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# The Role of Symmetry in the Aesthetics of Residential Building Façades Using Cognitive Science Methods

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**Abstract:** Symmetry is an important visual feature for humans and its application in architecture is completely evident. This paper aims to investigate the role of symmetry in the aesthetic judgment of residential building façades and study the pattern of eye movement based on the expertise of subjects in architecture. In order to implement this in the present paper, we have created images in two categories: symmetrical and asymmetrical façade images. The experiment design allows us to investigate the preference of subjects and their reaction time to decide about presented images as well as record their eye movements. It was inferred that the aesthetic experience of a building façade is influenced by the expertise of the subjects. There is a significant difference between experts and non-experts in all conditions, and symmetrical façades are in line with the taste of non-expert subjects. Moreover, the patterns of fixational eye movements indicate that the horizontal or vertical symmetry (mirror symmetry) has a profound influence on the observer's attention, but there is a difference in the points watched and their fixation duration. Thus, although symmetry may attract the same attention during eye movements on façade images, it does not necessarily lead to the same preference between the expert and non-expert groups.

**Keywords:** façade; aesthetics; eye tracking; expertise; symmetry

## 1. Introduction

The façade, as the outer surface of the building, is an important part of the urban-scape and has a significant influence on the aesthetic preferences and physiological reactions of people [1–3]. Given that the aesthetic experience of the façade as well as its perception and feeling by humans is mostly done through the visual sense and begins with the visual scan of the work, so the study of the interaction between “bottom-up” and “top-down” processes can be accompanied by a study of eye movement behavior in aesthetic experience [4,5]. When we observe an artwork and make an aesthetic judgment about it, we will become involved in the interaction between these two processes [6,7]. The study of the first process is mainly focused on relation among visual aspects of an artwork and visual features of an image such as contrast, balance, symmetry, etc. [5]. On the other hand, the second processes are

influenced by several factors such as education, inter-individual differences, degree of training in the arts, and interest in a specific work of art [5–11], as well as by a person's cultural background (see [8,9]).

The present study discusses the emergence of aesthetic experience when a person views the images of residential building façades. This experience is tested through examining the role of “symmetry” and “expertise” as influencing factors in the “bottom-up” process and “top-down” process on people's eye movements. The main reason of the concentration on the residential building façades is the significant portion of this land-use among other land-uses of urban space. Therefore, the multiplicity of ownership and taste in façade design in this building will affect the appearance of the city more [12].

By testing visual stimuli, architects can study users' emotional and cognitive needs, and by relying on the acquired knowledge, they can find the ways and means of interaction and the effects of architecture, and its components on humans. Nowadays, the cognitive sciences, as the knowledge that has penetrated the field of architecture and urban planning, provide a suitable field to explore the impact of architectural designs in the human cognitive and behavioral responses. Advances in technology provide suitable tools and methods used in behavioral and cognitive studies without the direct involvement of people [13–16]. In this regard, the present study relies on the eye-tracking tool as a mechanism used in the field of cognitive sciences, which is also used in aesthetic studies [5,9,17] and seeks to examine the following hypotheses:

**Hypothesis 1 (H1).** *The type of preferred façades (symmetrical façades/asymmetrical façades), as well as reaction time to their choice, are significantly affected by the expertise of subjects.*

**Hypothesis 2 (H2).** *Based on expertise, during the aesthetic judgment of the façade, the eye movements of observers are significantly affected by symmetry.*

## 2. Research Literature

### 2.1. Symmetry

In mathematics, symmetry holds if an object is invariant through any geometric transformation, such as reflection, rotation, and scaling. Symmetry, as one of the principles of design, provides a sense of harmony that can be considered as a complete form of balance. In addition to aesthetic aspects, it has always been considered in terms of stability [18].

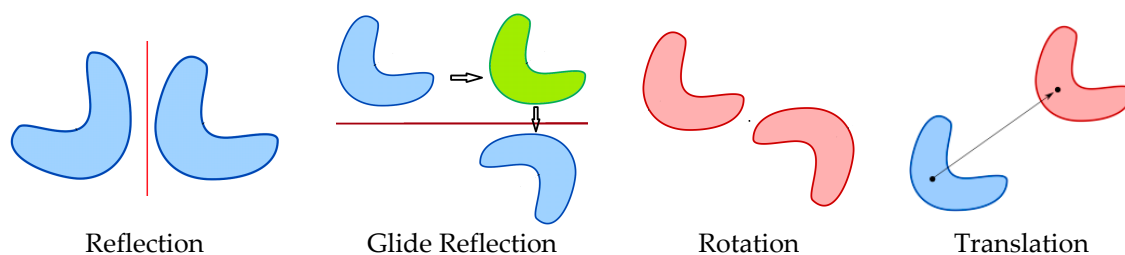
The most important types of symmetry are reflective or mirror, glide-reflection, rotational, and transitional symmetry [19], which are described below:

**Reflection/Mirror Symmetry:** This is when the repetition occurs through a hypothetical straight line, the reflection axis, and creates a mirror image. This type of symmetry plays an important role in all cultures [20] and it is a well-known fact that, in architecture, this type of symmetry is most common.

**Glide-Reflection Symmetry:** This kind of symmetry holds when a pattern is repeated through the combination of transitional and reflective motion by rotating around the axis of symmetry [21].

**Rotational symmetry:** This is another version of symmetry that rotates something around a fixed point called the center of rotation. The objects and their images have the same shape and size, but the object can rotate in different directions [22]. It is well-known that rotational symmetry contributes to the movement and rhythm of the architectural elements emphasizing the central point of the architectural space [23].

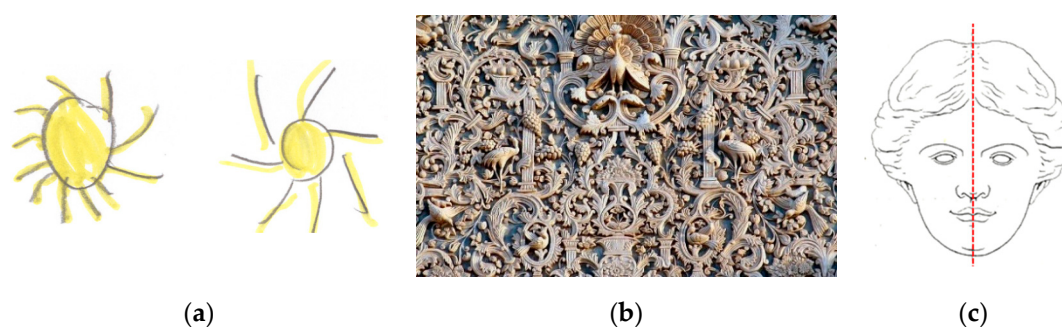
**Translation symmetry:** This is a type of symmetry obtained by transferring a shape or an object without changing the overall shape [21]. The second-most-common form of symmetry in architecture is translational symmetry. Translational symmetry includes the duplication of entire pieces of buildings, even if people believe that this monotonous repetition is boring [24]. One can see several types of symmetries, as shown in Figures 1 and 2.



