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0 Abstract

This paper investigates the role of spatial configuration in shaping residents' spatial cognition of their built environment. Using Hillier's (1996) definition of intelligibility as the relationship between local and global configurational factors, this research investigates the relationship between residents' cognition and the spatial configuration of an area. Two adjacent areas in Hampstead Garden Suburb in North London were investigated in detail. One area is relatively intelligible, the other less so. Structured interview surveys were carried out to elicit residents' cognition of their local area. Analysis of the spatial characteristics of the two areas using 'space syntax' methods provided a common basis for analyses of these data. The findings confirm that spatial configuration and spatial cognition are related to each other. Strong correlations were identified between residents' cognitive maps and spatial configuration. The degree of local integration of spatial configuration is the most significant factor in relations with the two variables of sketch maps, the frequency of appearance of configurational elements and the global syntactic characteristics of spatial configuration in sketch maps. The main finding is that the degree of intelligibility of the area is a significant intervening variable in relations between the two variables. The more intelligible area showed more powerful correlations between spatial configuration and spatial cognition, as well as giving rise to perceptions of greater legibility by local residents. These findings suggest that spatial configuration may play an important role in determining people's daily spatial experience by increasing or reducing their sense of spatial control in the environment.

1 Introduction

The literature on human cognition suggests that configurational aspects of built environment have significant cognitive consequences. Lynch (1960) notes that, in order to be 'imageable', an area needs to be apprehended as a pattern of high continuity, with a number of distinctive but interconnected parts. Hillier (1996) has argued that spatial configuration may face constraints on spatial experience since it appears to encourage or impedes aspects of human activity through spatial cognition and subsequent behavior. Golledge and Stimson (1997) have also emphasized that the path or network structure used in everyday spatial behavior becomes a critical feature of the image of a spatial environment. Others suggest that spatial layout of the built environment influences the accuracy of cognitive representations of real-world spatial information (e.g., Appleyard, 1969; O'Neill, 1991).

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intelligibility,
cognitive mapping,
sketch maps, spatial
control

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However, relatively few studies have incorporated global configurational aspects and their cognitive dimensions within a single framework in investigating the relationship between man and built environment. There thus is a gap in the field of knowledge of the relationship between global configurational aspects and their cognitive representation, and the role of spatial configuration within it.

There seems to be two causes to this gap. First, there has not been a proper analytical method for describing global configurational characteristics of cognitive representations. Moreover, methods for analyzing spatial configuration have been descriptive rather than analytic (e.g., Weisman, 1981). On the other hand, those studies that have investigated configurational characteristics objectively have mostly focused on the local characteristics of spatial configuration, not their global context (e.g., Sadalla & Magel, 1980). Secondly, mainly due to the different research viewpoints between syntactic approaches to spatial configuration (e.g., Hillier et al, 1993) and cognitive approaches to spatial configuration (e.g., O'Neill, 1991), the interaction between spatial configuration and spatial cognition have not been properly explored. In spite of convergence on treating a cognitive map as an important device that helps to bring spatial experience (Hart & Moore, 1973), yet few studies take an explicit theoretical position regarding underlying regularities between these two spatial and cognitive dimensions. As a result, very little empirical data is available on the relationship between them. This gap seems to be described in two ways: firstly, the neglect of perception-cognition studies within research based on syntactic descriptions of spatial configuration, and secondly, in a similar vein, the neglect of analytic descriptions of spatial configuration in research into cognitive representations.

In this context, this paper investigates the relationship between spatial configuration and spatial cognition at an empirical level. The main objective of the research is to investigate the association between configurational features and cognitive representations, and how configurational aspects of the environment affect cognitive representation. After this, the latent role of Hillier's morphological intelligibility defining the relationship between global and local spatial structure is explored. Thus it attempts to bring spatial and psychological dimensions into a single research framework in investigating the relationship between man and built environment. The paper is structured in four parts: the first focuses upon the analysis of configurational characteristics in the study area; the second presents the analysis of the residents' sketch maps; the third examines the relationship between these two; the fourth investigates the role of intelligibility in the above relationship.

2 Cognitive and morphological understanding of spatial configuration

2.1 Cognitive representation of spatial configuration using sketch maps

Hart and Moore (1971) define spatial cognition as the knowing of, internal or cognitive representation of the structure, entities, and relations of space; in other words, the internalized reflection and reconstruction of space in thought. Similarly Downs and Stea (1973) note that the process of cognitive mapping is a means of structuring, interpreting, and coping with complex sets of information that exist in different environments. The end product of the cognitive mapping process is a cognitive map.

'Sketch mapping' is widely used to represent human cognition. It has long appeared to be a useful instrument for recovering information about the way we represent the environment. Pictorial representation is the prevalent form of response of the sketch maps, since respon-

dents draw an image from memory on a blank sheet of paper. Thus, they are generally incomplete, distorted, mixed metric, or non-metric modes of representation, and also have varying forms of representation of elements by different people. However, they provide data, such as the number of features, the mix of point, line, and area features, and the topological relations of elements including the sequences of cues along routes or the sequence of segments and turns along routes. Additional information can be obtained from the system constructed as the basis for sketch maps, particularly the regularity or irregularity of frameworks such as street systems by using analytical tools to quantify their characteristics.

Sketch maps have hitherto been analyzed mainly in three ways. First, much research on sketch maps has involved recovering the perception of local configurational elements in different environments, and then comparing the recovered pattern to the real pattern. Sadalla and Magel (1980) investigated the effect of the number of turns in a path on perception of its length. They suggest that the number of turns in a path makes its perceived length greater. Similarly, numbers of intersections along a route have also been found to increase the estimated length of a route (Sadalla and Staplin, 1980). The prominence of the grid configuration in cognitive schemata of the physical environment is also suggested by several studies showing systematic distortions of non-grid structures. Evans (1980) also found that common distortions include the straightening of gradual curves, the squaring of non-perpendicular intersections, and the aligning of non-parallel streets. Tversky (1981) investigated the perception of intersections in sketch maps. According to his findings people tend to draw sketch maps with intersecting streets as closer to 90 degrees and draw a familiar street as parallel, when in fact it is not. As reviewed, very few studies have focused on the global aspects of spatial configuration in sketch maps objectively, although many researchers address the role of spatial configuration in cognitive representation (e.g., Zimring, 1981; Garling et al, 1986). At building scale, there has been little empirical research concerned with the direct relationship between spatial configuration and its cognitive representations. Weisman's study (1981) suggests a tentative understanding of this link. He rated the legibility of simplified floor plans which are classified from abstracted two-dimensional diagrams of real buildings into 'high' and 'low' groupings, and found these values to be a good predictor of the building users' self-reported incidence of 'being lost'. Users become disoriented in buildings where the overall configuration is confusing and hard to imagine. O'Neill (1991) also found that higher levels of configurational understanding are generally associated with more efficient wayfinding performance. Secondly, by reviewing studies of sketch maps, Pipkin (1981) notes that the contents of images are usually treated as dependent variables in relation to factors such as socio-economic status, length of residence and mobility characteristics, and the activity patterns (e.g., Appleyard, 1970). Thirdly, the frequency counts of the appearance of different features in sketch maps has been investigated to develop a composite map on which those places represented by the largest number of people are located (e.g., Lynch, 1960). Thus, existing analysis of sketch maps has concentrated on the disaggregation of represented elements.

