건축 디자인에서 날카로운 조형의 심미적 활용성에 관한 신경학적 연구

시각과 인지를 중심으로

A Neurological Study on the Aesthetic Utilization of Sharp Shape in Architectural Design

Focusing on sight and cognition

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Abstract

Sharp shapes's multiple visual stimuli attribute restricts its application in architecture. To apply the sharp modeling to architectural modeling, the characteristics of reducing the perception of threat and improving the sense of beauty should be studied. In the present study, the visual cognition and aesthetic processing structure of the brain are described by research on neuroscience. The findings reveal that spacial frequency will affect the aesthetic judgment. On this basis, the favorable feelings for sharp modeling can be aroused by transforming the sharpness into stimulus on low spacial frequency. In addition, it is also possible to improve the complexity of modeling at a high spacial frequency to strengthen peripheral visual information, enhance the sense of rhythm and induce the sense of beauty. Moreover, in the present study, it attempts to master the influence of modeling and significance cognitive process on aesthetic consciousness, and the way to apply sharp modeling to architectural modeling is also proposed.

Keyword

Sharp Shapes(날카로운 조형),Spacial Frequency(공간 빈도),Complication(복잡성),Vision and Cognition(시각과 인지),Aesthetic judgement(미적 판단)

요약

날카로운 조형은 위협과 관심이 공존하는 다중 시각 자극이다. 날카로움의 이런 특별한 속성은 건축적 활용의 한계를 초래해 왔다. 날카로움을 건축 조형으로 활용하려면 위협적인 느낌을 낮추면서, 미적 감각을 높이는 특성에 관한 연구가 필요하다. 본 연구는 신경 과학의 연구를 통해, 두뇌의 시각인지 및 심미 처리 구조를 기술하였다. 이들 연구에 따르면 공간 빈도(Spacial Frequency)가 심미적 판단에 영향을 미친다. 이를 바탕으로 날카로움을 낮은 공간 주파수의 자극으로 변환함으로써 날카로운 조형에서 호감에 유발할 수 있다. 또한 높은 공간 주파수에서 조형적 복잡성을 높일 수도 있다. 이를 통해 가장자리 시각 정보를 강화해 리듬감을 높이며 건축적 심미성이 유발된다. 본 연구는 조형과 의미 인지 과정이 미의식에 미치는 영향을 파악해, 날카로움을 건축 조형에 활용하는 방식을 제시하려 했다.

목차

1. Introduction

Studies have shown that the aesthetic quality of architecture has an impact on our mood, cognitive function, behavior, and even mental health (Adams, 2014; Cooper, Burton, Cooper, 2014; Hardiger, 2008; Qiao Ye, 2007). Veronica Cerina et al. believe that people prefer to attributes that can be easily recognized as safe and stable by residents. As a special form, sharp shapes can stimulate the brain to quickly extract the outline elements of the building to get attention(Xiao L,Fang HX,Lu YN,2021.p38),and at the same time, it is also associated with harm and danger(Bar M, Neta M,2007).Because this implicit threat awareness can be transformed into explicit preference bias (Whalen et al.1998), its application in architecture has certain limitations. Although sharp shapes brings threats and fears in most cases (Aronoff et al.1988), it can be found by observing previous architectural cases that sharp shapes has been applied and succeeded in attracting people's attention and arousing aesthetic resonance. However, there is a lack of relevant analysis and explanation about how sharp shapes promotes aesthetic pleasure.

William James proposed in 1890 that attention refers to the brain occupying in a clear and vivid form one of multiple objects or thoughts that may coexist in the mind(James W, Burkhardt F, Bowers F, et al,1890).Our conscious awareness is so limited that focusing on one thing prevents us from focusing on something else(Dehaene S,2014.p61).While the conscious mind is occupied, other information waits in an unconscious cache(Dehaene S,2014.p59).Modeling, as a primitive domain, is associated with individual's original abstract concepts and has unique effects in different situations, whether it is the figurative perception of shape or the simple abstract contour perception(Xiao L,Fang HX,Lu YN,2021.p36).From the perspective of neuroscience, this study seeks for the suitable method of sharp shapes in architecture. How to effectively interfere with the brain's perception of threat and promote the occurrence of aesthetic pleasure by using sharp shapes is an important topic of this study.