**Figure 1.** Most important types of symmetry.

Villarroel and Merino [25] studied the existence of symmetrical motifs in young children’s paintings from plant life. The results of this study investigated the notions that children employ several kinds of symmetry in their paintings and that dihedral symmetry is commonly used to illustrate elements of plant life such as trees, flowers, vegetables, sun, etc. (see Figure 2a). It should be noted that a dihedral group is a group of symmetries of a regular polygon, which includes rotations and reflections. Dihedral groups are among the simplest examples of finite groups, and they play an important role in group theory, geometry, aesthetics, and chemistry (see [26]).

On the other hand, the information obtained by symmetrical patterns have significant roles in both the processing of visual input and facilitating drawings. Pictorial motifs with dihedral symmetry which represent the information appearing on both sides of its line of symmetry, enable children to draw the other symmetrical side. Indeed, young children may use several types of symmetry to perform their depiction more quickly and effectively. In Ramachandran et al. [26], it is explained that the children in the model are demanding symmetry since the symmetry is in their pictures, a point that might be in line with the rules of neuro-aesthetics (see Figure 2a). Instances of the widespread usage of symmetry elements in architecture can be comprehended in the structure and ornamentation of Islamic buildings [21] like historical houses in Kashan-Iran (Figure 2b). Finally, as shown in Figure 2c, in the natural world, most biological objects, such as human faces, are symmetrical [27]. Wagemans showed that the human visual system attributes special status to mirror symmetry and this has a root in human evolutionary biology [28]. Anthropologist Karl Grammar, in collaboration with biologist Randy Thornhill, measured facial symmetry by measuring the distances from the landmarks of the face and found that symmetry is correlated with judging attractiveness [29].



**Figure 2.** Three kinds of symmetry: (a) A selection of dihedral symmetry in children’s painting [25]; (b) mirror symmetry in Borujerdi historical house modeling—detail of the exterior wall carvings [30]; (c) mirror symmetry in the face [31].

It is well-known that beauty is a result of the existence of symmetry [32–34]. Symmetry is an indicator of fitness that reflects a healthy nervous and immune system. This is true for infants and adults as well as people from different cultures. Beauty seems to have constants that are widespread among all ages and racial boundaries [35] because the principles of attractiveness in faces have a biological and evolutionary basis [36]. However, the recent studies [37] do not confirm the fact that symmetry may yield beauty. It seems that aesthetic preferences, as effective factors in the “top-down” process

of aesthetic judgment, might be formed by our own personal and educational experiences [37,38]. The difference between these opinions is the main topic examined in this article. We tested people by comparing two different groups in terms of expertise in the field of architecture.

## 2.2. Eye Movement

The eye can be considered the gateway for visual information to enter the brain. This organ is the only sensory receptor that is part of the central nervous system at the beginning of human development and is gradually separated from the brain and transferred to the outside of the head during fetal development [16]. Human vision is an active, dynamic process in which the viewer seeks out specific visual input as needed to support ongoing cognitive and behavioral activity [17,39–42]. Eye movements are an important part of the human visual system and are not accidental fixations during the evaluation and judgment of an invisible stimulus [42,43]. Therefore, eye movements can represent the processing activities of the human mind, including image scanning and cognitive visual-motor activity analysis [44]. These movement patterns are influenced by the specific characteristics of the image, perspective, and characteristics of the viewer. There are at least three reasons in psychological research for the popularity of eye movement recording: importance, urgency, and adaptability. Gaze movement is an important factor to examine because the motor-ocular system is undoubtedly the most widely used system among mammalian sensory-motor systems, supported by an extensive functional nervous system, and is now better understood than other early brain functional systems. Due to the anatomy of the eye, the effects of this system can be examined immediately psychologically and technically [13].

Tracking eye movement is a method of measuring and recording eye movements depending on the position of an observer's head or recording the gaze of the eye on visual scenes [45]. Therefore, observing and studying eye movements can show a person's real preferences [46]. Eye movements are used to understand human behavior for two reasons: First, the locations chosen for fixation make it possible to understand the moment-to-moment changes in the information required for the behaviors in which we participate. Second, even though our eyes move on average three or four times a second, we do not know this and are often unaware of where our eyes see it [47].

The evaluation of eye movements includes static indicators (the number of fixations and fixation duration) and dynamic indicators (the number of saccades, saccades duration, saccade amplitude, and scan path length) [48], which are used in the study of visual aesthetic studies to examine the perception, recognition, and evaluation of artworks [4,9,47,49]. According to previous studies, the most considerable eye movement indicators are as follow (Table 1).

**Table 1.** Definition of eye movement indicators.

Indicator	Description	Source
Fixation	<ul style="list-style-type: none"> <li>• Shortstops pause in gaze position in specific positions.</li> </ul>	[50]
Number of fixations	<ul style="list-style-type: none"> <li>• Number of fixations on areas with information relevant.</li> <li>• Related to participant attention.</li> <li>• Time of one fixation.</li> </ul>	[51] [5]
Fixation duration	<ul style="list-style-type: none"> <li>• Usually associated with a difficult and intensive cognitive process.</li> </ul>	[51] [52]
Saccade	<ul style="list-style-type: none"> <li>• Quick eye movements as the gaze travels from one fixation point to another.</li> </ul>	[53]
Saccade duration	<ul style="list-style-type: none"> <li>• The time between the departure of fixation and doing another one.</li> </ul>	[54]
Saccade amplitude	<ul style="list-style-type: none"> <li>• The amplitude of the saccade in visual degrees.</li> <li>• The distance traveled by a saccade.</li> </ul>	[54]
Scan path length	<ul style="list-style-type: none"> <li>• Gaze positions and eye movements during observing the stimuli.</li> <li>• The scan path is a set of fixations in chronological order.</li> </ul>	[53] [55]

### 2.3. “Top-Down” and “Bottom-Up” Processes in Aesthetic Judgment

As mentioned in the introduction, “top-down” processes are influenced by a person’s cultural background, education, degree of expertise, familiarity, and interest in a particular work of art, as well as interpersonal differences [5–11,56], while “bottom-up” processes are influenced by the sensory codes of external stimuli [5]. These processes affect people’s aesthetic judgment and perceptual process during an aesthetic judgment [13,56]. The research has shown that there is a definite relationship between human physiological behavior and aesthetic experience [5]. Since the aesthetic skill launches with a visual scan of the work, the multilevel interaction between these processes has also been considered in the study of eye movement behavior [4].

Numerous studies have been conducted to investigate the effect of façade features on aesthetic judgment. In Gifford et al. [57,58], 59 physical elements of 42 large contemporary buildings and large office buildings were individually scored considering clarity, friendliness, originality, meaningfulness, and ruggedness as relative cognitive properties of these buildings. In Ilbeigi et al. [59], a qualitative methodology is used to reach the aesthetic indicators of residential façades. They focused on the cognitive properties, aesthetic preferences, perception of architects and non-architects, and they showed that properties such as simplicity and uniqueness are common in both groups despite differences among architects and non-architects views. In Ruta et al. [60], it is shown that most of the participants prefer to select the curved façade rather than the sharp-angled and rectilinear ones. A recent study used EEG data of participants to show that curvature, but not symmetry architectural space, had a significant impact on preference, based on participants’ design expertise: non-experts rated curved spaces as more interesting compared to experts [61].