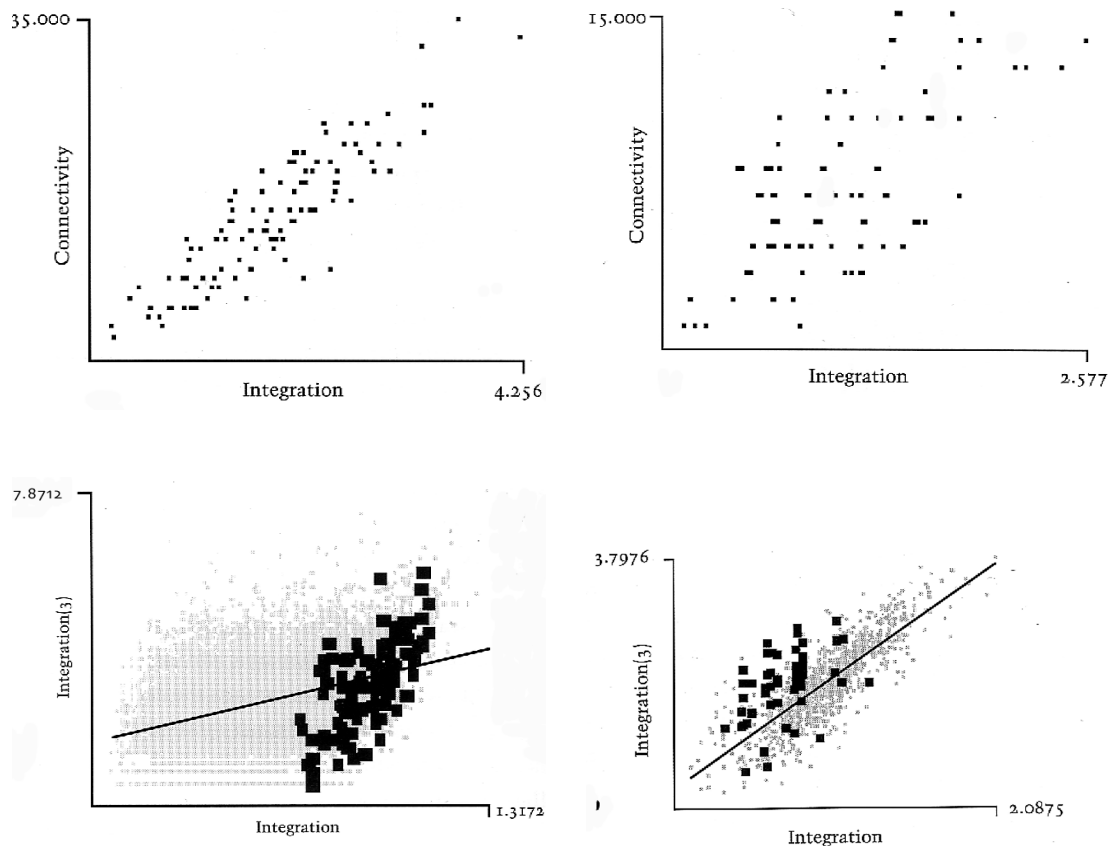
Cognitive studies provide us, therefore, with useful methods, but little in the way of a theoretical starting point for an inquiry into the role of global aspects of spatial configuration in spatial cognition. This appears to be primarily due to the absence of methods to describe both objective configurations in reality and subjective ones in cognitive representations. Hart and Moore (1973) argue, regarding the difficulty of describing configuration that, even though

psychologists and geographers alike converge in treating the understanding of spatial configuration as the ultimate stage of spatial cognition, configuration is perhaps the most difficult aspect of the environment to describe in an objective and analytical manner. Methods that have been used to date in analyzing cognitive maps thus seem to have neglected to describe the internal representation of spatial configuration as a global environment. The absence of a proper method for studying cognitive representation appears to constrain the exploration of the information that is contained in it. In order to describe and analyze the role of spatial configuration in the cognitive representation, a more analytical method is needed. If this were available then we would be able to understand cognition of the built environment in association with spatial configuration, which may encourage or impede its cognitive representation as many researchers have suggested.

2.2 Syntactic intelligibility and its possible role in spatial cognition

Lynch (1960) defines 'legibility' as the ease with which a system's parts can be recognized and can be organized into a coherent pattern. He states that if a city is legible it can be visually grasped as a related pattern of recognizable symbols, so a legible city would be one whose districts or landmarks or pathways are easily identifiable and are easily grouped into an overall pattern. He further argues that in the process of wayfinding, the strategic link is the environmental image, a generalized mental picture of the exterior physical world, which benefits from architectural legibility as experienced by an individual. Based on this conjecture, he suggests that the legibility may play a decisive role in acquiring a sense of spatial control in spatial experience. Kaplan and Kaplan (1983) also contend that legibility is one of the most salient aspects in an individual's effective functioning, since it allows one to explore extensively without becoming lost. In a similar vein Garling et al (1986) propose a model of preferable spatial forms that may affect spatial orientation and navigation through perception and cognition. Garling's study is unique in that the concern for legibility is shifted to a systematic description of spatial configuration. However, the three examples of studies have a common approach that emphasizes more abstract and affective qualities of spatial form rather than an objective and analytical description of it.

Hillier seems to have a similar theoretical stance regarding the role of spatial configuration in the built environment; however, his approach is quite different to the studies reviewed above. Hillier et al (1987) propose a syntactic definition of intelligibility to describe this qualitative aspect of spatial form analytically and quantitatively. The intelligibility of the form can be measured by analyzing the relationship between how spatial configuration can be seen from its parts and what it is like as an overall pattern, that is, as a distribution of integration. Hillier develops a metric for intelligibility by correlating a local measure of spatial configuration with a global measure. It is defined as the degree of correlation between the connectivity and integration values of the line in a configuration. Later, Hillier (1996) explains this notion using scattergrams that show the correlation between them. He notes that: "We can read the degree of intelligibility by looking at the shape of the scatter. If the points form a straight line rising at 45 degree from bottom left to top right, then it would mean that every time a space was a little more connected, then it would also become a little more integrated - that is to say, there would be a perfect 'correlation' between what you can see and what you can't see. The system would then be perfectly intelligible (pp129-130). For example, in figure 1(a), the



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points form a tighter and linear scatter, which indicates a strong degree of correlation, and therefore greater intelligibility. Figure 1(b) shows that the scatters are diffused and does not form a tight scatter, suggesting that the system is relatively unintelligible.

We then apply this notion to see how the spatial structure of an area relates to the larger-scale system in which it is embedded. Hillier (1996, p135) defines this notion as the relationship between global and local integration. This is illustrated by highlighting all the lines in an area in scattergrams of the whole system and examining the scatter of local against global integration. Figure 2(a) illustrates examples that can be read as intelligible in the whole system. A local area, represented as a cluster of dots, is 'intelligible' if the regression line for that cluster is steeper than that of the whole system, and at the same time, shows a strong correlation between global and local integration. This effect is read as a characteristic steepening of the cluster of points, which represent an area on the scattergram produced when local integration is plotted against global integration for every other space in the system. On the other hand, if a set of dots in the scattergram is not tight and does not form a linear scatter, it can then be described as a local area that is unintelligible in the global context (see figure 2(b)).

Based on his notion of intelligibility, he proposes that, although there are few direct empirical findings, intelligibility is related to the capacity of a space to give clues to the understanding of the whole system. Furthermore, he argued that it might be possible to predict the spatial structure of a whole settlement if it has high intelligibility from spatial relations held in local parts. Concurring with the hypothesis, Penn and Dalton (1994) suggest that the human mind may in effect be a correlation detector searching for perceptual information from the local spatial configuration in order to predict global location. They thus con-
 jec-

Figure 1 above.
Comparison of an
intelligible and an
unintelligible spatial
layout
(a) left An intelligible
spatial layout
(b) An unintelligible
spatial layout

Figure 2 below.
Comparison of an
intelligible and an
unintelligible area
within global context
(a) left An intelligible
area
(b) An unintelligible
area



Figure 3 Hampstead Garden Suburb, London (Ordnance Survey, 1996)

ture that if the mind has a problem with making sense of these data, it is because the correlation has broken down. They suggest that the unconscious process of recalling a 'map' in the human mind is essentially the search for correlations between factors as people move through space.