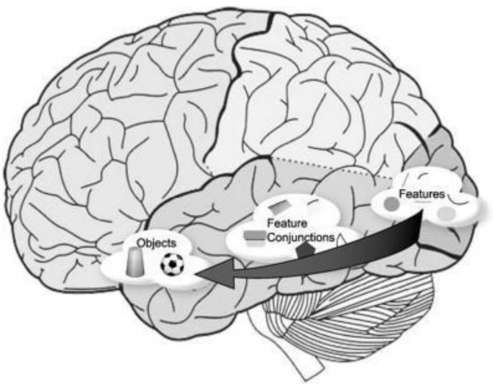
Based on the theoretical knowledge of neuroscience, this paper takes sharp shapes as the main research object, and the color and material of the object are not in the scope of this study. From the cognitive and aesthetic mechanism of the brain, understand the impact of spatial frequency on shape content extraction, and the aesthetic process and the preference, as well as the influencing factors of aesthetic judgment are summarized and analyzed, This paper also verifies the use value of sharp shapes through the theory of neuroscience, and obtains the application mode of sharp shapes in architecture that can activate people's aesthetic resonance through the impact of vision and cognition on aesthetic judgment.

2. Visual cognition

2-1. Visual cognition pathways in the brain

Vision dominates the perception of architectural modeling(Philip Ball et al,2019.p8). Cognitive process of shape can be divided into two stages: pattern recognition and shape recognition(Hwang Yeongji&Cho Taigyoun,2018). When an object is presented to our eyes, awareness of its color, shape and nature is generated through the delicate and complex brain activity of billions of neurons(Dehaene S,2014.p3). The brain's visual processing system is divided into two pathways, ventral and dorsal. The ventral pathway represents the shape and features of the object ("what"), while the dorsal pathway represents the location or spatial relationship of the object ("where")(Freud E, Plaut D C, Behrmann M.2016.p773).Neuronal activity in various brain regions somehow produces visual experience and recognition of features. The ventral pathway composed of V1, V2, V4, etc. is mainly responsible for processing the shape and color of objects (Ungerleider & AMP; Mishkin,1982). Neurons in primary visual areas are sensitive to basic visual features. V1 and V2 neurons extract features, such as edge and orientation (Hubel & Amp; Wiesel, 1962, 1968), which can help us determine the outline and shape of the object, identify, and determine the modeling unit; V4 neurons play an important role in the neural mechanism of basic shape recognition and are sensitive to two straight lines intersecting at a specific angle (Pasuqathy & Amp; Connor, 2002). The ventral temporal cortex (VTC) can recognize complex shapes in buildings (Figure 1) and then assemble their information to synthesize the modeling of the final architectural shapes. Therefore, ventral pathway is very important for the cognition of architectural modeling.

Fig.1 Shape recognition process of the ventral pathway (Stephanie M. McTighe et al.2010.p1409)



In addition to “visual-action”, the dorsal pathway also serves “visual-perception” (Goodale, M.A.& Milner, A.D. 1992). Cognitive content includes the position of the object, the direction of movement and understanding (Fang & AMP; He.2005, Fischer et al.2016). Studies have shown that the dorsal (V3A/B) pathway relates to the ventral (hV4/VO-1) pathway in the intermediate visual area and exchanges visual information (Takemura, H. et al. 2016). Dorsal pathway representations may encode and contribute to the perception of spatial properties beyond 3D structure(Freud E, Plaut D C, Behrmann M.2016.p780), For example, in a same-different face detection task, cofigural but not featural processing of faces was uncovered in the posterior dorsal pathway (Kravitz,D.J. et al. 2011)。Therefore, in visual cognition, the processing of dorsal pathway is essential for the complete perception of spatial information.

