THE ROLE OF SPACE SYNTAX IN SPATIAL COGNITION:
evidence from urban China

129
sp

Yixiang Long
College of Design, North Carolina State University
Perver K. Baran
College of Design North Carolina State University
Robin Moore
College of Design, North Carolina State University

Keywords:

Cognitive representations
Urban legibility
Landmarks
Spatial configuration
Space syntax

Yixiang Long
College of Design, North Carolina State University, Box 7701, Brooks Hall, Raleigh, N.C., 27695-7100 U.S.A.
Ylong@ncsu.edu
Perver K. Baran
College of Design, North Carolina State University, Box 7701, Raleigh, NC 27695, USA
perver_baran@ncsu.edu
Robin Moore
College of Design, North Carolina State University, Box 7701, Brooks Hall, Raleigh, N.C., 27695-7100 U.S.A.

Abstract

The urban environment, to some degree, can facilitate/limit one's orientation, depending on the structure and characteristics of the physical elements of the city. In this regard, Lynch's (1960) concept of imageability/legibility has been fundamental in the urban design, planning, architecture, and environmental design fields for a few decades. Lynch argued that a strong imageable city could facilitate humans' orientation in the city. However, urban design research has also criticized Lynch's work for ignoring the relational characteristics between physical elements of the urban environment (Golledge & Stimson, 1997; O'Neill, 1991). Recent research has suggested that space syntax methodology could address the limitations of Lynch's approach to urban spatial cognition (Kim & Penn, 2004; Penn, 2003; Kim, 2001). The discussed limitations in extant literature are being addressed in an ongoing research study undertaken in Changsha, China. In particular, we explore the relationship between humans' cognitive representations and overall spatial configuration of an urban environment and the effects that different spatial configurations of an urban environment have on legibility of the environment. We use a space syntax approach to measure spatial configuration of neighborhoods and sketch maps, recognition tests as well as interviews to measure humans' spatial representation and legibility of the environment. This paper will focus on the research methodology and present initial findings, that is, the relationships between perceived landmarks and spatial configuration.

Introduction

The city has been an object of curiosity for quite a long time. On one hand, humans create cities based on their activities; on the other hand, the city itself facilitates and limits our activities and behavior within it. An important aspect of activities in the city is orientation. The urban environment, in some degree, can facilitate or limit one's orientation depending on the structure and characteristics of the physical elements of city (Devlin, 2001; Rapoport, 1977; Lynch, 1960, 1981). Lynch (1960) argued that a strong imageable city could facilitate humans' orientation in the city. The imageability refers to the visual quality of the urban environment: the apparent clarity or legibility of the cityscape. For Lynch, imageability means "the ease with which its

parts can be recognized and can be organized into a coherent pattern". Based on interviews and sketch maps from residents in three American cities, he categorizes the inhabitants' image of the city into five physical elements: paths, landmarks, edges, nodes, and districts.

Lynch's earlier pilot work has a far-reaching influence on urban design, planning, architecture, and environmental design. However, scholars and researchers in the field of urban design have argued that Lynch has emphasized the physical elements of the urban environment, and has ignored the relational characteristics between these elements. Actually, this relationship, reflected in people's minds, is the fundamental root by which humans recognize a built environment, and this is seen as the precursor of humans' cognitive maps. After that, more detailed cognitive maps can be developed (Golledge & Stimson, 1997; O'Neill, 1991). In his later work, Lynch (1981) has also addressed the importance of spatial configuration in shaping the strong imageability of the urban environment. The discussed limitations in extant literature are being addressed in an ongoing research study undertaken in Changsha, China. In particular, we explore the relationship between humans' cognitive representations and overall spatial configuration of urban environment and the effects that different spatial configurations of the urban environment have on legibility of the environment.

129-02

Conceptual Framework and Study Objectives

Many studies have identified that spatial configuration affects people's spatial cognition (Tzamir, 1975; Lynch, 1960, 1981). Space syntax theory and methodology (Hillier, 1996; Hillier & Hanson, 1984) provide appropriate tools to describe and quantitatively measure spatial configuration of urban space. Most significant syntactical measures are integration and connectivity.

