Handbook of Behavioral and Cognitive Geography

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19. Architectural cognition and behavior

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19.1. INTRODUCTION

Architectural cognition is a term that is just beginning to emerge in the literature, but it is still rare to read about it in academic texts let alone see it accurately defined. However, as a starting point for this chapter, we suggest that the relationship between psychology and cognitive science could guide us in determining the relationship between architectural psychology—a subset of environmental psychology with a tradition going back to the latter half of the 20th century—and architectural cognition. In other words, architectural cognition is to architectural psychology as cognition is to psychology.

Today, architectural cognition continues environmental psychology's traditional interest in the mechanics of how an environment affects its inhabitants. This involves studies of environmental stimuli as well as studies of resultant human behavior. Architectural cognition, like cognition, has built upon recent developments in the fields of computer science and neuroscience, which, if not precisely revealing the internal, mediational process of the mind, at least provide researchers with a model upon which to base these processes. As a result, the building, the behavior, and the cognition of the building user are equally relevant in architectural cognition studies and all, usually jointly, can become the subject of a scientific analysis.

In earlier work by the authors (Conroy Dalton et al. 2012), it was suggested that there are three distinct ways in which cognition takes place in relation to architecture/buildings: (a) the impact of architectural structure, function, and form on human perception, cognition, and behavior; (b) the impact of cognitive factors on the design of architecture; and (c) the means of interaction and communication between the designer and user perspectives (see Figure 19.1). Architectural cognition embraces all three of these.

The first of these, the person using the building, has traditionally been the realm of environmental psychology. The second, the act of the architect designing the building, is known as "design cognition." The third, namely the act of the architect anticipating the behavior of the user, as well as any form of communication between the user and the designer, is probably the least researched part of this diagram (but is tentatively explored in Tenbrink et al. 2014).

This chapter will focus on the building user—how people interact perceptually and cognitively with buildings. We will primarily consider building-level characteristics but will also explore some factors and implications at the neighborhood/urban design level. By focusing on how the user interacts with the building, we propose that there are three distinct ways this interaction can occur: *outside-to-inside*, *inside*, and *inside-to-outside*. We also distinguish two modalities in which it can be undertaken: while being *stationary* and

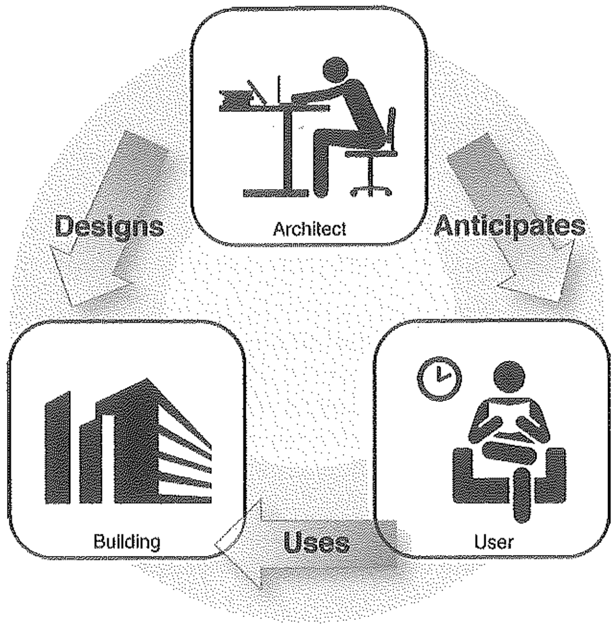
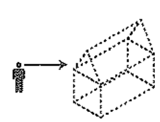


Figure 19.1 The three aspects of architectural cognition

while *moving*. The framework presented in this chapter therefore contains six modes: the way that we experience buildings from the outside (both statically and dynamically); the way that we experience buildings from the inside (statically and dynamically); and the way that we experience the outside world from within buildings (statically and dynamically). Table 19.1 shows each of these six modes, and indicates the main activities that take place in each of them.

The rest of this chapter will now summarize the primary research that belongs to each of the six categories in this framework.

OUTSIDE-TO-INSIDE + STATIC



19.2. LOOKING AT BUILDINGS

What processes occur when we pause and contemplate a building from afar? Weber, in his book on the aesthetics of architecture, points out that the period of time in which we view a building makes a difference to *how* we view it. He distinguishes between the "deliberate" and "spontaneous" consideration of architecture, whereby the first is predicated upon some type of "conscious reasoning" and the second is an "immediate apprehension" into which type he suggests that aesthetic judgements fall (Weber 1995).

Table 19.1 Framework for how users interact with buildings

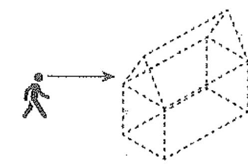
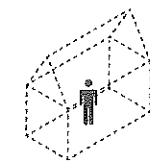
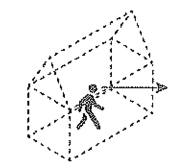
Relation	 Outside-to-Inside	 Inside (occupation)	 Inside-to-Outside
Static	Looking at buildings (from the outside) 1. Aesthetics 2. Meaning	Experiencing building interiors	Looking to the outside from inside
Dynamic	1. Approaching and entering a building 2. Moving through the city (past buildings)	1. Finding a new location in a building (path finding) 2. Following a habitual path (path following) 3. Free exploration	Finding exit and leaving building 1. Non-emergency 2. Emergency

Table 19.2 Related concepts of aesthetics and meaning

Duration of attention	Short (spontaneous)	Long (deliberate)
Weber's distinction	Aesthetic judgement	Conscious reasoning
Hillier's distinction	Aesthetics	Meaning

Aesthetics is the primary field that covers the act of "looking at buildings," and one which has a long history in architecture going back to Vitruvius and clearly brings together architectural theory, philosophy, and psychology/cognitive science. Aesthetics, in the context of architecture, is essentially about an individual's subjective, and often affective, response to the outward appearance of a building. The concept of "conscious reasoning" that Weber refers to bears a similarity to Hillier's work on the "meaning" of architectural form, which he also distinguishes as being entirely separate from aesthetics (Hillier 2011). This section will, therefore, focus on these two distinctive concerns, aesthetics and meaning, and their related cognitive concepts, which are summarized in Table 19.2.