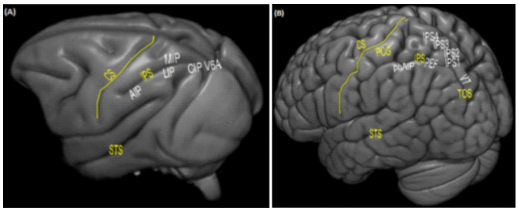


Fig 2.Visuomotor and Perceptual Representations in the Dorsal Pathway.(Freud E, Plaut D C, Behrmann M.2016.p775)

2-2. Visual cognition based on spatial frequency

From the perspective of morphology, the sharp shapes is composed of four elements: point, line, plane, and body(Wei RR, Cho TY。 2021.p252). From a neurological perspective, it can be divided into edge features of high spatial frequency (HSF) cognition (edges, boundaries, etc.), and global information of low spatial frequency (LSF) cognitive shape (plane, surface, etc.)(Wei RR, Cho TY.2021.p242-243). Since electrical signals enter the retina according to the spatial frequency of the object, it is necessary to observe the characteristics of the spatial frequency to grasp the time information that the brain perceives first(Hwang YJ,Cho TY.2018.p538). Spatial frequency (SF) (FIG. 3) is defined as the brightness change in the unit of space distance(He Zeyu et al.2020.p579), which is cycle/degree. It is based on the vibration waveform analysis theory proposed by the 19th century mathematical Fourier, describing the concept of the working characteristics of the visual system(RussellL., & Karen L.1990.p87-96).

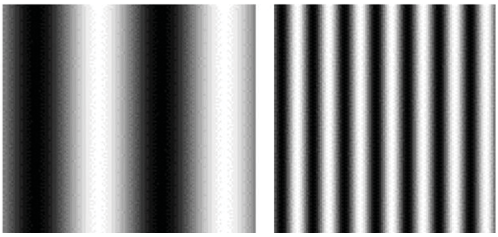


Fig.3 low spatial frequency (LSF), high spatial frequency (HSF) (Wei R R, Cho T Y.2021.p241)

Hegde(2008) showed that the first stage of visual analysis includes extracting basic visual features at different spatial frequencies and conveying different spatial frequencies.[1] Among them, low spatial frequency (LSF) information (< 8 c/d) is mainly related to the overall rough processing of architectural modeling, and the processing speed is fast. The information is transmitted through magnocellular channels to the dorsal stream and subcortical regions (Cushing, Im, Adams Jr, Ward, & Kveraga, 2019), which facilitates the detection of threatening or emergent visual events (Carretie, Hinojosa, Lopez-Martin, & Amp; Tapia, 2007). The relatively high spatial frequency (HSF) information (>24 c/d) is mainly related to the fine processing of architectural shape, and the processing speed is relatively slow. Information is transmitted to the ventral visual cortex through parvocellular channels (Cushing et al., 2019), whose ganglion cells have a small reception field and respond to changes in brightness that occur in smaller image regions (Merigan & AMP; Maunsell, 1993.He Zeyu et al.2020.p579). (FIG.4) Through the above research results, we can know that the stimulation of high spatial frequency corresponds to the modeling language of "angular and alert"(Hwang Y J,Cho T Y.2018. p538),in the process of shape recognition (as shown in Table 1), the high spatial frequency (HSF) is helpful for identifying the feature edge of the architectural modeling, which mostly involves fine processing of architectural modeling to identify the form values and shape values for shapes. Low spatial frequency (LSF) is conducive to the recognition of the overall shape of the building and transmits fuzzy perceptual information.

