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Testing the 'Wright Space': using isovists to analyse prospect-refuge characteristics in Usonian architecture

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Historians and critics argue that the innate appeal of Frank Lloyd Wright's architecture can be traced to the way in which it balances the properties of outlook, enclosure and mystery. Such properties, it has been theorised, are responsible for the positive emotional response felt by inhabitants of Wright's buildings. Hildebrand explains these psychological responses by proposing the existence of a particular pattern of prospect-refuge characteristics: the 'Wright Space'. In response to this claim, the present paper uses isovists to analyse the spatial and visual experience of moving through five of Wright's Usonian houses to seek evidence of this pattern. The mathematical properties of these isovists provide measures for comparing the spatio-visual character of different locations. The results of this research show some evidence of the spatial pattern identified by Hildebrand but it is insufficient to class this as either unique to Wright or especially significant.

Introduction

Frank Lloyd Wright, one of America's greatest architects, had a long and successful career resulting in the construction of over 300 residential designs. Wright's rise to prominence at the start of the Twentieth Century was founded on the success of his Prairie Style houses and in the following years he experimented with a mono-material construction system in California, producing his iconic Textile Block designs. However, in the 1930s Wright was forced to develop a new style of domestic architecture, the Usonian house, in response to the growing need for low-cost accommodation.¹ Despite being much smaller in scale than his previous works, historians and critics argue that the Usonian houses still feature a distinct internal plan-

ning strategy which is similar to that found in Wright's earlier works.² Moreover, like his early and more extravagant designs, Wright's Usonian houses are praised for evoking a positive emotional response from visitors and inhabitants. For example, Sergent observes that the 'materials and spatial characteristics of the Usonians gave a sense of serenity, variety, and security'.³ While multiple attempts have been made to explain these reactions,^{4,5,6,7} few have been as enduring as Hildebrand's application of prospect-refuge theory.⁸

Prospect-refuge theory, initially developed for analysing landscape preference,⁹ is founded in psychological and behavioural research which suggests that environments that provide a balanced combination of outlook and enclosure are particu-

larly conducive to survival and, thereby, stimulate a positive, emotional response. Hildebrand¹⁰ argues that the emotional reactions reported by occupants of Wright's domestic architecture are a direct result of the way Wright used space and form to emphasise these prospect and refuge characteristics. Furthermore, Hildebrand proposes that Wright's carefully designed living rooms and approach paths through these houses, constitute a powerful and recurring pattern, the 'Wright Space'.

Hildebrand's argument, whilst not universally accepted,¹¹ has nevertheless been widely adopted as both a legitimate explanation of the power of Wright's architecture and as an analytical and design strategy.^{12,13,14} On the basis of Hildebrand's work, prospect-refuge theory has entered the canon of architecture as an important phenomenal and psychological strategy for evoking a positive emotional experience.^{15,16} But, despite its apparent success, there is no empirical evidence that the Wright Space actually exists.

The present research uses isovist field analysis to measure the spatio-visual characteristics of the paths through five of Wright's Usonian houses. This information is then used to examine the evidence for the existence of the pattern identified by Hildebrand. The isovist method, a computational and mathematical approach, has previously been used to examine the behavioural and prospect-refuge related characteristics of architecture.^{17,18,19,20} An isovist is created by abstracting the planar limits of an environment into a simple polygon that records the geometry of a person's vision from a point in space. The numeric and geometric properties of the resultant polygon can then

be analysed. An isovist field consists of a set of isovists located at regular intervals throughout an environment. When examined in this way, isovist geometry can be used to capture the changing spatial and visual experience encountered as, for example, an occupant moves along a path through an environment.

The five Usonian houses selected for analysis in the present paper are the Jacobs house (1937), Schwartz house (1939), Lloyd Lewis house (1940), Affleck house (1941) and Palmer house (1950). These houses are of similar size and complexity, and conform to a small number of formal archetypes that Wright produced at this time. Not only did Hildebrand consider these houses in his original argument for the existence of a Wrightian spatial pattern, but two of them (Lloyd Lewis and Palmer) were the subject of his detailed graphic analysis to demonstrate the pattern.

The present paper commences with an introduction to prospect-refuge theory and the specific elements of the theory that Hildebrand identified as crucial to the experience of Wright's architecture. Following an overview of isovist field analysis, the method section details the procedures used to replicate Hildebrand's paths within a series of CAD models. Thereafter, the paper offers four hypotheses, each of which relates to patterns that should be found in the isovist field data if Hildebrand's theory is valid. Finally, the results are discussed in detail and the paper concludes by returning to the hypothesised indicators and comparing them with the actual results.

This research has several methodological limitations that must be acknowledged before progres-

sing. First, Hildebrand's argument for the existence of a Wrightian spatial pattern is made up of both tangible and intangible elements, whereas the variation of the isovist method used in this paper can only measure tangible spatio-visual properties. Thus, the paper cannot comment on the supposed psychological impact of light, colour, texture and other prospect-refuge 'symbols'. However, it has been argued that the actual importance of these elements is overstated in Hildebrand's work, especially given its overwhelming reliance on visual and spatial properties as evidence.²¹ This view is also supported by research into spatial psychology which demonstrates that people's reactions to such elements are influenced by a wide range of personal factors including age, cultural background and education.^{22,23} The present paper's focus on plan geometry is a further limitation, which means that it is unable to account for the impact of variations in floor and ceiling levels. While this is a practical limit, it has been demonstrated that two-dimensional planar geometry (a horizontal isovist) is a much stronger determinant of perceived spaciousness than the ceiling height of a room.²⁴ Thus, whilst acknowledging the limitations of the method, isovist analysis remains a viable approach to investigating the physical properties of Wright's spatial pattern.

Prospect-refuge theory

In 1975 Jay Appleton asked 'what do we like about' a space, and 'why do we like it?'.²⁵ Answering these questions—reiterated in various ways by different authors throughout the last four decades—has become the primary catalyst for research into environmental preference theory. Appleton's

response to these questions was to develop two inter-related concepts: habitat theory and prospect-refuge theory. Habitat theory addresses the question of why people prefer an environment, by arguing that all animals possess an innate biological motivation to seek environments that are favourable to their probability of survival. This biological motivator takes the form of an immediate and intuitive emotional response to a setting. The response is pleasurable, if the environment is perceived as conducive to survival and anxious or restless in situations that are unfavourable for this purpose. Appleton is careful to note that '[w]hat matters is not the *actual* potential of the environment to furnish the necessities for survival, but its *apparent* potential as apprehended immediately rather than calculated rationally'.²⁶ Stephen and Rachel Kaplan agree that the assessment of an environment occurs virtually instantaneously, intuitively and unconsciously.^{27,28,29,30} Furthermore, despite the presence of a 'highly regular and meaningful pattern' in the way people respond to spaces, 'participants are generally unable to explain their choices'.³¹ Thus, habitat theory serves to explain why particular environments are preferred over others but it does not define the characteristics of a preferred environment. For this purpose Appleton proposed prospect-refuge theory.

