

# FINDING THE BUILDING IN WAYFINDING

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**ABSTRACT:** This article uses a limited example to demonstrate that studies of wayfinding and spatial learning can benefit from a more rigorous analytic description of building layout and exploration paths that exhibit their own pattern. In at least one case, search patterns are strongly shaped according to the degree of integration of each space and each choice node of the circulation system within the overall layout. Given this over-riding trend, we formulate the idea of a *search structure* whereby the intelligible properties of layouts interact with navigation rules to produce characteristic patterns of exploration.

**The growing body of literature** about the way in which people explore, learn, and find their way around their architectural environment often appears to deal with the question: "How do people come to know their environment?" However, much less attention is given to the question: "What is there to be known about the environment?" So much so, that in a recent review of the literature, Golledge concluded, among other things, that "the fundamental question that all researchers would raise and that has barely been touched is: How do variations in the environment itself influence the cue selection and the storage of environmental information?" (Golledge, 1987, p. 164). The question

that interests us in this article, stated simply, is this: How far can we, on the basis of an analysis of the physical layout of built form, anticipate aspects of wayfinding behavior? The question can perhaps be interestingly rephrased: In what ways can building layout be treated as data relevant to the analysis of spatial cognition?

We believe that these questions have eluded satisfactory answers due to two kinds of difficulties: (a) There is a scarcity of theories and analytic techniques to deal with the architectural environment as a knowable morphology; (b) The ways of obtaining data and describing the empirical phenomena associated with wayfinding research may enhance our understanding of some of the variables involved while blinding us to others.

The aims of this article are largely methodological. We present a limited case study in which the techniques of syntactic analysis developed at University College London, are applied to describe and quantify structural properties of building layout. In this article, we argue that these properties help to throw new light on wayfinding performance. More particularly, we suggest that after relatively brief exposure to a building, people tend to consistently direct themselves toward the spaces from which the rest of the building is more easily accessible. Thus they seem to acquire an understanding of configurational properties rather than merely relying on landmarks, signs, or other cues. Interestingly, these same configurational properties are related to the likelihood of encountering others during ordinary building usage.

We also suggest a partially new emphasis in the identification and collection of relevant wayfinding data. More particularly, we suggest that our data must deliberately reflect the distinction between the general understanding of layouts and the search for specific destinations. From an "applied" or an "organizational" point of view, the second question is undoubtedly more urgent. From a theoretical point of view, however, we believe that we cannot fully deal with the second question until we also learn to deal with the first.

### THE DESCRIPTION OF BUILT FORM

Perhaps the easiest way of illustrating the endemic problems arising with our descriptions of built form is by referring to the deceptively suggestive idea of a *landmark*. Lynch (1960), to whom the idea is often referred, was careful to point out that, depending on people's familiarity with an urban context, many different things at many different scales could function as landmark references, from tall buildings to architectural details. Many years later Weisman (1987) also suggested that many different things may qualify places as landmarks, in the context of complex buildings, from their visual characteristics to their distinctiveness or their functional importance. Similarly, Evans, Smith, and Pezdek (1982), in their attempt to further test and extend the earlier findings of Appleyard (1970), report that the ability of people to recall a building and its location in an urban context depends on a wide range of factors including shape, the number of persons moving around the building, the degree of physical maintenance, and height. Thus, although the idea of *distinctive* may be at the core of what we mean by a landmark, the criteria of what characteristics produce distinction remain elusive and varied.

Faced with the idea of a landmark we are therefore in a peculiar situation. From the point of view of cognitive theory, the landmark seems to refer to a particular way of organizing, anchoring, or remembering information with reference to discrete points as distinct from the more abstract properties of relational patterns. Indeed, much discussion about landmarks is framed in terms of a hypothesized progression from an "egocentric" to a "hierarchically coordinated" to a "fully coordinated" form of representation (Golledge, 1987). From the point of view of a theory of built form that can be specified without relying on individual experience, however, the persistent lack of precise definition suggests that the idea of landmark hinders rather than helps understanding. It conflates many separate issues, some that are individual and idiosyncratic, and others

that are general and measurable, and some of which are more clearly understood than others, into a single notion.

If the landmark is a most popular concept, *configuration* is perhaps the most difficult one to describe in an objective and analytical manner, despite the fact that psychologists and geographers alike converge in treating the understanding of configuration as the ultimate stage of spatial cognition (Hart & Moore, 1973) and that several research projects and reviews have suggested that overall configuration and complexity are important influences on the ease of wayfinding (Evans, 1980; Gärling, Bök, Ergenzen, & Lindberg 1981; Gärling & Golledge, 1989). The term configuration itself may require some working definition. In this article, configuration refers to the way in which spaces are related to one another, not only pairwise but also with respect to the overall pattern that they constitute. In other words, configuration is about the overall pattern that emerges from pairwise connections rather than elements or single connections taken by themselves.

For the purposes of our present argument we limit our discussion to what we see as critical methodological issues and to selected examples from studies of wayfinding and cognition in buildings. Weisman (1981) found that judges' ratings of the complexity of drawings representing building layouts were correlated with students' self-reported frequency of getting lost in those buildings. Weisman compiled a table of 30 diagrammatic corridor patterns expected to be associated with differing degrees of wayfinding difficulty. At first sight a number of comparative dimensions are suggested: Sometimes the basic topological structure is at stake—corridors with or without loops—sometimes the number of corners, sometimes the length of different branches or the angles at which they intersect. Yet, the research produced no clarification as to which of these comparative dimensions might relate more suggestively to wayfinding performance. Instead, subjective assessments were obtained and the sample of corridor diagrams was rated according to the degree of complexity, the ease of memorization and description,

and the expected difficulty in wayfinding. Correlations were then sought between the kind of corridor layout that fared poorly in this assessment and the kind of corridor layout that was found in a sample of actual buildings with a record of wayfinding problems.

The obvious shortcoming of this approach is the absence of a clear analytical definition of the configurational variables involved: Lacking a reliable way of measuring configuration there would seem to be no reliable way of applying research findings to predict the performance of a proposed new plan. But Weisman's own findings added further puzzles. Whereas the judged complexity of plans was strongly correlated to the frequency of disorientation, the correlation between "anticipated" wayfinding ease (as judged according to the diagrams) and reported wayfinding performance was "less significant." This led Weisman to call for more objective measures of wayfinding behavior (an issue we will discuss later) but not, unfortunately, for a descriptive theory of built form.

Due to the difficulty of dealing with the configurational variables, a number of studies have chosen to simplify them (e.g., Evans, Skorpamich, Gärling, Bryant, & Bresolin, 1984 compared two specific paths rather than two overall environments) or to keep them constant, as with a number of studies that compare the performance of different groups within the same setting in order to test whether familiarity (Moeser, 1988), training (Hunt, 1985; Moeser, 1988; Weisman, 1987), signage (Beaumont, Gray, Moore, & Robinson, 1984), or other nonconfigurational variables might influence wayfinding performance.