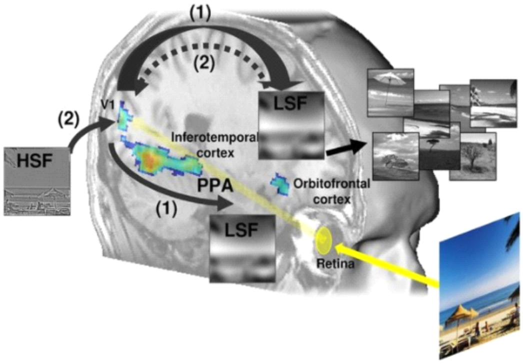
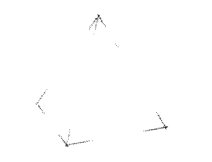
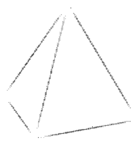
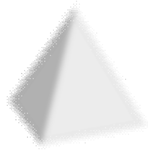
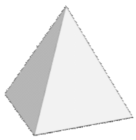


Fig.4 A schematic illustration of the proposed coarse-to-fine cortical model. (1) Los spatial frequency (LSF) information reaches high-order areas of the dorsal visual stream rapidly, enabling coarse initial parsing of the visual scene (providing the spatial organization of the scene through the frontal eye fields and possible interpretations of the category of the scene through the orbitofrontal cortex), prior to its complete propagation along the ventral visual stream (inferotemporal cortex) that ultimately mediates the scene recognition. (2) This initial low-pass analysis might be then "retro-injected" through feedback into lower level areas (including the primary visual cortex, V1) to guide a slower analysis of high spatial frequency (HSF) information through the ventral visual stream and select the relevant finer details necessary for the recognition and identification.(Kauffmann L, Ramanoël S, Peyrin C. 2014.p10)

[Table 1] Shape cognitive processes

High Spatial Frequency	Edge	

1) www.Wikipedia.com (2020.12.30)

	Boundaries	
+		
Low Spatial Frequency	Plane	
	Curved Surface	
=		
Overall perception		

3. Factors affecting aesthetic judgment

3-1. Aesthetic mechanism and aesthetic judgment

Zeki believes that beauty is something that corresponds to the brain's aesthetic mechanism. The aesthetic experience of beauty and art is based on neurobiology (Chatterjee & Amp; Vartanian, 2016). Visual aesthetics, or the ability to ascribe varying degrees of beauty to certain forms, colors, or movements, is widely believed to be a human trait acquired after the divergence of the human and ape lineages (Cela-Conde C J, Marty G, Maestú F, et al. 2004. p6321). Aesthetic appreciation is a complex process involving multiple processing processes such as perception, emotion, and memory, as well as evaluative judgment(Wei RR,Cho TY. 2021.p211). The perception of beauty (aesthetics) can be explained as the latest step in the evolutionary increase in cognitive ability. Existing studies have shown "significant lateral brain extension, especially lateral brain extension," especially in the frontal and parietal-occipital regions(Tobias P V,1987).Fluency is an important concept in visual aesthetics (Reber, Schwarz, & AMP; Winkielman, 2004). From a neuroscience perspective, the multi-stage integration theory of visual consciousness is based on evidence that the visual brain consists of several parallel multi-stage processing systems, each specialized in processing a given attribute(Bartels A, Zeki S,1998). In 2019, Lu Xin and Zhao Taigui showed through experiments that people's aesthetic judgment is affected by the meaning of objects (LX, Zhao Taigui,2018). This sense of visual beauty (" aesthetics ") or the ability of visual perception to add specific properties to other features of an object (such as shape, color, and movement) is fixed in the human evolutionary lineage as a trait that is not shared with any great ape. If the shape is attached to a certain meaning to recognize the concept, the aesthetic response will increase, and also affect the aesthetic judgment. In addition, it is advantageous for the observer to quickly recognize another threat (Hansen & Amp; Hansen, 1994; Lundqvist & O Hman, 2005), which is consistent with the evolutionary advantage of rapid threat detection proposed by Darwin (1872/1998) (cf. Niedenthal & AMP; Beishan,1994). Therefore, the nature and meaning of objects quickly recognized also have a certain impact on aesthetic activities.