Integration is an indicator of how easily one can reach a specific street segment and is measure of syntactical accessibility. Evidence has shown that streets with high syntactical accessibility attract a higher density of movements in urban areas (Raford & Ragland, 2006; Penn et al., 1998; Hillier, 1996; Hillier & Hanson, 1984). On the other hand, the literature on spatial cognition indicates that humans' cognitive maps are developed through movement. Movement around the city gives the individual a sense of global and local relationships of physical elements comprising the urban environment (Haq, 2001; Heft, 1983). Inherently, some areas in the city will attract more movement because of their high syntactical accessibility. Connectivity is a local syntactic measurement that takes into account relationships between a space and its immediate neighbor spaces. Streets with high connectivity values will be more accessible from different directions and give people more possible choices. These streets, in turn, are expected to be used more often than others.

If people tend to use certain paths (i.e., high integration, high connectivity) more often than the others, it is possible to assume that certain physical elements, such as landmarks and nodes that are on these paths, will be reflected clearly in their cognitive maps. Thus, this in turn will contribute to people's legibility and wayfinding performance.

The statistical correlation between global integration and connectivity defines the degree of intelligibility of a layout. An intelligible layout is one that is understandable by gleaning the structure of the global system on the basis of the structure of the local area. On the other hand, research in the area of spatial cognition has indicated that humans' memory appears to have the hierarchical structure associated with spatial images (Anderson 1995; Stevens & Coup 1978) since they need to transcribe short-term memory to long-term

memory (i.e., cognitive maps of urban environments). Thus, if the rules for building a hierarchical structure of an area in subjects' cognitive maps fit the actual hierarchical structure of configuration (measured by space syntax as intelligibility), this area will be more legibly perceived by people. As a result, the degree of importance of cognitive representations and their topological relationships will be clearly reflected or recalled in subjects' cognitive maps according to this hierarchical structure of memory.

People's spatial cognition is mainly studied through representations of cognitive maps and the concept of legibility. In this study, from the five elements that commonly appear in cognitive maps we focus on landmarks, paths, and districts. In addition, we examine if the more intelligible a neighborhood (measured by the value of intelligibility) results in a more legible environment. To our knowledge, only one study has explored this and found a positive relationship between intelligibility and legibility in the urban environment (Kim, 2001).

Research has shown that personal experiences also affect people's spatial cognitions (Hart & Moore, 1973; Appleyard, 1969). This includes five key indicators: familiarity, travel mode, location of home, associativity, and socio-economic characteristic. From these variables, in this study we consider only familiarity as a moderating variable. The conceptual framework used to guide this study is shown in Figure 1. Building on the conceptual framework, the objectives of this study are 1) to understand the relationships between cognitive representations and spatial configuration and 2) to examine the relationships between intelligibility and legibility in an urban environment.