Prospect-refuge theory invokes the lifestyles of animals and primitive man to explain environmental factors that are integral to a person's strategic appraisal of potential habitats. Prospect is an environmental characteristic conducive to locating and obtaining resources (food or water) while identifying potential hazards. Refuge is an environmental

characteristic derived from the presence of shelter or concealment and therefore is associated with safety. Thus, a predator might rely on the prospect characteristics of an environment to identify its prey and the refuge characteristics to assist the process of stalking. Conversely, a prey creature might use prospect characteristics to identify grazing areas and approaching predators, and use refuge characteristics for concealment or as a location to which they might flee. In prospect-refuge theory a 'hazard' is 'an incident or condition', which is 'prejudicial to the attainment of comfort, safety or survival'³² and may take the form of an animate pursuer, or an environmental threat (geographic features, weather conditions or extreme temperature). The ideal spatial conditions for survival, and also for generating an emotional sense of safety and wellbeing, are therefore those which provide a balanced combination of outlook and enclosure coupled with an ability to see or sense a hazard, while being sheltered from it.

While prospect-refuge theory and its founding logic has been extensively criticised^{33,34,35} and psychological evidence for its efficacy has been challenged,^{36,37,38} it has been especially influential in architecture.³⁹ Much of its impact can be traced to the way in which Hildebrand^{40,41} used this theory to explain the phenomenological power of some of the great works of twentieth-century design. Whilst past research has noted some of the characteristics that make a house feel safe and pleasurable⁴² it was Hildebrand's explanation using prospect-refuge theory that was amongst the most convincing. Not only did Hildebrand offer a seemingly plausible rationale, but by reviewing detailed

accounts of the experience of Wright's architecture he expanded prospect-refuge theory, adding several elements. For example, while, for people experiencing Wright's architecture, outlook and enclosure were amongst the most common themes, additional feelings associated with mystery were also prevalent. Thus, whereas Appleton's theory is often linked to the spatial properties of a single location (or view), Hildebrand observed that the experience of this space is dramatically heightened if it is approached in such a way that people are drawn, by qualities of mystery and complexity, to want to discover and inhabit it.

The Usonian style

In his 1932 autobiography Frank Lloyd Wright stated that the production of a moderately priced house was 'America's major architectural problem'.⁴³ Wright's solution, the Usonian house, featured several cost-saving elements including slab-on-ground construction, built-in furniture and a carport instead of a garage. Wright also developed a modular, prefabricated timber construction system which could be assembled on site to eliminate plastering and painting costs.⁴⁴ Wright not only reduced the size of his designs to accommodate a more modest income, but he prepared a series of archetypal planning configurations to suit different sites. On urban building plots Wright preferred an L-shaped plan, while for more open or private sites he chose from linear, hexagonal and diagonal archetypes.

Each Usonian house, regardless of the underlying geometric *parti* of its plan, had a relatively consistent set of relationships between functional spaces. Furthermore, they typically feature dining rooms

and kitchens that are merged into a larger living area. Whilst formal dining rooms had been a hallmark of his earlier Prairie houses, for the Usonian houses Wright chose to position the dining area as an extension of the living room and then delineate it spatially using built-in furniture and changes in materials. In a similar way, Wright called the kitchen the 'workspace' of the house and, rather than isolating it as a separate room, he located it in 'an open alcove adjacent to and part of the main living and dining area'.⁴⁵ But while these differences between the plan of the Usonian house and that of his earlier works are readily apparent, Wright also maintained, despite the challenges they posed for his client's budgets, two key design features: the presence of a carefully controlled path from the front door to a prominently positioned fireplace and an expansive living room.

In his autobiography Wright described the living room as a large space 'with as much vista and garden coming in as we can afford, with a fireplace in it, and open bookshelves, a dining table in the alcove, benches, and living room tables built in'.⁴⁶ The owner of one such living room, Theodore Baird, is quoted as saying that within the space he was always 'conscious of a direction, an opening out, [it is] a house [...] where the walls are not barriers [and] where there are satisfactions for the senses in just moving from one room to another'.⁴⁷ Baird's account, like others that have been collected by scholars, emphasises the positive emotional impact of the balanced combination of prospect and refuge found both in the living room and in the experience of moving through the house. This description is also notable for the way

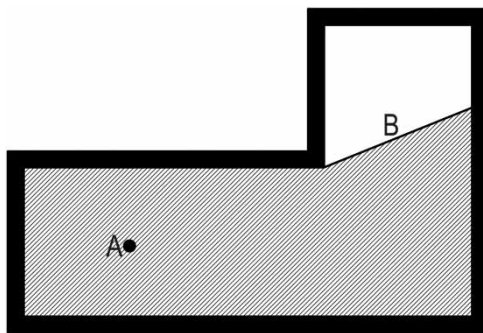
it stresses spatial and visual factors above all others, including the symbolic and phenomenal influences, for shaping the experience of the house.

Despite (or perhaps because of) their modest budgets, the Usonian houses are considered ideal examples of Wright's interior prospect-refuge pattern. They represent a distillation of the more complex pattern he developed in the Prairie Style and Textile Block houses. According to Hildebrand,⁴⁸ the key elements of the pattern, the design of the living room and of the path that connects this room to the home's entry, are all found in the Usonian houses.

Isovist analysis

Isovist analysis forms the basis for the current investigation of the spatial properties of Wright's Usonian architecture. An isovist is a two-dimensional representation of the portion of a space that is visible, in any direction, from a single vantage point. The isovist appears as a polygon; a geometric shape that replicates the visual boundaries of a space and which can be measured to determine a range of characteristics about a space. Furthermore, by moving the observation point the properties of the polygon change, thereby allowing comparisons between the spatial experiences found at different locations in a building or between locations in different buildings. Simple measures, such as the area and perimeter of the isovist polygon, allow for direct comparisons to be made between the volume of space visible from specific vantage points and they can be combined to create normalised results that allow for scale-free comparisons between isovists (Fig. 1).⁴⁹

Figure 1. An isovist observation point (A) and polygon (shaded) showing the portion of the environment that is visible from the observation point. The line (B) is an occluding radial and represents the portion of the environment that is just out of view.