19.3. AESTHETICS

Weber (1995) starts his book on the aesthetics of architecture with the question, "Do beautiful buildings and spaces have something in common despite differences in function, appearance, style, manner of construction, environmental and cultural conditions? Do they share common qualities that trigger similar experiences and judgements?" (p. 1). He then poses the question, "[are] aesthetic judgements . . . determined by characteristics of the object or by the viewer's own cognitive makeup?" (p. 4). This raises the first and most important consideration of work on aesthetics: *To what extent is our judgement a property of the object or the viewer?* And if it is entirely an individual response (i.e. there is no common agreement on what is "beautiful"), it is still the object that is acting as a stimulus to this response. What exactly is the nature of this stimulus? As Hillier (1992) asks: "What is it that we pick out on looking at these buildings that might provide the raw material for the higher order constructs of meaning or feeling?" (p. 2).

In architecture, writings on aesthetics tend to rapidly introduce terms such as "proportion," "scale," "balance," "order," "symmetry," and "harmony," often in a normative manner, explaining how one can use mathematics to design more aesthetically pleasing compositions. In architecture, this reliance on mathematics ranges from the use of classical systems of proportion, such as the golden section/ratio, to Le Corbusier's Modular (Corbusier 1954), to the field of computational aesthetics, such Birkhoff's "Aesthetic Measure," defined as the ratio between order and complexity (Birkhoff 1933), to information aesthetics and information theory (Moles 1966; Arnheim 1971). However, Cassirer (1951) cautions us that such mathematical considerations, in and of themselves, do not necessarily suffice: "Order, proportion, definite delimitation, and simple structure are usually taken as the characteristics of beautiful objects; yet these characteristics are obviously insufficient to comprehend all the elements which make up the aesthetically significant . . . as harmonious proportion and strict unity of form does not awaken in us the deepest emotions of the soul or the most intense artistic experiences" (p. 328). Scruton (1979) also finds these theories unsatisfactory as they claim to give only "a priori grounds for critical judgement" and "ignore some features[s] of architecture that [are] both intentional and of the greatest architectural significance" (p. 3).

In cognitive science, like Weber's question at the start of this section, there is a question about the affective relationship between stimulus and observer, given that the same stimulus can elicit very different judgements from people. This distinction can be characterized as *objectivist* (a property of the object) vs *subjectivist* (a property of the observer) views. Reber et al. (2004) argue that there is a middle ground between these views (they term it the *interactionist* view) based on the idea that "aesthetic pleasure is a function of the perceiver's processing dynamics: The more fluently the perceiver can process an object, the more positive is his or her aesthetic response" (p. 377). This perceptual fluency can be influenced by properties of the object, such as symmetry, visual clarity, figure-ground contrast, and lack of ambiguity (hence it relates to the early work of the Gestalt psychologists) as well as by characteristics of the observer, namely prior exposure/repetition of the stimuli ("mere exposure" effect) and individual expectations. It is a well-known fact (e.g. Gifford et al. 2002) that there are differences in aesthetic judgements between experts and novices (essentially architects and non-architects in this case), which could be accounted for by this theory of perceptual fluency.

19.4. MEANING

Meaning in architecture, according to Hillier, is all about noticing a relationship between things. He suggests that in architecture these relations can be based on "significance" and "signification." Significance is essentially about comparing an architectural "type" with all other examples of that type that we have previously experienced. For example, if we view a church, we compare it with every other example of a church we have seen (our "back catalogue" of churches if you like) and base its significance on its relation to the set of "all other churches," noticing inherent patterns of commonality; its meaning is derived from the outcome of this comparison. In contrast, "signification" is based on deriving meaning by reference to objects entirely external to the architecture, where their relationship is often semantic. So, again, in looking at a church, we may view the exaggerated verticality of the building's composition (tower/spire etc.) as being symbolic of the difference between man (low) and god (high).

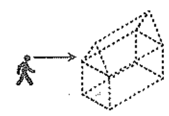
Meaning is related to concepts, categories, and classification in cognitive science. Cognitive scientists are interested in how we classify knowledge, how knowledge structures are represented, and how people acquire concepts (mental representations) of things. Concepts are fundamental to human thought, reasoning, and communication, as it is only by forming such abstract concepts that we can cope with the vast complexity of the world. The classic example in cognitive science is the concept of "dog": given the variety of different shapes and sizes of dogs, how is it we appear to have little difficulty recognizing them as individual instances of the abstract concept "dog"? It is clear that Hillier's definition of "significance" in architecture depends on the concept of "building." If we look at a specific building, we recognize it as a sub-type of the object class "building" (e.g. House → Residential Building → Building → Non-living thing → Object), and this is also clearly dependent upon our memories and past experiences of similar building types. Finally, in architecture, this is also related to a large body of research into the taxonomic classification of (usually physical) buildings characteristics, known as "typology" (although this work has scant interest in whether these "types" reflect our mental representations of them).