Keul et al. [62] examined six images taken from the architecture of residential houses that include elements such as façade, landscape, floor, furniture, and sky. Their assumption was based on the fact that the attention of architects, according to the expertise and training gained, is attracted to the façade as an element in architecture more than any other element in the image. Moreover, it is shown that there is a difference between expert and non-expert people and according to gender. The results of this laboratory study indicate that this difference exists only by regarding the elements of the façade and no significant difference was reported in the elements of the image concerning the influence of gender. Yousefi et al. [63] provided information on how to design an eye tracking test and analyze the data produced by eye tracking tools in the construction industry. They showed the buildings to non-experts from four different sides (north, south, east and west) in a virtual reality environment to subjects. In Cho [64], a study on two groups of experts and non-experts is conducted by examining how people view a façade considering hypotheses such as paying more attention to opening areas, doors, and windows. Sussmann and Ward [65] asked questions such as how do people get in a place? How do they look when they are in a place? They found that most people’s gaze was fixed on the central part of the place, which has a higher contrast, and then on the light, the blue sky, and the brick building. In that study, the main focus is on the image and the points that have high contrast.

According to [66], humans are highly sensitive to symmetry and saccades parallel to the axis of symmetry than along other orientations. Makin et al. [67] examined patterns of saccadic eye movements when participants observed patterns with a horizontal or vertical axis of mirror reflection and found that participants tend to make saccades along the axis of reflection.

For us, it is interesting to examine the eye movement during the aesthetic judgment of façades with special visual features like symmetry (“bottom-up”) and based on subjects’ expertise (“top-down”). Research on expertise is usually done with two approaches: (1) examining the impact of information on the experience of non-experts, or (2) comparing non-experts and experts [68]. In this study, the second approach has been considered.

### 3. Materials and Methods

#### 3.1. Visual Stimuli

The use of images is common in aesthetic assessment [14,69,70]. Based on [71], our assessment in Hypothesis 1 is subjective perception assessment and in Hypothesis 2 is laboratory experiments and analysis. In the laboratory step, we select images to achieve basic images for evaluating eye movements during aesthetic judgment.

The city of Tehran has 22 districts. In the first step, after sampling the districts based on their development index [72], 1300 residential building façade images were recorded. We removed 300 images due to similarity to other images and severe weakness of images. To prevent the researcher from applying his opinion in choosing the images, the remaining 1000 images were examined by 10 experts in the field of architectural education according to the two general questions of photographic quality (proper angle of the image, color quality and minimum observance of interfering factors in the image) and its score of aesthetic (0 to 9 Likert scale). Finally, based on what is considered in the background of similar research and studies [73], 110 images entered the laboratory study step. Considering the hypotheses, the authors divided the stimuli into two categories: symmetrical façades (55 images) and asymmetrical façades (55 images). Since participants used three keys for three levels of the score (pleasant, unpleasant, and moderate) during the eye movements record, the final answer of the experts was categorized according to Table 2. To do this, 110 visual stimuli were selected almost equally from all three categories (11 images that have the highest frequency of selection in each category).

**Table 2.** Likert scale of 0–9 and classification of the aesthetic level of façade images on this scale.

Score	0	1	2	3	4	5	6	7	8	9
Aesthetic level	unpleasant			moderate			pleasant			

#### 3.2. Participants

The present study tries to achieve its goals with an experimental strategy. The sampling method in this experiment is voluntary response sampling. Since it is assumed that the aesthetic preferences and the pattern of eye movement of subjects differ according to their expertise and visual literacy, two separate groups of participants are used. The study statistical population constitutes the first group. Experts in the field of architecture (including students who have completed a bachelor's degree or higher and have a history of professional activity, especially in the field of façade design, as well as professors of architecture in the field of courses such as architectural basic design and architectural design) constitute the second group. The other students and faculty members of the Shahid Rajaei Teacher Training University are known as non-experts with the condition of not having a history of activity and study in the field of architecture and visual arts. Sample groups include 38 participants (19 women, 19 men, and 21 experts, 17 non-experts) and 30 participants are right-handed. Since looking at images before the final experiment might affect people's eye movements and image selection attitude, two separate clusters are considered, experts who have selected test images and experts for eye movement recording. The average age of the group of experts is  $26.25 \pm 5.33$  years and the average age of the non-experts is  $23.44 \pm 4.55$  years.

#### 3.3. Eye Movements Task and Its Recording Device

How to display images in the task was designed in a "single-block" of 110 trials, and the images were displayed randomly in full color and full screen. The related process to each stimulus was divided into two parts: recording eye movements and recording an aesthetic judgment (see Figure 3). At the beginning of the session, participants were instructed in detail on how to experiment with how to use the buttons set on the keyboard in the aesthetic judgment section the stimuli were displayed randomly on the monitor screen. Each experiment began by displaying a fixed dot in the form of a central white

(+) on a black screen (for 300 milliseconds), followed by each stimulus image for 4 s. The display of each experiment ended with the answer to the pleasant question of the displayed image, and the next experiment began. Participants participated in the experiment individually and the experiment lasted about 13 min.

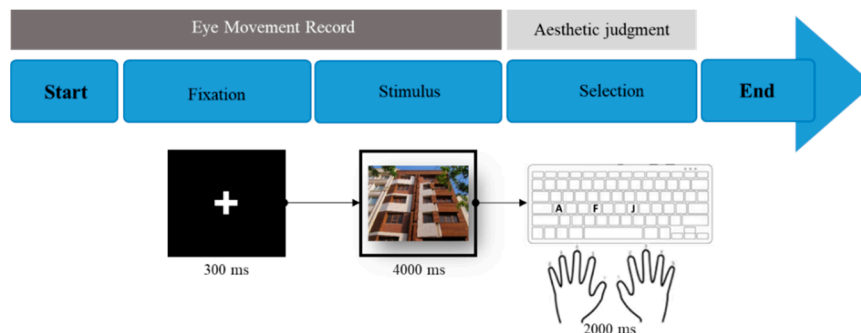


Figure 3. Experimental task.

The experiments were performed by the Psychtoolbox, Matlab R2014a software, and EyeLink toolbox to record eye movements in a dark room with light and sound insulation. Participants were sitting at a distance of 57 cm from the monitors (17-inch CRT display-Iyama HM204DT with an 85 Hz refresh frame rate and a resolution of 1280 × 1024 pixels). Moreover, the EyeLink 1000, developed by SR Research (Ontario, Canada) was used to register the eye movements (Figure 4). After the successful performance of the validation phase, the main test began.

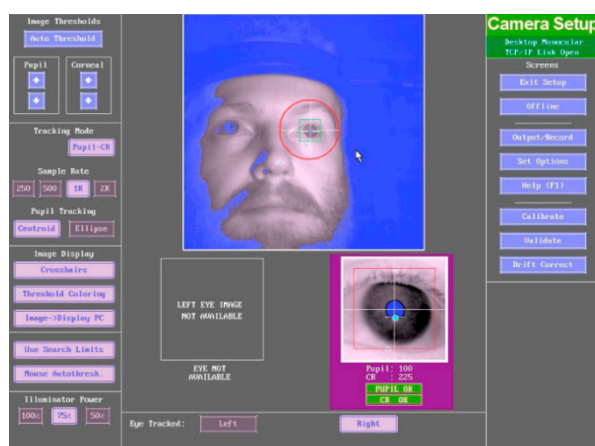


Figure 4. Camera setup screen (EyeLink 1000 Plus User Manual 1.0.6).

