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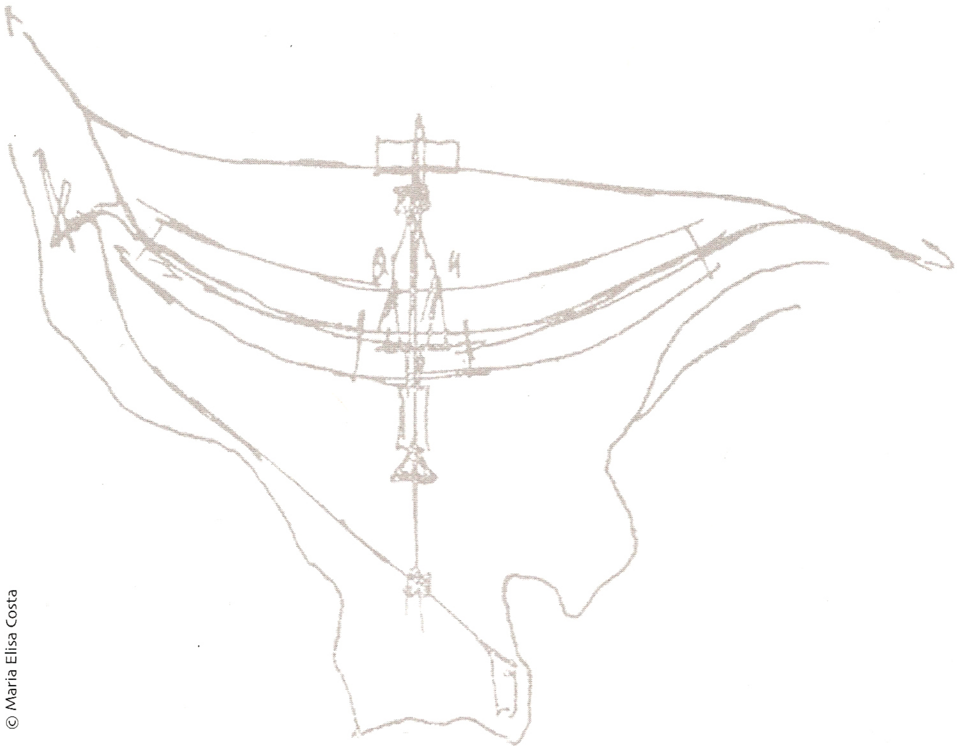

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CAN SPACE SYNTAX PREDICT ENVIRONMENTAL COGNITION?

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Saif-ul- Haq
Georgia Institute of Technology, Atlanta, United States

0 Abstract

Environmental cognition involves the interaction of human behavior-both internal cognitive processes such as perception, memory and reasoning and more molar behaviors such as wayfinding and route choice-with the "real world" that has specific form and content. However environmental cognition researchers have focused much more on behavior than on environmental form. On the other hand, Space Syntax theorists sometimes make psychological claims. For example, Hillier argues that intelligible layout contribute to the intuitive understanding of configuration (Hillier, 1996: pp. 40). Although Syntax researchers suggest that the diachronic nature of architectural experience may be picked up by the peripatetic observer (Hillier, 1996: chapter 6) and the property of integration is a useful measure for studying this, they do not probe the more complex processes of the human mind. Nevertheless, Space Syntax would seem to be a useful theory and methodology for understanding the role of environmental form in environmental cognition.

This paper reports the results of a wayfinding experiment that was undertaken to understand the relation between cognition and the environment. Wayfinding is thought to be important because it is one of the few human activities where there is conscious and deliberate use of the environment to produce quantifiable behavior.

Correlational analysis of movement with environmental variables revealed that relational values have stronger correlation and among them, syntax connectivity is the most significant ($p=0.768$ in open exploration and $p=0.724$ in directed search). Second, it was found that the property of mean depth of the space from where wayfinding is initiated is extremely important in understanding the way a building is explored; it is a strong indicator of the co-relation of space use and syntax variables. By knowing one property of the entry space, mean depth, we can have a fair indication of the relative importance that the other spaces in the system will have on spatial exploration. Third, it was also demonstrated that as people get to know their environment more, they tend to attain a better understanding of its overall configuration: correlations were higher between global syntax variables and later movement. This leads to the hypothesis that when relational and Euclidean understanding of space develops, it may not be 'map-like' but may consist of topological relationships that consider larger and larger systems. It also endorses the theory that configuration may have a cognitive component.

The paper also compares the results with two similar studies by Georgia Tech researchers and assess the effectiveness of Space Syntax variables in predicting wayfinding behavior

Keywords: Environmental Cognition, Space Syntax, Wayfinding, Hospital design

Saif-ul- Haq
Ph.D. Program,
College of Architecture,
Georgia Institute of Technology,
Atlanta, GA 30332-0155

tel. 404 894 6279
fax. 404 894 1629
email: saif.haq@arch.gatech.edu
email:saif.haq@alum.MIT.EDU

http://www.arch.gatech.edu/~shaq

1 Introduction

In an e-mail to the Space Syntax electronic discussion group, Jake Desyllas defined Space syntax as "... a Scientific Research Programme (SRP) investigating the role of spatial configuration as an independent variable in social systems. It is concerned with such problems as: how can we measure the configurational properties of spatial systems? What is the role of configuration in movement, co-presence and higher order social phenomena? (and) What is the nature of the relationship between social organization and spatial configuration?" This description adequately sums up the prevalent thrust of Syntax research which has traditionally been concerned with linking space with society.