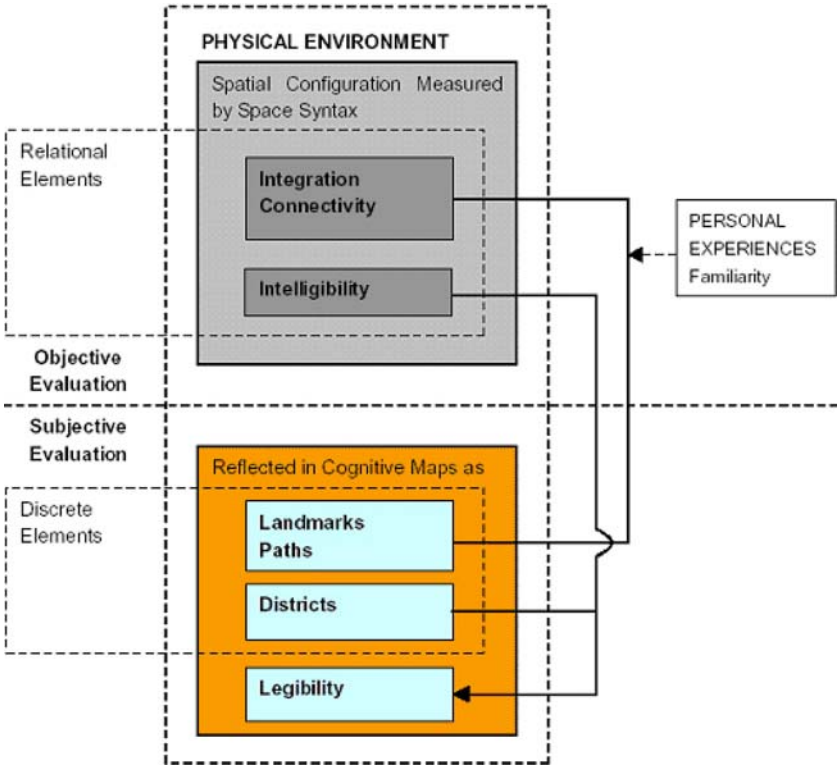


Figure 1:

Conceptual framework of the study

Methods

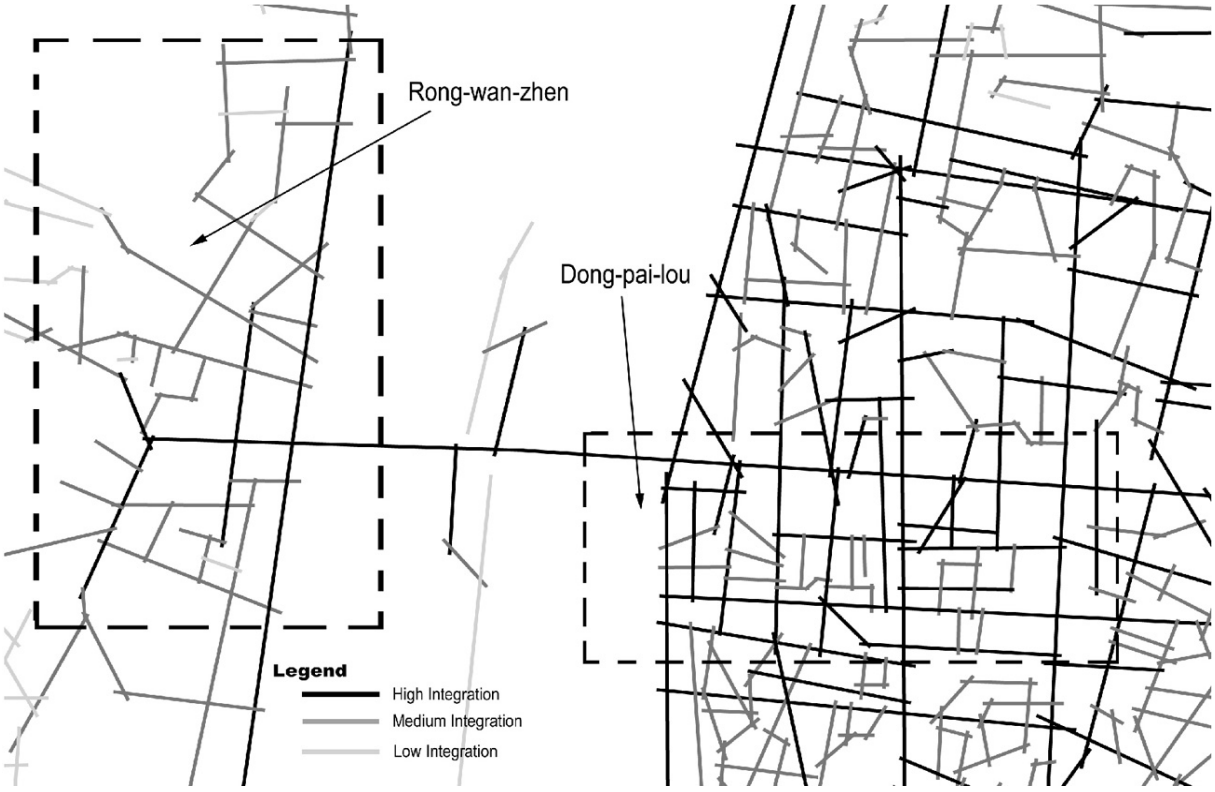
The study is being conducted in Changsha, China. Changsha is the capital city of the Hunan province and has a population of over two million people. Since the main objectives of the study revolve around the concept of intelligibility, two neighborhoods, one relatively intelligible and the other less so, are settings for this study. The selection was based on the axial map and syntactical analysis

