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Biophilia and Visual Preference for Chinese Vernacular Windows: An Investigation into Shape

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Abstract:

This study conducted a psychological experiment to test if there are differences of visual preference between 18 Chinese vernacular windows, and which biophilic factors can substantially affect the preference. The experiment recruited 95 Chinese adults to rate images of these windows on three biophilic qualities (perceived shape complexity, biomorphic form, fascination) and the visual preference. To summarize, the achieved results exposed some interesting findings. 1) Effects of window shapes on visual preference were significant, whereas geometric properties of these windows, such as the ratio of height-to-width and compactness, cannot deliver significant impact on the preference. 2) The visual preference for these windows with both urban and nature views was positively correlated with the three biophilic factors. 3) There was no association between perceived shape complexity and visual preference of windows without any views. 4) Apart from the rectangular window, the visual preference for these windows received no significant effects from the view.

Keywords:

Window shape, Visual preference, Vernacular architecture, Biophilia, China

1. INTRODUCTION

1.1 Window, Environmental Design, and Human Performance

Building windows can affect occupants' satisfaction and performance through several environmental factors, including thermal comfort and ventilation, noise, lighting, and view (Lin et al., 2022; Kaasalainen et al., 2020; Chen et al., 2019a;). Field studies showed that personal control of operable windows has been proved as an efficient way to adjust local thermal conditions and occupant comfort, and to achieve good indoor air quality through natural ventilation in various spaces (Meir et al., 2019; Simson et al., 2017; Adaji et al., 2019). Furthermore, the application of openable windows for natural ventilation has exposed the importance of proper settings to balance noise exposure and ventilation performance in urban buildings (Kim et al., 2017). With a main function of delivering daylight and view, windows can significantly take effect on occupants' health and well-being in buildings such as offices, schools, hospitals, and retail stores (Gerhardsson & Laike, 2021; Chen et al., 2019b; Woo et al., 2021). Since 1980s, the impact of window application on occupants' mood, satisfactions and performances has been widely studied by environmental designers and psychologist (Boubekri et al., 1991; Leather et al., 1998; Stone, 1998; Yildirim et al., 2007; Chen et al., 2019b; Shishegar et al., 2021; Gerhardsson & Laike, 2021). As a result, a number of design strategies and codes have been established in various buildings with an aim to improve human health and wellbeing through the application of windows (SLL, 2014; MHCLG, 2021).

1.2 Biophilia and Biophilic Design

The biophilia hypothesis was proposed by Erich Fromm (1973) and Edward O. Wilson (1984) as "humans possess an innate tendency to seek connections with nature and other forms of life”. Wilson (1984) investigated how this tendency might be a biologically based need, integral to our development as individuals and as a species. In a book, Kellert and Wilson (1993) brought together more scientific evidence to point out common human responses to perceptions of plants and animals and explained these responses using theories of human evolution. Two distinct sources which can deliver biophilia’s positive effects were identified as “Close proximity and visual contact with plants, animals, and other people” and “Positive response to artificial creations that follow geometrical rules for the structure of organisms” (Salingaros, 2019; Kellert & Wilson, 1993).

Biophilic design was described as “the deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and processes—known as biophilia into the design of the built environment” (Kellert et al., 2008). For the practice of biophilic design, there are three metric systems available in the built environment, such as Kellert model (Kellert and Calabrese, 2015; Kellert, 2018) in Table 1, Terrapin model (Browning et al., 2014) in Table 2, and Salingaros model (Salingaros, 2015 & 2019) in Table 3. For Table 1, three types of attributes relating to the application of biophilic design were categorized in Kellert model: direct experience of nature (eight items, e.g., light, air and water), indirect experience of nature (ten items, e.g., images of nature, natural materials), experience of space and place (six items, e.g., prospect and refuge). Based on previous theoretical works (Wilson, 1984; Kellert et al., 2008), Terrapin model (Table 2) introduced 14 typical biophilic design patterns to support architectural design and relevant applications in the built environment, which were categorized into three groups including nature in the space (seven patterns), natural analogues (three patterns), and nature of the space (four patterns). In Table 3, Salingaros model comprised ten items (eight low-level visual features and two higher-level visual features), which have been applied as components of a new algorithm "Biophilic Healing Index" to quantify the biophilic effect in a built environment (Salingaros, 2019). There was an advantage in Salingaros model that sums up ten biophilic qualities to obtain a single number for the biophilic index. As there was no uniform consensus when applying these models (Salingaros, 2019), it is still necessary to carry on working towards a valid design metric of environmental biophilic qualities.

1.3 Building Window and Its Biophilic Effect

The biophilic effects of window have been reflected in its design and application in buildings, especially when the goal of a biophilic space would be achieved. Based on the three models (Table 1, 2, 3) (Kellert and Calabrese, 2015; Kellert, 2018; Browning et al., 2014; Salingaros, 2015 & 2019), key biophilic qualities delivered by window systems are: (1) visual connection with nature (life), (2) thermal & airflow variability (air), (3) dynamic & diffuse light (sunlight), (4) biomorphic forms & patterns (fractals + curves + detail), and (5) organized-complexity. The rationale for each biophilic quality of windows is discussed as follows.

For the quality (1): 'visual connection with nature (life)', a window is expected to be applied to get a view to elements of nature, living systems and natural processes (Kellert, 2018; Browning et al., 2014), and therefore to improve occupants' health and wellbeing (Kaplan, 1993; Van Escha et al., 2019). In Alexander's "A pattern language" (Alexander et al., 1978), a very low windowsill (pattern 222) was recommended to improve view for an indoor space. Ulrich's pioneering work on healthcare facilities (1984) showed that viewing nature through window might influence surgery recovery rate. Two studies explicitly explained effects of window view features on the comfort and wellbeing among office workers (Aries et al., 2010; Van Escha et al., 2019). As proved in several experiments and surveys (Kaplan, 2001; Masoudinejad and Hartig, 2018), the window view including the sky and other features of the natural world can support psychological restoration (e.g. being away, fascination, restoration likelihood (Hartig et al., 1997)). The experiment exposed that the amount of sky and other environmental features can affect the restorative quality of window views and having more sky in window view lifted expectations of attention restoration in a dense urban area (Masoudinejad and Hartig, 2018).

For the quality (2): 'thermal & airflow variability (air)' and (3): 'dynamic & diffuse light (sunlight)', studies on window functions to deliver the natural light and ventilation (airflow) can be broadly found in literatures (CIBSE, 2015; SLL, 2014). Using openable windows combined with natural ventilation can help achieve an indoor environment that mimic natural environments, including subtle changes in air and surface temperatures, humidity, and airflow across the skin (Brager et al., 2004; CIBSE, 2005). Alexander's pattern 223 (deep reveals) enhanced the importance to set the window deep into the wall to soften light around the edge (Alexander et al., 1978). Daylighting or sunlight through the window will give rise to varying intensities of light and shadow that change over time (Abboushi et al., 2019; Salingaros, 2015).

For the quality (4): 'biomorphic forms & patterns (fractals + curves + detail)', the reflection of biomorphic forms & patterns can be found in the design of window components, including structures (mullion & transom, frame, light shelf), glass panes, sills, and reveals (Alexander et al., 1978; Browning et al., 2014). As discussed in studies (Salingaros, 2019; Salingaros, 2015), fractals, curves and details found in vernacular architectures (including their windows) may take significant effect on human emotional comfort. An experiment showed that naturalistic visual patterns would play an important role in aesthetic evaluations in architectural scenes (Coburn et al., 2019). The architectural scenes used in this study have included many façade / window systems. This finding (Coburn et al., 2019) could indirectly support the comment that humans have a visual preference for organic and biomorphic forms (Joyce, 2007; Browning et al., 2014).

