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Comparing properties of interiors and perceptions of comfort: Results of an empirical study

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Abstract: Past research into environmental psychology has identified *openness, enclosure, light, mystery* and *complexity* as the key criteria shaping perceptions of psychological comfort. It has been suggested that these properties are responsible for evoking positive aesthetic responses to an environment and they have also been repeatedly linked to the works of renowned architects including Alvar Aalto, Glenn Murcutt and Peter Zumthor. However, the precise spatial and visual properties that allegedly evoke feelings of comfort have never been adequately identified, in part because previous research has involved multiple confounding factors or has lacked a controlled testing environment. The present paper responds to this situation by presenting the results of an empirical study involving 159 participants with diverse backgrounds who rated 24 carefully graduated images of virtual interiors for their feelings of comfort. The findings indicate a very high, positive correlation between an increasing degree of openness and perceptions of comfort. Furthermore, a comparison of perceptual responses with actual geometric room measures identifies several that correlate closely with feelings of comfort.

Keywords: Design assessment; environmental preference; interiors; prospect-refuge theory.

1. Introduction

Winston Churchill famously remarked that ‘we shape our buildings; thereafter they shape us’. This statement suggests that the properties of space influence the way we feel and behave. Furthermore, such responses to architecture are often both instant and intuitive, occurring without necessarily knowing what exactly triggered these feelings. It has been suggested that past experiences, cultural background and socioeconomic status all have an impact on preferences (Heerwagen 1998; Gosling *et al.* 2013), and while there are individual differences, people often respond in similar ways to certain environmental settings (Ellard 2009). For example, past research suggests that the effects of colour and texture are minimal, but style, shape, decoration and material are possibly more influential in shaping the way people respond to architecture (Askari and Dola 2009). In particular, the level of visual contrast and visual complexity allegedly shapes human preferences for architecture (Moughtin *et al.* 1999; Stamps 2003). Other important factors include the proportions of openings, their positioning and relationships with solid elements (Conway and Roenisch 1994). Collectively, all of these characteristics of space influence human perceptions, but the factors that are most commonly cited as shaping feelings of psychological comfort in interiors are concerned with the relationship between enclosure and exposure.

Past research identifies a preference for spaciousness in interiors (Scott 1993; Franz *et al.* 2004) as well as for ceilings that are higher than standard (Baird *et al.* 1978; Stamps 2006), whereas in larger spaces (for example open-plan offices) partial enclosure and access to daylight are perceived as creating feelings of comfort (Scott 1993, Yildirim *et al.* 2007). Access to daylight and nature are not only preferred but are also potentially beneficial for wellbeing, stress relief and recovery (Farrenkopf and Roth 1980; Heerwagen and Orians 1993, Ulrich 1994), and visual connections satisfy the basic human need to derive information from the adjacent environment (Kaplan and Kaplan 1989).

A meta-analysis of theories of environmental perception reveals three main themes which are valuable in this context (Gosling *et al.* 2013). The first is Brunswik's (1956) *probabilistic functionalism* which suggests that cues, including flooring, windows, colour and light quality, can lead to valid evaluations of a space. The second theory is Gibson's (1979) ecological, perceptual approach of *affordances* that can be explained as detectable functions of an environment which allow actions. If a space is identified as functional, it will be preferred over others. The third idea is the most relevant to the present research. According to Berleyne (1971), *collative properties* (or the lack of such) – including novelty, incongruity (sensing that something is out of place), complexity and surprise – influence spatial perception. For example, an increase of pleasure occurs from observing an environment that has a certain degree of complexity; but if it is increased beyond a certain point, discomfort will be perceived (Berleyne 1951).