A structured grid is one in which integration and intelligibility is arranged in a pattern of some kind. In reality, lines and areas are prioritized for integration and intelligibility to varying degrees in order to create a system of differentiation. These laws might therefore be constraints on spatial cognition, since these seem to encourage or impede aspects of human activity. Through this objective property of intelligibility - a property of objects rather than a property of minds we can hypothesise that morphological intelligibility in spatial configuration might play a salient role in structuring human spatial experience. In this framework, it can be conjectured that the structures of the 'logical environment' and an individual's spatial experience are related fundamentally by the degrees of acquisition and transformation of structural information for everyday living, which is affected by the degree of inherent intelligibility of the spatial configuration.

3 Method

3.1 Syntactic description of Hampstead Garden Suburb

Hampstead Garden Suburb, the study area, is located about 5Km north of central London. It is encompassed by Finchley Road to the west and the A1 to the north, which consists of Falloden Way and Market Place, as shown in Figure 3. Hampstead Heath Extension defines the boundary of the Suburb to the south, and The Bishops Avenue is a boundary to the east.

A syntactic analysis of spatial configuration begins by representing the layout of the case study area as an axial map. Based on the computation of a axial map as reviewed in the previous section, we then produce a global integration map of Hampstead Garden Suburb

[illegible]

Figure 4 Digitizing axial lines on a sketch map

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Respondents were asked to draw a sketch map of the spatial layout of Hampstead Garden Suburb for 20 minutes, including streets, buildings and open spaces. The interviewee was instructed that the purpose of the sketch was as a guide for a visitor to orient himself or herself and to find his or her way in the Suburb. In order to set a uniform scale and orientation to the map, Golders Green Station and East Finchley Station were marked on the blank A4 sized paper. The former is situated on the lower left corner of the paper provided, and the latter on the right upper corner, which inevitably covers all the Suburb area. People are reminded to depict not only their neighborhood but also the whole Suburb. Figure 4 shows an axial map digitized based on a relatively well-drawn sketch maps.

The analysis of sketch maps has usually focused on the accuracy of the representation. Various methods have been used to determine this, including counting the number and types of features represented and measuring the accuracy of representation, such as relative distances and relative orientations between features. These methods have, however, encountered difficulty in measuring aspects of the global spatial layout of the sketch map and in measuring the more difficult aspects of ‘continuity’ that researchers such as Lynch have suggested are of importance in ‘imageability’ or ‘legibility’ of an area.

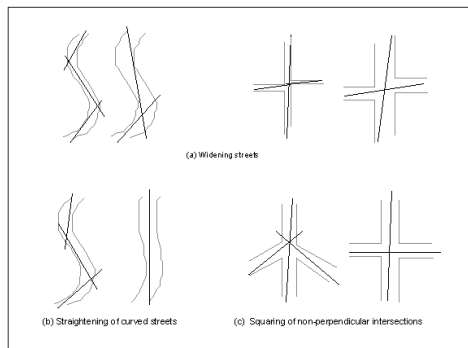


Figure 5 Distortions of reality in sketch maps

In this study, two techniques were used to elicit cognitive information from sketch maps. First, conventional analysis is performed by disaggregating depicted elements. The number of times each configurational element was drawn is counted. Secondly, a method has been developed for the analysis of global configurational aspects in sketch maps. Space syntax analysis was applied directly to the sketch maps in order that the syntactic characteristics of the whole map considered as a configuration of spaces and features could be quantified.

When drawing a sketch map, subjects are referred to two well-known places provided for orientation and scale. The scale given by distance between these two places is 1:10000. However, some sketch maps are either smaller or larger than this reference scale. These maps are then re-sized to 1:10000 approximately in order to digitize them for axial analysis. Axial lines are drawn based on the geometry of the sketch maps. All 73 sketch maps were digitized, and axial analysis was carried out to measure their syntactic characteristics.

The mean value of global integration and local integration was calculated for each space represented in 73 subjects' sketch maps. The main aim of this analysis was to allow a statistical comparison between the configuration represented in the sketch map and the configura-

tion of the real world map. This was achieved by transcribing configurational values of spaces featured in the sketch map into a single statistical database. Since the method of analysis of sketch maps raises a number of methodological issues the following sections describe this in more detail.

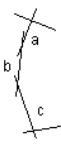

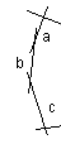
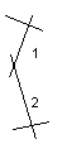
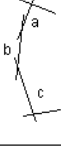

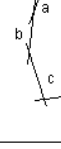
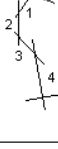
3.4 Translation of syntactic values of a sketch map to an axial map of the real world

Sketch maps generally contain errors and distortions and thus do not represent the real world exactly. Figure 5 shows distortions of reality in sketch maps. Left and right figures represent streets in the real world and in sketch maps respectively. Most common distortions are in generic aspects of the maps such as widening a street, straightening of a curved street, orthogonalising of non-perpendicular intersections and omitting less important spaces as. All these

distortions tend to result in fewer axial lines in sketch maps than in reality. Thus the sketch maps generally have fewer segments on a street and are more integrated. These characteristics of sketch maps are subjected to axial analyses in order to elicit syntactic characteristics of spatial configuration in sketch maps.

According to the syntactic analyses of sketch maps, each line has its own syntactic value. The following task is then to translate syntactic values measured in the sketch maps to the axial map of the real world. It is necessary to investigate a statistical relationship between syntactic properties in sketch maps and those in reality. This procedure involves defining which axial lines in sketch maps correspond to which lines of the real map. By examining sketch map features such as intersections, street layout, landmarks and their labels, this translation of syntactic values can be done.

Although the procedure shows a correspondence between axial maps of sketch maps and that of the real map, some confusion may arise especially when numbers of axial lines on a street are drawn differently by straightening a street that is curved in the real map. By investigating respondents' sketch maps, it was found that there are generally two ways to depict a street. One is to draw a whole street and the other to draw only part of a street. When a whole street is drawn, the number of digitized axial lines can be different compared to those in reality. The number of axial lines can be lesser than, the same as, or greater than reality. For

Axial lines in reality	Axial lines in sketch maps	Interpretation
		A street is drawn as one axial line although it is in three lines in reality. In this case, all segments (a, b, c) get same syntactic values processed by sketch map.
		A street is drawn in two lines. By examining a sketch map line-1 represents line-a, b and line-2 depicts line-c. Thus (a) and (b) have same syntactic values of line-1, and line-c gets a value of line-2.
		Only a part of a street is drawn in sketch map. Line-1 represents line-a, and whether it covers (b) or up to (c) is decided by examining a sketch map.
		A street is drawn in more segments in sketch maps than those of reality. This case was never encountered in this study. Line-c is drawn in two lines (3 and 4) in sketch maps, thus syntactic values of line-c takes average value of the two lines.

example, Finchley Road consists of 3 axial lines in reality. However it is generally less than 3 lines in the sketch maps. General rules applied in this study are explained in Figure 6 with possible examples.

The above method is applied to all 73 sketch maps and thus each axial line in reality has a number of syntactic values based on its appearance in sketch maps. These are then averaged. For example, Finchley Road is depicted 67 times in all 73 sketch maps. Accordingly, the syntactic value of Finchley Road is produced by taking the mean of 67 syntactic values in sketch maps. If an axial line does not appear in any sketch map then it is excluded from the analysis.

4 Spatial configuration and spatial cognition

4.1 Spatial morphology of Hampstead Garden Suburb

Figure 7 represents the global integration map of Hampstead Garden Suburb within its global context. The Suburb is composed of 158 lines related to the spatial property termed 'integration' in syntactic analysis. This reflects the permeability of each space from every other space in the area on all possible simplest journeys between spaces. The lines are represented from black to light grey in terms of its degree of integration. The black lines are most integrated, which have high integration value.