The first detailed explanation of the application of isovist analysis to architecture is typically traced to Benedikt⁵⁰ who also described how the properties of multiple observation points could be compared by creating an 'isovist field'. An isovist field is the set of all isovists, generated from a defined series of observation points (typically a grid of points) in a building. Benedikt demonstrated that this approach allows researchers to plot the changing spatio-visual properties of a building as a scalar map or to chart sequentially the measured values as a graph. The technique of isovist field analysis has since been refined and developed to take advantage of computational methods^{51,52} and is now commonly undertaken using radial line techniques which allow for the calculation of additional isovist properties based on the line lengths which define or generate the isovist.⁵³

Isovist analysis techniques have been used in architectural research to study spatial cognition,⁵⁴ wayfinding,⁵⁵ social structure⁵⁶ and phenomenology.⁵⁷ Importantly, isovists have also been used to examine prospect-refuge characteristics in

buildings.^{58,59,60} In this past research several measures derived from isovist geometry have been demonstrated as having a correlation with aspects of prospect-refuge theory. The four chosen for use in the present research are: isovist area, radial line length, occlusion and drift.

Isovist area (A) is a straightforward determination of the area of the polygon, measured in square metres. Relatively speaking, the smaller the area, the greater the feeling of refuge or of being hidden, enclosed or constrained. A radial is a line, measured in metres, which is drawn from the viewing position to a surface which blocks further sight. The lengths of radial lines represent the distance a person can see. The longest radial line ($RL_{(L)}$) is the maximum visible distance and it provides an indication of prospect, while the shortest radial line ($RL_{(S)}$) provides an indication of the proximity of solid surfaces, through which one cannot be assaulted, and therefore provides an indication of refuge. Typically, an environment providing a longer view is perceived as more spacious, up to a point where the ratio of the length to the width of a space approaches that of a corridor and then the effect is reversed as a person feels more constrained.^{61,62,63,64,65}

An occluded edge in an isovist is a perimeter face that does not correspond to (or is not aligned with) a visible built surface. Thus, an occluded line hides something from view, a property that is closely related to a sense of mystery.⁶⁶ In practice, absolute occlusivity (O), measured in metres, is the length of the open edges of the isovist whereas proportional occlusivity (O:P) identifies the percentage of the total perimeter that is open. This latter measure is

scale-free allowing isovists of different sizes to be compared. Occlusivity is not just an indicator of mystery, a refuge location will also typically have fewer positions that are hidden from view; however, it can also represent a location of secondary refuge, a place a person can move to from their current location in order to be hidden.

Drift is the difference between the viewer's location in the isovist and the centroid of the isovist, thus drift direction could be considered the direction of maximum prospect. In a square room and with a central viewing point, there is no difference between the generating location of the isovist and the centroid of the isovist; however, a difference will exist if an observer stands in the corner of the same room. Drift magnitude (D_M) is the length, measured in metres, of this difference and Drift direction (D_D) is its angle, measured in degrees and where the direction straight ahead is 0° and directly behind is $\pm 180^\circ$. A positive value indicates visual pull to the left, a negative values indicates a visual pull to the right. In order to survey the largest possible isovist area (and potentially the highest number of locations of interest or importance), a human observer with a limited ($\approx 180^\circ$) view cone must align their direction of view to the direction of isovist drift. Drift, therefore, has a high level of correlation to visual pull and intuitive directionality, the experiential property wherein the human eye is drawn (by combined spatial and formal cues) to look, and thereby move, in a direction.

Research method

All of the isovist analysis for this paper was undertaken using new CAD models of each of the five houses, constructed in accordance with the details

and dimensions contained in Wright's final construction drawings and interpreted using measured drawings and photographs of the completed buildings.⁶⁷ Floor plans derived from the CAD models were analysed using UCL Depthmap (version 10.14.00b) software.⁶⁸ Each plan depicted a horizontal section through the building at a height of 1.65 metres above the floor level. The 1.65 m height approximates the eye level of Wright, who habitually calibrated the vertical dimension of his designs to his own body.⁶⁹ The software created a uniform grid (100 mm spacing) of observation points in each floor plan before generating an isovist for each point and providing graphic and numeric documentation of the properties of each isovist. A sub-set of these results, which make up the path from the front door of the house, to the hearth and then to the centre of the living room, was extracted from the complete set of data. A stride length of 500 mm (also derived from Wright) was used to generate and report the value of every fifth observation point along each path.

The paths chosen for analysis in each house are those documented in Hildebrand. They typically trace the shortest route to the main hearth (at the side of the living room), before continuing to the centre of that room; a location identified by drawing a diagonal line between the room's corners. If a person must pass through the centre of the living room prior to reaching the hearth, the final stage is excluded. Hildebrand explicitly maps paths through multiple buildings according to these rules and implies that the path must not commence from the servant's entrance and it must avoid passing through service areas, such as kitchens. In

accordance with Hildebrand's diagrams, the paths being tested follow straight lines of movement with 90° turns.

There are two exceptions to these rules. First, Wright utilised an equilateral triangular grid for the Palmer House and its circulation and therefore the path analysed for that design also must make use of 60° turns to allow for a natural movement pattern. The second exception to the rules relates to the Schwartz house which does not have a defined living room, but does feature both a lounge and recreation room. Here we select the lounge room as the destination as this space features a larger number of elements from Hildebrand's prospect pattern than the recreation room.

The lack of information about the original context and surroundings of the buildings limits the analysis to internal, habitable spaces and considers all external doors and windows to be closed and opaque. This conforms to Hildebrand's diagrammatic analysis and concept of interior prospect and it also mirrors the actual experience of these houses at many times of the day. This decision, while consistent with the theory being tested, does limit the effectiveness of some possible determinants of prospect and it ignores the impact of external landscape symbols and hazards. A further methodological issue is that the living room of the Lloyd Lewis house is located on the first floor and so the pathway leading from the front door to the centre of the living room involves vertical circulation between levels. This presents a challenge for Depthmap due to the software's inability to link isovists across floors. The solution adopted in this paper follows past research⁷⁰ which relies on hybrid floor plans that

focus on locations of vertical circulation and incorporate spatial information from multiple floors.

The results derived from the analysis of each path are presented in three ways: an axonometric diagram, a set of graphs and a textual account. These methods of presentation are all cross-referenced to each other using annotated locations marked on the cutaway axonometric diagram. This diagram depicts the specific path being analysed and key moments along the path. While only the interior spaces are analysed mathematically, Hildebrand argues that the exterior path serves as a precursor to the larger experience of each house. Thus, these external routes are also discussed where information is available.

The second way the results are presented is as a series of graphs for each house. The first of three graphs shows the results for isovist area and longest and shortest radials, the second is for absolute and proportional occlusivity, and the final depicts drift magnitude and direction. In each case the horizontal axis of the graph is the same, the distance (and also time) from the front door on the left of the axis to the destination on the right. The vertical axes vary depending on the measures being presented. Such graphs mathematically show the changing spatio-visual experience of moving along these paths.^{71,72,73} This representation also encapsulates Appleton's⁷⁴ view of space as a continuous series of experiences in which prospect and refuge may alternate in order to provide balance.