At the same time, concern with configurational variables is persistently expressed in the literature (Gärling & Golledge, 1989; Weisman, 1985). Among other reasons, this is due to the obvious fact that navigation through any complex architectural environment cannot depend wholly upon direct visual perception—which is comparatively localized—but requires a more abstract understanding of the way in which local parts are interrelated into a whole pattern. Furthermore, some studies

(Beaumont et al., 1984) have cast doubt as to whether signage is in itself able to direct people and to act as a substitute for an intelligible architectural arrangement.

In this article we argue that further progress depends on the introduction and development of analytic and comparative techniques for describing the built environment, and on the configuration of layouts in particular, as a knowable structure. Our emphasis on the configuration of layouts is consistent with the discussion described earlier that overall configuration is influential in wayfinding and that understanding of configuration is often the final developmental stage of adult learning of settings. Methodologically, we share the suspicion, broadly discussed in the field (Evans, 1980; Hart & Moore, 1973), that the way people verbalize or draw their understanding of the environment may be quite different from how they actually conceptualize or navigate through it. In everyday life it is often easier to direct a stranger to a destination by using landmarks as signposts than to convey the more tacit understanding of paths, of shortcuts, and of the economy of the decisions that balance distance against interest, pleasure, a feeling of safety, or other considerations.

### THE EMPIRICAL PHENOMENA

In most of the literature, wayfinding performance is analyzed either according to self-report (Weisman, 1981) or according to the ability to recall and/or locate places on a plan of the premises (Evans et al. 1984; Moeser, 1988). Sometimes wayfinding performance is quantified in terms of the proportion of subjects who are able to reach a particular destination (Beaumont et al. 1984; Weisman, 1987). Direct observation of wayfinding is relatively rare, and even when it is attempted it is not always clear what is being recorded and how it might be analyzed. For example, Beaumont et al. (1984) tracked visitor's progress in a government office; the tracking data, along with interviews, was used to determine which factors influence wayfinding. However, the wayfinding performance itself is not described in any systematic

way. And Moeser (1988), who also did some tracking as part of training subjects to know a hospital building, was more interested in whether after the training people were better able to estimate distance or to mentally construct a path to a specified location than in the actual navigational performance during the training.

Studies that have used protocol analyses, sometimes called *loud thinking*, have asked wayfinders to report on their wayfinding decisions (see, for example, Passini, 1984). Whereas these studies have clarified those aspects of wayfinding accessible to conscious thought, they have not specified qualities of the building configuration.

It seems to us that further progress in the field depends upon sharpening our ability to describe the actual wayfinding performance of subjects as being, in itself, a spatial pattern that can be systematically described. Indeed, as subjects navigate through a building they may return more frequently to some key locations, or they may systematically prefer certain paths over others. Until we know how to identify and analyze such features more rigorously, on the basis of tracking records, we will not be able to identify the objective basis of those comments that are made explicit through questionnaires or interviews. What is worse, we may be blinded to any regular characteristics of wayfinding performances that are simply too difficult and too complex to become readily verbalized.

### THE IDEA OF THE SEARCH STRUCTURE

The third item on the agenda of our preliminary theoretical discussion will also allow us to introduce our own research premises and methods. *Wayfinding* is a term that can refer to a rather narrow concern: That is, how well people are able to find their way to their particular destination without delay or undue anxiety. For example, how well can a patient find the outpatient unit in the hospital from the entry? Such questions are important but may mask that people are operating within a particular set

of organizational and situational constraints: The organization may demand that people use the building in a natural and clear way or may demand that they use it counterintuitively. We are all familiar with organizations that use heroic measures of elaborate signs, handouts, painted lines, and guides to accomplish adequate wayfinding in an incomprehensible building. Asking the question in this way can mask the fact that certain things may be intelligible about a building irrespective of our ability to locate a particular destination.

In fact, we propose that the link between the general intelligibility of built form and specific wayfinding performance is the construction of what we would like to call a "search structure." Buildings, as purely spatial configurations, make themselves available to search in different ways. What makes the idea of a search structure theoretically interesting is the fact that the intelligibility of built form on the one hand and wayfinding performance on the other need not be related in any simple way, in spite of the contrary assumption that is often implicit in the literature. For example, within a labyrinthine museum exhibition layout that offers few circulation alternatives other than backtracking, people may be made to see the exhibits in a particular sequence, that makes it unlikely that any particular item will be missed. However, in this hypothetical case exhibition, visitors may have no sense whatsoever of the building's configuration or shape. On the other hand, in a museum building with a highly visible atrium, one may always have a sense of general location and orientation. However, one may be uncertain about the locations and relationships between exhibits, which may or may not be accessible from each other independently of the atrium. As a result, one may understand overall building form but may find wayfinding difficult. Similarly, the path may be so constrained that wayfinding is easy, but the user may not understand the overall building.

The theoretical question we would like to ask is this: How do buildings lend themselves to exploration—how do they become available as search structures, bringing together the intelligibility of architectural form and the ability to reach particular destina-



tions? We believe that learning to deal with this question in some general way is the precondition for understanding particular aspects of routine wayfinding performance under specific organizational constraints.

### AN EXERCISE IN OPEN SEARCH

Homey Hospital is a 100-bed hospital opened in 1986 and designed to depart from the institutional appearance of conventional hospitals. There is an extensive use of natural light, "homelike" natural materials and colors and symbols of home, such as providing a "living room" with a television. Efficient wayfinding was an explicit and major concern on the design agenda. The plan of the main floor of Homey Hospital is shown in Figure 1. In spite of the design intentions, as currently used, the hospital seems to generate a number of wayfinding problems, which are clearly indicated by the proliferation of formal and informal signs on its walls.

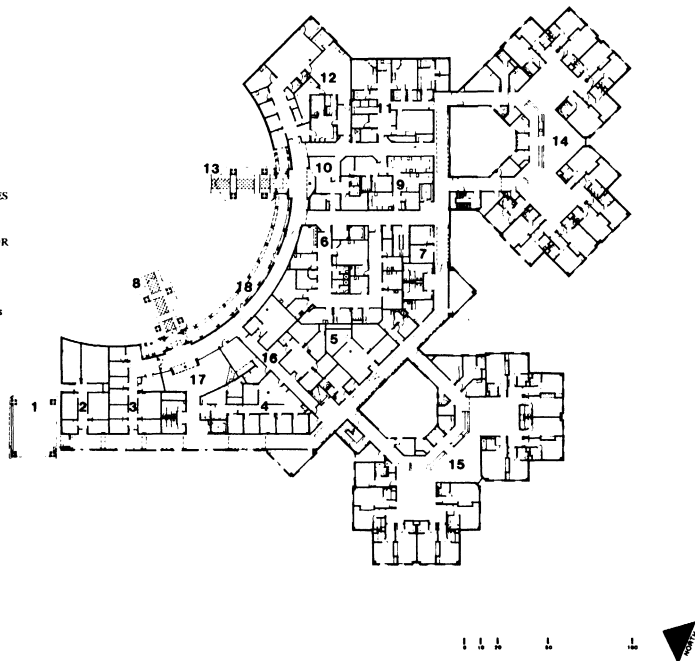
Interviews with staff suggested that wayfinding problems caused considerable loss of time to those who had to escort or direct patients. Also, outpatients and visitors did not make full use of hospital amenities. For example, some patients have been unwilling to walk only 100 feet to the TV lounge or to use the halls for exercise for fear of not being able to make their way back in time. But most of all, wayfinding problems seem to prevent a carefully designed building from being used to its full potential for professional and humane care.