Aesthetics can be hypothesized as a property perceived through specific brain processing systems, in which the prefrontal cortex plays a key role(Cela-Conde C J, Marty G, Maestú F, et al.2004.p6324).The Prefrontal dorsolateral cortex (PDC) is a brain region that serves as the center of the perception-action interface and is involved in a variety of brain functions. PDC plays an important role in functions related to decision making (Paulus M P, Hozack N, Frank L, et al. 2003, Petrides M, Alivisatos B,Frey S.2002) and visual-spatial work/memory (Glahn DC,KimJ, Cohen MS, et al.2002) .In determining the "beauty" condition of the stimulus, a judgment that requires visuospatial memory is required, so PDC and cingulated cortex are activated during the aesthetic judgment task (Dehaene S, Changeux J P.2000) .But the cingulated cortex is activated in both conditions (beautiful and not beautiful), and PDC is selectively activated by the beautiful stimulus(Zeki S , Bartels , 1999).Dorsolateral prefrontal nodes may be part of a neural network intrinsically associated with conscious aesthetic perception(Cela-Conde C J, Marty G, Maestú F, et al.2004.p6324). Aesthetic judgment is a process of deep consciousness acquired through vision-based cognitive processing, which can improve or decrease the aesthetic judgment of objects through cognition(Lyu X, Cho T Y.2019.p160). In aesthetic activities, the result of aesthetic judgment depends on the audience's visual perception and cognition of objective objects(Lyu X, Cho T Y.2019.p162). Therefore, we can know that visual aesthetic judgment is accomplished by activating PDC. Secondly, it may also be influenced by subjective consciousness and produce the aesthetic value judgment of the object of the aesthetic judgment element at the cognitive level(Lyu X, Cho T Y.2019.p162).So, we can see that aesthetic judgment should be a synthesis of both visual and cognitive aspects.

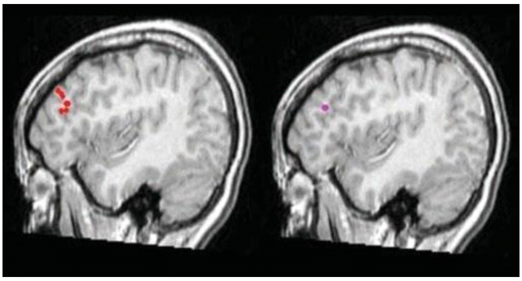
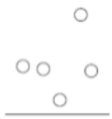


Fig.5. Activation of PDC (prefrontal cortex PP3 in human visual aesthetic perception) in response to stimuli identified by participants as beautiful (left) and unattractive (right)(Cela-Conde C J, Marty G, Maestú F. et al. 2004.p6123)

3-2. Preference for complexity

Buildings with high visual richness were preferred over buildings with low visual richness(Herzog T R, Shier R L.2000.p566-567). In terms of complexity, its effects are mostly positive, both in terms of simple and partial relationships(Herzog T R, Shier R L.2000.p572). Cohen (1972) used infants as experimental subjects to examine visual preferences for stimuli of varying size and complexity. The results show that the size of the pattern is more important for getting attention, while the complexity of the pattern is more important for maintaining attention(Cohen L B, DeLoache J S, Rissman M W.1975.p611). Frewald (1989) believed that Kaplans' environmental preference information model (R. Kaplan & Amp; Kaplan, 1989; S. Kaplan & Kaplan, 1978, 1982) argues that people's preference for old buildings comes from the fact that old buildings are superior to modern buildings in key predictors of

[Table 2] Shape Organization

Types	Single	Continuous	Disperse	Organizational
Graphic				
Instructions	A Single Element	Elements Arranged in A Regular Order	Elements Arranged Irregularly	Irregular Shapes Rearranged Many Times
Shape Organization	Disorderly	Orderly	Disorderly	Orderly
source : Hwang Yeongji, & Cho Taigyoun, “A Model of Creating the Characteristics of Form through a Neurologic Analysis: Characteristics of Form in Architecture”, Korea Society of Basic Design & Art, 19(4), p.542, 2018.				

information models: complexity, readability, mystery, and coherence. Other studies support visual richness (Day,1992; Nasar,1983) and complexity Stamps,1991,1994; Widmar,1984) as the utility of predicting building preferences(Herzog T R, Shier R L.2000.p558). Regardless of individual characteristics, repeated exposure to stimuli initially perceived as complex led to increased liking for those stimuli, while repeated exposure to stimuli initially perceived as simple did not lead to significant changes(Lévy C M, MacRae A, Köster E P.2006.p397).