For the quality (5): 'organized-complexity', the subdivision of glass pane window, which is determined by the layout of mullions (vertical bars) and transoms (horizontal bars), can directly influence the organized complexity of a view. As discussed in Alexander's pattern 239: small panes (Alexander et al., 1978), effects of the subdivision on a view were described as: (1) The way the window frames a view affects our contact with the view. (2) The extent to which the window frames the view increases the view, its intensity, its variety, and the number of views we seem to see. For the biophilic design, the organized complexity reflected by symmetries and fractal geometries in architectures (like the window subdivision) can create a visually nourishing environment that engenders a positive psychological or cognitive response (Salingaros, 2012). Abboushi et al. (2019) presented an interesting experiment focusing on the factual patterns composed of light and shadow produced by side windows. It has found that the window and shading device may enhance occupants' visual interest and mood through the generation of medium to medium-high complexity fractal light patterns in interior spaces (Abboushi et al., 2019).

These discussions above indicated that a deliberately designed window system in buildings can make substantial contributions to a biophilic indoor space.

1.4 Psychological Preference for Building Windows

In terms of architectural features, the psychological preference for windows has been studied in the built environment over 30 years (Masoudinejad & Hartig, 2018; Yeom et al., 2020). Several studies across difference periods found that windows were generally preferred (Butler and Biner, 1989; Stone and Irvine, 1994; Wang & Boubekri, 2010; Ko et al., 2020), whilst larger windows were preferred over smaller ones (Butler and Biner, 1989; SLL, 2014; Yeom et al., 2020). Butler and Biner (1989) also concluded that the amount of windows desired in a space could be reliably predicted based on occupants' requirements, e.g. having a view or good ventilation. One experiment using scale models showed that the room size and the type of the room affect window preferences (Butler and Steuerwald, 1991). In offices, window preferences can be significantly linked with its shape, gender of occupants, quality of office job and quality of view (Dogrusoy and Tureyen, 2007). This study (Dogrusoy and Tureyen, 2007) also concluded an interesting finding that horizontally continuous windows can receive higher preference levels than vertically distributed windows in urban buildings. On the other hand, it seems that window preferences have links with the preference for façade configurations. Stamps (1999) pointed out that the most important factor for visual preference for building facade turned out to be the surface complexity, which we believe received significant impacts of window configurations. This finding has been enhanced in another experiment focusing on the façade configuration preference in terms of window-to-solid wall ratios (Alkhresheh, 2012). It has been found that the most preferred façade configurations have the ratio range of 0.4~0.5 (Alkhresheh, 2012). These studies above might help produce useful and practical design implications for building façade systems based on human psychological performance.

1.5 Chinese Vernacular Window

Chinese vernacular windows can be broadly found in various ancient and old buildings, including houses, temples and garden buildings in China. They have been generally considered as one typical feature of Chinese traditional architecture (Hou, 2004; Li and Liang, 1983; Ji and Chen, 1988). Configurations and construction technologies of Chinese vernacular windows have been systematically developed over 2000 years (Li & Liang, 1983; Yao et al., 1986; Ji & Chen, 1988). Feng Shui (风水) was recognized as the basic environmental principle to guide their design in various spaces (Ji & Chen, 1988). However, Chinese vernacular windows were mainly studied in the field of humanity and arts design, with a focus on their aesthetic and cultural values (Pan, 2004; Dye, 1974). Since 1978, typical forms and styles of Chinese vernacular window have been increasingly transformed and thus applied in contemporary buildings and relevant design works in China (Chin, 1988). Two important cases were 'Fragrant Hill Hotel' (Owen, 1983) and 'Suzhou Museum' (Lin, 2017), which were both designed by I. M. Pei. The trend of 'reviving traditional Chinese architectural language (Chin, 1988)' may need more supports from the view of point of heritage policies (Blumenfield and Silverman, 2013). It is necessary to carry out more research activities on typical vernacular architectural elements, with an aim to produce effective guidelines and strategies for the conservation of Chinese architectural heritage. Given this situation in China (Blumenfield and Silverman, 2013), a new Chinese study has tried to test the environmental performance of vernacular windows (Liu et al., 2017). In general, few studies were implemented in terms of the impact of such vernacular architectural elements (e.g., window) on human psychological performance in both ancient and contemporary buildings.

1.6 The Present Study

Form the discussions above, we can find modern window systems have been widely studied based on environmental and human performances in buildings. From the perspective of biophilia, window has been proved as an effective environmental setting to improve occupants' satisfaction, health and wellbeing. We believe that Chinese vernacular window has been developed based on Feng Shui theory (Ji & Chen, 1988; Mak and Ng, 2005), which is regarded as one type of environmental planning strategy for selecting building sites and planning interior layouts. In addition, it seems that Feng Shui and biophilic design have some similar concepts and patterns according to architectural environmental design (Hudson, 2013). It would be interesting to investigate the impact of Chinese vernacular window on psychological human responses, and thus produce design implications for heritage conservations.

A research project was initiated in early 2019 to examine the relationship between biophilia, Chinese vernacular built environment and human performance in the context of rapid urbanization in China. This article reported results at the first stage of this project, focusing on visual preference for Chinese vernacular window shapes. The psychological experiment included 95 participants (Chinese adults), 18 typical Chinese vernacular window types and three different window views. The main hypotheses are presented as follows:

H1. There are significant differences of visual preference between these window shapes.

H2. Physical attributes (the ratio of height-to-width and compactness) of these windows significantly affect the preference.

H3. The preference for these windows is positively correlated with psychological variables (perceived shape complexity, biomorphic form, fascination) defined by the biophilic design principle.

H4. The preference for these windows receives significant effects from the views.

2. METHODS AND MATERIALS

2.1 Visual Stimuli

This experiment has investigated 18 typical Chinese vernacular windows in terms of shapes and configurations, which were defined through several references focusing on vernacular Chinese architecture (Li & Liang, 1983; Yao et al., 1986; Ji & Chen, 1988; Pan, 2004; Hou, 2004). As shown in Figure 1, these windows have been produced into 18 slides in Microsoft PowerPoint 2016 (names: W1-18) for the experiment, each of which has the black background, the window void part in light grey, and the window edge part in dark grey. With the same area of void part (light grey), each window image was used to simulate a window view observed from an indoor space during the experiment. The round (W7), rectangular (W8) and square (W12) shapes can be commonly found in many contemporary buildings, while other window shapes were just applied in Chinese vernacular architecture including temple, house, garden facility, etc (Li & Liang, 1983; Yao et al., 1986; Ji & Chen, 1988). For these windows, different views were applied in three studies: Study1 - blank view (no content, the void part in light grey), Study2 - urban view (the void part was replaced by the urban image in Figure 1), Study3 - nature view (the void part was replaced by the nature image in Figure 1). The blank view was applied to simulate the traditional window 'glazing' (a special white paper to cover window) used in Chinese vernacular buildings (Li & Liang, 1983). Urban and nature images were used as representatives of views found in urban areas, respectively.

2.2 Window Physical Attributes

Two typical geometric characteristics were introduced to express physical attributes of the 18 window shapes (Figure 1) in this study, such as 'A-ratio' and 'Compactness'.

In geometry and digital image, the aspect ratio of a geometric shape is the ratio of its sizes in different dimensions (Smith and Wormald, 1998). Based on the concept of aspect ratio used in the area of digital image, the 'A-ratio' (R_A) of window shape was defined as:

$$R_A = \frac{V_d}{H_d} \qquad (1),$$

where, as displayed in Figure 1, V_d is the distance along the vertical axis of each window void; H_d is the distance along the horizontal axis of each window void. This value can indicate how the window shapes horizontally and vertically.