Hampstead Garden Suburb is located between two highly integrated spaces, the A1 and Finchley Road. Nevertheless the area is relatively segregated within the global context; most of the lines are light grey despite its proximity to the two most integrated spaces. The axial map immediately shows a dramatic change in the scale of lines compared to the surrounding area in that generally the axial lines of the suburb are much shorter. But more importantly, the way shorter lines are related to each other and to the surrounding area, creates a high degree of axial discontinuity from the surrounding area, especially from the A1 and Finchley Road on the periphery. There is no single axial line that goes from the periphery into the center of the



Figure 6 Translation of syntactic properties from a sketch map to an axial map

Figure 7 Global integration map of Hampstead Garden Suburb

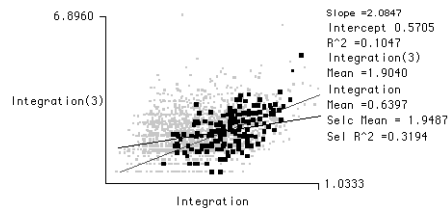
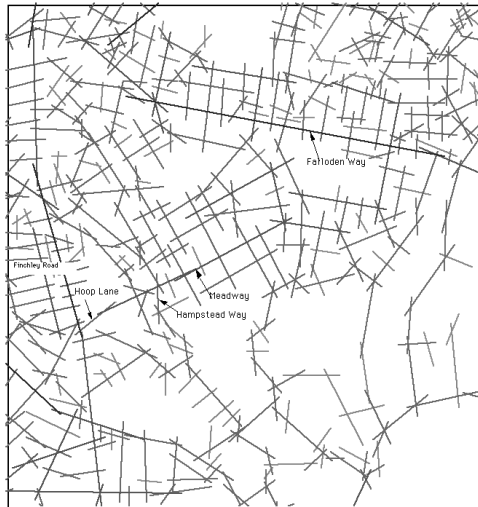


Figure 8 Local integration of Hampstead Garden Suburb

Figure 9 Spatial structure of the Suburb

context. Figure 9 is a scattergram plotting each line in the axial map as a point according to its degree of global integration on the horizontal axis and its degree of local integration on the vertical axis. Each point is an axial line, which makes up the axial map of the Suburb. All the open spaces in Hampstead Garden Suburb are picked out as dark in the scattergram. Although the regression line of the Suburb is slightly across the main regression line of London the scatter is not tight and does not form a linear set. The regression is even lower without the outlier of Finchley Road on the right upper in the scatter. This suggests that the Suburb does not have a strong relation between local and global integration of spaces.

In-depth investigation of spatial morphology reveals the two discrete systems in the Suburb, which are different in terms of their spatial configuration within a global context. By looking at their structure both within global context and without surrounding areas respectively, we can gain a more thorough understanding of morphological characteristics of the Suburb.

Table 1 shows the difference in the degree of global and local integration between the two systems within their global context. As can be seen from the table, there is a clear difference between the two areas in the local integration of the two systems. Sub-area B is locally more integrated at 2.142 than that of sub-area A at 2.015. As for global integration, there is a big difference between the two areas. Sub-area B, with global integration of 1.175, is much more globally integrated than that of area A at 0.874. Figure 10(a) shows the degree of intelligibility of the Old Suburb area, the dark points in the scatter, within the global context. The scattergram

Table 1 Syntactic characteristics in the Old and the New Suburb

	Hampstead Garden Suburb	Subarea-A	Subarea-B
Global integration	0.81	0.874	1.175
Local integration	1.949	2.015	2.142
Intelligibility	0.319	0.257	0.343

of the area indicates that its spatial structure is unintelligible. The scatter is dispersed and difficult to find any general trend. There is a poor relationship between global and local integration, indicating an unclear relation between the global and local structure at an r-squared of 0.257 ($p < 0.0001$). Moreover, it does not cross the regression line of all spaces to create a well-structured local area effect. The unstructured complexity and density of spaces has the effect of making the system unintelligible. On the contrary, the scattergram of the New Suburb picked up in dark in Figure 10(b), indicates that the spatial structure of this area is relatively intelligible. The regression line is steeper than that of the whole Suburb, suggesting a strong local area effect, thus the area is much more intelligible within the global context at an r-squared of 0.343 ($p < 0.0001$). This is a local intensification of the grid, which means the scatter crosses over the correlation of all the spaces into the higher levels of local integration. Open spaces in this area are laid out in a similar way to the pattern of the surrounding area. The findings suggest that the two systems in the Suburb are very different in terms of their spatial configuration within a global context.

The next question is how the two sub-areas differ in their internal structure without surrounding areas (see figure 11). By looking at the spatial structure both within global context and on its own, we can gain a more thorough understanding of the Suburb's morphological characteristics. Figure 12 illustrates the global integration of sub-area A (the Old Suburb). It shows that the syntactic core is in ringy and does not extend to the boundary, which is a closed rather than a permeable system. Figure 13(a)(b) shows the degree of intelligibility. The former show that the relationship between global to local integration of spaces is unclear, with an r-squared value of 0.2841. Similarly, in the latter, the r-squared is 0.33 in the relationship between global integration and local integration. In both scattergrams, the scat-

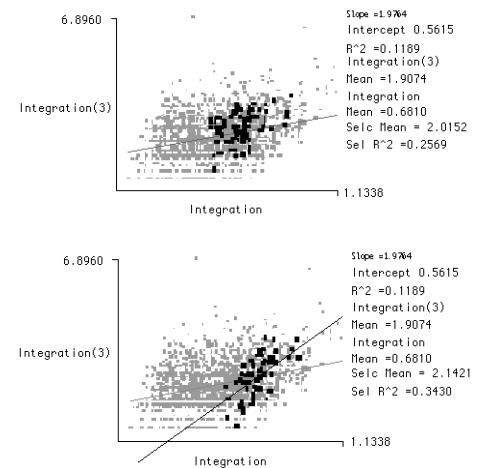


Figure 10a The Old Suburb area within its global context

Figure 10b The New Suburb area within its global context

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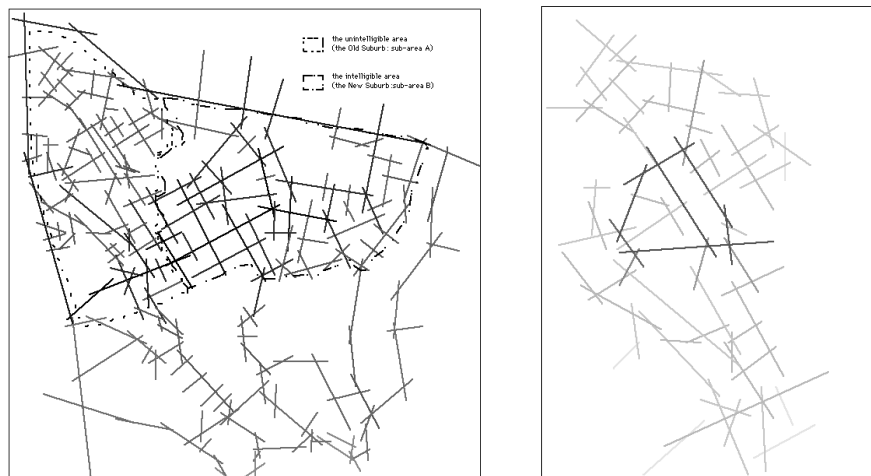
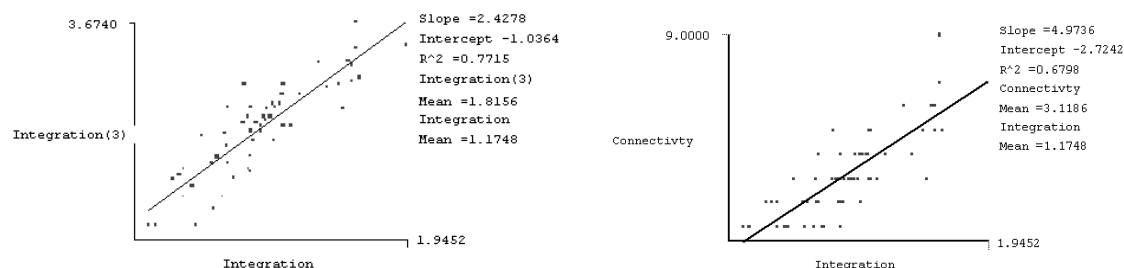