Recently however, practicing architects have posed a different kind of question. In the same discussion group, Tom Dine writes, "I wonder how Space syntax can be used as a way of describing the way spaces are experienced? ... What can Space Syntax tell us about what places 'seem like'? " In this regard, Syntax observers have tentatively argued that intelligible layout contribute to an intuitive understanding of configuration (Hillier, 1996: pp. 40). They also suggest that the diachronic nature of architectural experience, as understood through axial lines, may be picked up by the peripatetic observer (Hillier, 1996: pp. 215). However, they imply that this understanding is 'non-discursive' - i.e it can be understood but not described.

Pioneering work by Kevin Lynch has demonstrated that an understanding of the environment can be verbalized, especially if put in the context of travelling from one point to another (Lynch, 1960). To explore the issue of environmental understanding, environmental cognition researchers have developed tools of interviewing, sketch-mapping, behavior mapping etc. Unfortunately, they have tended to focus more on human internal processing then on the environmental form itself. Thus while the process of cognitive understanding has been well researched, its relationship with the environment is less known.

This paper, which reports the initial work for a Ph.D. dissertation in GeorgiaTech under Dr. Craig Zimring, will argue that Space Syntax can provide the necessary environmental understanding to undertake a study of the relationship between the mental structure and the environmental structure. Methodologically, wayfinding is considered appropriate because it includes a conscious and deliberate use of the environment to produce quantifiable behavior. In the hypothesized model that this study adopts, a cognitive understanding is posited between environmental variables and wayfinding behavior. The empirical research reported here demonstrates that there is good relationship between Syntax variables and deliberate use of spaces in a wayfinding situation. This substantiates previous research (Peponis, Zimring, & Choi, 1990; Willham, 1992; Zimring et.al., 1998). Also, it is seen that in the situation of open exploration, space use can be predicted by knowing the mean depth of the space from which the search is initiated. The study also demonstrates the viability of tracking in an open exploration and wayfinding situation. Finally, it explores additional spatial measures that may be helpful in expanding Space Syntax measures.

2 Environmental Cognition and Wayfinding

Environmental cognition encompasses the cognitive processes involved in acquisition and representation of spatial information in real world settings. It is the study of the inter-subjective information, images, impressions and beliefs that people have of their environment, the ways in which these conceptions arise from experience and the ways in which they affect subsequent behavior with respect to the environment. It involves interaction of the internal human processes such as perception, memory and reasoning and molar behaviors such as wayfinding and route choice with the "real world" that has specific form and content. However, researchers in this field have focused much more on the internal process and external behavior than on environmental form. One possible reason for this may be a shortage of tools to rigorously describe and quantify the environment. In this regard, Space Syntax offers a link between environmental cognition research and environmental variable research. 44.3

'Wayfinding' is a term that has not quite made it into the English language. Encyclopedia Brittanica (on line) does not list it, nor does the Oxford English dictionary1. Nevertheless, it has become an important area of focus within environment-behavior research. Although a common-sense understanding of wayfinding implies a role of the environment, yet this has been difficult to incorporate into research which has traditionally focused on behavioral and cognitive aspects such as cognitive mapping, memory, schema, decision making and information processing. When researchers do consider the environment, it is done from within a working definition of cognition and the wayfinding process. For example, Passini's model stresses recognition of environmental features as an important component of wayfinding (Passini, 1984) and so he describes the environment from this aspect. Similarly, Garling et. al's physical setting variables of (1) degree of differentiation, (2) degree of visual access and (3) complexity of spatial layout are developed from basic cognitive processes such as recognition of parts, localization of reference points, recall, selection and sequencing of destinations.

As considered in this research, wayfindingincludes both spatial orientation and the ability to find a particular destination. (Passini, 1984). It is spatial problem solving that includes cognitive mapping or information generating ability that allows us to understand the world around us, a decision making ability that allows us to plan actions and structure them into an overall plan and a decision executing ability that transforms decisions into behavioral actions. In this manner wayfinding behavior can be considered an expression of the internal cognitive processes.

Some wayfinding researchers have used the environment as predictor variables in wayfinding performance. For example, Best reported high correlation between 'lostness', i.e. deviations from a most direct route, and the number of choices in that route. (Best, 1970). Evans et. al. (1980) found that when color-coding was added, subjects' wayfinding performance and orientation improved. Braaksma et.al. described terminal buildings as a node-link network where each destination and origin was a node and visibility between them, either directly or through signs, the link (Braaksma & Cook, 1980). By measuring the connectivity of such a graph, indices for visibility in a building was developed and interviews with patrons showed that wayfinding problems were indeed associated with areas with low visibility indices. In 1981 Weisman found that 'simplicity' of floor plan configuration as rated by judges was a strong predictor of self reported wayfinding performance (Weisman, 1981). In a later study, Michael O'Neil defined layout complexity as the average number of connections per choice point in a floor plan, which he called 'Inter-Connection Density' (ICD). In studying buildings, he found that as ICD increased, both cognitive mapping ability and wayfinding performance decreased.