As introduced by Osserman (1978), the compactness was originally defined to measure the degree to which a geometric shape is compact. Compactness has been introduced in psychological studies to quantify perceptual stability and to understand the causes of perceived shape aesthetics (Friedenberg, 2012). The range of shape Compactness is from 0 to 1. This value can be calculated using the following equation (Osserman, 1978):

$$C_W = \frac{4\pi \times A_W}{(P_W)^2} \qquad (2),$$

where, C_w is the compactness; A_w and P_w are area and perimeter of the shape, respectively. In this study, the compactness of each window shape was calculated based on the area (A_w) and the perimeter (P_w) of its void part (the centre light grey part, see Figure 1). The 18 window shapes were produced with the same void area of 2.238 m^2.

Table 4 gives three physical attributes of the 18 window shapes, including A-ratio, Compactness, and their perimeters. The largest Compactness value of 1.0 is found for W6 and W7, whilst W15 has the lowest Compactness (0.53). In addition, for A-ratio, W15 and W18 see the largest and lowest values of A-ratio, respectively. Three umbers (I—III) are applied to indicate different levels of A-ratio and Compactness.

2.3 Psychological Variables

Four psychological variables were rated in terms of 18 window shapes combined with three views by independent groups. All variables were measured using a single item. These variables are 'Perceived Shape Complexity' (Stamp, 1999; Lindal & Hartig, 2013), 'Biomorphic Form' (Feuerstein, 2002; Kellert et al., 2008), 'Fascination (interesting view)' (Kaplan & Kaplan, 1989; Kaplan, 1995), and 'Preference' (Stamp, 1999; Herzog et al., 2011; Lindal & Hartig, 2013; Masoudinejad and Hartig, 2018). An 11-point continuous scale (0-10) was used for these ratings (Masoudinejad & Hartig, 2018; Lindal & Hartig, 2013; Monk, 1989). The definitions of rating variables can be found in the

Table 5. Except for ‘Preference’, other three variables can be used to assess the biophilic effect of these windows.

2.4 Participants

Participants were recruited from an institute engaging in building design & construction in Beijing, which the first author has a link with. Through the Human Resource staffs, the recruitment invitation was sent out to over 300 employees. As a result, 95 Chinese adults working in this institute agreed to attend the experiment including three studies (see section 2.1). All participations were voluntary and there were no specific requirements for their backgrounds (e.g. engineer, architect, etc.). According to two psychological experiments using window views (Yeom et al., 2020; Boubekri et al., 1991), the sample size (> 30) for participants in each study can be acceptable. Thus, 95 participants can deliver a proper sample distribution for all studies of the experiment.

The participants’ distribution of three studies was planned as follows: Study1 --- 31 subjects, age: 28.94 (±3.92), male (20) and female (11); Study2 --- 32 subjects, age: 28.75 (±3.93), male (25) and female (7); Study3 --- 32 subjects, age: 30.06 (±2.80), male (24) and female (8); Total – 95 subjects, age: 29.25 (±3.59). Participants were randomly selected for each experiment.

2.5 Procedure

All experiments were conducted in a small and quite conference room. The window images were displayed on a screen using a projector. During each experiment, only maximum two participants and the experimenters were allowed to stay in this room. A total of 48 sessions were thus completed according to three studies: blank, urban and nature views. Each session proceeded as follows. After explaining the task and obtaining informed consent (through a signed form), participants rated 22 window images using four rating variables (Table 5). The first two slides were used as samples to help participants get used to the task and the rating scale. The last two slides were just used to avoid any end-of-set effects that might have influenced the ratings (mentioned by Herzog et al., 2011). Thus, only the ratings of the middle 18 images were used for the analysis. The time for viewing and rating each slide was maximum 20 seconds in all sessions.

3. RESULTS

Statistical analysis in this study was conducted using IBM SPSS (v25) (www.ibm.com). Appendix A (1-4) shows descriptive statistics of mean, standard deviation (SD), standard error (SE) of the ratings for four psychological variables respectively, in terms of window shapes (18 types) and window views (three types).

3.1 Content analysis: correlations among physical and psychological variables

Table 6 presents correlation analysis among two physical variables and four psychological variables with three views. First, there is a strong correlation between two physical variables of windows, i.e. A-ratio and compactness. Second, some correlations can be found between physical variables and psychological variables. Shape complexity was negatively correlated with A-ratio for each view. For biomorphic form, the blank view can deliver a substantial positive correlation with compactness according to the 18 window shapes. However, with the exception of the blank view, strong correlations were achieved between fascination and A-ratio for other views. It can be found that the preference was not correlated with physical variables with any view. Third, there are positive bivariate correlations among shape complexity, biomorphic form, and fascination with any view. Preference was highly correlated with other psychological variables under most conditions. The exception (no correlation) occurred between preference and shape complexity and with the blank view.

3.2 Effects of window shape and view on psychological variables

For each window view, one-way ANOVA was conducted to analyse the impact of window shape on ratings for psychological variables (Table 7). With urban view or nature view, significant main effects of window shape can be found on ratings for all psychological variables, $p < 0.05$. However, with blank view, the ratings for fascination were not significantly linked with the window shape, $F(17, 504) = 0.869$, $p = 0.612$, $\eta_p^2 = 0.027$.

Post hoc tests (Tukey's honestly significant difference, $\alpha=.05$) revealed some significant differences of mean ratings for preference (Table 8). W7 (round) with blank view has achieved higher ratings than those of W3 and W6. Urban view can bring in more differences between window shapes. W13 received higher ratings than five window shapes including W1, W3, W6, W8 (rectangular), and 12 (square), whilst W5 had higher ratings than W3. The differences between W13 and W1 or W3 were substantially big. For nature view, ratings of normal shapes including W7 (round), W8 (rectangular), and W12 (square) were higher than those of W1, W3 and W6. In addition, ratings of W1 were lower than those of W4, W5 and W13.

Given each window shape, one-way ANOVA was used to explore how the window view affects ratings of psychological variables. It can be found there was no significant effect of view on ratings for biomorphic form for all window shapes ($p > 0.05$). Only significant results were reported in the Table 9 in terms of window shape and three other items. Shape complexity and fascination can see the significant effects with six and four window types respectively. With ratings for preference, Post hoc tests (Tukey Tukey's honestly significant difference, α=.05) showed there was a clear difference found in W8 (rectangular), MD (Blank - Urban) = 1.377, p = 0.049, 95% CI [0.003 2.750]. Clearly, ratings for preference among most window types received no effects from the view.

4. DISCUSSIONS

Given the results achieved above, some discussions are presented below to address the four hypotheses mentioned in section 1.6.

Hypothesis 1: The results revealed that window shapes studied here could affect the judgement regarding visual preference, which is in line with this hypothesis. As the preference for these windows was highly correlated with their biophilic qualities (complexity, biomorphic form, interesting view), it was not difficult to find the variations of acceptance among the 95 participants.

Hypothesis 2: The results did not support this hypothesis in that there were no relationships found between two physical attributes (A-ratio & compactness) and the preference. The variations of the ratio of height-to-width (i.e., A-ratio) did not substantially influence the preference for these window shapes. This might be caused by one fact that the window shapes selected were horizontally symmetrical. According to definitions and values of physical attributes (equation 1 & 2, Table 4), it seems that changing the geometric properties of windows would not substantially change view features and their amounts, especially with a fixed void area in our study. Thus, small variations in views may not lead to significantly different preferences.

