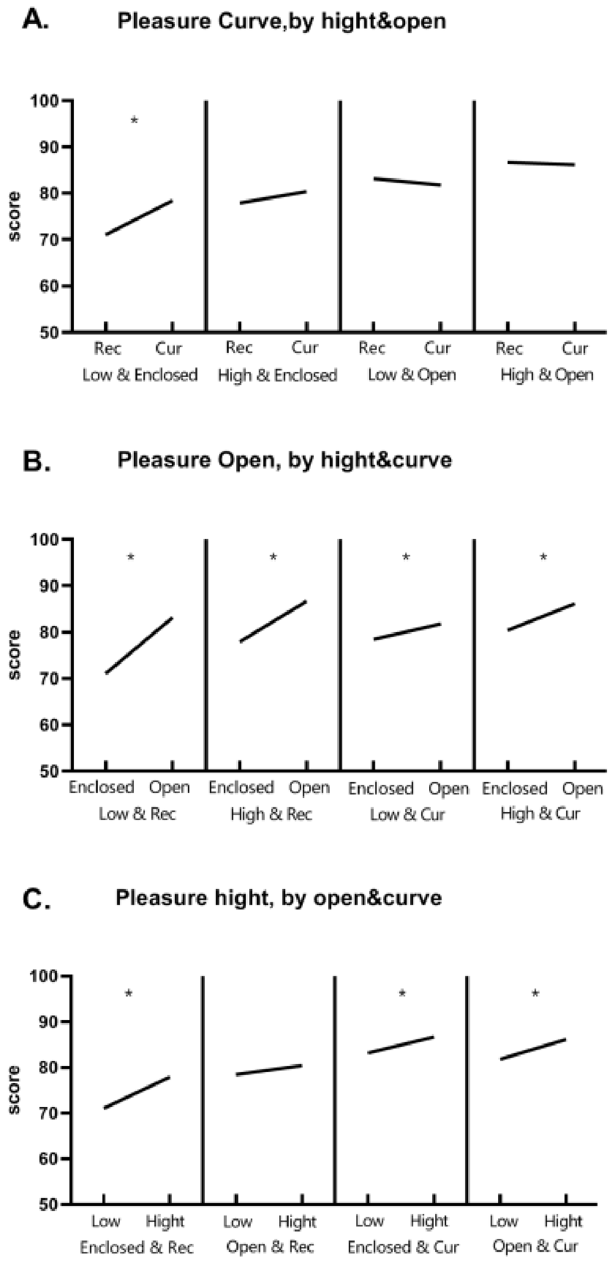


Figure 4-4 The influence of three building factors on pleasure value score in the Stimulus time experiment.

A shows the main effect of the contour type with different combinations of ceiling height and degree of openness.
B shows the main effect of the degree of openness with different combinations of ceiling height and

contour type.
C shows the main effect of ceiling height with different combinations of contour type and degree of openness.
A shows that the main effect of contour type differs with different combinations of ceiling height and degree of openness.

The specific results are as follows: when buildings are enclosed and have low ceilings, curvilinear contours are more likely to be pleasing than rectilinear contours ($p<0.05$); however, there is no difference in the pleasure value of different contour types in enclosed buildings with high ceilings, open buildings with high ceilings, and open buildings with low ceilings.

B shows that the main effect of the degree of openness differs with different combinations of ceiling height and contour type.Although open buildings is more likely to be pleasing than enclosed building in all four combinations ($p<0.05$), the degree of the effect is different; that is, compared with that of buildings with low ceilings and curvilinear contours and buildings with high ceilings and curvilinear contours, the pleasure value of buildings with low ceilings and rectilinear contours and buildings with high ceilings and rectilinear contours is more affected by ceiling height.

C shows that the main effect of ceiling height differs with different combinations of contour type and degree of openness. Although buildings with high ceilings are more likely to be pleasing than buildings with low ceilings in each of the four combination, when buildings are open and have rectilinear contours, the effect of ceiling height on pleasure value is not statistically significant ($p>0.05$).

The effects of the other three items, including an enclosed building with rectilinear contours, enclosed building with curvilinear contours, and open building with curvilinear contours, on pleasure value were statistically significant.

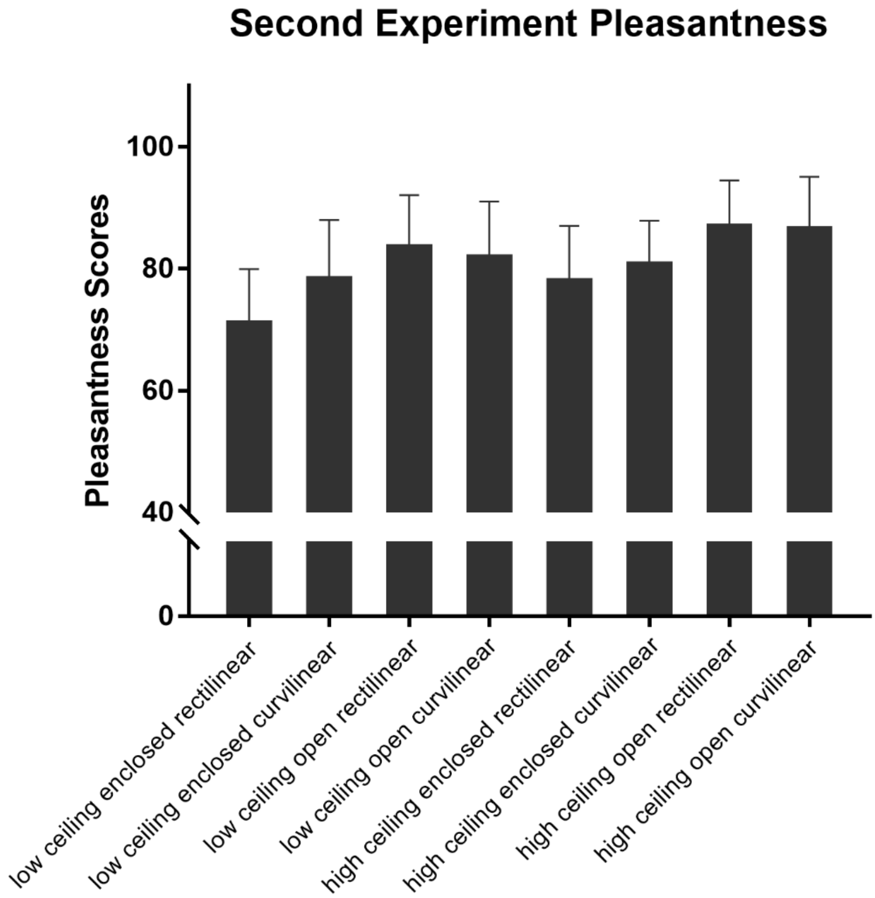


Figure 4-5 shows the pleasure value score given by each group in Stimulus time experiment.

The first digit of the abscissa represents the ceiling height , the second digit represents the degree of openness , and the third digit represents the contour type.

The ANOVA table showed that the main effects of, ceiling height, openness and contour were statistically significant, indicating that on the whole, pictures containing high ceiling were more likely to cause beauty than pictures containing low ceiling（$F_{(1,20)}=17.95$, $p<0.001$）. And pictures containing open were more likely to cause beauty than pictures containing closed（$F_{(1,20)}=62.18$, $p<0.001$）.Pictures containing curvilinear are more likely to cause beauty than pictures containing rectilinear（$F_{(1,20)}=20.25$, $p<0.001$）. The third-order interaction between ceiling height, degree of openness and contour type was statistically significant, so a simple-simple effect analysis was then conducted.

Table 4-3 η²p is partial ETA squared (partialη²), is an effect quantity commonly used in the analysis of variance and represents the variance proportion of the dependent variable explained by a certain independent variable.

Factors	MS	*MSE*	*df1*	*df2*	*F*	*p*	*η²p*	*η²p 90% CI*
Ceiling height	704.381	39.243	1	20	17.95	<0.001	0.473	0.183～0.634
Degree of openness	2016.214	32.427	1	20	62.18	<0.001	0.757	0.552～0.832
Contour type	514.5	25.413	1	20	20.25	<0.001	0.503	0.213～0.655
Ceiling height×Degree of openness	2.381	14.418	1	20	0.17	0.689	0.008	0.000～0.150
Ceiling height×Contour type	85.714	14.252	1	20	6.01	0.023	0.231	0.018～0.443
Degree of openness×Contour type	486.881	23.018	1	20	21.15	<0.001	0.514	0.225～0.663
Ceiling height×Degree of openness×Contour type	228.667	9.829	1	20	23.26	<0.001	0.538	0.251～0.680

$^{*}p<0.05$

Some scholars have suggested that the evaluation criteria of η²p are small effect (≥ 0.01 and < 0.06), medium effect (≥ 0.06 and < 0.14), and large effect (≥ 0.14), but there is no unified evaluation standard at present.

Usually, the effect is reported as 90% CI rather than 95% CI.

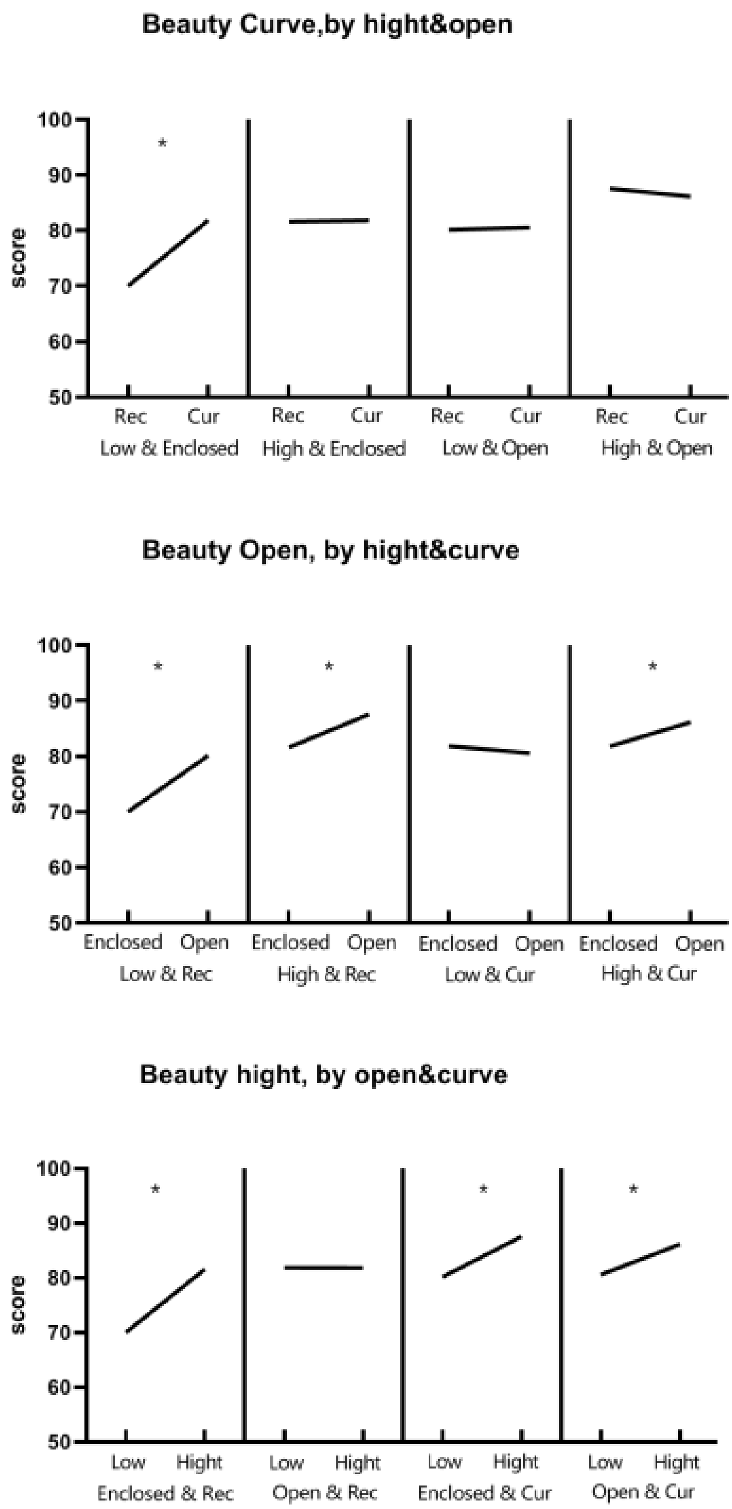


Figure 4-6 The influence of three building factors on beauty value score in the Stimulus time experiment.

A shows the main effect of the contour type with different combinations of ceiling height and degree of openness.

B shows the main effect of the degree of openness with different combinations of ceiling height and contour type.

C shows the main effect of ceiling height with different combinations of contour type and degree of openness.

A shows that the main effect of the contour type differs with different combinations of ceiling height and degree of openness.The specific results are as follows: when the building has a low ceiling and is enclosed, curvilinear contours are perceived as having higher esthetic value than rectilinear contours ($p<0.05$), while the other three groups, including enclosed buildings with high ceilings, open buildings with low ceilings, and open buildings with high ceilings, show no difference in esthetic value between the types of contours.

B shows that the main effect of the degree of openness differs with different combinations of ceiling height and contour type.、The specific results are as follows: open buildings with low ceilings and rectilinear contours, high ceilings and rectilinear contours, or high ceilings and curvilinear contours are considered to have higher esthetic value than enclosed buildings ($p<0.05$), but buildings with low ceilings and curvilinear contours show no difference in esthetic value between different degrees of openness.

C shows that the main effect of ceiling height differs with different combinations of contour type and degree of openness.The effect of ceiling height on esthetic value is statistically significant when buildings are enclosed and have rectilinear contours, enclosed and have curvilinear contours, or open and have curvilinear contours ($p<0.05$). The effect is greatest in the case of enclosed buildings with rectilinear contours. In the case of open buildings with rectilinear contours, esthetic value was not affected by ceiling height.

4.3.1. Color and grayscale graph experiment data analysis

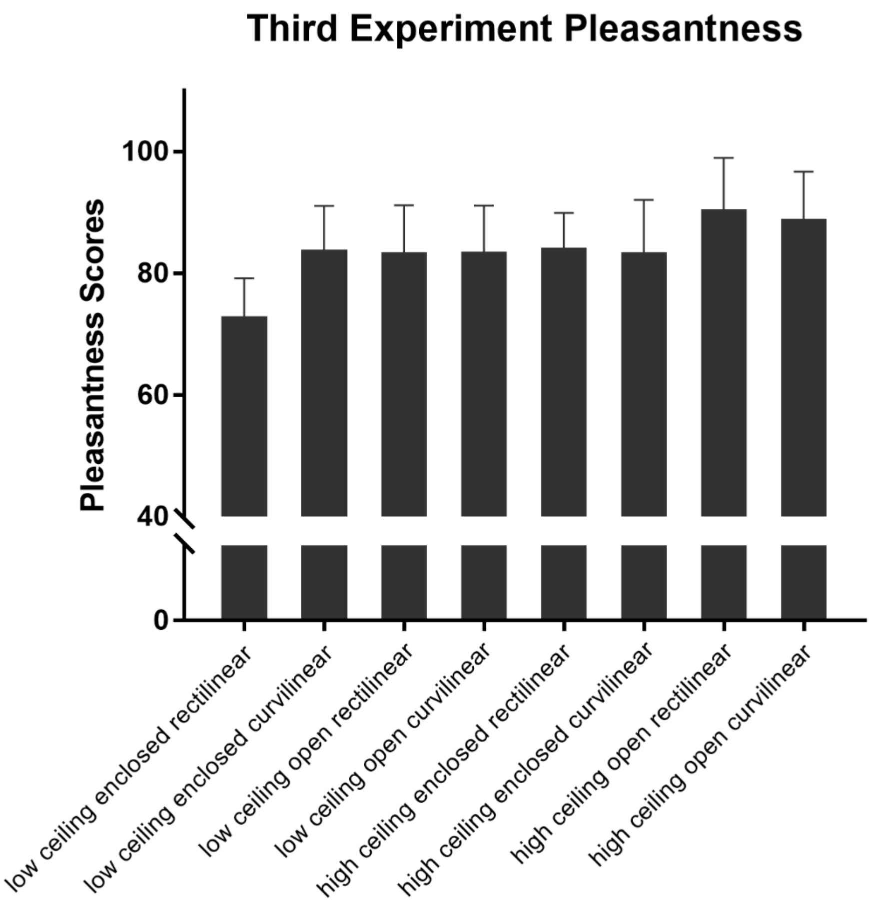


Figure 4-7 shows the pleasure value score given by each group in color-gray experiment.

The first digit of the abscissa represents the ceiling height , the second digit represents the degree of openness , and the third digit represents the contour type.

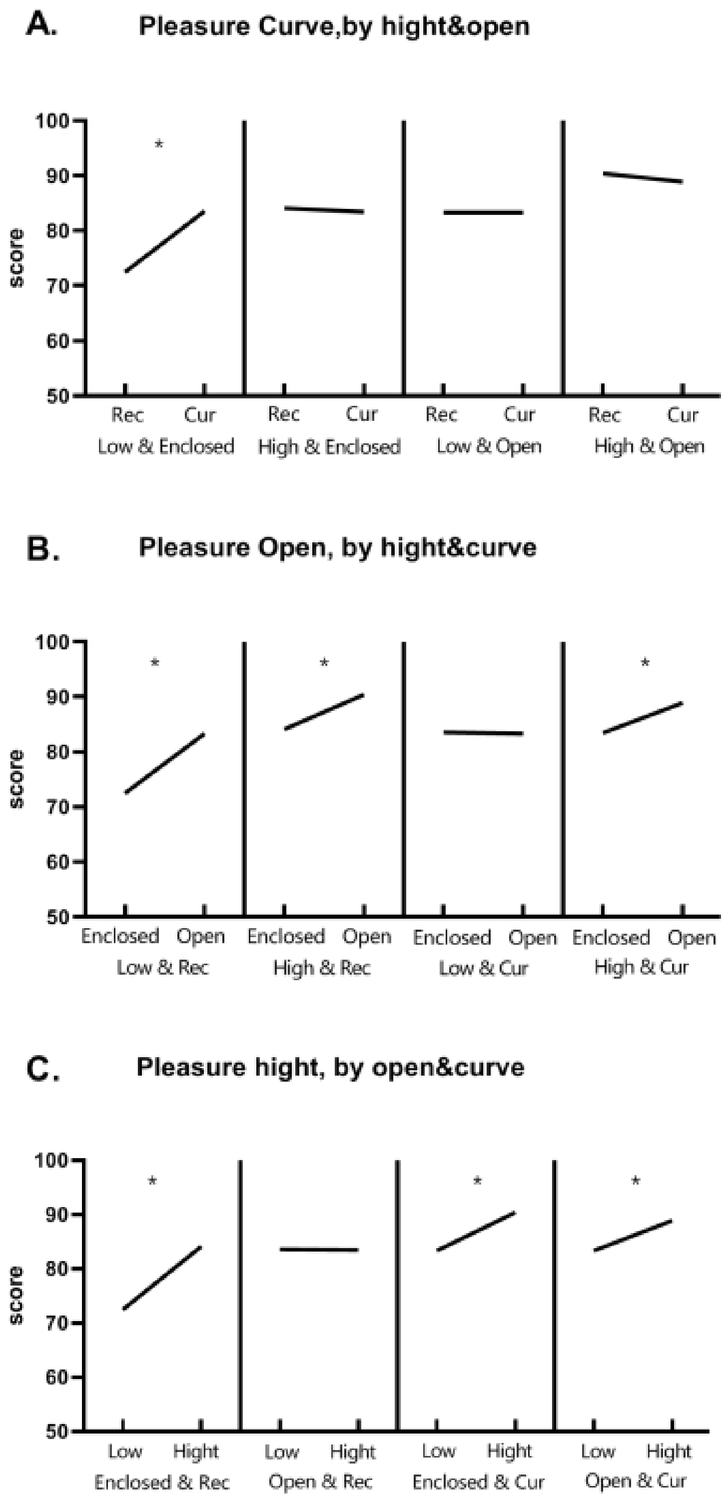
The ANOVA table showed that the main effects of, ceiling height, openness and contour were statistically significant, indicating that on the whole, pictures containing high ceiling were more likely to cause pleasure than pictures containing low ceiling（$F_{(1,20)}=50.51$, $p<0.001$）. And pictures containing open were more likely to cause pleasure than pictures containing closed（$F_{(1,20)}=81.39$, $p<0.001$）.Pictures containing curvilinear are more likely to cause pleasure than pictures containing rectilinear（$F_{(1,20)}=6.64$, $p=0.018<0.05$）. The third-order interaction between ceiling height, degree of openness and contour type was statistically significant, so a simple-simple effect analysis was then conducted.

Table 4-4 η^2p is partial ETA squared (partialη^2), is an effect quantity commonly used in the analysis of variance and represents the variance proportion of the dependent variable explained by a certain independent variable.

Factors	MS	*MSE*	*df1*	*df2*	*F*	*p*	η^2p	η^2p 90% CI
Ceiling height	1524.024	30.174	1	20	50.51	<0.001	0.716	0.488～0.804
Degree of openness	1314.881	16.156	1	20	81.39	<0.001	0.803	0.629～0.864
Contour type	210.381	31.681	1	20	6.64	0.018	0.249	0.026～0.459
Ceiling height × Degree of openness	3.429	34.929	1	20	0.1	0.757	0.005	0.000～0.129
Ceiling height × Contour type	460.024	14.199	1	20	32.4	<0.001	0.618	0.349～0.737
Degree of openness × Contour type	372.024	15.924	1	20	23.36	<0.001	0.539	0.252～0.681
Ceiling height × Degree of openness × Contour type	277.714	14.039	1	20	19.78	<0.001	0.497	0.207～0.651

*$p<0.05$

Some scholars have suggested that the evaluation criteria of η^2p are small effect (≥ 0.01 and < 0.06), medium effect (≥ 0.06 and < 0.14), and large effect (≥ 0.14), but there is no unified evaluation standard at present. Usually, the effect is reported as 90% CI rather than 95% CI.



$p<0.05$

Figure 4-8 The influence of three factors of building on pleasure value score in color-gray experiment.

A shows the main effect of the contour type with different combinations of ceiling height and degree of openness.

B shows the main effect of the degree of openness with different combinations of ceiling height and contour type.

C shows the main effect of ceiling height with different combinations of contour type and degree of openness.

A shows that the main effect of contour type differs with different combinations of ceiling height and degree of openness.

The specific results are as follows: when buildings are enclosed and have low ceilings, curvilinear contours have higher pleasure value than rectilinear contours ($p<0.05$), but there is no difference in pleasure value from different contour types in enclosed buildings with high ceilings, open buildings with high ceilings, or open buildings with low ceilings.

B shows that the main effect of the degree of openness differs with different combinations of ceiling height and contour type.The specific results are as follows: when the building has a low ceiling and rectilinear contours, a high ceiling and rectilinear contours, or a high ceiling and curvilinear contours, a high degree of openness is more pleasing than a low degree of openness ($p<0.05$), and the effect is the greatest when the building has a low ceiling and rectilinear contours.When the building has a low ceiling and curvilinear contours, the degree of openness does not affect the pleasure value.

C shows that the main effect of ceiling height differs with different combinations of contour type and degree of openness.When the building was open and had rectilinear contours, the effect on the pleasure value was not statistically significant ($p>0.05$).The effects of the other three items, including in enclosed buildings with rectilinear contours, enclosed buildings with curvilinear contours, and open buildings with curvilinear contours, on the pleasure value were statistically significant, and the effect in enclosed buildings with rectilinear contours was the largest.

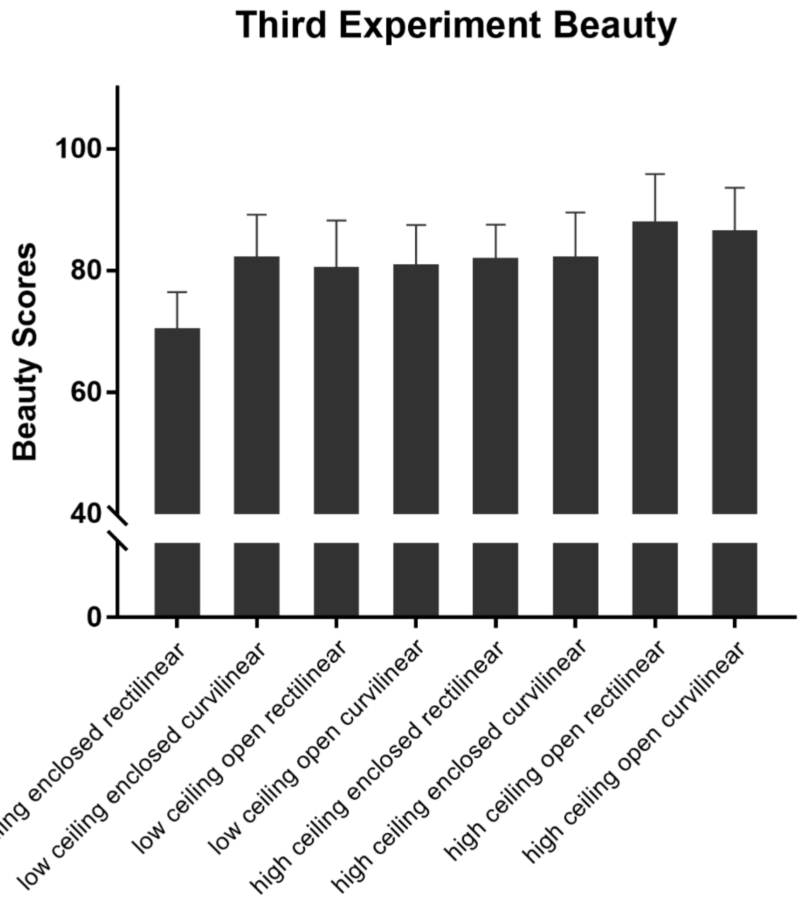


Figure 4-9 shows the beauty value score given by each group in color-gray experiment.

The first digit of the abscissa represents the ceiling height , the second digit represents the degree of openness , and the third digit represents the contour type.

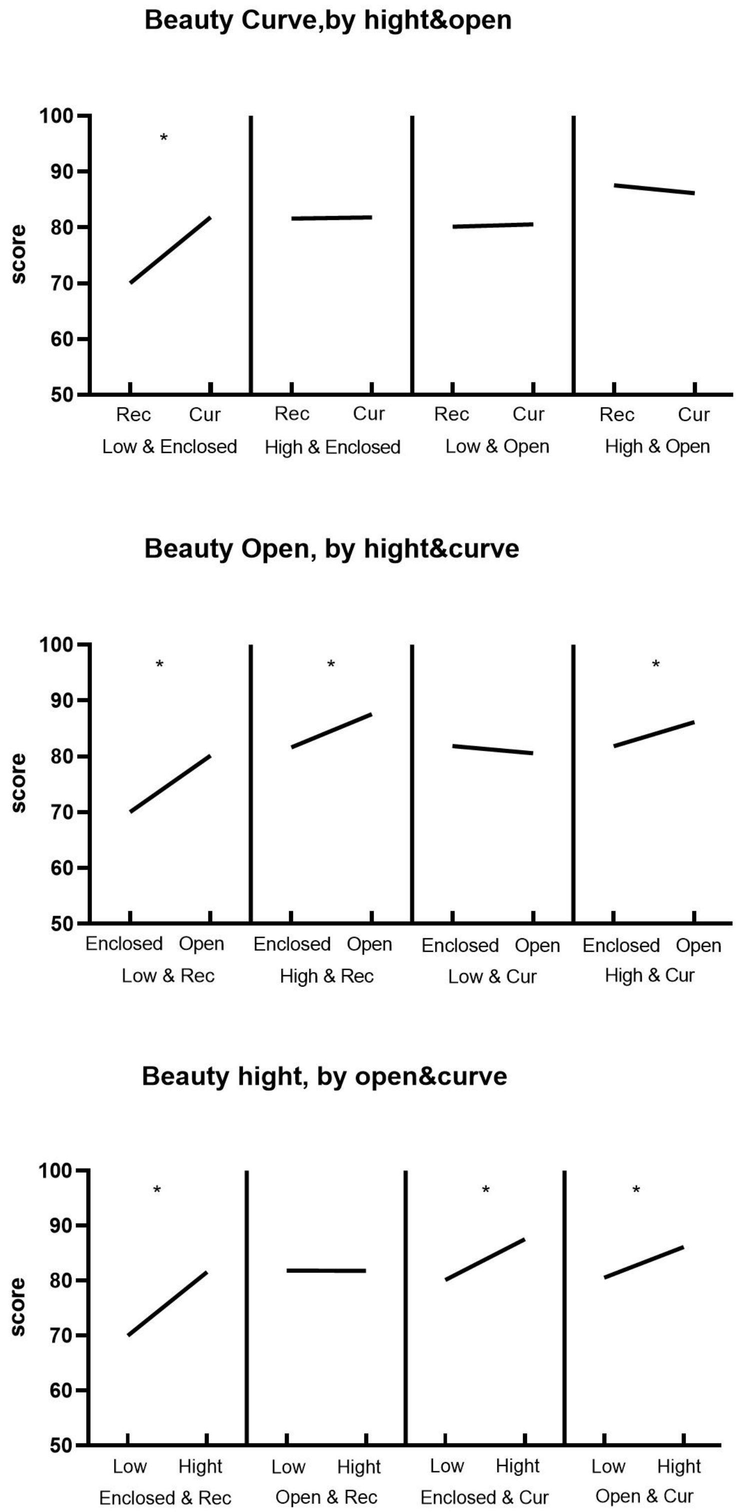
The ANOVA table showed that the main effects of, ceiling height, openness and contour were statistically significant, indicating that on the whole, pictures containing high ceiling were more likely to cause beauty than pictures containing low ceiling（$F_{(1,20)}$=48.83, p<0.001）. And pictures containing open were more likely to cause beauty than pictures containing closed（$F_{(1,20)}$=69.31, p<0.001）.Pictures containing curvilinear are more likely to cause beauty than pictures containing rectilinear（$F_{(1,20)}$=16.97, p<0.001）. The third-order interaction between ceiling height, degree of openness and contour type was statistically significant, so a simple-simple effect analysis was then conducted.