An intuitive examination of the plan reveals several characteristics that might be responsible for wayfinding problems. First, in the interests of eliminating length, corridors are broken into segments that reduce the extent of direct visibility toward the various facilities. Second, corridor junctions are slightly offset with respect to each other so that one cannot register many connections at once. Third, corridors have similar width and length, meaning that they cannot be easily distinguished. Fourth, most corridors do not open to any significant space at

### Homey Hospital

- 1 AMBULANCE DOCK
- 2 HEALTH
- 3 BUSINESS
- 4 ADMINISTRATION
- 5 EDUC/RESEARCH/CONSULT
- \*6 DIAGNOSIS/TREATMENT
- 7 SUPPORT/STAFF
- 8 MAIN ENTRY
- 9 LAB
- \*10 OUTPATIENT RECEPTION
- \*11 RADIOLOGY
- 12 REHABILITATION THERAPIES
- 13 OUTPATIENT ENTRY
- 14 MEDICAL PAVILION
- \*15 ASSESSMENT PAVILION
- 16 ADMINISTRATION CORRIDOR
- 17 TV LOUNGE
- 18 LOGGIA

\* Locations used in Wayfinding Tasks



**Figure 1: Plan of Homey Hospital Showing the Locations of Main Departments, Including Those That Were Used for the Wayfinding Experiment**

either their end or along their length, which compounds the difficulty of distinguishing between them. Fifth, the creation of recesses and slightly wider spaces in front of some of the departments means that the actual entrances cannot be seen until one is very close to them. Sixth, some departments do not have a clear "reception point" so that it is not obvious when one has actually "arrived." All of these potential problems are compounded by an inconsistent signage system.

In addition to pursuing these characteristics, whose relevance is suggested by the existing literature (Carpman, Grant, & Simmons, 1986), we have used Homey Hospital as a laboratory for exploring some of the theoretical ideas presented above while at the same time dealing with a specific problem. As part of our studies, we asked 15 undergraduate and graduate students, from the schools of architecture and psychology, to engage in a number of search, wayfinding, and orientation tasks. Subjects were met at the visitors' parking lot, and their first task was to spend up to 15 minutes walking freely around the building in order to familiarize themselves with it, with the knowledge that they would then be asked to perform specific wayfinding tasks. All of the subjects except one said they knew the building well before the 15 minutes were over and voluntarily stopped the open search phase. The exercise was carried out on Saturdays, when the outpatient departments were not in operation and when the likelihood of meeting people in the hospital corridors was greatly reduced. Subjects were instructed to use all signs and cues but not to ask any questions during the open search phase. They were to feel free to go anywhere unless stopped by the researcher, who followed them, recording their path on a hospital plan.

#### A SYNTATIC ANALYSIS OF OPEN SEARCH PERFORMANCE

In order to analyze the tracking records from the open search phase, we first analyzed the plan of the building, using the theory of *space syntax* developed at University College London (Hillier,

Burdett, Peponis, & Penn, 1987; Hillier, Hanson, & Graham, 1987; Hillier & Hanson, 1984; Hillier, Hanson, & Peponis, 1984; Peponis 1985). Space syntax focuses on the way in which the spatial structures of complex buildings and urban areas become a recognizable part of culture by both reflecting and creating patterns of use and encounter. As part of this project, space syntax has aimed to give an analytic definition of the properties of layouts that are involved with the way people locate themselves and circulate in buildings. Here we give a very brief introduction to the key technical ideas that we use in our analysis, referring the reader to the above-mentioned publications for a fuller account.

Space syntax describes layouts in terms of the pattern of connections between spaces. The precondition for all further analysis is the identification of "units" of space. In the interests of consistency, but also for theoretical reasons, two conventional ways of breaking up a layout into its constituent spaces have been established.

The first deals with two-dimensional extension and is called a *convex map*. The convex map comprises the fewest and fattest convex spaces that can cover the layout. By definition, a convex space has all of its two-dimensional extension directly visible from each of its points. Convex spaces are the largest units that can be fully perceived at one time within a building and can thus be taken to represent the "local constituents" of a layout. Convex spaces are the most elementary units of analysis.

The second deals with linear extension and is called an *axial map*. The axial map comprises the smallest possible number of straight lines that must be drawn in order to cover all the available connections from one convex space to another. Thus the axial map tries to recapture the overall sense of connections that is given to a person moving about a building. Axial lines represent the longest views across spaces whose full area may not be visible. Axial spaces can therefore be taken to represent the *global constituents* of a layout.

The basis of our analysis in this article is the axial map. We have selected this because previous research findings have

suggested that the axial representation of layouts is most strongly related to patterns of use. Also, axial relationships would intuitively appear to be more critical when the exploration of an unfamiliar environment is at stake. Whether this methodological choice was justified can perhaps be judged according to the results that we have obtained.

Once the units of analysis have been identified, the main aim of syntax is to quantify the extent to which each of the spaces is directly or indirectly connected to other spaces. A connection between two spaces or axial lines is direct, or *shallow*, when few intervening spaces have to be traversed in order to reach one from the other. Conversely, a connection is indirect, or *deep* when a large number of intervening spaces must be traversed, even after the shortest route to a destination is identified. A space is said to be *integrated* when *all* the other spaces of the building are relatively shallow from it. Conversely, a space is said to be *segregated* when all the other spaces of the building are relatively deep from it. Hence integration is a measure of the relative position of a space or axial line vis-à-vis the general pattern of the building configuration.

Central to the theory of space syntax is that space use is related both to spatial configuration and organizational rules and practices. Unless rules or other organizational factors intervene, the building layout creates probabilities of encountering others: One is more likely to encounter other people in more highly integrated spaces, although integration may vary for different categories of people. A given corridor may be relatively shallow to staff spaces, for instance, but deep to public spaces.