Peponis et.al. used Space Syntax theory and methodology to examine spatial search behavior (Peponis et.al., 1990). They asked 15 subjects to explore a small hospital in 'open exploration' and then asked them to find several locations in 'directed search'. The researchers recorded their routes for both phases and found that the subject's open search patterns were strongly predicted by the space syntax measure of 'integration'. In addition, when people were lost, they tended to use integrated paths. This research suggested that people understand and use an abstract set of global relationships within the environment when they make wayfinding choices.

Later, Zimring et.al. replicated the Peponis et al. study and further quantified the description of spaces (Zimring & Willham, 1998). They re-analyzed the original data to investigate if any other measures influenced the wayfinding process and also duplicated the experiment using the same building and the same methodology, with 12 older people as the subjects. Their description of the spaces considered local, relational and global parameters. Local parameters included the characteristics of specific spaces, relational parameters were derived from visual relationships with adjacent spaces and global parameters were calculated from relationship with all the spaces in the system. Zimring et al concluded through the use of correlational research, that new comers rely on the local measures for wayfinding, but as learning occurs relational and global measures become more important.

The Peponis et al and Zimring et al studies were suggestive that the overall pattern of layout was important for predicting the search patterns of way-finders. This seems to provide additional clarity about the role of choice and complexity in buildings. They have demonstrated that Syntax measures feature strongly in correlational analysis with behavior. However, both studies used a single building, and it is unclear whether this finding generalizes to more complex settings.

3 The Research

This study was aimed at understanding the environment as predictor variables for wayfinding performance. Furthermore, it sought both to replicate and extend the Peponis et al (1990) and the Zimring et al (1998) study. Specifically it dealt with exploring more local and relational values and extending the analysis between behavior and environmental variables.

3.1 Subjects and setting

This research was carried out on the ground floor of a 21 story urban hospital in Atlanta, Georgia (Figure # 1); the largest hospital in the state. The hospital recently completed a 318 million dollar architectural renovation and addition; however, due to cost overruns, the signage was not updated.

Only the ground floor of this hospital was used in the experiment. Three entrances out of six were chosen as starting points for open exploration and four locations within the hospital were chosen for the search tasks (See figure # 2). The entry points were selected because they all had 'you-are-here' maps just inside the door. Destinations were chosen that some were beside syntactically integrated and others were beside segregated corridors, were in both renovated and un-renovated parts of the hospital and were both near and far from atriums and entry points.

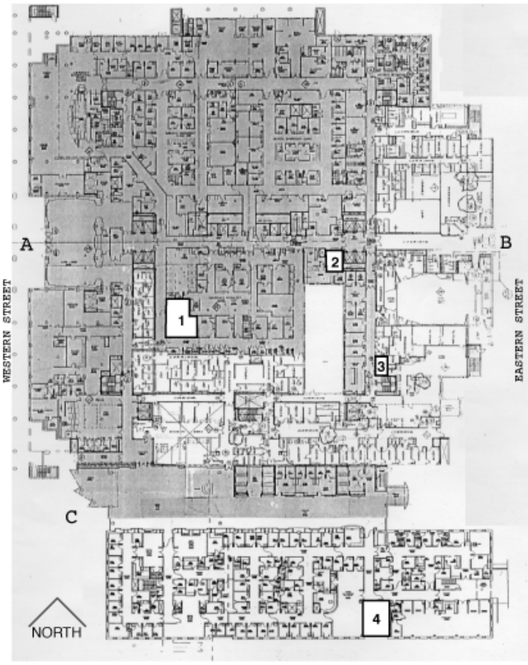

Figure 1: Exterior view of hospital

Figure 2: Plan showing areas used in the studyA,B and C are entry points for the subjects and 1,2,3,and 4 are locations for directed searches.

Twelve male and nineteen female undergraduate students from the human subjects pool of the Psychology department of Georgia Institute of Technology participated2. They were between 18 to 25 years; one male was 32. The subjects were carefully screened so that none of them had visited a large hospital complex more than once in the previous 12 months.

3.2 Research Procedures

The subjects were individually met on Georgia Tech campus and were driven past the hospital to a parking garage. From there, they were escorted to one of the entry points of the hospital. Nine, thirteen and nine students started from entrance A, B, and C respectively (Figure # 2). They were then asked to freely explore the ground floor of the building (open exploration) and to learn about its layout and locations as best as they could, so that they would be able to carry out specific searches within the environment later. They were allowed only to go into the spaces accessible to the public; if they were confused and tried to go inside restricted areas, the researcher would stop them. They stopped when they were satisfied with their open search, or after 20 minutes. They were then taken to one of the selected locations within the building and were asked to walk to another one (directed search). For this task they were given a maximum of 15 minutes after which that task was abandoned. When they found the destination (or if their time was up they were escorted to that destination) they were asked to go to the next one. This procedure was repeated until each participant had journeyed, or had tried, to and from all the selected locations.