Hypothesis 3: The results showed that the preference for window shape had a positive correlation with judgements regarding two biophilic qualities: biomorphic form and fascination. As discussed in section 1.2 & 1.3, the biophilia principle can support that human are aesthetically attracted to natural contents and biomorphic forms and patterns. It was not surprising that window shapes with more biomorphic elements received more preference in our study (e.g. W13 vs W8). In addition, our study found that the judgement regarding biomorphic form was positively correlated with compactness when using the blank view (Table 6). This exposed that a higher level of biophilic form can reflect a higher compactness, which would be considered as more perceptually stable. As discussed in relevant studies, the greater architectural variation of building facades evoked higher levels of judgement regarding fascination, which in turn positively affected restoration likelihood and preference judgments. Thus, the variation of window shape combined with views in our study can drive different levels of the judgement regarding fascination and thus lead to different levels of preference. Interestingly, except for the blank view, strong negative correlations were achieved between fascination and A-ratio with urban and nature views. This finding might be transformed to support that the level of fascination for a thin and tall shape was lower than that of a wide and short shape. This can be explained by a biophilic criterion "gravity" (see Table 3). Given the fact that the blank view did not deliver significant impact of shape on the judgement regarding fascination (Table 7), this biophilic quality might receive more influence from view contents and features.

As another biophilic quality, perceived shape complexity positively correlated with the preference for urban and nature views, but not the blank view. This finding can give a partial support for Hypothesis 3. It has been pointed out that the perceived surface complexity of façade could be positively related to preference (Lindal & Hartig, 2013). In our study, the window image overlapped by urban/nature view can be considered as a façade surface with distinct architectural diversity (see Figure 1). However, blank windows were only judged according to the silhouette complexity. As effect of silhouette complexity is less clear than surface complexity for the judgement of visual preference, it was not supervising that there was no significant relationship found between window shape and preference with the blank view here.

Hypothesis 4: As regards the effect of view, it can be found that only one common type (W8: rectangular) had significant preference differences between blank view and urban view. The view did not take substantial effect on the preference between other 17 window shapes. Then, this hypothesis cannot receive strong support from the achieved results. As the rectangular window can be commonly found in urban buildings, it might be normal to see that an urban view through this window received lower preference level than the blank view. In addition, a meta-analysis (Stamp, 2004) concluded that studies of the preference for natural and /or urban environments in a large scope have not yet produce replicated results. The acceptance of window view may still need more investigations, especially for the participants living in cities.

5. CONCLUSIONS

This study has conducted a psychological experiment to test if there are differences of visual preference between 18 Chinese vernacular windows, and which biophilic factors can substantially affect the preference. The experiment recruited 95 Chinese adults to rate images of these windows on three biophilic qualities (perceived shape complexity, biomorphic form, fascination) and the visual preference.

5.1 Findings

In sum, the achieved results from the experiment exposed some interesting findings as follows.

(1) Effects of the Chinese vernacular window shapes on participants' visual preference were significant, whereas the geometric properties of these windows, such as the ratio of height-to-width and compactness, would not deliver significant impact on the preference.

(2) With both urban and nature views, the biophilic qualities of the Chinese vernacular windows, including perceived shape complexity, biomorphic form, and fascination (interesting view), have proved to be positively correlate with participants' visual preference.

(3) For the Chinese vernacular windows without any views, there was no association between perceived shape complexity and participants' visual preference.

(4) Apart from the rectangular window, participants' visual preference for the Chinese vernacular windows received no significant effects from the view outside of the windows (nature or urban).

5.2 Limitations and Future Work

There were some limitations found in this study. First, no specific spaces were applied with these windows in the experiment. Second, the application of simple physical attributes of windows might not be able to fully reflect their real configurations. Third, with a narrow range of physical properties, the 18 typical window types might bring in inconsistence when testing their impacts on psychological responses. Forth, no structure and pane details of window (e.g., frame, subdivision, mullion), which may take significant effects on human emotional comfort, were included in the window configurations. Last, the specific views applied in this experiment might give rise to some biased psychological judgements of participants.

Thus, some future work can be drawn from the discussions above. 1) A simulated 3D environment with these vernacular windows (VR or AR, full-scale room) would be a more effective way for such studies. 2) More window configurations and components would be investigated, including mullion & transom, frame, light shelf, glass panes, sills, and reveals. 3) A variety of views (built & nature environments) would be tested in terms of the biophilic qualities delivered by the space with various windows.

Disclosure statement

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Data Availability Statement

Not Applicable

References

Abboushi, B., Elzeyadi, I., Taylor, R., Sereno, M. (2019). Fractals in architecture: The visual interest, preference, and mood response to projected fractal light patterns in interior spaces. Environmental Psychology, 61, 57-70. DOI: 10.1016/j.jenvp.2018.12.005

Adaji, M.U., Adekunle, T.O., Watkins, R., Adler, G. (2019). Indoor comfort and adaptation in low-income and middle-income residential buildings in a Nigerian city during a dry season. Building and Environment, 162, 106276. DOI:10.1016/j.buildenv.2019.106276.

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., & Angel, S. (1978). A pattern language. New York: Oxford University Press.

Alkhresheh, M. M. (2012). Preference for void-to-solid ratio in residential facades. Environmental Psychology, 32, 234-245. DOI: 10.1016/j.jenvp.2012.02.003

Aries, M. B., Veitch, J. A., & Newsham, G. R. (2010). Windows, view, and office characteristics predict physical and psychological discomfort. Environmental Psychology, 30(4), 533–541. DOI: 10.1016/j.jenvp.2009.12.004

Blumenfield, T., Silverman, H. (2013). Cultural heritage politics in China. New York, USA: Springer.

Boubekri, M., Hull, R. B., Boyer, L. L. (1991). Impact of Window Size and Sunlight Penetration on Office Workers' Mood and Satisfaction: A Novel Way of Assessing Sunlight. Environment and Behavior, 23(4), 474-493. DOI: 10.1177/0013916591234004

Brager, G., Paliaga, G., de Dear, R. (2004). Operable windows, personal control and occupant comfort. ASHRAE Transactions, 110(2), 17-35.

Browning, W., Ryan, C., Clancy, J. (2014). 14 patterns of biophilic design: improving health and well-being in the built environment. New York, USA: Terrapin Bright Green LLC.

Butler, D. L., and Biner, P. M. (1989). Effects of Setting on Window Preferences and Factors Associated with Those Preferences. Environment and Behavior, 21(1), 17-31. DOI: 10.1177/0013916589211002.

Butler, D. L., and Steuerwald, B. L. (1991). Effects of view and room size on window size preferences made in models. Environment and Behavior, 23, 334–58. DOI: 10.1177/0013916591233005

Chen, X., Zhang, X., & Du, J. (2019a). Glazing type (colour and transmittance), daylighting, and human performances at a workspace: A full-scale experiment in Beijing. Building and Environment, 153, 168-185. DOI:10.1016/j.buildenv.2019.02.034.

Chen, X., Zhang, X., & Du, J. (2019b). Exploring the effects of daylight and glazing types on self-reported satisfactions and performances: a pilot investigation in an office. Architectural Science Review, 62(4), 338-353. DOI:10.1080/00038628.2019.1619068.

Chin, H. Y. M. (1988). The reawakening of the Chinese heritage through a cultural embassy: transformation of the Chinese architectural language (Thesis of March). USA: Massachusetts Institute of Technology.

CIBSE (Chartered Institute of Building Service Engineers). (2015). CIBSE Guide A: Environmental Design. Norfolk, UK: Page Bros. (Norwich) Ltd.

CIBSE (Chartered Institute of Building Service Engineers). (2005). CIBSE Applications Manual AM10: Natural ventilation in non-domestic buildings. Norfolk, UK: Page Bros. (Norwich) Ltd.

Coburn, A., Kardan, O., Kotabe, H., Steinberg, J., Hout, M. C., Robbins, A., MacDonald, J., Hayn-Leichsenring, G., Berman, M. G. (2019). Psychological responses to natural patterns in architecture. Environmental Psychology, 62, 133-145. DOI: 10.1016/j.jenvp.2019.02.007

Dogrusoy, I. T., and Tureyen, M. (2007). A field study on determination of preferences for windows in office environments. Building and Environment, 42, 3660-3668. DOI: 10.1016/j.buildenv.2006.09.010

Dye, D.S. (1974). Chinese Lattice Designs. New York. USA: Dover Publications.