The final way in which the results are presented is as a short description of the experience of the path. To allow for these new, empirically derived

accounts to be compared more directly to past works, standard spatial and phenomenological descriptors are used instead of mathematical ones. Thus, for example, occlusivity results are presented descriptively as complexity and mystery while drift magnitude and direction are translated in terms of visual pull and the discovery impulse. Bracketed mathematical values inform each description allowing for cross-referencing to results in the graphs.

Hypotheses

Hildebrand⁷⁵ argues that Wright utilised a strikingly similar pattern of prospect and refuge elements in each of his designs and that a large part of this pattern is reliant on the way vision is controlled or shaped by space and form. If this is true, then evidence of this pattern will be present in the data captured by the isovist analysis. Specifically, Hildebrand identifies the presence of three measurable features. First, the approach paths through the houses are narrow and constrained before opening out into living areas where the location of highest refuge is adjacent to the hearth and the centre of this room offers a slightly more elevated prospect, providing a balanced relationship between outlook and enclosure. Second, Wright imbued the approach path to these locations with a high level of mystery and complexity, while the hearth should have a much lower level of mystery. Third, the approach path is designed to draw the occupant through the house to the centre of the living room. This means that the directional or visual pull of the space must be forward, and that it should be stronger at the start, and

decrease as the centre of the living room is reached. If these elements of the pattern exist in the five Usonian Houses, then the following mathematical results will be evident.

1. Isovist area and longest radial length should typically increase over the length of the path and the living room centre will provide a balance of prospect and refuge while the hearth is more refuge focused.
2. Occlusivity, both absolute and proportional, should typically reduce over the length of the path.
3. Drift direction will be less than $\pm 90^\circ$ and drift magnitude will reduce over the length of the path.
4. Finally, data derived from the five houses will, regardless of other absolute indicators described previously, signify the presence of a consistent pattern, expressed mathematically as a comparison of linear trend-lines using the 'least-boxes' method.

Results

Jacobs House (1936)

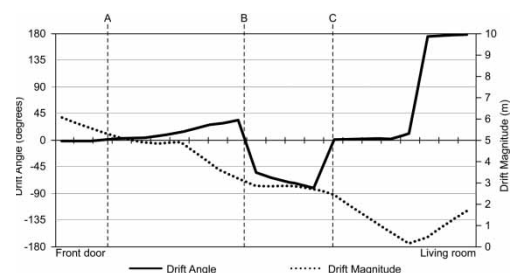
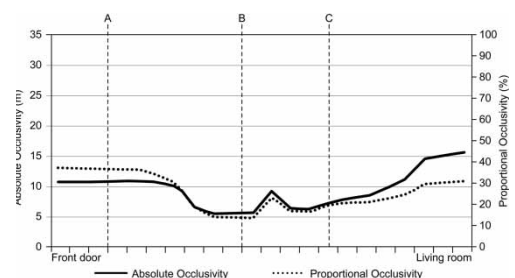
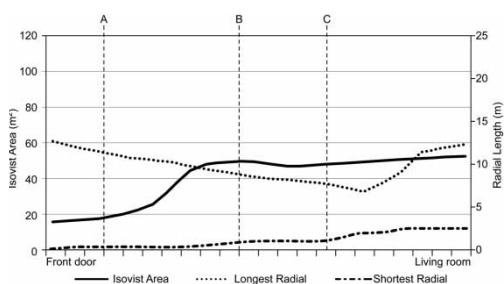
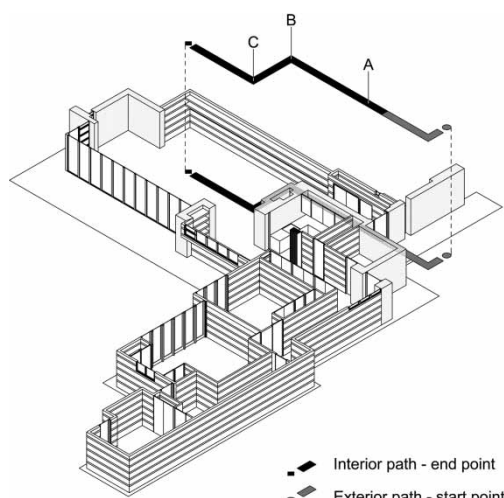
The Herbert Jacobs house in Madison, Wisconsin, was the first of the Usonian designs to be completed. It consists of an L-shaped plan, designed to ensure privacy from the street while maximising the area available for a rear garden. Internally, its walls are richly modelled, stepping into and around the entry, creating alcoves for the kitchen and dining areas and dissolving the boundaries of the space with mitred glass corners. Sergeant's account of the house stresses the need 'to move about to

Figure 2. Jacobs house:
axonometric view of the
path.

Figure 3. Jacobs house:
isovist area and radial
line lengths.

Figure 4. Jacobs house:
absolute and
proportional occlusivity.

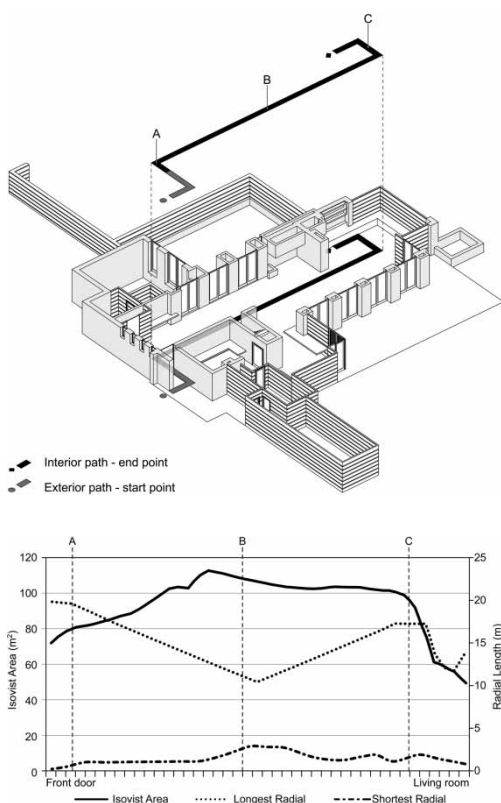
Figure 5. Jacobs house:
drift angle and
magnitude.



comprehend it⁷⁶ while noting that the space also has a mysterious quality, associated with the way 'its boundaries always slip beyond view'.⁷⁷ Sergent concludes that the spatial experience of the Jacobs house is both 'complex and ambiguous'.⁷⁸

The path through the Jacobs house has only two turns (figs 2–5 inclusive). It commences in the foyer (A), where a long view ($R_L = 11.63$ m) creates a

clear and direct visual pull ($D_M = 5.33$ m, $D_D = 0.37^\circ$) into the house. This gradually reduces as the visitor progresses to the edge of the living room (B), before dropping near the hearth ($RL_L = 9.41$ m). The level of mystery is lowest ($O:P = 14\%$) between the entry to the living room (B) and the hearth (C). When approaching the centre of the living room glimpsed views past the kitchen become available increasing mystery and view distance and generating a new visual pull in this direction. The living room centre offers the highest levels of prospect ($A = 52.73$ m² and $RL_L = 12.35$ m) and mystery ($O:P = 31.11\%$) along with a slight directional force ($D_M = 1.67$ m) towards the hearth, suggesting the living room centre is a destination



space offering a balance of prospect, refuge and mystery.