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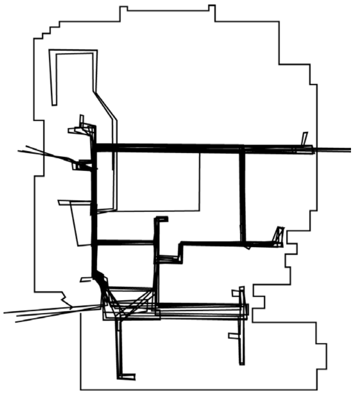


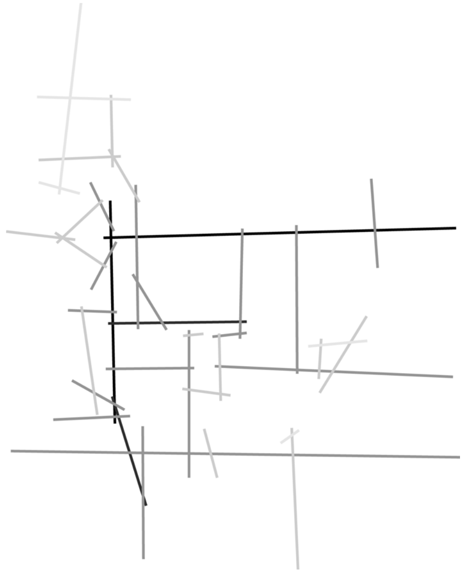


Figure 3: Hospital outline showing search structure

Figure 4: Axial line system of Public spaces in the setting.(Dark lines are more integrated)

The four locations were each treated both as an origin and a destination. This resulted in 12 routes for the directed search. In total, the 31 research subjects carried out 195 directed searches. The routes were counter-balanced for order.

The researcher followed each subject and recorded their routes on a plan of the building. Whenever a person took more than three steps in any direction into a space, the subject was noted as using that space. (Figure # 3)

3.3 Independent Variables: The Environment

The environment was quantified as two systems, an axial line system and an interconnected system of nodes. The layout was reduced to a set of convex spaces and the longest lines connecting these spaces produced the axial system or axial map (Hillier, Hanson, & Peponis, 1984; Hillier, Hanson, & Peponis, 1987; Hillier, Hanson, Peponis, Hudson, & Burdett, 1983; Hillier, 1984). This axial map is thus composed of the fewest and longest possible straight lines of uninterrupted visibility and movement that can cover the plan. It is the most economical way of describing the layout as a pattern of visibility and potential movement, calling attention to the changes in direction and the numbers of transitional spaces that are necessary to walk from one space to another. On the other hand, nodes are basically areas where a decision regarding direction is needed by a traveler in the spatial system. In terms of this research, these are intersections of two or more axial lines. The values of axial lines and nodes were grouped into three categories depending on their relationship to other lines and nodes in the system: These are global, relational and local values.

The values of the axial lines were calculated by Space Syntax methodology. These are Public Integration: This is the integration value based on the system of corridors and spaces that are open to the public. (This is a "global" variable.)

All Integration: This is integration value of each line which is based on all the spaces in the hospital. This is the spatial system which would be accessible to a staff member who had a pass key to open all the doors. (This value is also in the global scale)
Public Integration(3): Integration values of depth 3 read from the public system only. (Global scale)

All Integration(3): Integration values of depth 3 read from the entire hospital configuration. (Global scale)

Public Connectivity: This is a count of other axial lines of the public system which intersect the origin line. (Local scale)

All Connectivity: This is a count of other axial lines of the total system which intersect the origin line. (Local scale)

The part of the spatial system accessible to the public in the research setting had 39 axial lines and the entire hospital had 377. Figure # 4 and # 5 show the axial lines of the public system and the entire hospital respectively.

There were 46 nodes in the public area. Since they were, by definition, a product of the axial lines, they were considered to have the average value of its producing lines. Thus, they had the same six variables. Additionally, we considered four more spatial variables (variables 1,2 and 4 were used by Willham (1992)): (1) Degree, (2) DP degree, (3) Nodes recognized and (4) Isovist area.

Degree is the number of choices available at any node. This includes the approach segment, i.e. the ability of the way-finder to backtrack. This is a local. For example, the degree of A in figure # 6 is 4.

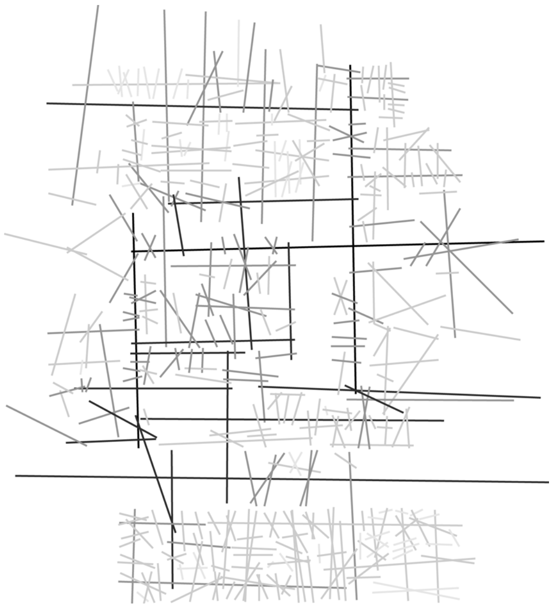
DP degree is defined as the number of other nodes that can be seen from one node. Conversely, DP degree indicates the number of nodes from which a node can be seen. This therefore evokes the possibility of coming to one node from others. For example, the node A in figure # 6 has DP degree value 5. This measure is considered relational because it implies views through adjacent nodes.