The architectural fascination with spatial psychology and environmental preference theory can also be traced to Jay Appleton's *The experience of landscape* (1975). In this work, Appleton develops a theory – prospect-refuge theory – to explore and explain the properties of environments that influence innate feelings of security and stimulate perceptual preference. He asserts that it is the combination of certain characteristics of outlook and enclosure, coupled with the direction of light that generate this emotional response. Prospect is required to provide a sense of power or control, whereas refuge is needed to evoke feelings of safety and security. Prospect-refuge theory could be understood as describing a particular spatial setting or pattern, which is composed to educe feelings of safety and pleasure, when observing an environment (Dosen and Ostwald 2013a).

In the 1990s, Grant Hildebrand (1991, 1999) applied this theory to architecture and added complexity and order, and the opportunity for exploration, to the properties required of an environment to evoke feelings of comfort. Several of these are related to the Kaplans' information model (Kaplan and Kaplan 1989). Complex and mysterious environments trigger a need to move around and explore space. Thus, Hildebrand expanded Appleton's prospect-refuge theory to also emphasize the importance of several additional properties in architecture. In a revised edition, Appleton (1996) embraced Hildebrand's exploration of the aesthetics of built environment and even encouraged future research and broader interdisciplinary outcomes. Nevertheless, despite prospect-refuge theory being repeatedly used in architectural design primers, and being linked to works of highly awarded architects, there is only limited empirical evidence for prospect-refuge theory. Ironically, most studies that are cited in an architectural context relate only to the experience of natural or urban environments (Dosen and Ostwald 2016). Furthermore, the computational-mathematical methods that are common in architectural analysis are only rarely linked to human perceptions.

This situation is the catalyst for the present paper which outlines results of an empirical study involving 159 participants with diverse backgrounds who rated 24 carefully graduated images of virtual interiors for feelings of comfort. The geometric and isovist properties of these 24 virtual interiors were also measured, providing a limited means of correlating feelings with geometry. The 24 test rooms varied in terms of fenestration (size and location) and roof form. In the following section, the methods are explained and participant demographic information is provided. Then the results of both survey data (perceptual responses) and room and isovist measures (geometric data) are presented and compared.

The limitations of the present research include that the virtual environment represents a relatively small and simple room which is viewed from a fixed position. The static viewpoint allows for the survey to be effectively run online, but it might limit the experience of the space. Also, even though participants are from various countries and backgrounds they do not evenly represent all groups, or at least some divisions result in very small groups that are not representative.

2. Method

This paper uses a combined survey method and mathematical analysis approach to examine varying dimensions of openings and their impact on feelings of comfort.

For the survey, participants were invited to assess, on a 7-point-Likert scale, 24 fixed-perspective, rendered colour-images of rooms that were generated from the virtual test environment. For each of the rooms, participants were invited to signal their level of agreement (from 'strongly disagree' to 'strongly agree') with the statement 'I feel comfortable in this room'. The methods used in 30 past studies in this field have previously been compared and examined and the present method responds to the gaps identified in that study (Dosen and Ostwald 2013b). In particular, a virtual test environment was chosen which allows the production of stimuli with graduated variations under controlled conditions, while still maintaining a high degree of perceptual realism (Bülthoff and van Veen 2001; de Kort et al. 2003). An online questionnaire was chosen to allow participants flexibility for undertaking the survey to a convenient time, and while there could be some concerns about viewing conditions, for example, the time of the day or other physical conditions under which the images were viewed, there are arguments that most viewing conditions can be disregarded as they result in the same outcomes (Stamps 2006). It is more important to allow participants to progress through the survey at their own pace, as forcing a short viewing time can result in ill-considered decisions.

The 24 virtual rooms (5 x 5 meters) are of contemporary appearance and include some relatively neutrally coloured furniture and decoration to provide a sense of scale. No human figures are depicted. The distant view from the room is of trees and water, although its opacity is reduced to focus attention on the room and its features, and a general sense of outlook. The 24 rooms vary only in terms of window location and size, and roof pitch direction. All other features are the same.

