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Understanding Space: the nascent synthesis of cognition and the syntax of spatial morphologies

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The Workshop

In September 2006, a one-day workshop took place that formed an opening session of the Spatial Cognition '06 Conference, and was held in Bremen, Germany. The theme of this workshop was space syntax and spatial cognition and it represented the culmination of an idea first mooted at the Spatial Cognition '04 conference (Frauenchiemsee, Germany) and furthered developed by discussions at the Fifth International Space Syntax Symposium in Delft, 2005. The significance of this workshop was, at one level, personal: for some time researchers into space syntax at University College London and into spatial cognition at the Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition (Universities of Bremen and Freiburg) had been seeking ways to initiate an interdisciplinary collaboration. Such an opportunity, as this workshop represented, to bring together the two wider research communities formed a vital strand of this ambition: our expectations, however, were perhaps more modest – we were simply planning a day of interesting discussions and debates in order to establish an agenda for any future collaboration. In reality, the response of the conference delegates far exceeded our expectations and the quality of participation was extremely high. The workshop was attended by thirty-three academics, from as far a field as the USA, Australia and Japan and representing a wide range of academic disciplines (architecture, geography, psychology, computer science and the social science). During the course of a lively and stimulating day, ten accepted papers were presented (out of eighteen originally submitted) as well as a number of posters. The high quality of the accepted papers owed much to the diligence of our stellar programme and reviewing committee[1], in whom we were particularly fortunate.

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[1] Dennis Doxtater (U. Arizona); Gerald Franz (MPI Biocybernetics, Tübingen); Saif Haq (TexasTech); Ben Kuipers (Austin); Alan Penn (UCL London); John Peponis (Georgia Institute of Technology); Juval Portugali (Tel Aviv University); Martin Raubal (Universität Münster, now at UC Santa Barbara); Roy Ruddle (U. Leeds); Barbara Tversky (Stanford); Jan Wiener (College de France, Paris); Jean Wineman (U. of Michigan); Craig Zimring (Georgia Institute of Technology); Gerald Weisman, University of Wisconsin-Milwaukee.

The original call for papers proposed a series of theoretical and methodological topics, which the workshop organizers felt formed a general framework of the issues that needed to be addressed as part of any future collaborative research programme.

The theoretical topics were:
- How can the cognitive processes of individual users be addressed by space syntax?
- How should space syntax methods be adapted to make the transition from the social/group level to individual cognition?
- Does space syntax help us to better understand the cognitive import of physical properties of the environment like complexity, visibility, legibility, intelligibility?
- What is the correspondence between space syntax measures and cognitive processes?
- Can we map concepts such as 'intelligibility' to cognitive processes or human memory?
- How can network effects be separated from psychological effects?
- Can spatial cognition reveal the 'non-discursive' features of the design process?

Methodological topics according to the call for papers:
- Collecting behavioural data for space syntax analysis.
- Space syntax of complex indoor settings (multi-level, visibility vs. walkability, etc.)
- Global, local, route-specific measures.
- Axial analysis, visibility graph analysis.
- Finding the right computational tools for space syntax analysis.
- How to design experiments to validate space syntax theory.
- Systematic variation of environmental properties vs. correlational studies.
- Simulated environments and agents as methodological tools.

The relative importance and relevance of some of these issues can be evidenced in the papers themselves, which essentially speak for themselves (and most eloquently). Suffice to say, that as a research agenda, the organizers of the day felt that they provided a set of real problems that urgently need to be addressed: a set that could never be addressed in just a single workshop, but should perhaps be held up as an agenda for future research endeavour.

What is space syntax?

Space syntax is a term that is used to describe a family of theories and techniques concerning the relationship between space and society. It emerged from a dynamic and active research group based at University College London, in the early 1970s, and led by Professor Bill Hillier. The original driving force behind space syntax research was prompted by a goal to understand the relationship between space and society (rather than space and an individual subject) (Hillier and Hanson, 1984). Initially it