Nodes recognized is a version of DP degree: the number of nodes that can be actually recognized from any one node. This is always equal to or less than DP Degree. From a given node, if another node was too distant or was not distinctive, then it was considered 'not recognized'.

Lastly, isovist areas are the area of the isovists drawn from each intersection of the axial lines (Benedikt, 1979). They were determined for all the 46 nodes in the part of the hospital which was open to the public.

An important distinction to note here is that while connectivity is a local measure for axial lines, it is relational for the nodes. This is because from an axial line, all connections are visible from it, but from a node, connections to corridors are seen through those corridor segments and are hence relational for this purpose.

After the axial lines were digitized into a computer, and the program Axman PPC was used to generate the values of each line. This was done in two levels. They were (1) Considering only the public spaces (Figure # 4) i.e. corridors and rooms where a visitor can go unescorted AND (2) considering all the spaces in the hospital floor (Figure # 5)



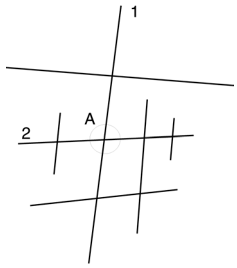


Figure 5: Axial line system of all spaces in the setting. (Dark lines are more integrated)

Figure 6: Diagram explaining degree and DP Degree.

Therefore, for each line in the layout, two values for each Syntax variable i.e. integration, integration of depth 3, and connectivity were generated. Since they were derived from the public system and the total system, they are represented with the prefix 'Pub' and 'All' respectively.

4 Results

4.1 Analysis of Axial lines and 'Open exploration'

The correlational analysis of wayfinding behavior in open exploration with axial line values is given in Table 1. The best prediction for use of an axial line during open search is given by a local value, Public Connectivity (r=0.768). The next best predictor is Public Integration(3) (r=0.744). Peponis et.al. (1990) in their earlier study had reported correlations of 0.757, p<.01 and 0.617, p<.05 with public integration and all integration respectively.

It is important to note that in open explorations, when people are trying to understand the layout, their use of a space is best predicted by a local quality, a syntax variable, public connectivity. This is the number of public accessible connections in a space. This measure gives a sense of how well a space is connected to other spaces; in other words how much further exploration can be carried out. Therefore, people tend to go to such areas which offer a better sense of other spaces through visual connections.

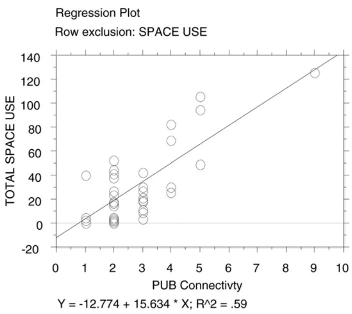


Table 1

Variable Type	*Axial Line value*	*Peponis et.al 1990*	*Haq, 1998*
Global	Pub RRA	0.757	.620
Global	All RRA	0.617	.669
Global	Public RRA (3)		.744
Global	All RRA (3)		.590
Local	Public Connectivity		.768
Local	All Connectivity		.615

Table 1. Correlations (r-values) of Axial line values with their use in open exploration. (p-values are <.0001)

Chart # 1: Plot shows regression of Public Connectivity and Space Use
Table # 2: Correlations (r) of Node Values with use in Open Exploration (p values <.0001).

4.2 Analysis of Nodes and 'Open Exploration'

The best predictor of use of nodes during open exploration is a relational value, DP Degree (r=0.723), as is shown in Table 2. Hence, during open exploration, as people are learning the hospital their search is predicted by the number of other choice points that can be seen from a node space. This a relational value because information is gained by views through adjacent nodes and corridors. However, DP degree is analogous to 'Space Syntax' connectivity because both reflect the amount of choices

Table 2

Variable Type	*Node values*	*Peponis et. al. 1990*	*Willham, 1992*	*Haq 1998*
Global	Public RRA	0.778		.588
Global	All RRA	0.606	0.537	.699
Global	Public RRA (3)			.652
Global	All (RRA)			.637
Relational	Public Connectivity			.605
Relational	All Connectivity			.675
Local	Degree		0.816	.142
Relational	DP Degree		0.533	.723
Relational	Nodes Recognized			.642
Relational	Isovist Area			.480

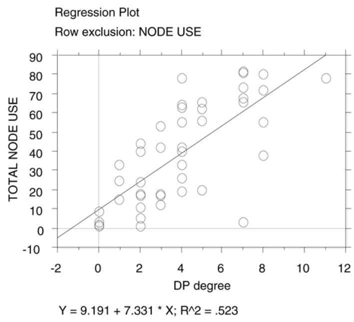


Table 2: Correlations (r) of Node Values with use in Open Exploration (p values <.0001).