performed for the whole city. Two neighborhoods, Dong-pai-lou and Rong-wan-zhen, were chosen based on the criteria described in previous studies (Kim 2001; Hillier 1996). These two neighborhoods have a similar size (about 2 square kilometers), number of spaces (38 axial lines), building types (mixed with different building heights), and land uses (both having commercial, retail, residential, and governmental uses), but differ in the degree of intelligibility (0.58 for Dong-pai-lou vs. 0.37 for Rong-wan-zhen) (see Figure 2). This indicates a much clearer relationship between global and local structures in the Dong-pai-lou neighborhood than in Rong-wan-zhen.

Figure 2

Global integration map of the two neighborhoods

129-04



Study objective 1 and study objective 2 have been addressed by correlational and experimental research, respectively. The syntactical properties of the two neighborhoods, as measured by a space syntax approach, are independent variables. In particular, we calculate global integration, local integration, and connectivity measures of the two layouts following the approach developed by Hillier and Hanson (1984). These measures were calculated using the axial map of the whole city. In the correlational research, human's cognitive representations as dependent variables were measured both by sketch maps, semi-structured interviews, and drawings of the perceived neighborhood boundaries. In the experimental research, a participant's legibility of the neighborhoods as dependent variables is measured by sketch maps, recognition test, and post-experimental interviews.

For the correlation study, sixty-seven residents living in two neighborhoods were conveniently selected to draw the sketch maps of the neighborhoods. For measuring human spatial cognition, residents were asked to draw the sketch maps of the neighborhood for half an hour, including streets and buildings. The interviewee was instructed that the purpose of the sketch map is as a guide for a visitor to orient himself/herself and to find his/her way in the neighborhood. In order to set a uniform scale and orientation to the map following the methodology used by Kim (2001), Ju-zhi-zhou Bridge and Xiang River were marked as reference points on the blank A4 sized paper.

To measure the frequency and accuracy of sketch maps, the elements drawn (i.e., landmarks and paths) were ranked on an ordinal scale as correctly located and labeled, partly-correctly located and correctly labeled, incorrectly located and correctly labeled, and not being drawn on the sketch map. The relationships between spatial configuration and cognitive representations are being addressed by analyzing the relationship between syntactical measures of the neighborhood layouts and the data from the sketch maps.

In the experimental study that focused on study objective 2, forty-nine college students, divided into two groups, traveled throughout one of the neighborhoods for an hour. After that, sketch maps, recognition tests, and interviews were conducted to measure the perceived legibility of the traveled neighborhoods. The mean accuracy of the sketch maps based on encoding system used in correlational research, mean correctness of recognition tests, and mean scores of interviews are being compared across the two neighborhoods. Because the data collection for the study was completed in December 2006, in the following section we discuss only the preliminary results related to study objective 1. In particular, we present the initial findings related to the relationships between spatial configuration and cognitive representations, focusing only on landmarks.

Preliminary Results and Discussion

Initially, we conducted bivariate correlation analysis to understand the relationships between syntactical measures of the layouts and one aspect of cognitive representations (i.e., landmark scores). As shown in Table 1, in both neighborhoods, global integration has the highest correlation with the landmark scores. In addition, the correlation coefficients for all syntactical measures are higher for the Dong-pai-lou neighborhood (higher intelligibility) than for the Rong-wan-zhen neighborhood.

Figure 3

Correlation coefficients between landmark scores and syntactical measures for Rong-wan-zhen and Dong-pai-lou neighborhoods

	Global Integration	p	Local Integration	p	Connectivity	p
Rong-wan-zhenIntelligibility, .37	0.596	.004	0.591	.005	0.465	.034
Dong-pai-louIntelligibility: .58	0.731	.001	0.631	.003	0.531	.013

We also performed bivariate and multiple regression analyses to examine the predictive power between the landmark scores as a dependent variable and the other three syntactical measures as independent variables. In most of the tested models, we detected colinearity among the space syntax measures. Overall, the results of the regression analysis showed that global integration is the only variable explaining the variation in landmark scores. For the Rong-wan-zhen neighborhood, global integration explains 35.4% of the variation in landmark scores (R^2=0.354, p=0.004), while, for the Dong-pai-lou neighborhood, it explains 53.5% of the variation in landmark scores (R^2=0.535, p=0.000).

