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Investigating the syntax line: configurational properties and cognitive correlates

Saif Haq
College of Architecture, TexasTech University, Lubbock, TX 79409-2091, USA;
e-mail: saif.haq@ttu.edu or saif.haq@alum.mit.edu
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Abstract. Space syntax research has had significant success over the years and has served to illustrate the importance of configurational measures, especially those that take into account all the spaces in a system. Here, assumptions of axial lines as elementary spatial units have been overwhelming. Although based on a theoretical construct of visibility, this postulation has rarely been extended to perception or cognition and this has given rise to questions about geometric and metric considerations. The research presented here was carried out in three large urban hospitals. In them, 128 volunteers performed 'open searches', where they attempted to become familiar with the hospital; 'directed searches', where they sought specific locations; and various cognitive mapping tasks such as pointing to locations that were not within sight and sketching the main corridors and routes of the hospital. The hospitals themselves were analyzed through conventional syntax measures of axial lines and a segmented version of those lines. Correlational and regression analyses revealed that, although use of space was best predicted by local measures (connectivity), distribution of people was better explained through integration-3. Performance comparisons between the environmental measures given by 'whole' and 'segmented' lines suggested that, at least in complex architectural settings, original syntax definitions of axial lines as uninterrupted visibility lines have more predictive power and better cognitive presence than 'segmented' lines. The results also support previous findings of intelligibility as a factor in predicting space use by extending it to the cognitive realm. Additionally, it has brought out the reverse role of intelligibility-3. It was also found that mean depth of an entry effects the way a building is explored; therefore, knowledge of this spatial property may provide a fair indication of the relative importance which each space will have on wayfinding.

Introduction

Configurational analysis has proven to be extremely useful in the study of human movement in various environments. Penn (2001) estimates that about 60% to 80% of the variance of movement rates in urban areas can be accounted for by configurational variables that are revealed by space syntax analysis—provided that land uses and development densities are relatively homogeneously distributed. In this regard the axial line as a spatial unit, and its property of integration-max, has proven to be very useful. However, the lack of geometric and metric considerations has been a consistent criticism of this research program. For example, in certain urban conditions a line may be miles long and some locations on that line may be more populated than others. Regardless, presences of people (POP) at any point on the line are averaged over its entire length, thus ignoring metric variability. Also, by reducing all the spaces to nodes on a graph, as a prerequisite for calculating configurational measures, syntax analysis ignores geometric variability. Addressing such concerns, Hillier (1999) has argued that geometric and metric properties are somehow internalized into the structure of the graph as connectiveness and incident angles. He has discussed the case for London, and it will be interesting to see how far this theory will extend to other cities. On the other hand, Penn (2001) has suggested that by (apparently) ignoring both human criteria and important environmental characteristics, such as distance and direction, syntax theory becomes more 'predictive' and less 'explanatory'. To explain why space syntax 'predicts', he suggests more exploration into human cognition.

From the point of view of the human immersed in a configuration of spaces, there is indeed a lesser stock of research that has tracked actual movement and coupled it with cognitive representations. In this paper I report the results of an exploratory experiment carried out in three urban hospital complexes in which environmental cognition and the role of configurational variables were considered. The techniques of space syntax were extensively used and the following questions broadly considered. To what extent are configurational variables predictive of wayfinding behavior and environmental cognition? In this regard, what measures of configuration have more predictive power? What role does the overall measure of complexity (syntax intelligibility) have on environmental cognition? And, does the property of an entry point affect wayfinding? Additionally, from the point of view of spatial cognition, I develop an alternative description to axial lines and test the resultant configurational analysis with data from wayfinding and environmental cognition.

Space syntax and environmental cognition

The theory of space syntax deals with the *relational* aspects of space. It takes into account those properties that are derived from the relationship which each space has with all the others in a system. The relationship that it considers is topological, that is, the number of 'steps' or 'turns' one needs to take to go from one space to all others, or vice versa. With this premise, syntax has successfully used graph theory to define those relational measures and computer tools have been produced to quantify them and to provide numerical and display values for each space. These relational measures are also called *configurational values*. The more important measures are *integration-max*, *integration-3*, and *integration-1* or *connectivity* (Hillier and Hanson, 1984). Integration-max is a global measure that takes into account all the spaces, and hence all the 'steps' required to go from one to all others in a spatial system; thus it describes the relationship of each space to the system as a whole. Integration-3 measures the relationship of one space to others up to three steps or turns away from it. Connectivity is a local measure that describes the relationship of each space with its immediate neighbors. In addition, there is *intelligibility* which is a higher order variable that refers to the entire system. It is measured by the correlation between immediately available relationships to neighboring spaces, as measured by connectivity, and the relationship of the pattern as a whole, as measured by integration-max:

> "This is called 'intelligibility' because it indexes the degree to which the number of immediate connections a line has—*which can therefore be seen from that line*—are a reliable guide to the importance of that line in the system as a whole" (Hillier et al, 1987a, page 237, emphasis added).

Higher correlation between connectivity and integration means more intelligibility of the entire system of spaces under consideration. In this paper an additional higher order variable is proposed: *intelligibility-3*. This is the correlation between connectivity and integration-3, and is an index of the importance of a line to a lower order intelligibility value.

The configurational values of each space given by syntax are used as independent variables in statistical analysis where dependent variables are observations of behavior, usually POP. In most of them, integration-max has proved to be the most valuable, generating "models for predicting urban movement, ... strong theoretical results on urban structure, ... a general theory of the dynamics linking the urban grid, movement, land uses and building densities in 'organic' cities, [and] ... a practical method for the application of these results and theories to design problems" (Hillier, 1999, page 169). The impressive portfolio of results that backs this claim consistently shows a high correlation between POP through various urban spaces (adjusted for length) and integration-max values of those spaces. (see, for example, Hillier, 1993; Hillier et al, 1987a; Peponis et al, 1989). Other research suggests that the role of integration-max as a predictor of POP depends on the intelligibility of the entire system (Hillier, 1987a) and on the spread of the integration core (Peponis et al, 1989) (an integration core is the top 5% or 10% of the integrated areas).

Such successes provide an index to the significance of the configurational process of environmental analysis. This apparently simple measure of space, how one is connected to some and sequentially to all other spaces in the system, and the elegant method of quantifying it, is the largest contribution of space syntax research. Its importance certainly makes intuitive sense, and it has been demonstrated to be an important spatial property. However, considerations of the theoretical construct called 'axial line' as a spatial unit in space syntax research has been ubiquitous. Almost all the empirical results reported in the literature are based on the assumption of a unit space being an axial line. Only recently have other unit spaces, such as 'informationally stable convex spaces' (Peponis et al, 1997), 'isovists' (Turner and Penn, 1999), and 'nodes' (Haq, 1999a; 1999b; Haq and Zimring, 2001; Peponis et al, 1990) been considered. Nevertheless, the use of axial lines arguably predominates in space syntax research.