In conclusion, therefore, when we look at buildings we are doing a number of things. First we are recognizing them as buildings and most likely as a sub-type of building (i.e. a house or church), we may make semantic connections with external concepts such as "power" or "sacredness," we may make judgements as to whether we find it visually pleasing, and, finally, we may have an emotional response to it. Table 19.3 lists some of the key architectural concepts and the key cognitive concepts associated with looking at buildings.

Table 19.3 Architectural and cognitive concepts associated with looking at buildings

Architectural concepts	Cognitive concepts
Form	Object recognition
Meaning	Concepts and categories
Proportion	Memory
Scale	Judgements
Aesthetics	Affect
Order	Perceptual fluency
Balance	Mere-exposure effect
Harmony	
Beauty	
Type and typology	

OUTSIDE-TO-INSIDE + DYNAMIC



1. Approaching and entering a building.
2. Moving through the city (past buildings).

19.5. APPROACHING AND ENTERING A BUILDING

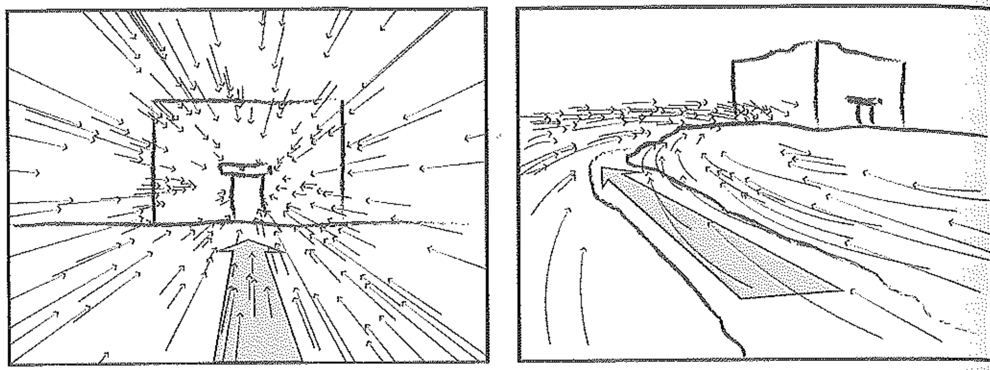
The idea of how to approach and enter a building, what is communicated to the user, and how the user, in turn, understands this interaction is something that is considered particularly important in architecture and has a long history in architectural theory. Most notably in the 19th century, Choisy made a study of ancient Greek architecture, and noted that, whilst the designs of Greek temples were highly ordered and based on clear mathematical principles, their placement on site and path of approach seemed inexplicably disordered. Through careful analysis, published in his *Histoire de l'Architecture*, Choisy (1899) suggested that their siting was deliberate, based upon a series of staged views intended to be experienced in a definite sequence (Van Zanten 1977). This focus on the designed approach and a highly controlled user experience became ratified in Beaux Arts principles, known as the "marche" of the scheme (Anderson 1979), which in turn was also influenced by earlier ideas of the staged "drama" of The Picturesque in landscape design. Another architectural term, to which this relates, is the "procession," about which the architect Philip Johnson (1965) states "the main point [of architecture] . . . is the organization of procession" (p. 168), the procession being the designed or staged route up to, or through, a building.

According to Ching (1979), a building can be approached in one of three ways, the "frontal," the "oblique," and the "spiral." Ching says: "Prior to actually entering a building's interior, we approach its entrance along a path. This is the first phase of the circulation system, during which we are prepared to see, experience, and use the building's spaces" (p. 248). This is echoed by Arthur and Passini (1992), who refer to the "frontal," "oblique," and "indirect" approaches to an entrance. They comment, in turn, that "the design of a path can tell the user whether he or she has access to the destination or not. Subtle clues make a difference in interpreting whether a path is private or public. Sometimes the message is confusing" (p. 130). Such cues strongly relate to Gibson's (1977) theory of affordances, defined as "a specific combination of the properties of [an object's] substance and its surfaces taken with reference to [the user]" (p. 67). It is such affordances, the "possibility of action", as Pallasmaa (2012) suggests, that "separates architecture from other forms of art" (p. 63). It is clear that a path's affordances can suggest, for example, its accessibility. Arthur and Passini (1992) note that a well-designed path leading to a building will communicate four things to the prospective visitor: (a) the direction of movement; (b) an understanding of the circulation system; (c) the relative importance of the destination; and (d) the degree of access (public/private). Combining all of this information (cues and affordances), the user is then able to make a decision as to whether it is the correct path.

Ching (1979) also notes how the experience of approaching a building is temporal and that it can be a compressed, direct, and short, or else, drawn-out, indirect, and lengthy experience. Clearly, one of the key cognitive processes that this relates to is that of anticipation, essentially the ability of people to predict the results of a highly complex set of interactions between themselves, their given situation or context, and any associated actions. Anticipation (along with prediction, preparation, prospection, or expectation) is considered a key component of predictive neural processing (Bubic et al. 2010). When a person is approaching a building, and perhaps following a path to get there, they anticipate both events and possible actions along the route and their subsequent arrival at the main entrance to the building. Where architectural theorists perhaps differ from cognitive scientists is in their treatment of the concept of anticipation. For architects, anticipation is something to be encouraged; the idea prevails that a heightened sense of anticipation will make the act of approaching a building more pleasurable. Johnson (1965) says: "It is known to the veriest tourist how much more he enjoys the Parthenon because he has to walk up the Acropolis [and] how much less he enjoys Chartres Cathedral because he is unceremoniously dumped in front of it" (p. 168). Thiel (1997) refers to anticipation as a "future experience" and highlights its importance as a criterion for judging the performance of public buildings. Johnson (1965) agrees with this; his advice to architects is that they should "proceed on foot again and again through [their] imagined buildings. Then after months of approaching and re-approaching, and looking and turning, then only draw them up for the builder" (p. 172).