Figure 11. Left. Two subareas in the Suburb by intelligibility

Figure 12. Right. Global integration of Subarea A

Figure 13a Scattergram between global integration and local integration in Subarea A

Figure 13b Scattergram between global integration and connectivity in Subarea A



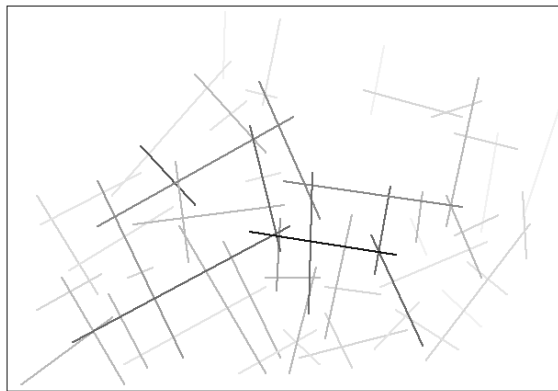
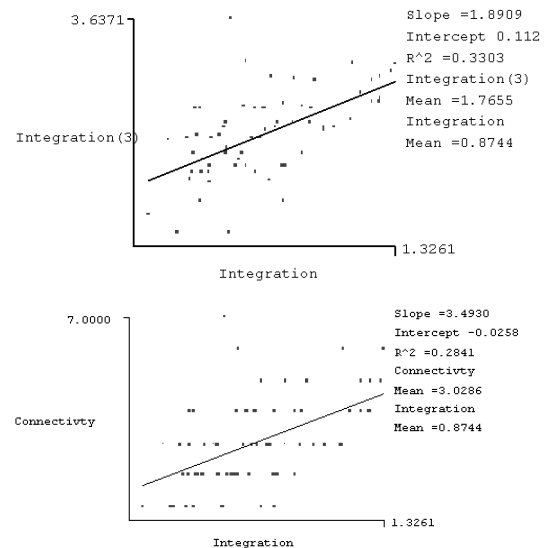


Figure 14. Left.
Global integration of
Subarea B

Figure 15a
Scattergram between
global integration and
local integration in
Subarea B

Figure 15b
Scattergram between
global integration and
connectivity in
Subarea A



ters are dispersed, hence it is difficult to find any general trend. There are poor relationships between global and local spatial characteristics, indicating a very unclear relation between the global and local structure. On the contrary, Figure 14 illustrates clearly the core of sub-area B (the New Suburb) is a Y shape, stretching outwards from the center. This system is highly permeable inwards as well as outwards. The scattergram of the New Suburb, Figure 15(a)(b), indicate that the spatial structure of this area is relatively intelligible. The r-squared values are 0.6798 between global integration and connectivity and 0.772 between global integration and local integration, which indicate strong relationships between global and local structure. This area is highly intelligible in itself. Table 2 summarizes the above findings.

Table 2 Syntactic
characteristics of the
two subareas
without their
surrounding areas

	The Old Suburb area sub-area A	The New Suburb area sub-area B
Global integration	0.874	1.175
Local integration (3)	1.765	1.816
Intelligibility		
R squared (global integration-connectivity)	0.284, $p < 0.0001$	0.680, $p < 0.0001$
R squared (global integration-local integration(3))	0.33, $p < 0.0001$	0.772, $p < 0.0001$

From these findings we can conclude that there is a fundamental difference in spatial configuration between the two areas, in terms of their own internal structure as well as within their global context. This difference in the organization of the spatial elements brings a variance in the permeability in the two areas. This may influence the experience of the built environment psychologically as well as physically. These issues comprise the main arguments in this research.

4.2 Spatial configuration in real world and in sketch maps

4.2.1 Configurational features in reality and frequency in sketch maps

A composite image of the Suburb was drawn according to the number of times each feature was depicted on the sketch maps. Table 3 shows the frequency of paths by segments that are mostly depicted spaces on the maps. For example, Finchley Road 2 is ranked as the most

often mentioned at 79.5%, 58 out of 73 sketch maps. Using this method, we can obtain the frequency of all the spaces on the maps. Once we get the frequency data, we can conduct correlation analysis with the syntactic properties of those spaces in the real world.

Table 4 shows the correlation coefficients between the frequency in sketch maps and the syntactic variables from axial analysis of real map. As can be seen from the table the frequency is generally well associated with the syntactic characteristics. Local integration shows the best correlation with frequency at $r = 0.708$. Figure 16 shows the scattergram between local integration and frequency. The scatter is messy at the bottom, but generally the positive relationship can be clearly seen between the two variables. The regression analysis is successful by showing an r -squared value of 0.501 ($p < 0.0001$). The result suggests that if the space is locally integrated it tends to be depicted in sketch maps more often. Most spaces that appear with a lower frequency are cul-de-sacs and footpaths, which are represented as 'x' and 'o' in the scatter. This suggests that most people do not refer to them often. The result shows that local integration is a good indicator in explaining the relationship between spatial configuration in reality and the frequency of configurational elements in sketch maps. This suggests that spatial configuration positively affects the acquisition of configurational knowledge.

Street name	Frequency
Finchley Road 2	58
Hoop Lane	55
Meadway 1	50
Hampstaead Way 6	35
Falldon Way	34

Table 3. Above. Most often depicted spaces in sketch maps

Table 4. Below. Correlation coefficients between the frequency and syntactic values of reality

	Frequency
global integration	0.456, $p < 0.0001$
local integration	0.708, $p < 0.0001$

49.13

	Sample A (an unintelligible area)	Sample B (an intelligible area)
global integration		
r	0.331	0.501
r squared	0.11	0.251
p	0.0008	<0.0001
local integration		
r	0.61	0.696
r squared	0.372	0.484
p	<0.0001	<0.0001

The next step is to investigate the role of intelligibility in the revealed association. The frequency of each space on the sketch maps is counted separately for the two samples, and these are subjected to correlation and regression analysis on the syntactic variables. Table 5 shows that, for global integration, sample B from the intelligible New Suburb shows a stronger correlation at $r = 0.501$ than sample A in the Old Suburb at 0.331. Similarly, this kind of relationship exists between the frequency and local integration. Sample B shows a better relationship at $r = 0.696$ than the other's at $r = 0.61$. It can be concluded that sample B, who live in an intelligible part of the area, show a stronger association between the frequency and the syntactic variables than sample A, who reside in the unintelligible area.

It can be inferred from these findings that if an individual lives in an intelligible area, he or she can acquire and represent quantitative configurational knowledge much comprehensively than an individual in an unintelligible area. The intelligibility of spatial configuration proved to be a salient intervening variable in acquiring spatial knowledge.

4.2.2 Syntactic properties in reality and in sketch maps

Syntactic properties of the sketch maps are calculated by axial analysis. The mean global integration and local integration of each depicted space was calculated from all 73 sketch maps. After this, the values of syntactic variables in sketch maps were transformed to those of the axial map of the real world. Figure 17, for example, displays the mean local integration of the spaces in the Suburb using an axial map from black for the highest through to light grey for the lowest. The figure picks up Meadway as dark and several light grey groups.