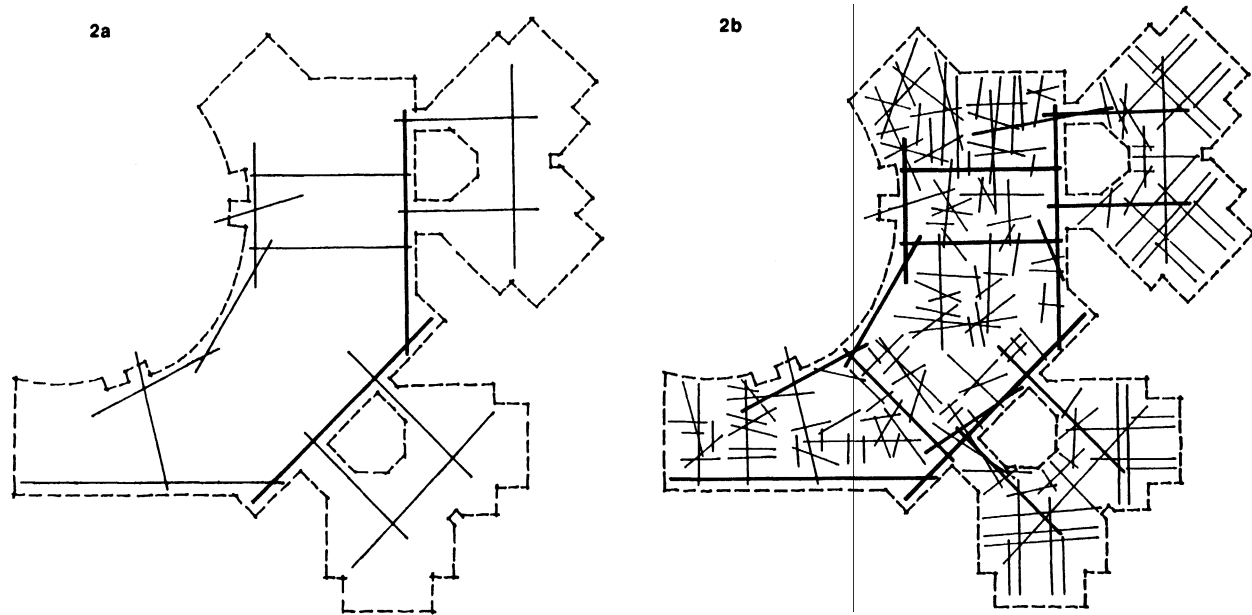
Integration or segregation is judged according to a measure technically referred to as *RRA value*. The calculation of RRA values is obtained by a computer analysis of a graph representing the number of changes of direction or space between a space and all other spaces. RRA values are based on counting the least number of spaces that must be traversed from each space to all the others.<sup>1</sup> When dealing with an axial map, high integration means that few changes of direction are necessitated in order to move from a space to other parts of the system.

It must be emphasized that integration does not describe metric distance: It is the number rather than the size of spaces that are considered in computing depth or integration. Consequently, the syntactic description of accessibility differs from those more frequently used in the literature.

Not only can we use *integration values* to differentiate one space from another within the same building, we can also use the average integration value of a building as a whole in order to compare it to other buildings. Previous theoretical and empirical findings, some of which are mentioned and discussed below, suggest that integration is the central analytical concept of syntactic analysis.

Among other things, the analysis of integration leads to the identification of the *integration core* comprising a given proportion of the axial spaces that are most integrated, usually the 10% with the highest integration rank. It will be shown below that the integration core may be critically involved with the pattern of wayfinding.

Figure 2 shows the axial map and the 10% integration core of Homey Hospital. This, interestingly, is clearly biased toward the back of the building: A visitor has to venture a long way into the building before reaching the core. Because the integration core is the domain from which the rest of the building is more easily available, this means that most of the connections between spaces are not revealed at the earlier stages of exploration. Furthermore, the most integrated corridors are not directly connected to the primary diagnostic, treatment, and therapy rooms. Thus the spaces most likely to be used by patients as they traverse the building are not necessarily directly linked to the key areas where patients and staff interact. This may also play a role in generating wayfinding problems. However, it may be an important medical and organizational requirement to provide some separation between main circulation and primary-use spaces, such as examining and treatment rooms (Hillier et al., 1984). The important design issue, rather, is how to provide the required degrees of local separation for organizational



**Figure 2: Axial Map of Homey Hospital**

NOTE: Thick lines represent the integration core—the 10% of the total number of spaces that rank highest according to the syntactic measure of accessibility. 2a shows the main circulation system only, and 2b covers all spaces.

functioning as well as the overall pattern of integration which facilitates movement and orientation.

In order to ascertain whether the pattern of integration was relevant to the way in which the building was searched, we studied the correlation between the degree of integration of the different axial spaces and the total frequency of use of each space by the 15 subjects during the open search. For the purposes of such computation we ignored backtrackings other than those which covered a considerable length, at least from one corridor junction, or end point, to another. To our surprise, the correlation coefficient turned out to be quite strong and statistically significant, whether we consider integration with respect to the circulation system only ( $r = -.757$ )<sup>2</sup> or with all rooms on the main floor, including those only available to staff ( $r = -.617$ ).<sup>3</sup> (The all-rooms correlation is  $-.746$  after eliminating the administration corridor, which was clearly under-used.)<sup>4</sup>

To refine the analysis we then decided to deal not with axial lines but with *choice nodes*. A node was defined as the intersection between at least two axial lines<sup>5</sup> and was a place where an individual had to choose in which direction to proceed. Nodes were given the average integration value of the lines which define them. The correlation between the overall frequency of use of each node during the open search and its integration value was also surprisingly strong and significant, whether we considered integration with the circulation system only ( $r = -.778$ ) or with the whole floor ( $r = -.606$ ;<sup>6</sup>  $r = -.759$  when eliminating search into the two circulation dead ends).

Both results suggest that open search was biased toward some spaces more than toward others, in proportion to their degree of integration. Explaining this may be open to both speculation and further work. We propose, however, that our analysis has revealed a phenomenon that permits us to talk more objectively about *search performance* as something with regularity that is dependent on specifiable and measurable qualities of the overall building configuration. In the next section we extend the analysis by considering the performance of



*directed* wayfinding tasks in which people were asked to find specific locations.

### DIRECTED SEARCH AND INTEGRATION

After the completion of the open search phase, subjects were asked to perform directed searches for specific locations. As before, subjects were allowed to proceed as they wanted and to read any signs that were available but were prevented from asking questions. More particularly, different subjects were asked to perform different path combinations so that when considering the group as a whole, each of four main hospital units—the assessment unit, the radiology department, the diagnosis and treatment area, and the outpatients' reception—acted as both origin and destination from the other three units. Figure 1 indicates the location of the four units. The 15 subjects performed 83 tasks. As before, subjects were followed by a researcher, and directed search paths were recorded on plans of the hospital. In only one case was a subject totally unable to locate one destination (the diagnostic area) from a point of departure (the reception).

One way we analyzed these data was as follows. Each search path was transcribed as a sequence of choice nodes in which the wayfinder had to make a decision about direction. For each task, we determined what was the path, or the set of paths, that could reach the destination using the minimum number of nodes. Nodes used in excess of this minimum number were defined as redundant. Redundancy was treated as a measure of *wayfinding difficulty*.