Finally, it is clear that many of the cues available for a building user approaching a building are visual (although Arthur and Passini (1992) caution against taking only an oculocentric approach to designing this experience); it should also be noted that the three different approaches to a building mentioned earlier in the text, namely the frontal, oblique, and indirect, afford three very different kinds of visual experiences. If we consider Gibson's work again, the visual variances in these different approaches can be examined in terms of optic flow, which Marr (1982) terms, "the use of the retinal velocity field induced by motion of the observer to infer the three-dimensional structure of the visible surfaces around him" (p. 212). In other words, as we move through an environment, parts of our visual field move faster, relative to other parts, and some parts move hardly at all. These relative differences provide a rich source of information about the environment. If we approach a building "frontally," then the building is the focus of our attention and acts as the "singularity in the optical flow field" (p. 213). This is a very different visual experience to approaching a building "obliquely," where the focus of our attention (the building) is likely to be in motion, relative to other parts of the scene; for the "indirect" approach, the building's apparent motion can be increased further by adding rotational, visual motion to the scene. If we consider the approach to a building in terms of attention and information, it is clear that these different modes of approach described by Ching (1979) and Arthur and Passini (1992) are very different visually, perceptually and cognitively, as well as architecturally. Figure 19.2 shows the relationship between these different modes of approach and the resultant differences in optic flow produced. In Table 19.4 are listed some of the key architectural concepts and some of the key cognitive concepts associated with approaching a building.

As mentioned at the beginning of this section, we also experience buildings as we move past them, for example when walking through a busy town or city. The primary



Source: After Ching 1979.

Figure 19.2 The effect of angle of building approach on patterns of optic flow

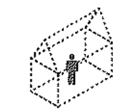
Table 19.4 Architectural and cognitive concepts associated with approaching a building

Architectural concepts	Cognitive concepts
Processional	Anticipation (context, action, result)
Picturesque	Optic flow and depth cues
Beaux arts' 'Marche'	Decision making
Viewpoints/vistas	Problem solving
Sequence	Affect
Hierarchy	Attention
Path	Distal and proximal stimuli
Threshold	Visual sequence
	Affordance

difference between moving past, compared with approaching, buildings is that for the former, the architecture is often relegated to the "background" since the subject might not be attending to it directly, whereas, for the latter, this action is purposive, attentive, and anticipatory. Despite the seeming "background" nature of buildings in the city, research has been conducted into people's perception of this phenomenon. Brettel (2009) considers the effects of "order" and "disorder" on people's qualitative judgement of different routes through different cities; she found that perceptions of "order" and "disorder" appear to be a product of the rhythm of sequences of buildings, open spaces and junctions along specific urban routes. Mavridou considers the effect of the scale and proportion of relative building heights, in an immersive virtual environment, on the cognition of the moving observer (Mavridou 2012) and Emo (2014) uses methods of eye tracking at road junctions to understand the relationship between urban stimuli and the potential route choice decisions made by people. Emo discovers that, rather than features of individual buildings being important, it is the more structural elements of the built environment, such as the amount of visible sky or ground and the presence of long lines of sight, that appear to influence the route choices of moving observers. This, in turn, provides an explanation for the finding, fundamental to space syntax research, that by modeling a neighborhood or

city as a network of longest lines of sight and applying topological measures of "centrality" to the resultant network, pedestrian movement flows can be accurately predicted (Penn et al. 1998).

INSIDE (OCCUPATION) + STATIC



Experiencing building interiors

What kind of cognitive processes take place when we are inside and inhabiting architecture? In many respects, the answer to this is *everything*, since the majority of our lives are spent inside buildings, sleeping, eating, working, or at leisure, in which case architecture forms the setting for the majority of our cognitive processes and subsequent actions—also known as a "behavioral setting" (Barker 1968). How many of these everyday, routine cognitive processes are either consciously focused on the design or appearance of the building (a direct influence) or are merely being modified or affected by the architecture (an indirect influence)? The indirect influence of architecture is, for the most part, how architecture makes us *feel* when we are inside a space, in other words, the realm of what might be called traditional environmental psychology rather than cognitive science. The architect Zumthor (2006) describes how, on entering a room, he forms an immediate impression of the space's "atmosphere" or "quality," "I enter a building, see a room, and—in a fraction of a second, have this feeling about it" (p. 13). There is some controversy around to what extent emotion is a cognitive process; however, at least since the 1960s (Schacter and Singer 1962), it has been proposed that there are cognitive aspects to emotion since it is possible to intentionally regulate our emotions, which is clearly a higher-level neural function (Ekman and Davidson 1994; Ochsner and Gross 2005).