## 4. Results

Here, we present the main results of this study.

### 4.1. Study of the First Hypothesis

As mentioned in the literature review, in the “top-down” process, the aesthetic judgment of humans can be influenced by their expertise. In this study, the aesthetic study of residential building façades in two categories of symmetrical and asymmetrical façades is considered. The first hypothesis is examined in two parts: (1) examining the differences in aesthetic judgment and (2) examining the reaction time of subjects to the choice of images.

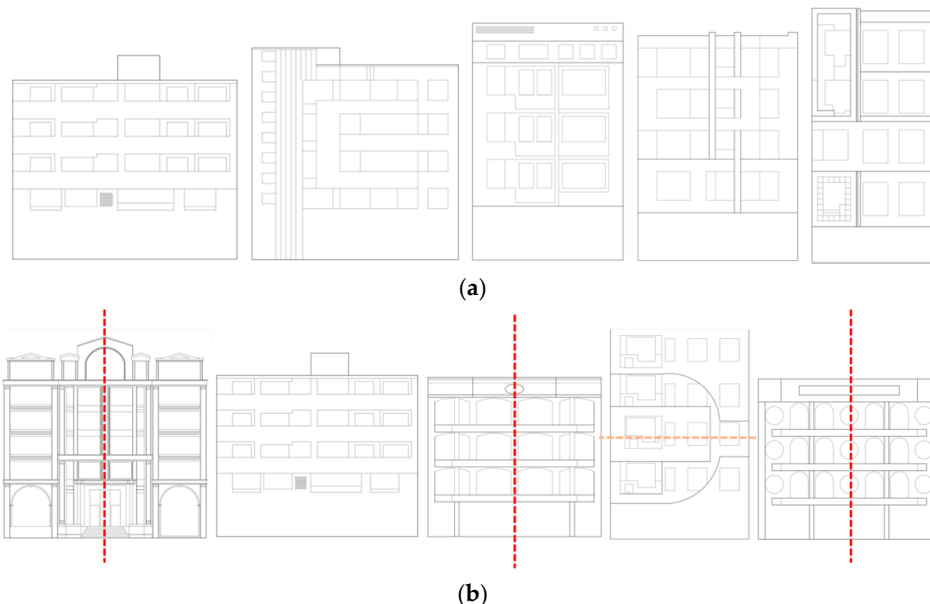
To compare the response of these two groups, the *T*-test of two independent samples was used. In this test, it is necessary to first check the conditions of Levene’s test. Levene’s test is a test for identifying equality and non-equality of variances. According to Levene’s test results, the significance

level (sig) is higher than 0.05 and it means that the null hypothesis cannot be rejected. This tells us that we should look at the “Equal variances assumed” row for the t-test results. In equal variances, since  $p < 0.05$  (that is less than our chosen significance level  $\alpha = 0.05$ ), we can reject the null hypothesis. This means that the degree of the pleasantness of the façades has a significant difference between experts and non-experts in all façades. An examination of the first five preferred façades of the two groups of experts and non-experts shows that among the experts, preferred façades were unanimously selected by about half of the participants and among non-experts with an average of more than 70% (Figure 5).



**Figure 5.** Five preferred façades of each group from 110 images displayed in the laboratory step and the frequency of participants’ responses.

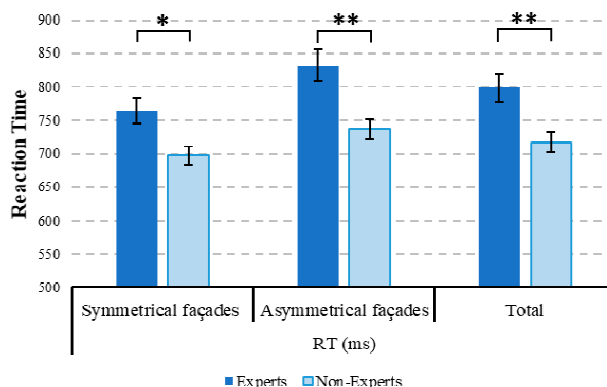
The results show a difference between experts and non-experts’ tastes; thus, the presented façades are more in line with the tastes of non-experts. The important point in the preferred façades of non-experts is the significance of mirror symmetry (Figure 6b) that often has symmetry in the whole composition and its components.



**Figure 6.** Two-dimensional images of preferred façades of the two groups. (a) Preferred façades of experts; (b) preferred façades of non-experts.

In the second part of the first hypothesis, the reaction time to image selection is evaluated. These data could give us an insight into what happens in the brain and how expert and non-expert

subjects perceive façades differently because reaction time can reflect cognitive load during judgment processing. The increase in reaction time during image selection indicates that people are trying harder to process information and make decisions. According to Figure 7 and based on the Wilcoxon statistical test, the comparison between the response of experts and non-experts in all façades, asymmetrical façades ( $p < 0.001$ ), and symmetrical façades ( $p < 0.05$ ) shows a significant difference.



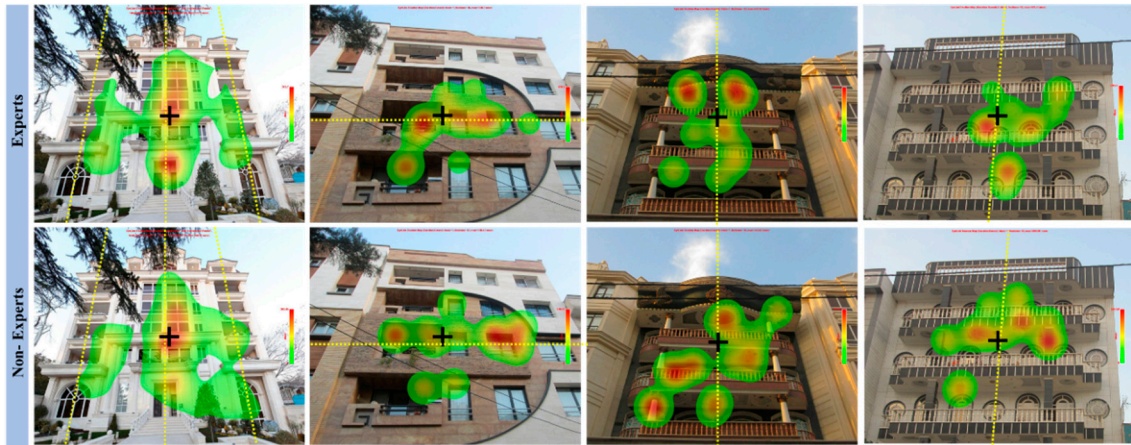
**Figure 7.** Comparison of reaction time values between expert and non-expert observers. (\*) represents  $p < 0.05$  and (\*\*) represents  $p < 0.001$  (Wilcoxon rank-sum Test) and error bars are standard error of mean (SEMs).

The average reaction time in asymmetrical façades is longer than the average reaction time in all images and symmetrical façades. This means that the aesthetic processing of the asymmetrical façades in both groups indicates a higher cognitive load than all of the façade images and symmetrical façades. Moreover, the results suggest that experts experienced higher cognitive load in their aesthetic judgment than non-expert participants.