Table 4-5 η^2p is partial ETA squared (partialη^2), is an effect quantity commonly used in the analysis of variance and represents the variance proportion of the dependent variable explained by a certain independent variable.

Factors	MS	*MSE*	*df1*	*df2*	*F*	*p*	*η²p*	*η²p 90% CI*
Ceiling height	1584.857	32.457	1	20	48.83	<0.001	0.709	0.478～0.800
Degree of openness	961.929	13.879	1	20	69.31	<0.001	0.776	0.584～0.845
Contour type	320.381	18.881	1	20	16.97	<0.001	0.459	0.169～0.624
Ceiling height × Degree of openness	5.357	21.957	1	20	0.24	0.627	0.012	0.000～0.166
Ceiling height × Contour type	480.095	18.095	1	20	26.53	<0.001	0.57	0.288～0.703
Degree of openness × Contour type	446.881	16.281	1	20	27.45	<0.001	0.578	0.298～0.709
Ceiling height × Degree of openness × Contour type	252.595	6.295	1	20	40.12	<0.001	0.667	0.416～0.771

$p<0.05$

Some scholars have suggested that the evaluation criteria of η^2p are small effect (≥ 0.01 and < 0.06), medium effect (≥ 0.06 and < 0.14), and large effect (≥ 0.14), but there is no unified evaluation standard at present.Usually, the effect is reported as 90% CI rather than 95% CI.



**p<0.05*

Figure 4-10 The influence of three factors of building on beauty value score in the third experiment.

A shows the main effect of the contour type with different combinations of ceiling height and degree of openness.

B shows the main effect of the degree of openness with different combinations of ceiling height and contour type.

C shows the main effect of ceiling height with different combinations of contour type and degree of openness.

A shows that the main effect of the contour type differs with different combinations of ceiling height and degree of openness.The specific results are as follows: when an enclosed building has a low ceiling, curvilinear contours have higher esthetic value than rectilinear contours ($p<0.05$), while the other three groups, including enclosed buildings with a high ceiling, open buildings with a low ceiling, and open buildings with a high ceiling, do not show any difference in esthetic value with different contour types.

B shows that the main effect of the degree of openness differs with different combinations of ceiling height and contour type. The specific results are as follows: open buildings with low ceilings and rectilinear contours, high ceilings and rectilinear contours, or high ceilings and curvilinear contours are considered to have higher esthetic value than enclosed buildings ($p<0.05$), but when buildings have low ceilings and curvilinear contours, there is no difference in esthetic value between different degrees of openness.

C shows that the main effect of ceiling height differs with different combinations of contour type and degree of openness. The effect of ceiling height on esthetic value is statistically significant when buildings are enclosed and have rectilinear contours, enclosed and have curvilinear contours, or open and have curvilinear contours ($p<0.05$). The effect is greatest in the case of enclosed buildings with rectilinear contours. The esthetic value is not affected in the case of open buildings with rectilinear contours.

4.4.Results

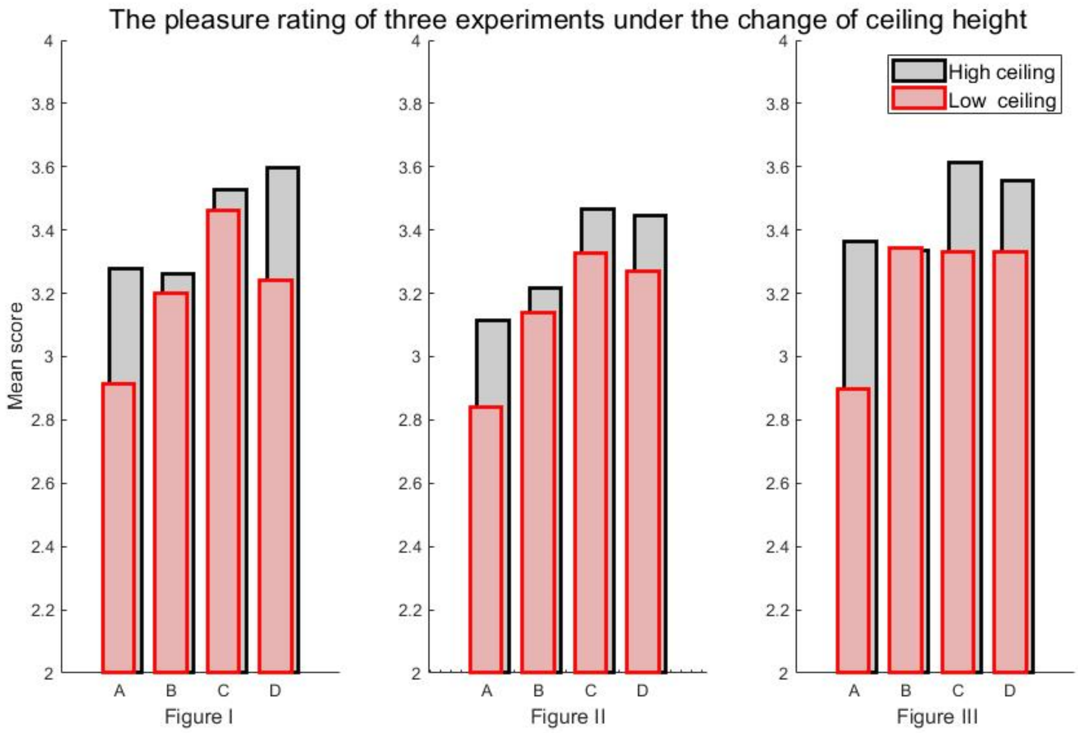


Figure 4-11 Using the pleasure value score of the three groups, the ceiling height was compared as a single variable

The red column is buildings with low ceilings and the gray column is buildings with high ceilings. Along the X axis, A represents a low degree of openness and rectilinear contours, B represents a low degree of openness and curvilinear contours, C represents a high degree of openness and rectilinear contours, and D represents a high degree of openness and curvilinear contours.

Fig. I shows the experimental results of the 3000 ms initial stimulation, Fig. II shows the results of the 200 ms initial stimulation, and Fig. III shows the results of the 200 ms grayscale stimulation.

The Y axis is the average pleasure value score.

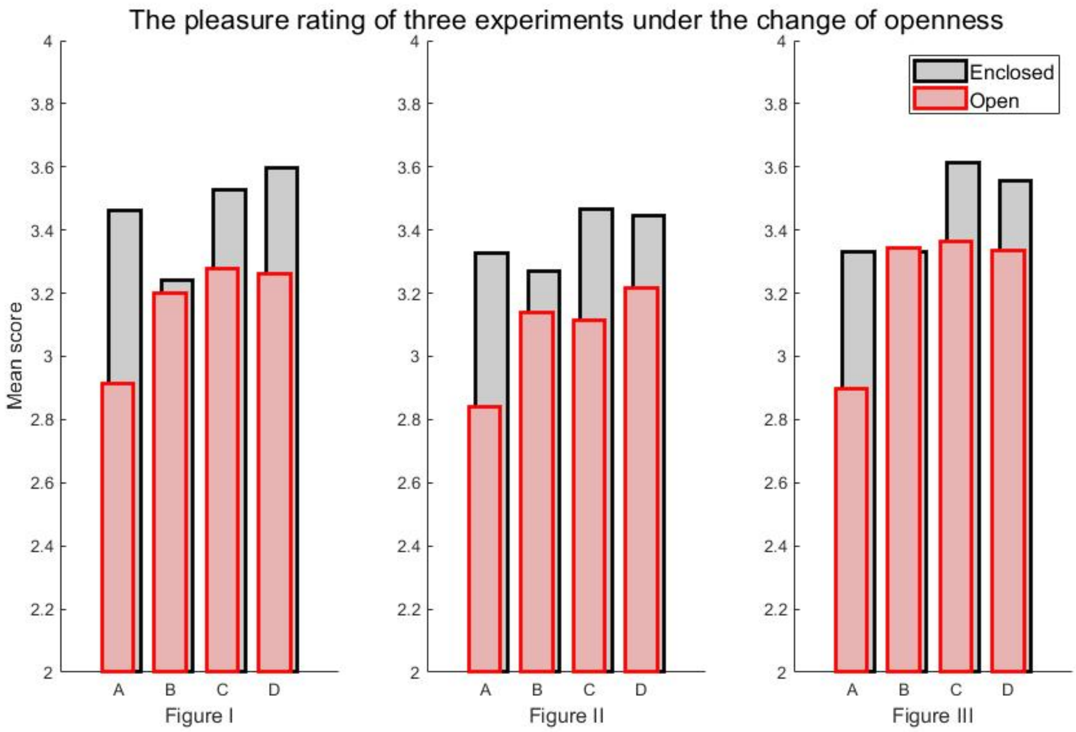


Figure 4-12 Using the pleasure value score of the three groups, the openness was compared as a single variable.

The red column is buildings with enclosed and the gray column is buildings with open.

Along the X axis, A represents a low ceiling and rectilinear contours. B represents a low ceiling and curvilinear contours. C represents a high ceiling and rectilinear contours. D represents a high ceiling and curvilinear contours.

Fig. I shows the experimental results of the 3000 ms initial stimulation, Fig. II shows the results of the 200 ms initial stimulation, and Fig. III shows the results of the 200 ms grayscale stimulation.

The Y axis is the average pleasure value score.

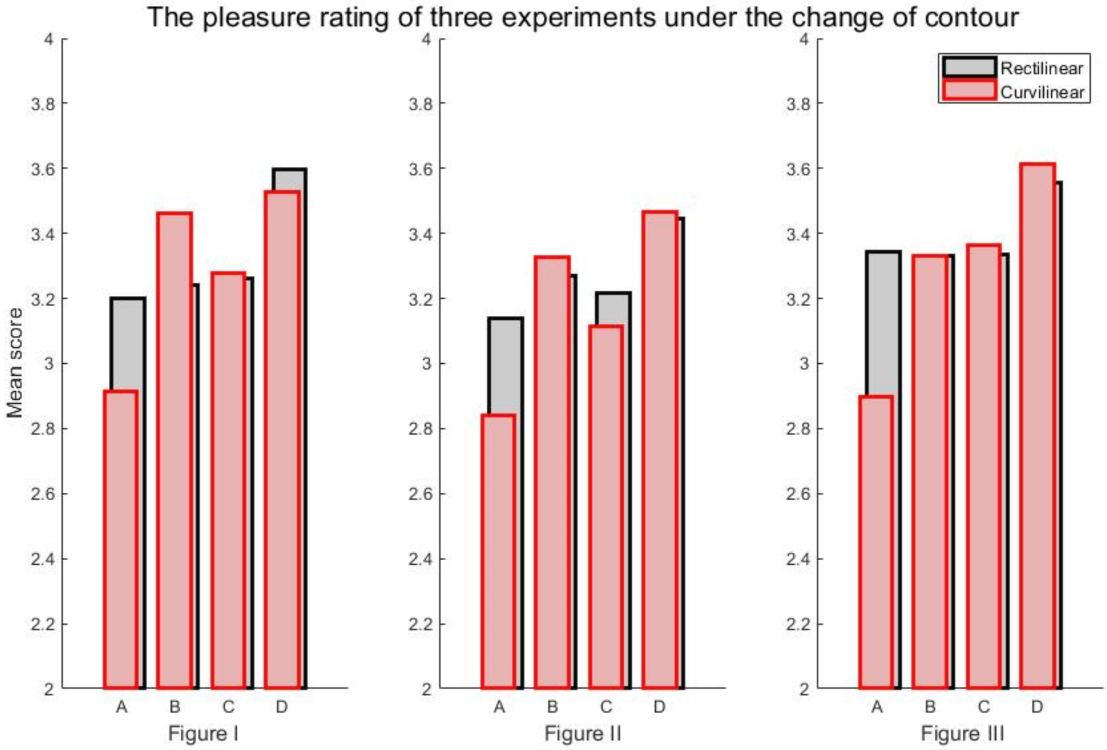


Figure 4-13 Using the pleasure value score of the three groups, the contour was compared as a single variable.

The red column is buildings with rectilinear and the gray column is buildings with curvilinear.

Along the X axis, A represents a low ceiling and low degree of openness. B represents a low ceiling and high degree of openness. C represents a high ceiling and low degree of openness. D represents a high ceiling and high degree of openness

Fig. I shows the experimental results of the 3000 ms initial stimulation, Fig. II shows the results of the 200 ms initial stimulation, and Fig. III shows the results of the 200 ms grayscale stimulation.

The Y axis is the average pleasure value score.

The analysis of the data uses the nlme packet of R to establish a linear mixed effect model (random intercept model): Yij = β 0i + β 1 * factors + ε. Yij is the score, factors is the element, disordered multi-classification variable, the value of 1: 8 is the individual ID, β 0i is the random intercept of each individual, β 1 is the slope of the variable element, ε is the error. The interaction between factors and individuals was not considered. Group was divided into groups, disordered and multi-classified variables, with a value of 1, 2, 3, 29 in group 1, 21 in group 2 and 21 in group 3, with a total of 71 cases. When the p value is less than 0.05, it is statistically significant.

Table 4-6 In the case of second experiment ceiling high correlation pleasure score, the change of ceiling height p value is statistically significant when the three elements of this experiment are low openness and rectilinear, high openness and rectilinear and high openness and curvilinear.

Ceiling height / openness / contour	$\overline{X} \pm S$	Ceiling height / openness / contour	$\overline{X} \pm S$	P value
low ceiling enclosed rectilinear	71.05±8.66	high ceiling enclosed rectilinear	77.90±8.83	<0.0001*
low ceiling enclosed curvilinear	78.43±9.46	high ceiling enclosed curvilinear	80.38±7.13	0.1605
low ceiling open rectilinear	83.14±8.49	high ceiling open rectilinear	86.67±7.47	0.0120*
low ceiling open curvilinear	81.76±8.91	high ceiling open curvilinear	86.14±8.55	0.0019*

$^*p<0.05$

Table 4-7 In the case of second experiment openness-related pleasure score, no matter how the ceiling height and contour change in the three elements of this experiment, the change of ceiling height p value is statistically significant.

Ceiling height / openness / contour	$\overline{X} \pm S$	Ceiling height / openness / contour	$\overline{X} \pm S$	P value
low ceiling enclosed rectilinear	71.05±8.66	high ceiling enclosed rectilinear	83.14±8.49	<0.0001*
low ceiling enclosed curvilinear	78.43±9.46	high ceiling enclosed curvilinear	81.76±8.91	0.0173*
low ceiling open rectilinear	77.90±8.83	high ceiling open rectilinear	86.67±7.47	<0.0001*
low ceiling open curvilinear	80.38±7.13	high ceiling open curvilinear	86.14±8.55	<0.0001*

$^*p<0.05$

Table 4-8 In the case of second experiment contour related pleasure score comparison, when the ceiling height is low and the openness is low in the three elements of this experiment, the change of contour p value is statistically significant.

Ceiling height / openness / contour	$\overline{X} \pm S$	Ceiling height / openness / contour	$\overline{X} \pm S$	P value
low ceiling enclosed rectilinear	71.05±8.66	high ceiling enclosed rectilinear	78.43±9.46	<0.0001*
low ceiling enclosed curvilinear	83.14±8.49	high ceiling enclosed curvilinear	81.76±8.91	0.3201
low ceiling open rectilinear	77.90±8.83	high ceiling open rectilinear	80.38±7.13	0.0757
low ceiling open curvilinear	86.67±7.47	high ceiling open curvilinear	86.14±8.55	0.7056

*$p<0.05$

After combing the evaluation of second experiment pleasure, it was found that there were 8 groups of comparisons with statistical significance. Among them, 3 groups were related to the change of ceiling height, 4 groups were related to the change of openness, and 1 group was related to the change of contour.

The analysis of variance table (Table 3-10) shows that there was no significant difference in pleasure value scores among the three test groups (group item: $F_{(2,68)} = 1.12$, $p = 0.334$), indicating that fixation time and color did not generally affect subjects' perceived pleasure value of an image. However, when we stratified the images according to different properties, we found that fixation time and color can affect the pleasure value of certain images (group×ceiling height×openness×contour type fourth-order interaction term: $F_{(2,68)} = 4.44$, $p = 0.015$).

The subsequent simple-simple effect analysis showed that when the image had high ceiling + enclosed + rectilinear properties, the difference between the three experimental groups was statistically significant ($F_{(2,68)} = 3.98$, $p = 0.023$). Further post hoc comparison indicated that the pleasure value score in the third experiment was higher than that in the second experiment ($t_{68} = 2.76$, $p = 0.022$). Under other combination conditions, there was no significant difference in pleasure value score among the three experimental groups.

This finding shows that when the building is enclosed and has a high ceiling and rectilinear contours, the black and white picture is more likely than the color picture to be pleasing to the subjects. In addition, the pleasure value scores of other images were not affected by fixation time and color.

Table 4-9Analysis of variance

Factors	MS	*MSE*	*df 1*	*df 2*	*F*	*p*	η^2p	η^2p *90% CI*
Group	402.909	361.207	2	68	1.12	0.334	0.032	0.000～0.106
Ceiling height	3706.07	31.535	1	68	117.52	<0.001	0.633	0.512～0.709
Group×Ceiling height	36.441	31.535	2	68	1.16	0.321	0.033	0.000～0.108
Degree of openness	6450.267	25.877	1	68	249.27	<0.001	0.786	0.707～0.830
Group×Degree of openness	49.411	25.877	2	68	1.91	0.156	0.053	0.000～0.141
Contour type	376.508	20.455	1	68	18.41	<0.001	0.213	0.083～0.342
Group×Contour type	34.164	20.455	2	68	1.67	0.196	0.047	0.000～0.132
Ceiling height×Degree of openness	0.004	17.468	1	68	0	0.988	0	0.000～1.000
Group×Ceiling height×Degree of openness	2.843	17.468	2	68	0.16	0.85	0.005	0.000～0.033
Ceiling height×Contour type	298.353	14.2	1	68	21.01	<0.001	0.236	0.101～0.364
Group×Ceiling height×Contour type	129.873	14.2	2	68	9.15	<0.001	0.212	0.072～0.330

Degree of openness×Contour type	1116.945	15.688	1	68	71.2	<0.001	0.511	0.368～0.609
Group× Degree of openness×Contour type	2.28	15.688	2	68	0.15	0.865	0.004	0.000～0.029
Ceiling height× Degree of openness×Contour type	920.639	14.308	1	68	64.34	<0.001	0.486	0.340～0.588
Group×Ceiling height×Degree of openness×Contour type	63.567	14.308	2	68	4.44	0.015	0.116	0.013～0.224

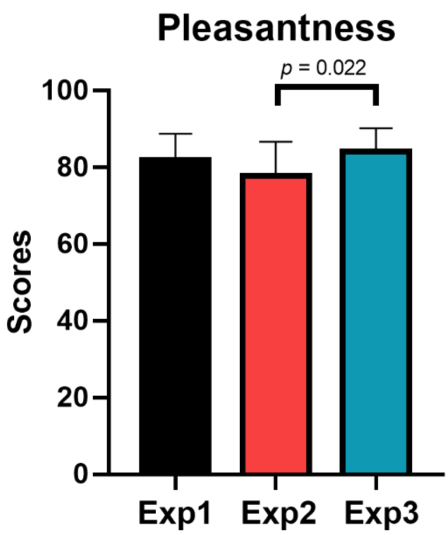


Figure 4-14 indicates that when the picture group has high ceilings + enclosed + rectilinear properties, grayscale images are more likely to be pleasing to the subjects in the three groups of experiments.

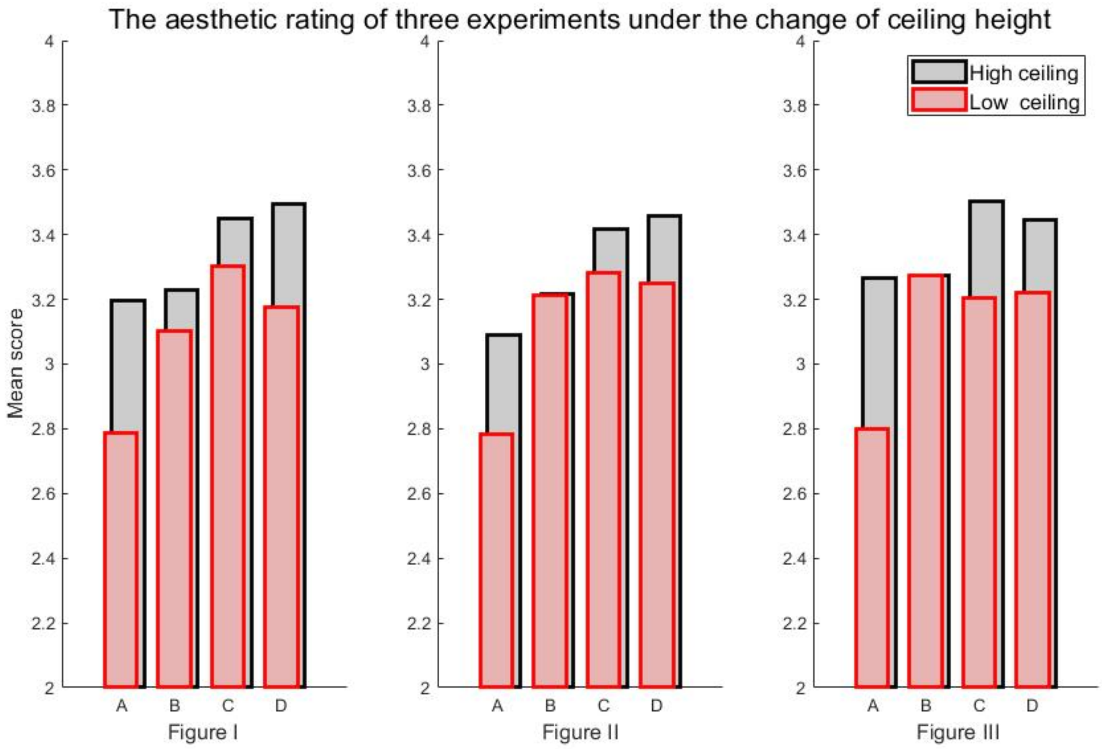


Figure 4-15 Using the aesthetic value score of the three groups, the ceiling height was compared as a single variable.

The red column is buildings with low ceilings and the gray column is buildings with high ceilings.

Along the X axis, A represents a low degree of openness and rectilinear contours, B represents a low degree of openness and curvilinear contours, C represents a high degree of openness and rectilinear contours, and D represents a high degree of openness and curvilinear contours.
Fig. I shows the experimental results of the 3000 ms initial stimulation, Fig. II shows the results of the 200 ms initial stimulation, and Fig. III shows the results of the 200 ms grayscale stimulation.
The Y axis is the average aesthetic value score.

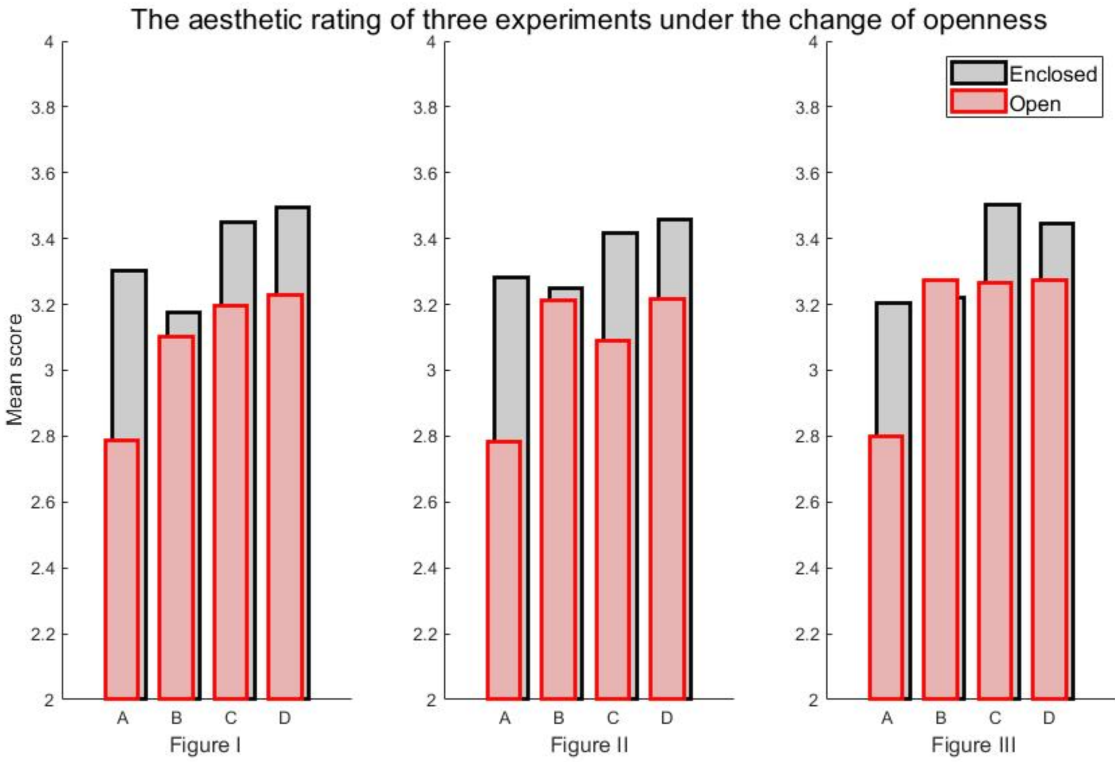


Figure 4-16 Using the aesthetic value score of the three groups, the openness was compared as a single variable.

The red column is buildings with enclosed and the gray column is buildings with open.

Along the X axis, A represents a low ceiling and rectilinear contours. B represents a low ceiling and curvilinear contours. C represents a high ceiling and rectilinear contours. D represents a high ceiling and curvilinear contours.

Fig. I shows the experimental results of the 3000 ms initial stimulation, Fig. II shows the results of the 200 ms initial stimulation, and Fig. III shows the results of the 200 ms grayscale stimulation. The Y axis is the average aesthetic value score.