Accepting that an emotional response to a building falls within the field of "architectural cognition," what kinds of features of buildings might elicit an emotional response and what kinds of responses? Does architecture have the power to make us feel positive emotions such as calmness, contentment, delight, amusement, or curiosity or, conversely, negative emotions such as, irritation, anxiety, worry, or even just boredom? Mallgrave (2010), in his work on neuroscience and architecture, suggests that, "the importance of our emotional well-being cannot be overestimated by architects." However, he goes on to lament that, "little research has thus far been done on how the variables of the built environment affect our emotional life" (pp. 191–192), although in his later book, Mallgrave (2013) suggests that our emotional response to an environment is embodied, holistic, and bottom-up. It is, however, worth remembering that the architectural setting is only part of many stimuli that can alter our emotional state. As de Botton (2008) pragmatically reminds us in his book on *The Architecture of Happiness*: "The noblest architecture can sometimes do less for us than a siesta or an aspirin . . . Even if we could spend the rest of our lives in the Villa Rotunda or the Glass House, we would still often be in a bad mood" (p. 17).

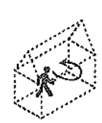
If we move on from the influence of architecture on our emotional state, we can examine the ways in which we consciously focus on the architecture around us. Such behavior would fall within the definition of what Rasmussen (1964/1959) first termed "experiencing architecture" in his book of the same title. He argued that,

> It is not enough to see architecture; you must experience it. You must observe how it was designed for a special purpose . . . You must dwell in the rooms, feel how they close about you, observe how you are naturally led from one to the other. You must be aware of the textural effects, discover why just those colors were used, how the choice depended on the orientation of the rooms in relation to windows and the sun . . . You must experience the great difference acoustics makes in your conception of space; the way sound acts in an enormous cathedral, with its echoes and long-toned reverberations, as compared to a small paneled room well padded with hangings, rugs and cushions (p. 33).

This act of architectural experiencing, as outlined by Rasmussen, is clearly a very deliberate, conscious, and controlled act, that involves many of the processes considered fundamental to cognition, such as object and pattern recognition, focused attention (both auditory and visual are mentioned by Rasmussen above), memory, object and relational concepts, and reasoning.

Collen (2009) further suggests that we experience architecture in four ways and by means of perception, cognition, and action. The first two ways are *sensing what is* (and he suggests that we do this either from a fixed position or by moving around, in a similar way that the framework in this chapter has emphasized the difference between static and dynamic architectural cognition). Collen's third way of experiencing architecture is by interacting with those very objects that we have already sensed statically or dynamically (i.e. in the first two ways). These objects can be moveable objects such as furniture within the room, or objects that form part of the architecture such as walls (which can, for example, be touched or leaned against), floors, stairs, or doors, etc. Finally, the fourth way, according to Collen, is to fully integrate the information gathered from these previous stages (p. 55). Therefore, it could be proposed that we perceive aspects of a building that suggest actions/interactions, or even *afford* actions to us, to use Gibson's terminology (Gibson 1979). For example, the size and shape of a door connecting two rooms, in combination with the position and shape of the door handle, might suggest to us, or *afford*, the action of reaching out and grasping the handle with our hand, turning the handle, and with a pulling-motion, opening the door, and then moving through it (see also Norman's (1988) book for an extended discussion of the relationship between the design of our everyday world and such affordances).

INSIDE (OCCUPATION) + DYNAMIC



Most navigational tasks within the dynamic building experience seem to fall under one of three broad categories:

1. finding a new location inside or a new route to get to a familiar location (path finding);

2. following a known path (path following); or
3. exploration (goal- and context-dependent).

The first two subsections below focus on indoor wayfinding studies, and special attention is given to the last category. As presented in the "Dynamic Outside-to-Inside" section, the dynamic processes involved in traversing built spaces are seen, in architecture, as a platform for designing interesting, engaging, and mesmerizing spaces. Consequently, transitional spaces of public buildings are hardly ever designed for their pure navigability, but rather for a combination of users' excitement, functional requirements, real-estate value maximization, *and* navigability (and often at the expense of navigability).

19.6. FINDING A NEW LOCATION IN A BUILDING (PATH FINDING)

Large public buildings introduce wayfinding challenges. Two main reasons for this are a user's unfamiliarity with the building (Gärling et al. 1983) and the features of the building itself, such as its circulation network (Best 1970), architectural legibility (Weisman 1981), and layout complexity (Gärling et al., 1986). This section will focus on large public buildings, as they are both: (a) likely to be unfamiliar to a large proportion of their visitors; and (b) often complex, in order to provide sufficient space—and organization of those spaces—to serve their social functions. When entering a large, unfamiliar building, a user would generally expect signage to sufficiently support their wayfinding effort. However, as common experience and formal research shows, this is often untrue; signage is often unable to prevent navigational errors, especially in more complex settings (O'Neill 1991). As a result, signage is never the only (and rarely the primary) element affecting indoor path finding, but rather one of many factors involved, to varying degrees, in navigational decision-making processes.

Faced with a choice between two alternative paths, we are likely to use different environmental cues and decision-making strategies to find our way through a complex building. Lines of sight leading from the navigator's location towards possible destinations, as well as their angle in relation to the believed destination-heading, have been shown to be the major factors influencing this decision (Conroy Dalton 2003; Wiener et al. 2012). Wiener et al. recorded eye movements as participants made decisions about selecting a left or right corridor in a goal-seeking task presented within a virtual-reality simulation of an indoor environment. Participants preferred to choose paths that offered longer lines of sight (a phenomenon earlier described by Conroy Dalton 2003), making this decision after gazing primarily at the area surrounding the horizon of the scene view. The authors suggest that humans might make similar decisions based on the geometry of the offered choices.