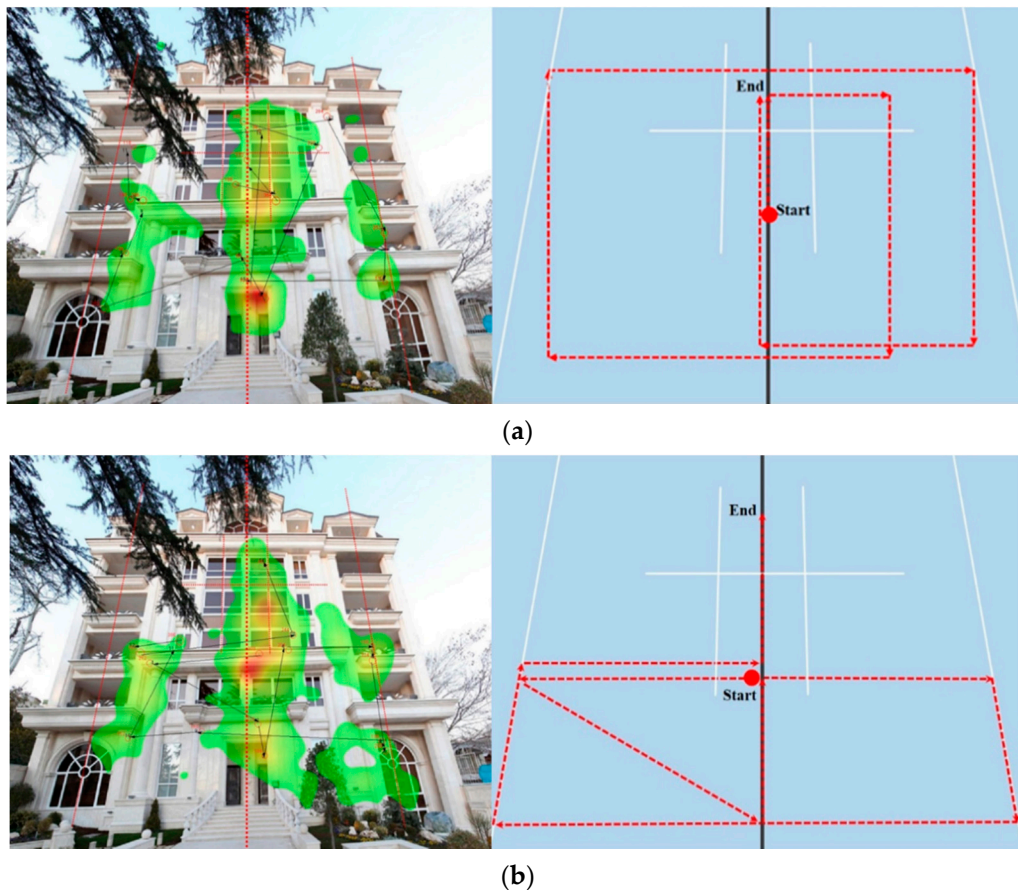
#### 4.2. Study of the Second Hypothesis

In the second hypothesis, the existence of differences in eye movements of expert and non-expert people (“top-down” process) during observing symmetrical façades (“bottom-up” process) was examined. In this section, heat maps and gaze plot were used to study the pattern of eye movements (Figures 8 and 9). Gaze plot shows the location, order, and time spent looking at locations on the stimulus. The heat map can show a graphical representation of a person’s eye movement behavior [74] and reveal the focus of visual attention for many participants at a time. In heat maps, the red color indicates the points that have received the most visual attention while viewing the image, and the green color indicates the average attention.

A comparative study of the heat maps in both groups shows that in these symmetrical façades with a horizontal or vertical axis of mirror reflection, attention to the mirror symmetry axis is more than the other point of an image (Figure 8). These two groups are similar in this respect, but according to the heat map, the fixation duration to the image elements varies between them. An examination of the pattern of eye movement is shown as an example in one of the gaze plots (Figure 9a). In this image, we can see the order of saccades from different parts of the image. According to experts, attention is first drawn from the center of the image to the top and then downwards along the axis of symmetry. Then continue the path of the eye to the left of the image and then to the right. Due to the symmetrical design of this façade, paying attention to the center of the image and the decorative frame of the façade and the entrance is not unexpected. However, compared to the non-expert, it can be seen that, in the gaze plot, first the visual attention is drawn from the center of the image to the left and bottom of the image in the middle part, and again the center and then to the right of the image and then to the left is targeted. Finally, it is directed to the middle part of the top of the image (Figure 9b).



**Figure 8.** Heat map of a symmetrical façade preferred by non-experts compared with the expert group. Interpretation of colors in a heat map related to visual attention to images. Areas that have the highest number of fixations are colored by red, and areas with the lowest number of fixations are colored by green.



**Figure 9.** Example of a gaze plot and simplified pattern of eye movement path for a single eye-tracking participant of each group that is looking at a symmetrical façade. (a) Expert one; (b) Non-Expert one.

## 5. Conclusions and Future Research

The important facts concerning the investigation of human behavior are knowing how people impose the information provided by their environment and what they find out. These give us a better idea for the human evaluation basis of their environment and an idea of how they interact

with the environment when making decisions. In the meantime, the combination of the results of eye movements in the complex process of aesthetic experience provides a deeper understanding of the mental processes that lead to aesthetic experience. Because aesthetic evaluation can be influenced by objective façade indicators such as symmetry (“bottom-up” process) as well as cognitive variables such as expertise (“top-down” process), this research analyzed the differences in the eye movement patterns and cognitive behavior of subjects in both expert and non-expert groups during the aesthetic judgment of residential building façades.

We argued that, in the aesthetic judgment of the façades, there is a significant difference between experts and non-experts, which confirms the results of Kim et al. in [53] and Massaro et al. [5]. The non-experts focused more attention on the symmetrical façades. Based on a recent study [75], this is maybe due to the fact that symmetry makes easier the image processing, [71,75,76]. While the symmetry plays a significant role in judgments of beauty, it enhances aesthetic preferences for visual patterns [77]. It was stated in [4] that the easier perceptual processes of an object during aesthetic judgment leads it to be more preferred. This means that symmetry can be useful in aesthetic evaluation (see [78–81]). Symmetry can be detected by humans during 0.05 s [82], and most people feel more emotionally and physiologically comfortable with the elements and structures of architecture created using the language of traditional forms that are closer to the language of nature [83]. This is an important point of biological and socio-cultural view and provides a method with available, fast, and with positive effect processing in façade evaluation. Moreover, based on the study of Haas and Weber [84], it seems that there is a relationship between perceived balance and mental interest in a building.

The research reviewed confirms the important role of symmetry in people’s aesthetic preferences. A large number of visual arts studies [37,38,85,86] reveal that the expert group like both asymmetric and simple patterns more than non-experts because of the importance of asymmetrical depictions in art [7], while the second group choose the symmetric and complex patterns. Finally, based on the results of this study and according to the results of [77], we can say that, at the first level of perception, having an academic education in the art or architecture fields can decrease the importance of symmetry during the aesthetic judgment.