We then computed the average frequency of redundant use of each node as follows. First we calculated the redundant frequency associated with each task and divided by the number of subjects who performed the task in order to get a task mean. Then, we calculated the overall mean of all the task means. To our surprise, we found a high and statistically significant corre-

**TABLE 1**  
**Correlations Between the Frequency of**  
**Redundant Use of Choice Nodes and Their Degree of**  
**Integration, According to Various Categories of Wayfinding Tasks**

*Total Node Redundancy*  $r = -.653$

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|                           |             |
|---------------------------|-------------|
| Diagnosis as origin       | $r = -.573$ |
| Radiology as origin       | $r = -.591$ |
| Assessment as origin      | $r = -.413$ |
| Reception as origin       | $r = -.632$ |
| Diagnosis as destination  | $r = -.669$ |
| Radiology as destination  | $r = -.717$ |
| Assessment as destination | $r = -.646$ |
| Reception as destination  | $r = -.322$ |

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lation between the redundant frequency of node usage and the degree of integration of the node ( $r = -.754$  for the circulation system,  $r = -.653$  for all rooms on the floor). To confirm our finding, we proceeded to calculate separate correlations for various groups of tasks, as summarized in Table 1.

Although several correlations are not significant at the  $p < .01$  level, there is a consistent trend, suggesting that the redundant search for particular destinations is also biased so that more integrated nodes are more frequently traversed, almost irrespective of what the point of origin or destination may be (with the exception of the assessment unit as a destination, which produces a low correlation). Those subjects who, for failing to develop locational knowledge during the open search phase, or for lack of luck did not reach their destination efficiently, seemed to wander more along integrated spaces.

On the other hand, there seemed to be no correlation between the degree of integration of each origin or each destination and the amount of redundancy associated with it. Although we have only four origins and four destinations and cannot therefore claim any statistical reliability for our results, no suggestive pattern emerges as to which origins or destinations generate more wayfinding difficulties. These findings suggest that the degree of wayfinding difficulty depends on both configurational factors and other aspects of the design, such as

signage, which are extraneous to layout. For example, several subjects passed by their intended destinations failing to notice them, either because of poor signage or because they were influenced by their own conception of where they should be going. Thus the properties of integration account for the bias in the direction of redundant search when subjects are unsure of the location of their destinations, but do not seem to explain which destinations are more difficult to find or which origins fail to generate a good sense of direction. The implied rule seems to be "when in doubt go to an integrated space."

We feel that the finding, however limited, supports our broad hypothesis about the relationship between search performance and integration. Another, more detailed, implication is that our methods can be used as fruitfully to describe directed search performance as a phenomenon related to building configuration as they can be used to describe open search. We also feel that this finding, if corroborated by other studies, has far-reaching implications for design. If people tend to bias their search along the integration core, positioning the key elements of the building program in relationship to the core, and designing and configuring the core with care become critical considerations, parallel to the acknowledged need to have clear, visible, and consistent signage.

For example, whereas in Homey Hospital all four destinations were close to the core, the staff reported that actual wayfinding was difficult. We cannot judge the absolute wayfinding difficulty because we have no comparative quantitative data from other buildings. However, we can hypothesize that the difficulty in Homey Hospital might be due to the shape and dimensions of the corridor system, the lack of appropriate design of entrances, and the inconsistent and nonprominent signage.

#### **A TENTATIVE DISCUSSION: THE ARTICULATION OF MORPHOLOGICAL AND COGNITIVE DIMENSIONS.**

Previous syntactic analyses have established strong and consistent correlations between syntactic integration and the

density of people, particularly those moving in urban areas (Hillier et al., 1987; Peponis, Hadjinikolaou, Livieratos, & Fatouros, 1989). This finding has led to the suggestion that space generates its own form of "community": a "virtual community," based on mutual awareness of where interaction is likely to occur rather than on active interaction itself. What is important, from the point of view of our discussion, is that as people get to know a layout as a relational pattern, they also build expectations of probabilities of encounter. Configuration, it turns out, is a concept that may refer to both the pattern of built space and to some spatial effect upon the pattern of use.

At Homey Hospital we have also observed normal patterns of use during typical working days. An observer followed a standard path through the hospital, selected to give access to all spaces other than medical rooms and single cellular offices. In order to make the task manageable and ensure uniformity, the observer recorded only those people who were bypassed at right angles as the observer proceeded through the spaces. The procedure was repeated 20 times at regular intervals, so as to cover a full working day. Analysis revealed good correlation between the integration of axial lines and the density of moving people ( $r = -.520$ ), which survives when we consider the density of staff only ( $r = -.523$ ), but which becomes much weaker when we consider the density of patients and their escorts ( $r = -.399^7$ ). Thus, as far as staff are concerned, we could identify a spatially predictable pattern of movement without taking into account specific organizational routines or other specialized knowledge that might require them to use the building in ways other than what the configurational patterns suggest. On an ordinary day, getting to know Homey Hospital as a plan with syntactic qualities such as integration is associated with also getting to know a predictable pattern of overall staff movement.

This is not without implications for the study of wayfinding. It seems natural that spaces that are not simply more integrated but, that are also more populated may appear more attractive to novice searchers simply because they offer more opportunities for asking for information and more reassurance that help

is available should any problem arise. Indeed, at least one study has reported that the presence of other people was one of the "cues" followed by subjects in the navigation through a building (Beaumont et al., 1984). Appleyard (1970) and Evans et al. (1982) have reported a similar finding concerning the effect of denser use upon the identification of buildings as landmarks in the urban context.

Thus previous syntactic findings established that the description of configuration may include not simply something to do with the building but also something to do with its use. Indeed, the basic correlation between movement and integration is in itself a justification of the usefulness of describing spatial patterns in terms of their properties of syntactic integration. The findings we report here suggest that the association between normal movement and integration also has a cognitive dimension: Those who explored Homey Hospital as first time visitors, at a time when the building was almost deserted, seemed to distribute themselves in the same way as do members of staff in their routine movements. Space seems to generate a probabilistically predictable presence of other people according to the same properties that seem to structure its open and directed searches. We ask the reader to bear with us on a discussion of this hypothesis.

Our findings do not directly show, nor was this our research aim, that integration features in people's cognitive representations of environments. Our theoretical framework has merely enabled us to observe a systematic morphological pattern. The presence of this pattern might have a potential bearing on at least two topics of discussion recurrent in the literature on spatial cognition.

It is often suggested (Hart & Moore, 1973; Gärling & Golledge, 1989; Golledge, 1987; Moore, 1974) that the development of cognitive frameworks that proceeds from what might be referred to as "egocentric/sensorimotor space" to "operational space with fixed but only partially coordinated references" and ultimately to "formal space with hierarchical coordination" is mirrored in the progression of spatial learning from knowledge of a limited area to knowledge of "routes" and eventually to "survey"

knowledge of whole configurations. Our findings suggest that this sequence may not be correct, or at least may be oversimplified. Our subjects appeared to exhibit an inherently configurational regularity in search performances with no knowledge of routes whatsoever. Furthermore, this regularity can act like the background against which routes linking known origins to specified destinations are sought. Thus our findings are consistent with the idea that some knowledge of configuration can develop independently rather than by somehow aggregating the knowledge of specific routes, at least where cognitively competent adults are involved. The analysis of search performances suggested that people acquire an intuitive grasp of integration presumably through the interaction with the building. But this grasp, if indeed it was present, did not in itself guarantee an efficient knowledge of particular routes.