Environmental analysis of space syntax typically begins with unit spaces being understood as 'convex spaces' and 'axial lines' (Hillier and Hanson, 1984). Description of an axial line is based on the concept of a convex space; this is defined to be that two-dimensional space in which every point is visible from every other point within it (Hillier and Hanson, 1984). Axial lines consider the *entry/exit points* of convex spaces and are formed by the straight lines that can connect the maximum number of such spaces through their openings. They are thus understood as a one-dimensional extension that connects the maximum number of convex spaces. Hillier and others suggest that axial lines are "the longest ... straight lines(s) that go through all convex spaces" (Hillier et al, 1987b, page 222). Axial extension of a space provides a global cohesion of the system of spaces. Theoretically, to a spatially immersed person, a convex space will provide local information about the space itself whereas its extension, the axial line, will provide a sense of connections to other areas. Putting these thoughts in terms of legibility and movement, Hillier says that "a convex space describes where you are in a system, whereas axial lines give information about where you might be going" (Hillier et al, 1987b, page 222). Such statements immediately evoke concerns of scale, geometry, and other spatial properties that are coupled with spatial cognitive processes. However, space syntax literature minimally extends the physical descriptions of spaces and spatial layouts to cognitive realms. For example, Hillier has suggested that the axial structure of a system of spaces, such as a town, may be detected by a peripatetic observer. He has also suggested that configuration is non-discursive, that is, we understand it, but do not have the means to talk about it (Hillier, 1996, page 38).

On the other hand, the axial line understood as paths of movement fits quite well with some paradigmatic assumptions of environmental cognition researchers. First, the assertion that human cognitive representations are built up not by perception of space, but through actions in space (Piaget and Inhelder, 1967). Second, the identification of three classes of spatial relations that form the content of spatial cognition: topological, projective, and Euclidean (or metric) relations and the fact that, ontogenetically, understanding of topological relations precedes projective and Euclidean relations (Piaget and Inhelder, 1967). Third, Shemyakin's (1959) distinction between two fundamentally different types of topographical representations: route maps and survey maps. Route maps are constructed by mentally tracing the route of locomotion through an area; survey maps are representations of the general configuration of the mutual disposition of local objects. These ideas come together in the classic work of Lynch (1960) in which he demonstrated that an understanding of the environment can be verbalized, especially if put in the context of traveling from one point to another. Additionally, he identified paths and nodes (among others) as elements of 'imagibility' or, perhaps, the building blocks of cognitive maps. Lynch's findings have been substantiated by scores of subsequent researchers (see Haq, 2001, for a summary). Table 1 gives an indication of the environmental variables that have subsequently been thought to be important, and this clearly shows the omnipresence of lines or paths and nodes. This table also brings out a more recent addition to the list of influencing environmental elements: configuration, or the way various spaces are put together. A considerable body of research, as well as common sense, suggests that despite individual differences people have difficulty in finding their way in and in describing complex settings. Unfortunately, the spatial definition of complexity has been hard to describe. Some attempts were undertaken by Braaksma and Cook (1980), O'Neill (1991), and Weisman (1981; 1989), but these were made difficult because the researchers confronted multiple tasks of developing both a theory of configuration and the tools for quantification and also carrying out empirical testing—all at the same time.

Space syntax considers axial lines as routes or movement paths, has a sophisticated method and computer tools to evaluate various kinds of topologically derived configurational values, and has a tradition of research on human movement. Arguably, these make it suitably poised for environmental cognition research and it is indeed moving into that realm.

There is a small stock of research within the space syntax community in which the cognitive aspects of a person moving through a configuration of spaces have been considered. However, this has been very influential, both in responding to the needs of environment cognition research and in clarifying some issues of space syntax. These studies have progressively served to shift the emphasis from integration-max to integration-3 and connectivity.

The pioneering work was undertaken by Peponis et al (1990), and is significant for a number of things, including its methodology. Peponis et al distinguished between two phases of wayfinding: open exploration or exploratory movement, where fifteen subjects were asked to explore a hospital building; and directed search or focused wayfinding, where four locations within the hospital were searched for. The environmental component consisted both of syntax axial lines and of the intersections of the lines, called nodes. In this study, the researchers considered only integration-max. They reported that both exploration in novel settings and errors in searches were biased towards spaces with greater integration-max values ($r = -0.757$ and $r = -0.754$, respectively). Later, Choi (1999) tracked people in museum settings and found that line integration-max was the highest predictor of people who visited it ($r = -0.508$), whereas connectivity was highest when repeat visits were considered ($r = 0.623$). Choi did not consider integration-3, but in subsequent studies this has been found to be important. Working with novice wayfinders in three urban hospitals, Haq and Zimring (2001) reported that total use of a space, that is, one that considered repeat visits, was also best predicted by connectivity ($r = 0.768$, 0.884, and 0.786). Earlier (Haq, 2001) I had shown that the number of people who visited a space was more correlated with integration-3 ($r = 0.692$, 0.859, and 0.814). The subjects were also asked to draw sketch maps of two settings, and the total number of lines drawn in their sketch maps correlated highly with connectivity values of the real lines ($r = 0.556$ and 0.678) (Haq, 2001; Haq and Zimring, 2001). In another study, Kim (2001) had

Table 1. Various environmental elements and properites that have been found to be influential in environment-cognition and wayfinding research.

Year	Author	Environment elements that are important in cognitive mapping and wayfinding research						
		Local order environmental measures					Other environmental measures	Other nonenvironmental measures
		lines	points	areas	elements	edges		
1960	Lynch	paths	nodes	districts	landmarks	edges		
1969	Stea	paths	points			boundaries and barriers		
1969	Appleyard	paths	nodes and points	districts	landmarks	edges		
1970	Best						choices in a route	
1971	Norberg-Schulz	paths	places	domains				
1975	Siegel and White	routes	nodes				configuration	
1976	Tobler						configuration	
1978	Kuipers	paths	places				relative locations	travel instructions
1978	Kuipers						topological relations	
1978	Golledge		anchor points					
1980	Braaksma and Cook						visibility between destinations; visiblity graph	
1980	Evans et al						color differentiation	
1981	Weisman						visual access; architectural differentiation; signs; plan configuration	
1983	Heft						transitions between vistas	
1984	Gärling et al	←	———	places	———	→	spatial relations between places	travel plans
1986	Gärling et al						degree of visual differentiation; degree of visual access; complexity of layout	
1989	Leiser et al						node-link network	
1989	Rovine and Weisman				landmarks			
1990	Peponis et al						syntax integration	
1991	O'Neill						interconnection density	
1992	Gross and Zimring							schema
1995	Evans et al				landmarks		pathway configuration	
1995	Gopal et al						configuration (neural network model)	
1999	Haq	lines	nodes				integration-3; connectivity	
2001	Kim	lines					integration-3	

seventy-six residents of two halves of a suburb in London sketch the map of their home area. He used syntax techniques to analyze the sketch maps and found that the integration-3 of sketch maps correlated with integration-3 of the real settings at $r = 0.728$. Also, he reported that a simple count of the axial lines as they appeared in the maps correlated at $r = 0.708$ with integration-3 values of the real settings.

As mentioned above, the point of departure of most space syntax research had been twofold: identification of spatial units, and calculation of configurational measures. With cognition and various other human aspects becoming more and more prominent, it seems pertinent to enquire into both these premises. For example, regarding axial lines, what makes the axial map a valid representation of the environment? To what extent does the theoretical definition 'longest lines to connect all convex spaces' map into visibility lines or access lines within space? How does it relate to our cognitive maps? And, what is the relationship between integration-max, integration-3, and connectivity? Theoretically, they measure different things, but is this a valid statistical construct? These are some of the questions addressed in the research presented here.