Feuerstein, G. (2002). Biomorphic Architecture: Human and Animal Forms in Architecture. Stuttgart, Germany: Axel Menges.

Friedenberg, J. (2012). Aesthetic judgment of triangular shape: compactness and not the golden ratio determines perceived attractiveness. i-Perception, 3, 163-175.

Fromm, E. (1973). The anatomy of human destructiveness. New York: Holt, Rinehart and Winston.

Gerhardsson, K. M., & Laike, T. (2021). Windows: a study of residents' perceptions and uses in Sweden. Buildings and Cities, 2(1), 467–486. DOI: 10.5334/bc.120.

Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. Scandinavian Housing & Planning Research, 14, 175-194. DOI:10.1080/02815739708730435

Herzog, T.R., Gray, L.E., Dunville, A.M., Hicks, A.M., Gilson, E.A. (2011). Preference and tranquillity for houses of worship. Environment and Behaviour, 45(4), 504-525. DOI: 10.1177/0013916511410422

Hou, Y. (2004). Aesthetics of Chinese Architecture '中国建筑美学'. Harbin, China: Heilongjiang Science and Technology Press. *In Chinese*.

Hudson, K. PC. (2013). Holistic Dwelling: integrating biophilic design, environmental psychology, and Fengshui (Thesis of PhD). USA: University of Hawaii.

Ji, C., Chen, Z. (1988). The Craft of Gardens: Annotation '园冶注释' . Beijing, China: China Architecture and Building Press. *In Chinese*.

Joye, Y. (2007). Architectural Lessons From Environmental Psychology: The Case of Biophilic Architecture. Review of General Psychology, 11 (4), 305-328. DOI: 0.1037/1089-2680.11.4.305

Kaasalainen, T., Mäkinen, A., Lehtinen, T., Moisio, M., Vinha, Juha. (2020). Architectural window design and energy efficiency: Impacts on heating, cooling and lighting needs in Finnish climates. Journal of Building Engineering, 27, 100996. DOI:10.1016/j.jobe.2019.100996.

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. New York: Cambridge University Press.

Kaplan, R. (1993). The role of nature in the context of the workplace. Landscape and Urban Planning, 26, 193–201. DOI: 10.1016/0169-2046(93)90016-7

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. Environmental Psychology, 15, 169-182. DOI: 10.1016/0272-4944(95)90001-2

Kellert, S. R., and Wilson, E. O. (1993). The biophilia hypothesis. Washington, USA: Island Press.

Kaplan, R. (2001). The nature of the view from home: Psychological benefits. Environment and Behavior, 33, 507-542. DOI: 10.1177/00139160121973115

Kellert, S.R., Heerwagen, J., Mador, M. (2008). Biophilic design: the theory, science and practice of bringing buildings to life. New Jersey, USA: John Wiley & Sons.

Kellert, S.R. and Calabrese, E. (2015). The Practice of Biophilic Design. www.biophilic-design.com (final access: 1st December 2019)

Kellert, S. R. (2018). Nature by design. New Haven: Yale University Press.

Kim, M. K., Barber, C., Srebric, J. (2017). Traffic noise level predictions for buildings with windows opened for natural ventilation in urban environments. Science and Technology for the Built Environment, 23:5, 726-735, DOI: 10.1080/23744731.2016.1262708.

Ko, W.H., Schiavon, S., Zhang, H., Graham, L.T., Brager, G., Mauss, I., Lin, Y. (2020) The impact of a view from a window on thermal comfort, emotion, and cognitive performance. Building and Environment, 175, 106779. DOI:10.1016/j.buildenv.2020.106779.

Leather, P., Pyrgas, M., Beale, D., & Lawrence, C. (1998). Windows in the workplace: Sunlight, view, and occupational stress. Environment and Behavior, 30(6), 739–762. DOI: 10.1177/001391659803000601

Lin, T.Y., Le, A.V., Chan, Y.C. (2022). Evaluation of window view preference using quantitative and qualitative factors of window view content. Building and Environment, 213,108886. DOI: 10.1016/j.buildenv.2022.108886.

Li, J., Liang, S. (1983). Treatise on Architectural Methods or State Building Standards: Annotation '營造法式注释'. Beijing, China: China Architecture and Building Press. *In Chinese*.

Lin, C. (2017). The performative space for city identity narrative: A case study of Suzhou Museum. Communication and the Public, 2(1), 52-66. DOI: https://doi.org/10.1177/2057047317695813

Lindal, P. J., Hartig, T. (2013). Architectural variation, building height, and the restorative quality of urban residential streetscapes. Environmental Psychology, 33, 26-36. DOI: 10.1016/j.jenvp.2012.09.003

Liu, T., Zhang, X., Du, J. (2017). A daylighting simulation study of the form of traditional Chinese windows based on a window-to-wall ratio of 0.1. Xin Jianzhu: New Architecture. 05, 156—159. *In Chinese*.

Mak, M. Y., and Ng, S. T. (2005). The art and science of Feng Shui — a study on architects' perception. Building and Environment, 40 (3), 427-434. DOI: 10.1016/j.buildenv.2004.07.016

Masoudinejad, S., Hartig, T. (2018). Window View to the Sky as a Restorative Resource for Residents in Densely Populated Cities. Environment and Behavior, 00(0), 1-36. DOI: 10.1177/0013916518807274

Meir, I. A., Schwartz, M., Davara, Y., Garb, Y. (2019). A window of one’s own: a public office post-occupancy evaluation. Building Research & Information, 47 (4), 437-452. DOI: 10.1080/09613218.2018.1434366.

MHCLG (Ministry of Housing, Communities & Local Government). (2021). Guidance Notes for Design Codes. London, UK. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957205. Final access: 10/04/2022.

Monk, T.H. (1989). A visual analogue scale technique to measure global vigor and affect. Psychiatry Research, 27, 89–99. DOI: 10.1016/0165-1781(89)90013-9

Osserman, R. (1978). Isoperimetric inequality. Bulletin of the American Mathematical Society, 84 (6), 1182-1238.

Owen, C. (1983). Exploring a new vernacular: Fragrant Hill Hotel. Architecture: The AIA Journal, 9, 34-42.

Pan, J. (2004). Chinese Traditional Lattice Windows ‘中国传统窗棂’. Beijing, China: People's Fine Arts Publishing House. *In Chinese*.

Salingaros, N.A. (2012). Fractal Art and Architecture Reduce Physiological Stress. Journal of Biourbanism, 2 (2), 11-28.

Salingaros, N.A. (2019). The Biophilic Healing Index Predicts Effects of the Built Environment on Our Wellbeing. Journal of Biourbanism, 8, 13-34.

Salingaros, N.A. (2015) Biophilia and Healing Environments: Healthy Principles for Designing the Built World. New York: Terrapin Bright Green, LLC.

Shishegar, N., Boubekri, M., Stine-Morrow, E.A.L., Rogers, W.A. (2021). Tuning environmental lighting improves objective and subjective sleep quality in older adults. Building and Environment, 204, 108096, DOI:10.1016/j.buildenv.2021.108096.

Simson, R., Kurnitski, J., Maivel, M. (2017). Summer thermal comfort: compliance assessment and overheating prevention in new apartment buildings in Estonia. Journal of Building Performance Simulation, 10(4), 378-391, DOI: 10.1080/19401493.2016.1248488.

SLL (Society of Light and Lighting). (2014). LG10 Daylighting — a guide for designers. Norfolk, UK: Page Bros. (Norwich) Ltd.

Smith, W.D. and Wormald, N.C. (1998). Geometric separator theorems and applications. In Proceedings 39th Annual Symposium on Foundations of Computer Science (Cat. No. 98CB36280) (pp. 232-243). IEEE.