Schwartz House (1939)

The Schwartz house uses a variation of the L-shaped plan, with the larger wing being dominated by a recreation and lounge space. Sergent describes this interior as possessing 'great spatial variety, intimacy,

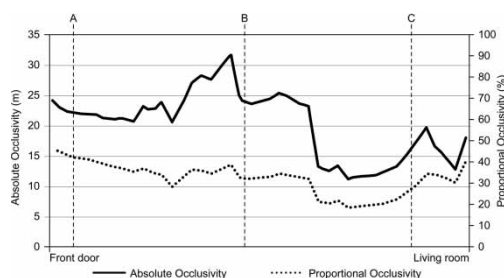


Figure 6. Schwartz House: axonometric view of the path.

Figure 7. Schwartz house: isovist area and radial line lengths.

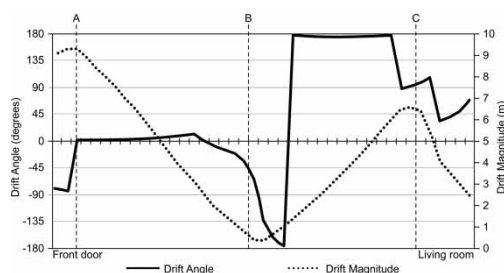


Figure 8. Schwartz house: absolute and proportional occlusivity.

Figure 9. Schwartz house: drift angle and magnitude.

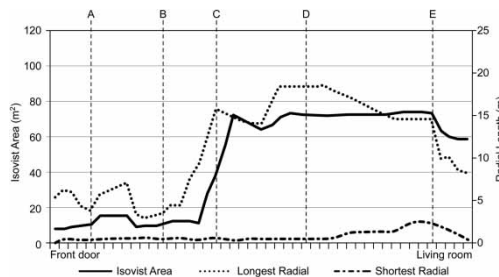
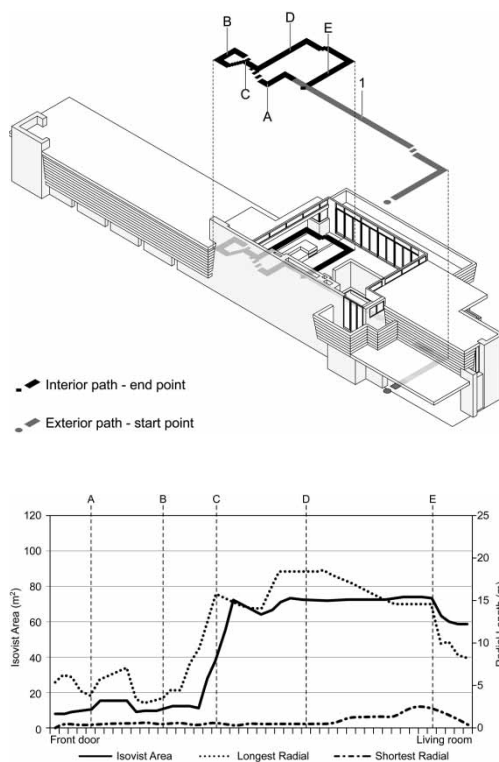
and grandeur'.⁷⁹ Entry to the house is through the carport and once inside the visitor makes one right-angle turn to pass the kitchen, master bedroom and stairs and traverse the recreation room before entering the lounge and approaching the hearth (figs 6–9 inclusive). In the entry space (A) the visitor experiences the longest view distance ($RL_{(L)} = 19.62$ m) and strongest visual pull ($D_M = 9.36$ m) of all the five houses analysed. This draws the occupant forward, past the point of maximum prospect ($A = 103.92$ m²), to the centre of the recreation room (B) where the occupant is furthest from any walls ($RL_{(S)} = 2.93$ m) and the sense of direction is weakest ($D_M = 0.36$ m). Passing beyond this point to the lounge room requires moving in the opposite

Figure 10. Lloyd Lewis house: axonometric view of the path.

Figure 11. Lloyd Lewis house: isovist area and radial line lengths.

Figure 12. Lloyd Lewis house: absolute and proportional occlusivity.

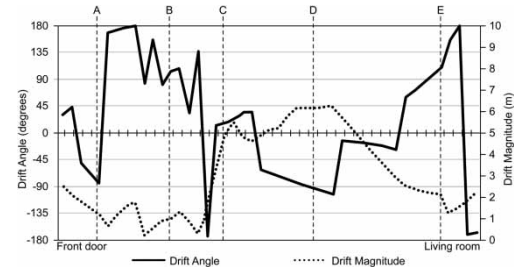
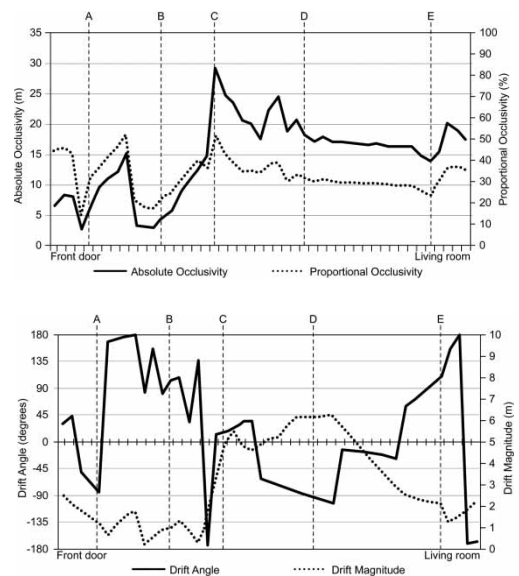
Figure 13. Lloyd Lewis house: drift angle and magnitude.



direction to the visual pull and into the protected corner nook (C). Ultimately, the lounge room and particularly the hearth, is a strongly refuge-dominant space ($A = 50.76 \text{ m}^2$, $RL_L = 13.55 \text{ m}$, $D_M = 2.45 \text{ m}$, $O:P = 39.74\%$).