The research

This study was based on the earlier work of Peponis et al (1990). It considered spatial, behavioral, and cognitive variables and aimed to investigate the characteristics and alternative descriptions of space syntax axial lines and the relationship between the various configurational properties, that is, integration-max, integration-3, and connectivity. It also aimed to investigate these from the point of view of wayfinding and of environmental cognition.

At the very beginning, a distinction was made between the syntax definition of an axial line and a cognitively argued version of it. This last was based on the work of Heft (1983; 1996; 1997), who had extended the pioneering work of Gibson (1979) into a wayfinding perspective and argued that information critical to wayfinding is revealed when an individual moves along a path as a series of successive vistas and a sequence of transitions or nodes between those vistas (Heft, 1983). Heft says:

> "A vista is defined as an extended region of the landscape that can be seen from one's present location ... the view of each successive vista is occluded from view by visual barriers and, ... each successive vista is *revealed at the edge* of the visual barrier and simultaneously, the vista just traversed leaves the field of view" (Heft, 1983, page 137, original emphasis).

From this perspective, Heft described a route as two nested sequences of information: a sequence of vistas and a sequence of transitions that connect those vistas. Furthermore, he asserted that transitions are more important because they serve to give continuity to the vistas. Because wayfinding involves the perception of information over time, and the most important information for this task is in the invariant sequence of transitions *between* vistas, Heft hypothesized that wayfinding behavior can also be studied from the point of view of such vista transitions, and provided empirical results to support his assertion. He used forty-six subjects in an experiment that incorporated edited versions of a film to replicate a route with nine transitions or turns through an urban neighborhood. One group saw a 'transition' film which showed all the turns in sequence, each episode starting 2 seconds prior to the turn and ending 2 seconds after. A second group was shown a 'vistas' film which contained the walk beginning 2 seconds after the completion of each turn and ending 2 seconds before the next turn. Later, all 46 subjects were taken to the site and asked to indicate the correct turn at every corner. Analysis of variance showed that the transitions group had indeed committed fewer errors. Following up with a second experiment, using another forty-eight subjects, he also found that information about transitions *fed in a sequential* *manner* is sufficient information for wayfinding purposes. Such information is not only better than information from the vistas only, it is comparable to information from both vistas and transitions combined.

That study brought new attention to the vision lines (vistas) and nodes (transitions) of a route and, by extension, of an environment. Lynch (1960) defined nodes as the junctions of two paths or corridors; Heft considered them as transitions between vistas. From a cognitive viewpoint, nodes are considered important because they are locations of pause, or where new environmental information is gained by a moving observer and decisions regarding travel directions are made. Expanding on this idea, a corridor, or an axial line, may also be understood as segmented into a number of smaller sections divided at the intersections of other lines. Thus a *segmented* version of axial lines can be generated and subjected to a space-syntax analysis. In this condition of syntax mapping, each segmented line will be uninterrupted and all turns or connections will be at the end points of the lines only. Tracking records of people in such lines will also be easier, because if a person visits a line and does not backtrack or stop then the entire length of the line will be used. Therefore, the criticism of averaging the counts of certain populated sections within a line can be avoided. Such a segmented axial line system was considered in this research and was compared with both wayfinding and with cognitive tasks, as well as with the typical syntax axial map.

The research was carried out in three large urban hospital complexes located in a major US city: Urban Hospital, University Hospital, and City Hospital. These settings each have a number of buildings connected via interior corridors to produce a continuous 'maze-like' quality. Only the floor that is available from the street entrance was used in this experiment.

The three environments were analyzed in two ways: as 'whole', and as 'segmented' axial line representations. This produced six systems. The first involved the reduction of the public areas into convex spaces and the production of linear extensions of them. Because all the corridors in these hospitals were straight lines, the axial map closely represented the corridor layout. In cognitive terms the 'whole' axial lines could be termed *uninterrupted visibility lines*, with various other lines being incident on them. The resultant axial map was subjected to a syntax analysis with the aid of the computer program Spatialist (Peponis et al, 1998) to determine configurational values. Results and analyses of these whole-line systems for integration-3 are shown in figures 1, 3, and 5 (over), in which the heavier lines depict the 10% integration-3 core.

A second method of analysis reduced the environment into a collection of nodes (intersections of axial lines). Syntax analyses (integration-3) of the axial lines connecting these nodes are shown in figures 2, 4, and 6. In these 'segmented-line' maps all connections are at the ends of the lines. It is hypothesized that this will provide a more accurate relationship with tracks of moving people because a line, if traversed (and not backtracked), will be used in its entirety and so in-line variability of use will be eliminated.

Three kinds of configurational variables were considered for the two kinds of representations: integration-1, also called connectivity; integration-3; and integration-max.

In these settings 128 participants carried out the following tasks: open exploration, directed searches, pointing to unseen but previously visited locations, and sketch mapping the hospital layout (see table 2, over). Other tests were also performed but are not reported here because they are not relevant to the discussion. The subjects consisted of 62 males and 66 females, mostly aged from 17 to 25 (mean 19.5 years). They were carefully screened to ensure that none of them had visited a large hospital complex more than once in the twelve months prior to the experiment.

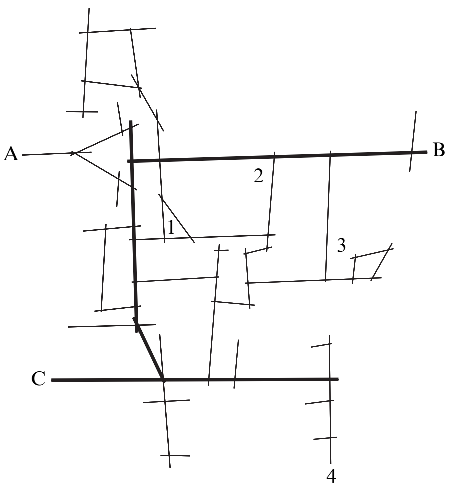

Figure 1. Urban hospital: 'whole' lines, showing core of integration-3.

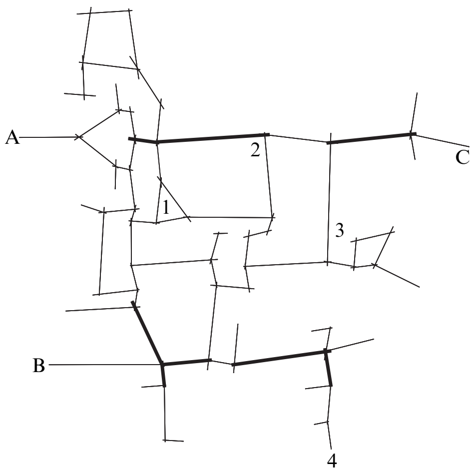

Figure 2. Urban hospital: 'segmented' lines, showing core of integration-3.

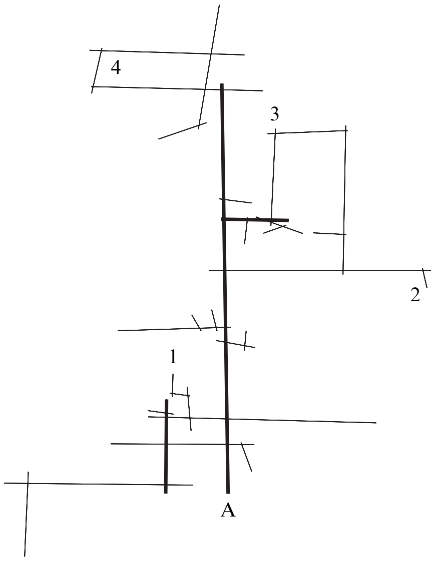

Figure 3. University Hospital: 'whole' lines, showing core of integration-3.