Stamps, A. E. (1999). Physical determinants of preference for residential facades. Environment and Behavior, 31(6), 723-751. DOI: 10.1016/j.jenvp.2012.09.003

Stamps, A. E. (2004). Mystery, complexity, legibility and coherence: A meta-analysis. Environmental Psychology, 24, 1-6. DOI: 10.1016/S0272-4944(03)00023-9

Stamps, A. E. (1999). Physical determinants of preference for residential facades. Environment and Behavior, 31(6), 723-751. DOI: 10.1016/j.jenvp.2012.09.003

Stone, N. J., and Irvine, J. M. (1994). Direct or indirect window access, task type, and performance. Environmental Psychology, 14(1), 57–63. DOI: 10.1016/S0272-4944(05)80198-7.

Stone, N. J. (1998). Windows and Environmental Cues on Performance and Mood. Environment and Behavior, 30(3), 306-321. DOI: 10.1177/001391659803000303

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. Science, 224(4647), 420-421.

Van Escha, E., Minjockb, R., Colarellic, S. M., Hirschc, S. (2019). Office window views: View features trump nature in predicting employee well-being. Environmental Psychology, 64, 56-64. DOI: 10.1016/j.jenvp.2019.05.006

Wang, N., and Boubekri, M. (2010). Investigation of declared seating preference and measured cognitive performance in a sunlit room. Environment Psychology, 30, 226-238. DOI: 10.1016/j.jenvp.2009.12.001

Wilson, E. O. (1984). Biophilia. Cambridge: Harvard University Press.

Woo, M., MacNaughton, P., Lee, J., Tinianov, B., Satish, U. and Boubekri, M. (2021). Access to Daylight and Views Improves Physical and Emotional Wellbeing of Office Workers: A Crossover Study. Frontiers in Sustainable Cities, 3, 690055. DOI:10.3389/frsc.2021.690055

Yao, C., Zhang, Z., Liu, D. (1986). Principles for Traditional Architectures and Buildings '营造法原'. Beijing, China: China Architecture and Building Press. *In Chinese*.

Yeom, S., Kim, H., Hong, T., Park, H.S., Lee, D. (2020) An integrated psychological score for occupants based on their perception and emotional response according to the windows' outdoor view size. Building and Environment, 180, 107019. DOI:10.1016/j.buildenv.2020.107019.

Yildirim, K., Akalin-Baskaya, A., Celebi, M. (2007). The effects of window proximity, partition height, and gender on perceptions of open-plan offices. Environment Psychology, 27, 154-165. DOI: 10.1016/j.jenvp.2007.01.004

Figure

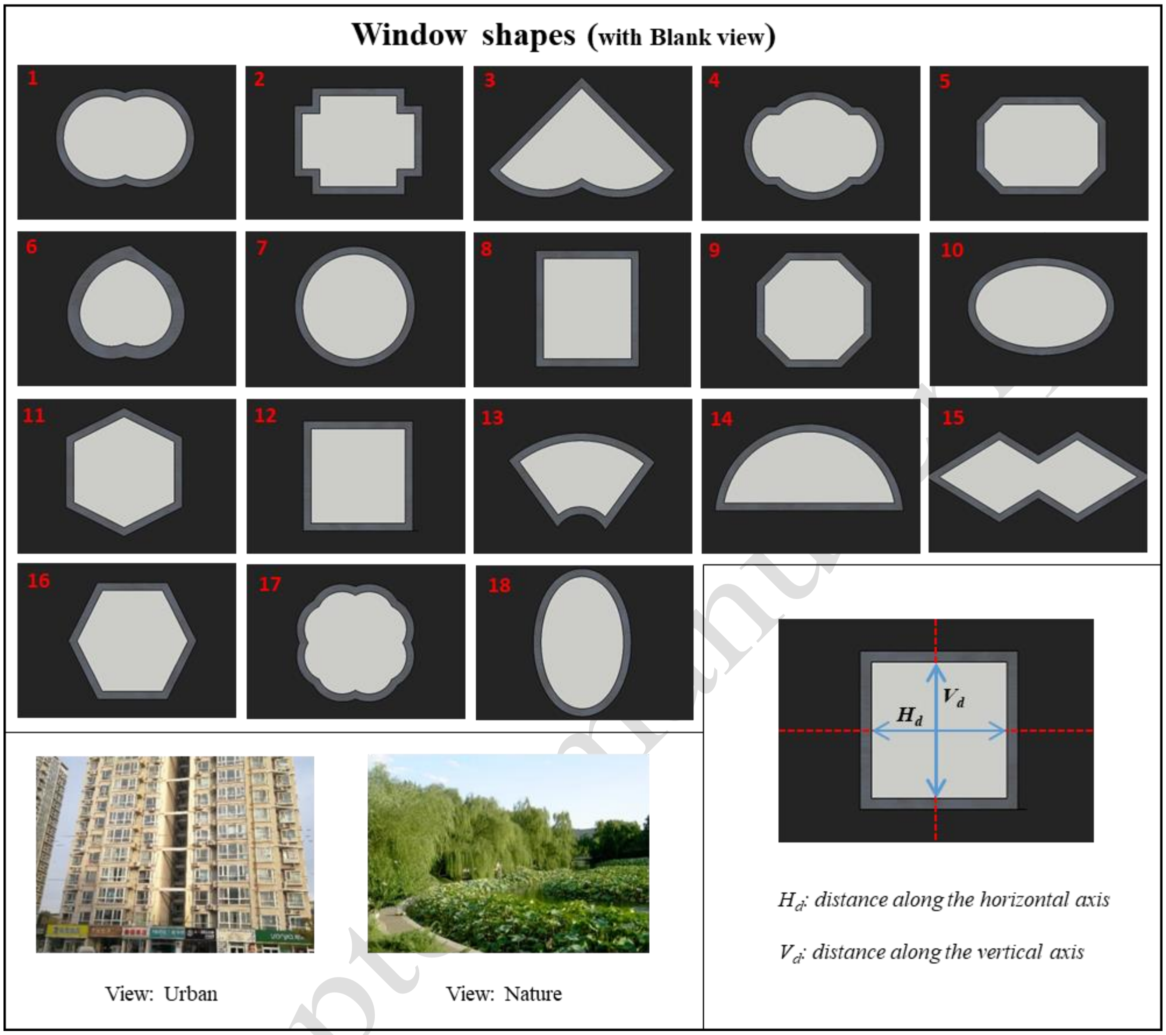

Figure 1. Chinese vernacular window: shapes (18 types: W1-18), views (3 types: Blank, Urban, Nature), and physical attributes (V_d and H_d).

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Table 1. Checklist of biophilia design criteria in Kellert model (Kellert and Calabrese, 2015; Kellert, 2018).

Direct Experience of Nature	**Indirect Experience of Nature**	**Experience of Space and Place**
• Light	• Images of nature	• Prospect and refuge
• Air	• Natural materials	• Organized complexity
• Water	• Natural colors	• Integration of parts to wholes
• Plants	• Simulating natural light and air	• Transitional spaces
• Animals	• Naturalistic shapes and forms	• Mobility and wayfinding
• Weather	• Evoking nature	• Cultural and ecological attachment to place
• Natural landscapes and ecosystems	• Information richness	
• Fire	• Age, change, and the patina of time	
	• Natural geometries	
	• Biomimicry	

Table 2. Checklist of biophilia design criteria in Terrapin *model (Browning et al., 2014).*

Nature in the Space Patterns	**Natural Analogues Patterns**	**Nature of the Space Patterns**
1. Visual Connection with Nature 2. Non-Visual Connection with Nature 3. Non-Rhythmic Sensory Stimuli 4. Thermal & Airflow Variability 5. Presence of Water 6. Dynamic & Diffuse Light 7. Connection with Natural Systems	8. Biomorphic Forms & Patterns 9. Material Connection with Nature 10. Complexity & Order	11. Prospect 12. Refuge 13. Mystery 14. Risk/Peril

Table 3. Checklist of biophilia design criteria in Salingaros model (Salingaros, 2015 & 2019).