Chart 2: Plot shows regression of DP Degree and Node use

available. Therefore, here too, we may safely suggest that possibility of further exploration is a good predictor of space use by exploring people.

In this case, correlations with Public Integration and All Integration was 0.588 and 0.699 which also gives good support for Peponis et al and Zimring et.al. studies (See Table # 2)

4.3 Analysis of Nodes and 'Directed Searches'

For each directed search the topologically shortest route was determined (i.e. the route which passes through the least number of nodes from the origin to the destination). The nodes which lie in that route were called 'path nodes'. Nodes not on the shortest route was considered redundant. Total number of redundant nodes was a measure of wayfinding difficulty.

Redundant node use was correlated with environmental values of the nodes. The results are shown in Table # 3. Here it is seen that Public Connectivity, a relational quality, again has the highest correlation, (r=0.724). Also, DP degree has a similarly high correlation (r=0.719). The preference for Public Connectivity and DP degree, like the previous finding, suggest possibilities for further movement. This is also consistent with the earlier observations that possibilities of exploration is the best predictor of space use.

Table 3

Variable Type	*Unit of analysis*	*Peponis et.al. 1990*	*Willham 1992*	*Haq 1998*
Global	Pub RRA	0.754		.662
Global	All RRA	0.653	0.537	.704
Global	Public RRA (3)		.713	
Global	All RRA (3)		.588	
Relational	Pubic Connectivity			.724
Relational	All Connectivity			.600
Local	Degree	0.604	.121	
Relational	DP Degree	0.616	.719	
Relational	Nodes Recognized			.317
Relational	Isovist Area			.207

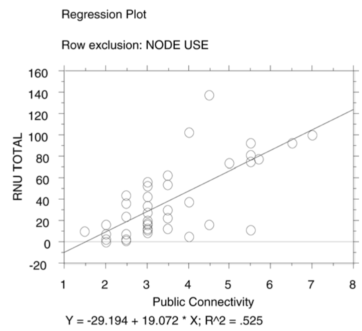


Table 3: Correlations (r values) between Node Values and Redundant Node Use in Directed Search. (p values <.0001)

Chart 3: Plot shows regression of Public Connectivity and Redundant Node use

As before, both Public Integration and All Integration have enough significance to support the earlier studies (r=0.602 and 0.704 respectively) of Peponis et.al. and Zimring et.al. (See table # 3)

Reflecting on the repeated findings of a preference for areas with high possibilities of exploration, it appears that people make route choices based on the extent, or presumed extent, of exploration that each unit of space offers. This is hereby termed "expectation of exploration". In a situation of open search, 'expectation of exploration' of axial layout is given by public connectivity, while for nodes it is a function of its DP degree, (other) nodes recognized and public connectivity. In directed searches, considering the effect of configurational learning, an additional factor is public integration. These can be used as parameters in a regression model to predict use of a space.

44.10

A linear model using these variables produced encouraging results (see Table # 5). It was already seen that public connectivity predicts 59% (r=0.768) of the variance of axial line use in open exploration. The model to predict node use in open search, using parameters of DP degree, (other) nodes recognized and public connectivity produced r=0.780 (p=<.0001) which predicts 61% of the variance. However, collinearity problems between nodes recognized and public connectivity is encountered. On reflection it is realized that both of these variables are derived from similar considerations. Therefore a smaller model which considers DP degree and nodes recognized as predictors of node use in unfamiliar situations was used. This model gives r=0.778 which also predicts about 61% of the variance in node use. Finally to predict node use in directed search, the parameters of DP degree, nodes recognized and public integration was proposed. But from the decrease of nodes recognized as a predictor between open exploration and directed search, it is understood that as configurational learning increases, reliance on relational variables decreases. This model therefore uses the parameters of DP degree and public integration. This gives a r-value of .75 (p=.0000) which predicts 56% of the variation in redundant node use. It is not known if this becomes a cognitive ability, but from the experiment we can propose an implicit rule: 'in search mode or in times of uncertainty, always proceed to the area which offers the highest 'expectation of exploration'.

Table 4

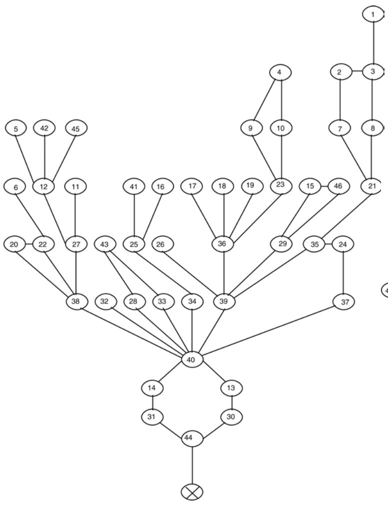
Routes	*Route description*	*Redundancy*
Route 5	X Ray to Lab	10.65
Route 3	Snack Bar to Lab	7.44
Route 2	Snack Bar to GYN/OB	1.21
Route 6	Lab to X Ray	1.1
Route 1	GYN/OB to Snack Bar	1.04
Route 10	X Ray to GYN/OB	1.039
Route 12	X Ray to Snack Bar	0.81
Route 9	GYN/OB to X Ray	0.8
Route 4	Lab to Snack Bar	0.73
Route 8	GYN/OB to Lab	0.68
Route 7	Lab to GYN/OB	0.57
Route 11	Snack Bar to X Ray	0.5