Higher reaction times indicate a higher cognitive load. Since participants with higher expertise needed a longer time to reach their decision, it could be inferred that they had a higher cognitive load. Moreover, the results show that the average reaction time in asymmetrical façades is longer than the average reaction time in symmetrical façades. According to [28,87,88], this matter also confirms that symmetry can influence stimuli processing faster than asymmetrical stimuli.

On the other hand, it is important to report that, in this study, the eye movement around the axis of symmetry is in line with previous findings of symmetry and eye movements in other fields [66,67,89,90]. However, there are differences in attention points and the duration of fixating on those points. Thus, although symmetry may attract the same attention during eye movements on façade images, it does not necessarily lead to the same preference between the expert and non-expert groups. These differences in their preferences can result from the different decoding processes of façade images, between experts and non-experts.

The results from this study present an idea for future research to study different decoding processes of façade images, between experts and non-experts. Examining people’s eye movement patterns and studying the type of images that they prefer enables architects to get acquainted with the important physical elements during the aesthetic judgment of façades and the difference between the two groups in visual attention. So, architects can effectively predict the visual effects of their future design. This matter leads to more appropriate façade designs.

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## References

1. Choo, H.; Nasar, J.L.; Nikrahei, B.; Walther, D.B. Neural codes of seeing architectural styles. *Sci. Rep.* **2017**, *7*, 40201. [\[CrossRef\]](#)
2. Jurgenhake, B. Signs and Symbols of the Domestic Façade in the City: Changes, Confusion or Decline? Presented at the ENHR 2013 Conference “Overcoming the Crisis, Integrating the Urban Environment”, Tarragona, Spain, 19–22 June 2013.
3. Jack, L.N. Urban design aesthetics: The evaluative qualities of building exteriors. *Environ. Behav.* **1994**, *26*, 377–401.
4. Locher, P. The usefulness of eye movement recordings to subject an aesthetic episode with visual art to empirical scrutiny. *Psychol. Sci.* **2006**, *48*, 106–114.
5. Massaro, D.; Savazzi, F.; Di Dio, C.; Freedberg, D.; Gallese, V.; Gilli, G.; Marchetti, A. When art moves the eyes: A behavioral and eye-tracking study. *PLoS ONE* **2012**, *7*, e37285. [\[CrossRef\]](#)
6. Cupchik, G.C.; Vartanian, O.; Crawley, A.; Mikulis, D.J. Viewing artworks: Contributions of cognitive control and perceptual facilitation to aesthetic experience. *Brain Cogn.* **2009**, *70*, 84–91. [\[CrossRef\]](#)
7. Leder, H.; Belke, B.; Oeberst, A.; Augustin, D. A model of aesthetic appreciation and aesthetic judgments. *Br. J. Psychol.* **2004**, *95*, 489–508. [\[CrossRef\]](#)
8. Locher, P.J. A measure of the information content of visual art stimuli for studies in experimental aesthetics. *Empir. Stud. Arts* **1995**, *13*, 183–191. [\[CrossRef\]](#)
9. Locher, P.J. The contribution of eye-movement research to an understanding of the nature of pictorial balance perception: A review of the literature. *Empir. Stud. Arts* **1996**, *14*, 143–163. [\[CrossRef\]](#)
10. Christensen, B.T.; Ball, L.J. Dimensions of creative evaluation: Distinct design and reasoning strategies for aesthetic, functional and originality judgments. *Des. Stud.* **2016**, *45*, 116–136. [\[CrossRef\]](#)
11. Senzaki, S.; Masuda, T.; Ishii, K. When is perception top-down and when is it not? Culture, narrative, and attention. *Cogn. Sci.* **2014**, *38*, 1493–1506. [\[CrossRef\]](#)
12. Zahedan, A.; Masoud Lavasani, M. Experience of constituting residential façade in district 17 of Tehran. *MANZAR J.* **2014**, *6*, 50–55.
13. Huston, J.P.; Nadal, M.; Mora, F.; Agnati, L.F.; Conde, C.J.C. *Art, Aesthetics, and the Brain*; Oxford University Press: New York, NY, USA, 2015.
14. Coburn, A.; Vartanian, O.; Chatterjee, A. Buildings, beauty, and the brain: A neuroscience of architectural experience. *J. Cogn. Neurosci.* **2017**, *29*, 1521–1531. [\[CrossRef\]](#)
15. Leder, H.; Nadal, M. Ten years of a model of aesthetic appreciation and aesthetic judgments: The aesthetic episode—Developments and challenges in empirical aesthetics. *Br. J. Psychol.* **2014**, *105*, 443–464. [\[CrossRef\]](#)
16. Vartanian, O.; Navarrete, G.; Chatterjee, A.; Fich, L.B.; Leder, H.; Modroño, C.; Skov, M. Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. *Proc. Natl. Acad. Sci. USA* **2013**, *110* (Suppl. S2), 10446–10453. [\[CrossRef\]](#)
17. Dupont, L.; Ooms, K.; Antrop, M.; Van Eetvelde, V. Comparing saliency maps and eye-tracking focus maps: The potential use in visual impact assessment based on landscape photographs. *Landsc. Urban Plan.* **2016**, *148*, 17–26. [\[CrossRef\]](#)
18. Ajdari, M. Balance and Symmetry of Architectural Design-Principles of Aesthetics in Iranian Traditional Architecture. In Proceedings of the 5th International Conference on Research in Engineering, Science and Technology, Istanbul, Turkey, 14 March 2016; pp. 1–10.
19. Tsai, L.Y. *Math 113 Finite Math with a Special Emphasis on Math and Art*; University of Miami: Miami, FL, USA, 2010.
20. Hann, M. *Symbol Pattern & Symmetry, The Cultural Significance of Structure*; Bloomsbury: London, UK; New Delhi, India; New York, NY, USA; Sydney, Australia, 2013.
21. Kojić-Prodić, B.; Štefanić, Z. Symmetry versus asymmetry in the molecules of life: Homomeric protein assemblies. *Symmetry* **2010**, *2*, 884–906. [\[CrossRef\]](#)