Low-level Visual Features	1.Sunlight; 2. Colour; 3. Gravity; 4. Fractals; 5. Curves; 6. Detail; 7. Water; 8. Life
Higher-level Visual Features	9. Representations-of-nature 10. Organized-complexity

Table 4. Window physical attributes: perimeter (P_w), A-ratio and Compactness.

	W1	W2	W3	W4	W5	W6	W7	W8	W9
P_w (m)	5.47	6.31	6.26	5.51	5.55	5.10	5.30	6.00	5.45
A-ratio (unitless)	0.66	0.83	1.00	0.77	0.76	0.96	1.00	1.12	1.00
Compactness (unitless)	0.94	0.71	0.72	0.93	0.91	1.00	1.00	0.78	0.95
	W10	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**
P_w (m)	5.47	5.58	5.98	6.02	6.27	7.25	5.58	5.42	5.47
A-ratio (unitless)	0.67	1.10	1.00	0.66	0.55	0.19	0.91	1.00	1.50
Compactness (unitless)	0.94	0.90	0.79	0.78	0.72	0.53	0.90	0.96	0.94

Note: *Area of window void: A_W=2.238 m^2 (based on AutoCAD drawing);*
A-ratio levels used for analysis: I (<0.8), II ([0.8 1.1]), III (>1.1);
Compactness levels used for analysis: I (<0.7), II ([0.7 0.9)), III ([0.9 1.0]).

Table 5. Definitions of rating variables used in this study.

Perceived Shape Complexity --- How much do you think that this window is complex in its shape design?

Biomorphic Form --- How much do you think that this window shape is a simulation of natural features?

Fascination --- How much do you think that this window view can draw your attention to many interesting things?

Preference --- How much do you like this window?

Note: 0=none at all (lowest possible rating); 10=very high.

Table 6. Descriptive statistics and correlation matrix for six variables.

All views (N=95)	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
A-ratio[a]	-	-	1					
Compactness[a]	-	-	0.160**	1				
Shape complexity[b]	4.17	2.22	-0.178**	-0.055*	1			
Biomorphic form[b]	4.18	2.17	-0.020	0.100**	0.265**	1		
Fascination[b]	4.39	2.09	-.096**	0.030	0.293**	0.641**	1	
Preference[b]	4.24	2.19	0.014	0.036	0.120**	0.583**	0.688**	1
Blank view (N=31)	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
A-ratio[a]	-	-	1					
Compactness[a]	-	-	0.160**	1				
Shape complexity[b]	3.78	2.19	-0.243**	-0.056	1			
Biomorphic form[b]	4.14	2.32	0.017	0.134**	0.153**	1		
Fascination[b]	4.61	2.13	-0.044	0.082	0.092*	0.651**	1	
Preference[b]	4.51	2.32	0.058	0.042	-0.042	0.563**	0.724**	1
Urban view (N=32)	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
A-ratio[a]	-	-	1					
Compactness[a]	-	-	0.160**	1				
Shape complexity[b]	4.67	2.16	-0.171**	-0.041	1			
Biomorphic form[b]	4.31	1.94	-0.062	0.082	0.366**	1		
Fascination[b]	4.53	2.00	-0.159**	-0.013	0.451**	0.590**	1	
Preference[b]	4.18	1.92	-0.080	0.036	0.261**	0.544**	0.622**	1
Nature view (N=32)	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
A-ratio[a]	-	-	1					
Compactness[a]	-	-	0.160**	1				
Shape complexity[b]	4.05	2.23	-0.129**	-0.071	1			
Biomorphic form[b]	4.07	2.24	-0.020	0.082	0.285**	1		
Fascination[b]	4.04	2.11	-0.089*	0.020	0.353**	0.680**	1	
Preference[b]	4.03	2.29	0.050	0.030	0.189**	0.638**	0.706**	1

Note: *Values in the correlation matrix are for Pearson correlations. *p < 0.05; **p < 0.01.*
a Higher values indicate higher levels.
b Ratings given on an 11-point scale (0 = none at all, 10 = very high).

Table 7. ANOVA analysis of the impact of window shape on ratings for psychological variable (three views).

Variables	Window views								
	Blank			Urban			Nature		
	F(17, 504)	p	η_p^2	F(17, 504)	p	η_p^2	F(17, 504)	p	η_p^2
Shape complexity	22.139	0.000	0.411	12.954	0.000	0.283	10.088	0.000	0.235
Biomorphic form	2.912	0.000	0.084	2.231	0.003	0.064	2.190	0.004	0.063
Fascination	0.869	0.612	0.027	3.771	0.000	0.103	1.916	0.015	0.055
Preference	2.396	0.001	0.070	2.720	0.000	0.077	3.541	0.000	0.097

Note: *Significance was achieved at the level of $p < 0.05$.*

Table 8. Significant differences of mean ratings for preference: Tukey HSD (three views).

Tukey HSD	Pair comparison: Preference					
			Mean differences	**Sig.**	**95% CI**	
	I	**J**	**(I-J)**		**Lower Bound**	**Upper Bound**
Blank view	W7	W3	2.1290	0.027	0.1086	4.1494
	W7	W6	2.0968	0.032	0.0764	4.1172
Urban view	W13	W1	2.0000	0.003	0.3575	3.6425
	W13	W3	2.3438	0.000	0.7013	3.9862
	W13	W6	1.7500	0.023	0.1075	3.3925
	W13	W8	1.8125	0.014	0.1700	3.4550
	W13	W12	1.6563	0.046	0.0138	3.2987
	W5	W3	1.6875	0.037	0.0450	3.3300
Nature view	W1	W4	-1.9375	0.049	-3.8709	-0.0041
	W1	W5	-2.0312	0.028	-3.9647	-0.0978
	W1	W7	-2.0937	0.019	-4.0272	-0.1603
	W1	W8	-2.1250	0.015	-4.0584	-0.1916
	W1	W12	-2.1250	0.015	-4.0584	-0.1916
	W1	W13	-2.0312	0.028	-3.9647	-0.0978
	W3	W7	-1.9687	0.041	-3.9022	-0.0353
	W3	W8	-2.0000	0.034	-3.9334	-0.0666
	W3	W12	-2.0000	0.034	-3.9334	-0.0666
	W6	W7	-1.9688	0.041	-3.9022	-0.0353
	W6	W8	-2.0000	0.034	-3.9334	-0.0666
	W6	W12	-2.0000	0.034	-3.9334	-0.0666

Table 9. ANOVA analysis of the impact of view on psychological variable (for each window shape, significance was achieved at the level of p < 0.05).