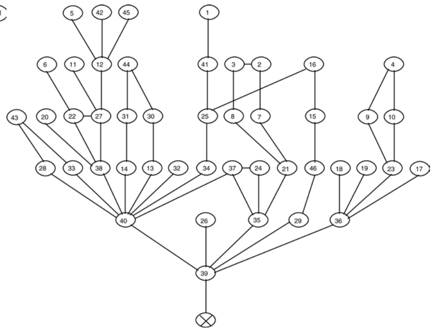
Table 4. Redundancy values of the 12 routes that were used in the experiment.

4.4 Analysis of the effects of entry points on open exploration

The next level of analysis considered the effect of the entry points on open exploration. It dealt with the question, does the property of an entry have an influence on the way a building is explored? If so, how and to what extent? The three entries vary by their property of mean depth and that from entry B, the layout has the least value, followed by C and A respectively (See Figures 7, 8 and 9).

When the frequency of use of axial lines by the subjects from each of the three entries were correlated with syntax values, it was seen that people who started from the entry with less depth i.e. B, had the highest correlation and vice versa. (See Table # 6)





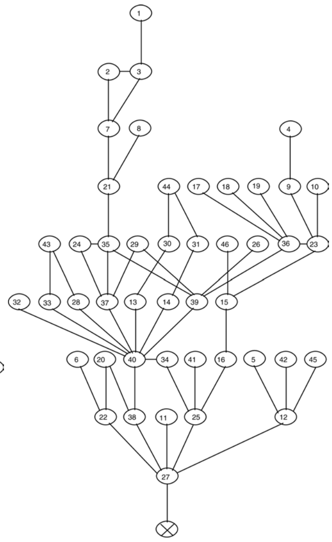


Table 6

	All RRA	*Public RRA*	*All Connectivity*	*Public Connectivity*
Frequency of use from A	0.444	0.430	0.395	0.523
Frequency of use from B	0.684	0.614	0.585	0.659
Frequency of use from C	0.633	0.522	0.558	0.571

Figure 7: Justified map from A (Mean Depth = 6.3778)

Figure 8: Justified map from B (Mean Depth = 3.8445)

Figure 9: Justified map from C (Mean Depth = 4.6223)

Previous correlational analysis had determined that Public Connectivity is a useful parameter in predicting use of axial lines. Therefore, to further explore the effect of entry points on open exploration, a regression model was proposed with Public Connectivity and Mean Depth of entry space as predictors of total axial line use. This resulted in r=.721, predicting 52% of the variance. Also, the co-efficient of Mean Depth was calculated as negetive 1.433. This means that use of an axial line is inversely correlated with mean depth of the starting point; i.e. people who entered from spaces with lesser mean depth had a better opportunity to explore the layout, given the fact that they all had a fixed amount of time to do so.

4.5 Analysis of individual routes and Signage

We then looked closely at individual routes with respect to their wayfinding difficulty. For this reason we calculated the total redundant node use for each task in directed search, divided it by the product of the number of subjects and the number of nodes in that task. This gave us a 'redundancy' value for each route that could be used to compare them with one another. Redundancy was considered as an index of wayfinding difficulty. The values for the 12 routes are shown in Table 4.

The routes X-Ray to Emergency Care Lab (Route # 5) and Snack bar to Emergency Care Lab (Route # 3) stand out as having very high redundancy. The emergency care laboratory is located in the central east-west corridor whose integration value is among the highest of all spaces any way we look at the configuration. Also, these routes are the shortest in the experiment. Therefore, this finding seemed extremely puzzling.

The field notes revealed two interesting patterns. First, subjects who were lost spent much of their time in the emergency area and in the clinic zone. They had been looking for 'Emergency Care Laboratory' in the emergency area and in the treatment areas. This suggests that they had gained a 'mental representation' of the functions of the hospital and were associating functional areas. Post-experiment conversations between the researcher and the subjects support this statement. This finding suggests that people 'mentally group' functions and activities; this warrants further research. Second, it was noticed that a lot of people had walked by the emergency care laboratory, but had failed to see it. This indicates the importance of signage and of other local qualities. The name of the laboratory was just a small computer print posted to the wall, but it was the only location in this well integrated corridor. Global and relational properties may feature in predicting the presence of people in an area but strong local qualities are also necessary for recognition and hence efficient destination-finding. The nature and quantification of local characteristics remains to be researched. Lynch's landmarks may be important local qualities, but are difficult to quantify (Lynch, 1960).