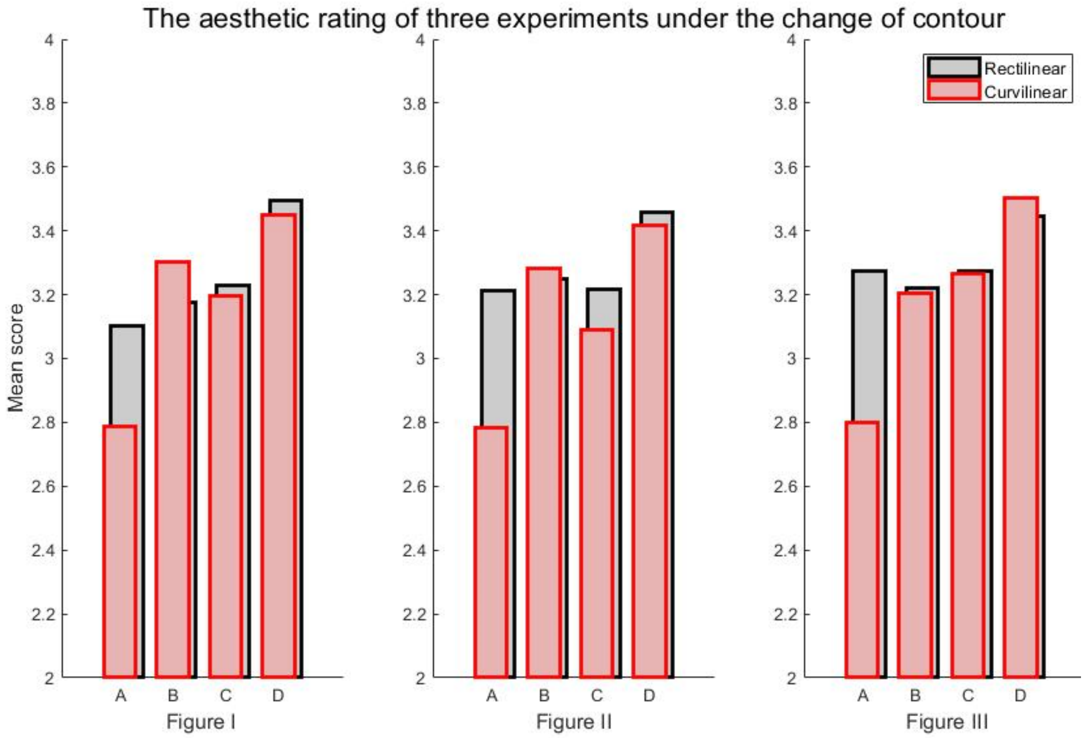


Figure 4-17 Using the aesthetic value score of the three groups, the contour was compared as a single variable.

The red column is buildings with rectilinear and the gray column is buildings with curvilinear.

Along the X axis, A represents a low ceiling and low degree of openness. B represents a low ceiling and high degree of openness. C represents a high ceiling and low degree of openness. D represents a high ceiling and high degree of openness

Fig. I shows the experimental results of the 3000 ms initial stimulation, Fig. II shows the results of the 200 ms initial stimulation, and Fig. III shows the results of the 200 ms grayscale stimulation. The Y axis is the average aesthetic value score.

The analysis of the data uses the nlme packet of R to establish a linear mixed effect model (random intercept model): $Yij = \beta\ 0i + \beta\ 1 * factors + \varepsilon$. Yij is the score, factors is the element, disordered multi-classification variable, the value of 1: 8 is the individual ID, β 0i is the random intercept of each individual, β 1 is the slope of the variable element, ε is the error. The interaction between factors and individuals was not considered. Group was divided into groups, disordered and multi-classified variables, with a value of 1, 2, 3, 29 in group 1, 21 in group 2 and 21 in group 3, with a total of 71 cases. When the p value is less than 0.05, it is statistically significant.

Table 4-10 In the case of the comparison of the second experiment ceiling height correlation beauty score, when the three elements of the experiment are low and the contour is rectilinear, the openness is high and the contour is rectilinear, and the openness is high and the contour is curvilinear, changing the ceiling height p value has statistical significance.

Ceiling height / openness / contour	$\overline{X} \pm S$	Ceiling height / openness / contour	$\overline{X} \pm S$	P value
low ceiling enclosed rectilinear	69.62±8.73	high ceiling enclosed rectilinear	77.24±8.79	<0.0001*
low ceiling enclosed curvilinear	80.29±9.16	high ceiling enclosed curvilinear	80.38±8.27	0.9484
low ceiling open rectilinear	82.05±7.56	high ceiling open rectilinear	85.48±8.32	0.0210*
low ceiling open curvilinear	81.24±9.22	high ceiling open curvilinear	86.48±9.01	0.0005*

*p<0.05

Table 4-11 In the case of second experiment openness-related beauty score, when the ceiling height is low and the contour is rectilinear, the ceiling height is high and the height of the ceiling is rectilinear, and the height of the ceiling is high and the contour is curvilinear, the change of openness p value is statistically significant.

Ceiling height / openness / contour	$\overline{X} \pm S$	Ceiling height / openness / contour	$\overline{X} \pm S$	P value
low ceiling enclosed rectilinear	69.62±8.73	high ceiling enclosed rectilinear	82.05±7.56	<0.0001*
low ceiling enclosed curvilinear	80.29±9.16	high ceiling enclosed curvilinear	81.24±9.22	0.5178
low ceiling open rectilinear	77.24±8.79	high ceiling open rectilinear	85.48±8.32	<0.0001*
low ceiling open curvilinear	80.38±8.27	high ceiling open curvilinear	86.48±9.01	<0.0001*

*p<0.05

Table 4-12 In the case of second experiment contour related beauty score, when the ceiling height is low and the openness is low and the ceiling height is high and the openness is low, the change of contour p value is statistically significant.

Ceiling height / openness / contour	$\overline{X} \pm S$	Ceiling height / openness / contour	$\overline{X} \pm S$	P value
low ceiling enclosed rectilinear	69.62±8.73	high ceiling enclosed rectilinear	80.29±9.16	<0.0001*
low ceiling enclosed curvilinear	82.05±7.56	high ceiling enclosed curvilinear	81.24±9.22	0.5825
low ceiling open rectilinear	77.24±8.79	high ceiling open rectilinear	80.38±8.27	0.0341*
low ceiling open curvilinear	85.48±8.32	high ceiling open curvilinear	86.48±9.01	0.4972

*p<0.05

After combing the aesthetic evaluation of second experiment, it is found that there are 8 groups of comparisons with statistical significance.

Among them, 3 groups were related to the change of ceiling height, 3 groups were related to the change of openness, and 2 groups were related to the change of contour.

The analysis of the three groups of experimental results shows that the esthetic and pleasure value scores of high ceilings, open spaces and curvilinear contours are superior to the esthetic and pleasure value scores of low ceilings, enclosed spaces and rectilinear contours, respectively. Relatively speaking, the influence of ceiling height and degree of openness is more significant than that of contour type.

The analysis of variance table (Table 3-14) showed that there was no significant difference in esthetic value scores among the three test groups (group item: $F_{(2,68)} = 0.11$, $p = 0.895$), indicating that fixation time and color did not generally affect the subjects' esthetic value judgment of an image. When we layered the picture according to different attributes, we still did not find an effect of fixation time and color on the esthetic value of the picture (group×ceiling height×degree of openness×contour type fourth-order interaction term: $F_{(2,68)} = 0.33$, $p = 0.723$).

Table 4-13 Analysis of variance

Factors	MS	*MSE*	df_1	df_2	*F*	*p*	η^2p	η^2p *90% CI*

Group	40.695	367.986	2	68	0.11	0.895	0.003	0.000～0.022
Ceiling height	4200.19	33.588	1	68	125.05	<0.001	0.648	0.530～0.720
Group×Ceiling height	66.64	33.588	2	68	1.98	0.145	0.055	0.000～0.144
Degree of openness	5364.897	25.816	1	68	207.81	<0.001	0.753	0.664～0.805
Group×Degree of openness	68.317	25.816	2	68	2.65	0.078	0.072	0.000～0.169
Contour type	964.281	19.158	1	68	50.33	<0.001	0.425	0.275～0.536
Group×Contour type	43.52	19.158	2	68	2.27	0.111	0.063	0.000～0.155
Ceiling height×Degree of openness	0.461	14.232	1	68	0.03	0.858	0	0.000～0.029
Group×Ceiling height×Degree of openness	9.043	14.232	2	68	0.64	0.533	0.018	0.000～0.078
Ceiling height×Contour type	470.643	13.285	1	68	35.43	<0.001	0.343	0.193～0.464
Group×Ceiling height×Contour type	88.976	13.285	2	68	6.7	0.002	0.165	0.040～0.280
Degree of openness×Contour type	1352.167	16.211	1	68	83.41	<0.001	0.551	0.413～0.642
Group×Degree of openness×Contour type	7.133	16.211	2	68	0.44	0.646	0.013	0.000～0.064
Ceiling height×Degree of openness×Contour type	895.672	10.788	1	68	83.03	<0.001	0.55	0.412～0.641

Group×Ceiling height×Degree of openness×Contour type	3.521	10.788	2	68	0.33	0.723	0.01	0.000～0.054

The linear mixed effect model (random intercept model) is established by using the nlme packet of R:

$Y_{ij} = \beta_{0i} + \beta_1 * \text{factors} + \varepsilon$

Y_{ij} is the score, factors is the element, disordered multi-classification variable, the value is 1 to 8, i is the individual ID, β_{0i} is the random intercept of each individual, β_1 is the slope of the variable element, ε is the error. The interaction between factors and individuals was not considered. Group was divided into groups, disordered and multi-classified variables, with a value of 1, 2, 3. 29 in group 1, 21 in group 2 and 21 in group 3, with a total of 71 cases.

Pleasure score result:

Table 4-14 The P-value matrix of group 1 elements

	low ceiling enclosed rectilinear	low ceiling enclosed curvilinear	low ceiling open rectilinear	low ceiling open curvilinear	high ceiling enclosed rectilinear	high ceiling enclosed curvilinear	high ceiling open rectilinear	high ceiling open curvilinear
low ceiling enclosed rectilinear		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
low ceiling enclosed curvilinear			<0.0001	0.3234	0.0695	0.1654	<0.0001	<0.0001
low ceiling open rectilinear				<0.0001	0.0001	<0.0001	0.1475	0.0028
low ceiling open curvilinear					0.4045	0.6880	<0.0001	<0.0001
high ceiling enclosed rectilinear						0.6654	<0.0001	<0.0001
high ceiling enclosed curvilinear							<0.0001	<0.0001

high ceiling open rectilinear								0.1162
high ceiling open curvilinear								

Table 4-15 The P-value matrix of group 2 elements

	low ceiling enclosed rectilinear	low ceiling enclosed curvilinear	low ceiling open rectilinear	low ceiling open curvilinear	high ceiling enclosed rectilinear	high ceiling enclosed curvilinear	high ceiling open rectilinear	high ceiling open curvilinear
low ceiling enclosed rectilinear		<0.0001	<0.000 1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
low ceiling enclosed curvilinear			0.0009	0.0173	0.7056	0.1605	<0.0001	<0.0001
low ceiling open rectilinear				0.3201	0.0002	0.0479	0.0120	0.0319
low ceiling open curvilinear					0.0061	0.3201	0.0005	0.0019
high ceiling enclosed rectilinear						0.0757	<0.0001	<0.0001
high ceiling enclosed curvilinear							<0.0001	0.0001
high ceiling open rectilinear								0.7056
high ceiling open curvilinear								

Table 4-16 The P-value matrix of group 3 elements

	low ceiling enclosed rectilinear	low ceiling enclosed curvilinear	low ceiling open rectilinear	low ceiling open curvilinear	high ceiling enclosed rectilinear	high ceiling enclosed curvilinear	high ceiling open rectilinear	high ceiling open curvilinear

low ceiling enclosed rectilinear		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
low ceiling enclosed curvilinear			0.8709	0.8709	0.7207	0.9223	<0.0001	0.0004
low ceiling open rectilinear				1.0000	0.6031	0.9482	<0.0001	0.0002
low ceiling open curvilinear					0.6031	0.9482	<0.0001	0.0002
high ceiling enclosed rectilinear						0.6491	<0.0001	0.0013
high ceiling enclosed curvilinear							<0.0001	0.0003
high ceiling open rectilinear								0.3144
high ceiling open curvilinear								

Aesthetic score result:

Table 4-16The P-value matrix of group 1 elements

	low ceiling enclosed rectilinear	low ceiling enclosed curvilinear	low ceiling open rectilinear	low ceiling open curvilinear	high ceiling enclosed rectilinear	high ceiling enclosed curvilinear	high ceiling open rectilinear	high ceiling open curvilinear
low ceiling enclosed rectilinear		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
low ceiling enclosed curvilinear			<0.0001	0.0925	0.0313	0.0041	<0.0001	<0.0001
low ceiling open rectilinear				0.0037	0.0149	0.0865	0.0007	<0.0001

low ceiling open curvilinear					0.6328	0.2269	<0.0001	<0.0001
high ceiling enclosed rectilinear						0.4640	<0.0001	<0.0001
high ceiling enclosed curvilinear							<0.0001	<0.0001
high ceiling open rectilinear								0.3239
high ceiling open curvilinear								

Table 4-17 The P-value matrix of group 2 elements

	low ceiling enclosed rectilinear	low ceiling enclosed curvilinear	low ceiling open rectilinear	low ceiling open curvilinear	high ceiling enclosed rectilinear	high ceiling enclosed curvilinear	high ceiling open rectilinear	high ceiling open curvilinear
low ceiling enclosed rectilinear		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
low ceiling enclosed curvilinear			0.2324	0.5178	0.0398	0.9484	0.0006	<0.0001
low ceiling open rectilinear				0.5825	0.0013	0.2585	0.0210	0.0031
low ceiling open curvilinear					0.0073	0.5605	0.0045	0.0005
high ceiling enclosed rectilinear						0.0341	<0.0001	<0.0001
high ceiling enclosed curvilinear							0.0007	0.0001

high ceiling open rectilinear								0.4972
high ceiling open curvilinear								

Table 4-18 The P-value matrix of group 3 elements

	low ceiling enclosed rectilinear	low ceiling enclosed curvilinear	low ceiling open rectilinear	low ceiling open curvilinear	high ceiling enclosed rectilinear	high ceiling enclosed curvilinear	high ceiling open rectilinear	high ceiling open curvilinear
low ceiling enclosed rectilinear		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
low ceiling enclosed curvilinear			0.1958	0.3313	0.8570	0.9712	<0.0001	0.0014
low ceiling open rectilinear				0.7457	0.2649	0.2084	<0.0001	<0.0001
low ceiling open curvilinear					0.4283	0.3495	<0.0001	<0.0001
high ceiling enclosed rectilinear						0.8854	<0.0001	0.0008
high ceiling enclosed curvilinear							<0.0001	0.0013
high ceiling open rectilinear								0.2806
high ceiling open curvilinear								

Table 4-19 Comparison of the scores of the first and second groups of experiments

Comparison	Pleasantness			Beauty		
	Experiment 1	Experiment 2	*P Value*	Experiment 1	Experiment 2	*P Value*
low ceiling enclosed rectilinear	72.0 (67.0-78.0)	71.0 (64.5-77.5)	0.419	70.0 (63.0-74.0)	72.0 (64.5-76.0)	0.988
low ceiling enclosed curvilinear	80.0 (73.5-84.5)	81.0 (72.0-85.0)	0.531	78.0 (72.0-82.0)	83.0 (76.0-85.0)	0.249
low ceiling open rectilinear	84.0 (79.5-94.5)	85.0 (77.0-89.5)	0.173	80.0 (77.5-88.5)	83.0 (75.5-87.5)	0.822
low ceiling open curvilinear	80.0 (76.0-85.0)	82.0 (76.5-87.5)	0.756	76.0 (74.0-84.0)	82.0 (73.0-87.0)	0.446
high ceiling enclosed rectilinear	81.0 (76.5-87.0)	79.0 (70.0-84.0)	0.069	79.0 (75.5-84.5)	77.0 (71.0-83.5)	0.247
high ceiling enclosed curvilinear	79.0 (77.0-86.5)	80.0 (76.0-86.5)	0.583	80.0 (76.0-86.5)	78.0 (75.0-88.0)	0.893
high ceiling open rectilinear	86.0 (83.5-93.5)	87.0 (82.5-92.5)	0.482	85.0 (81.5-89.5)	85.0 (80.0-88.0)	0.731
high ceiling open curvilinear	88.0 (85.0-94.5)	86.0 (80.0-91.5)	0.094	86.0 (82.0-93.0)	86.0 (79.5-90.5)	0.718

Table 4-20 Comparison of the scores of the second and third groups of experiments

Comparison	Pleasantness			Beauty		
	Experiment 2	Experiment 3	*P Value*	Experiment 2	Experiment 3	*P Value*
low ceiling enclosed rectilinear	71.0 (64.5-77.5)	72.0 (67.5-78.5)	0.559	72.0 (64.5-76.0)	70.0 (65.5-74.0)	0.873
low ceiling enclosed curvilinear	81.0 (72.0-85.0)	81.0 (77.0-91.0)	0.062	83.0 (76.0-85.0)	81.0 (75.5-88.0)	0.542
low ceiling open rectilinear	85.0 (77.0-89.5)	84.0 (75.5-90.5)	0.941	83.0 (75.5-87.5)	81.0 (74.5-86.0)	0.434
low ceiling open curvilinear	82.0 (76.5-87.5)	84.0 (76.0-91.0)	0.554	82.0 (73.0-87.0)	78.0 (75.5-86.5)	0.792
high ceiling enclosed rectilinear	79.0 (70.0-84.0)	85.0 (78.0-87.5)	0.012	77.0 (71.0-83.5)	82.0 (77.5-85.0)	0.065
high ceiling enclosed curvilinear	80.0 (76.0-86.5)	84.0 (75.5-91.5)	0.234	78.0 (75.0-88.0)	81.0 (76.0-86.0)	0.566
high ceiling open rectilinear	87.0 (82.5-92.5)	92.0 (85.0-96.0)	0.153	85.0 (80.0-88.0)	86.0 (82.5-94.5)	0.418
high ceiling open curvilinear	86.0 (80.0-91.5)	89.0 (82.0-96.0)	0.290	86.0 (79.5-90.5)	85.0 (79.5-90.0)	0.897

Table 4-21 Comparison of ceiling height scores among three groups

Group	Pleasantness			Beauty		
	Low ceiling	High ceiling	*P Value*	Low ceiling	High ceiling	*P Value*
Experiment 1	312.0 (298.5-345.5)	336.0 (223.5-357.0)	<0.001	303.0 (289.5-321.5)	330.0 (311.5-349.5)	<0.001
Experiment 2	323.0 (294.0-332.5)	330.0 (310.0-350.0)	0.001	319.0 (289.0-329.0)	324.0 (311.0-347.0)	0.001
Experiment 3	325.0 (293.5-345.5)	351.0 (327.0-366.0)	<0.001	309.0 (296.0-332.5)	331.0 (317.5-356.5)	<0.001

Table 4-22 Comparison of openness scores among three groups

Group	Pleasantness			Beauty		
	Enclosed	Open	*P Value*	Enclosed	Open	*P Value*
Experiment1	312.0 (297.5-331.0)	338.0 (326.0-369.0)	<0.001	301.0 (290.5-321.5)	330.0 (311.5-344.0)	<0.001
Experiment 2	307.0 (287.0-331.5)	342.0 (317.5-364.0)	<0.001	311.0 (292.0-329.5)	334.0 (315.0-348.0)	<0.001
Experiment 3	318.0 (306.5-346.5)	348.0 (322.0-368.0)	<0.001	309.0 (296.0-337.5)	328.0 (315.0-354.0)	<0.001

Table 4-23 Comparison of contour scores among three groups

Group	Pleasantness			Beauty		
	Rectilinear	Curvilinear	*P Value*	Rectilinear	Curvilinear	*P Value*
Experiment 1	323.0 (311.5-349.0)	328.0 (314.5-348.5)	0.173	316.0 (301.0-328.5)	320.0 (304.0-337.5)	0.004
Experiment 2	325.0 (299.0-337.5)	328.0 (304.5-347.5)	0.011	317.0 (299.0-331.5)	328.0 (305.0-348.5)	<0.001
Experiment 3	331.0 (303.0-351.5)	343.0 (316.5-362.0)	0.023	316.0 (300.0-338.5)	323.0 (313.5-349.0)	<0.001

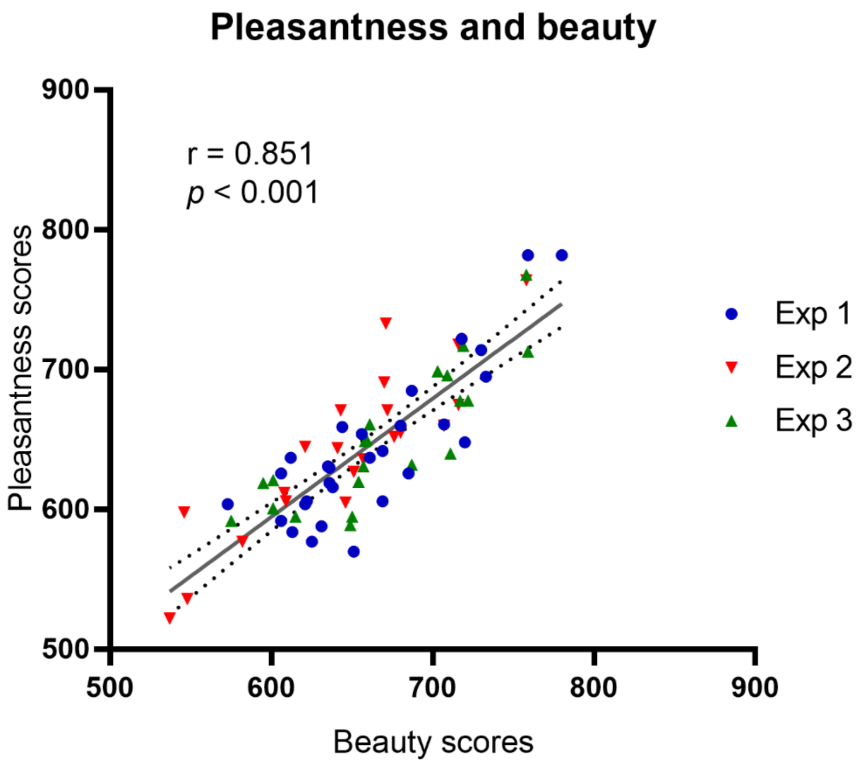


Figure 4-18 Correlation between the pleasure and esthetic value scores of all subjects in this study

After taking pleasure value as a response variable, the interaction items of the test group and esthetic value were included in the model, and the interaction items between the test group and esthetic value were not statistically significant (the results are not shown). The correlation between the pleasure and esthetic value scores did not differ among the three trials, so the correlation between the pleasure and esthetic value scores of all 71 subjects in the three trials was calculated (using pool analysis) and is shown in Fig. 5-4 as r total =0.851, p total < 0.001, indicating that the pleasure and esthetic value scores remained strongly correlated regardless of the duration or color of the stimulus.

There was a strong correlation between the pleasure and esthetic value scores of the 71 subjects in this study.

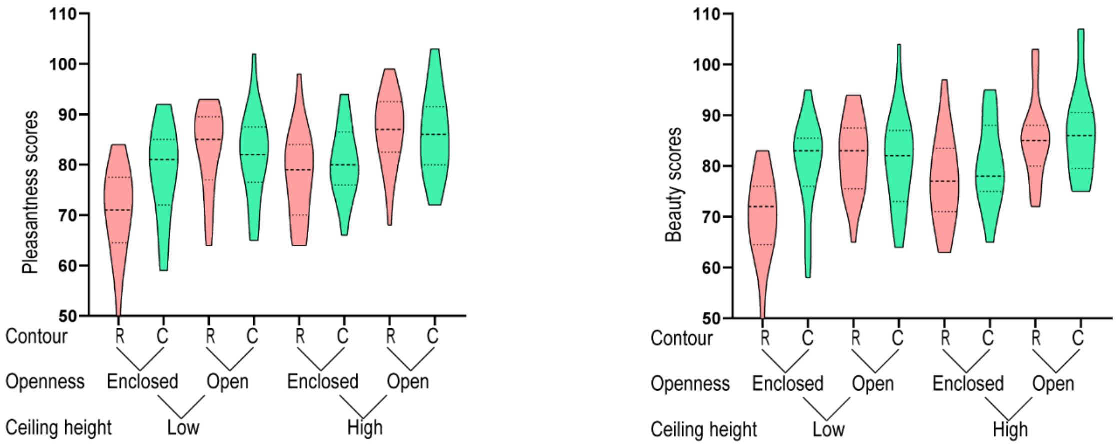


Figure 4-19 Results for the color-image condition.

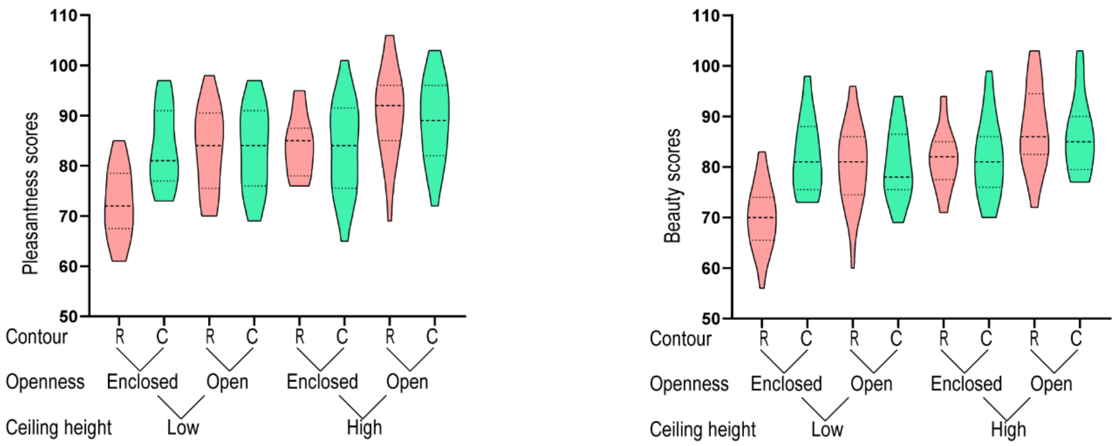


Figure 4-20 Results for the grayscale-image condition.

4.5. Discussion

At the end of the first experiment, we determined some possible applications of the newly gained knowledge from the results obtained under the 3000 ms stimulation condition. The purpose of such a long stimulation was to track the eye movement of the subjects to analyze whether they paid attention to the preset characteristics of the experiment when observing different pictures.

However, the stimulation time of 3000 ms may trigger additional cognitive processes, and the comparison and recollection with the previous pictures can lead to errors caused by other factors than the stimulus itself, which will increase the subjectivity of the esthetic and pleasure value judgement in the exploration of architectural features and increase the uncertainty of the results caused by the changes of feature attributes.

If the experiment can separate the subjects from their emotions, we can compare and judge the brain's first response, the results can better show the influence of architectural features on people and compare people's preferences for different architectural features.

Caitlin Mullin's research shows that people prefer to choose a location in a restaurant where they can observe the restaurant as a whole or look outside, and esthetic judgments can be made through implicit tests 50 ms [4]. In an experiment involving complex image stimulation, people tended to prefer simple outdoor scenes, but no significant relationship was found between the complexity of the indoor scene and the esthetic judgment of the scene. This shows that even if the architectural image is complex and chaotic, such features may not affect the esthetic judgment of the image. Thus, the differences in esthetic value judgments obtained in the current experiment were more likely affected by the architectural features themselves.
Based on the literature review, we determined that we would use a stimulus with a short exposure time to verify the conjecture from the first experiment and compare the differences in the judgment of the esthetic and pleasure value between the 3000 ms and 200 ms conditions.
The second experiment no longer tracked eye movements, and the stimulation lasted only 200 ms. Comparing the results of the first and second experiments enabled us to understand the effects of the different stimulation times on the judgment of the esthetic and pleasure value.

In one experiment, Gegenfurtner used 30-50 ms color image stimuli to compare varying levels of image luminance and showed that color images can provide better memory guidance in both man-made and natural scenes[5]. For example, when an architectural scene triggers emotion and memory, color stimulation may increase the perception of esthetic value.