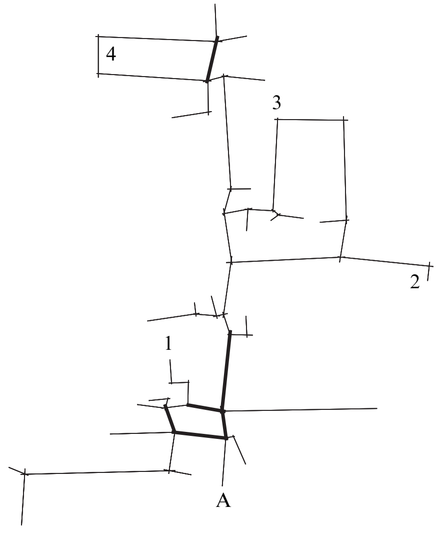

Figure 4. University Hospital: 'segmented' lines, showing core of integration-3.

The paths taken by the participants were recorded in two ways: (1) use of 'whole' and 'segmented' lines in a search condition called 'open exploration', where participants were asked to choose their own route to become familiar with the setting; and (2) use of 'redundant' lines during directed search, that is, the use of lines that were not on the shortest path when participants were asked to find specific locations. Peponis et al (1990) had initially developed this methodology to consider the redundant use of nodes.

Open exploration was started from one preselected entry point into the hospital, and the subjects were instructed not to talk to anyone but to try and fulfill their tasks using only the environmental cues, including signage. For the directed search, which was carried out after open exploration, the subjects were taken to one of four preselected locations within the building (shown in figures 1–6 as numbers 1–4) and

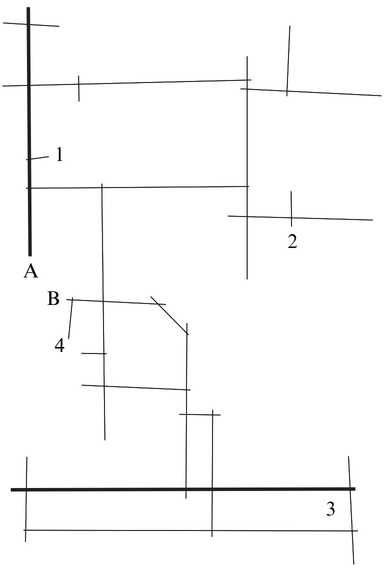

Figure 5. City Hospital: 'whole' lines, showing core of integration-3.

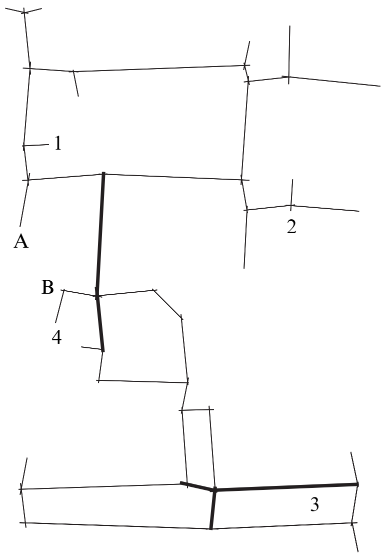

Figure 6. City Hospital: 'segmented' lines, showing core of integration-3.

Table 2. Comparison between the various tasks in the three environmental settings.

	Urban Hospital	University Hospital	City Hospital	All Hospitals
Number of male students	13	13	36	62
Number of female students	19	16	31	66
Total students	32	29	67	128
Number of entries used	3	1	2	6
Subjects doing open exploration from A	10		45	
Subjects doing open exploration from B	13		22	
Subjects doing open exploration from C	9			
Time given for open exploration (minutes)	20	15	15	
Time given for directed search (minutes)	15	10	10	
Number of pointing tasks		377	871	1248
Average pointing error		23.303	37.854	

were asked to walk to another of the preselected locations. When they found that destination they were asked to go on to the next one. (If participants could not find their destination within a preset time period—which had been shown during pretests as adequate for even the slowest walkers—they were escorted to the destination.) This procedure was repeated until each participant had found, or had attempted to find, their way to and from all the selected locations All four locations in each hospital were treated both as an origin and a destination. This resulted in twelve routes in each setting. In total, the 128 research subjects carried out 508 directed searches. The searches were counterbalanced such that each task was completed in all possible orders to control for fatigue or learning effects. Total and redundant use of a line was calculated as well as the number of people who used a line. Whereas total use considered repeat visits, redundant use was obtained by counting the number of subjects who visited a line. (Total use of line is termed TUL, people in line PIL, total use of redundant line TURL, and people in redundant lines as PIRL.)

Sketch mapping and pointing data were collected in University Hospital and City Hospital, generating data for 95 participants. The subjects carried out two tasks: pointing to out-of-sight locations, and sketching the environment in which they had operated. After each directed search, the subjects were asked to point to the location(s) that they had started from. Each person performed thirteen pointing tasks at different times and with increasing familiarity with the setting, but facing a common direction. The pointing tasks were carried out by using a circular piece of cardboard with angles marked on it in 10-degree intervals and a pointer attached to the center. The angular deviations between pointed and actual locations, in degrees, were recorded. In the two hospitals the subjects performed 377 and 871 pointing tasks, respectively (see table 2). In addition, each subject was asked to draw a plan of the hospital they had walked in. They were instructed to draw all the paths that they remembered, and to put in all the locations they could recall beside those paths. These drawings were analyzed in two ways: appearance of 'whole' lines and of 'segmented' lines. For the whole lines, the number of times each corridor or line appeared in sketch maps was counted. To make sure that the occurrences of lines in the maps were correctly accounted for, two independent raters in each hospital judged a sample of the sketch maps. The researcher judged all of them. In University Hospital, two raters and the experimenter rated ten maps; that is, each rater had to judge 320 axial lines. They were in total agreement 239 times, or 74.69% of the time (Cohen's $\kappa = 0.4937$). Average agreement per map was 23.9 times out of 32—maximum 31 and minimum 15. In City Hospital, two raters and the experimenter judged twenty-five maps which included 600 axial lines. Here they agreed 499 times, or 83.16% of the time (Cohen's $\kappa = 0.6633$).

Values for the appearance of segmented lines in sketch maps were determined by an independent researcher in the following way: first, nodes, that is, intersections of corridors, were identified. From these, lines were determined and counted. It was seen that in some cases a line was not comprehended as continuous and was drawn twice. These were, however, only counted once. Rater reliability would have been better if more raters had been included. However, time and cost constraints prevented this.

Results and conclusions

Syntactic comparison between the settings

A space syntax comparison of the six systems is presented in table 3. From this, a number of findings emerge. In all the cases, intelligibility-3 is higher than intelligibility, and the value of intelligibility-3 is very high (at the level of 0.9; see table 3, rows 2 and 3). Also, intelligibility of the segmented-line systems was always *lower* than for the whole-line systems (table 3, row 2), but intelligibility-3 was always *higher* (see row 3). In addition,

Table 3. Space-syntax comparison of the three environmental settings.