In everyday life, organizational constraints and practical requirements prevent people from freely exploring hospitals and impose specific spatial and functional sequences. Thus even a competent wayfinder might not reach an understanding of the overall building configuration. This is, after all, a key mechanism of social and organizational control. But, our common experience of aimlessly strolling about in traditional urban environments is at least one realistic context in which we might develop a sense of configuration without presupposing specific routes to any particular destinations. Similarly, a building occupant who is called upon to know an entire building may spend some time exploring it.

The second theoretical issue we wish to discuss concerns the relationship between abstract and concrete dimensions of spatial cognition. Theories of development and learning (Hart & Moore, 1973) often suggest that survey-type knowledge has increasingly abstract terms of reference, such as, for example, cardinal points or other systems of reference. But, as Hart and Moore (1973) have pointed out "it remains necessary . . . to describe how this system of reference is related to the environment, for clearly, no system of reference is useful if fully abstracted from the environment in which the individual must act

(p. 283). Our analysis suggests that quite an abstract set of relationships, which seems able to structure the cognitive terms of reference, is already built into the building—indeed some psychology students participating in the experiment reported that their preference for the back corridor was based on the impression that more spaces and uses seemed to branch off from it. Integration is a property that is both formally sophisticated, because it assumes that the whole system is understood from the point of view of each of its constituent spaces, and, apparently, intuitively accessible. This lends even more force to the idea that we have to become more sensitive to the configurational properties of layouts—“find the building,” which is at the same time abstract and concrete—in studies of wayfinding.

#### THE DIFFICULTY OF REACHING DIAGNOSIS

As discussed above, our findings seem to suggest that search patterns are subject to an interesting bias toward integration, without, however, shedding direct light on the relative ease or difficulty with which different destinations were reached. In this section we briefly explore whether origins or destinations varied with respect to their associated wayfinding difficulty, as indexed by the amount of redundancy. We take into account the fact that some tasks were performed later than others and therefore subjects had the advantage of greater familiarity with the building. To adjust for this fact, we multiplied the amount of redundancy involved in each individual wayfinding performance by the order of that task within the subject's task sequence. Table 2 aggregates the redundancy figures according to the origin and the destination of the tasks.<sup>8</sup>

Table 2 suggests that locations differ more when they are considered as destinations rather than as origins. More particularly, the Diagnosis and Treatment area is by far the most difficult destination, followed by Assessment. By comparison, Reception and Radiology are easy destinations. This raises the question: Why do two locations, both of which are on quite

**TABLE 2**  
**Relative Redundancy Figures, by Origin and Destination**

|                 |        |
|-----------------|--------|
| From Reception  | 7.270  |
| From Assessment | 5.949  |
| From Diagnosis  | 3.617  |
| From Radiology  | 6.817  |
| To Reception    | 1.233  |
| To Assessment   | 6.756  |
| To Diagnosis    | 14.619 |
| To Radiology    | 1.044  |

integrated corridors generate more wayfinding difficulties than others?

In dealing with this question we have come to appreciate an interesting distinction: The Assessment Unit was on a corridor that was frequently used during both the open and the directed searches, whereas Diagnosis was on a much less used corridor. Even though people frequently passed the Assessment Unit, they missed the signs for it. In the case of Diagnosis, people seemed less willing to venture into this section of the building. In other words, our data suggest that whereas some destinations may not be easily reached for lack of clear identification—lack of signage, marked entrance, or other directly perceivable cues—others seem to lie completely outside the *search track*. It seems we have to draw a distinction between *local* and *global* causes of wayfinding difficulty.

#### IS THERE A PATTERN TO SEARCH SEQUENCES?

In order to understand better the apparent avoidance of the Diagnosis corridor, we decided to return to the examination of the search paths. Our statistical findings on the role of integration could clearly not provide the required explanation. We therefore decided to complement our analysis of the *frequencies* with which the different spaces were traversed during



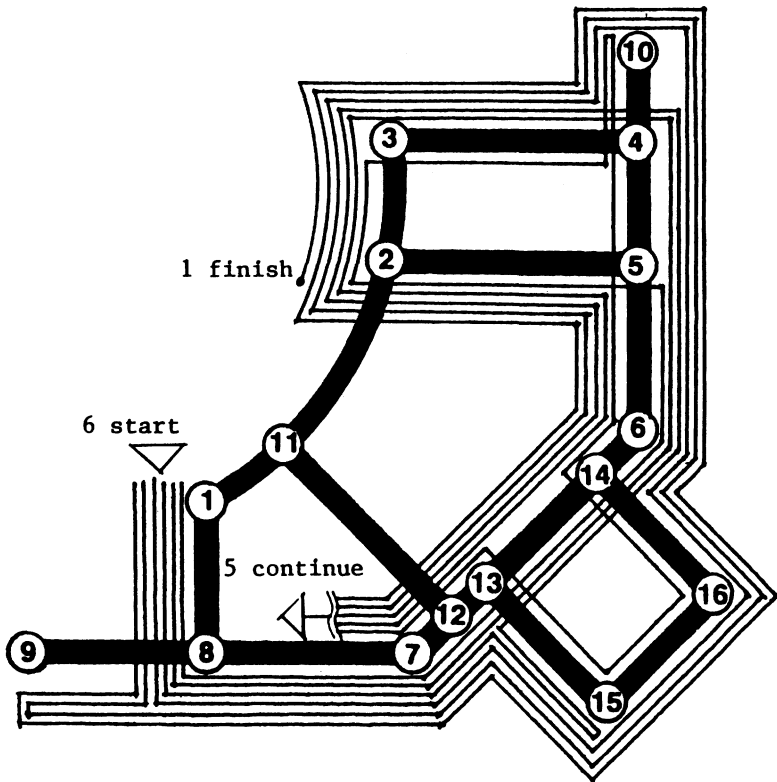


one alternative over the others. Only eight nodes give choices other than backtracking, and only two choices are provided in each case. Thus the binomial distribution could readily be used to decide whether the frequencies with which choices were made suggested any bias.

To some extent, the analysis led to a restatement of facts that had been spotted previously. For example, very few people entered the administration corridor (Nodes 11 and 12), which had closed doors on both ends. A slightly more interesting finding indicated a stronger preference for one dead end rather than for another. The dead end past Node 4 was entered more frequently, maybe because the possibility of further circulation round the corner could not readily be excluded, and the dead end past Node 9 was avoided because a glazed door unambiguously marked the edge of the building.