22. Brandmüller, J.; Hroudá, B.; Wickede, A.V. Symmetry in Archaeology. In *Symmetry: Unifying Human Understanding*; Hargittai, I., Ed.; Pergamon Press Ltd.: Oxford, UK, 1986; pp. 783–787.
23. Williams, K. Architecture and Mathematics: Art, Music and Science. In *Bridges: Mathematical Connections in Art, Music and Science*; Bridges Conference: Winfield, KS, USA, 1998; pp. 11–20.
24. Salingaros, N.A. Why monotonous repetition is unsatisfying. *Meand. Math.* **2011**. Available online: <https://arxiv.org/abs/1109.1461> (accessed on 24 May 2020).
25. Villarroel, J.D.; Merino, A.M. Symmetrical motifs in young children’s drawings: A study on their representations of plant life. *Symmetry* **2019**, *11*, 26. [[CrossRef](#)]
26. Ramachandran, V.S.; Hirstein, W. The science of art: A neurological theory of aesthetic experience. *J. Conscious. Stud.* **1999**, *6*, 15–51.
27. Dobson, J.; Gorman, L.; Moore, M.D. Consumer choice bias due to number symmetry: Evidence from real estate prices. *J. Res. Consum.* **2010**, *17*, 1–12.
28. Wagemans, J. Detection of Visual Symmetries. *Spec. Vis.* **1995**, *9*, 9–32. [[CrossRef](#)]
29. Grammer, K.; Thornhill, R. Human Facial Attractiveness and Sexual Selection: The Role of Symmetry and Averageness. *J. Comp. Psychol.* **1994**, *108*, 233–242. [[CrossRef](#)]
30. Persian Tourism. Available online: <http://www.persiantourismguide.com/2015/08/29/borujerdis-house/#prettyPhoto> (accessed on 18 June 2020).
31. Wikipedia, the Free Encyclopedia. Available online: [https://en.wikipedia.org/wiki/Facial\\_symmetry](https://en.wikipedia.org/wiki/Facial_symmetry) (accessed on 3 August 2020).
32. Rosa, M.; Orey, D. Symmetrical Freedom Quilts: The Ethno mathematics of Ways of Communication Liberation and Art. *Rev. Lat. Am. de Etnomatemática* **2009**, *2*, 52–75.
33. Zaidel, D.W.; Cohen, J.A. The face, beauty, and symmetry: Perceiving asymmetry in beautiful faces. *Int. J. Neurosci.* **2005**, *115*, 1165–1173. [[CrossRef](#)]
34. Zaidel, D.W.; Hessamian, M. Asymmetry and symmetry in the beauty of human faces. *Symmetry* **2010**, *2*, 136–149. [[CrossRef](#)]
35. Chatterjee, A. *The Aesthetic Brain: How We Evolved to Desire Beauty and Enjoy Art*; Oxford University Press: New York, NY, USA, 2014.
36. Ruggles, D.H. *Beauty, Neuroscience, and Architecture: Timeless Patterns and Their Impact on Our Well-Being*; Fibonacci: LLC, Kentucky, 2018.
37. Leder, H.; Tinio, P.P.; Brieber, D.; Kröner, T.; Jacobsen, T.; Rosenberg, R. Symmetry Is Not a Universal Law of Beauty. *Empir. Stud. Arts* **2019**, *37*, 104–114. [[CrossRef](#)]
38. Weichselbaum, H.; Leder, H.; Ansorge, U. Implicit and Explicit Evaluation of Visual Symmetry as a Function of Art Expertise. *i-Perception* **2018**, *9*, 2041669518761464. [[CrossRef](#)]
39. Henderson, J.M. Regarding scenes. *Curr. Dir. Psychol. Sci.* **2007**, *16*, 219–222. [[CrossRef](#)]
40. Castelano, M.S.; Henderson, J.M. Initial scene representations facilitate eye movement guidance in visual search. *J. Exp. Psychol. Hum. Percept. Perform.* **2007**, *33*, 753–763. [[CrossRef](#)]
41. Schraa-Tam, C.K.; van Broekhoven, P.; van der Geest, J.N.; Frens, M.A.; Smits, M.; van der Lugt, A. Cortical and cerebellar activation induced by reflexive and voluntary saccades. *Exp. Brain Res.* **2009**, *192*, 175–187. [[CrossRef](#)]
42. Castelano, M.S.; Mack, M.L.; Henderson, J.M. Viewing task influences eye movement control during active scene perception. *J. Vis.* **2009**, *9*, 6. [[CrossRef](#)]
43. Filin, A.V. *Avtomatya Saccad [Automatism of Saccades]*; Moscow State University: Moscow, Russia, 2002.
44. Zvyagina, N.; Sokolova, L.; Morozova, L.; Lukina, S.; Cherkasova, A. Eye Tracking and Autonomic Nervous System Reactivity During Perception of Visual Environments of Different Comfort. *Eur. Sci. J.* **2014**, *10*. [[CrossRef](#)]
45. Netek, R. Implementation of Ria concept and Eye tracking system for cultural heritage. *Opgeroepen op Sept.* **2011**, *9*, 2012–2019.
46. Klingner, J.M. Measuring Cognitive Load during Visual Tasks by Combining Pupillometry and Eye Tracking. Ph.D. Thesis, Stanford University, Stanford, CA, USA, 2010.
47. Ebert, A.; Veer, G.; Domik, G.; Gershon, N.; Scheler, I. *Building Bridges: HCI, Visualization, and Non-Formal Modeling*; Springer: Berlin/Heidelberg, Germany, 2013.
48. Jowers, I.; Prats, M.; McKay, A.; Garner, S. Evaluating an eye tracking interface for a two-dimensional sketch editor. *Comput.-Aided Des.* **2013**, *45*, 923–936. [[CrossRef](#)]