In Oliva and Schyns's experiment, 160 images were categorized into three groups with varying features normal shading, abnormal shading, grayscale), and each image was displayed for 120 ms, which required subjects to quickly identify and describe the image. The results showed that the recognition of a normal color image is faster than that of a grayscale version of the same image[6]. Normal color plays a major role in simulating the visual experience of a real-life scene. Color helps cognitive system recognition [7][8].Spence found that color has an advantage in visual scene recognition memory in the early stage of visual processing [9]. His experiments also confirm our previous conjectures. Graf and Landwehr proposed the pleasure-interest model, which holds that the judgment of the pleasure value of an esthetic object is stimulus-driven and shares characteristics with automatic processing [10]. In one experiment, John W. Mullennix and colleagues studied subjects' preference for black and white or color art photography. The specific process was as follows: the 29 subjects (4 men and 25 women) in the experiment looked at 32 color photos sequentially and then corresponding black and white photos that had been taken two weeks after the color photos. The results showed that among the seven photos with significant differences between the color and black and white versions, the score of former was always higher than that of the latter version.

However, the semantic difference scores of six black and white images revealed that they were considered more unexpected, obvious, full of life, concrete, expressionless, quiet, or realistic than their color counterparts [11]. The current experiment showed that although the grayscale stimuli had a lower recognition speed and may have had lower pleasure and esthetic value scores than the color stimuli, the former had higher semantic description scores, And such description words may indicate positive associations with the architectural image stimuli.

The above three groups of experiments show that when people look at buildings, regardless of whether the image is in color or grayscale and whether it is carefully examined or only briefly glimpsed, open buildings are always considered to have higher esthetic and pleasure value than enclosed buildings. Buildings with high ceilings are generally considered to have higher esthetic and pleasure value than those with low ceilings.

The contour of the building affects people's sense of esthetic and pleasure value only in certain circumstances. In the first experiment, we analyzed the main effects of various building factors on the pleasure value scores. The results showed that the main effects of ceiling height and the degree of openness were statistically significant, indicating that in the 3000 ms color stimulation condition, the subjects were more likely to find buildings with high ceilings to have high pleasure value than buildings with low ceilings, and they were more likely to find open buildings to have high pleasure value than enclosed buildings.

This may be because people feel relaxed and happy in buildings with high ceilings and open areas.

However, the main effect of contour type was not significant, indicating that we are not sure which other features of buildings affect the pleasure value of rectilinear or curvilinear contours.

To investigate the influence of building contour type on people's perceived pleasure value under different conditions, we performed a simple-simple effect analysis. The results show that in the 3000 ms color stimulation condition, when buildings are enclosed and have low ceilings, such buildings with curvilinear contours are considered to have higher esthetic value than those with rectilinear contours, which can lead to a higher perceived pleasure value of the former.

This result is consistent with the finding of many other experiments that people prefer curves to straight lines [3, 12-14] . However, when buildings are open and have low ceilings, our results were the opposite; that is, such buildings with rectilinear contours were perceived to have higher pleasure value, and this difference may be due to the subjects' different cultural backgrounds, as, for example, the contours of traditional Chinese buildings are usually dominated by straight lines.

When testing the effect of openness on pleasure value with different combinations of building features, we found that regardless of how the ceiling height and contour type were combined, open buildings always had higher pleasure value scores than enclosed buildings, and only the combination of a low ceiling and curvilinear contour showed no significant difference between open and enclosed buildings. This may be because when a low ceiling is matched with a curvilinear contour, the difference in openness causes greater visual differences with different combinations of features. We found that a high ceiling was always perceived to have a higher pleasure value than a low ceiling, but the pleasure value of the former was not significantly higher than that of the latter in open buildings with rectilinear contours or in enclosed buildings with curvilinear contours, which may be caused by insufficient sample size.

In comparing the esthetic scores of different buildings, we found that the main effects of ceiling height, degree of openness and contour type were statistically significant, which indicated that in the 3000 ms color stimulation condition, the buildings with high ceilings were considered to have higher esthetic value than those with low ceilings, open buildings were perceived to have higher esthetic value than enclosed buildings, and buildings with curvilinear contours were thought to have higher esthetic value than those with rectilinear contours.

The results of simple-simple effect analysis show that in the 3000 ms color stimulation condition, the direction of the esthetic value score was consistent with that of the pleasure value score, except that there were slight differences in the effect of some factors. For example, when open buildings have low ceilings, those with rectilinear contours are considered to have a slightly higher esthetic value and significantly higher pleasure value than those with curvilinear contours.

For example, in both open buildings with rectilinear contours and enclosed buildings with curvilinear contours, those with high ceilings were always considered to have higher esthetic value than those with low ceilings, and the results indicating this are very clear ($P < 0.05$). In contrast, it was uncertain whether buildings with high ceilings have higher pleasure value than those with low ceilings, and the effect of the esthetic value is more powerful than that of the pleasure value.

When testing the effect of the degree of openness on esthetic value with building feature different combinations, there was no significant difference between the esthetic and pleasure values; that is, except for in buildings with low ceilings and curvilinear contours, open buildings were considered to have higher esthetic and pleasure values than enclosed buildings.

In the second experiment, we shortened the duration of stimulation to 200 ms to measure the effects of three building factors, ceiling height, openness and contour type, on the subjects' perceived pleasure and esthetic values in a very short period of time (their initial reaction).

According to the main effect analysis of various factors, the main effect of contour type on pleasure value was statistically significant ($p= 0.009$); that is, in the 200 ms stimulation condition, curvilinear contours were found to have higher pleasure value than rectilinear contours, which is different from the results in the 3000 ms condition.

The next simple-simple effect analysis showed that in the enclosed building with the low ceiling, curvilinear contours were considered to have higher pleasure value than rectilinear contours, while in the remaining three combinations of building features (enclosed buildings with a high ceiling, open buildings with a low ceiling, and open buildings with a high ceiling), there was no relationship between contour type and the subjects' perceived pleasure value, and the abnormal phenomenon of an open building with a low ceiling observed in the first experiment was not observed here.

This result further shows that the influence of the contour of the building on the pleasure value perceived by the subjects differs with different combinations of ceiling height and openness. We speculate that this variation in influence likely comes from the different cultural backgrounds of the participants; that is, compared with the curvilinear esthetic found in the architecture of Western countries, the esthetic in eastern countries tends towards more rectilinear contours. Even if curvilinear contours are considered to have higher esthetic value by most humans, this tendency is weakened among Asian populations because of cultural differences. Furthermore, the influence of this contour type is not regulated by the duration of the stimulation.

In the comparison of different building feature combinations in the first and second experiments, the effect of the degree of openness or the ceiling height on the pleasure value was slightly different. We found the results of the second experiment (in which the stimulation lasted for 200 ms) to be more consistent with those reported in other studies, which may be because the duration of the 3000 ms stimulation allowed the subjects time to recall other memories or draw comparisons.

In addition, certain aspects of the picture may have caused interference with stimulus and directly affected the subjects' sense of pleasure. As for the esthetic value scores in the second experiment, similar to the first experiment, the main effects of ceiling height, degree of openness and contour type were statistically significant.

A simple-simple effect analysis showed that in the case of open buildings with low ceilings, the esthetic value of rectilinear and curvilinear architectural contours were similar. This finding differs from the abnormal results of the first experiment and thus further shows that buildings with curvilinear contours specifically need a low ceiling and enclosed space to be considered to have high esthetic value among those with Asian esthetic backgrounds.

In buildings with low ceilings and curvilinear contours, the effect of openness on esthetic value was similar to that in the first experiment, and the change in stimulus exposure time may not have affected the effect of the degree of openness on esthetic value. Finally, in the case of open buildings with rectilinear contours, the esthetic value was not affected by the ceiling height, which is a different finding than that in the 3000 ms experiment. We speculate that it takes a certain amount of time to observe the open areas and rectilinear contours areas to produce the feeling that a "high ceiling is more beautiful than a low ceiling".

Based on the results of the second experiment, in the third experiment, we replaced the color pictures with grayscale pictures, although the contents of the pictures remained unchanged, in order to explore the effects of the three building factors on subjects' perceived pleasure and esthetic values with a shorter stimulus exposure time (200 ms) and with grayscale images.

The main effects of ceiling height, degree of openness and contour type on the esthetic value perceived by the participants in the third experiment were statistically significant, which was a similar finding to that in the second experiment.

A simple-simple effect analysis shows that when studying the effect of building contour type on esthetic value, except in enclosed buildings with a low ceiling, curvilinear contours have a higher pleasure value than rectilinear contours; in other cases, contour type does not have any effect on pleasure value.

After all three experiments, the pleasure value advantage of curvilinear over rectilinear contours was maintained only in the case of enclosed buildings with a low ceiling, indicating that the subjects were particularly sensitive to the pleasure value of building contours in this combination, regardless of the length of stimulus exposure or the image color, which do not affect the pleasure value results.

In the 200 ms grayscale condition, the effect of degree of openness on the pleasure value with different combinations of ceiling height and contour type was similar to that found in the first experiment, while the effect of ceiling height on pleasure value was similar to that found in the second experiment.

The main effects of ceiling height, degree of openness and contour type on the esthetic value score in the third experiment were statistically significant, which was a similar finding to that in the second experiment.

The results of the simple-simple effect analysis were also consistent with that of the 200 ms color condition, indicating that the change from a color to a grayscale stimulus does not affect esthetic judgment.

In looking at the results of all three experiments, we can see that in the first experiment, open buildings with a low ceiling and rectilinear contours were found to have a higher esthetic value than such buildings with curvilinear contours, and in buildings with rectilinear contours, those with high ceilings were considered able to have a higher esthetic value than those with low ceilings. However, the same results did not appear in the subsequent two experiments, indicating that the duration of the stimulus exposure may have impacted the esthetic value perceived by the subjects.

The numerical simulation allows us to obtain the overall situation of the evolutionary game. We brought the replicated dynamic equations into MATLAB R2021b and simulated the evolutionary trajectory of the 3 ESSs. The MATLAB simulation program and equation analysis are shown in

Figure 4-1, Figure 4-2, Figure 4-3, Figure 4-4. The initial values of parameters are set based on logical relationships by analyzing the parties of the game. Generally, the final convergence of the curve is only influenced by the logical connection, while the values of the initial parameters only affect the fluctuations of the curve[10]. The initial values corresponding to the three ESSs are set in Table 4-4. The evolutionary trends of the three ESS points are shown in Figure 4-5, Figure 4-7, Figure 4-9 and. The evolutionary trend of the three ESS points with an initial probability of 0.5 is shown in Figure 4-6, Figure 4-8, Figure 4-10. The x-axis represents the probability that the government chooses to regulate, and the y-axis represents the probability that the construction company elects to adopt ARC technology. From those figures, the evolutionary trend of stakeholders eventually converges to the corresponding stable point, whatever the initial probability, given the constant logical relationship.

Through a correlation analysis, we found that there was no difference in the correlation among the conditions in the three experiments. All three groups showed a strong correlation, and the same strong correlation was observed after merging the results.

This finding can be explained by the esthetic value being highly correlated with the pleasure value because the subjects usually felt pleasure when viewing what they perceived to be a beautiful building.

Pleasure is related to the brain area that recognizes esthetic emotion and higher cognition.

The results show that when subjects make esthetic judgments on pictures that make people happy, they consider these pictures to be beautiful, while changing the duration of the stimulus exposure or the color of the stimulus does not play a decisive role in the overall esthetic and pleasure value the subjects perceive.

4.6. Conclusions

We suggest that the change in the duration of the stimulus exposure did affect the degree of attention subjects paid to the details of the pictures in some experiments, and the effect of interference on the subjects also changed. Indeed, the change in the stimulus exposure from 3000 ms and 200 ms had no effect on the pleasure and esthetic value scores of the second group.

The same results also appeared when the stimulus color was changed. The scores of the 200 ms color condition and 200 ms grayscale condition affected the subjects' judgment of the pleasure and esthetic value scores in one experiment but not affect the scores in the other two.

Therefore, the results of this paper show that when the subjects evaluate the stimulus, a change in the duration and color of the stimulus do not notably interfere with the overall value scores. When an architectural scene with a variety of factors was displayed, it was shown that the subjects rated the pleasure and esthetic values differently with longer observation times but did not do so with shorter observation times, the length of the observation time and the color of the image do not affect the correlation between the perceived pleasure and esthetic values.

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Chapter 5

THE INFLUENCE OF AGE ON THE AESTHETIC JUDGMENT OF ARCHITECTURAL INTERIOR FEATURES.

CHAPTER FIVE: THE INFLUENCE OF AGE ON THE AESTHETIC JUDGMENT OF ARCHITECTURAL INTERIOR FEATURES.

5.1 Contents

Compared to aesthetics-related studies of younger people, older adults are a group that has received less attention. Today's older adults are mostly different from younger people in terms of cultural learning, and their cognitive state and level of depression may also be different. In a previous experiment architectural interior features on aesthetic judgments of young Chinese people we made an analysis and learned that ceiling height, openness and contour are statistically significant. Perhaps it is because modern aesthetic education is converging in the world at large and the aesthetic preferences of young people in China do not differ much from those in the West. However, Chinese older people lived in a vastly different environment during their adolescence, and their aesthetic habits may have differed since childhood.

Therefore, this chapter attempts to investigate the aesthetic differences in the architectural interior features of older Chinese people, taking them as the object of study. Understanding the aesthetic profile of the elderly may allow them to better design buildings appropriate to their age, and may also explore whether aesthetic preferences in the context of aging are influenced by cognitive state and depression levels.

5.2. Methodology

5.2.1. *Differences Between Older and Younger Participants*

With the growing problem of aging in the world, we need to pay more attention to the importance of the elderly in our research. In recent years, there has been an increasing number of studies on architecture in which the subjects are older adults. Some studies of the built environment have concluded that older people are more familiar with and prefer the natural environment, and are less familiar with and prefer the built environment and urban street environment than teenagers and adults**[1]**. This is consistent with the need to design for the physical and cognitive health of older adults in order to meet the demands of an active and less stressful environment. More medical researchers collaborating with architects across disciplines could also lead to a greater sense of well-being and health security for older adults in their everyday environments**[2]**. In addition to health considerations, promoting a sense of familiarity and security can also help enhance the residential satisfaction of older adults**[3]**.

Due to the weakened eyesight and reduced color sensitivity of the elderly, a great deal of research has been proposed regarding the color preferences of buildings for different age groups. There are studies on the color preferences of elderly people in housing**[4]**. There are also attempts to explore the design criteria for color in bathrooms of environments in which older people live**[5]**. Or studies that experiment with specific differences in color perception between older and younger people**[6]**.

There are also studies on the design of lighting space patterns in elderly facilities that explore the effects of vision on the elderly in addition to color**[7]**. All of these suggest that the effect of vision might change the observation of architectural interior features by older adults, further influencing their aesthetic judgment of architectural interiors.

Shepley did not obtain meaningful results for the experiment to understand the relationship between age, perception, and preference for changes in the perceptual responses and preferences of different age groups to specific categories of built environments**[7]**, perhaps due to too many confounding factors in the experimental design. The experiments in this chapter were conducted with older people in the same way as in Chapter 3, making the results of older and younger people somewhat comparable and meaningful as possible.

The age of the building in Mura's study can be considered as a variable that can influence people's preference, and some long-established traditional buildings will be more popular**[9]**. Traditional architecture may influence people's preference for architectural aesthetics. One of the reasons for using older people as the subject population in this chapter is the difference between the built environment in the era in which older people grew up and the built environment in the era in which younger people grew up. In the experiment in Chapter 3, we tried to explore whether people who grew up with different cultural backgrounds and aesthetic education would have different aesthetic preferences for the same architectural interior features. However, it is possible that because of the convergence of modern aesthetic education and the gradual absence of national boundaries in architectural design styles across much of the world, the architectural environment to which older people are accustomed may cause their preferences for architectural interior features to differ from those of younger people. The cognitive age of older adults influences the interior design characteristics of their residences. The younger the cognitive age of seniors, the more they live in a contemporary style bedroom or living room. In addition, the older their cognitive age, the more they lived in Korean traditional style bedrooms or living rooms**[9]**. This also proves that age can have an effect on the preference and choice of living environment.

5.2.2. *Basic assumptions*

In the experiments of the young people in Chapter 2, the results of the ratings of aesthetics and pleasantness of both ceiling height, openness and contour were statistically significant. However, a more in-depth analysis by means of simple-simple effects tests reveals that in contour, an architectural feature, we do not obtain superior scores in most cases for curved contours. This may indicate that the conclusion that curved contours are superior to straight contours is uncertain in some cases, and that older people, with weaker visual acuity compared to younger people, may overlook the difference in contour during the observation of architectural interior pictures. Moreover, because of the different architectural environments they have been exposed to since childhood, compared to modern architecture where they are more likely to be exposed to buildings with curved contours, older people live in an environment where they are more likely to be exposed to traditional Chinese buildings, self-built brick buildings with relatively simple structures, or buildings with relatively the same style such as Khrushchev buildings that were built on a large scale for policy reasons. Among them, there are more buildings with straight contour, which may lead to more familiarity of older people with buildings with straight contour, which in turn makes straight contour more advantageous in the aesthetic judgment of architectural interior features.

In the comparison of the two dimensions of ceiling height and openness, the influence of stressful environments on the elderly may be highlighted, leading to a possible preference for open, relaxed architectural environments. Therefore, high ceiling buildings and high openness buildings may gain a greater advantage in the aesthetic judgment of the interior features of buildings for the elderly.

5.2.3. *Setup of the experiment*

Subjects in this study were right-handed, without visual impairment or color blindness, with normal or corrected vision, and without psychiatric or neurological history. The experimental protocol of this study was approved by the Research Ethics Committee of Zhejiang University School of Medicine (2021-010). All participants signed a written informed consent prior to the experiment, and each participant received an award upon completion of the experiment. A total of 150 participants, including 73 males and 77 females, of whom 66 were 65-70 years old, 26 were 70-75 years old, 33 were 75-80 years old, and 25 were 80 years old and older, were included in this study. Of these subjects, 9 were illiterate, 32 had primary education, 85 had secondary education, and 24 had university or higher education. In addition to this, 121 had normal cognitive function and 29 had impaired cognitive function. 111 were not depressed, 29 were mildly depressed, and 10 were moderately depressed.

Participants were divided into 5 groups of 30 participants each, and each group was given a set of pictures (40) and was required to rate the aesthetics of each picture on a scale of 1-5. The experimental material was 200 architectural pictures[11], divided into 5 groups of 40 pictures each (Figure 5-1), and assigned to different groups of subjects. Each picture contained three features, arranged in order. Height, openness, and silhouette, all of which were dichotomized, and these three features were combined into eight categories of five images each.

The reason for dividing the 200 images into 5 groups is that older people have limited energy and find it difficult to maintain concentration and patience for long periods of time. In the previous experiment in Chapter 2 with young people as subjects, each of the 200 pictures was presented randomly for 3s, followed by an aesthetics and pleasantness rating using a keypad, during which the subjects' attention points needed to be recorded using an eye-tracking device, such that a complete experiment took 35-75 minutes. The use of the eye-tracking device was abandoned in this experiment because it was found that no pattern of observation points was observed in the experiment with young people. Because the pleasure score and the aesthetics score were found to show a strong correlation in the experiment with young people, we eliminated the pleasure score from the scoring items in order to reduce the misunderstanding of the elderly and the experiment time. However, the experiment time was still too long, and 200 images needed to be grouped for the experiment. The 200 pictures stimuli in the original experiment, each picture contains three kinds of architectural interior features, we can divide them into 8 groups, 25 pictures in each group have the same level of architectural interior features, we arrange the 25 pictures in each group according to the aesthetic rating of young people, and select the high score with low score with the way to divide into 5 groups. All groups of architectural interior feature types were grouped in the same way, so that we obtained five new groups having the same original experiment containing all combinations of architectural interior features, with 40 images in each group and five combinations of each architectural interior feature type (Figure 5-2).

The experiments were conducted in three community hospitals in Hangzhou, Zhejiang Province, China. Before the experiment, the instructor guided the subjects to sit correctly, place their hands on the scoring buttons (1-5), and relax. During the experiment, the subject was asked to keep his/her posture stable. The subject pressed the start button (0) to begin the experiment.

Analysis method reference: (Cotter and Silvia et al. 2017[12]; Nadal and Schiavi et al. 2018[13]; Skov and Vartanian et al. 2021[14]) . Each picture was presented for the same time of 3 s as the young people's experiment in Chapter 2(Figure 5-3), and this presentation time reduces the experimental errors caused by distractions in older people. The aesthetics rating option will appear after the pictures are presented, and subjects are required to follow the textual prompts to give an aesthetics rating of 1-5. This part of the rating time is the end of the button press, which can prevent the elderly from missing the rating due to untimely response or thinking. Although the number of pictures and items were reduced, the average usage time of the experiment reached 15-30 minutes.

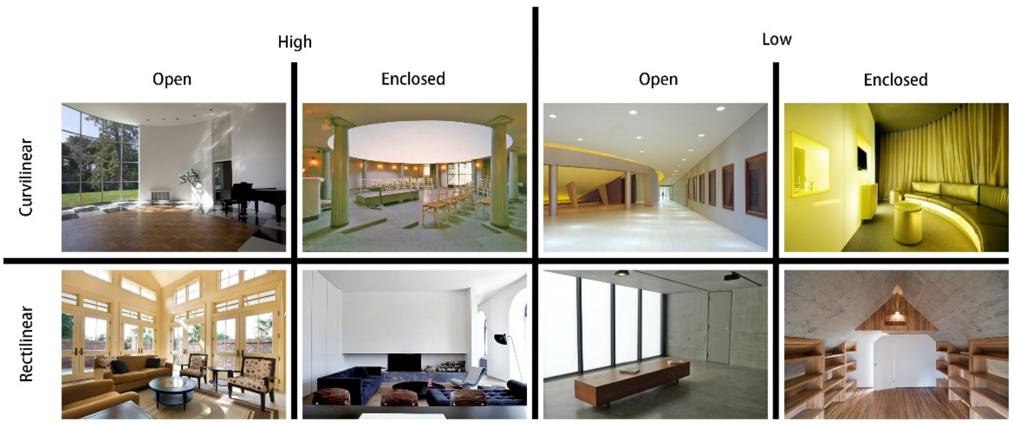

Fig. 5-1 The experimental material[11].

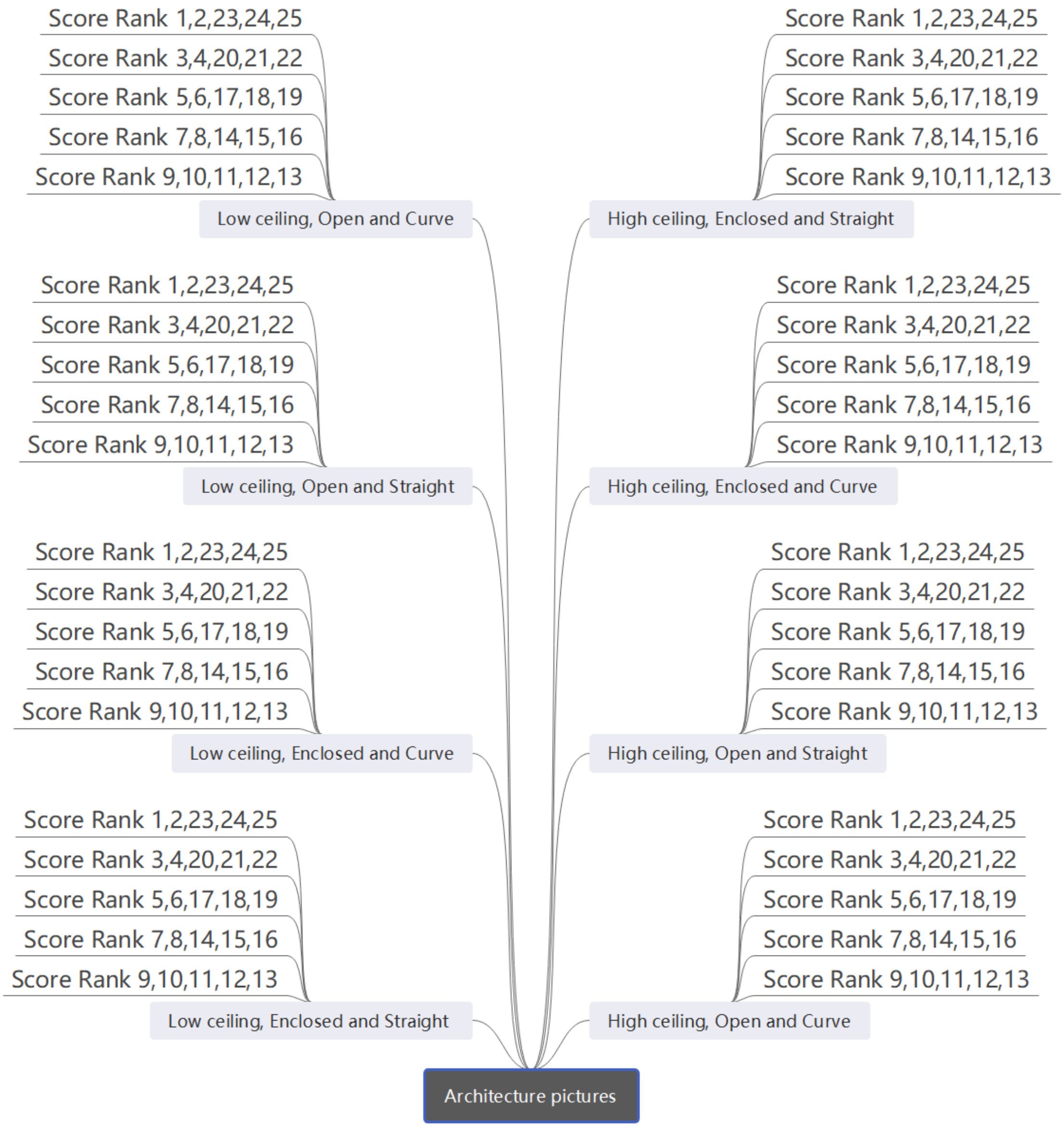

Fig. 5-2 Experimental picture material grouping.

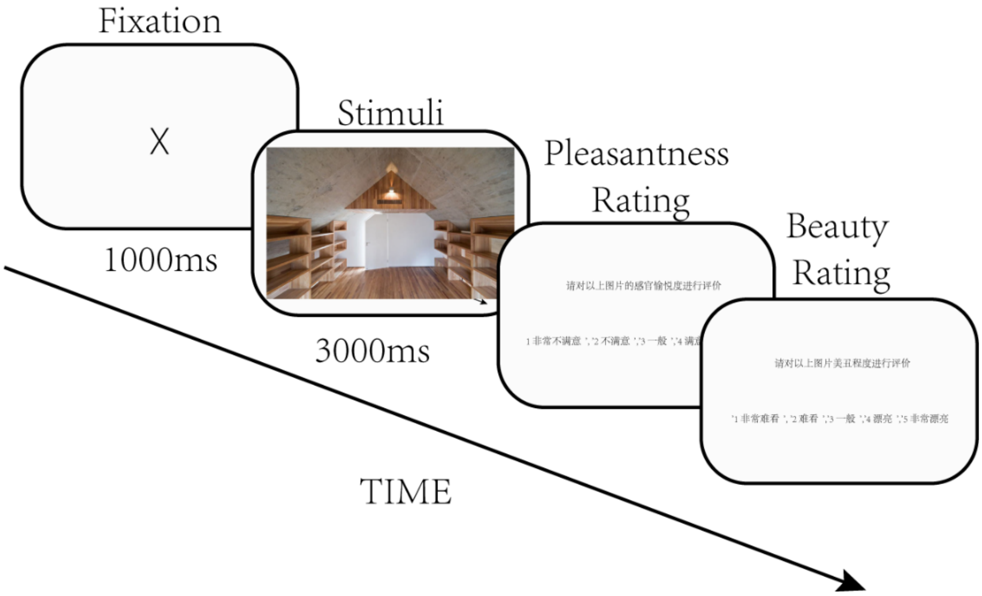

Fig. 5-3 Illustration of the experimental procedure.