	Shape complexity			Fascination			Preference		
	F(2, 92)	p	η_p^2	F(2, 92)	p	η_p^2	F(2, 92)	p	η_p^2
W6	-	-	-	4.555	0.013	0.090	-	-	-
W7	11.635	0.000	0.202	2.957	0.057	0.060	-	-	-
W8	4.441	0.014	0.088	-	-	-	3.257	0.043	0.066
W11	-	-	-	3.438	0.036	0.070	-	-	-
W12	6.460	0.002	0.123	-	-	-	-	-	-
W14	3.217	0.045	0.065	3.789	0.026	0.076	-	-	-
W16	3.865	0.024	0.078	-	-	-	-	-	-
W18	4.857	0.010	0.096	-	-	-	-	-	-

Appendix A: Descriptive statistics of experiment results

1. Descriptive statistics: Perceived Shape Complexity.

Descriptive statistics: Perceived Shape Complexity

		Window types																		
View		**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**	**Total**
Blank	Mean	3.76	4.40	4.82	5.26	4.13	5.13	1.69	1.58	3.50	2.66	3.63	1.40	4.68	3.47	5.61	3.42	6.48	2.44	3.78
	SD	1.84	1.66	1.92	1.41	1.86	2.19	1.43	1.46	1.73	1.80	1.52	1.21	1.89	1.66	2.01	1.46	1.81	1.56	2.19
	SE	0.33	0.30	0.34	0.25	0.33	0.39	0.26	0.26	0.31	0.32	0.27	0.22	0.34	0.30	0.36	0.26	0.32	0.28	0.093
	N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	558
Urban	Mean	4.47	4.84	5.72	5.66	4.56	6.25	3.50	2.72	4.13	3.59	4.38	2.84	5.31	4.59	6.16	4.53	7.06	3.81	4.67
	SD	2.09	2.14	2.43	2.04	1.70	2.08	1.81	1.49	1.56	1.70	1.54	1.44	1.91	1.93	2.23	1.32	1.87	1.79	2.16
	SE	0.37	0.38	0.43	0.36	0.30	0.37	0.32	0.26	0.28	0.30	0.27	0.25	0.34	0.34	0.39	0.23	0.33	0.32	0.09
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576
Nature	Mean	3.63	4.28	5.22	4.75	3.66	5.44	2.19	2.13	3.94	3.19	4.25	2.53	4.66	4.13	5.59	4.25	5.84	3.31	4.05
	SD	2.03	2.16	2.30	1.90	1.94	2.40	1.33	1.60	1.93	1.84	1.74	2.18	1.96	1.70	1.97	2.06	2.34	1.94	2.23
	SE	0.36	0.38	0.41	0.34	0.34	0.42	0.24	0.28	0.34	0.33	0.31	0.39	0.35	0.30	0.35	0.36	0.41	0.34	0.093
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576

2. Descriptive statistics: Biomorphic Form

Descriptive statistics: Biomorphic Form																				
		Window types																		
View		**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**	**Total**
Blank	Mean	3.00	3.00	3.29	4.58	4.13	4.48	4.84	3.92	3.94	4.71	4.10	3.89	4.32	4.15	3.61	4.31	5.90	4.42	4.14
	SD	2.19	2.14	2.33	2.43	1.98	2.55	2.71	2.78	1.95	1.97	2.18	2.48	2.12	2.22	1.87	2.12	2.23	2.11	2.32
	SE	0.39	0.39	0.42	0.44	0.36	0.46	0.49	0.50	0.35	0.35	0.39	0.44	0.38	0.40	0.34	0.38	0.40	0.38	0.098
	N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	558
Urban	Mean	3.50	4.22	3.56	4.91	4.53	4.56	4.38	3.69	4.38	4.53	4.19	3.94	5.13	4.44	3.91	4.09	5.38	4.28	4.31
	SD	1.90	2.07	1.85	2.16	1.93	2.27	2.32	1.91	1.76	1.50	1.64	1.95	1.86	1.83	1.51	1.44	2.28	1.84	1.94
	SE	0.34	0.37	0.33	0.38	0.34	0.40	0.41	0.34	0.31	0.27	0.29	0.34	0.33	0.32	0.27	0.26	0.40	0.32	0.081
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576
Nature	Mean	3.13	3.69	3.09	4.53	4.56	3.66	4.41	4.06	4.19	4.50	3.59	4.44	4.66	3.63	3.53	4.44	5.25	4.00	4.07
	SD	1.95	2.38	1.87	2.12	2.12	2.22	2.33	2.68	1.99	2.16	1.92	2.66	2.06	1.90	2.30	2.21	2.55	2.03	2.24
	SE	0.34	0.42	0.33	0.38	0.38	0.39	0.41	0.47	0.35	0.38	0.34	0.47	0.36	0.34	0.41	0.39	0.45	0.36	0.093
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576

3. Descriptive Statistics: Fascination

Descriptive statistics: Fascination																				
		Window types																		
View		**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**	**Total**
Blank	Mean	4.37	4.42	4.35	4.87	5.00	4.55	5.10	4.00	4.69	4.68	4.65	3.84	5.10	4.58	4.35	4.61	5.13	4.68	4.61
	SD	2.26	2.38	2.40	2.19	1.88	2.36	1.94	2.41	1.94	2.01	1.98	2.18	2.09	2.09	2.27	1.78	2.31	1.83	2.13
	SE	0.41	0.43	0.43	0.39	0.34	0.42	0.35	0.43	0.35	0.36	0.35	0.39	0.37	0.38	0.41	0.32	0.41	0.33	0.090
	N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	558
Urban	Mean	4.59	4.72	4.53	5.22	4.56	5.06	3.88	3.09	4.75	4.00	4.53	3.63	5.78	4.56	5.09	4.16	5.34	4.00	4.53
	SD	2.28	2.07	2.33	1.75	1.79	2.50	1.93	1.86	1.65	1.48	1.80	1.77	1.68	1.90	1.96	1.55	2.15	1.83	1.99
	SE	0.40	0.37	0.41	0.31	0.32	0.44	0.34	0.33	0.29	0.26	0.32	0.31	0.30	0.34	0.35	0.27	0.38	0.32	0.083
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576
Nature	Mean	3.81	4.28	3.78	4.69	4.38	3.38	4.34	3.44	4.25	3.84	3.56	3.78	5.22	3.44	3.97	4.00	4.81	3.78	4.04
	SD	1.87	2.26	2.24	1.97	2.04	1.98	2.15	2.20	1.92	1.99	1.64	2.57	2.17	1.68	2.32	2.05	2.29	1.88	2.11
	SE	0.33	0.40	0.40	0.35	0.36	0.35	0.38	0.39	0.34	0.35	0.29	0.46	0.38	0.30	0.41	0.36	0.41	0.33	0.088
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576

4. Descriptive Statistics: Preference

Descriptive statistics: Preference

View		**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**	**Total**
		Window types																		
Blank	Mean	3.42	4.45	3.26	4.77	4.74	3.29	5.39	5.06	5.00	4.74	5.06	5.03	4.81	4.32	4.03	4.58	4.77	4.39	4.51
	SD	2.57	2.51	2.28	2.22	2.14	2.08	2.32	2.39	2.00	2.38	2.42	2.36	2.36	2.27	2.15	1.96	2.19	2.12	2.32
	SE	0.46	0.45	0.41	0.40	0.39	0.37	0.42	0.43	0.36	0.43	0.43	0.42	0.42	0.41	0.39	0.35	0.39	0.38	0.098
	N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	558
Urban	Mean	3.50	4.41	3.16	4.47	4.84	3.75	4.09	3.69	4.59	4.06	4.25	3.84	5.50	4.16	3.97	4.28	4.78	3.88	4.18
	SD	2.06	2.09	1.57	1.80	1.94	1.87	1.82	2.04	2.05	1.68	1.57	1.76	2.03	1.87	1.51	1.78	2.04	2.09	1.92
	SE	0.36	0.37	0.28	0.32	0.34	0.33	0.32	0.36	0.36	0.30	0.28	0.31	0.36	0.33	0.27	0.32	0.36	0.37	0.08
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576
Nature	Mean	2.69	3.97	2.81	4.63	4.72	2.81	4.78	4.81	4.59	4.06	3.91	4.81	4.72	3.19	3.63	4.25	4.09	4.22	4.04
	SD	1.75	2.47	1.80	2.09	2.39	2.04	2.42	2.42	1.90	2.31	1.89	2.92	2.37	1.71	2.17	2.14	2.51	2.03	2.29
	SE	0.31	0.44	0.32	0.37	0.42	0.36	0.43	0.43	0.34	0.41	0.33	0.52	0.42	0.30	0.38	0.38	0.44	0.36	0.095
	N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	576