ENVIRONMENTAL PREFERENCE AND SPATIOVISUAL GEOMETRY

A method for combining isovists and psychological testing

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Abstract. During the past few decades, several theories have emerged which suggest that certain spatial and formal features may not only influence psychological wellbeing but also our aesthetic preference for environments. The most common approach to understanding these theories of environmental or spatial preference is reliant on the analysis of survey responses. However, a small number of computational studies have also been undertaken which have examined the geometric properties of spaces that have been produced in accordance with these theories. While both of these methods are valuable, there is a lack of connection between their results. Therefore, this paper describes a way in which two different approaches to spatial perception – isovist analysis and spatial psychology – can be combined to provide a mathematical basis for the analysis of human perceptual responses to space.

Keywords. Isovists; habitat preference; design assessment; spatial perception; prospect-refuge theory.

1. Introduction

Spatial perception can be defined as the ability to sense the dimensions and arrangement of environmental features present in a natural or built environment. After experiencing such spatial conditions it is common for people to intuitively assess their reactions to the environment and thereby decide whether they “like” or “dislike” it; this is known as “spatial preference” and it is often associated with psychological wellbeing. What is not well understood is the set of factors that have the greatest impact on a person’s judg-
ment about spatial preference. Over the last four decades several theories have emerged – including arousal theory, habitat theory and prospect-refuge theory – that suggest certain formal and spatial patterns may account for environmental preference. The majority of the theories that are relevant to architectural design involve qualitative approaches in which a designer or a scholar argues, more or less subjectively, for the hypothetical benefits of a particular combination of spaces and forms. In parallel with these approaches there are also quantitative methods for testing spatial preference that are founded on a philosophical position but which rely on the analysis of human responses that are gained through surveys, interviews and observational studies. Although such studies appear to be objective many are vague and empirically debatable due to inappropriate selection of participants and sample sizes of stimuli (Stamps 2005; Dosen and Ostwald 2013).

In parallel, several quantitative studies have used a computational or mathematical approach to investigate spatial dimensions. Such approaches include those using isovists (Stamps 2005; Ostwald and Dawes 2013), visibility graph analysis (Turner et al. 2001) and fuzzy spatial analysis or inference systems (Arabacioglu 2010). While these methods are highly systematised, and have mathematically rigorous foundations, they are typically devoid of any connection to human perceptions, responses or behaviours. Surveys, on the other hand, quite often use images of interiors seeking people’s responses to space, though they are rarely associated with specific spatio-visual properties that can be measured and used, for example, for computational analysis. Therefore, the purpose of this paper is to develop a method for combining the psychological with the computational. In particular, for showing how stimulus images can be used as the basis for both surveys of spatial preference and for the analysis of the geometrical properties. Through this process, it is possible to analyse correlations between human perceptions of environments and the mathematical properties of these same spaces.

While the approach proposed in this paper is applicable to any of the dominant theories for analysing spatial preference in architecture, the primary example presented here is the testing of prospect-refuge theory. Furthermore, because this paper is focussed on a methodological advancement, its content is largely concerned with the challenges of combining psychological and mathematical understandings of space, not on reporting particular survey results or outcomes of such an analysis. A final limitation of the research is that the basis for comparison is largely visual. Thus, spatial preference can be influenced by many other psychological and phenomenal factors, but, as in the vast majority of research into environmental preference in architecture, the focus of this paper is on the visual and associated geometric properties of space.
This paper commences with a background to psychological and mathematical testing of prospect-refuge theory before discussing six precedents that exist for combining the two. Thereafter, it proposes a method for constructing a reasonable basis for correlation of results for the two approaches.

2. Background

Prospect-refuge theory proposes that environmental preference can be traced to the presence of a spatial setting that offers both outlook and a place to hide (Appleton 1975). Appleton argues that “the ability to see without being seen” (73) is an “immediate source of aesthetic satisfaction” (73). His theory is based on experience and behaviour. Appleton proposes that we evaluate environments functionally and that our perception of safety can be related to preference. Therefore, prospect and refuge are important strategic concepts that shape our appreciation of environmental aesthetics. To these factors, Kaplan and Kaplan (1982) also add light and mystery as additional components that influence environmental preference. Hildebrand (1991) who applied prospect-refuge theory to architecture, includes complexity and order as additional criteria. In all of these examples the theories suggest that a particular interior spatial configuration should elicit positive psychological responses.

At around the same time that prospect-refuge theory was being proposed, Benedict (1979) introduced a method for describing environments using spatio-visual geometry that he called isovists and isovist fields. An isovist is, according to Benedict, “the set of all points visible from a given vantage point in space” (47). The simplest representation of an isovist is as a polygon, possibly accompanied by a table of quantitative data derived from its properties and a qualitative description (Hanson 1998). Figure 1 shows that for a particular observation location (the vantage point) a certain shape of view (isovist polygon) occurs. The most complex isovist polygons occur at intersections of main view connections. Thus, prospect (meaning the area that can be seen) correlates positively to increasing isovist area. Various other isovist properties have also been theorised as having corollaries to particular prospect-refuge characteristics (Stamps 2005; Dawes and Ostwald 2013).