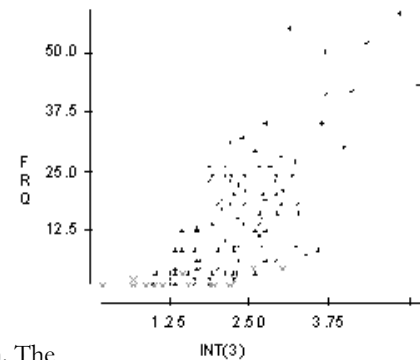


Figure 16 Scattergram between frequency and local integration

Table 5 Comparison of the association of frequency with syntactic variables between the two samples



Figure 18
Scattergram between
local integration of
reality and global
integration of sketch
maps

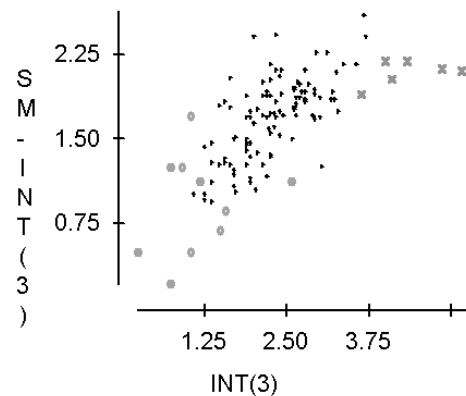
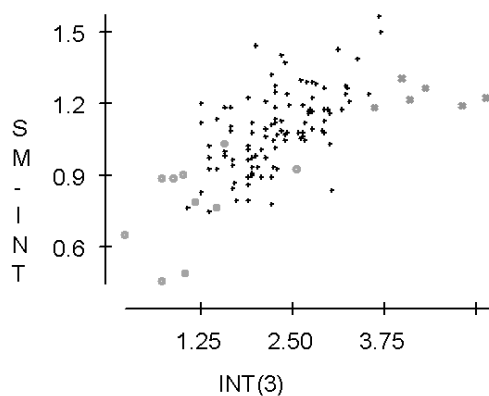
**Table 6 Association
between spatial
configuration in the
real world and in
sketch maps**

	r	r-squared	p
global integration of sketch maps :	0.486	0.236	<0.0001
global integration of real map			
global integration of sketch maps :	0.648	0.42	<0.0001
local integration of real map			
local integration of sketch maps :	0.7	0.49	<0.0001
global integration of real map			
local integration of sketch maps:	0.728	0.53	<0.0001
local integration of real map			

Table 6 shows correlation and regression analyses between variables from the real world and from the sketch maps respectively. Global integration in the sketch map and local integration in reality are well correlated at $r = 0.648$ ($p < 0.0001$). Similarly, the coefficient between local integration in the sketch map and local integration in reality is also high at $r = 0.7$ ($p < 0.0001$). This relationship is further examined by the regression analysis. Figure 18 shows the association between the local integration of reality horizontally and the global integration of the sketch maps vertically. The regression gives an r-squared of 0.42 ($p < 0.0001$). Figure 19 illustrates the scatter of local integration in reality horizontally to local integration in the sketch maps vertically, showing a tighter and better relationship at an r-squared of 0.49, $p < 0.0001$) than Figure 18. From the two figures it can be concluded that there is a clear pattern of the association between syntactic values in reality and those of cognitive maps, confirming local integration as a good predictor of cognitive representations of spatial configuration.

This suggests that there exists a positive relationship between spatial configuration in reality and its cognitive representation. The local integration of reality shows a slightly better correlation with local integration of sketch maps than global integration. It is, once again, the best predictor in the relationship between spatial configuration in the real world and the internalized configuration in sketch maps, confirming the previous finding that local integration is most closely related to the frequency of features drawn on the sketch maps. This suggests that local integration is strongly related not only with simple information referring to appearance in sketch maps, but also with the complex information referring to global configurational knowledge.

Figure 19
Scattergram between
local integration of
reality and local
integration of sketch
maps



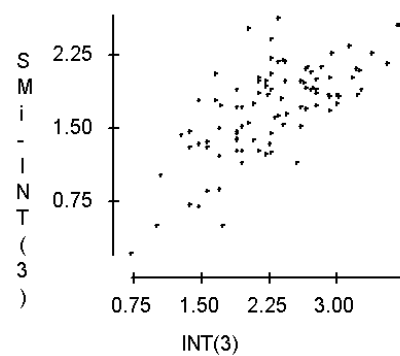
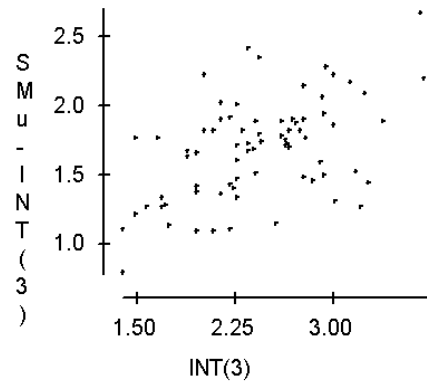
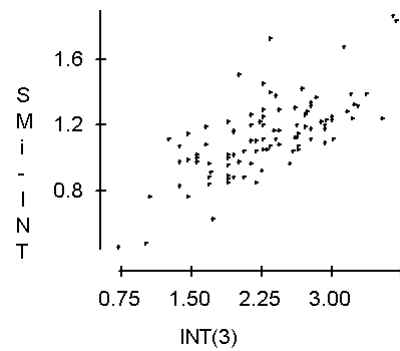
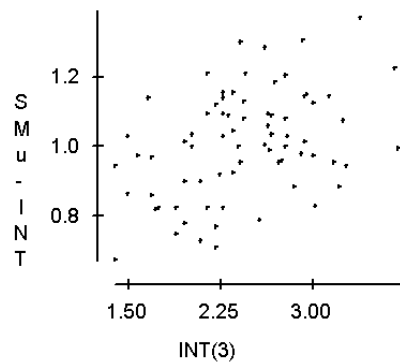


Figure 20 The effect of intelligibility on the association between spatial configuration in reality and in sketch maps
(a) Scattergram between global integration of sketch maps and local integration of reality in Subarea A
(b) Scattergram between global integration of sketch maps and local integration of reality in Subarea B
(c) Scattergram between local integration of sketch maps and local integration of reality in Subarea A
(d) Scattergram between local integration of sketch maps and local integration of reality in Subarea B

49.15

A close examination of the scatters reveals two outlier groups, one in the upper right part represented as an 'x', and another in the lower left marked as 'o'. The first outlier group is the boundary of the Suburb, and the second group is the cul-de-sacs. As can be seen from the two figures, the boundaries have a high local integration value, but these spaces are not recognized that much on the sketch maps. Conversely, cul-de-sacs are characterized not only by low local integration in reality but also by their low frequency of appearance on the sketches.

The next question is regarding the role of intelligibility on the associations identified. By answering this question, we can understand what spatial arrangements positively or negatively affect the acquisition of spatial knowledge, and how they characterize the spatial configuration of cognitive maps. The syntactic characteristics of the two groups were calculated separately. Correlation and regression analyses were then carried out for the two samples independently, between global integration and local integration, and local integration and local integration, of the real map and of the sketch maps.

Table 7 shows correlation coefficients and r-squared values of the two samples. In the relationship between global integration of the sketch maps and the local integration of reality, there is a big difference between the two samples. The correlation coefficient is 0.706 ($p < 0.0001$) in sample B, whilst the correlation is relatively weak at 0.407 ($p < 0.0001$) in sample A. The scattergrams show the difference more clearly (Figure 20(a)(b)). The figures show that there is a tighter, more linear relationship in the scatter of sample B, which is even stronger than all other samples' scatters. On the other hand, the regression is not as successful in the scatter of sample A, which does not show any particular pattern in the relationship.