But the most interesting finding clearly concerned the Diagnosis corridor running between Node 5 and Node 2. Those who approached it from either direction along the back of the building (Node 5) systematically avoided entering it. On the other hand, those who approached it from either direction along the front entered or bypassed it with equal probability. It seems, therefore, that the overall underuse of the Diagnosis corridor relative to its degree of integration results from a strong bias against entry from the back. No obvious pull toward architectural cues or landmarks could explain this bias. On the contrary, the view from the back included a glimpse into the front loggia and courtyard through a window. Also Node 5 is widened and includes an elevator, cues that this is an important corridor. This part of the analysis seemed, therefore, to confront us with a puzzle.

Our next step was to consider paths comprising many nodes and to ask whether our subjects seemed to have independently followed similar sequences. All subjects chose to enter the building from the entry nearest to the visitors' parking lot (Node 1). Upon entry they had two main choices: (a) to proceed straight toward the back and then along the back corridor, or (b) to turn left and walk along the front. If we ignore some minor discrep-

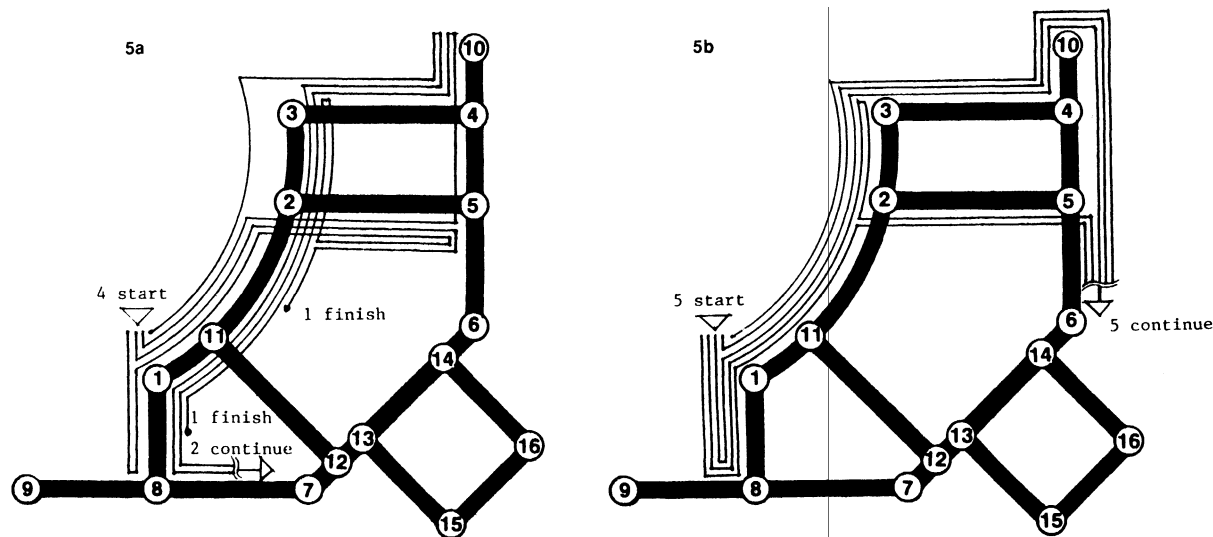


**Figure 4: Search Pattern of the Six Subjects Who Explored the Back Corridor First**

NOTE: It can be seen that, with minor deviations, subjects followed the same route over a considerable number of spaces. (The lines in the figure indicate the number of people who went through each space, but there is no correspondence between a line and a particular individual. Only that part of the search sequence over which a common trend is obvious is represented.)

ancies, we can consider two major groups, the "front first" group comprising nine people and the "back first" comprising six.

We have not yet developed a way of measuring the degree of convergence or channeling of search sequences<sup>9</sup> but in Figures 4 and 5a, 5b we have represented that part of the open search for which some convergence seemed present on careful visual examination.



**Figure 5: Search Patterns of the Nine Subjects Who Explored the Front Corridor First**

NOTE: It can be seen that subjects diverged quite early. One group, represented in 5a, did not opt for the back corridor during the first stages of exploration, whereas the other group, represented by 5b, did. Even after the two groups are represented separately, however, they display further divergence. (The lines in the diagram indicate the number of people who went through each space, but there is no correspondence between a line and a particular individual. Only that part of the search sequence over which a common trend is obvious is represented.)

With minor deviations, the "back first" group displayed a consistent pattern characterized by: (a) almost even possibility of continuing on or diverging into the Assessment Unit; (b) almost even possibility of entering or not the cul-de-sac at the end of the back corridor; (c) movement toward the front along the Reception corridor; (d) return to the back corridor along the Diagnosis corridor, after a short passage along the front of the building.

On the other hand, the "front first" group displays a less clear pattern, mainly because, after some pathmaking around the area of the two transverse corridors (Reception and Diagnosis), some members of the group proceeded along the back and others returned along the front. We can, however, identify: (a) an even possibility of continuing along the front corridor or entering the diagnosis corridor; (b) a strong possibility of exploring the short dead end upon arrival at the back corridor.

This part of our analysis seemed, therefore, to add its new puzzles. Why should the back first group adhere to a relatively standard sequence longer than the front first group? Why should sequences display standardization at all?

#### **ARE THERE NAVIGATION RULES INVOLVED IN SEARCH PERFORMANCE?**

These questions make the issue of navigation rules unavoidable. The issue first arises with our finding on the correlation between search frequency and integration. Previous computer simulations at University College London, have shown that randomly moving automata that make an unbiased decision at each choice node would not tend to move according to integration. The fact that our subjects directed themselves toward more integrated spaces suggests that they moved following more sophisticated rules. The question as to what these rules may entail becomes all the more interesting in the light of the sequences identified above.

Subjects undertaking to search a building of which they have no prior knowledge are likely to bring with them some set of

parsimonious rules to guide their exploration. Parsimony is a requirement because rules need to be relevant and adaptable to a range of unknown environments. The rules may be both *procedural*—knowledge about how to act—and substantive—knowledge about the way in which buildings are organized; they could apply to all buildings or be specific to certain types (Zimring & Gross, in press). Quite aside from the theoretical discussion concerning such rules, there have been several attempts to give formal computational models of at least some critical aspects of them (Kuipers, 1978; Leiser & Zilbershatz, 1989). Here, we have no intention of attempting to directly use these models or provide any specific alternatives. Given the potential interest of interfacing our analysis with the development of computational navigation models in particular, and to the discussion of navigation rules in general, we make some preliminary comments.

One obvious rule that seems implicit in the performance of our subjects is the avoidance of unnecessary backtracking. If we exclude the backtracking generated by the two dead ends, there have been only 14 other cases of backtracking over a total of 316 transitions across circulation nodes. The question is whether, against the background of a plan that offers a limited number of circulation choices, this rule could be construed as a sufficient restriction upon an otherwise random search process. We have already suggested that this is not the case. At some of the nodes subjects seemed to choose each available direction with equal probability, but at other nodes there was a distinct bias. What other rules would we have to postulate?