5.3. Experimental data analysis

The experiment adopted a three-way repeated measures design, in which the 3 factors were ceiling height, openness and contour, which were all intra-group factors. Specifically, to examine the influence of ceiling height, openness and contour on the viewer's perceived pleasantness and beauty, as well as the possible interaction effect, three-way intra-group repeated measures analysis of variance (ANOVA) was adopted. First, for each participant, the sum of the scores for the 5 pictures in each set was calculated and treated as one "repeated measures" result for that participant (with a value range of 5–25 points). Because each participant was tested using 8 sets of pictures, 8 "repeated measures" results were obtained for each participant. Finally, the scoring results for all participants were used as response variables, and the 3 factors, i.e., ceiling height, openness, and contour, were used as intra-group factors in the repeated measures ANOVA model. The three-way repeated measures ANOVA model included 3 main effect terms (ceiling height, openness, and contour), three two-way interaction terms (ceiling height × openness, openness × contour, and ceiling height × contour) and one three-way interaction term (ceiling height × openness × contour). First, the total variation was decomposed to set up an ANOVA table based on model structure, and then, the significance of the main effect and if the interaction effects of each factor was tested. If a three-way interaction item was statistically significant, then a simple-simple effect test was performed, i.e., under different experimental treatments of the combination of 2 factors, the influence of the remaining factor on the dependent variable was tested. The effect of multiple comparisons [15] were corrected using Bonferroni correction. All the data in this study were analyzed using the bruceR [16]package of R (version 3.6.3), and two-sided tests were performed, for which the significance level was set to $\alpha = 0.05$. According to Barr et.al.[17], in order to reduce Class I errors and increase the efficiency of the test, the initial model should contain as many random slopes as possible, and then the full model is refined by gradually eliminating models that fail to converge, have malformed covariances, and are overfitted, in order to find the best model that fits the data structure and experimental design .

Individuals and pictures were included as level two random variables with numbers of 150 and 200, respectively. Hight, Openness, and Contour were level one fixed effect variables, as within-subject variables, and were included as triple interactions and as slopes for different individuals, respectively, and different pictures were included as random intercepts. Other individual characteristics such as gender, cognition, and age were gradually incorporated into the model as between-subjects variables (fixed). The likelihood ratio test showed that the above model differed from the model without the random slope term, the model with only one random effect variable, and the null model, while it did not differ from the full model and was therefore the best model.

Bonferroni correction： Let $H_1,...,H_M$ be a family of hypotheses and $P_1,...,P_m$ their corresponding p-values. Let m be the total number of null hypotheses, and let m_0 be the number of true null hypotheses. The familywise error rate (FWER) is the probability of rejecting at least one true H_i, that is, of making at least one type I error. The Bonferroni correction rejects the null hypothesis for each $p_i \leqslant a/m$, thereby controlling the FWER at $\leqslant a$ .Proof of this control follows from Boole's inequality, as follows:

$$\text{FWER} = P\left\{\bigcup_{i=1}^{m_0}\left(p_i \leq \frac{\alpha}{m}\right)\right\} \leq \sum_{i=1}^{m_0}\left\{P\left(p_i \leq \frac{\alpha}{m}\right)\right\} \leq m_0\frac{\alpha}{m} \leq m\frac{\alpha}{m} = \alpha.$$

```
library(bruceR)

mydata<-read.table("mydata.txt",head=T)


# Repeated measures ANOVA with hight, open, and curve as intra-group factors.

ff1<-MANOVA(data=mydata, subID="id", dv="pleas", digits = 6, aov.include = T, within=c("hight", "open", "curve"))

summary(ff1)

anova(ff1)
```

```
#simple-simple effect analysis
EMMEANS(ff1,"curve",by=c("hight","open"))
EMMEANS(ff1,"open",by=c("hight","curve"))
EMMEANS(ff1,"hight",by=c("curve","open"))
```

5.3.1. Data collation process

We first asked the subjects to fill in the questionnaire information, including name, age, gender, education, hometown, chronic disease status, and cognitive function and depression level. The cognitive function was judged by the Mini-mental State Examinatio (MMSE), while the depression level was judged by the PATIENT HEALTH QUESTIONNAIRE (PHQ-9). Excluding subjects who did not complete the experiment or could not perform the task well, we obtained information on 150 subjects and experimentally derived their scores for each picture selected, and after superimposing the scores of photos of the same combination of architectural interior features, we obtained the sum of each subject's aesthetic scores for each category of the same combination of architectural interior features (Table 5-1).

The MMSE test consists of simple questions in different categories, such as asking when and where the test is given, repeating a sequence of words, arithmetic questions, language use and comprehension, and simple actions. Any score greater than or equal to 25 (out of 30) represents normal intelligence. Less than 25 points can indicate severe (≤9), moderate (10-20), or mild (21-24).

The PHQ-9, one of the clinical rating scales for depression, is a depression self-assessment tool based on the American Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) and consists of 9 entries. Numerous clinical studies have shown that the PHQ-9 is a self-rating scale with good reliability and validity. It has been translated into several national language versions for clinical use in assessment-based antidepressant treatment.

The experiments were conducted in the hospital lounge area and at the information desk on a table with a laptop and a keyboard. The laptop was used to display the questions and pictures from the experiment. The keyboard was used to initiate the test and record the responses. The keys with numbers 1 through 5 (on the left side of the keyboard) were used to indicate the subject's answers. the 0 key (on the right side of the keyboard) was used to initiate the test. Subjects pressed the 0 key after the staff explained the procedure to start the test. The software is an experimental program prepared for MATLAB 2018.

The relevant experimental code is as follows:

```
%+ 1000ms    pic 3000ms variable ITI rate
clear;clc;rng('shuffle')
tic
warning('on');
Screen('CloseAll');
ITI= 0.1;
%%
%Define keyboard parameters
key0 = KbName('0)');
key1 = KbName('1!');
key2 = KbName('2@');
key3 = KbName('3#');
key4 = KbName('4$');
key5 = KbName('5%');
key8 = KbName('8*');
%%
% Screen('Preference', 'SkipSyncTests',0);    % SYNCHRONIZATION FAILURE
Screen('Preference', 'SkipSyncTests',1);    % SYNCHRONIZATION FAILURE
%%%
subj=input('Subject number: ','s');
name = input('Name:  ','s');
%%%
SaveFile    = [subj '_' name];
%Any key to continue
```

```
pause;

%Open Window
screens = Screen('Screens');
screenNumber = max(screens);
[width,height]=Screen('WindowSize',screenNumber);
[wPtr,rect]=Screen('OpenWindow',screenNumber,0,[],32,2);%0 0 640 480
%[wPtr,rect]=Screen('OpenWindow',screenNumber,0,[0 0 640 480],32,2);%0 0 640 480
[x,y]=WindowCenter(wPtr);
HideCursor;

%shift_length=120*percent;
Screen('TextSize',wPtr,40);                    % TEXT SIZE
Screen('TextFont',wPtr,char('SimHei'));
result = [];

%Generate stimulus matrix
a = ones(5,1);
b = zeros(5,1);
c = (1:5)';
A = [a,a,a,c;
     a,a,b,c;
     a,b,a,c;
     a,b,b,c;
     b,a,a,c;
```

```
    b,b,a,c;
    b,a,b,c;
    b,b,b,c];
r = randperm(size(A,1));      %Generate a random sequence of rows about the number of rows
B=A(r, :);                                %Reorder A according to this sequence
DrawFormattedText(wPtr,double('Press '0' to start the official experiment'),'center','center',[255 0
0]);
vbl=Screen('Flip', wPtr);
while 1
    [keylsDown,t,keyCode]=KbCheck;
    if keyCode(key0)
        break
    end
end
for i =1:40
    condition1= B(i,1);
    condition2= B(i,2);
    condition3= B(i,3);
    Num= B(i,4);
    ITI_trial = ITI;
    [beauty] = run_trial_A(wPtr, height, condition1,condition2,condition3,Num,ITI_trial);
    result(i,1).condition1 = condition1;
    result(i,1).condition2 = condition2;
    result(i,1).condition3 = condition3;
    result(i,1).Num = Num;
    result(i,1).beauty = beauty;
```

```
end
save([subj '_' name '.mat'],'result');
ShowCursor;
Screen('CloseAll');          %END
toc
function [ rate_beauty] = run_trial_A(wPtr, height,
condition1,condition2,condition3,Num,ITI_trial)
    %Define keyboard parameters
    key1 = KbName('1!');
    key2 = KbName('2@');
    key3 = KbName('3#');
    key4 = KbName('4$');
    key5 = KbName('5%');
    key8 = KbName('8*');
    cwd = 'D:\work\research\Exold\A';
    %Presenting 1000 ms X on the screen
    t_fixation = '+';
    DrawFormattedText(wPtr, t_fixation, 'center', 'center', [220 220 0]);
    Screen('Flip', wPtr);
    WaitSecs(1);
    %Read and render images
    picpath = ([cwd sprintf('/%d%d%d/',condition1,condition2,condition3)]);
    pic_all = dir(fullfile(picpath,'*.jpg'));
    pic = imread([picpath, pic_all(Num).name]);
    sti_pic = Screen('MakeTexture', wPtr,pic,[]);
    Screen('DrawTexture',wPtr,sti_pic,[]);
```

```
%Pic Show
Screen('Flip', wPtr);
WaitSecs(3);
%Pic Offset
Screen('FillRect', wPtr, [0,0,0]);      %Fill the screen with the background color
Screen('Flip', wPtr);                   %Display the filled screen
WaitSecs(ITI_trial);
%Evaluation
t_instruction= 'Please evaluate the beauty and ugliness of the above pictures';
t_rate_2 = ['1 very ugly', '2 ugly', '3 average', '4 beautiful', '5 very beautiful    '];
DrawFormattedText(wPtr, double(t_instruction), 'center', 1/2*height-100, [220 220 0]);
DrawFormattedText(wPtr, double(t_rate_2), 'center', 1/2*height, [220 220 0]);
Screen('Flip', wPtr);
while(1)
    [~,~,keyCode]=KbCheck;
    if keyCode(key1)
        rate_beauty=1;
        break
    elseif keyCode(key2)
        rate_beauty=2;
        break
    elseif keyCode(key3)
        rate_beauty=3;
        break
    elseif keyCode(key4)
```

```
            rate_beauty=4;
            break
        elseif keyCode(key5)
            rate_beauty=5;
            break
        end
    end
    while KbCheck
    end
    Screen('FillRect', wPtr, [0,0,0]);      %Fill the screen with the background color
    Screen('Flip', wPtr);                   %Display the filled screen
end
```

Table 5-1 Data Summary

Data Summary

Number	Name	Age	Sex	Education	Hometown	Diabetes	Hypertension	Coronary heart disease	Stroke	Hyperlipidemia	Cognitivefunction	Depression	Group	000	001	010	011	100	101	110	111
13	林夏先	80-	Male	Illiterate	Zhejiang	No	Yes	No	No	No	Normal	Normal	A	13	17	17	14	15	14	15	14
14	彭基年	65-70	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	B	14	13	18	14	17	15	18	21
15	危欢春	65-70	Female	Primary School	Non-Zhejiang	No	No	No	No	No	Damaged	Normal	B	12	16	13	15	21	17	13	13
16	孙素英	65-70	Female	University and above	Zhejiang	No	Yes	No	No	No	Normal	Mild depression	B	16	15	18	17	20	16	17	22
17	董云斐	75-80	Female	University and above	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	B	14	13	16	12	13	12	15	18
18	袁海根	75-80	Male	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	B	15	17	17	17	16	18	17	17
19	卢菊生	75-80	Male	Primary School	Zhejiang	No	No	Yes	Yes	No	Normal	Mild depression	B	24	24	25	25	25	25	25	25
20	傅荣珍	70-75	Female	Secondary Schools	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	B	13	11	14	15	12	16	20	21
21	钱翡翠	70-75	Female	Primary School	Zhejiang	No	No	Yes	No	No	Damaged	Normal	B	16	17	16	19	19	21	17	19
22	陈鑫伟	65-70	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Normal	Normal	B	17	17	18	16	17	19	15	20
23	徐心正	70-75	Male	Secondary Schools	Non-Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	B	14	15	14	16	15	17	19	19
24	李玉辉	65-70	Male	Secondary Schools	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	B	15	14	16	17	15	17	18	18
25	胡国民	75-80	Male	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	B	14	15	12	19	17	17	17	16
26	唐建萍	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	Yes	Normal	Normal	B	15	15	17	20	13	18	20	23
27	董霞琴	65-70	Female	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	B	16	15	18	16	15	18	20	21
28	汤桂凤	65-70	Female	Primary School	Zhejiang	No	No	No	No	No	Normal	Normal	B	15	15	17	19	14	19	17	20
29	吴华加	65-70	Female	Primary School	Zhejiang	No	No	No	No	No	Normal	Normal	B	22	19	20	23	20	19	23	23
30	阮荣珍	70-75	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	B	20	16	19	20	16	17	21	20
31	李根龙	65-70	Male	Secondary Schools	Zhejiang	No	No	No	No	Yes	Normal	Normal	B	15	17	15	18	17	17	17	18
32	马科金	70-75	Male	Secondary Schools	Non-Zhejiang	Yes	Yes	Yes	No	Yes	Damaged	Mild depression	B	16	16	15	17	15	15	18	20
33	贺爱文	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	B	15	16	19	18	19	21	20	23
34	黄伯煊	75-80	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Damaged	Normal	B	13	15	15	17	13	16	16	16
35	鲁远平	65-70	Male	Secondary Schools	Zhejiang	Yes	No	Yes	No	No	Normal	Normal	B	20	18	20	20	19	20	21	20
36	刘存杰	65-70	Male	Secondary Schools	Non-Zhejiang	No	Yes	No	No	Yes	Normal	Normal	B	15	16	16	16	15	17	16	16
37	俞丹凤	75-80	Female	Primary School	Zhejiang	Yes	Yes	Yes	No	No	Normal	Normal	B	17	16	18	17	12	18	18	19
38	严小根	65-70	Male	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	B	13	14	16	19	11	15	17	16
39	刘德顺	70-75	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	B	16	14	18	18	17	19	19	19
40	庄军伟	65-70	Male	University and above	Zhejiang	Yes	No	No	No	Yes	Normal	Normal	B	16	18	17	19	17	19	18	19
41	傅海鹰	65-70	Male	University and above	Non-Zhejiang	No	Yes	No	No	No	Damaged	Normal	B	16	16	19	18	16	17	17	20
42	翁珠莲	80-	Female	Primary School	Zhejiang	No	Yes	Yes	Yes	Yes	Damaged	Moderate depression	B	15	15	15	17	12	16	17	17
43	季木林	75-80	Male	Primary School	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	B	12	13	14	15	11	15	18	17
44	郑锡元	70-75	Male	Primary School	Zhejiang	No	Yes	Yes	No	No	Normal	Mild depression	A	15	20	19	18	15	16	18	20
45	周伯拯	65-70	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	A	16	19	18	14	14	13	18	16
46	杨美英	70-75	Female	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	A	12	19	18	17	12	11	14	14
47	来荣富	65-70	Male	Secondary Schools	Zhejiang	No	No	No	No	Yes	Normal	Normal	A	13	15	18	14	16	16	17	14
48	田国梅	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Moderate depression	A	14	19	18	17	17	13	16	21
49	周海新	70-75	Male	Primary School	Zhejiang	Yes	Yes	Yes	Yes	No	Normal	Mild depression	A	19	20	20	18	18	17	18	19
50	杨继成	80-	Male	Primary School	Zhejiang	No	Yes	No	Yes	No	Normal	Normal	A	15	15	19	16	16	14	15	16
51	陆素珍	80-	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	A	15	18	18	16	15	15	17	16
52	王银英	65-70	Female	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	A	15	17	16	15	14	15	15	16
53	陈秋珍	65-70	Female	Illiterate	Zhejiang	No	Yes	No	Yes	No	Damaged	Normal	A	18	21	19	18	18	18	20	18
54	杨秋香	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Damaged	Normal	A	16	17	17	18	17	13	16	12
55	赵玉缘	80-	Female	Primary School	Zhejiang	Yes	Yes	Yes	Yes	No	Damaged	Moderate depression	A	16	17	17	15	14	12	17	14
56	姚姗妹	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	A	14	15	16	14	18	15	16	18
57	吴持喜	75-80	Male	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	A	14	15	15	13	16	11	17	16
58	吴雪美	75-80	Female	Primary School	Zhejiang	No	Yes	No	Yes	No	Normal	Mild depression	A	17	17	16	14	15	10	15	15
59	应兰珍	75-80	Female	Primary School	Zhejiang	No	Yes	Yes	Yes	No	Normal	Normal	A	16	17	19	15	14	13	16	15
60	沈金莲	70-75	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Mild depression	A	15	18	17	18	15	15	17	15
61	顾荣美	75-80	Female	Illiterate	Zhejiang	Yes	Yes	No	No	Yes	Damaged	Normal	A	16	18	16	19	17	14	17	19
62	徐士珍	75-80	Female	Primary School	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	A	15	17	18	14	16	17	16	17

Data Summary

Number	Name	Age	Sex	Education	Hometown	Diabetes	Hypertension	Coronary heart disease	Stroke	Hyperlipidemia	Cognitivefunction	Depression	Group	000	001	010	011	100	101	110	111
63	鲁惠根	65-70	Female	Primary School	Zhejiang	No	No	Yes	No	Yes	Damaged	Mild depression	C	19	19	18	16	20	14	15	19
64	曹宝忠	80-	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Moderate depression	A	17	16	20	17	17	14	19	18
65	金杏莺	80-	Female	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	A	17	15	18	16	17	14	19	18
66	朱密迦	80-	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	A	17	16	18	18	15	17	18	18
67	张培中	65-70	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	A	13	18	17	14	17	17	17	15
68	刘冬平	65-70	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Damaged	Normal	A	14	17	17	14	15	13	15	16
69	郑日新	65-70	Male	University and above	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	A	16	16	18	17	16	16	19	18
70	严锡忠	80-	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Normal	Moderate depression	A	18	19	20	18	18	15	17	16
71	梁明合	65-70	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	C	20	20	20	20	20	20	20	20
72	方秋珍	75-80	Female	University and above	Zhejiang	No	No	Yes	Yes	No	Normal	Moderate depression	C	14	11	17	12	14	14	17	15
73	冯彩领	80-	Female	University and above	Zhejiang	No	No	No	Yes	No	Normal	Normal	C	18	19	18	16	18	15	15	20
74	陈菊明	75-80	Female	Primary School	Zhejiang	No	No	Yes	No	No	Damaged	Normal	C	18	19	18	17	19	16	19	17
76	王志贤	75-80	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	C	18	15	18	18	19	18	17	18
77	邓芳强	70-75	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	C	17	19	19	19	19	17	19	20
78	周阿文	80-	Female	Illiterate	Zhejiang	Yes	Yes	No	No	No	Damaged	Mild depression	C	16	16	16	11	15	15	17	16
79	鲁瑞强	70-75	Male	University and above	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	C	17	17	13	13	16	14	15	15
80	闵美华	65-70	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Damaged	Normal	C	16	20	14	18	17	18	21	21
81	钱金宝	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Damaged	Mild depression	C	16	18	18	15	20	17	20	19
82	任野俐	65-70	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	C	17	18	16	17	20	15	19	20
83	赵丽华	65-70	Female	Secondary Schools	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	C	15	18	17	17	18	14	19	18
84	陈德政	80-	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	C	15	15	15	15	15	15	15	15
85	秦金妹	80-	Female	Secondary Schools	Non-Zhejiang	Yes	No	Yes	Yes	Yes	Normal	Moderate depression	C	17	17	15	18	16	16	17	20
86	张国荣	65-70	Male	University and above	Zhejiang	No	No	No	No	No	Normal	Normal	C	18	17	18	20	19	17	20	18
87	朱益琴	70-75	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	C	17	19	18	18	18	19	18	20
88	陈兰英	80-	Female	Illiterate	Zhejiang	Yes	Yes	No	Yes	Yes	Normal	Normal	C	15	15	15	17	14	14	15	15
89	王冰泉	70-75	Male	University and above	Zhejiang	Yes	Yes	No	No	No	Normal	Moderate depression	C	16	17	16	18	16	16	17	18
90	陈鉴安	75-80	Male	Secondary Schools	Zhejiang	Yes	No	No	No	No	Normal	Normal	C	17	20	20	19	19	19	19	20
91	马惠民	65-70	Male	Secondary Schools	Zhejiang	Yes	No	No	No	No	Damaged	Normal	C	16	19	16	18	17	18	18	20
92	徐萍	65-70	Female	Secondary Schools	Zhejiang	No	Yes	No	Yes	No	Normal	Normal	C	15	18	18	19	16	15	14	22
93	章孝霄	65-70	Female	Illiterate	Non-Zhejiang	No	No	No	No	No	Damaged	Mild depression	C	18	19	16	19	20	17	19	20
94	孙金妹	75-80	Female	Primary School	Zhejiang	No	No	Yes	No	No	Normal	Mild depression	C	19	20	20	16	18	18	18	19
95	夏家骥	70-75	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	C	15	16	17	18	15	18	19	19
96	骆方根	80-	Male	Primary School	Zhejiang	No	Yes	No	No	No	Normal	Normal	C	14	14	15	16	17	15	19	18
97	杨可思	65-70	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	C	16	19	17	17	16	17	19	19
98	胡俊锋	65-70	Male	University and above	Non-Zhejiang	No	Yes	Yes	No	No	Normal	Normal	C	15	17	19	19	18	17	20	19
99	侯文英	80-	Female	Primary School	Zhejiang	No	Yes	Yes	No	Yes	Normal	Mild depression	D	16	16	19	16	15	17	16	17
100	沈惠琳	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	D	18	17	17	19	19	17	18	17
101	杜秋容	65-70	Male	University and above	Zhejiang	No	No	No	No	Yes	Normal	Mild depression	D	16	19	18	17	16	16	17	17
102	汪玉书	80-	Male	University and above	Non-Zhejiang	No	Yes	No	No	No	Normal	Normal	D	18	14	18	16	15	18	16	17
103	魏锦林	75-80	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Mild depression	D	19	20	20	20	20	19	20	20
104	章敏	75-80	Female	Primary School	Zhejiang	No	Yes	Yes	Yes	No	Normal	Mild depression	D	18	18	19	20	16	17	18	19
105	周文娅	75-80	Female	Secondary Schools	Zhejiang	Yes	Yes	Yes	Yes	Yes	Normal	Mild depression	D	20	17	22	17	15	17	12	17
106	马有为	80-	Male	Secondary Schools	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	D	18	15	19	19	17	18	16	17
107	钱根花	75-80	Female	Secondary Schools	Zhejiang	No	Yes	No	No	No	Damaged	Mild depression	D	16	18	20	20	14	17	20	20
108	何金仙	70-75	Female	Illiterate	Zhejiang	No	Yes	No	Yes	No	Normal	Normal	D	16	18	15	16	15	17	19	17
109	郑桂香	70-75	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Damaged	Normal	D	19	19	20	15	19	19	19	18
110	骆志坤	70-75	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Damaged	Normal	D	16	18	19	18	13	18	16	16
111	鲁美云	80-	Female	Primary School	Zhejiang	No	Yes	No	Yes	No	Normal	Normal	D	15	16	15	16	15	16	17	15
112	范君	65-70	Female	Secondary Schools	Zhejiang	Yes	Yes	Yes	No	Yes	Normal	Mild depression	D	20	17	21	19	15	17	17	19
113	沈国泉	65-70	Male	Secondary Schools	Zhejiang	No	Yes	No	No	Yes	Normal	Mild depression	D	19	18	20	20	18	20	16	18

Data Summary

Number	Name	Age	Sex	Education	Hometown	Diabetes	Hypertension	Coronary heart disease	Stroke	Hyperlipidemia	Cognitivefunction	Depression	Group	000	001	010	011	100	101	110	111
114	吴国良	65-70	Male	Primary School	Zhejiang	No	Yes	No	No	No	Normal	Normal	D	18	20	19	18	16	18	15	18
115	刘国瑛	70-75	Male	University and above	Non-Zhejiang	No	Yes	No	No	No	Normal	Normal	D	18	18	19	19	13	19	16	16
116	卢连生	65-70	Male	Secondary Schools	Zhejiang	Yes	No	No	No	No	Normal	Mild depression	D	15	18	18	14	14	14	18	14
117	曾志良	80-	Male	University and above	Zhejiang	Yes	Yes	Yes	Yes	Yes	Normal	Normal	D	17	15	18	16	16	18	18	17
118	祝美康	80-	Female	Secondary Schools	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	D	20	19	20	19	17	18	18	18
119	陈宝明	65-70	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Normal	Mild depression	D	19	20	19	20	18	18	18	17
120	杨依群	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	D	17	19	19	17	16	18	17	21
121	沈群	80-	Female	Secondary Schools	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	D	21	19	19	17	17	19	18	20
122	王丽萍	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	Yes	Normal	Mild depression	D	19	19	21	19	16	19	19	20
123	曹淑英	70-75	Female	Secondary Schools	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	D	19	20	20	20	17	19	20	20
124	马原芳	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Mild depression	D	18	18	20	20	19	17	19	17
125	英小娟	65-70	Female	Primary School	Zhejiang	No	No	No	No	No	Damaged	Mild depression	E	19	20	19	20	18	20	18	20
126	葛水林	75-80	Male	Secondary Schools	Zhejiang	No	No	No	No	Yes	Damaged	Moderate depression	D	17	15	15	16	15	14	14	16
127	赵亦君	70-75	Female	Illiterate	Zhejiang	Yes	Yes	No	No	No	Damaged	Mild depression	E	12	13	11	12	16	15	16	12
128	保林成	80-	Male	Primary School	Non-Zhejiang	Yes	Yes	Yes	No	No	Normal	Normal	D	20	21	21	20	20	19	21	20
129	罗希兰	65-70	Female	Secondary Schools	Non-Zhejiang	Yes	No	No	No	No	Normal	Normal	D	15	14	19	17	18	17	18	16
130	郑青云	70-75	Female	Primary School	Zhejiang	No	No	No	No	No	Normal	Normal	E	16	19	17	18	17	19	19	18
131	谢金英	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	Yes	Damaged	Normal	E	17	17	16	15	17	17	19	17
132	应宝玉	70-75	Female	Secondary Schools	Zhejiang	No	Yes	Yes	No	Yes	Normal	Normal	E	17	17	17	19	18	19	19	19
133	章关金	65-70	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	E	19	17	19	18	19	20	19	19
134	史丽瑛	65-70	Female	Secondary Schools	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	E	18	15	19	18	19	17	20	18
135	陈屏芬	65-70	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Normal	Normal	E	14	16	18	12	15	16	19	13
136	陈庆芬	65-70	Female	Secondary Schools	Zhejiang	No	No	No	Yes	No	Normal	Moderate depression	E	18	14	19	14	18	14	20	14
137	吴亚萍	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	E	18	18	23	22	19	22	24	18
138	郑华堂	75-80	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	E	20	20	20	20	20	20	20	19
139	汉雨平	65-70	Male	Primary School	Zhejiang	No	Yes	No	Yes	No	Damaged	Normal	E	16	14	17	17	18	19	19	17
140	冯安康	70-75	Male	University and above	Zhejiang	No	Yes	No	No	No	Damaged	Normal	E	17	19	18	19	19	20	20	19
141	韩爱和	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	Yes	Normal	Normal	E	12	13	14	13	17	14	18	16
142	蒋龙富	65-70	Male	Primary School	Zhejiang	No	Yes	No	No	No	Normal	Normal	E	14	14	18	15	16	15	18	16
143	王春娣	65-70	Female	Illiterate	Zhejiang	No	Yes	No	No	Yes	Normal	Normal	E	17	16	20	16	18	16	20	16
144	金列干	75-80	Male	Secondary Schools	Zhejiang	No	Yes	Yes	No	No	Normal	Normal	E	15	16	16	16	16	17	16	18
145	王年根	65-70	Male	Primary School	Zhejiang	No	Yes	Yes	Yes	Yes	Normal	Normal	E	16	19	17	18	19	18	18	18
146	吴玲玲	75-80	Female	Secondary Schools	Zhejiang	No	No	No	Yes	Yes	Normal	Normal	E	17	18	20	20	17	19	20	20
147	赖志泉	75-80	Male	Secondary Schools	Zhejiang	Yes	No	Yes	No	No	Normal	Normal	E	15	14	17	20	15	18	18	18
148	施允友	70-75	Male	Primary School	Non-Zhejiang	No	No	No	No	No	Normal	Normal	E	14	14	14	16	15	15	16	14
149	董木英	80-	Female	Primary School	Zhejiang	Yes	Yes	Yes	Yes	No	Damaged	Mild depression	E	19	18	18	19	17	19	16	20
150	周济法	80-	Male	Secondary Schools	Zhejiang	No	Yes	No	No	No	Normal	Normal	E	15	15	17	17	15	17	19	18
151	劳小花	75-80	Female	Primary School	Zhejiang	No	Yes	No	No	No	Damaged	Normal	E	17	19	19	17	20	19	19	17
152	陈根弟	65-70	Male	Secondary Schools	Zhejiang	No	Yes	No	Yes	Yes	Normal	Normal	E	15	17	19	16	19	19	18	18
153	张立武	75-80	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	E	18	19	20	20	19	21	21	18
154	汪庆兴	75-80	Male	University and above	Zhejiang	No	Yes	No	No	No	Normal	Normal	E	22	20	23	23	22	23	25	21
155	王安	75-80	Male	Secondary Schools	Zhejiang	No	Yes	Yes	No	Yes	Normal	Normal	E	19	20	19	20	18	22	21	22
156	孙庆平	75-80	Male	University and above	Zhejiang	Yes	Yes	No	No	No	Normal	Normal	E	16	17	18	19	17	18	19	19
157	任斐	65-70	Male	Secondary Schools	Non-Zhejiang	Yes	No	No	No	No	Normal	Normal	E	15	15	16	16	16	15	16	16
158	陈金富	75-80	Male	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	D	20	17	19	21	17	19	21	20
159	应建平	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Mild depression	C	16	17	16	18	16	15	19	19
160	王连娣	75-80	Female	Secondary Schools	Zhejiang	Yes	Yes	No	No	Yes	Normal	Normal	C	17	20	18	19	19	20	20	20
161	李萍	65-70	Female	Secondary Schools	Zhejiang	No	No	No	No	No	Normal	Normal	A	16	17	18	16	15	13	16	16
162	王志祥	65-70	Male	Secondary Schools	Zhejiang	Yes	Yes	No	No	No	Normal	Mild depression	A	14	18	17	17	14	11	16	13
163	诸红卫	70-75	Female	Secondary Schools	Zhejiang	No	Yes	No	Yes	No	Normal	Normal	A	16	20	17	16	17	14	18	17
50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

5.3.2. Repeated-measures ANOVA with three within-group factors

Following Barr et.al. [17], to reduce Class I error and increase test efficiency, the initial model should contain as many random slopes as possible, and then the full model is refined by gradually eliminating models that fail to converge, have malformed covariances, and are overfitted to find the best model for the data structure and experimental design. A linear mixed model was used to explore the relationship between the three features and scoring. The lmerTest in R, bruceR package was used for modeling (Table 5-2).