The 24 specific variations are divided up as follows: Eight room variations each for three opening types were prepared. These three fenestration types include: (A) an enclosed window band, (B) a full height opening that is divided by columns, and (C) a full height opening without columns. Of the eight room variations, six variations (Room 2 to 7) have flat ceilings but increase in window opening width (Table 1). In addition, the first and last variations (Rooms 1 and 8 of each fenestration type) feature a low (downward sloping) and high (upward sloping) skillion roof that emphasises enclosure and exposure. Furthermore, half of these room variations (Rooms 3, 5, 7 and 8) have corner windows while the others offer only front views. Figure 1 presents three examples of the 24 stimuli.

Table 1: Room variations (Rooms 1 to 8 vary in opening width, location and roof/ceiling form, Types A to C vary in opening height).

	Type A **'Narrow height window band'**	**Type B** **'Full height window with columns'**	**Type C** **'Full height window, no columns'**
Room 1 Small opening, centre of front wall; skillion roof (downward).	Test room 1 A (See Figure 1)	Test room 1 B	Test room 1 C
Room 2 Small opening, centre of front wall; flat ceiling.	Test room 2 A	Test room 2 B	Test room 2 C
Room 3 Corner window, with small opening to front wall; flat ceiling.	Test room 3 A	Test room 3 B	Test room 3 C
Room 4 Window across partial front wall; flat ceiling.	Test room 4 A	Test room 4 B	Test room 4 C
Room 5 Corner window and across partial front wall; flat ceiling.	Test room 5 A	Test room 5 B (See Figure 1)	Test room 5 C
Room 6 Window across entire front wall; flat ceiling.	Test room 6 A	Test room 6 B	Test room 6 C
Room 7 Corner window and across entire front wall; flat ceiling.	Test room 7 A	Test room 7 B	Test room 7 C
Room 8 Corner window and across entire front wall; skillion roof (upward).	Test room 8 A	Test room 8 B	Test room 8 C (See Figure 1)

Figure 1: Example of three stimuli varying in ceiling and opening types: Room 1 of opening type A (window band), Room 5 of type B (full height columns), and Room 8 of type C (full height).

The geometric properties of the rooms used for the survey stimuli are represented by the following four metrics: (1) the area of all openings, (2) the perimeter of all openings, (3) the wall-to-window-area ratio (WWR) (a measure for the degree of enclosure), and (4) the window-opening-width of all openings.

3. Results

First, the mean ratings of perceptual responses to comfort are presented and the data is discussed by demographic groups. Then, a relationship between the survey data and geometric room properties is tested with a Pearson's correlation test.

Of the 159 participants, 91 are males. The majority of participants are from Australia (59%), Asia (17%) and Europe (19%), while only a small number of participants from North-America and Africa (5%) (grouped as 'other' in the data). The ages of the participants ranged from 18 to 70 and they have been sorted in four groups: 18 - 25 (44%), 26 - 35 (23%), 36 - 45 (19%) and 46 or above (14%). Altogether 60% of the participants had at least one year training in architectural design (although only 20% of these had more than 5 years, and 12% between 3 to 5 years). While 22% of participants grew up in rural areas, only 13% lived there more recently. 43% grew up in suburban areas and 40% were living there predominantly during the past ten years. Most participants live now in urban areas (46%) although only 34% grew up in such a denser environment. Only 10% of the participants live in a one-room apartment.

3.1. Survey responses

The survey results for comfort in Figure 2 display the mean perceptual responses for each of the 24 room variations. The bars, which represent the three opening types (A, B or C) for all room variations (1 to 8) illustrate a general, but small upward trend.