Table 7 The effect of intelligibility on the association of spatial configuration in reality and in sketch maps

	Sample A (an unintelligible area)	Sample B (an intelligible area)
global integration of sketch maps :		
local integration of real map		
r	0.407	0.706
r squared	0.165	0.498
p	<0.0001	<0.0001
local integration of sketch maps :		
local integration of real map		
r	0.516	0.689
r squared	0.267	0.475
p	<0.0001	<0.0001

In the case of the relationship between local integration in the real map and local integration in the cognitive maps, the comparison of the association between the two samples reveals that sample B is higher at r-squared at 0.475 ($p < 0.0001$) than sample A of r-squared = 0.267 ($p < 0.0001$). Figure 20(c)(d) shows the scatters between the two samples. The figures confirm the difference of associations between the two samples by showing that sample B has a much tighter and more linear scatter than sample A, which indicates a better relationship between spatial configuration and spatial cognition for the people living in the intelligible area.

Several points can be drawn from the relationship between the spatial configuration of the real world and its cognitive representation. Firstly, a positive relationship exists between the spatial configuration of reality and its cognitive representation. Secondly, local integration, the syntactic property that comes from the immediate environment, shows the best relationship with the sketch map variables. Thirdly, the intelligibility of residents' neighborhood affect positively the relationship between syntactic properties of the real world and cognitive representation.

4.3 Comparison of syntactic characteristics of sketch maps between the two samples

Once the positive role of intelligibility on the association is detected, it is further examined by comparing the syntactic characteristics of cognitive representation between the two groups: people living in the intelligible area and in the unintelligible area, how the intelligibility of people's immediate neighborhood brings difference in their cognitive representation. The mean syntactic characteristics of the sketch maps between the two groups are compared. Table 8 shows the syntactic characteristics of the sketch maps between the two groups. The average amount of spaces depicted on the sketch maps is 23.9 and 25.4 in sample A and B respectively.

Table 8 Comparison of syntactic characteristics between the two samples

Subareas	No. of spaces	CON	INT(3)	Depth	INT	INTEL (Int.-Con.)	INTEL (Int.-Int3)
Sub sample A (an unintelligible area)	23.900	2.496	1.489	3.360	0.940	0.740	0.769
Sub sample B (an intelligible area)	25.400	2.587	1.532	3.067	1.093	0.812	0.866
T-test p value of two groups	0.708	0.414	0.526	0.063	0.012	0.010	0.001
* Alpha level of t-test is 0.050							
* CON: connectivity; INT(3): local integration; INT: global integration; INTEL: intelligibility							
* Depth is measured from the most integrated space							

tively. The t-test confirms no significant difference between the two groups (α level = 0.05, $p = 0.708$). It suggests that there is no significant difference in the number of spatial features drawn on the sketch maps between the two.

The connectivity of the sketch maps of sample A and B are 2.496 and 2.587 respectively. The t-test does not show any significant difference in the mean connectivity of the two samples' sketch maps ($p = 0.414$, α level = 0.05). However we can see that sketch maps done by people in the intelligible area are generally better connected than those of people in the unintelligible area. Similarly, local integration shows no statistical difference between the two samples. The average local integration of sketch maps of sample A and B are 1.489 and 1.532 respectively. The t-test shows no difference between the two sub-samples (t-test $p = 0.526$, α level = 0.05). The configurational elements of sketch maps from the intelligible area are slightly more integrated locally, however, as revealed by the t-test. The difference is not at a significant level.

As for depth from the most integrated space on the sketch maps, sample A is 3.36 and sample B is 3.067. The t-test shows again no statistical difference between the two sub-samples ($p = 0.063$, α level = 0.05). This suggests that both samples depict a similar depth from the most integrated space in their cognitive maps. However, the sketch maps of sample B have a shallower depth than those of sample A.

The global integration of sketch maps represents how configurational elements on the sketches are interrelated with each other. The mean global integration of sample A is 0.94, and that of sample B is 1.093, as shown in Table 8. The t-test shows a significant difference between the two groups ($p = 0.012$, α level = 0.05). The sketch maps of subjects in the intelligible area are more integrated globally than those of subjects in the unintelligible area. This suggests that the intelligibility of an area in which people reside positively affects their representation of global spatial configuration. In other words, the ability to relate the spatial elements in sketch maps is differentiated by intelligibility even though the amount of sketched elements remains the same.

After detecting the effect of intelligibility on drawing a sketch map, the next investigates whether it affects the intelligibility of sketch maps themselves. The intelligibility of the sketch maps is measured in two ways: firstly, by the correlation between global integration and connectivity; and secondly, by the correlation between global integration and local integration. As can be seen from Table 8, the intelligibility of sample A is 0.74 and 0.812, and that of sample B is 0.769 and 0.866 respectively. This suggests that the sketch maps of sample B are more intelligible than those of sample A in terms of both measures. The t-test confirms the significant difference between the two samples at α level 0.05; the t-test p values of the samples are 0.01 and 0.0008 respectively. They suggest that there is a fundamental difference in the way spatial configuration is understood and represented according to the intelligibility of an individual's immediate environment. An individual who resides in the more intelligible area within the global context, has a more intelligible sketch map of the whole area than those residents in the unintelligible area.

From the findings we can conclude that there is a positive impact of intelligibility on the relationship between spatial configuration in the real world and in the human mind. This means that intelligibility enables people to exploit the information present in spatial configuration in order to acquire configurational knowledge. Thus cognition can derive much more information from the built environment if an area is intelligible.

5 Discussion and conclusions

This paper uncovered some underlying regularities in the relationship between spatial configuration and spatial cognition. Firstly, a positive relationship is found between the spatial configuration in the real world and its image in human cognition. The frequency with which configurational elements are identified on the sketch maps is highly correlated with all the syntactic values. The syntactic properties of spatial configuration on the sketch maps are also associated with syntactic variables in the real world. Secondly, local integration, the syntactic property that comes from the immediate environment, shows the best relationship with the sketch map variables, the frequency and the local integration. Thirdly, the positive role of the intelligibility has been found in all the detected relationship above. This evidence suggests that the image of spatial configuration in cognition is highly associated with that of the physical built environment.

The findings have implications in investigating the relationship between man and built environment methodologically as well as theoretically. In methodological perspective, for a long time, Lynch's analysis of a sketch map, which disaggregate depicted features by the five elements - paths, edges, districts, nodes, landmarks - has been centered on the analysis of cognitive representation. His contention on 'imageability' is based on this aggregation. However, an obvious problem with respect to his analysis is that, since it is based on disaggregation of represented spatial elements, it cannot account for the aggregation of spatial elements, even though he admitted the importance of the pattern of high continuity and of the interrelationship of each element for evoking a strong image. Thus he seems to have failed to incorporate configurational effects on imageability. The research investigating the effect of spatial configuration on spatial cognition has not examined the global characteristics of spatial configuration in cognitive representations, either by concentrating on their local characteristics (e.g., Sadalla & Staplin, 1980) or describing their global characteristics intuitively (Weisman, 1981). As reviewed in the first section of this paper, very few studies have focused on the global aspects of spatial configuration in sketch maps objectively although many researchers address the role of spatial configuration in cognitive representation (e.g., Garling et al, 1991). This has been partly caused by the fact that there have been no appropriate methods to analyze the elements on the sketch maps as interwoven parts of a whole especially in terms of their configurational context. Space syntax methods adopted in this study enable us to analyze the cognition of spatial configuration in a sketch map as a pattern of spatial continuity. By analyzing the representations of the physical environment syntactically, we investigate how people cognize and represent spatial configuration.

Secondly, in the research investigating human spatial experience, both the cognitive approach and the syntactic approach have revealed gaps in their research framework. Despite considerable contribution in investigating man and the built environment, cognitive approaches seem to side-step the central problem of interaction between spatial configuration and human spatial experience. In other words, they lack incorporating global configurational aspects as objectively into the research framework. This does not mean that environmental cognition is not considered a notion of spatial configuration, but it tends to imply that the methods adopted are needed to understand the configuration both in the mind and reality as an analytical and objective interpretation. In a similar context, the syntactic approach has not consolidated cognitive maps in investigating human spatial experience. It has attempted to explain spatial behavior by a theory of 'natural movement' (e.g., Hillier et al, 1993), which

explains space use patterns are mostly resulted from spatial configuration, even though syntactic description of spatial configuration is based on visibility at the psychological level. Thus it also needs to investigate a salient role of internalized representation of spatial configuration in its research agenda, which may mediate the relationship.