		Urban Hospital		University Hospital	
		whole lines	segmented lines	whole lines	segmented lines
1	Number of lines	43	77	32	59
2	Intelligibility	0.704	0.581	0.831	0.446
3	Intelligibility-3	0.953	0.984	0.927	0.978
4	Integration-max	1.775	1.026	2.317	1.174
5	Integration-3 max	3.75	2.75	3.462	2.929
6	Connectivity-max	9	5	8	6
7	Integration average	0.99	0.769	1.05	0.74
8	Integration-3 average	1.56	1.878	1.25	1.81

the segmented-line systems have comparatively low intelligibility values but very high intelligibility-3 values.

In terms of whole-line intelligibility, University Hospital had the highest value, followed by Urban Hospital, and then by City Hospital. This sequence did not hold for the segmented-line systems; their results were Urban Hospital, University Hospital, and City Hospital (table 3, row 2). The heavy lines in figures 1 – 6 depict the integration-3 core of the settings. Among the whole-line analyses of the three hospitals, only Urban Hospital has a continuous integration-3 core. The cores of the other two are segmented. The main part of the core of University Hospital is arranged along a long corridor that connects almost all the destinations (figure 3). The core of City Hospital, on the other hand, is scattered equally to the two ends of the layout (figure 5); interestingly, this matches the actual situation. City Hospital is a collection of three buildings that have different functions, and which are connected by a central corridor which does not have major activities in it. Each building has its own functional core, and this is picked up by the integration-3 core. Therefore it seems that, at least in this case, the integration-3 core relates to the actual situation. Regarding the segmented-line systems, integration-3 cores are scattered in two or more parts all over the layouts.

Space syntax argues that if a system has higher intelligibility then "the whole can be read from the parts" (Hilier et al, 1987a, page 237). This indicates that intelligible systems will provide a greater possibility of understanding(1) the overall configuration from local information. This of course assumes that all the connections are *perceivable* from any point on the line. Evaluation of the layouts as segmented systems assumes that corridors are broken up into smaller units and that visual access may not be continuous along adjacent segments. From this condition of analysis, the intelligibilities of the three hospitals indicate that the segmented systems are comparatively more difficult to understand than the whole-line systems. In other words, if the hospitals were arranged such that only the end connections were visible from any point in the corridor, then the layout would be less intelligible: the segmented lines will not be as effective as whole lines in 'reading' the sense of global configuration. On the other hand, because intelligibility-3 is higher, the attainment of level-3 global information from local cues will be higher in the segmented-line system.

An additional syntactic analysis was carried out. This included all the spaces that are available to a staff member carrying a master key to unlock all doors. In this case,

Table 3 (continued).

	Number	City Hospital		3 hospitals whole lines	All 6 versions
		whole lines	segmented lines		
1	Number of lines	24	48	99	283
2	Intelligibility	0.557	0.321		
3	Intelligibility-3	0.970	0.984		
4	Integration-max	1.263	1.013		
5	Integration-3 max	2.2	2.654		
6	Connectivity-max	4	5		
7	Integration average	0.779	0.680		
8	Integration-3 average	1.347	1.843		

(1) The term 'understand' is used here as a synonym for 'read', as used by Hillier et al (1987a); it does not imply any cognitive dimension. However, the issues of cognitive correlates of syntax values are addressed later in this paper.

there was much less variation between the intelligibility of the three settings: 0.435, 0.420, and 0.412 for University Hospital, Urban Hospital, and City Hospital, respectively. Thus the overall axial complexity of the three settings can be said to be similar; but they vary in the manner in which their public spaces are laid out. This, of course, attests to the validity of these three hospitals being chosen as experimental settings. Also, it demonstrates that settings with similar characteristics in overall configurations may indeed present different properties to their visitors if they are restricted to the public system only. Therefore, any study should distinguish between these two systems.

Another factor to note is that intelligibility-3 of the public lines of all the six conditions of the three settings were not only high, but also quite similar (from 0.927 to 0.984; see table 3, row 3). This indicates that the local conditions of all the settings give a very good indication of lower level integration (that is, integration-3). It would be interesting to carry out axial analysis of other complex buildings to examine if such patterns are displayed elsewhere.

Behavior and the environment

The effects of line variables on behavior were modeled by correlating subjects' use with environmental values. In all the cases reported here, unless otherwise mentioned, *r*-values are statistically significant with $p < 0.05$.

Correlating TUL in open exploration with various line values, it was found that in five out of the six cases the highest *r*-value was given by connectivity of the axial lines (0.836, 0.636, 0.884, 0.786 and 0.530 in Urban Hospital whole-line and segmented-line, University Hospital whole-line, and both conditions of City Hospital, respectively; see table 4, row 3). Furthermore, connectivity was the highest predictor in all the 3 whole-line systems and deviated only in the segmented version of University Hospital.

When the number of subjects who visited each line during open exploration, that is, PIL, was considered, then the emphasis shifted to integration-3 (table 5, over). In this case also, five out of six instances provided the highest correlation with integration-3. (0.775 in Urban Hospital whole lines, 0.859 and 0.570 in the 2 conditions of University Hospital, and 0.814 and 0.639 in the two conditions of City Hospital; see table 5, row 6). As in the condition of TUL, all the whole-line systems had the highest correlation, and in only one segmented system integration-3 was not the highest predictor.

Table 4. Correlations (*r*-values) of axial-line values with total use of line (TUL) in open exploration.

			Urban Hospital		University Hospital	
			whole lines	segmented lines	whole lines	segmented lines
1	Connectivity	first 5 use	0.773	0.424	0.723	0.407
2		last 5 use	0.821	0.524	0.845	0.525
3		all use	0.836	0.636	0.884	0.566
4	Integration-3	first 5 use	0.736	0.420	0.738	0.381
5		last 5 use	0.788	0.512	0.781	0.505
6		all use	0.805	0.631	0.829	0.567
7	Integration-max	first 5 use	0.666	0.344	0.689	0.655
8		last 5 use	0.702	0.408	0.792	0.410
9		all use	0.691	0.521	0.819	0.678
10	Length	all use	0.818		0.866	

The important thing to note here is that when repeat visits were considered, then connectivity emerged as the strongest predictor, but when number of people who visited a line was considered, integration-3 gained prominence. This pattern holds true even when the 3 whole-line systems were considered together ($r = 0.641$, table 4, row 3; $r = 0.583$, table 5, row 6), and also when all the six systems were taken together $r = 0.493$, table 4, row 3; $r = 0.509$, table 5, row 6). An important aspect to be noted here is that the whole-line systems display a similar pattern with connectivity and integration-3 in all the analyses. Variations were only observed in the segmented-line systems.

Connectivity is the number of accessible connections that are available in a corridor. It measures how well a space is connected to other immediate spaces. From the point of view of the situated observer, it gives a sense of how much further exploration a space will allow (assuming that all the corridor connections are recognized). Therefore, it seems reasonable that in the initial stages of exploration, people tend to revisit such areas, which offer a better sense of other spaces through visual connections. On the other hand, integration-3 is a configurational measure that takes into account the relationships of a space to others that are three steps removed from themselves. This is a lower order configurational variable. The fact that it is the strongest predictor for distribution of people (PIL) when they are unfamiliar with the setting and cannot possibly know its configurational qualities provides a puzzling finding. This will be taken up later in this paper.