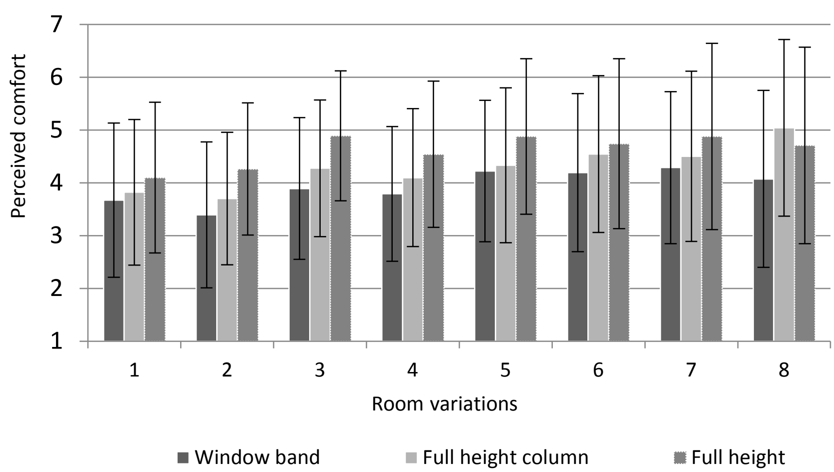

Figure 2: Mean ratings for perceived comfort (N = 159) for room 1 to 8, grouped by opening type (A – C).

All opening types indicate a similar rise within a score range of 3 to 5 (on a 7-point-Likert scale) with the exception of room 8, the largest opening with a high skillion roof. Room 8 of opening type B (the full height window with columns), was rated highest for perceived comfort with a mean rating of 5.0440 while room 8 of opening types A (the window band) and C (the full height opening were both rated lower than room 7 of the same opening type. Thus, on average the widest and highest opening with the high skillion variation was perceived as most comfortable when there are columns, which allow some concealment. The window band (opening type A) was assessed on average lowest for perceived comfort by indicating a slightly increasing rating with an increase of the opening width (from room 1 to 8). The highest ratings were given for the full height opening type without columns (opening type C) with the exception of room 8 as described above. The lowest ratings with a mean of 3.3962 were given for room 2 of opening type A, the smallest opening with a flat ceiling, while room 1 with a low skillion was perceived on average slightly more comfortable with a mean of 3.6730.

The range of mean ratings is 6 in all but two of the 24 cases: room 2, of opening type B, includes only ratings from 1 to 6 and room 3 of opening type C from 2 to 7. In most cases at least one of the 159 participants always felt either very comfortable, or not at all comfortable, irrespective of the room geometry. The lowest standard deviation occurs for room C3 (1.2304, mean for C: 1.5007) and B2 (1.2556, mean for B: 1.4346). The standard deviation is highest for rooms C8 (1.8601) and C7 (1.7659), followed by the larger openings of opening types B and C. This indicates that there was least agreement on assessing the rooms with the widest views.

A Pearson's correlation test between the ratings for perceived comfort by opening types shows a significant correlation (or similarity) between mean ratings for openings of type A (the window band) and B (the full height windows that are divided by columns) as well as between those for opening types A and C (the full height openings), but there is no significant similarity between perceptual responses for opening types B and C (r_{AB}=0.780, r_{AC}=0.822 and r_{BC}=0.697; p_{AB}=0.023, p_{AC}=0.012 and p_{BC}=0.055). This can result from the very high ratings for opening type C from room 3 onwards, while opening types A and B show a similar, but less marked increase in ratings. Interestingly, the ratings for opening types A and C follow the same ups and downs indicating higher ratings for perceived comfort for corner window variations than for pure front views with the same opening area (rooms 3 and 5 in comparison to room 4 and 6). Thus, the ratings for perceptions of comfort increase for all opening types with an increasing opening width.

3.2. Perceived ratings divided by demographic factors

Overall, a division by demographic factors confirms that there are relatively small differences in ratings for perceived comfort. The largest difference occurs between participants who are trained in architectural design and those that have no training with the former group providing slightly lower ratings in 75% of all cases. However, only 20% of the mean results show a significant difference in comfort ratings when assessing the larger full height openings with flat ceilings of opening types B and C, and a significance test indicates a high positive correlation in ratings for comfort by educational background (correlation coefficient r_A=0.829, r_B=0.895, r_C=0.817 and p_A=0.011, p_B=0.003 and p_C=0.013). A comparison by gender indicates with no significant differences in ratings that the perceptions of comfort are very similar, though females felt most comfortable in rooms with large openings with the columns interrupting them, while males perceived two thirds of the other openings as slightly more comfortable. A significance test indicates a highest, positive correlation for opening type C (r_A=0.825, r_B=0.887, r_C=0.905 and p_A=0.012, p_B=0.003 and p_C=0.002). Thus, there was most agreement between male and female participants when assessing the full height openings.