The issue becomes yet more complex when we are required to find our way around a building with multiple levels. Hölscher et al. (2006) showed how participants pick different navigational strategies and prefer to follow well-known paths when such knowledge is unavailable to them; if not, they either head first towards the horizontal position of the target or prefer to reach the correct vertical level before moving horizontally. Difficulty of the task and familiarity with the environment were listed as main factors affecting the choice of strategy, while staircase design was shown to be the main environmental element generating wayfinding difficulties.

The studies described above follow the line of thinking suggested by Gibson (1979) that assumes that the visual information accessible to the building's user provides "cues" potentially useful for further action, which decreases the need to rely on other sources of knowledge (such as memory of the building's layout). Researchers have therefore attempted to quantify those aspects of visual information accessible from those indoor spaces that might be relevant for human cognition. Benedikt (1979) popularized the concept of an *isovist*, which is defined as the two-dimensional polygon representing the area visible from its generating point on a top-down plan of the surrounding architectural space. Such a formalization allows us to consider the amount of visual information potentially available to a building user from each given point in space. Furthermore, the shape of this polygon (and its mathematical representation) can be indicative of the potential visual experience of that space. A more "spiky" isovist, for instance, can usually be found in rooms where the visual information is less stable as the perceiver moves through it. More regular isovist shapes approximating a circle will typically indicate that bodily movement will provide little new information. Turner et al. (2001) expanded this approach by calculating isovist properties for all possible generating points within a layout (at a chosen resolution) and using the space syntax-inspired graph-theory methods to account for the configurational aspect of the visual information's distribution in space. This, for instance, allows us to account for how distant a user is (in terms of the number of turns needed to be taken) to all other visual information in a building.

Indoor path finding is therefore hardly ever characterized by a complete lack of knowledge about the surrounding environment; a building's design provides navigators with a plethora of information which is used in combination with their existing knowledge and preferred wayfinding strategies to make decisions. Wayfinding activity inside buildings can be understood within a framework of three distinct factors and their interrelations: the building itself; the navigators' individual strategies and abilities; and the navigator's knowledge of the environment. Carlson et al. (2010) describe the relations between these factors: the *compatibility* of the building with wayfinder's individual strategies; the building's *correspondence* with wayfinder's knowledge (cognitive map) of it; and the *completeness* of that knowledge with regard to individual strategies (or what people, having different navigational strategies, remember of a building travelled with the use of such distinct strategies). A more detailed differentiation of specific cases involving distinct configurations of factors determining wayfinding performance (with the focus on navigator's knowledge and external constraints of the environment) is provided by Wiener et al. (2009; see also Montello 2014).

While wayfinding studies typically describe the process from the viewpoint of the user, relatively little has been said on the specific design properties of the building apart from the characteristics of its local features (staircases, visible path choices, etc.). However, the influence of a building on wayfinding performance can also lie in its overall layout, such as corridor configuration. As a result, the very location and "connectivity" (how well connected a space is to other spaces) of some locations in a building might facilitate their use. This has been studied by Peponis et al. (1990), who analyzed how the corridor structure of a complex hospital influenced the movement of people hitherto unfamiliar with that environment. The authors derive the concept of an "integration core"—a set of the 10% most-connected corridors that form the main axis of navigation through the building. As they demonstrate, this subset of key corridors is preferred during wayfinding search even when shorter paths are available. As building users prefer first to return to a more familiar area, move along more familiar routes, and deviate only when necessary to their destination, this "integration core" appears to be used in a disproportionally frequent manner. This demonstrates the mechanism through which building users acquire a set of predominantly used paths, possibly making them habitual over time. Another factor mentioned by the authors as potentially affecting this process is the use of spaces by other people (Beaumont et al. 1984; Peponis et al. 1990).

19.7. FOLLOWING A HABITUAL PATH (PATH FOLLOWING)

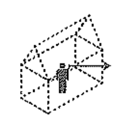
As we are likely to explore some paths more than others, we also get exposed to their content more frequently. Counterintuitively, this does not always directly convert into a better memory of those places. Applied studies of spontaneous memory have demonstrated that people are very unlikely to remember the locations of objects they never needed to use, such as fire extinguishers in their own office buildings (Castel et al. 2015). Habitual following does not accumulate knowledge of irrelevant details of the environment—at least for as long as they remain irrelevant. This is partially because people look more often at those objects which are relevant for their current task (Droll and Eckstein 2009). Similarly, people remember landmarks based, to a great extent, on the spatial importance of an object's location for their navigation (Miller and Carlson 2011).

19.8. EXPLORATION: TASK-DEPENDENT TRAVERSING AND BUILDING EXPLORATION

Many buildings serve functions that involve dynamic activities which incorporate wayfinding, although it is not the central component. Art galleries encourage viewing art while standing and walking, shopping malls afford strolling around the displays, and some religious buildings host processional rituals. In these cases, our cognitive processes are mostly dependent on the actual goal of our activity (Tatler and Land 2015), but we can identify some generic principles through which buildings affect them. First, a building's layout has an obvious influence on visitors' movement, pre-determining to various degrees what paths are possible. Choi (1999) describes this in detail using the example of museums. Some limit the connections between rooms so that it is possible to follow only a single path without backtracking, while others maximize the number of open connections between spaces so the visitor may follow multiple paths. Wineman and Peponis (2010), in the same context of museum exhibitions, proposed adding another distinction under the concept of *spatially guided movement*. The authors suggest that specific characteristics of individual exhibits (such as their location in space or visibility from other exhibits) can "nudge" visitors toward exploring the exhibition within a surprisingly similar set of route-patterns, yet still leave room for individual choice. The concept of spatial guidance therefore goes beyond what buildings *physically allow*, and suggests that there will be similar patterns of human behavior in buildings because of what they *encourage*.