Our record of search sequences suggests the following dual rule which seeks to maximize information gain on the basis of directly perceivable evidence: (a) If all else is equal, continue along the same line; (b) divert from the line of movement when a new view allows you to see more space and activity or provides a longer view and lets you see further ahead. These rules would account for the even probabilities of making or not making certain decisions. For example, at Node 13 (Figure 4) the view into the Assessment Unit is almost as long as is the view ahead,

but it opens onto a wider open space where the arrangement of sitting furniture and of the nurse's station suggests, even in the absence of people, that something is happening. Thus subjects could be enticed to enter. Similarly, at Node 2 (Figure 5b) the view toward the back is almost as powerful as is the view ahead because the presence of the second entrance and the broadening of the space suggest that something is happening ahead even before the full size of the reception area can be appreciated. Hence the equiprobable distribution of movement.

But the addition of these rules would still not account for certain features of search sequences, including most notably the avoidance of entry into the diagnosis corridor from the back, and the decision of all back first subjects to return to the back corridor before fully exhausting the front one. This brings us to an important consideration. It seems that in order to explain such behavior, we would have to postulate rules that cannot merely be applied according to directly perceivable "local" information but require some working definition of the overall configuration. For example, the following rule might be applicable: Confirm the unexplored parts before the already explored ones, and confirm the more complex and less recently explored parts rather than the simpler and more recent. This rule would require subjects to build up some memory of what they have already traversed. The rule might account, for example, for the decision of back first subjects to venture toward the front before rechecking the back corridor, which they knew to be rich in information after having traversed it once. In extrapolating rules that require some sort of "memory built up" we do no more than Leiser and Zilbershatz (1989) anticipate in their computational model.

This brings us to our final contention. It seems that the working definition of the overall configuration does not develop merely according to the memory of what has been traversed but also on the basis of partial information about spaces seen but not reached. For example, on the basis of what they could see, the back first subjects could probably extrapolate that the front corridor would take them only to the initial entry point. Rather than confirm this by exhausting the route, they opted to return

to the more complex back corridor. Only such ability to project as well as to remember would actually explain the reluctance to enter the Diagnosis corridor from the back. The view through the corridor and through the window at its end, would allow an easier projection of where the corridor might lead, as compared to the views along the back corridor which encourage no easy anticipation.

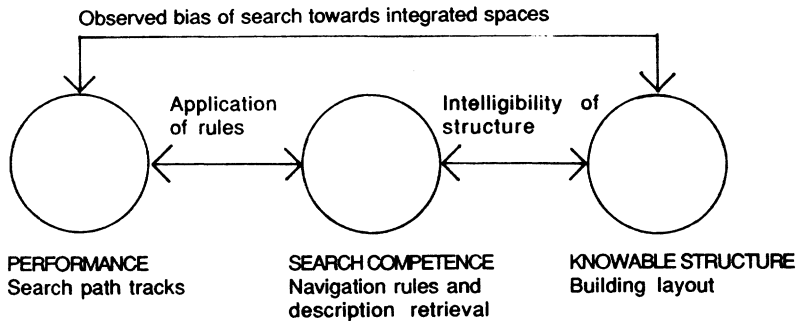
Our analysis is, of course, conjectural. Our conjectured rules do not necessarily account for all observed phenomena. Furthermore, because we extrapolate the rules "after the event" we do not claim to have tested them. One test would involve their translation into a computer model in an attempt to simulate actual search performances. Even if this were achieved, there would be no indication that an alternative set of rules could generate the same observable performance. The main point, however, is this. The study of navigation rules cannot be limited to considerations of directly perceivable local information nor even to an ability to register and remember traversed paths. There are at least suggestive indications that rules comprise an intelligent component enabling subjects to reconstruct or project working definitions of overall configurational patterns. These patterns concern not only the relationships between spaces but also the anticipated probability of encountering others.

The early phases of search sequences also seem to confirm that the knowledge of routes and the knowledge of configurations may not always be neatly separated into distinct stages of learning. How far this hypothesis can be translated into a computational model, and how far such model could account for our main findings concerning the space-use frequencies is a question beyond the scope of this article.

#### **CONCLUDING COMMENTS: A TENTATIVE MODEL OF SEARCH STRUCTURE**

As developed above, our analysis suggests that wayfinding involves three kinds of parameters. First, the properties of





**Figure 6: A Preliminary Model of Wayfinding**

building layouts can be understood as abstract and knowable relational patterns. The main property that we have dealt with here is the pattern of integration that concerns the relation of each space to the global structure of a building. Second, the observed search and wayfinding paths, as recorded in our tracking, have been shown not only to be structured in relationship to the pattern of integration but also to display regularities over and above those that the pattern of integration alone allows us to predict. Third, navigation rules may mediate the relationship of these two observable morphologies. The nature of these navigation rules and how they are cognitively organized is an interesting question that deserves further examination (Zimring & Gross, in press). This is summarized in Figure 6.

The implication for design is to redirect our attention from an exclusive focus on local characteristics, such as signs and landmarks, to one that also considers the overall structure of the building. As buildings get larger and more complex, it becomes increasingly difficult to provide adequate wayfinding simply with signs and other cues if the suggested pattern of movement ignores the ways people use and understand configuration. Our particular suggestion is that wayfinding, assisted by proper signage and proper consideration of functional and organizational parameters, will seem natural rather than forced when

important facilities and key points, such as the entrance, are carefully positioned with respect to the integration core and when the latter is carefully designed.

## NOTES

1. Smaller integration values (known as RRA values) indicate greater integration.
2. Unless otherwise noted, all correlations are significant at  $p < .01$  or better.
3.  $p < .05$ .
4. Given that subjects remained on the main circulation system, we are not surprised that correlations between integration of the main corridors and their search are better than correlations with the integration with all rooms. After all, integration is a measure of overall building relationships, and the subjects only had access to the circulation system. However, as they searched, they were able to see into spaces through doors and internal windows, so it is not surprising that the search also considered these relationships.
5. In order to translate search paths into node sequences more accurately, we also treated corridor end points as pseudonodes because they could only be revealed to be genuine end points after one got very close to them.
6.  $p < .05$ .
7.  $p < .1$ .
8. For the purposes of compiling the table, we have first computed the average redundancy involved with a particular task (say, finding Reception to finding Diagnosis) and then the mean of those averages that correspond to tasks sharing either a common origin or a common destination (say all tasks departing from Reception and directed to either Diagnosis or Radiology or Assessment).
9. This would require assessing the number of people involved, the number of nodes which they all take in the same sequence, and the number of nodes along which some might deviate. Instead, we have relied on a diagram to represent those parts of the open search over which an eyeball exploration suggested more convergence than divergence. The rest of the search paths, where these were further extended, seemed particular to individual subjects.

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