The findings seem to have more theoretical importance. First, a strong correlation is found between sketch maps and a purely measure of the spatial patterns. No account has been taken of the location of attractors or landmarks in constructing this relationship. The positive association lends a strong evidence that spatial configuration causes the most fundamental difference for the psychological detector when representing spatial layout of a built environment. The cognition of spatial configuration result naturally from the way that the spatial configuration is ordered. The syntactic description of spatial configuration reflects human cognitive understanding of spatial structure in some degree. It thus can be said that the description is a flexible and complex representation to capture and explain the results of cognitive mapping. This perspective to the syntactic description of spatial reality is intuitive to use and would provide powerful reasoning capabilities and methods for examining perception and cognition in understanding configuration. These findings also provide strong empirical support for some conjectures, referring to the psychological effects of spatial configuration, raised by the syntactic approach (Steadman, 1983; Hillier, 1987; Penn and Dalton, 1994).

49.19

Secondly, the transmission of configurational knowledge from the built environment can be facilitated or impeded by spatial configuration in reality. The findings show that people in an intelligible area build better-developed cognitive maps than the people in an unintelligible area, and at the same time, their configurational knowledge is more intelligible and comprehensive.

As Golledge and Stimson (1997) pointed out, configurational knowledge consists of two complementary sets of spatial knowledge in the process of spatial learning in everyday experience, the intuitive knowledge of a more immediate environment at a perceptual level and the knowledge of global structure at a cognitive level, resulting from long-term exposure to the built environment. It suggests that spatial structure has an obvious structure that can be grasped immediately, and a potential structure, which will allow one gradually to construct a more complex and comprehensive picture. The former is spatial knowledge of the immediate environment, referring configurational knowledge, and the latter relates to the more global configurational knowledge, coming from a global context. Reviewing the findings of this research in Golledge and Stimson's perspective, it can be said that the frequency, which reflects the knowledge of local structure, may refer to simple quantitative knowledge. On the other hand, the syntactic properties of sketch maps, which refer to global spatial knowledge in human cognition, may refer to more complex configurational knowledge of reasoning about spatial layout.

This research shows that when there is a poor relationship between global and local structure in the built environment, the mind has difficulty in figuring out the spatial layout of an area. In other words, if the relationship between global and local spatial relationship has been broken down, as in an unintelligible area, then the acquisition of spatial knowledge of global and local information of an area appears also to be difficult due to this broken relationship. It suggests that morphological intelligibility facilitates the acquisition of global understanding from local understanding. In other words, in an intelligible area, on the basis

of locally acquired spatial knowledge, it is possible to build up useful global spatial knowledge. The degree of relation between these two sets of spatial knowledge result in differences in the degree of spatial learning. Therefore, the intelligibility of configurational knowledge in the human mind, resulting from the intelligibility of the real world, appears to give an indication of the degree of the transmission of configurational knowledge in spatial experience. In this context, it is likely that Lynch's imageability that resulted from legibility of spatial continuity as he defined can be based on spatial configuration and the degree of its intelligibility at a cognitive level in the mind. In other words, configurational characteristics are likely to be a prerequisite to acquire legibility of the built environment.

Thirdly, all the findings regarding the role of syntactic intelligibility suggest that cognition is linked to the spatial configuration of individual areas and to the way that spatial properties of an area interacts with surrounding areas. They suggest that the intelligibility is an intervening variable, which promotes the interaction, and at the same time, it facilitates a clear image of spatial layout, thus people who live in an intelligible area have better legibility of spatial layout than those in an unintelligible area. They also have a more intelligible cognitive map of the whole area. Considering the series of findings, it can be said that intelligibility affects and characterizes the interactive process of the interface between man and the built environment.

The findings provide strong empirical support for hypotheses, referring to the impact of intelligibility at spatial exploration, as raised by the morphological studies (Penn & Dalton, 1994; Hillier, 1996) in man and environment relation. Particularly, reviewing Hillier's definition of intelligibility, it opens up further discussion about extending its current definition in terms of its revealed role in spatial cognition. Hillier defines intelligibility as the relationship between global and local properties of spatial structure. However, as identified by this research, it is not only a thing in reality but a thing which exists in the mind as well. The empirical findings suggest that an axial representation of spatial configuration is not just representing a syntactic view of the physical environment but also reflecting our memories of experience as well. It provides a linkage between the way people perceive their physical environment and the ways in which they communicate about it. However, the intelligibility is purely morphological, which is a mathematical way of describing spatial configuration. As shown by this work, morphological intelligibility leads to more intelligible cognitive mapping of an area, through comprehensive configurational knowledge. Intelligibility thus is not only a static property of system but also the process by which the mind acquires spatial knowledge. The extended notion of intelligibility recognizes the importance of spatial reasoning in the human mind - it is not just a topological geometry for representing the physical environment. On this basis, the intelligibility needs to consider two complementary sources: the psychological approach at the cognitive level about the way people experience and perceive the physical environment as well as the formal mathematical approach.

This research has shown how the syntactic description of spatial configuration and the theoretical positions of spatial cognition can be combined in an integrated approach in investigating human spatial experience. This incorporation of spatial configuration implies a specific conception in understanding the role of spatial configuration in environmental cognition and behavior. An important consequence of this conception is that understanding human spatial experience must be carried on in a continuous conversation with both objectivity of configuration and subjectivity of cognition or it will lose its proper object of inquiry.

References

- Appleyard D, 1970, "Styles and methods of structuring a city", *Environment and Behavior*, June, pp 100-124
- Blades M, 1990, "The reliability of data collected from sketch maps", *Journal of Environmental Psychology*, vol. 10, pp 327-340
- Downs M, Stea D, 1973, "Cognitive maps and spatial behavior: process and products", *Image and Environment*, Aldine, pp 8-26
- Garling T, Gary W, Evans G W, 1991, "Environment, Cognition and Action: The need for integration", *Environment, Cognition and Action*, Plenum Press, pp 2-13
- Golledge R G, Stimson R, 1997, *Spatial Behavior*, The Guild Press
- Hart R A, Moore G T, 1971, "The development of spatial cognition", *Image and Environment*, Aldine, pp 246-288
- Hillier B, Hanson J, 1984, *The Social Logic of Space*, Cambridge University Press
- Hillier B, Hanson J, Peponis J, 1987, "The syntactic analysis of settlements", *Architecture et Comportement/Architecture and Behavior*, vol. 3, no. 3, pp 217-231
- Hillier B, Penn A, Hanson J, Grajewski T, Xu J, 1992, "Natural Movement: Or, Configuration and Attraction in Urban Pedestrian Movement", *Environment and Planning B: Planning and Design*, vol. 20, pp 29-66
- Hillier B, 1996, *Space is the Machine*, Cambridge University Press
- Kim Y O, 1999, Spatial Configuration, Spatial Cognition and Spatial Behavior: the role of architectural intelligibility in shaping spatial experience, PhD Thesis, University of London
- Lynch K, 1960, *The Image of the City*, MIT Press
- O'Neill M J, 1991, "Effects of signage and floor plan configuration on wayfinding accuracy", *Environment and Behavior*, vol. 23, pp 553-574
- Penn A, Dalton N, 1994, "The architecture of society: stochastic simulation of urban movement", *Simulating Society*, University College London Press
- Steadman P, 1983, *Architectural Morphology*, Pion
- Pipkin J S, 1981, *Cognitive Behavioral Geography and Repetitive Behavioral Problems in Geography Revisited*, Menthuen
- Weisman G, 1981, "Evaluating architectural legibility: wayfinding in the built environment", *Environment and Behavior*, vol. 13, pp 189-204