Krukar (2015) further explored this framework by showing that not only movement but also eye gaze and memory are affected by the "background influence" of a building to a very diverse extent: while some of the cognitive processes are directly determined by the shape of the environment, others remain under the strict control of building users—with their own preferences and habits so strong that even a purposefully inefficiently designed space does not affect them. This is still an open area of research, with eye-movement and physiological measures offering new means to record the influences of space on human engagement with the art or other exhibits (Tröndle et al. 2014). Beyond the limited context of museums, some aspects of a building's spatiality have been linked to generic properties of our memory. A series of virtual reality experiments have shown how "crossing the door" between rooms makes people remember less information about objects that were carried between (as opposed to within) spaces (Radvansky and Copeland 2006).

INSIDE-TO-OUTSIDE + STATIC



1. Looking to the outside from inside.
2. Thinking about the outside.

When we are inside a building, we can look to the outside, typically through windows. But what cognitive processes are taking place when we do this? Two main research areas investigating how humans cognitively engage with the outside of the building have focused on the actions of *looking to the outside* and *thinking about the outside* (while occupying the inside).

When considering the *looking to* mode it is worth noting that, owing to modern architectural and urban planning, access to natural lighting is legally regulated in most countries; visual access to the outside has been traditionally understood as a measure of well-being (Farley and Veitch 2001). The positive influence of outdoor views on our well-being has been, for the most part, researched in the context of healthcare, especially since Ulrich (1984) demonstrated that patients staying in rooms with natural views required fewer painkillers and shorter hospitalization times compared with those staying in rooms with a view of a brick wall. Today, the detailed computation of outside views is included in the planning of hospital room layouts using dedicated software (Schultz and Bhatt 2013).

The importance of access to outside views has also been considered in office design. Counterintuitively, there is no consistent evidence for the role of outside views in improving work performance, although they do seem to enhance various aspects of employee's subjective satisfaction (Farley and Veitch 2001). In the private apartment context, where views to outside are often incidental, brief, and frequent, Kaplan (2001) reviews their numerous benefits to well-being, while Markus (1967) focuses on aspects of window size, design, and placement that might influence interactions with the window/outside. In residential as well as public and commercial building contexts, it is therefore valuable to have access to desirable, outside views, and this often directly impacts real-estate market

value (Benson et al. 1998). Formal models have been created to classify and compare these views on an urban scale, potentially allowing urban planners to design cities in a manner that maximizes such outdoor view access (Fisher-Gewirtzman 2014).

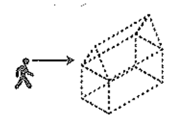
Seeing outdoor areas from the inside can have wayfinding benefits, too. Expanding on the knowledge of the building's layout-shape gained before entering (i.e. while approaching it from the outside: see the "Outside-to-inside + Dynamic" section), outdoor views can assist orientation inside the building by aiding *spatial updating* (Hölscher et al. 2006). These views assist with understanding which part of a complex structure is currently occupied by a user, which direction a user faces, and how close they are to its outer wall, which is especially important to users less familiar with the building's interior.

When considering the importance of outside views, it is worth mentioning that not all views are considered equally important. *What* is seen is one important factor, with a major distinction arising between seeing the natural vs built environment (Farley and Veitch 2001; Kaplan 2001). The formal arrangement of the viewing area is another important component: in some cases it might be critical to provide outdoor visual access from a specific point in a room (the head of a bed in a hospital), whilst in other cases, having particular visual access from *any* point in a room might be important. Having any part of one's bathroom visible from any part of a stranger's apartment can be a source of privacy discomfort, even if it rarely happens that anyone would jointly occupy the two points at the same time (for a formal classification of these relations using a 3-D isovist method, see Lonergan and Hedley 2016).

Our *thinking* about locations outside buildings can also be affected by the fact that we are located inside. In their study, Meilinger et al. (2016) asked participants to identify 10 familiar landmarks on the city map, while seated at a table inside one of five pubs/cafes in the German town of Tübingen. The orientation of one's body (seated at a table) as well as the cafe's location with respect to the tested landmarks both affected participants' spatial memory. Moreover, as buildings typically impose a strong environmental context, studies on the impact of context on human memory are also relevant. People can more easily recall information if the mental representation of the environmental context in which this information was remembered is accessible in the recalling situation (Smith 2013); in other words, being located in a place that is identical, similar, or at least reminiscent of the surrounding in which something happened, will help us to recall that situation.

It is important to note that the process of perceptual or cognitive engagement with the outside can be purposefully enhanced (as it often is in the design of apartments, offices, or hospitals) or purposefully limited. This is often the case in buildings hosting cultural activities (theaters, concert halls, art galleries) or in restaurants, bars, or cafes trying to create "atmosphere" (Kotler 1973). Kaplan et al. (1993) describe how the sense of *being away* contributes to the restorative character of museum spaces—their ability to help us recover from mental tiredness. In his manifesto of modern art curatorship, O'Doherty (1986) wrote that "the outside world must not come in, so windows are usually sealed off" (p. 15) in order to contribute to the overwhelming feeling of "a unique chamber of esthetics" (p. 14) that we experience in so many modern "white cube" art galleries. Finally, being able to look outside is intuitively understood as the converse ability of the outside to "look" at us inside. Yet, owing to the scale of some buildings and relevant design characteristics of the windows (Markus 1967), this feeling can greatly vary—for instance, when we are offered a hotel room with a glass outer wall, which, to any outside viewer, is only one of a thousand identical glass rectangles on the building's monumental facade.