====== ANOVA (Within-Subjects Design) ======

Table 5-2. Model assignment table

Variable name	Variable type	Assignment (0 for reference)	Fixed OR random effects
Beauty	Continuous variable	Continuous variable	Dependent variable
Ceiling height(A1)	Low	0	Fixed effect
	High	1	
Openness(A2)	Enclosed	0	Fixed effect
	Open	1	
Contour(A3)	Rec	0	Fixed effect
	Cur	1	
participant	Factor	1～150	Random effects
picture	Factor	1～200	Random effects

Table 5-3. Descriptives

"A1" "A2" "A3"	Mean	S.D.	n
A10 A20	A30 16.426667	(2.177822)	150
A10 A20	A31 17.046667	(2.165429)	150
A10 A21	A30 17.686667	(2.111447)	150
A10 A21	A31 17.253333	(2.320572)	150
A11 A20	A30 16.640000	(2.247385)	150
A11 A20	A31 16.780000	(2.462797)	150
A11 A21	A30 17.893333	(2.098727)	150
A11 A21	A31 17.913333	(2.325628)	150

Total sample size: N = 150

The final model is as follows: Beauty~ Height * Openness * Contour + (Height + Openness + Contour | parti) + (1 | picture).

Where individuals and pictures were used as level two random variables with numbers of 150 and 200, respectively. Height, Openness, and Contour were level one fixed-effect variables, which were within-subject variables and were included as triple interactions and were used as slopes for different individuals, respectively, and different pictures were included as random intercepts. Other individual characteristics such as gender, cognition, and age were gradually incorporated into the model as between-subjects variables (fixed). The likelihood ratio test showed that the above model differed from the model without the random slope term, the model with only one random effect variable, and the null model, while it did not differ from the full model and was therefore the best model(Table 5-4) -(Table 5-15).

ANOVA Table:

Dependent variable(s):   scores

Between-subjects factor(s): –

Within-subjects factor(s): A1, A2, A3

Covariate(s): –

Table 5-4. ANOVA Table

	MS	MSE	df1 df2	F	p		η^2p [90% CI of η^2p]	η^2G
A1	12.403333	3.770783	1 149	3.289326	.072	.	.021599 [.000000, .074551]	.002066
A2	278.403333	2.673468	1 149	104.135669	<.001	***	.411383 [.315114, .495635]	.044410
A3	2.253333	2.822125	1 149	0.798453	.373		.005330 [.000000, .041381]	.000376
A1 * A2	15.870000	1.854899	1 149	8.555720	.004	**	.054303 [.010406, .123807]	.002642
A1 * A3	0.013333	2.276756	1 149	0.005856	.939		.000039 [.000000, .002645]	.000002
A2 * A3	25.813333	1.865347	1 149	13.838356	<.001	***	.084982 [.026948, .163494]	.004291
A1 * A2 * A3	16.333333	2.428971	1 149	6.724384	.010	*	.043181 [.005686, .108215]	.002719

MSE = mean square error (the residual variance of the linear model)

η^2p = partial eta-squared = SS / (SS + SSE) = F * df1 / (F * df1 + df2)

ω^2p = partial omega-squared = (F - 1) * df1 / (F * df1 + df2 + 1)

η^2G = generalized eta-squared (see Olejnik & Algina, 2003)

Cohen's $f^2 = \eta^2p / (1 - \eta^2p)$

Levene's Test for Homogeneity of Variance:

No between-subjects factors. No need to do the Levene's test.

Mauchly's Test of Sphericity:

The repeated measures have only two levels. The assumption of sphericity is always met.

Table 5-5. Univariate Type III Repeated-Measures ANOVA Assuming Sphericity

	Sum Sq	num Df	Error SS	den Df	F value	Pr(>F)
(Intercept)	355214	1	3354.3	149	15778.7421	< 2.2e-16 ***
A1	12	1	561.8	149	3.2893	0.0717439 .
A2	278	1	398.3	149	104.1357	< 2.2e-16 ***
A3	2	1	420.5	149	0.7985	0.3729974
A1:A2	16	1	276.4	149	8.5557	0.0039834 **
A1:A3	0	1	339.2	149	0.0059	0.9391030
A2:A3	26	1	277.9	149	13.8384	0.0002816 ***
A1:A2:A3	16	1	361.9	149	6.7244	0.0104583 *

Table 5-6.Anova Table (Type III tests)

	Num Df	Den Df	MSE	F	ges	Pr(>F)
A1	1	149	3.7708	3.2893	0.002066	0.0717439 .
A2	1	149	2.6735	104.1357	0.044410	< 2.2e-16 ***
A3	1	149	2.8221	0.7985	0.000376	0.3729974
A1:A2	1	149	1.8549	8.5557	0.002642	0.0039834 **
A1:A3	1	149	2.2768	0.0059	0.000002	0.9391030
A2:A3	1	149	1.8653	13.8384	0.004291	0.0002816 ***
A1:A2:A3	1	149	2.4290	6.7244	0.002719	0.0104583 *

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

EMMEANS(ff1,"A1",by=c("A2","A3"))

------ EMMEANS (effect = "A1") ------

Table 5-7.Joint Tests of "A1"

Effect	"A2"	"A3"	df1	df2	F	p	η²p [90% CI of η²p]
A1	A20	A30	1	149	1.543	.216	.010 [.000, .053]
A1	A21	A30	1	149	1.262	.263	.008 [.000, .049]
A1	A20	A31	1	149	1.584	.210	.011 [.000, .054]
A1	A21	A31	1	149	14.759	<.001 ***	.090 [.030, .170]

Note. Simple effects of repeated measures with 3 or more levels are different from the results obtained with SPSS MANOVA syntax.

Table 5-8.Estimated Marginal Means of "A1"

"A1"	"A2"	"A3"	Mean [95% CI of Mean]	S.E.
A10	A20	A30	16.427 [16.075, 16.778]	(0.178)
A11	A20	A30	16.640 [16.277, 17.003]	(0.183)
A10	A21	A30	17.687 [17.346, 18.027]	(0.172)
A11	A21	A30	17.893 [17.555, 18.232]	(0.171)
A10	A20	A31	17.047 [16.697, 17.396]	(0.177)
A11	A20	A31	16.780 [16.383, 17.177]	(0.201)
A10	A21	A31	17.253 [16.879, 17.628]	(0.189)
A11	A21	A31	17.913 [17.538, 18.289]	(0.190)

Table 5-9.Pairwise Comparisons of "A1"

Contrast	"A2"	"A3"	Estimate S.E.	df	t	p	Cohen’s d [95% CI of d]
A11 - A10	A20	A30	0.213 (0.172)	149	1.242	.216	0.095 [-0.056, 0.246]
A11 - A10	A21	A30	0.207 (0.184)	149	1.123	.263	0.092 [-0.070, 0.254]
A11 - A10	A20	A31	-0.267 (0.212)	149	-1.259	.210	-0.119 [-0.305, 0.068]
A11 - A10	A21	A31	0.660 (0.172)	149	3.842	<.001 ***	0.294 [0.143, 0.445]

Pooled SD for computing Cohen’s d: 2.248

No need to adjust p values.

Disclaimer:

By default, pooled SD is Root Mean Square Error (RMSE).

There is much disagreement on how to compute Cohen’s d.

You are completely responsible for setting `sd.pooled`.

You might also use `effectsize::t_to_d()` to compute d.

> EMMEANS(ff1,"A2",by=c("A1","A3"))

------ EMMEANS (effect = "A2") ------

Table 5-10.Joint Tests of "A2"

Effect "A1" "A3"	df1	df2	F	p	η^2p [90% CI of η^2p]
A2 A10 A30	1	149	85.119	<.001 ***	.364 [.266, .452]
A2 A11 A30	1	149	47.165	<.001 ***	.240 [.148, .333]
A2 A10 A31	1	149	1.285	.259	.009 [.000, .049]
A2 A11 A31	1	149	39.578	<.001 ***	.210 [.121, .302]

Note. Simple effects of repeated measures with 3 or more levels are different from the results obtained with SPSS MANOVA syntax.

Table 5-11.Estimated Marginal Means of "A2"

"A2" "A1" "A3"	Mean [95% CI of Mean]	S.E.
A20 A10 A30	16.427 [16.075, 16.778]	(0.178)
A21 A10 A30	17.687 [17.346, 18.027]	(0.172)
A20 A11 A30	16.640 [16.277, 17.003]	(0.183)
A21 A11 A30	17.893 [17.555, 18.232]	(0.171)
A20 A10 A31	17.047 [16.697, 17.396]	(0.177)
A21 A10 A31	17.253 [16.879, 17.628]	(0.189)
A20 A11 A31	16.780 [16.383, 17.177]	(0.201)
A21 A11 A31	17.913 [17.538, 18.289]	(0.190)

Table 5-12.Pairwise Comparisons of "A2":

Contrast	"A1"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A21 - A20	A10	A30	1.260	(0.137)	149	9.226	<.001 ***	0.560 [0.440, 0.680]
A21 - A20	A11	A30	1.253	(0.182)	149	6.868	<.001 ***	0.557 [0.397, 0.718]
A21 - A20	A10	A31	0.207	(0.182)	149	1.134	.259	0.092 [-0.068, 0.252]
A21 - A20	A11	A31	1.133	(0.180)	149	6.291	<.001 ***	0.504 [0.346, 0.662]

Pooled SD for computing Cohen's d: 2.248

No need to adjust p values.

Disclaimer:

By default, pooled SD is Root Mean Square Error (RMSE).

There is much disagreement on how to compute Cohen's d.

You are completely responsible for setting `sd.pooled`.

You might also use `effectsize::t_to_d()` to compute d.

> EMMEANS(ff1,"A3",by=c("A1","A2"))

------ EMMEANS (effect = "A3") ------

Table 5-13.Joint Tests of "A3"

Effect	"A1"	"A2"	df1	df2	F	p	η^2p [90% CI of η^2p]
A3	A10	A20	1	149	14.881	<.001 ***	.091 [.031, .171]
A3	A11	A20	1	149	0.538	.464	.004 [.000, .036]
A3	A10	A21	1	149	6.005	.015 *	.039 [.004, .102]
A3	A11	A21	1	149	0.013	.911	.000 [.000, .000]

Note. Simple effects of repeated measures with 3 or more levels are different from the results obtained with SPSS MANOVA syntax.

Table 5-14.Estimated Marginal Means of "A3"

"A3"	"A1"	"A2"	Mean [95% CI of Mean]	S.E.
A30	A10	A20	16.427 [16.075, 16.778]	(0.178)
A31	A10	A20	17.047 [16.697, 17.396]	(0.177)
A30	A11	A20	16.640 [16.277, 17.003]	(0.183)
A31	A11	A20	16.780 [16.383, 17.177]	(0.201)
A30	A10	A21	17.687 [17.346, 18.027]	(0.172)
A31	A10	A21	17.253 [16.879, 17.628]	(0.189)
A30	A11	A21	17.893 [17.555, 18.232]	(0.171)
A31	A11	A21	17.913 [17.538, 18.289]	(0.190)

Table 5-15.Pairwise Comparisons of "A3"

Contrast	"A1"	"A2"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A31 - A30	A10	A20	0.620	(0.161)	149	3.858	<.001 ***	0.276 [0.135, 0.417]
A31 - A30	A11	A20	0.140	(0.191)	149	0.734	.464	0.062 [-0.105, 0.230]
A31 - A30	A10	A21	-0.433	(0.177)	149	-2.451	.015 *	-0.193 [-0.348, -0.037]
A31 - A30	A11	A21	0.020	(0.178)	149	0.112	.911	0.009 [-0.148, 0.165]

Pooled SD for computing Cohen's d: 2.248

No need to adjust p values.

Disclaimer:

By default, pooled SD is Root Mean Square Error (RMSE).

There is much disagreement on how to compute Cohen's d.

You are completely responsible for setting `sd.pooled`.

You might also use `effectsize::t_to_d()` to compute d.

5.3.3. Comparison between image groups

Table 5-16. ANOVA Table for Group 1

	MS	MSE	df1	df2	F	p	η^2p [90% CI of η^2p]	η^2G
A1	44.204167	3.316236	1	29	13.329622	.001 **	.314901 [.100538, .505582]	.062198
A2	61.004167	1.340374	1	29	45.512810	<.001 ***	.610805 [.412250, .731840]	.083854
A3	10.837500	2.035776	1	29	5.323523	.028 *	.155098 [.009771, .356298]	.016000
A1 * A2	19.837500	1.639224	1	29	12.101762	.002 **	.294434 [.085338, .488133]	.028903
A1 * A3	21.004167	1.530029	1	29	13.727956	<.001 ***	.321287 [.105477, .510956]	.030551
A2 * A3	26.004167	1.892098	1	29	13.743564	<.001 ***	.321535 [.105671, .511164]	.037551
*A1 * A2 * A3*	*87.604167*	*1.474856*	*1*	*29*	*59.398441*	*<.001 ****	*.671940 [.494424, .775027]*	*.116170*

> EMMEANS(ff1,"A1",by=c("A2","A3"))

------ EMMEANS (effect = "A1") ------

Table 5-17.Pairwise Comparisons of "A1" for Group 1

Contrast	"A2"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A11 - A10	A20	A30	0.367	(0.309)	29	1.187	.245	0.189 [-0.136, 0.513]
A11 - A10	A21	A30	-0.900	(0.277)	29	-3.250	.003 **	-0.463 [-0.754, -0.172]
A11 - A10	A20	A31	-3.233	(0.439)	29	-7.372	<.001 ***	-1.663 [-2.125, -1.202]
A11 - A10	A21	A31	0.333	(0.408)	29	0.817	.420	0.171 [-0.258, 0.600]

------ EMMEANS (effect = "A2") ------

Table 5-18. Pairwise Comparisons of "A2" for Group 1

Contrast	"A1"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A21 - A20	A10	A30	2.300	(0.284)	29	8.091	<.001 ***	1.183 [0.884, 1.482]
A21 - A20	A11	A30	1.033	(0.273)	29	3.781	<.001 ***	0.532 [0.244, 0.819]
A21 - A20	A10	A31	-1.433	(0.324)	29	-4.423	<.001 ***	-0.737 [-1.078, -0.396]
A21 - A20	A11	A31	2.133	(0.403)	29	5.290	<.001 ***	1.097 [0.673, 1.522]

------ EMMEANS (effect = "A3") ------

Table 5-19. Pairwise Comparisons of "A3" for Group 1

Contrast	"A1"	"A2"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A31 - A30	A10	A20	2.033	(0.376)	29	5.408	<.001 ***	1.046 [0.650, 1.441]
A31 - A30	A11	A20	-1.567	(0.338)	29	-4.636	<.001 ***	-0.806 [-1.161, -0.450]
A31 - A30	A10	A21	-1.700	(0.296)	29	-5.740	<.001 ***	-0.874 [-1.186, -0.563]
A31 - A30	A11	A21	-0.467	(0.345)	29	-1.353	.186	-0.240 [-0.603, 0.123]

Table 5-20. ANOVA Table for Group 2

	MS	MSE	df1	df2	F	p	η^2p [90% CI of η^2p]	η^2G
A1	92.504167	2.780029	1	29	33.274536	<.001 ***	.534320 [.317060, .676612]	.055228
A2	178.537500	4.882328	1	29	36.568112	<.001 ***	.557712 [.345215, .693668]	.101386
A3	44.204167	1.893822	1	29	23.341249	<.001 ***	.445944 [.218953, .610511]	.027175
A1 * A2	2.204167	2.531753	1	29	0.870609	.358	.029146 [.000000, .063145]	.001391
A1 * A3	12.604167	2.552443	1	29	4.938080	.034 *	.145503 [.006372, .345986]	.007902
A2 * A3	0.337500	1.320259	1	29	0.255632	.617	.008738 [.000000, .132678]	.000213
A1 * A2 * A3	6.337500	2.716810	1	29	2.332699	.138	.074449 [.000000, .259970]	.003989

Table 5-21. Pairwise Comparisons of "A1" for Group 2

Contrast	"A2"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A11 - A10	A20	A30	0.267	(0.498)	29	0.535	.596	0.115 [-0.326, 0.556]
A11 - A10	A21	A30	1.300	(0.372)	29	3.496	.002 **	0.563 [0.234, 0.892]
A11 - A10	A20	A31	1.833	(0.292)	29	6.279	<.001 ***	0.794 [0.535, 1.052]
A11 - A10	A21	A31	1.567	(0.483)	29	3.240	.003 **	0.678 [0.250, 1.106]

Table 5-22. Pairwise Comparisons of "A2" for Group 2

Contrast	"A1"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A21 - A20	A10	A30	1.133	(0.274)	29	4.131	<.001 ***	0.491 [0.248, 0.733]
A21 - A20	A11	A30	2.167	(0.614)	29	3.528	.001 **	0.938 [0.394, 1.482]
A21 - A20	A10	A31	1.933	(0.314)	29	6.154	<.001 ***	0.837 [0.559, 1.115]
A21 - A20	A11	A31	1.667	(0.461)	29	3.618	.001 **	0.721 [0.314, 1.129]

Table 5-23. Pairwise Comparisons of "A3" for Group 2

Contrast	"A1"	"A2"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A31 - A30	A10	A20	-0.000	(0.307)	29	-0.000	1.000	-0.000 [-0.272, 0.272]
A31 - A30	A11	A20	1.567	(0.444)	29	3.530	.001 **	0.678 [0.285, 1.071]
A31 - A30	A10	A21	0.800	(0.416)	29	1.922	.065 .	0.346 [-0.022, 0.715]
A31 - A30	A11	A21	1.067	(0.318)	29	3.356	.002 **	0.462 [0.180, 0.743]

Pooled SD for computing Cohen's d: 2.310

No need to adjust p values.

Table 5-24. ANOVA Table for Group 3

	MS	MSE	df1	df2	F	p	η²p [90% CI of η²p]	η²G
A1	18.150000	1.701724	1	29	10.665653	.003 **	.268889 [.067751, .465821]	.021374
A2	26.666667	2.201149	1	29	12.114883	.002 **	.294659 [.085500, .488327]	.031092
A3	2.016667	2.827011	1	29	0.713356	.405	.024008 [.000000, .175864]	.002421
A1 * A2	28.016667	1.447701	1	29	19.352521	<.001 ***	.400238 [.173741, .575040]	.032615
A1 * A3	8.066667	1.566667	1	29	5.148936	.031 *	.150779 [.008217, .351684]	.009614
A2 * A3	2.016667	1.775287	1	29	1.135966	.295	.037695 [.000000, .202858]	.002421
A1 * A2 * A3	26.666667	1.977011	1	29	13.488372	<.001 ***	.317460 [.102507, .507740]	.031092

------ EMMEANS (effect = "A1") ------

Table 5-25. Pairwise Comparisons of "A1" for Group 3

Contrast	"A2"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A11 - A10	A20	A30	0.900	(0.255)	29	3.525	.001 **	0.458 [0.192, 0.724]
A11 - A10	A21	A30	0.933	(0.409)	29	2.279	.030 *	0.475 [0.049, 0.902]
A11 - A10	A20	A31	-1.167	(0.349)	29	-3.340	.002 **	-0.594 [-0.958, -0.230]
A11 - A10	A21	A31	1.533	(0.302)	29	5.073	<.001 ***	0.781 [0.466, 1.096]

------ EMMEANS (effect = "A2") ------

Table 5-26. Pairwise Comparisons of "A2" for Group 3

Contrast	"A1"	"A3"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A21 - A20	A10	A30	0.467	(0.317)	29	1.472	.152	0.238 [-0.093, 0.568]
A21 - A20	A11	A30	0.500	(0.364)	29	1.372	.181	0.255 [-0.125, 0.634]
A21 - A20	A10	A31	-0.500	(0.392)	29	-1.276	.212	-0.255 [-0.663, 0.153]
A21 - A20	A11	A31	2.200	(0.327)	29	6.736	<.001 ***	1.120 [0.780, 1.460]

------ EMMEANS (effect = "A3") ------

Table 5-27. Pairwise Comparisons of "A3" for Group 3

Contrast	"A1"	"A2"	Estimate	S.E.	df	t	p	Cohen's d [95% CI of d]
A31 - A30	A10	A20	1.033	(0.305)	29	3.387	.002 **	0.526 [0.208, 0.844]
A31 - A30	A11	A20	-1.033	(0.364)	29	-2.843	.008 **	-0.526 [-0.905, -0.148]
A31 - A30	A10	A21	0.067	(0.407)	29	0.164	.871	0.034 [-0.390, 0.457]
A31 - A30	A11	A21	0.667	(0.391)	29	1.707	.098 .	0.339 [-0.067, 0.746]

Table 5-28. ANOVA Table for Group 4

	MS	MSE	df1	df2	F	p	η²p [90% CI of η²p]	η²G
A1	39.204167	2.307615	1	29	16.989042	<.001 ***	.369415 [.145549, .550495]	.050475
A2	27.337500	1.751293	1	29	15.609894	<.001 ***	.349920 [.128722, .534671]	.035743
A3	0.704167	1.497270	1	29	0.470300	.498	.015958 [.000000, .156291]	.000954
A1 * A2	0.004167	1.711063	1	29	0.002435	.961	.000084 [.000000, .000000]	.000006
A1 * A3	24.704167	2.755891	1	29	8.964131	.006 **	.236121 [.047565, .436193]	.032411
A2 * A3	11.704167	1.617960	1	29	7.233905	.012 *	.199645 [.028410, .401591]	.015622
A1 * A2 * A3	0.337500	1.268534	1	29	0.266055	.610	.009091 [.000000, .134098]	.000457

Table 5-29. Pairwise Comparisons of "A1" for Group 4

Contrast	"A2"	"A3"	Estimate S.E.	df	t	p	Cohen's d [95% CI of d]
A11 - A10	A20	A30	-1.533 (0.348)	29	-4.404	<.001 ***	-0.798 [-1.169, -0.428]
A11 - A10	A21	A30	-1.367 (0.451)	29	-3.030	.005 **	-0.712 [-1.192, -0.231]
A11 - A10	A20	A31	-0.100 (0.337)	29	-0.297	.769	-0.052 [-0.411, 0.307]
A11 - A10	A21	A31	-0.233 (0.313)	29	-0.745	.462	-0.121 [-0.455, 0.212]

Table 5-30. Pairwise Comparisons of "A2" for Group 4

Contrast	"A1"	"A3"	Estimate S.E.	df	t	p	Cohen's d [95% CI of d]
A21 - A20	A10	A30	1.033 (0.282)	29	3.670	<.001 ***	0.538 [0.238, 0.838]
A21 - A20	A11	A30	1.200 (0.366)	29	3.275	.003 **	0.625 [0.235, 1.015]
A21 - A20	A10	A31	0.300 (0.375)	29	0.800	.430	0.156 [-0.243, 0.555]
A21 - A20	A11	A31	0.167 (0.263)	29	0.634	.531	0.087 [-0.193, 0.367]

Pooled SD for computing Cohen's d: 1.921

No need to adjust p values.

Table 5-31. Pairwise Comparisons of "A3" for Group 4

Contrast	"A1"	"A2"	Estimate S.E.	df	t	p	Cohen's d [95% CI of d]
A31 - A30	A10	A20	-0.167 (0.356)	29	-0.468	.643	-0.087 [-0.466, 0.292]
A31 - A30	A11	A20	1.267 (0.339)	29	3.739	<.001 ***	0.660 [0.299, 1.020]
A31 - A30	A10	A21	-0.900 (0.333)	29	-2.700	.011 *	-0.469 [-0.824, -0.114]
A31 - A30	A11	A21	0.233 (0.351)	29	0.664	.512	0.121 [-0.253, 0.496]

Pooled SD for computing Cohen's d: 1.921

No need to adjust p values.