This pattern of connectivity, integration-3, and use was also repeated when subjects were asked to find specific places within the setting. In this scenario, redundant use of lines was considered. When TURL was the dependent variable, then the following picture emerged. In three cases, the highest correlation was given by connectivity: in the Urban Hospital and University Hospital whole-line systems, and the City Hospital segmented-line system (0.637, 0.779, and 0.428, respectively; see table 6, row 1, over). Connectivity was also important for all the six systems combined ($r = 0.333$; see table 6, row 1).

A clearer result was obtained by considering people in redundant lines (PIRL). Here, the highest correlation was given by integration-3 in five instances. These are the 'whole' systems of the three hospitals, the three 'whole' systems combined in one dataset, and all six systems combined in another dataset ($r = 0.552$, 0.775, and 0.608 in Urban Hospital, University Hospital, and City Hospital, respectively; 0.391 and 0.339 for the combined systems; see table 7, row 2, over).

Table 4 (continued).

			City Hospital		3 hospitals whole lines	All 6 versions
			whole lines	segmented lines		
1	Connectivity	first 5 use	0.620	0.351		
2		last 5 use	0.716	0.484		
3		all use	0.786	0.530	0.641	0.493
4	Integration-3	first 5 use	0.633	0.348		
5		last 5 use	0.717	0.501		
6		all use	0.775	0.527	0.628	0.486
7	Integration-max	first 5 use	0.685	0.467		
8		last 5 use	0.714	0.722		
9		all use	0.636	0.495	0.301	0.316
10	Length	all use	0.607			

Table 5. Correlations (*r*-values) of axial-line values with people in line (PIL) in open exploration.

			Urban Hospital		University Hospital	
			whole lines	segmented lines	whole lines	segmented lines
1	Connectivity	first 5 use	0.790	0.422	0.795	0.423
2		last 5 use	0.828	0.522	0.854	0.568
3		all use	0.736	0.656	0.814	0.564
4	Integration-3	first 5 use	0.761	0.420	0.783	0.393
5		last 5 use	0.808	0.510	0.806	0.545
6		all use	0.775	0.653	0.859	0.570
7	Integration-max	first 5 use	0.704	0.348	0.749	0.654
8		last 5 use	0.733	0.447	0.835	0.543
9		all use	0.658	0.554	0.750	0.667
10	length	all use	0.688	0.225	0.736	

Table 6. Correlations (*r*-values) of axial-line values with total use of redundant lines (TURL) in directed search.

		Urban Hospital		University Hospital	
		whole lines	segmented lines	whole lines	segmented lines
1	Connectivity	0.637	0.505	0.779	0.302
2	Integration-3	0.636	0.482	0.743	0.331
3	Integration-max	0.470	0.517	0.777	0.673
4	Length	0.623		0.741	

Table 7. Correlations (*r*-values) of axial-line values with people in redundant lines (PIRL) in directed search.

		Urban Hospital		University Hospital	
		whole lines	segmented lines	whole lines	segmented lines
1	Connectivity	0.518	0.513	0.732	0.333
2	Integration-3	0.552	0.490	0.775	0.361
3	Integration-max	0.430	0.556	0.707	0.592
4	Length	0.525		0.687	

Here again, in the case of directed search, connectivity and integration-3 appear in identical scenarios as in open exploration. When repeat visits were considered connectivity gained an advantage, but integration-3 was the best predictor of the distribution of lost people.

The cognitive aspects of lines and settings

Both exploration and search are purpose-driven behavior. They involve the making and execution of spatial decisions. Therefore, the record of an exploration or search track can be considered as a representation of environmental learning.

Sketch mapping was carried out by all the subjects in two of the three settings: University Hospital and City Hospital. The appearance of whole and segmented axial lines in cognitive maps was correlated to their configurational values. As shown in table 8 (over), the highest correlation in three out of four cases was with integration-3.

Table 5 (continued).

			City Hospital		3 hospitals whole lines	All 6 versions
			whole lines	segmented lines		
1	Connectivity	first 5 use	0.686	0.363		
2		last 5 use	0.765	0.490		
3		all use	0.784	0.635	0.542	0.490
4	Integration-3	first 5 use	0.696	0.367		
5		last 5 use	0.785	0.507		
6		all use	0.814	0.639	0.583	0.509
7	Integration-max	first 5 use	0.721	0.530		
8		last 5 use	0.799	0.746		
9		all use	0.564	0.568	0.188	0.222
10	Length	all use	0.598	0.282		

Table 6 (continued).

		City Hospital		3 hospitals whole lines	All 6 versions
		whole lines	segmented lines		
1	Connectivity	0.646	0.428	0.446	0.333
2	Integration-3	0.657	0.414	0.448	0.331
3	Integration-max	0.594	0.387	0.225	0.282
4	Length	0.417	0.248		

Table 7 (continued).

		City Hospital		3 hospitals whole lines	All 6 versions
		whole lines	segmented lines		
1	Connectivity	0.559	0.480	0.358	0.328
2	Integration-3	0.608	0.477	0.391	0.339
3	Integration-max	0.436	0.368	0.090	0.202
4	Length		0.342		

This included both the whole-line systems ($r = 0.561$ and 0.697, see table 8, row 3). When the two whole-line systems were considered together, the best predictor was also integration-3 ($r = 0.534$, table 8, row 2), as it was when all the four systems were combined ($r = 0.468$, see table 8, row 2).

From these results it may be assumed that integration-3 has a cognitive component. To understand further the implications of integration-3 and the cognitive correlates of intelligibility through a different cognitive test—pointing to unseen destinations by the 96 subjects—a multiple regression model was proposed. This model took integration-3 of the lines and intelligibility of the settings as predictor variables for errors in pointing. It produced results as follows: $r = 0.310$ and 0.266 for the two whole-line systems together and the two segmented-line systems together, respectively; and $r = 0.174$ for the four systems combined. Although the predictabilities of these models were not very high, they were, however, quite significant: $p = < 0.0001$ in all cases. Most importantly,

Table 8. Correlation of line values with their appearance in cognitive maps.

		University Hospital		City Hospital		2 hospitals whole lines	All 4 versions
		whole lines	segmented lines	whole lines	segmented lines		
1	Connectivity	0.556	0.468	0.678	0.704	0.494	0.440
2	Integration-3	0.561	0.494	0.697	0.738	0.534	0.468
3	Integration-max	0.424	0.622	0.401	0.517		0.213
4	Length	0.505	0.272	0.606	0.418		

the coefficients for integration-3 and intelligibility for these three cases was always a *negative* number. This indicates that there will be fewer errors in pointing when a person with some experience of a setting is located in areas with more integration-3 values. Another finding of significance is that in settings of higher intelligibility there will be less pointing errors.

When the two test results are considered in tandem, two conclusions emerge: first, integration-3 is featured in the cognitive abilities of humans as it relates to their moving inside complex buildings; second, cognitive performances are better in settings of higher intelligibility.

Correlations of total use of lines in open exploration with connectivity, integration-3, and integration-max are shown in table 9. These values may also be called the *predictability* of the three environmental variables. If this predictability is correlated both with intelligibility and with intelligibility-3, a very interesting pattern is seen. As shown in table 10, although predictability has very high and *positive* correlation with intelligibility, it has a high but a *negative* correlation with intelligibility-3 (see also figures 7 and 8). Although with only six observations this is not a statistically significant result, nevertheless, the trend is clear. Settings with higher intelligibility

Table 9. Predictability values and intelligibilities of the six settings.