3. Methodologies

Despite the challenges inherent in spatial preference research – such as low sample sizes and a selection of participants that does not consider diverse cultural, local and educational backgrounds – a number of studies have correlated isovist properties to the perceptual properties of space. This section summarises and compares the approaches of six studies that combine com-
putational-mathematical and perceptual approaches to the analysis of space. These studies are not necessarily focussed on architecture (some are about urban environments) or prospect-refuge theory, but they are all relevant to the present paper.

Franz, von der Heyde and Bülthoff (2004) investigated correlations between human responses to a virtual environment and the analysis of isovists and visibility graphs from that environment. They derived 33 characteristics from the isovists to test these as predictors of experiential qualities of interiors in a virtual art gallery. Key characteristics they tested include spaciousness, complexity and order (which can be related to isovist area, number of vertices or jaggedness, and symmetry); further, they considered perceptual factors including pleasure, beauty and level of visual interest. Participants were asked to rate panoramic images, freely exploring each scene from a fixed observation point. According to the researchers their limited experiment “empirically demonstrated significant correlations” between spatial properties and the perceptual responses to the spaces (Franz et al 2004, 9).

In an earlier experiment Franz et al (2003) used 16 unfurnished, rectangular shaped rooms to examine correlations of spatial qualities, including openness, room proportions (width / height or width / length), area, and sill height with ratings of participants and their perception of interestingness, pleasure, beauty, calm, spaciousness, openness, brightness, and normality. Expected correlations confirmed that perceived openness and brightness highly correlated to actual openness, and to physical brightness of the space. While an obvious conclusion, it reinforced the simple message that human perceptual responses and mathematical data derived from the same space can be effectively correlated.

Wiener et al (2007) confirm the usefulness of isovist analysis and suggest this approach is a promising tool for predicting experiential qualities of architecture and movement through space. They examined prospect-refuge criteria by asking participants to navigate through a virtual art gallery to find the best position to hide and also to observe. The participants were then
asked to rate each location for spaciousness, pleasantness, beauty, interestingness, complexity, and clarity. The researchers then produced an isovist polygon for the selected locations to determine the isovist area, number of vertices and jaggedness. Finally, results of both approaches were then correlated. Interestingly, the selected locations were very close to the isovist points with the smallest and largest areas.

Dalton et al (2010) used a space syntax approach to investigate interactions between room shape and size, and the memorability of image stimuli or words that have been displayed on screens in such spaces. After a two week exposure to stimuli office workers were invited to complete an online questionnaire. The isovist area to perimeter ratio (as suggested by Conroy 2001) has been used to examine correlations between spatial properties and human responses. Overall, these studies found that images are remembered better within larger isovist areas while words were better able to be memorised in smaller isovist areas.

Meilinger, Franz and Büthoff (2012) developed an isovist-based environmental analysis to investigate correlations between human spatial perception (wayfinding) and the geometry of an urban environment. Participants were asked to learn two different routes through a town. Partial isovists (captured perspectives of intersections) were used to symbolise expected directional biases. The participants had to indicate the correct path when facing 23 images of (T- and non-T) intersections. Directed partial isovists were used for the intersections which were described by eleven isovist statistics (including vertices, convexity, area, perimeter, openness and jaggedness). Non-T-intersections were recognised faster and more accurately which indicates that geometrical properties are connected with mental representations of an environment during the process of wayfinding. Non-T-intersections that show more variation can be associated with complexity. The researchers suggest that geometry might be less important for wayfinding for grid-like, repetitive intersections.

In the final example, Dzebic (2013) describes an experiment where participants were asked to rate 12 variations of a room (9 x 12 m in size), varying in positioned room dividers, for pleasantness, interestingness, beauty, complexity, clarity, and spaciousness. These perceptual responses were then correlated to isovist areas and number of vertices along with visibility graph analysis. In a second experiment, the researcher examined perceptual responses of participants and isovist properties in a complex, real university building. Again, isovist area was significantly positive correlated to perceived spaciousness. The number of vertices was negatively correlated with sociability.
4. Discussion and Proposal

The isovist (or isovist field) approach provides a quantitative method that directly relates space to vision in a way which potentially allows useful insights to be uncovered into spatial cognition (Meilinger et al. 2009) and wayfinding (Conroy 2001). The spatial structure of a work environment and its integration to the whole building highly correlates with the performance of employers as, for example, large areas that allow visual contact encourage social contact between users (Penn 1999). Geometrical properties (including area and perimeter) from an isovist field offer a way of measuring and mathematically comparing the properties of interior spatial configuration (Ostwald and Dawes 2013). Further spatial criteria relevant to isovists are openness, compactness and convexity (Batty 2001).