was thought that by holding a 'spatial configuration[2]' to be an artifact of the society that constructed it, then by studying such a system of spaces, it should be possible to more fully understand the society itself (as would be true of studying any other kind of artifact). However, the relationship between space and society is a two-way relationship: not only does a society create the spatial systems that it uses, but a group of people (be it the inhabitants of a settlement, an urban neighbourhood or the users of a complex building) is directly affected and influenced by the spaces they inhabit. In particular, one extremely powerful way in which a pattern of spaces, or a configuration, affects its users is through pedestrian movement. Any set of spaces, of sufficient complexity to be described as a configuration, forms a spatial hierarchy in which some spaces become more strategic and others less so. These strategic or, on average, more accessible spaces will tend to attract a higher rate of pedestrian movement than other, more segregated, spaces. This is clearly explained in Bafna's excellent introduction to space syntax (Bafna, 2003). One of the key methods of analysis used in space syntax research is a graph-based technique that is able to identify and represent this varying pattern of more-to-less strategic spaces. Although such techniques were not originally developed as tools for predicting pedestrian movement, it has been found that there does exist a powerful relationship between movement and spatial structure and so this graph-based analysis may be used to predict relative rates of pedestrian flow. It is this predictive ability of space syntax analyses that has caused it to be adopted as a design tool by many architects and urban planners.

The terms space syntax betrays its early analogies to linguistic theories. It was felt that, just as there is a limited combination of words, which can be assembled into a meaningful sentence, there are a limited number of meaningful spatial configurations. Although it is possible to generate (using generative algorithms) a near-infinite number of, for example, building plans, only a small number of these bear any relationship to real-world designs (Hillier, 1996). The linguistic analogy is that although it is possible to randomly generate grammatically correct sentences, only a small number of these would make any sense. The conclusion is that configurations of spaces have not only a grammar, but also a 'syntax': the pattern of relationships between spaces. It is this pattern of spatial relations that permit configurations to be meaningful and it is hypothesized that people have an innate ability to 'read' or comprehend these meanings. It is this aspect of attempting to understand how the meaning of spatial environments is communicated that connects space syntax to other academic fields interested in environmental cognition. How is it that a spatial configuration becomes meaningful? How are meanings transmitted? How are the understood? What range of meanings is encapsulated?

By starting to ask such questions, the centre of space syntax research starts to shift its emphasis from society as a whole (i.e. the origins of space syntax) to a line of enquiry that is firmly focused on the individual. And this, in turn, can be seen as the start of the journey which leads to a potential convergence with disciplines such as

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[2] A configuration, in space syntax terminology, is a set of spatial relations in which each relationship affects, and is affected by, all others; the modification of any single spatial relation, will have an affect on the whole configuration. Usually, a configuration is of such complexity that words do not exist to describe it in the way that words such as 'adjacent' and 'between' can be used to describe a more simple spatial relationship.

psychology that have their origins in the relationship between an individual and their context. Along this journey, there have been certain significant landmark events.

Finding the Building in Wayfinding

In 1990 a paper was published in the journal Environment and Behaviour, called *Finding the Building in Wayfinding* by Peponis, Zimring and Choi from the Georgia Institute of Technology. Zimring was (and still is) an environmental psychologist who has spent the majority of his career working with architects and in architectural academia. His early research emerged from the North American tradition of research into environmental psychology and environmental behavioural research (exemplified by organizations such as EDRA, the Environmental Design Research Association, and by techniques such as post-occupancy evaluation, POE), which developed at the end of the 1960s. Peponis, in contrast, is an architect and academic, and in 1990 had only just arrived at Georgia Tech, from the London space syntax group, where he had worked closely with Hiller, his doctoral supervisor.

Zimring and Peponis' first collaboration produced one of the most, to this day, highly cited space syntax papers as well as being one of the most highly cited papers on wayfinding. The key behind the success of this paper was their realisation that the majority of wayfinding research, at that point in time, had failed to take account of the spatial variables involved in how we navigate around complex environments: hence the title of the paper. This paper presents the results of a pioneering wayfinding experiment, in which correlations were found between measures of a building's spatial configuration and indicators of wayfinding performance: the authors not only conducted a 'classic' wayfinding experiment but attempted to set that against detailed spatial analyses of the experiment setting. This paper is held to be significant for this reason, but, in the context of this introduction, it further represents the first time that a mainstream paper attempted to address this interface between the individual and their cognition of a complex spatial system against a background of space syntax research. This paper can therefore be seen to have paved the way, not only for future research into wayfinding and navigation but, more importantly, for this shift of focus of space syntax itself.

The next milestone in the convergence of space syntax and spatial cognition was the 2001, or Third, International Space Syntax Symposium, which also happened (perhaps not coincidentally) to have taken place at the Georgia Institute of Technology. Among the line-up of invited keynote speakers, were Barbara Tversky, Benjamin Kuipers and John O'Keefe, three people who, from their difference perspectives (psychology, AI/robot navigation and neuroscience) have made some of the greatest contributions to the field of spatial cognition. At this symposium there was a clear and identifiable group of papers, which were engaging with spatial cognition. A selection of the best of these were revised and re-published as a special issue of Environment and Behaviour, edited by Conroy Dalton and Zimring (Issue 1, 2003).