Hospital	Intelligibility	Intelligibility-3	Connectivity	Integration-3	Integration-max
Urban	0.704	0.953	0.836	0.805	0.691
Urban, segmented lines	0.581	0.984	0.636	0.631	0.521
University	0.837	0.927	0.884	0.829	0.819
University, segmented lines	0.446	0.978	0.566	0.567	0.678
City	0.557	0.970	0.786	0.775	0.636
City, segmented lines	0.321	0.984	0.530	0.527	0.495

Table 10. Correlations of predictability and intelligibilities.

	Predictability		
	public connectivity	public intelligibility-3	public intelligibility
Intelligibility	0.916	0.896	0.777
Intelligibility-3	−0.868	−0.827	−0.896

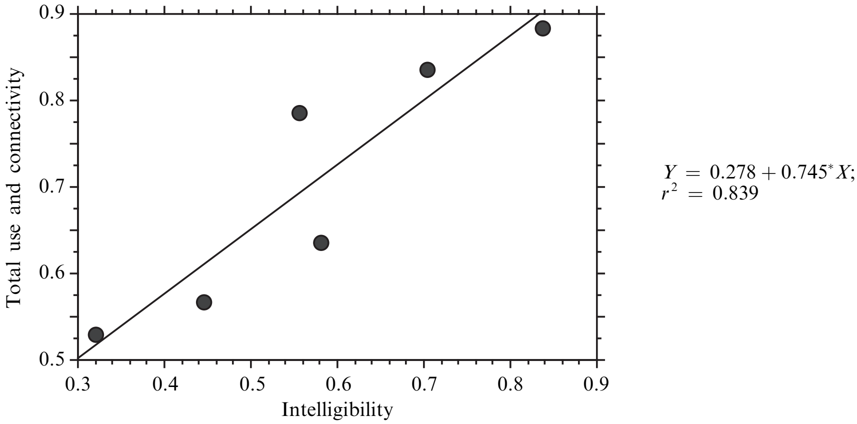

Figure 7. Correlation of predictability (total use and connectivity) and intelligibility ($r = 0.916$).

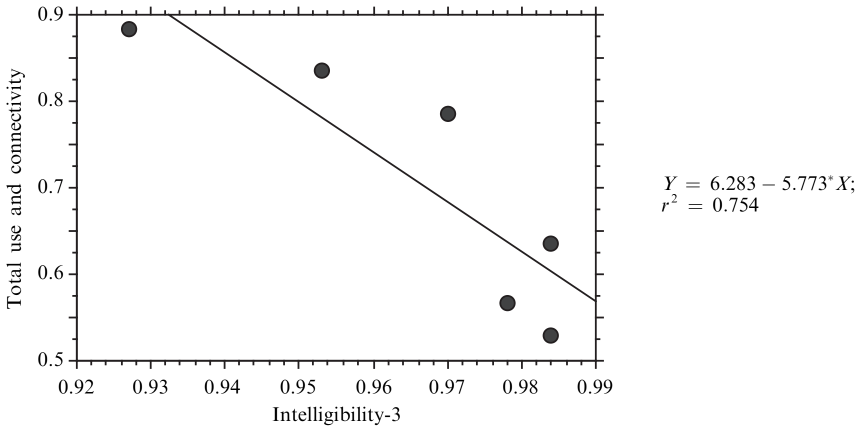

Figure 8. Correlation of predictability (total use and connectivity) and intelligibility-3 ($r = -0.868$).

provide better predictability through their configurational variables, but settings with high intelligibility-3 provide less predictability.

This finding was also verified through a second test involving pointing errors. As discussed before, in the multiple regression models for pointing errors, intelligibility always produced a negative coefficient. However, if intelligibility was replaced by intelligibility-3 in the same model, then the coefficient became *positive in all cases*. This indicates that settings with more intelligibility-3 may produce more cognitive performance errors.

In previous studies it has been asserted that prediction of POP depends on intelligibility of the setting (Hillier et al, 1987a). The results of the present study add clarity to those findings, specifically because wayfinding (which, arguably, is a decision-based movement) and cognitive tests are considered through data both from sketch mapping and from pointing to unseen destinations. Additionally, it brings out the reverse role of intelligibility-3.(2)

The effects of entry points on open exploration

In the next level of analysis the effect of the entry points on open exploration was considered: does the property of an entry influence the way a building is explored? If so, how, and to what extent? In this experiment two settings were explored from more than

(2) A more detailed look at the effects of intelligibility can be found in Haq and Girotto (2003).

one entry point. In Urban Hospital each participant started from one of three entries, and in City Hospital from one of two. Different entries of any layout usually vary in the property of mean depth. This value is derived after considering the topological relationship of all other spaces in a spatial system with respect to itself. For example, entry C of Urban Hospital (whole lines) has the least mean depth in that setting (2.881), followed by B (3.452), and then A (4.452) (see figure 1 and table 11). On the other hand, the two entry points of City Hospital (whole lines) have values of 3.478 and 3.261 for A and B, respectively (see figure 5 and table 11). Similarly, the mean depths also vary in the segmented-line systems. In these cases, because there are more axial lines in a similar distribution to the whole lines, depth values are higher. The mean depth values of the four settings are shown in table 11.

Table 11. Mean depth from various entrances.

	Hospital setting		Mean depth from entrance		
			A	B	C
1	Urban	whole lines	4.452	3.452	2.881
2		segmented lines	7.303	5.974	6.329
3	City	whole lines	3.478	3.261	
4		segmented lines	5.213	4.574	

To explore the effect of entry points on open exploration, a multiple regression model was proposed with public connectivity and mean depth of entry space as predictors of total axial line use. Public connectivity was chosen because it was found to be the highest predictor of TUL. In the four syntactic conditions of Urban Hospital and City Hospital, this model predicted 61%, 33%, 57%, and 26%, respectively, of the variance. From the same model, it was seen that the coefficient of mean depth was *always* calculated as a negative number. Hence, it can be said that total use of an axial line is inversely correlated with mean depth of a starting point. In other words, people who entered from spaces with lesser mean depth revisited spaces more often. This is important given the fact that the subjects had a fixed amount of time. In general, it can be stated that the configurational property of the entry might influence the way a building is explored; people will tend to go to more connected areas in proportion to the mean depth of the entry from which they start their search tasks.

In terms of wayfinding, this is significant because it raises the very important question of where wayfinding starts. If the property of the entry itself can feature in wayfinding consideration, then it can be used to some advantage in building design—especially in the context of wayfinding and location of strategic areas.

This concept can also be extended to the task of linking any building with the larger environment. For example, in consideration of city streets, what should be the most effective location for an entry to a complex? A designer may then look at the effect of that entry on the interior spaces. Thus one may work back and forth to derive a proposal for an entry location that will be most meaningful to visitors. Additionally, designers may use this knowledge to manipulate the entry to suit organizational policies.

The importance of entry properties has been reported before (Haq, 1998); it seems to be substantiated here with more data.