The psychological testing of prospect-refuge theory suggests that changes of room width and ceiling height, floor area, openness, and light level (Franz et al. 2003, 2004, Wiener and Franz 2005, Stamps 2005) all have an impact on human preference. The standard perceptual features that have been tested including openness, enclosure, mystery, and complexity can all potentially be measured using isovists. Furthermore, Joedicke (1985) describes spaciousness as the most basic quality of space which he defines as an important component of the affective experience of architecture. Other common variables for affective response are pleasure, arousal, and dominance (Mehrabian 1996).

Stamps (2005) suggests that the statistical measure skewness, which is derived from isovists geometry, might be an indicator of prospect and refuge characteristics while Dawes and Ostwald (2013) propose several alternative measures. In a very simple way, standard perceptual features such as openness or enclosure can be related to the actual area of openings as an indicator for prospect or refuge but also visual complexity. Then, perceptual preference ratings for these features (as a percentage) can be directly connected to the opening area (or isovist area). Also, the properties of the isovist perimeter are a variable that allows for conclusions to be drawn about the degree of prospect, refuge or complexity. It potentially increases, for example, with an increasing number of openings. The largest values for isovist perimeter can be measured when wide openings are interrupted by columns or wide posts which add to the degree of visual complexity. In addition to this, the ratio of isovist area to room area is an indicator of refuge-dominance (isovist area < room area, only occurs with at least one wall concavity), the lack of visual complexity (no prospect, isovist area = room area), and prospect (isovist area > room area). The latter, prospect, needs to be examined in more detail as in an architectural context a room usually has at least one window. Therefore,
the degree of openness determines the level of dominance, or balance, of prospect and refuge. The question is now which other spatial properties, that are relevant to perceptual responses, can vary with differences in survey images to empirically test correlations in future studies?

Some studies (Wiener et al 2007, Franz et al 2003) argue how relevant isovists are to examine behavioural performance during a navigation task, demonstrating that basic characteristics of isovists such as area were well perceptible. They suggest two varying room sizes, either width and length or width and height. Changes of ceiling height are easier to recognise in images than changes of room depth where the image depicts one room only. Higher ceilings are also an indicator of increasing prospect or exposure (higher / larger opening areas), suggesting measuring the vertical properties of space for future research. A more challenging issue is to relate isovist properties to complexity and mystery. Wiener et al (2007) have confirmed expected correlations for spaciousness (isovist area) and complexity (number of vertices and jaggedness) with pleasantness, beauty, and interestingness. Also in Dzebic’s (2013) study the highest correlation occurred between isovist area and spaciousness, followed by pleasantness and beauty. The number of vertices, which can be related to both complexity and mystery, was positively correlated with interestingness. Overall, an ordinary, rectangular shaped room, that is typical for a modern building plan, needs to be tested in a series of images with varying properties for any useful results to be derived. In response to all of these factors we propose the following.

A set of stimuli images (virtual interiors) is constructed with a controlled set of permutations. Thus, the floor plan remains the same but the openings in the walls vary in a controlled fashion, and also the ceiling heights. In order to accommodate variations of ceiling heights and window dimensions (width and also height), stimuli images must allow for the examination of each variation independently (Figure 2). Typical window types such as symmetrically ordered, one-sided or corner windows vary from a small, enclosed width to a medium width and wide opening as well as in height from a full ceiling height to an opening with a sill and a window band. All windows are shown in a second variation separated by columns that interrupt the view partially. Such breaks can become a measurement for visual complexity and mystery, revealing views and at the same time hiding a part of the view. For each of these variations in view a set of two isovists can be developed; the first a plan isovist and the second a sectional one.
Figure 2. Suggested stimuli, varying in window size and ceiling height, with isovist shape.

Figure 3. Isovis area and perimeter values for the examples above, by opening width.
The measured isovist values (area and perimeter) for nine room variations can be charted (Figure 3). Every room has identical internal dimensions (6 x 5 m). The isovist perimeter values increase significantly with an increasing number of openings for the two rooms that have windows interrupted with columns (indicator for visual complexity). Survey responses and measured properties can be combined in a similar way in such charts, comparing, for example, the perceived visual complexity or perceived openness (shown as line in %) with the isovist area (bar in %) and revealing possible correlations. In addition, statistical methods such as probability and a regression analysis can be used to examine the significance of findings as well as the prediction of perceptual space and affective responses.

5. Conclusions

The small number of isolated studies which have sought to combine perceptual and mathematical analysis of space have all confirmed the usefulness of the approach. Single isovist measures including the ratio of isovist area and perimeter possibly allow for spatial dimensions to be related to perceptual features such as openness, enclosure, spaciousness, complexity, and order. The use of virtual stimuli is suggested for an empirical test varying criteria in an appropriate way that is relevant to the particular space. Height, as seen by the observer, must be considered for future testing of spaces as well.

Ultimately, through the method presented in this paper, it is possible to draw both, psychological and mathematical lessons or data from perceptual responses to space.

References


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