INSIDE-TO-OUTSIDE + DYNAMIC



Finding the exit and leaving the building (two modes):
1. Non-emergency.
2. Emergency.

Leaving the building, under normal circumstances, is a process that uses similar wayfinding strategies to those already described in previous parts of the framework (Inside + Dynamic). A case which has not yet been described in this chapter, despite being covered in a wide range of research literature, is emergency egress. How people leave a building in case of emergency has been of interest to researchers from two distinct perspectives. One has focused on modeling crowd behavior at an aggregate level (Helbing et al. 2000). This includes processes such as faster, uncoordinated movement of the crowd (especially around bottlenecks), "herding" (following the actions of others), and a crowd's ignorance of alternative exit routes. Such computational models are based on empirical findings on human behavior in similar situations or surveys (Kinsey et al. 2012) and can be used to test the performance of buildings in case of emergency. Another line of research is focused on individual cognitive processes occurring under stressful situations involving finding one's way out of a building. This includes retracing the route to the initial entrance instead of finding the nearest exit (Johnson 2005) and reduced—"tunnel"—vision, potentially affecting the ability to follow signage (Easterbrook 1959; see also Christianson 1992).

Whether we leave a building under stress or in more typical circumstances, there is one more experiential event worth reviewing from the cognitive viewpoint. It is the pronounced shift of environmental context that one experiences when leaving a (structured, quiet, known) building onto a (busy, chaotic, relatively unstructured) city street. A great number of environmental factors affecting our cognitive processes rapidly change during this indoor-to-outdoor transition and are inevitably linked to the scale in which we experience the space (Montello 1993). For instance, lines of sight and distance to other objects suddenly become longer, our navigation is likely to depend on different types of landmarks, and our understanding of vertical transitions becomes less important (see Kray et al. 2013 for a comprehensive review of these and other differences). The social organization imposed by space also changes—from a highly structured classification of functional spaces to a dominance of transitional spaces traversed through by groups of strangers with unknown agendas. It is this transformation between the spaces of the "inside" and the "outside" that remains a relatively unexplored area of research in architectural cognition.

19.9. CONCLUSIONS

It should be clear from the previous sections that the framework presented in this chapter for considering the user's interactions with, and cognition of, architecture is useful for classifying and describing the manifold experiences and actions that take place in built spaces. We have given only the briefest of summaries of each of the six modes, as many of these, *aesthetics* for example, are the focus of entire books. However, the summaries provided in the sections above should be sufficient to provide a basic understanding of the critical issues in each mode. Taken together, this framework clearly articulates the scope of the emerging field of architectural cognition, especially with respect to the building user.

Finally, having completed this chapter, it might seem as if the very act of interacting with architecture is incredibly complex. If so, we can be reassured by Rasmussen (1964/1959), who reminded us sensibly that "architecture is produced by ordinary people, for ordinary people; therefore it should be easily comprehensible to all. It is based on a number of human instincts, on discoveries and experiences common to all of us at a very early stage in our lives" (pp. 14–15).

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20. Artificial intelligence and behavioral geography

Paul M. Torrens

I pointed out that his copy of *Binary File Transfer Monthly* was possibly the most boring document I had ever seen in my life. (Coupland 1995: 167)

20.1. INTRODUCTION

Artificial intelligence (AI) and behavioral geography have long enjoyed a symbiotic relationship. While AI was initially viewed as a tool that geographers could use to automate their work, that vista is shifting. Indeed, many authors—among them, Thrift and French (2002), Graham (2005), and Stephenson (1993)—have suggested that AI has become an autonomous producer, of a sort, *of geography*. This new view, of AI creating and shaping geography, is profound, in its suggestion that we have somehow ceded geography-making to machines and software. In this chapter, I will make the argument that the geography-smithing capabilities of AI are perhaps set to have the most significant impact in behavioral geography. In this chapter, I will review the growing fusion between AI and behavioral geography, beginning in the 1980s, when it was hoped that AI would help geographers *do* geography with greater efficiency, speed, and accuracy, and when there was significant enthusiasm for the technology ahead of something of a retreat from the community's good graces in the 1990s and 2000s. From there, I will pivot the discussion to the early 21st century, when the development of AI took off against a backcloth of ubiquitous computing and matured consumer AI products that made use of spatial data and geographical context to ascribe intelligence to devices and software. I will also discuss a range of potential applications in which AI and behavioral geography are closely intertwined, in the milieu of machine and computer vision, virtual worlds, agent-based models, human–computer interaction, and cyber–physical systems. The motivation, in highlighting these applications of behavioral geography and AI over other uses, relates partially to my own vantage on the topic, as well as to near-future developments for AI and behavioral geography. This latter topic serves as the focus for concluding remarks.

20.2. BACKGROUND

The development of AI can be traced back to the very beginnings of the age of digital computers. Alan Turing was among the first to sketch the tableau for AI while outlining his ideas for intelligent machines. After years working on the problem of whether machines could be fashioned to compute, Turing (1936, 1938) posited the simple and provocative question of whether machines could think (Turing 1950). This set into motion decades of deliberation about what might be considered as intelligent in a machine, and how machine AI may compare with or contrast to human intelligence.