The Fourth International Space Syntax Symposium, in London in 2003, elicited some highly relevant papers on space syntax and spatial cognition, not least of which

was Hillier's attempt to determine whether there is a syntax of spatial cognition (2003). He argued that the actively cognizant individual plays a vital role the shaping and functioning of the city. In particular, Hillier was concerned with subjects' cognition of the urban grid, and how this becomes internalized in a manner that is both perceptual and conceptual, "serving at once as an abstracted representation of the space of the city and as a means of solving problems, such as navigational problems." Hillier went on to debate how it is that we acquire such a concept of the urban grid. In addition to Hillier's paper, a plenary talk by Conroy Dalton, presented originally as a response-talk to a keynote by Tversky, introduced the idea of the typical spatial representations used in space syntax being, what Conroy Dalton termed, 'embodied diagrams', namely diagrams that are imbued with a manifold set of meanings pertaining to the experience of being embodied within an everyday spatial context. This talk was put together with the intention of laying the foundations of the common ground shared between space syntax and spatial cognition. The text of the oral-only presentation was subsequently published as a paper in World Architecture Magazine in 2005 (Conroy Dalton 2005).

2005 was also the year of Hillier and Iida's most recent paper on spatial cognition, a significant paper on the psychological effects of urban movement in which the authors ask whether *"the correlations that are found with syntactic variables at the level of aggregate flows are due to cognitive factors operating at the level of individual movers, or… are simply mathematically probable network effects"?*. The data underpinning this paper is extremely thorough and hence persuasive of the paper's suggestion that geometric (perception of angles turned while navigating) and topological complexity have a far greater and measurable effect on how people navigate in cities than metric distance. They conclude that these effects arise from a cognitive basis as opposed to purely being a mathematical effect of the configuration of the urban grid.

These landmark events and series of papers, distributed over the last fifteen years, represent a slow, steady, yet increasing preoccupation with spatial cognition, by space syntax researchers. This preoccupation seems set to continue: at the next space syntax symposium, it appears, from the preliminary list of papers that the emphasis on spatial cognition is increasing. So where do we go next? And, perhaps more importantly, is this convergence mirrored in any way by the experiences of the cognitive scientists interested in space use and spatial behaviour?

What is spatial cognition?

Spatial cognition research is concerned with the acquisition, organization, utilization, and revision of knowledge about spatial environments. Cognition refers to any of the 'higher-level' brain functions that begin to organize and structure the raw sense data, which represents our 'input' about our surroundings. Recently, 'space' is getting to be a popular academic subject, with a recognition that and understanding of context is vital to the understanding of all types of human behaviour. One way for a lay-person to understand what spatial cognition is about is that it is concerned with how "that stuff out there" (external to us), "gets in here" (is internalized in some

manner). Like in any area of cognitive science, understanding both the underlying cognitive representation formats and the cognitive operations performed on such representations are key issues in spatial cognition. E.g., researchers on 'cognitive mapping' and wayfinding will be interested in both the representational format of spatial information as well as in the mental operations that translate such information into navigation behaviour or map drawing.

Cognitive scientists often have created formal models of wayfinding behaviour that allow larger structures and patterns to emerge. Other cognitive science researchers measure reaction time to investigate information processing. Space syntax research has developed quantitative descriptors of the topological form of settings that are good predictors of where people will be found walking. Environment and behaviour researchers have developed tools such as sketch maps, think-aloud protocols, and tracking of individuals. There are clear opportunities for synergy. The spatial description tools of space syntax can be applied to the analysis of human movement patterns on the level of aggregate movement data, but also have appeared to be applicable more recently to cognitive phenomena such as the layout of sketch maps (Kim & Penn, 2004) and exploration of wayfinding behavior of individual test participants (e.g., Haq & Zimring, 2003; Conroy Dalton, 2003). The modelling precision of cognitive science can be applied to the real-world settings that environment and behavior researchers study. Although cognitive science researchers tend to be concerned with cognitive processes rather than designing good environments, the greater precision in defining the independent variable that space syntax provides can also be applied to cognitive science.