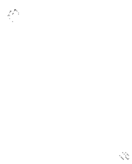
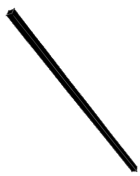
Gestalt psychology says we see the world as a whole. Research shows that the shape of visual objects with order structure can be easily recognized(Hwang YJ,Cho TY.2018.p542). Visual areas V1 to V4 respond more strongly to clear shapes and objects than to messy shapes(Wei R R, Cho T Y. 2021.p252). It can be seen from Table 2 that it is difficult for a single object to form order, which is formed by multiple identical or similar elements arranged together by some kind of regular repetition (Weiranran,2021). For regular shapes, the brain's perception of shape is relatively simple, making it easier to feel good. On the contrary, favorability is reduced (Hwang Yeongji & Cho Taigyoun, 2018). According to the Fluency Theory, when dealing with objects, the more quickly they are processed, the more positive recognition will be obtained. Therefore, learning objects are processed at a very fast speed, resulting in positive emotional compensation (Huang,2018). When observing orderly forms or colors in architectural shapes, these visual mechanisms can regulate the aesthetic pleasure associated with them (Alexander,2002). Aesthetic value is the aesthetic feeling generated after aesthetic judgment and easy handling (Huang Youngji,2018). Through orderly arrangement, the single shape can improve the cognitive speed of the brain, improve visual richness and cognitive fluency, so as to obtain positive emotional compensation and produce aesthetic preference.

4. Aesthetic perception of sharp shapes

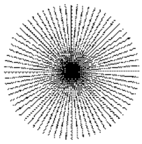
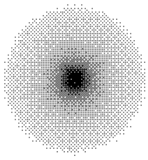
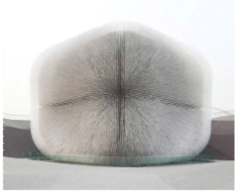
4-1. Visual cognition of sharp building

The cognition of objects is the first step of aesthetic generation. Analyze the shape of architectural elements from a neuroscientific perspective. Line is the most important and obvious element in architectural vision. Shape cognition is the foundation of architectural modeling, and the change of shape also determines the change of architectural modeling. From the analysis of the recognition mechanism of the brain, we can know that HSF can effectively help the brain recognize the edge forms of architectural modeling, such as angles, lines, and curves, so as to achieve the purpose of shape recognition and thus help us identify the visual value of architectural modeling. The cognitive process of building shape is analyzed with the theoretical knowledge of neuroscience. V1 neurons in the brain's main visual cortex are extremely sensitive to the direction of lines. V4 neurons are sensitive to certain angles. The following table takes the British pavilion at the World Expo in Shanghai as an example to analyze the visual cognition process of its modeling by the brain. First, the visual system recognizes shapes, and then the same elements form a group of high-density modeling through orderly arrangement, becoming a visual whole.

[Table 3] Cognition of Shape Units

Cognition of Shape Units			
Shape (V4)	Boundaries (V1)	Shape Area (VTC)	
			

[Table 4] Cognition of Architectural Modeling

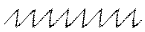
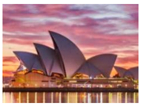
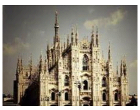
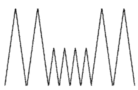
Cognition of Architectural Modeling						
	=		=		=	
Shape Unit		Order Arrangement (HSF)		Significance perception (LSF)		Architectural Modeling (source : www.google.com)