A comparison by the participant's background indicates on average slightly lower ratings for comfort from those who grew up or lived in an urban area while those from suburban areas have provided higher mean scores. The majority of those who live in a one-room apartment is from an urban area and has rated most room variations slightly lower for perceived comfort; and they have rated the largest, high skillion opening variations of opening types B and C even significantly lower in comparison to those who have one or more bedrooms (mean difference for room 8 of type B: 1.1549 and for type C: 1.2380 at a 5% significance level). Interestingly, the latter group has always rated corner window variations higher for perceived comfort than same-sized openings that offer only front views, while those living in a one-room apartment confirmed this in only two thirds of these cases. A comparison between age groups shows relatively similar results though the youngest participants have rated on average the window band relatively high for perceived comfort while the older two age groups felt more comfortable in rooms with larger openings. A comparison by continent where participants reside indicates that European participants felt most comfortable in larger opening variations while Asian participants felt least comfortable in these room variations and Australians rated the window band openings higher than others for perceived comfort. However, significant differences occur only between the ratings for room variations 6, 7 and 8 of opening type B, the full height opening that is divided by columns.

3.3. Room measurements

In this section, metric properties of the 24 test rooms are compared with perceptions of comfort, to determine which properties most closely correlate.

A Pearson's correlation test indicates a high to very high, negative correlation between the mean ratings of perceived comfort and the wall-to-window-area ratio, which is a measure for the actual degree of enclosure (Figure 3). A significance test shows a very high, negative correlation for opening type C with a probability against 1% that this is a chance finding (r_C=-0.872; p_C=0.005), while the correlation results for opening types A (the window band) and B (the full height opening that is divided by columns) are slightly lower and significant at a 5% level (r_A=-0.749 and r_B=-0.818; p_A=0.032 and p_B=0.013). Thus, the least enclosed openings (type C) achieved the highest ratings for perceptions of comfort with one exception: room 8, the largest opening with the high skillion, was rated lower than the variation of opening type B. Therefore, the difference between the lowest and highest score (or range) in mean ratings for perceived comfort is highest for opening type B while it is very similar between opening types A and C. Also, a comparison between opening width and ratings for comfort indicates a very high correlation with opening types A and B and a high correlation with C. However, there is no significant correlation between perceived comfort of opening type C and the room properties area and perimeter of openings, although the correlation factor r is very high for opening types A and B for both room measures. This likely relates to the relatively high scores of perceived comfort for opening type C from room 3 while the ratings for the larger room variations are not much higher. For opening type A it is a similar trend with lower, but also increasing ratings for the smaller openings and a higher, but nearly horizontal trend for the larger openings.

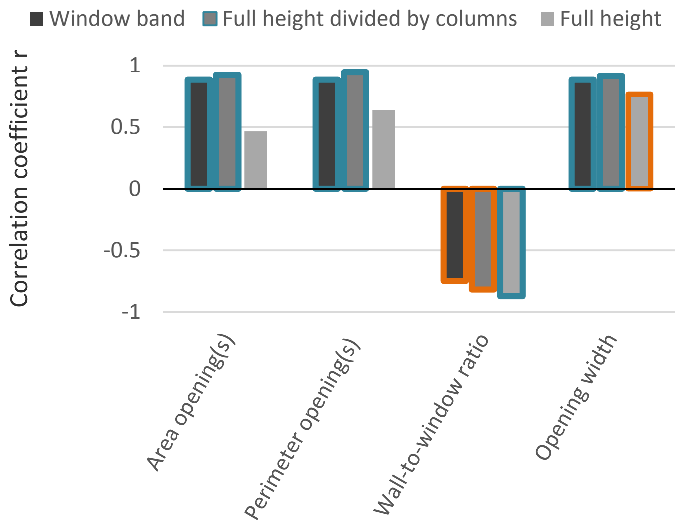

Figure 3: Correlation coefficient *r* between mean ratings for perceived comfort and room properties; significant at 5% (orange) and 1% (turquoise outline) level.