Lloyd Lewis House (1940)

Designed for the journalists Lloyd and Kathryn Lewis and constructed in Libertyville, Illinois, on the Des



Plaines River, the Lloyd Lewis house has a truncated L-shaped plan with an unusual external spatial sequence culminating in an extensive, formal loggia (figs 10–13 inclusive). The entry foyer (A) is visually constrained with both limited view distances ($RL_S \sim 0.45 \text{ m}$, $RL_L \sim 3.94 \text{ m}$) and a strong sense of refuge ($A \sim 10.44 \text{ m}^2$) before passing the first stair landing (B) whereupon an extensive ($RL_L = 15.83 \text{ m}$) vista down the bedroom corridor becomes available. The visual pull, after leaving the front door and reaching the landing is both strong ($D_M = 4.91 \text{ m}$), and typically in a different direction (up to 180°) to that of the direction of travel. Furthermore, this starting sequence to the first landing is constrained ($RL_S = 0.456 \text{ m}$ – 0.77 m) and of variable mystery ($O:P =$

14.64%-52.26%). However, from the top of the second landing, the entire living room and portions of the kitchen, dining room and sanctum become visible causing a rapid rise in prospect ($A = 28.71\text{--}73.20\text{ m}^2$). Mystery is at its peak at the top of the stairs (C) and then reduces again closer to the hearth. From the top of the stairs (C) visual pull increases towards the living room, but the waist-high book shelves force the occupant to move perpendicular to this direction ($D_D = -79.74^\circ$) before finally crossing the living room centre (E) and approaching the hearth. The living room offers moderate visible area and glimpsed views to adjacent spaces suggesting a static environment at the end of an often-counterintuitive path with only brief instances of mystery and a visual pull that typically operates contrary to the direction of travel. Sergent describes the Lloyd Lewis house as having 'one of Wright's simplest and most successful Usonian interiors',⁸⁰ a fact that might be supported by the low levels for mystery throughout, but the path itself is also one of the least directed of Wright's Usonian works and reminiscent of the Prairie Style houses.⁸¹

Affleck House (1941)

The Affleck house in Bloomfield Hills, Michigan, is approached through an initially understated path, by way of the rear of the carport. Its materials and forms are strongly horizontal and, with one exception, the experience of this house is embedded in its planning not its section (figs 14–17 inclusive). The exception relates to the constrained entry court which features a 'top-lit loggia, whose open wall overlooks a pool and streamlet that eventually runs into a pond'.⁸² The path through the house

consists of only three left-hand turns. The experience of the entry (A) is constrained ($A = 8.70\text{ m}^2$) and the majority of it is visible or un-occluded ($O:P = 30.33\%$) with only a gentle visual pull forward into the house ($D_M = 2.74\text{ m}$). As the visitor leaves the vestibule, attention briefly focuses on the corridor to the bedrooms before turning toward the centre of the living room, drawing the visitor toward this location (B) ($D_M = 16.07\text{ m}$). The path to the centre of the living room follows a left-hand spiral, until the hearth is reached. From the centre of the living room (B) to the hearth (C) the visual pull increases and area decreases gently; however, experience does not change significantly. Moreover, along the complete path through the house the level of mystery remains relatively stable, suggesting that while the size of the view changes with each step, the proportion of the view that is just beyond sight is similar ($O:P \sim 31\%$). The path through the Affleck house is one of limited mystery and gradually increasing prospect with a visual pull that initially distracts from and then leads the occupant to the living room centre and then does not encourage further exploration beyond this point.

Palmer House (1950)

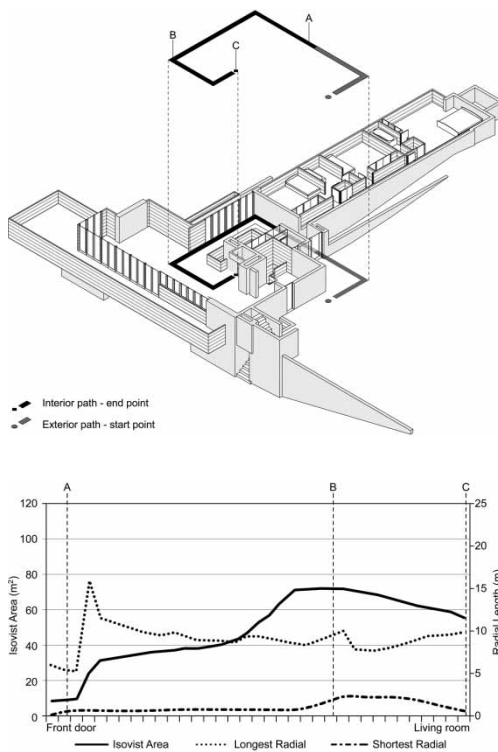
Rosenbaum argues that the Mary and William Palmer house in Ann Arbor, is 'perhaps the highest expression of [Wright's] Usonian art'⁸³ and Maddex describes it as '[o]ne of Wright's most welcoming Usonian houses'.⁸⁴ The Palmer house is famous for its triangular planning, allegedly developed from the geometry of the site. Detailed throughout with furniture, fittings and built-in cup-

Figure 14. Affleck house: axonometric view of the path.

Figure 15. Affleck house: isovist area and radial line lengths.

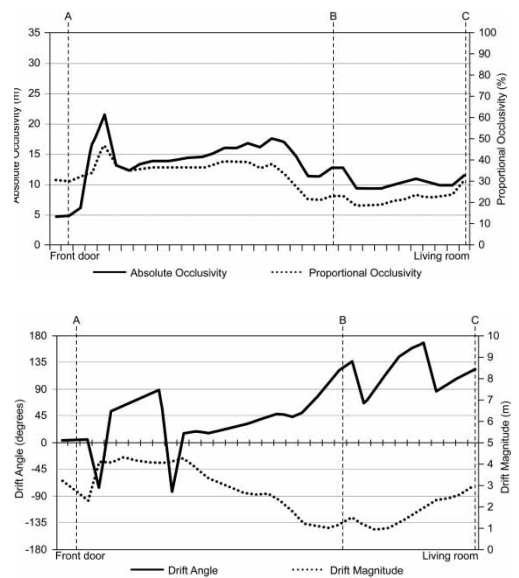
Figure 16. Affleck house: absolute and proportional occlusivity.

Figure 17. Affleck house: drift angle and magnitude.



boards that replicate its triangular *parti*, it features no 90° angles in plan, and thus movement into and through the house must typically conform to its equiangular constraints (figs 18–21 inclusive).