Relationship between line variables

So far, an important task has been to look for the highest correlation and attempt to detect a pattern. Needless to say, such a pattern does exist and integration-3 and connectivity seem to be the more robust variables in predicting use of lines both in exploration and in searches: integration-3 for the distribution of people in line (PIL and PIRL), and connectivity for total and repeat visits (TUL and TURL). Previously, while tracking people in museum settings, Choi (1999) had found that connectivity predicted TUL ($r = 0.623$) and integration-max predicted PIL ($r = 0.508$). Earlier, Peponis et al (1990) had demonstrated that TUL and TURL of exploring and wayfinding people were better predicted by integration-max ($r = 0.755$ and -0.754, respectively).

It seems imperative that a discussion regarding connectivity, integration-3, and integration-max is initiated. Intelligibility is the correlation between connectivity and integration, and intelligibility-3 is the correlation between connectivity and integration-3. Neither Peponis et al (1990) nor Choi (1999) had reported the intelligibility or intelligibility-3 values of the settings in which they carried out their work. In all the six cases in this present study, intelligibility-3 was more than 0.9 (see table 3, row 3), that is, connectivity and integration-3 were very highly correlated. Moreover, the intelligibility values of the whole-line systems were rather significant (0.704, 0.837, and 0.557), but less so for the segmented-line systems (0.581, 0.446, and 0.321).

In all the cases reported here, correlations of line use with integration-3 is very close to that of the correlations of line use with connectivity (see tables 4, 5, 6, and 7). Statistically, the difference between the effects of connectivity and integration-3 is very small: that is, their mathematical units seem to be measuring similar attributes—at least in the case of the three hospitals and the six analyses of them. Theoretically, however, these two are very well distinguished: connectivity is local information whereas integration-3 is nonlocal but less than global. It certainly makes intuitive sense to theorize that when people are not sure of their destination they will go to areas that provide more spatial information, as given by their connections to other areas. In this case, the cognitive process has been described as 'expectation of exploration, that is, people expect more information and proceed to areas that satisfy that expectation (Haq, 1998; 1999a).

At this point integration-3 and its role in purpose-driven movement remain to be explained. A core argument in syntax literature is that layout restricts or permits movement in certain ways, and that this influences which spaces will have more presence of people. This is because of the confluence of paths to and through all spaces in the system, which is articulated through the model of an axial integration map. It does not imply any decisionmaking by the subjects involved. From such a basis the concept of a 'virtual community' has been proposed, and presence of people in line (POP) has been described as a factor of integration (Hillier, 1989; Hillier et al, 1987a). However, in the cases reported here, integration-3 has been found to be the highest predictor of the distribution of people in purpose-oriented behavior such as exploration and wayfinding. Of additional interest is the fact that the r-values given by integration-3 are closer to those of connectivity than to those of integration-max (see tables 4–8). Furthermore, integration-3 was the highest predictor of corridors that were drawn in the sketch maps by the subjects.

The tasks that the participants carried out for this experiment included exploration of a new environment and destination finding within it about 15 or 20 minutes later. In this situation the subjects perhaps started with some cognitive understanding or schema of hospital buildings (Gross and Zimring, 1992) and received local information about the physical setting as they walked within it. The environmental information that was immediately available was local. It can thus be said that the movement of the participants was conditioned by three things: their schema, locally available information, and the configurational structure of the environment which restricted or permitted movement in certain ways. If the schema is held constant, then the environmental factors are local information and spatial opportunities as given by their configuration. The equilibrium of these two, if understood as an intermediate level of integration, can begin to explain the fact that in most cases in this study, integration-3 was the highest predictor of people in the corridors. Thus one may assume that the distribution of people beginning interactions with an environment is structured by a lower level of integration. This deduction was also validated by cognitive-mapping results that clearly exhibited the predominance of integration-3.

It may now be stated that, although integration-max is a good predictor of people when the general presence is mapped, integration-3 is the most important predictor for exploring and wayfinding people in new settings. In addition, connectivity maps the repeat visits by explorers and wayfinders. At this point, a recent report by Hillier should be highlighted: in reference to his 1993 paper, he has admitted (in endnote 2) that "a series of studies since then have shown that 'local', or radius-3 integration is normally a better predictor of pedestrian movement" (Hillier, 2001, page 2.27). In light of the study presented here, this comment takes on very high significance.

Concluding comments

Two other issues now remain to be discussed. First, the relevance of syntactically defined configurational analysis and, second, the definition of lines themselves. The importance of the first of these hardly needs emphasis; this becomes easy to understand when the world is considered from the point of view of wayfinding. More likely than not, we think in topological terms and this is exhibited in the commonplace scenario of direction giving, where we usually give directions in terms of paths and turns, rather than distances and angles (Hammer, 1999). Previous studies have demonstrated the importance of configurational variables, and the present work has shown its importance in wayfinding and environmental cognition. As an additional indicator, it can be seen (from tables 4 and 5) that in all the cases reported, the use of the last five lines in open search is always more correlated to all topological variables than use of the first five. Therefore, within a few minutes of exposure to a new setting, subjects tend to gravitate towards areas that have higher topological values. Such results serve to indicate that topological configuration may be something that humans are able to pick up quite quickly in their relationship to an environment. From this, it may be argued that as people get to know the environment more, their topologically constructed configurational knowledge increases. In other words, when relational and Euclidean understanding of space develops, it may not be 'map-like', but may consist of topological relationships that consider greater and greater depth and larger and larger systems.(3) Although a clearer pattern could not be distinguished, this brings out the need for a more critical and empirical evaluation of the differences between connectivity, integration-3 (or 4, or 5, etc) and integration-max. This can perhaps be done in settings of different intelligibilities. Variation of entire layouts may be difficult in real-life situations, but it is possible in virtual settings. Thus this becomes a promising area for future research.

The second issue, of line definition, has been a constant criticism of space syntax; its lack of geometrical and metric properties is one that is most contested. Indeed, Tedjo and Funahashi (1999) have shown that in three out of four cases of strolling behavior (two each in Japan and Indonesia) line length had more predictive power than line integration. However, that was not the case in this study. Correlations of line length with TUL and PIL in open exploration, TURL and PIRL in directed search, and with appearance in cognitive maps are shown in tables 4 to 8. Although they are high and significant, they do not have the highest prediction.

(3) This conclusion was presented earlier (Haq, 1999a). The additional data and further analysis presented in this paper support it.

Definitions of axial line as the longest connector between convex spaces leave out its cognitive implications. As mentioned before, axial lines can be extremely long, or can fail to incorporate undulations in the topography. This remains a serious issue. The segmented version of axial maps used in this study was defined from the point of view of nodes as a break in those lines and places of possible cognitive emphasis. It was hypothesized that this method of analysis will relate better with tracking and cognitive-mapping data. Unfortunately, the results indicate that this version of axial mapping had less predictive power than that of whole lines. Again, the question of scale and dimension comes in. Although very long lines cannot be comprehended, extremely short ones may not be considered as complete cognitive units. The balance lies somewhere in between, at a scale or size that the mind recognizes. Research into the scale of this recognition is an important next step for space syntax. Perhaps architects intuitively design buildings with human scale and perception in mind, and so each corridor or visual axis is not unduly elongated. A better way of addressing metric distance is important, especially in research from a cognitive viewpoint and in research that is carried out in large-scale settings. Perhaps looking at nodes themselves as space syntax units is a way to achieve this; however, that is the subject of a subsequent paper.

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