Table 5-32. ANOVA Table for Group 5

	MS	MSE	df1	df2	F	p	η²p [90% CI of η²p]	η²G
A1	47.704167	1.359339	1	29	35.093648	<.001 ***	.547537 [.332862, .686269]	.037780
A2	33.004167	1.900718	1	29	17.364049	<.001 ***	.374515 [.150082, .554595]	.026446
A3	5.104167	4.155891	1	29	1.228176	.277	.040630 [.000000, .208056]	.004184
A1 * A2	5.704167	0.824856	1	29	6.915346	.014 *	.192546 [.025098, .394621]	.004673
A1 * A3	1.837500	0.940948	1	29	1.952817	.173	.063090 [.000000, .243795]	.001510
A2 * A3	23.437500	1.678879	1	29	13.960205	<.001 ***	.324957 [.108356, .514029]	.018926
A1 * A2 * A3	5.704167	1.238649	1	29	4.605150	.040 *	.137037 [.003521, .336690]	.004673

------ EMMEANS (effect = "A1") ------

Table 5-33. Pairwise Comparisons of "A1" for Group 5

Contrast "A2" "A3"			Estimate	S.E.	df	t	p	Cohen’s d [95% CI of d]
A11 - A10	A20	A30	1.067	(0.283)	29	3.764	<.001 ***	0.574 [0.262, 0.885]
A11 - A10	A21	A30	1.067	(0.267)	29	4.000	<.001 ***	0.574 [0.280, 0.867]
A11 - A10	A20	A31	1.333	(0.260)	29	5.135	<.001 ***	0.717 [0.431, 1.003]
A11 - A10	A21	A31	0.100	(0.268)	29	0.372	.712	0.054 [-0.242, 0.349]

------ EMMEANS (effect = "A2") ------

Table 5-34. Pairwise Comparisons of "A2" for Group 5

Contrast "A2" "A3"			Estimate	S.E.	df	t	p	Cohen’s d [95% CI of d]
A21 - A20	A10	A30	1.367	(0.286)	29	4.785	<.001 ***	0.735 [0.421, 1.049]
A21 - A20	A11	A30	1.367	(0.294)	29	4.656	<.001 ***	0.735 [0.412, 1.058]
A21 - A20	A10	A31	0.733	(0.365)	29	2.009	.054 .	0.394 [-0.007, 0.796]
A21 - A20	A11	A31	-0.500	(0.274)	29	-1.822	.079 .	-0.269 [-0.571, 0.033]

Table 5-35. Pairwise Comparisons of "A3" for Group 5

Contrast "A2" "A3"			Estimate	S.E.	df	t	p	Cohen’s d [95% CI of d]
A31 - A30	A10	A20	0.200	(0.305)	29	0.656	.517	0.108 [-0.228, 0.443]
A31 - A30	A11	A20	0.467	(0.335)	29	1.394	.174	0.251 [-0.117, 0.619]
A31 - A30	A10	A21	-0.433	(0.377)	29	-1.151	.259	-0.233 [-0.647, 0.181]
A31 - A30	A11	A21	-1.400	(0.433)	29	-3.232	.003 **	-0.753 [-1.229, -0.277]

5.3.4. Analysis of the correlation between cognitive function and aesthetic evaluation

We used the coef ( ) function to extract the slope of the final model regarding Height, Openness, Contour and aesthetics in each individual, organized as a frequency histogram (**Fig. 5-4**). Then general linear regression analysis was done with depression level (dependent variable) and logistic regression with cognition (dependent variable) as independent variables, respectively, where factors such as gender and age were included in the model as covariates. The results were as follows (**Table 5-36**) (**Table 5-37**).

Table 5-36. Individuals' sensitivity to Hight, Openness and Contour in relation to the degree of depression

	β	Std.Error	*P*
(Intercept)	0.30	0.09	0.001
Hight	0.63	0.94	0.504
sex	-0.16	0.10	0.099
age	0.07	0.04	0.103
(Intercept)	0.26	0.22	0.250
Openness	0.28	0.85	0.744
sex	-0.16	0.10	0.103
age	0.07	0.04	0.112
(Intercept)	0.35	0.12	0.004
Contour	-0.20	0.77	0.794
sex	-0.16	0.10	0.108
age	0.07	0.04	0.101

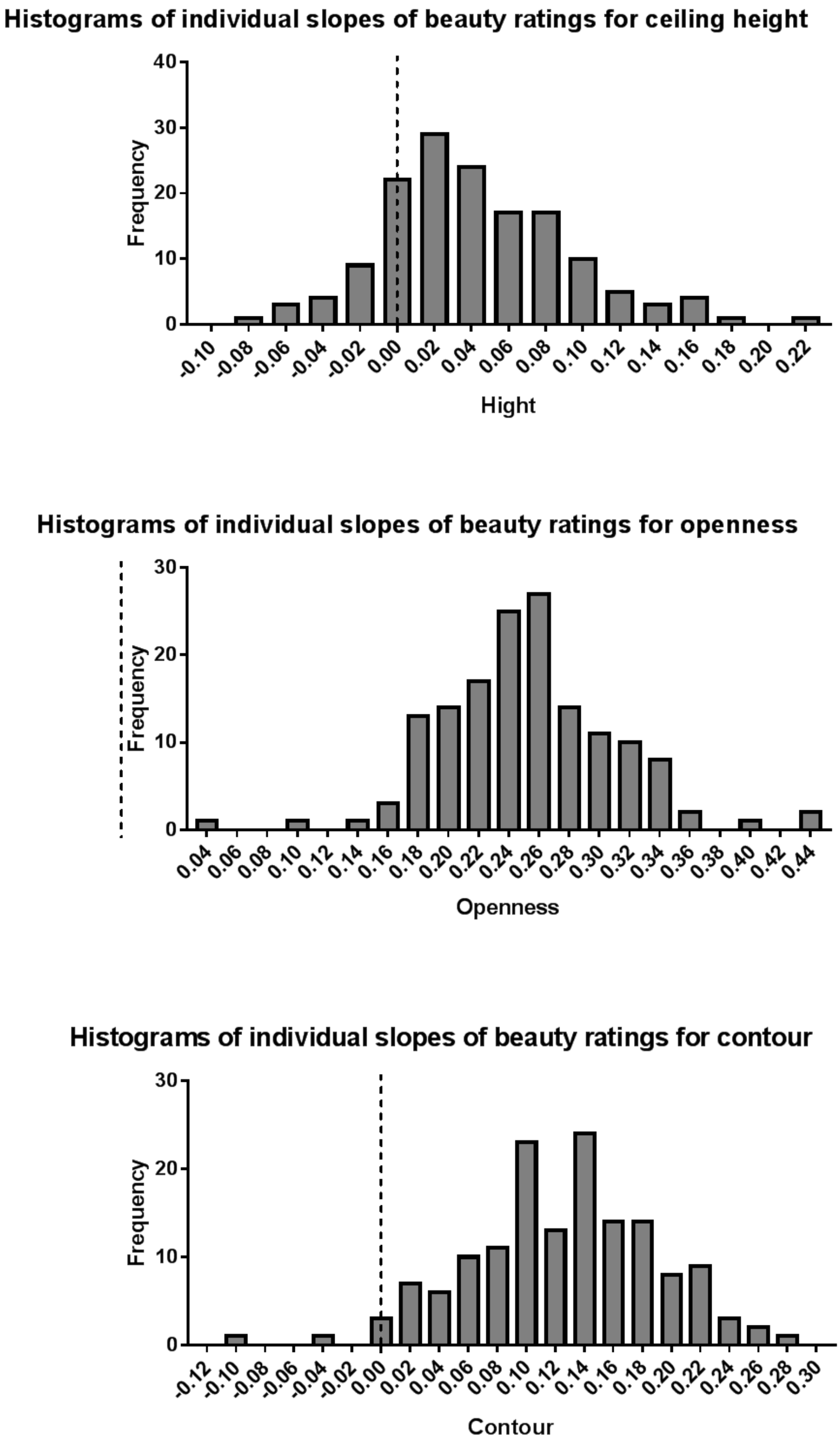

Fig. 5-4 Frequency histogram

5.3.5. Analysis of the correlation between depression level and aesthetic evaluation

Table 5-37. Individuals' sensitivity to Hight, Openness and Contour in relation to the degree of cognition

	logit(P)	Std.Error	*P*
(Intercept)	-0.73	0.37	0.046
Hight	-5.92	4.34	0.173
sex	-0.90	0.44	0.043
age	-0.09	0.19	0.633
(Intercept)	-0.16	1.00	0.870
Openness	-3.27	3.87	0.398
sex	-0.91	0.44	0.040
age	-0.07	0.19	0.713
(Intercept)	-1.17	0.51	0.021
Contour	1.73	3.28	0.599
sex	-0.92	0.44	0.037
age	-0.09	0.19	0.641

5.4. Comparison of experimental results

Through ANOVA we can find that only openness is statistically significant, which is different from the results in Chapter 2 where all architectural interior characteristics of young people are significant. This may be caused by the fact that older people live in a different architectural environment and receive a different aesthetic education than younger people. The reason why buildings with high openness are significant for both young and old people is perhaps that an open built environment gives the feeling of reduced stress, which is most easily observed. We obtained the difference in the combination of interior features of each type of building by subtracting the scores of enclosed pictures from the scores of open pictures in each group. By comparing the difference in the scores of interior features of buildings by different age groups, we found that all age groups of subjects felt that the aesthetic rating of open was better than enclosed (**Fig. 5-5**). We also found significant openness for each group in the grouped results, indicating that this result is very stable (**Fig. 5-6**).

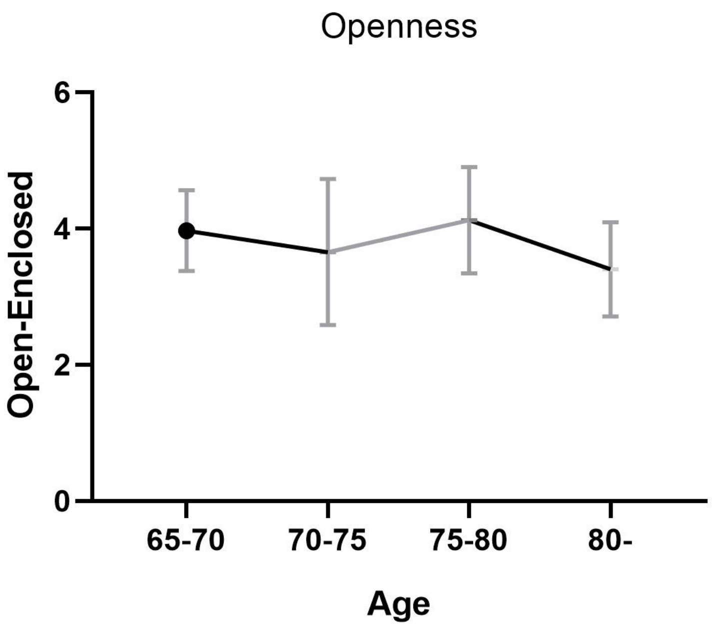

Fig. 5-5 Comparison of the difference in aesthetic evaluation of Openness in different age groups

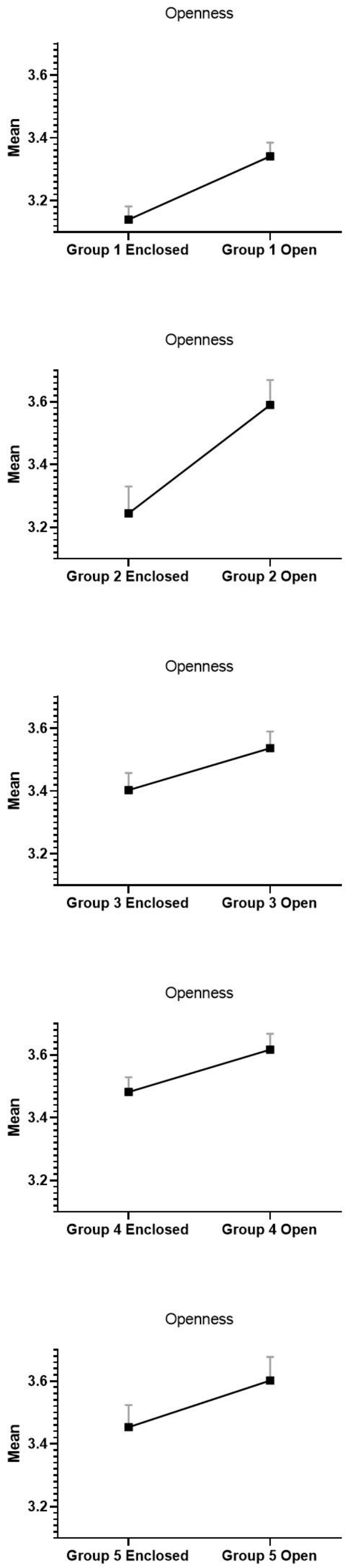

Fig. 5-6 Comparison of mean values of Openness among groups

We found that the ANOVA results for the elderly were statistically insignificant for ceiling height, possibly because ceilings cannot be observed well, or because there are different aesthetic judgments about ceiling height with age. So we further looked for results in the differences in ratings by age, and we subtracted the scores of all combinations of architectural interior features with high ceilings from the corresponding combinations of architectural interior features with low ceilings to derive the average high-low difference. We can observe (**Fig. 5-7**) that the advantage of high ceilings gradually disappears with age, and even low ceilings are superior to high ceilings in the evaluation of subjects over 80 years old. Then we observe the different groupings (**Fig. 5-8**) and find that the low ceiling is superior to the high ceiling in groups 1 and 4, which may be due to the fact that the age structure of the subjects in groups 1 and 4 has a larger proportion of older subjects.

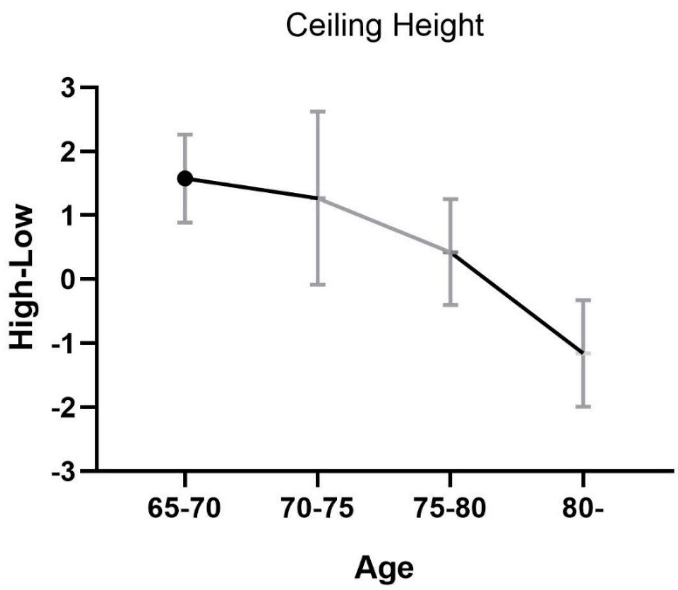

Fig. 5-7 Comparison of the difference in aesthetic evaluation of Ceiling height in different age groups

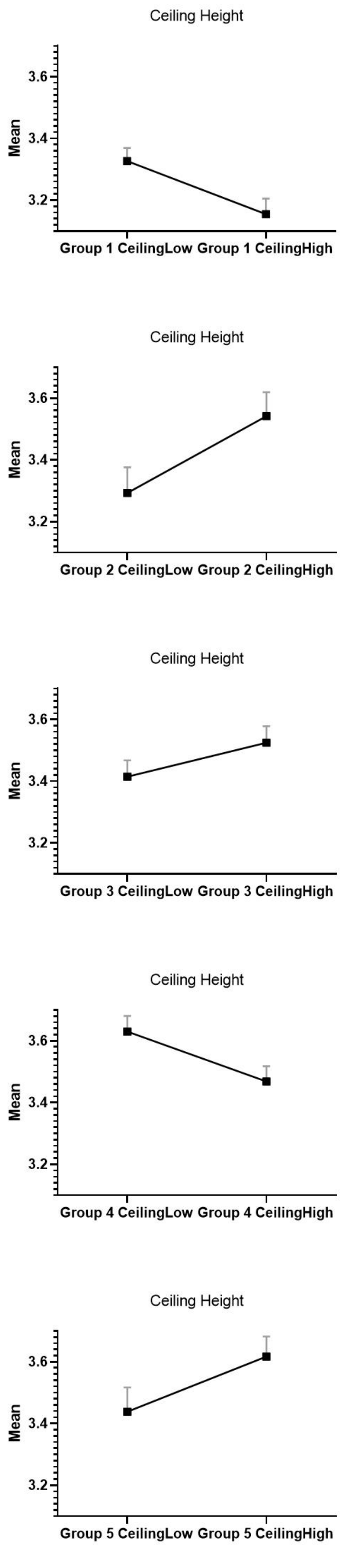

Fig. 5-8 Comparison of mean values of Ceiling height among groups

Our statistic for contour in ANOVA is not significantly consistent with previous predictions, as we saw such a trend in Chapter 2 through a simple simple effects test, and we speculate that older adults who are influenced by traditional Chinese aesthetics and more familiar with traditional Chinese architecture will have a better acceptance of straight contours. We further explored the results of the differences in ratings by age group, and we subtracted the scores of all combinations of architectural interior features with curved contours from the scores of the corresponding combinations of architectural interior features with straight contours to derive the average high and low differences. We can observe (**Fig. 5-9**) that in addition to subjects aged 70-75 years showing a clear preference for curved contours, we also observe that subjects aged 80 years and older prefer straight contour buildings. By the mean scores of linear contours and curved contours for each subgroup we found that linear contours were more dominant in the first and fifth groups, while curved contours were superior to linear contours in the second, third and fourth groups（**Fig. 5-10**）.

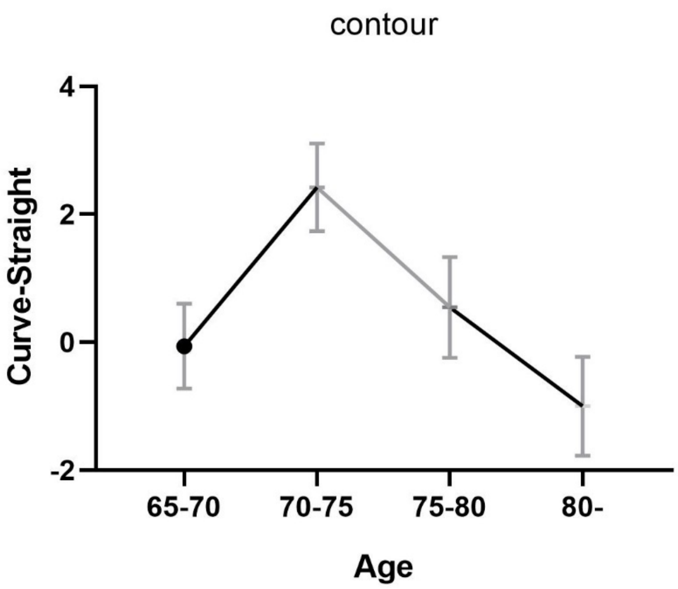

Fig. 5-9 Comparison of the difference in aesthetic evaluation of Contour in different age groups

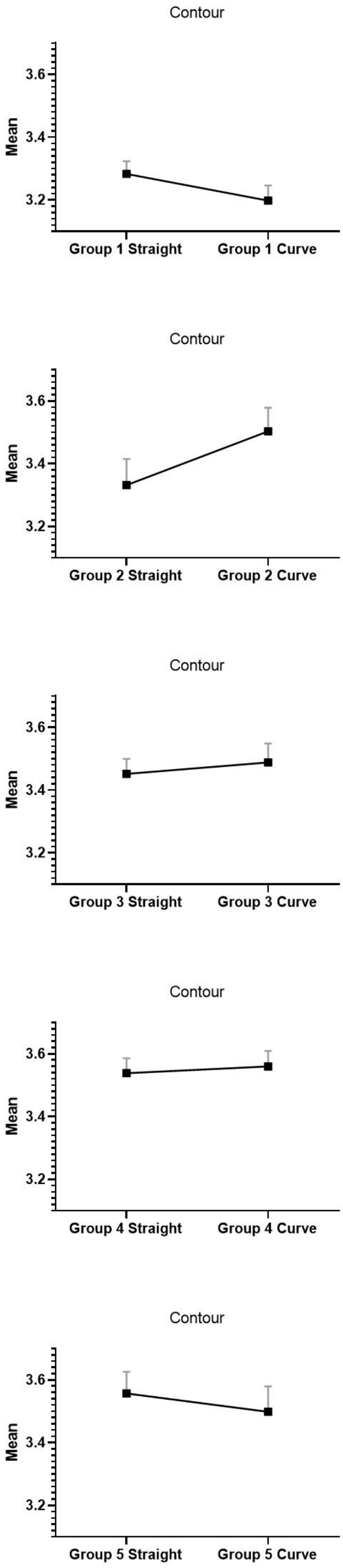

Fig. 5-10 Comparison of mean values of Contour among groups

To investigate whether depression and cognitive functioning affect older subjects' aesthetic judgments of architectural interior features. We did not find an association between individual sensitivity to Hight, Openness and Contour and individual cognitive and depression levels after statistical analysis (**Table 5-36**) (**Table 5-37**).

To explore in more detail the effects of ceiling height, openness, and contour on the aesthetic judgments of elderly subjects, we compared the data in further detail using simple-simple effects （**Fig. 5-11**）.

A illustrates that the main effect pattern of Contour is not all the same under different combinations of Hight and Openness levels. Specifically, Cur was more likely to cause Beauty than Rec when the building was Low and Enclosed, with statistically significant results ($p<0.05$), while Rec was more likely to cause Beauty under the combination of Low and Open conditions ($p<0.05$); when the building was High and Enclosed and High and Open, no Beauty differed across Contour levels.

B indicates that the main effect pattern of Openness is not all the same under different combinations of Hight and Contour levels. Specifically, when the building was Low and Rec, or High and Rec, or High and Cur, Open was more likely to cause Beauty than Enclosed, with statistically significant results ($p<0.05$), while when the building was Low and Cur, no difference was seen for Beauty at different Openness levels.

C shows that the main effect pattern of Hight is not all the same under different combinations of Contour and Openness levels. When the building is Open and Cur, High is more likely to cause Beauty than Low ($p<0.05$); no difference is seen for Beauty buildings under other combinations of features.

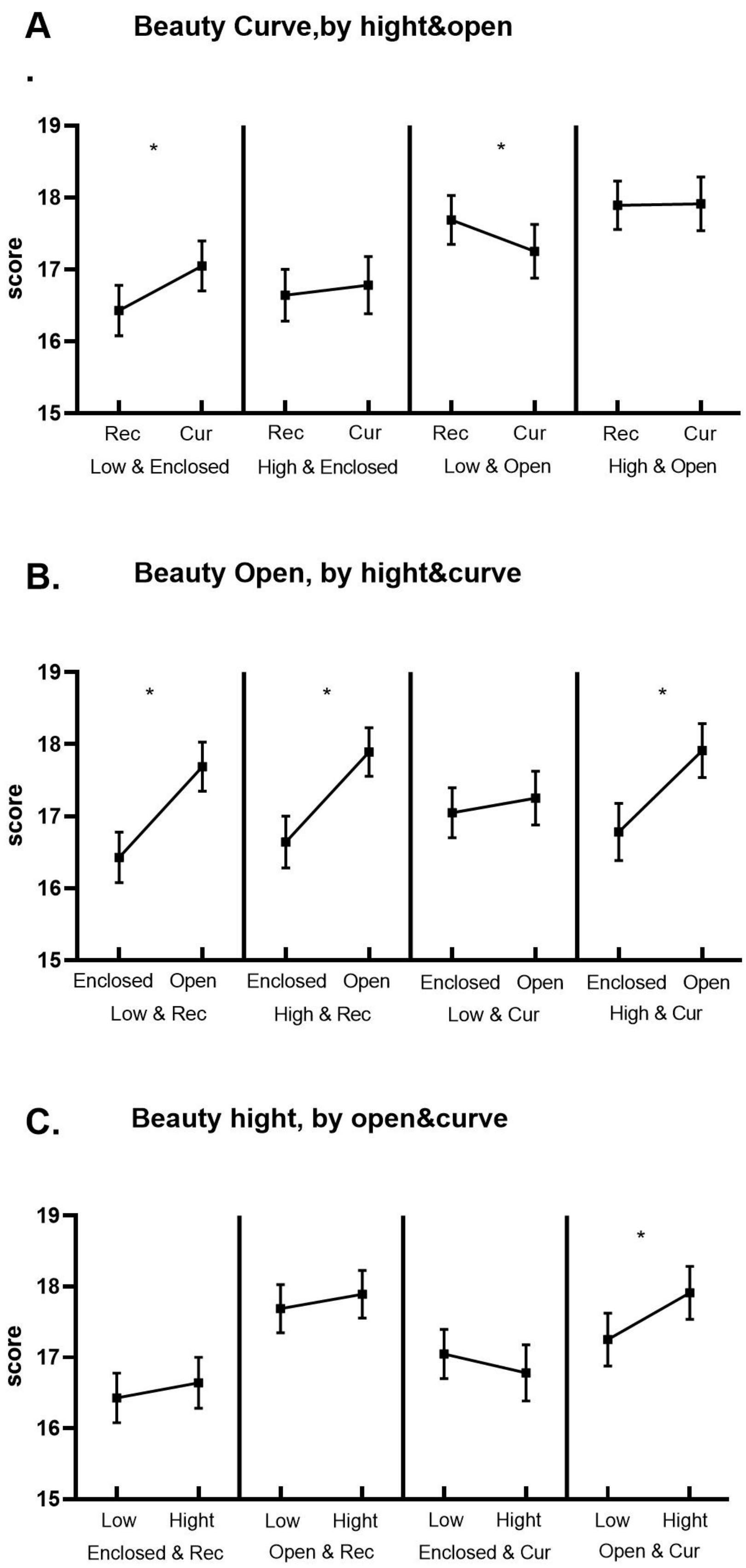

Fig. 5-11 Simple simple effect for architectural interior features and aesthetics

Then we added the simple simple effect results for each group：

Results by group.

Group 1: Hight and Contour and Openness interaction terms were statistically significant ($p<0.001$)A The main effect pattern of Hight was not identical across combinations of Contour and Openness levels, and Low had higher Beauty scores than High when Enclosed and Cur or Open and Rec.B shows that the main effect pattern of Openness is not the same for different combinations of Hight and Contour levels. When Low and Cur, Enclosed scores higher than Open.C: The main effect pattern of Contour is not identical for different combinations of Hight and Openness levels. cur scores higher than Rec when Low and Enclosed. cur scores lower than Rec when Low and Open and High and Enclosed（**Fig. 5-12**）.

Group 2: No statistically significant Hight and Contour and Openness interaction terms were seen ($p=0.138$)Overall (main effect) High was scored higher than Low, Open was scored higher than Enclosed, and Cur was scored higher than Rec（**Fig. 5-13**）.

Group 3: Hight and Contour and Openness interaction terms were statistically significant ($p<0.001$)A The main effect pattern of Hight was not identical across different combinations of Contour and Openness levels. high had higher Beauty scores than Low for Rec and Enclosed, Open and Rec, and Open and Cur. low had higher scores than High for Enclosed and Cur.B shows that the main effect pattern of Openness is not the same for different combinations of Hight and Contour levels. high and Cur, Open scores higher than Enclosed.C indicates that the main effect pattern of Contour is not identical for different combinations of Hight and Openness levels. low and Enclosed, Cur scores higher than Rec. high and Enclosed, Cur scores lower than Rec（**Fig. 5-14**）.

Group 4: No statistically significant Hight and Contour and Openness interaction terms were seen ($p=0.610$)Overall (main effect) High was higher than Low score and Open was higher than Enclosed score（**Fig. 5-15**）.

Group 5: Hight and Contour and Openness interaction terms were statistically significant ($p=0.040$)A The main effect pattern for Hight was not identical across different combinations of Contour and Openness levels. high was rated higher than low for Beauty when Enclosed and Rec, Open and Rec, and Enclosed and Cur.B Explains that the main effect pattern of Openness is not identical for different combinations of Hight and Contour levels. open scores higher than Enclosed for Low and Rec, High and Rec.C shows that the main effect pattern of Contour is not the same for different combinations of Hight and Openness levels. high and Open, Cur has a lower score than Rec（**Fig. 5-16**）.