Overall, the partial results of the study have shown that global integration plays an important role in explaining landmark scores. Residents in both neighborhoods tend to recognize and remember more those landmarks that are located on globally highly integrated street segments than landmarks located on segregated street segment. Also, the results have shown that the explanatory power of global integration is much higher in the more intelligible neighborhood (i.e., Dong-pai-lou) than in the less intelligible neighborhoods. This result is not surprising since the space syntax research has already suggested that the association between space syntax measures and observed movement weakens in unintelligible environments (Hillier,

1996). If cognitive maps are developed through movement, then the association between cognitive representation (i.e., landmarks) and syntactical measures will also weaken in unintelligible environment.

References

Anderson, J.R., 1995, *Cognitive Psychology and Its Implications*, W.H. Freeman and Company, New York.

Appleyard, D.A., 1976, *Planning a Pluralistic City*, MIT Press Cambridge, MA.

Devlin, A.S., 2001, *Mind and Maze: Spatial Cognition and Environmental Behavior*, Praeger, Westport, CT.

129-06

Golledge, R.G., Stimson, R., 1997, *Spatial Behavior: A Geographic Perspective*, Guilford New York.

Haq, S.U., 2001, "Complex Architectural Settings: An Investigation of Spatial and Cognitive Variables through Wayfinding Behavior", *PhD dissertation*, G.I.T., Atlanta.

Hart, R.A., Moore, G.T., 1973, "The Development of Spatial Cognition: A Review", R. Downs, D. Stea (Eds.), *Image and Environment*, Aldine, Chicago, 246-295.

Heft, H., 1983, "Wayfinding as the Perception of Information Over Time", *Population & Environment: Behavioral & Social Issues*, 6, 3, 133-150.

Hillier, B., 1996, *Space is the Machine*, Cambridge University Press, UK.

Hillier, B., Hanson, J., 1984, *The Social Logic of Space*, Cambridge University Press, Cambridge UK.

Kim, Y.O., 2001, "The Role of Spatial Configuration in Spatial Cognition", J. Hanson (Ed.), *Proceedings*, 3rd International Space Syntax Symposium, Atlanta GA.

Kim, Y.O., Penn, A., 2004, "Linking the Spatial Syntax of Cognitive Maps to the Spatial Syntax of the Environment", *Environment and Behavior*, 36, 4, 483-504.

Lynch, K., 1960, *The Image of the City*, MIT Press Cambridge, MA.

Lynch, K., 1981, *A Theory of Good City Form*, MIT Press Cambridge, MA.

O'Neill, M.J., 1991, "Evaluation of a Conceptual Model of Architectural Legibility", *Environment and Behavior*, 23, 3, 259-284.

Penn, A., 2003, "Space Syntax and Spatial Cognition or Why the Axial Line?" *Environment and Behavior*, 35, 1, 30-65.

Penn, A., Hillier, B., Banister, D., Xu, J., 1998, "Configurational Modeling of Urban Movement Networks", *Environment and Planning B: Planning and Design*, 25, 59-84.

Raford, N., Ragland, D.R., 2006, "Pedestrian Volume Modeling for Traffic Safety and Exposure Analysis: Case of Boston, Massachusetts", *Transportation Research Board 85th Annual Meeting Compendium of Papers CD-ROM*, Paper # 06-1326.

Rapoport, A., 1977, *Human Aspect of Urban Form*, Pergamon Press Inc, Elmsford, NY.

Stevens, A., Coup, P., 1978, "Distortions in Judged Spatial Relations", *Cognitive Psychology*, 10, 422-437.

Tzamir, Y., 1975, "The Impact of Spatial Regularity and Irregularity on Cognitive Mapping", *Tech. Rep.*, Technion-Israel Institute of Technology, Center for Urban and Regional Studies, Haifa Israel.