49. Karatekin, C. Eye tracking studies of normative and atypical development. *Dev. Rev.* **2007**, *27*, 283–348. [[CrossRef](#)]
50. Holmqvist, K.; Nyström, M.; Andersson, R.; Dewhurst, R.; Jarodzka, H.; Van de Weijer, J. *Eye Tracking: A Comprehensive Guide to Methods and Measures*; Oxford University Press: New York, NY, USA, 2011.
51. Gegenfurtner, A.; Lehtinen, E.; Säljö, R. Expertise differences in the comprehension of visualizations: A meta-analysis of eye-tracking research in professional domains. *Educ. Psychol. Rev.* **2011**, *23*, 523–552. [[CrossRef](#)]
52. Zangemeister, W.H.; Sherman, K.; Stark, L. Evidence for a global scan path strategy in viewing abstract compared with realistic images. *Neuropsychologia* **1995**, *33*, 1009–1025. [[CrossRef](#)]
53. Kim, M.; Kang, Y.; Bakar, S.A. A Nightscape Preference Study Using Eye Movement Analysis. *ALAM CIPTA Int. J. Sustain. Trop. Des. Res. Pract.* **2013**, *6*, 85–99.
54. Seideman, J.A.; Stanford, T.R.; Salinas, E. Saccade metrics reflect decision-making dynamics during urgent choices. *Nat. Commun.* **2018**, *9*, 2907. [[CrossRef](#)]
55. Locher, P.J. Contemporary experimental aesthetics: Procedures and findings. *Handb. Econ. Art Cult.* **2014**, *2*, 49–80.
56. Holzinger, A. *Biomedical Informatics: Discovering Knowledge in Big Data*; Springer: Berlin/Heidelberg, Germany, 2014.
57. Gifford, R.; Hine, D.W.; Muller-Clemm, W.; Reynolds, D.J., Jr.; Shaw, K.T. Decoding modern architecture: A lens model approach for understanding the aesthetic differences of architects and laypersons. *Environ. Behav.* **2000**, *32*, 163–187. [[CrossRef](#)]
58. Gifford, R.; Hine, D.W.; Muller-Clemm, W.; Shaw, K.T. Why architects and laypersons judge buildings differently: Cognitive properties and physical bases. *J. Archit. Plan. Res.* **2002**, *19*, 131–148.
59. Ilbeigi, M.; Ghomeishi, M. An assessment of Aesthetics in Conceptual Properties and its Relation to Complexity among Architects and Non-Architects in Residential Façade Design in Iran. *J. Build. Sustain.* **2017**, *2*, 1.
60. Ruta, N.; Mastandrea, S.; Penacchio, O.; Lamaddalena, S.; Bove, G. A comparison between preference judgments of curvature and sharpness in architectural façades. *Archit. Sci. Rev.* **2019**, *62*, 171–181. [[CrossRef](#)]
61. Shemesh, A.; Talmon, R.; Karp, O.; Amir, I.; Bar, M.; Grobman, Y.J. Affective response to architecture—investigating human reaction to spaces with different geometry. *Archit. Sci. Rev.* **2017**, *60*, 116–125. [[CrossRef](#)]
62. Keul, A.G.; Hutzler, F.; Frauscher, G.; Voigt, A. Architrack: Evaluating architectural preferences via eyetracker. In *Designing Social Innovation: Planning, Building, Evaluating*; Martens, B., Keul, A.G., Eds.; Hogrefe Publishing: Boston, MA, USA, 2005; pp. 55–63.
63. Yousefi, M.V.; Karan, E.; Mohammadpour, A.; Asadi, S. Implementing eye tracking technology in the construction process. In Proceedings of the 51st ASC Annual International Conference Proceedings, College Station, TX, USA, 22–25 April 2015.
64. Cho, H. A Study on the Comparison of the Visual Attention Characteristics on the Façade Image of a Detached House Due to the Features on Windows. *J. Asian Archit. Build. Eng.* **2016**, *15*, 209–214. [[CrossRef](#)]
65. Sussman, A.; Ward, J. Eye-tracking boston city hall to better understand human perception and the architectural experience. *New Des. Ideas* **2019**, *3*, 53–59.
66. Meso, A.I.; Montagnini, A.; Bell, J.; Masson, G.S. Looking for symmetry: Fixational eye movements are biased by image mirror symmetry. *J. Neurophysiol.* **2016**, *116*, 1250–1260. [[CrossRef](#)]
67. Makin, A.D.J.; Poliakoff, E.; Rampone, G.; Bertamini, M. Spontaneous ocular scanning of visual symmetry is similar during classification and evaluation tasks. *i-Perception* **2020**. [[CrossRef](#)]
68. Leder, H.; Gerger, G.; Brieber, D. Aesthetic Appreciation: Convergence from Experimental Aesthetics and Physiology. In *Art, Aesthetics and the Brain*; Huston, J.P., Nadal, M., Mora, F., Agnati, L.F., Cela-Conde, C.J., Eds.; Oxford University Press: New York, NY, USA, 2015; pp. 57–78.
69. Berman, M.G.; Hout, M.C.; Kardan, O.; Hunter, M.R.; Yourganov, G.; Henderson, J.M.; Jonides, J. The perception of naturalness correlates with low-level visual features of environmental scenes. *PLoS ONE* **2014**, *9*, e114572. [[CrossRef](#)]
70. Santos, R. Cronbach's Alpha: A Tool for Assessing the Reliability of Scales. *J. Ext.* **1999**, *37*, 9–35.
71. Tang, J.; Long, Y. Measuring visual quality of street space and its temporal variation: Methodology and its application in the Hutong area in Beijing. *Landsc. Urban Plan.* **2019**, *191*, 103436. [[CrossRef](#)]

72. Mirzaei, J.; Ahmadi, S.; Lorestani, A. Spatial Analysis of Prosperity Levels in Tehran Metropolis from the Perspective of Urban Economics. *IUESA* **2015**, *3*, 59–77.
73. Olszewska, A.A.; Marques, P.F.; Ryan, R.L.; Barbosa, F. What makes a landscape contemplative? *Environ. Plan. B Urban Anal. City Sci.* **2018**, *45*, 7–25. [[CrossRef](#)]
74. Brunye, T.T.; Carney, P.A.; Allison, K.H.; Shapiro, L.G.; Weaver, D.L.; Elmore, J.G. Eye movements as an index of pathologist visual expertise: A pilot study. *PLoS ONE* **2014**, *9*, e103447. [[CrossRef](#)]
75. Tinio, P.P.; Gerger, G.; Leder, H. Birds of a feather. Generalization of facial structures following massive familiarization. *Acta Psychol.* **2013**, *144*, 463–471. [[CrossRef](#)]
76. Rhodes, G. The evolutionary psychology of facial beauty. *Annu. Rev. Psychol.* **2006**, *57*, 199–226. [[CrossRef](#)]
77. Lindell, A.K.; Mueller, J. Can science account for taste? Psychological insights into art appreciation. *J. Cogn. Psychol.* **2011**, *23*, 453–475. [[CrossRef](#)]
78. Shaweesh, A.I.M.; Clement, J.G.; Thomas, C.D.L.; Bankier, A. Construction and use of facial archetypes in anthropology and syndrome diagnosis. *Forensic Sci. Int.* **2006**, *159*, S175–S185. [[CrossRef](#)]
79. Salinger, N.; Masden, K. Neuroscience, the natural environment, and building design. In *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*; Wiley: Toronto, ON, Canada, 2008.
80. Salinger, N.A. Why we need to “grasp” our surroundings: Object affordance and prehension in architecture. *J. Archit. Urban.* **2017**, *41*, 163–169. [[CrossRef](#)]
81. Hollander, J.B.; Sussman, A. *Cognitive Architecture*; Routledge: New York, NY, USA, 2015.
82. Eberhard, J.P. *Brain Landscape the Coexistence of Neuroscience and Architecture*; Oxford University Press: New York, NY, USA, 2009.
83. Salinger, N.A. Socio-cultural identity in the age of globalization. *New Des. Ideas* **2018**, *2*, 5–19.
84. Hasse, C.; Weber, R. Eye movements on façades: The subjective perception of balance in architecture and its link to aesthetic judgment. *Empir. Stud. Arts* **2012**, *30*, 7–22. [[CrossRef](#)]
85. Gartus, A.; Völker, M.; Leder, H. What Experts Appreciate in Patterns: Art Expertise Modulates Preference for Asymmetric and Face-Like Patterns. *Symmetry* **2020**, *12*, 707. [[CrossRef](#)]
86. Reber, R.; Wurtz, P.; Zimmermann, T.D. Exploring “fringe” consciousness: The subjective experience of perceptual fluency and its objective bases. *Conscious. Cogn.* **2003**, *13*, 47–60. [[CrossRef](#)]
87. Reber, R.; Schwartz, N.; Winkelman, P. Processing fluency and aesthetic pleasure: Is beauty in the perceiver’s processing experience? *Personal. Soc. Psychol. Rev.* **2004**, *8*, 364–382. [[CrossRef](#)]
88. Barlow, H.B.; Reeves, B.C. The versatility and absolute efficiency of detecting mirror symmetry in random dot displays. *Vis. Res.* **1979**, *19*, 783–793. [[CrossRef](#)]
89. Makin, A.D.; Bertamini, M.; Jones, A.; Holmes, T.; Zanker, J.M. A gaze-driven evolutionary algorithm to study aesthetic evaluation of visual symmetry. *i-Perception* **2016**, *7*, 2041669516637432. [[CrossRef](#)]
90. Makin, A.D.J.; Pecchinenda, A.; Bertamini, M. Implicit affective evaluation of visual symmetry. *Emotion* **2012**, *12*, 1021–1030. [[CrossRef](#)]