4-2. The method of inducing aesthetic experience

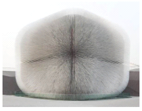
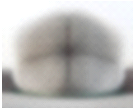
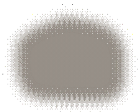
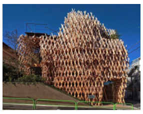
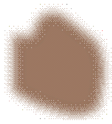
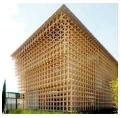
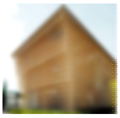
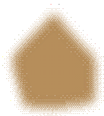
Good impressions from visual objects are not random, but the result of millions of years of evolution as human perception and cognition developed(Micchael S. Gazzaniga, Park In yun Station. 2009. p297). As the process of aesthetic judgment is carried out simultaneously with the visual aesthetic judgment and aesthetic judgment of cognition, they are independent but affect each other(Lyu X, Cho T Y.2019.p162). There are two ways to think about how sharp shapes can effectively interfere with the brain's perception of threat. First, the cognitive speed and perception of sharp shapes can be improved. As shown in Table 5, orderly shapes can bring positive emotional responses, and the pleasure of emotional rewards can be felt when the target information is quickly processed. Order is used to enhance the complexity of architectural modeling, so that these buildings can be perceived more quickly by using sharp shapes; Through order to enhance the complexity of modeling, HSF recognition can help the brain maintain sharp visual features in the cognitive process to improve the favorability of architectural modeling, so that the brain has aesthetic preference for it and get attention. The sharp shapes on the building is constantly combined and arranged to form an orderly whole that is easier to be perceived by the brain, thus increasing the favorability of the shape. One of the important influences of order on architectural modeling is to help people recognize architectural elements and separate architectural modeling from surrounding environment, so as to help people identify the overall architectural modeling.

The second is that a modeling whole can be formed through high-density combination and arrangement to blur the sharp outline and reduce the recognition of sharp shapes (see Table 6). LSF is used to identify the characteristics that preferentially perceive the meaning of the overall shape of a building, hinder the brain's perception of sharpness and reduce visual pressure and threat, thus creating a favorable impression of the shape of the building. The overall shape of the UK

[Table 5] HSF awareness in selected buildings (source:www.google.com)

Architectural	Hsf	Linear Extraction Graph
		
		
		

[Table 6] LSF awareness in selected buildings (source:www.google.com)

Architectural	Lsf	Perceptual shape
		
		
		

Pavilion made up of numerous sharp acrylic rods in Table 6 is considered to look like a "Dandelion", which indicates that although visualization can ensure an objective understanding of the objective shape, the perception of meaning is also affected by professional knowledge, experience, and culture to a certain extent. These factors exist in the subjective consciousness of the human brain, so aesthetic judgment will be partly affected by subjective factors to a certain extent. Beauty is experiential, but it is experience in action, rather than passive intuition and experience of the present(Gao J P. 2021. p150) . Therefore, when judging "beauty", aesthetic consistency will be displayed in most cases.

5. Conclusion

Based on interdisciplinary theoretical knowledge, this paper analyzes the methods of sharp shapes to reduce threat and promote aesthetic experience from the perspective of cognition. Aesthetic perception and judgment are sensory conscious reactions based on vision. Although sharp shapes can be threatening, when used properly they can distract the brain and reduce its perception. The brain's preference for complexity and regular shapes proves that buildings with regular repetition are more likely to be recognized quickly and attracted to people. Looking at actual cases, we can see that people's love of art is not only a brain response to a particular order of shapes, but also the superposition of the brain's cognitive process of the meaning of objective shapes. The aesthetic judgment of sharp shapes is influenced by cognition and perception. In the application of sharp shapes, order can be combined with architectural modeling design, and people's aesthetic preference can be stimulated by the brain's rapid recognition of sharp outline and the preference principle of order and repetition. In addition, high-density modeling expression can be used to blur the sharp contour edges, stimulate the brain to enhance the perception of the overall meaning of the building, so as to divert the perception and attention of the sharp shapes, and enhance people's favorable impression of it through the cognition of the meaning of the modeling. The core of art is the abstract expression of vision and cognition, and the production of aesthetics is the result of the complement of vision and cognition. As a common way of artistic expression, sharp shapes was used, from the point of view of nerve aesthetic, to solve the application limitation of sharp shapes from both visual and cognitive aspects, which can effectively shift the brain's attention from the threat and terror of sharp shape to the aesthetic pleasure of order cognition and meaning perception and produce visual beauty and aesthetic identity.

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