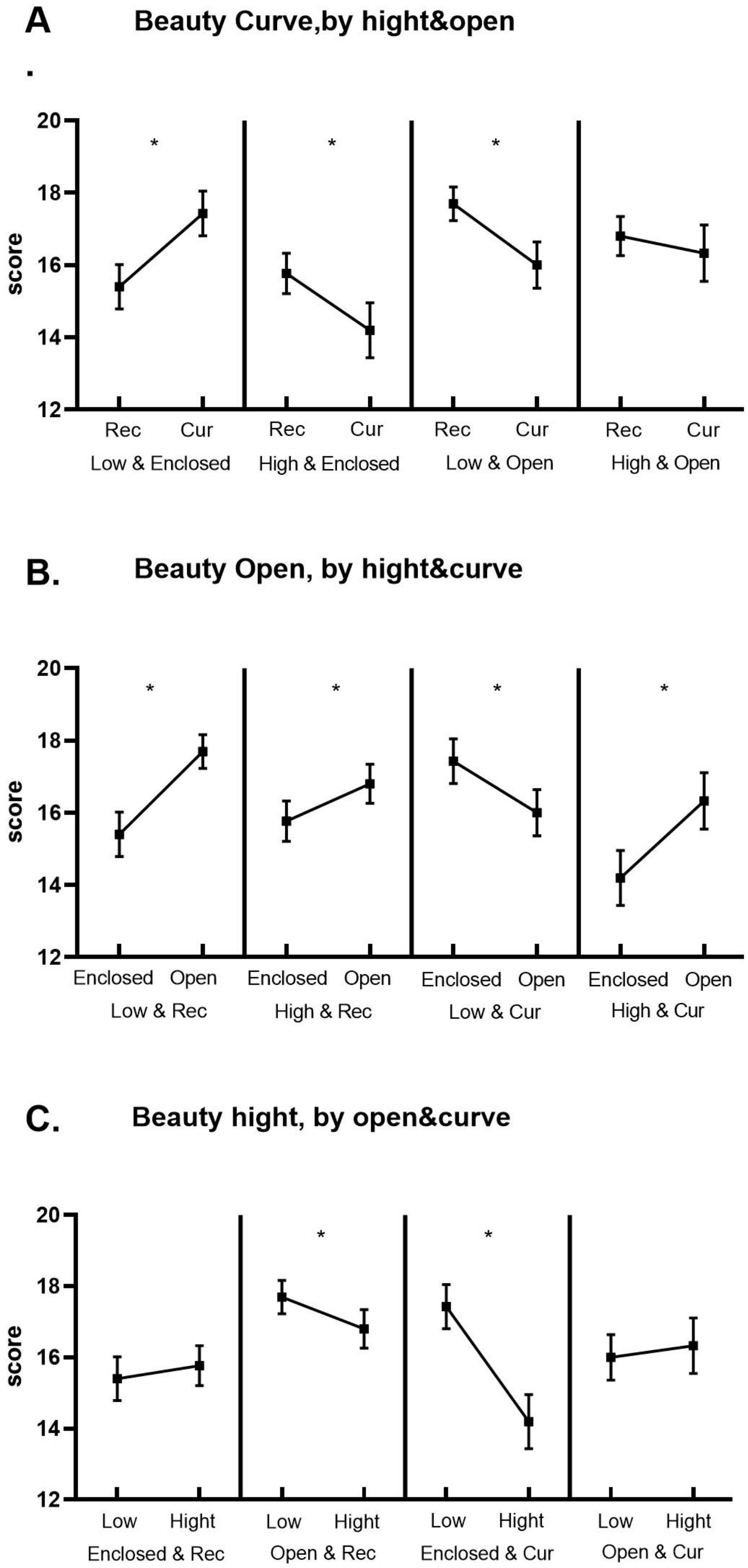

Fig. 5-12 Simple simple effect for architectural interior features and aesthetics (Group 1)

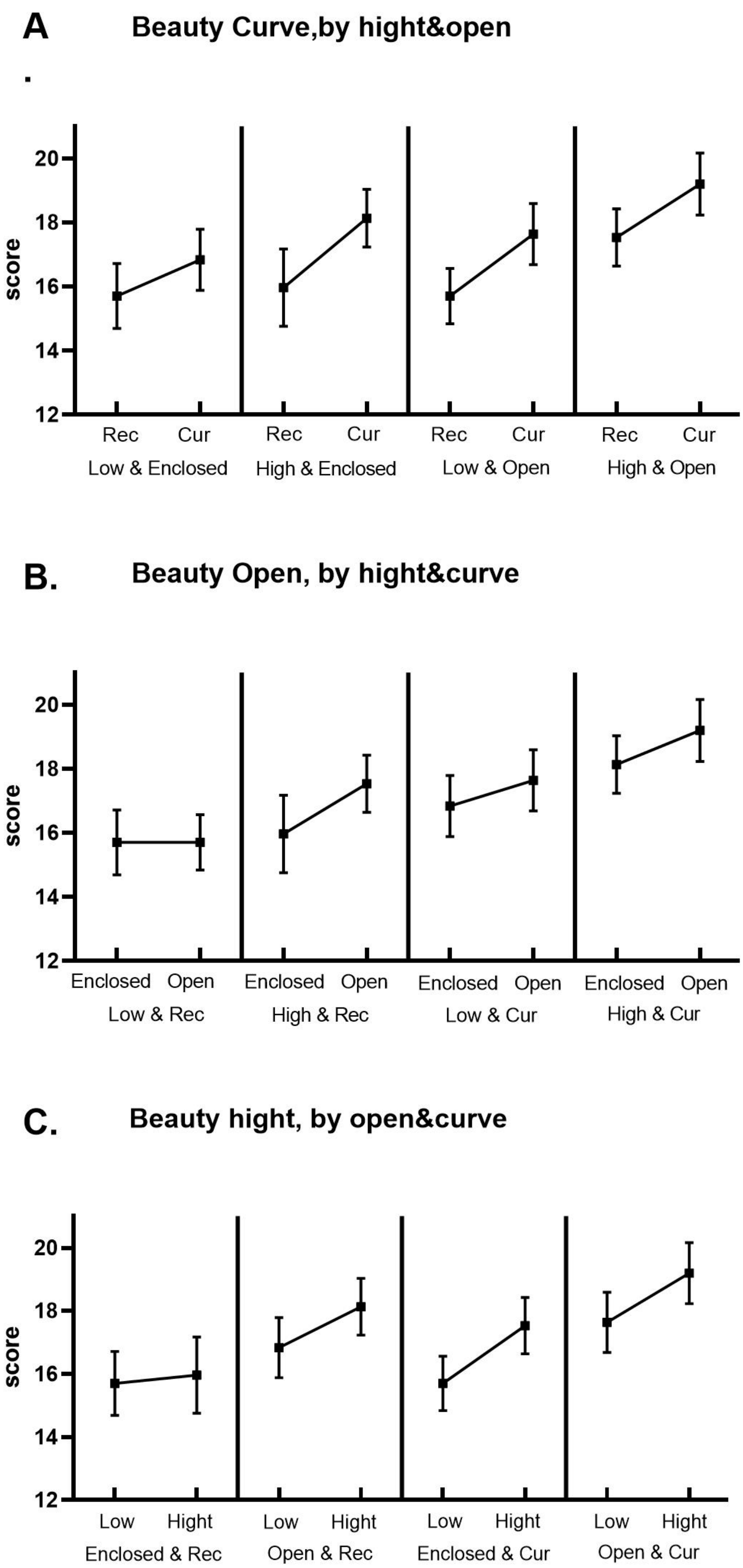

Fig. 5-13 Simple simple effect for architectural interior features and aesthetics (Group 2)

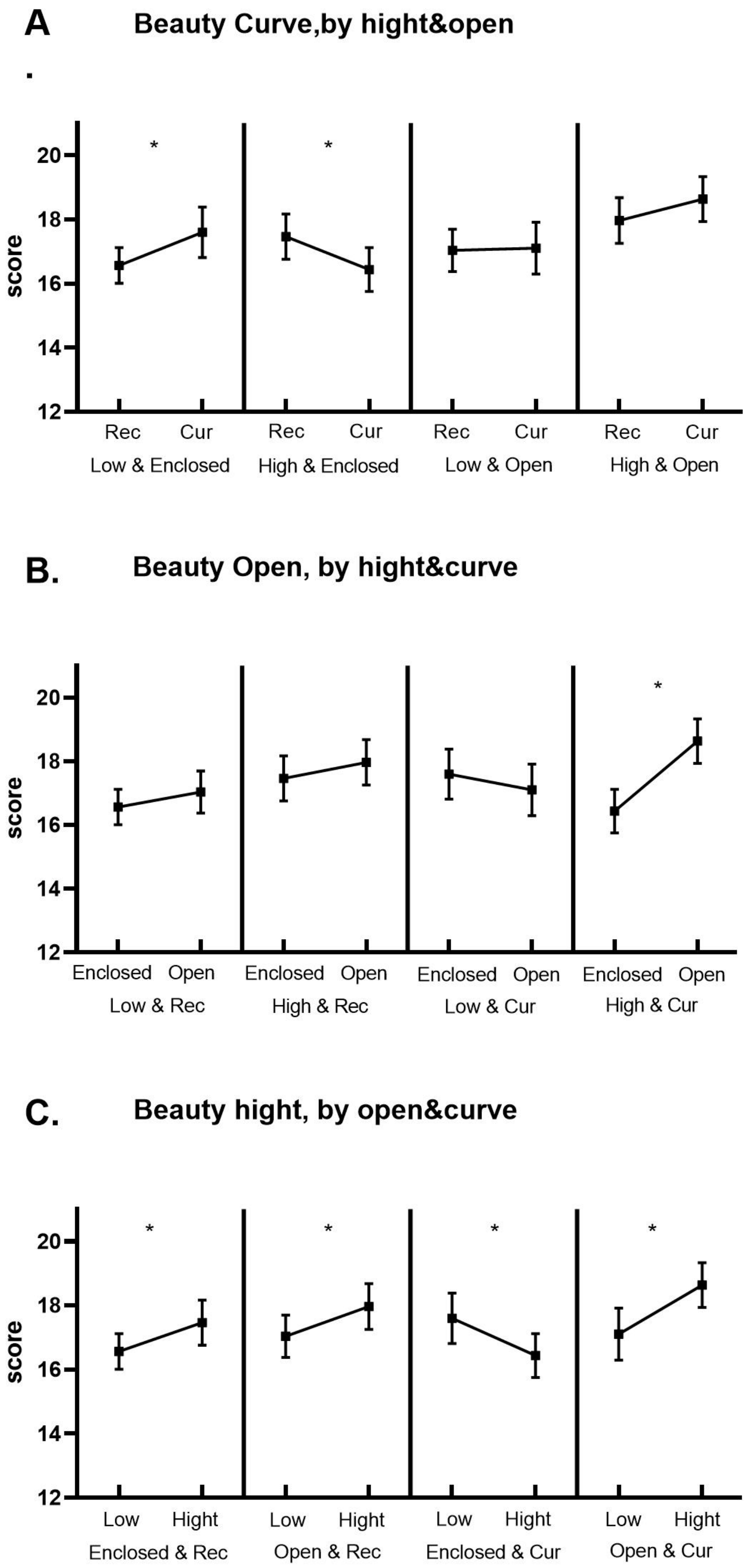

Fig. 5-14 Simple simple effect for architectural interior features and aesthetics (Group 3)

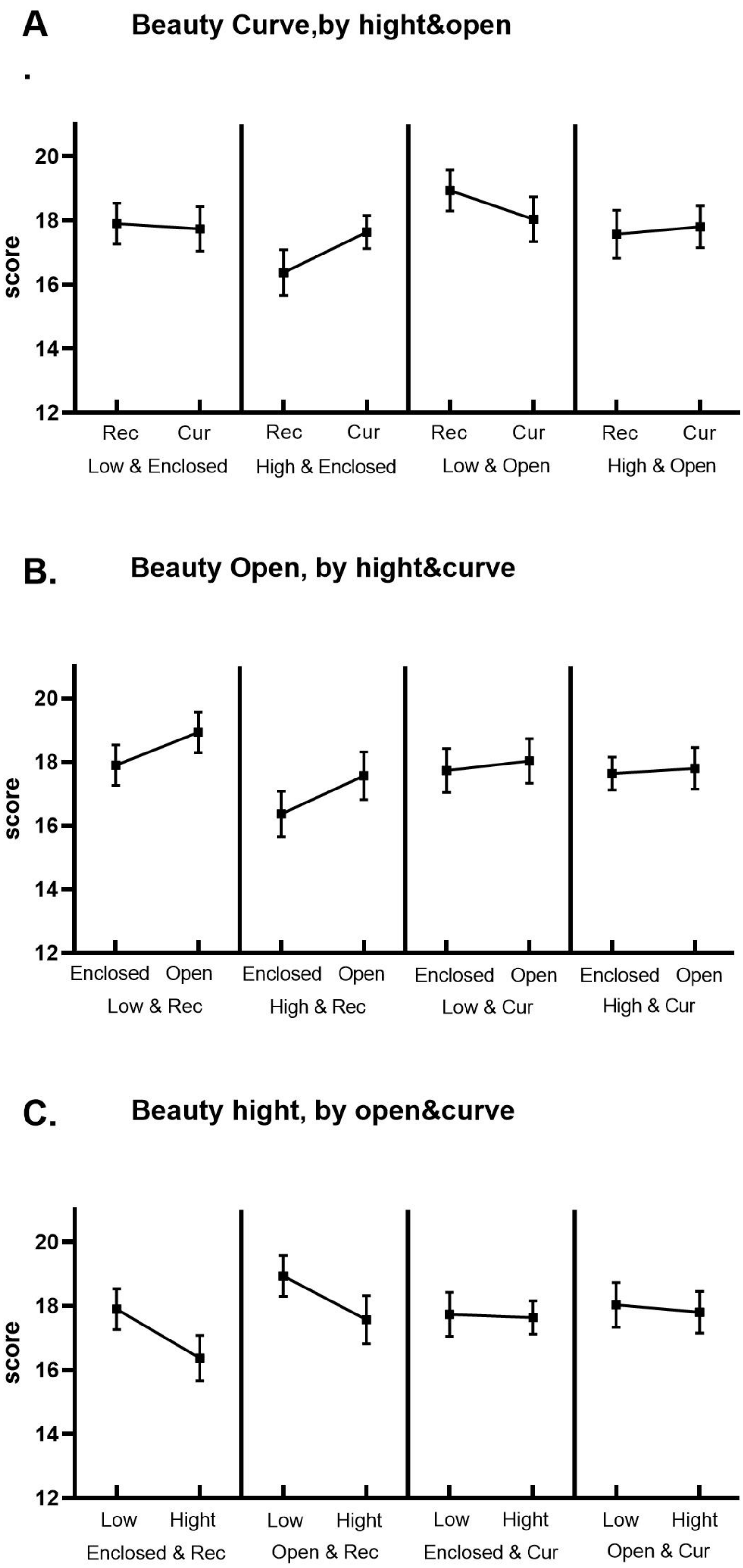

Fig. 5-15 Simple simple effect for architectural interior features and aesthetics (Group 4)

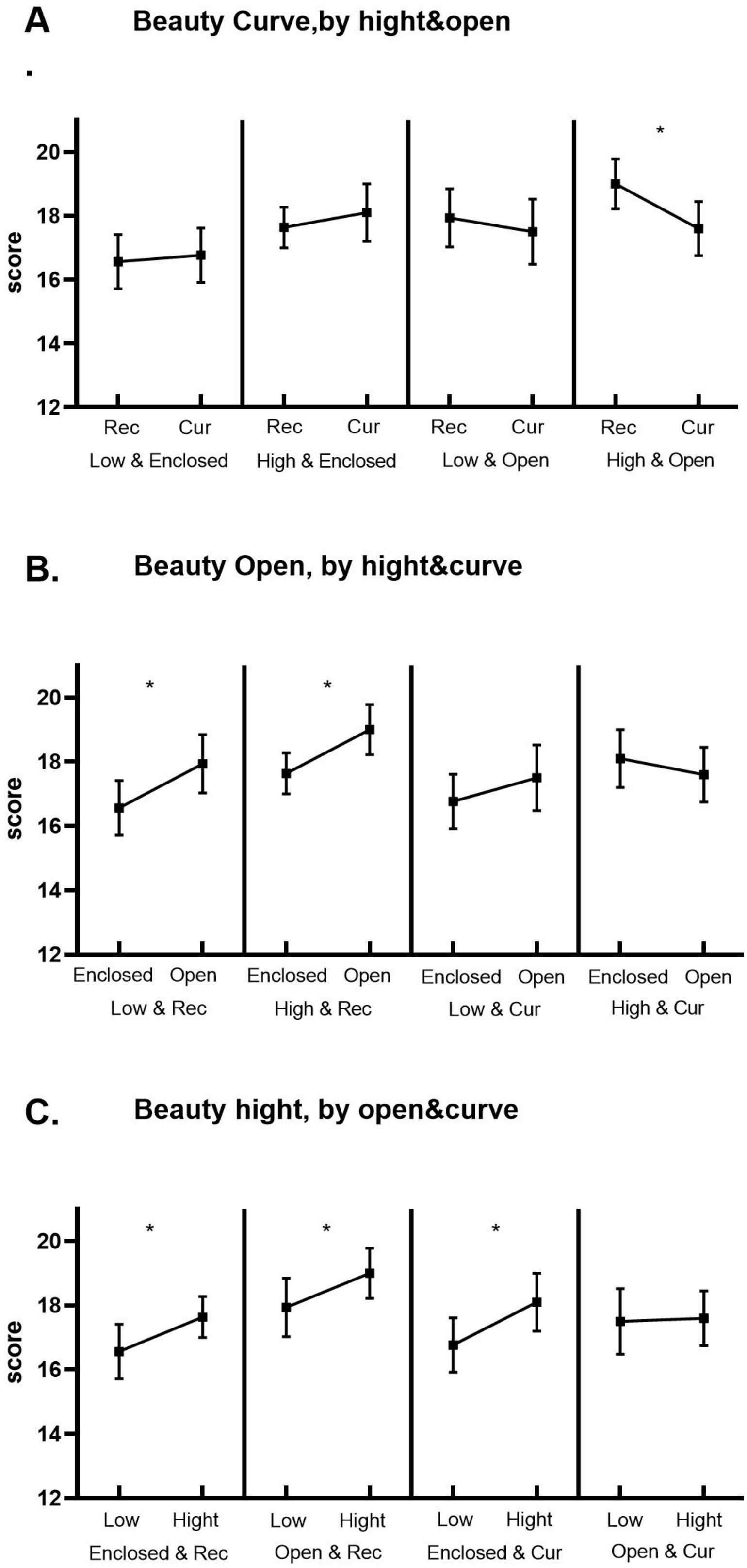

Fig. 5-16 Simple simple effect for architectural interior features and aesthetics (Group 5)

5.5. Discussion

The subjects in the experiment were all 65 years old or older, and the participants' cognitive status and depression were found to differ significantly in the pre-experimental questionnaire stage, which was expected to cause differences in the experimental results, but the differences were not significant after analysis. This indicates that the cognitive status and depression did not affect the results of the judgment on architectural aesthetics. Through observation of the participants during the experiment, it was found that more participants had difficulty making decisions or occasionally drifted off, but the final results were not affected.

In this experiment, 200 images were divided into 5 groups of 40 images each in order to prevent inattention of the elderly, which may vary according to individual likes and dislikes. The sorting grouping was based on the aesthetic ratings of young people in previous experiments, not on the preferences of the elderly, so the grouping situation may lead to uneven ratings of the picture groups. Some participants were a bit impatient or asked if the experiment was over, so they should do a good job of emotional de-escalation in future experiments.

5.6. Conclusion

In this experiment we found that the effect of openness, an architectural interior feature, on aesthetics is stable and not affected by age. This is the same as the results of the experiment with young people, which shows that the elderly are still sensitive to the difference of openness and prefer the building interior with high openness, which can play a certain reference for architects when designing elderly housing or elderly-friendly buildings. The variation of ceiling height and contour can only affect a part of the elderly, and the influence of ceiling height on aesthetic judgment is related to the age of the subjects, the older they are the less they prefer high ceilings, and the subjects over 80 years old prefer low ceiling architectural interior spaces. This may also be related to the living environment, as many senior citizens live in low-ceilinged housing and are more familiar with low-ceilinged environments. In contrast, there was no significant effect of contour on the aesthetic judgment of the elderly, which might be related to the aesthetic education the elderly received from childhood and the traditional architectural environment they lived in, where curved contour architecture was less common in the younger age group.

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Chapter 6

CONCLUSION AND FUTURE WORK

CHAPTER SEVEN: CONCLUSION AND FUTURE WORK

7.1 Conclusion

Architectural design used to be a job that relied heavily on the aesthetics of the architect, but nowadays architecture increasingly needs to take into account the feelings of the user. Designs that are aesthetically pleasing to the majority of non-specialist users are more likely to be appreciated by the general public. Architectural designers can use psychology, brain science, and behavioral science to understand the subjective aesthetics of the general public, and through a range of literature we can understand how differences in certain architectural features can affect the emotional and aesthetic judgments of users. We are not sure whether the differences in aesthetic judgments of architectural features are related to the aesthetic education received. Therefore, in addition to comparing the results of experiments in Chinese populations with the results of Western aesthetic judgments of architectural features, we also try to understand whether age causes differences in aesthetic judgments. Therefore, this paper hopes to investigate the effects of ceiling height, openness and silhouette on different populations under various conditions through a series of instruments. In addition to the influence of architectural features on aesthetic judgments, we also try to explore the influence of street features on aesthetic judgments in traditional Chinese ancient villages.

In Chapter 1, RESEARCH BACKGROUND AND PURPOSE OF THE STUDY. In Chapter 1 we present the background of architecture-related aesthetic research, including the current status and bottlenecks of architectural aesthetic research, and the kinds of directions of architectural aesthetic research. These related studies are then presented to help the reviewer understand the purpose and reasons for the research in this paper by presenting how they can contribute to this work on architectural design.

In Chapter 2, LITERATURE REVIEW OF RELATED STUDIES. Focusing on architectural interior features, this chapter examines the influence of relevant architectural features on human aesthetic judgments of architecture that mainstream studies have focused on, as well as the shortcomings of these studies. Based on the previous studies, what improvements will be made in this paper to verify the experimental results in a more rigorous way or to arrive at a different perspective from the previous studies.

In Chapter 3, AESTHETIC JUDGMENT OF ARCHITECTURE FOR CHINESE OBSERVERS. Using previous experiments on architectural interior features conducted in the West, the subjects were replaced with Chinese subjects. Since the subjects in the Western experiments grew up with Western aesthetic education, while the subjects in this chapter were raised with Chinese aesthetic education, it is possible to compare whether different traditional aesthetic education has an impact on the aesthetic judgment of architectural interior features.

In Chapter 4, THE INFLUENCE OF VIEWING TIME AND COLOR ON ARCHITECTURAL

AESTHETIC JUDGMENT. Since prolonged gaze at the pictures may cause more attention to distracting factors other than architectural interior features and may stimulate subjects to recall and reflect on them affecting the accuracy of aesthetic judgments.From the previous literature review, it is known that 200 ms can already trigger subjects' aesthetic judgments. Therefore, the first experiment in this chapter shortened the presentation time of the stimulus pictures from 3 s to 200 ms. In order to exclude the confounding factor of the selection of the experimental stimulus architectural pictures, the second experiment in this chapter decolored the stimulus pictures and tried to investigate the difference between the decolored architectural interior picture stimuli and the colored stimuli on human aesthetic judgments.

In Chapter 5, THE INFLUENCE OF AGE ON THE AESTHETIC JUDGMENT OF ARCHITECTURAL INTERIOR FEATURES. Because the aesthetic education of modern young people is relatively similar, the architecture in the living environment is also more similar. Therefore, in order to more accurately investigate whether receiving different aesthetic education has an impact on the aesthetic judgment of architectural interior features, and the difference in aesthetic judgment between older and younger people for the same architectural interior pictures. This chapter attempts to investigate the effect of age on aesthetic judgments of architectural interiors by limiting the age of the subjects to 65 years or older.

In Chapter 6, CONCLUSION AND FUTURE WORK. This chapter provides a summary of the chapters and the related research to be conducted in the future.

Based on the above, the following conclusions can be drawn

1) The current results suggest that Chinese observers prefer architectural space with high ceilings and open space. The preference to curvilinear contours interacts with ceiling heights and openness. The preference to high ceilings, open space, and curvilinear contours has also been shown for Western observers Since the current study only employs Chinese observers as the participant, it cannot quantify whether the preference to architectural features varies across cultures. The current study find that the preference to curvilinear contours depends on the ceiling height and openness of the space. Future studies are needed to test whether Western observers also prefer curvilinear contours only when the ceiling is low and the space is enclosed. Although previous studies have not analyzed how the preference to contour relies on ceiling height and space openness, a recent study has shown that experience can strongly modulate preference to curvilinear contours. The study shows that, within the Western culture, self-identified architects and designers show stronger preference to curvilinear contours than non-experts. In sum, combing the current results and previous results, it is shown that human observers prefer high ceilings and open space, and also prefer curvilinear contours in some conditions.

2) In this study, we find that when viewing images of architectural space for only 200 ms, observers prefer space with higher ceilings, higher degree of openness, and curvilinear contours, compared with space with lower ceilings, lower degree of openness, and rectilinear contours. These conclusions hold for both color and grayscale images of architectural space, and are consistent with previous studies in which aesthetic ratings were collected for images presented for a much longer time, i.e., 3000 ms. Viewing time can strongly influence perception. Furthermore, previous study shows that participants recognize normal color images faster than grayscale images, indicating that color plays an important role in the early stages of visual processing and aids the human cognitive system in rapid recognition. Color, however, is a feature that can be dissociated from architectural features such as ceiling height,whether the conclusions of previous studies on color images can generalize to grayscale images. Previous studies using color images have shown that observers prefer high ceilings, open space, and curvilinear contours, and the current study show that observers prefer the same set of features when viewing grayscale images. In sum, here we demonstrated that ceiling height, openness, and contour can reliably influence the viewers' aesthetic judgment, despite of changes in the stimulus duration and color. The results suggest that future studies can collect aesthetic ratings of architectural spaces in a more effective way.

3) In this experiment we found that the effect of openness, an architectural interior feature, on aesthetics is stable and not affected by age. This is the same as the results of the experiment with young people, which shows that the elderly are still sensitive to the difference of openness and prefer the building interior with high openness, which can play a certain reference for architects when designing elderly housing or elderly-friendly buildings. The variation of ceiling height and contour can only affect a part of the elderly, and the influence of ceiling height on aesthetic judgment is related to the age of the subjects, the older they are the less they prefer high ceilings, and the subjects over 80 years old prefer low ceiling architectural interior spaces. This may also be related to the living environment, as many senior citizens live in low-ceilinged housing and are more familiar with low-ceilinged environments. In contrast, there was no significant effect of contour on the aesthetic judgment of the elderly, which might be related to the aesthetic education the elderly received from childhood and the traditional architectural environment they lived in, where curved contour architecture was less common in the younger age group.

7.2 Future work

With the rapid economic growth of China, rural areas across the country are undergoing significant transformation. The need to meet the demands of a growing population and a desire to live in modern, well-equipped rural communities has led to the construction of more and more modern rural developments. Among all the provinces in China, Zhejiang Province stands out as the most developed rural economy, and is therefore seeing the greatest number of these modern rural communities being built.

However, this rapid transformation has come at a cost. The traditional rural heritage of China is being lost at an alarming rate, with both cultural and natural heritage sites suffering considerable damage. In response, there is a growing awareness of the importance of environmental protection, natural heritage conservation, and cultural heritage preservation in China. More and more people are recognizing the value of rural heritage, and the Chinese government is promoting rural development programs that focus on preserving and continuing this heritage.

In fact, since 2012, the Ministry of Housing and Urban-Rural Development, along with other government departments, has been evaluating traditional villages across the country. They have identified and protected 6,819 traditional villages in China, along with 520,000 historical buildings and traditional dwellings, and 3,380 intangible cultural heritages above the provincial level. This is a major effort to preserve and inherit China's rural heritage.

As part of this effort, a project is underway to analyze and quantify data on the spatial elements of traditional Chinese rural areas using computer technology and AI algorithm analysis （Fig. 6-1）. The aim is to identify the factors that most affect people's perception of traditional rural heritage value through Neuroarchitecture research. The project also aims to explore the possibility of using computer technology, such as CAAD, data science, parametric modeling, computer rendering, and VR, to generate inherited Chinese traditional rural area heritage value spaces. The ultimate goal is to design a green, sustainable, intelligent, and healthy future rural area in Zhejiang, China, while preserving and continuing the traditional Chinese rural area heritage value.

Fig. 6-1 Semantic segmentation of ancient village

In addition to the aesthetic judgment of architectural interior features, it is important to understand the influence of traditional architectural and street features on aesthetic judgment in today's society. An aesthetic experiment conducted on elderly subjects revealed that age has an impact on aesthetic judgments, which is likely related to traditional aesthetic education from childhood and the living environment. Therefore, traditional buildings, streets, and villages may have features that are favored by local people, and these elements should be taken into account in future rural development planning.