The exterior approach path from the carport to the Palmer house is largely linear with only a single 60° direction change (1) to reach the front door. The entry space (A) has a strong general sense of both refuge ($A = 26.77 \text{ m}^2$) and mystery ($O:P = 57.70\%$) along with a single long view to the



dining area ($RL_L = 9.20 \text{ m}$), establishing directionality ($D_M = 3.93 \text{ m}$). The path into the living room offers a steadily increasing prospect that stabilises once within the room (B) and view distances that increase near the hearth ($RL_L = 9.14 \text{ m}$) (C) before dropping slightly at the room centre ($RL_L = 9.01 \text{ m}$). Mystery also decreases as the occupant approaches and then enters the living room before stabilising as the entry passes out of sight (B) ($O:P = 25.04\%$). After entering the living room, visual pull directs attention to a region between the living and dining areas and moving towards the hearth requires resisting this increasingly strong sense of direction. The path to the living room threshold is one of discovery while the path within this space is

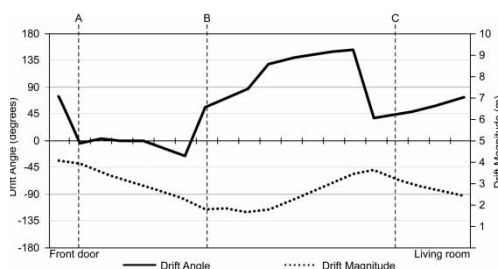
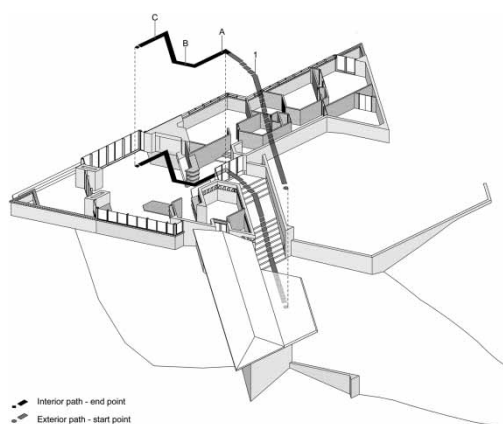


Figure 18. Palmer house: axonometric view of the path.

Figure 19. Palmer house: isovist area and radial line lengths.

Figure 20. Palmer house: absolute and proportional occlusivity.

much more passive. The centre of the living room in the Palmer house is one of high prospect ($A = 49.88 \text{ m}^2$), little mystery ($O:P = 26.56\%$) and only moderate directionality ($D_M = 2.52^\circ$ $D_D = 69.26^\circ$).

Figure 21. Palmer house: drift angle and magnitude.

Discussion

The mathematical trends revealed in the results for isovist area show that four of the houses feature a general rise in area across the length of the path, suggesting a shift from smaller to larger spaces, or from a refuge-dominant to a prospect-dominant experience (Fig. 22A). The only exception is the Schwartz house, where the occupant passes from a small entry vestibule through the prospect-dominant recreation room and then to the refuge-dominant nook of the lounge room, which has a marginally downward trend line. It must be remembered that the Schwartz house has no 'living area' only 'recreation' and 'lounge' rooms, and had the recreation room been used as the destination space this house would demonstrate a trend of rising isovist area conforming to the pattern established by the other houses. However, despite the broad similarity in four of the trend lines, the

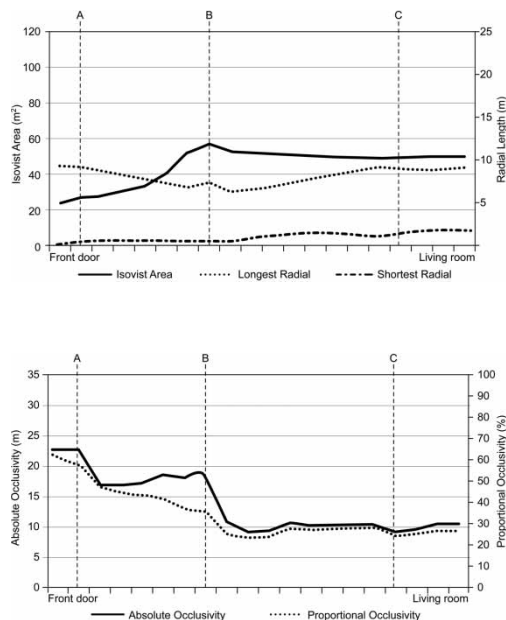
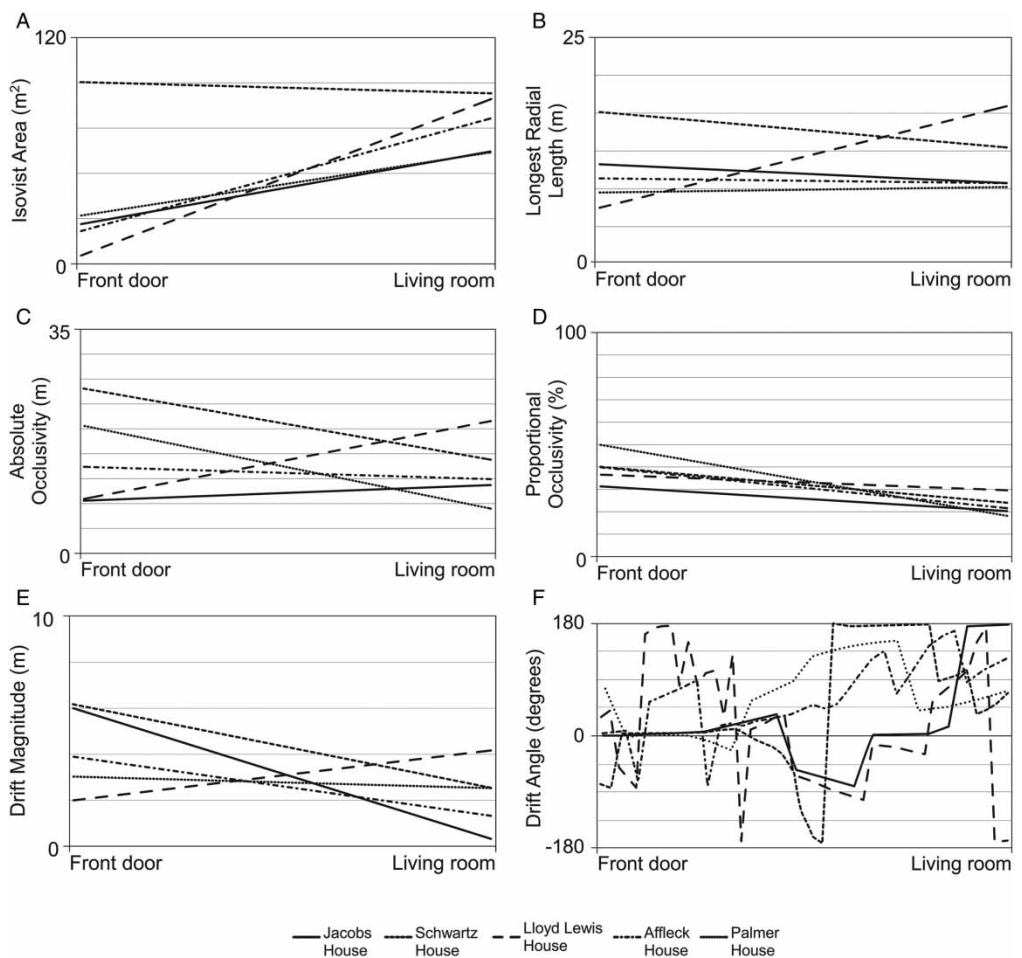


Figure 22. Isovist area trend lines. The length of each trend line is normalised to a single experience of motion commencing at the front door and ending in the living room, regardless of their physical length or number of steps:

A. Isovist Area;
B. Longest Radial Line;
C. Absolute Occlusivity;
D. Proportional Occlusivity;
E. Drift Magnitude;
F. Drift Angle.



graphs of each house are notably different. The Jacobs and Palmer houses both feature a rapid rise in area to a peak followed by a slight fall to a

relatively stable state thereafter. The Lloyd Lewis and Affleck houses each have steep sections separating plateaus in the data. One common feature of

all of the paths is that the area seen from the hearth is slightly smaller than the area seen from the centre of the room. While the visible area tends to increase along the length of the paths, longest view distance tends to decrease which indicates that spaces shift from long and linear to short and broad (Fig. 22B). The exception is the Lloyd Lewis house where long views only become prevalent after navigating the constricted entry and staircase and entering the living room.