4. Discussion and conclusions

Overall, the mean ratings for perceptions of comfort increase in line with increasing opening size, which does not support the classical argument repeated by architectural designers that settings which are balanced in outlook and refuge are most preferred (Appleton 1975; Hildebrand 1991, 1999). On the contrary, the survey results indicate that prospect-dominance is perceived as most comfortable. However, Appleton's and Hildebrand's arguments include several confounding factors which were not examined in this paper. For example, Appleton argues that symbolic properties associated with outlook may influence perception, while Hildebrand claims that spaces with internal prospect (visual connections between the rooms) are more significant. Thus, the simple test room in the present study cannot be used to examine every criteria identified in past research as possibly significant.

The variations of opening type B seem to be the closest to a setting of some balance of prospect and refuge, as the columns allow some concealment and increase in their number with an increasing number of openings. The highest rating for comfort was given for the largest opening of type B, and especially females perceived and rated the larger openings of type B even higher than those of the full height openings without columns. Nevertheless, the ratings for opening type C, are altogether on average higher than those for opening type B. A common argument in prospect-refuge theory is that a balance of prospect and refuge – the most preferred setting within an environment – occurs in a centre area of a room. However, as the present test environment excludes visual connections to adjacent rooms, this could explain the preference for prospect-dominance. Closer to the edge of outlook, near the façade, and with protective walls at the back, a sort of balance of prospect and refuge occurs which is broadly supportive for both, prospect-refuge theory as well as for prospect-dominance in the case that openings are only on one side of the room. Interestingly, corner windows have been perceived in five of the six cases as more comfortable than those openings of equivalent opening size but which offer a front view only.

The survey data of perceived comfort indicates that there are very few, significant differences between the groups. The largest disparity, with only five significant results of the 24 cases, occurs for a comparison by professional background, which indicates that participants who had no training in architectural design provided on average higher ratings for perceived comfort than those who were trained in design. The older age groups of participants and those who live in homes with at least one separate bedroom have rated on average opening types B and C higher for comfort. Participants from urban areas provided on average lower ratings in opposite to those from suburban areas. Females as well as European participants rated the larger openings of type B and C higher, while Asian participants rated these on average lower.

All geometric room properties show for opening types A and B significant correlations with perceptions of comfort while this is not the case for opening type C when comparing area and perimeter with mean results. For opening type C, the most exposing fenestration type, only opening area and the wall-to-window-area ratio indicate a significant correlation with perceived comfort, of which the latter room measure is the most precise in capturing the geometric differences between the 24 room variations.

Despite some partially supportive results for prospect-refuge theory, more testing is required. A limitation of the present study is the simplicity of the rooms. Future studies are suggested that test also larger openings in one room and also openings on more than two façade sides, which might be judged differently, possibly leading to lower ratings for perceived comfort. Internal views have only been rarely examined, and also vertical connections (or three dimensions) should be considered. In addition, other room dimensions could vary, for example the width of walls, floor or ceilings, to learn when a space may be experienced as too complex or too exposed or enclosed and not so comfortable anymore.

In summary, the results of this paper indicate that people like large, wide openings and corner windows that allow one to derive even more information from the outside world. Windows that are divided by columns also elicit high feelings of comfort from some demographic groups. Such findings are relevant to designers and authorities responsible for decision-making about architectural form. Curtain wall façade systems that include flexible, exterior shading devices can be a solution for allowing the right levels of openness desired by the tenant and inviting daylight into habitable spaces in a controlled manner.

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