Signage can have a local / 'identification' characteristic, a relational / 'directional' one and a more global 'you-are-here' kind of information. For example, in the experiment, while we were tracking the first few subjects, we noticed a good number not using 'global' signage during their tasks. This seemed odd, particularly in the light of research regarding 'you-are-here' maps (Levine, Marchon, & Hanley, 1984). Therefore in the later stages of the research, we made a careful note of the use of the three 'you-are-here' maps. Among the 15 subjects recorded, only 60% looked at the maps. Of them 11.11% used it once, 33.33% twice, another 33.33% thrice and 22.22% used them four times. It should be pointed out that the 'you-are-here' maps in the research setting were not correct. They reflect the proposed pattern of the hospital that was not implemented. Some people may have understood it quickly and did not come again to look at the map, while others did not. That could not be determined. In a previous study, Moeser reported that plans put on walls to aid orientation was not used by the users she studied (Moeser, 1988). In this case it was seen that 40% of the subjects did not even bother to look at you-are-here maps. This could be an important pre-consideration for wayfinding 'signage' design.

5 Conclusions

From the different analyses presented so far, a number of conclusions may be drawn and things needing further research identified. Space-Syntax-based topological values of an environment are potentially effective measures in predicting wayfinding problems in specific areas of complex buildings. It can be used to develop a quantifiable structure of the wayfinding environment. This is also substantiated by previous research (Peponis et.al. 1990, Zimring 1998).

Both this experiment and the previous research have found consistently significant correlations of space-use with Space Syntax variables. It is reiterated that behavior as operationalized by space use is derived from a wayfinding situation and so it is driven, to some extent at least, by some cognitive understanding of the environment. This brings out the importance of Space Syntax to Environmental Cognition.

This research additionally suggests that gradually, as people get to know an environment better, they seem to gain a knowledge of the overall configuration. This suggestion is graphically demonstrated in the correlation of node use with nodes recognized. Whereas in open exploration r= .642, it dropped sharply in directed search to r=.317 (Compare Tables # 2 and # 3). Obviously the subjects were influenced by other things when they knew the environment better. In this regard, Peponis et.al suggested that "some knowledge of configuration develops independently rather than by somehow aggregating the knowledge of specific routes, at least where cognitively competent adults are involved" (Peponis et. al., 1990: pp. 576). This is also supported by this research. It was seen that correlation of node use with Public Integration and All Integration was .588 and .699 in open search. These by themselves are significant, but increased to 0.622 and 0.704 in directed search. Additionally, it was seen that some subjects in the experiment did display an understanding of the external roads as being a part of the configurational system while they were exploring the hospital interior. Therefore, not only is a sense of configuration intuitively grasped, it also increases with a short exposure to a layout. This points to a hypothesis that configuration may have a cognitive dimension.

Added to this is the fact that frequency of use of any space is a function of the properties of the point of origin or entry to a configurational system. Mean depth of a entry can thus be used to predict the use of all other spaces in the configuration. This is a potentially important finding and may have profound design implications. However this has to be fully researched.

Correlational analysis of Syntax and other values with space use also suggest that in unfamiliar environments, people make route choices at least partially based on what they can see ahead of them and what those spaces offer as further exploration possibilities. This is somewhat familiar to the category of 'mystery' proposed by Kaplan and Kaplan, as the "promise of future information" (Kaplan & Kaplan, 1982).

This leads to the hypothesis of 'expectation of exploration'. It is a potentially important concept to study preference of spaces in wayfinding situations. However, it has not been defined rigorously. For example, the variable "nodes recognized" does not have a strict and objective definition. Other factors that are potentially important in this respect may have been left out, such as. light and color variations. Also, the unit of analysis was nodes and axial lines. Proper re-translation of these into architectural elements remain an objective for future research. Finally, decomposition of any layout into its constituent axial lines has a component of subjectivity in itself that should be carefully researched. In spite of these, and because of the support by the regression models, 'expectation of exploration' appears to be a promising concept and an encouraging direction for further research.

Although the use of open exploration as a methodology has helped in clarifying theoretical points, yet in a real wayfinding situation visitors may start in the directed search mode. On the other hand, employees may want to find the 'lay of the land'. A distinction between these two scenarios is important and future experiment design should take this into consideration.

In terms of applied wayfinding, Syntax analysis of any plan, at one level, may identify potential locations of signage, on another level the axial hierarchy of the environment revealed by Space Syntax may be used not only as a guide for locating commonly sought after locations, but also as a way of arranging destinations to produce a wayfinding-friendly environment.

The study also showed that everyone does not give equal value to maps. Either they do not understand it or do not notice it. In this experimental setting the you-are-here maps were very prominently displayed and the entry points were chosen because of their availability. It was highly improbable that the subjects failed to notice them. Therefore, we may infer that people who did not look at them did so intentionally. If that is the case, then other options should be considered in providing information. This also brings out the importance of configuration in the human processing of environmental information.

Finally, this experiment showed the importance of all the three levels of environmental variables. Global, relational and local levels are each important in their own way and it is a complex interaction of them which produce a good wayfinding environment. Thus, more stringent measures in these three categories needs to be developed.

6 Notes

1 Neither the 20 volume Oxford English Dictionary (1989), nor the New Shorter Oxford Dictionary (1993) list this term.

2 This experiment was carried out with authorization dated 2/17/97 of Institutional Review Board, Georgia Tech Research Institute, Atlanta.

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