There is no pattern in the results for absolute occlusivity (Fig. 22C). The Jacobs house has an almost flat trend line, while the Affleck and Schwartz houses both feature gently declining occlusivity. The Palmer house has a strong decrease in mystery as the occupant approaches the living room while mystery in the Lloyd Lewis house increases along the path. A stronger pattern of results is revealed in the proportional occlusivity data, where all of the paths display a decrease across their lengths (Fig. 22D). This indicates that while the absolute value of mystery varies across the houses, the isovists all become, relative to their scale and design, less occluded as the occupant approaches the end of each path. Again, the shape of each separate graph indicates little in the way of a consistent pattern within this overall trend. Furthermore, a decline in relative mystery as a person moves through the major thoroughfares of a house towards its core or largest room is a seemingly natural condition that does not necessarily constitute a unique pattern.

Three of the houses feature trends for drift magnitude that are generally decreasing across the length of the path, while one, the Lloyd Lewis

house, increases (Fig. 22E). Once again, this could imply there is a partial pattern in the way that space unfolds in each house, from spaces with higher longest radials to those with shorter equivalents. This broadly conforms to the general claim that people are led into and through Wright's architecture in a process of discovery. However, when the data for drift direction are also compared using a normalised path length (a linear trend line cannot be produced for angular data like this), it is readily apparent that the direction of drift, the visual pull Wright's architecture is so famous for, is completely inconsistent across the houses, and, up to 40% of the time, is in the reverse direction (Fig. 22F).

Conclusion

The first hypothesis of this paper predicted an increase in prospect across the experience of the path, as represented by increasing isovist area. Isovist area data reflected this hypothesis in 80% of cases and longest radial data decreased in 60% of cases because the gain in area came from more compact, less linear experiences. The second hypothesis was that higher levels of occlusivity should be present along the path leading to the living room, than either near the hearth or within the living room. While actual occlusivity levels vary between houses, proportional occlusivity showed a significant pattern of decreasing in every house by similar rates over the length the path. The third hypothesis was that the drift direction would typically be less than $\pm 90^\circ$ and that the drift magnitude would be higher at the start of the path than at its conclusion. Across the complete lengths of the

paths being analysed, 60% of the paths conformed to either of these conditions and yet only two houses conformed to both conditions. Thus, in combination, the data supports the first hypothesis and provides some more limited evidence to support the second and third hypotheses.

At the start of this paper it was proposed that, if the Wright Space exists, then a clear pattern or trends should be present in the data, regardless of all other theorised properties. Of the seven different mathematical indicators that were examined, three results (isovist area, longest radial line and proportional occlusivity) present the existence of a pattern, while drift magnitude, drift direction and absolute occlusivity partially confirm some of the features suggested by Hildebrand's theory. However, in every case except proportional occlusivity, at least one house presented data contrary to the hypothesis. All of which suggests that Hildebrand's arguments for the emotional power of Wright's Usonian houses might be valid even if they are not applicable to every one of Wright's designs.

If we accept that there is a partial pattern in the data, the question raised by this finding is whether the Wright space is unique to Wright and thereby significant in itself. While a full answer to this question is outside the scope of the present analysis, several of the mathematical patterns that were revealed in this study are those which common sense suggests might be present in the passage through any house from a small entry foyer to the centre of the main living space. For example, the Sears, Roebuck and Co pattern-book of United States house designs from the 1930s has many standard plans which feature a front door opening

directly into the living room or into a vestibule adjacent to the living room and then require between two and four turns to complete the path to the centre of the living room.

These typical suburban house plans, which were being constructed at the same time as Wright's Usonian works, feature more traditional and enclosed planning strategies and only limited views to adjacent spaces; however, many of them would also feature larger isovists near the living room centre and, across the length of the path, a minor decrease in drift magnitude and longest radial line length, and slightly decreasing proportional occlusivity, as found in Wright's designs. Such spatio-visual properties might be mathematically similar to those found in Wright's architecture; however, the designs clearly lack the subtlety of Wright's work. Wright's more open approach to planning creates spaces where portions of the house are gradually revealed and obscured to create a constantly shifting environment that encourages exploration, whereas the traditional plans in the Sears, Roebuck and Co pattern-book describe a series of largely enclosed rooms. Without a full isovist analysis of several of these designs it is impossible to determine whether a significant difference exists between Wright's architecture and contemporaneous suburban houses, but there are likely to be some mathematical similarities.

Ultimately, the Wright Space might well exist; however, many of the features of the Wright Space continue to defy quantitative explanation and additional measures are required to provide a more definitive answer.

A useful first step in enhancing isovist analyses of Wright's architecture might be including the third

dimension. Hildebrand discusses Wright's use of ceiling height variations to reinforce prospect and refuge experiences, and a study comparing correlations of ceiling height and traditional isovist measures might reveal unique patterns. Proportional occlusivity, the only measure showing a consistent trend in the Usonian houses, might form the basis of a more sophisticated measure of the seen and un-seen properties of a design. Introducing a coding system for occlusivity might help to explain the sensation of mystery that allegedly occurs where an occupant moves between spaces with similar occlusivity values, but with different view properties; for example, in order to gain a view of the dining nook a person might have to relinquish the ability to surveil the front door, but the degree of unseen space may remain the same. The sensation of spaces 'sliding' into and out of view, which such an example emphasises, is commonly attributed to Wright's open-planned designs, but is less likely to be found in the enclosed Sears, Roebuck and Co designs. A final, previously mentioned, limiting factor in the present study is the treatment of all windows as opaque surfaces. Even without the ability to incorporate and interpret the symbolic aspects of a distant view, allowing isovists to penetrate the building's skin will produce some significantly different results to those documented above. These results may, or may not, lend credence to Hildebrand's analysis. Alternatively, future analyses based on visual methodologies such as analyses of visual saliency might prove more useful in identifying and quantifying the particular spatio-visual characteristics that generate the positive emotional responses felt by those occupying Wright's architecture.

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