In recent years, researchers in the cognitive science community have made attempts to utilize space syntax techniques to better understand the relation of cognitive phenomena and properties of the environment. This is most prominently visible in a special issue of Environment & Behavior (Issue 1, 2003), but also in e.g., Wiener and Franz (2005). Yet scepticism is voiced as to how well the phenomena originally captured with space syntax methods for aggregate behavioural data translate to individual cognitive processes. How can the requirements and benefits of spatial cognition and space syntax most adequately be brought together?

Areas of overlap

To claim that there is a strong degree of overlap between space syntax and spatial cognition would be erroneous, as there are many examples on either side of the academic fence that would be of little or no interest to the other, for example 'spatial genotypes' in space syntax (of little interest to the spatial cognitive scientist) or, conversely, space and verbal memory tasks (of little interest to the space syntax researcher) to name but a few. However, although the areas of overlap may not be broad, I would argue that they are frequently highly pertinent and, indeed, central to both fields. In the next section we will discuss some of the areas of overlap that were raised at the workshop, through the medium of the papers presented on the day.

The workshop began with our keynote speaker, Professor Bill Hillier, presenting a paper entitled, *Studying Cities to Learn about Minds: how geometric intuitions shape*

urban space and make it work. In this paper, Hiller argues that by examining the products of human creativity, we can understand a significant amount about the way that the human mind works, and, in particular, our cognition of space. This is quite a new approach to spatial cognition, and one that has yet to be approached from within the cognitive science community. The case that Hillier uses as an example for this paper is the city. What particularly seems to intrigue Hillier is that fact that the inhabitants of a city appear to try to impose a geometric order upon the city, which, in many cases, it does not intrinsically posses. He goes on to argue that all cities are pervasively ordered by our geometric intuition, so that neither the forms of the cities nor their functioning can be understood without insight into their distinctive and pervasive emergent geometrical forms.

Hillier's theme of inhabitants' perception of the built environment, at the scale of the cityscape, was further developed by Mavridou, in her excellent paper, *Perception of Architectural and Urban Scale in an Immersive Virtual Environment*. In this paper, Mavridou presents the results of a series of experiments, which have been conducted within a virtual environment. Essentially she takes a pair of similar, theoretic, urban-like environments (superficially similar, yet configurationally quite different) and alters specific variables (for example building heights) that can be held to be associated with urban scale. She then performs a set of qualitative experiments, designed to assess the subject's perceptions of scale within these environments. As a result of this study, Mavridou creates a hypothesis for the perception of urban scale, namely that the perception of form affects the perception of both geometrical and topological properties of space. Her paper culminates in a new definition of scale, which focuses on the relation of form to space.

A virtual reality, urban simulation was also put to effective use in the paper *From Isovists via Mental Representations to Behaviour: first steps toward closing the causal chain* by Meilinger, Franz and Bülthoff. In this paper, the authors present a collaborative research project of behavioural scientists and a trained architect, Gerald Franz. The study investigates the role of spatial properties for the task of learning a route in a complex urban setting. It is performed in a highly detailed Virtual Reality model of the old-town of Tübingen. The authors present convincing evidence that isovist measures capture spatial properties of urban intersection in a manner that is predictive both of human navigation behaviour and its underlying spatial representation.

Staying with both the urban theme and with the use of isovists, Davies, Mora and Peebles take a more practical, problem-directed line of enquiry in their paper, *Isovists for Orientation: can space syntax help us predict directional confusion?* This paper is concerned with the potential problems that people have in orientating themselves in an urban environment, with respect to an accompanying map. The focus of this paper is whether a study of isovist attributes may assist in the identification of spatial orientation problems at specific locations. Again, this paper presents an experiment: in it subjects are required to match a map to a visual (3D) scene and state their perceived orientation. The accuracy and difficulty of this task is measured and then correlated to the spatial attributes of the isovist at that location. The practical goal of this study is to improve maps by adding additional information at those locations found to be problematic.

Maps also feature in the paper, *Architecture of Mind and World: how urban form influences spatial cognition* by Dara-Abrams, which represents another contribution from cognitive science. In this paper the author investigates the nature of systematic distortions typically found in the cognitive maps people form about their spatial environments. These distortions are theoretically tied to heuristics of cognitive simplification. With the help of established spatial judgement and memory tasks, i.e., pointing and map arrangement, Dara-Abrams shows that especially the space syntax measure of integration predicts the degree of mental distortion and may thus provides access to underlying cognitive processes and representations. This paper, in particular, relates very strongly to Hillier's opening paper.

Another practical problem introduced in the workshop, was that of whether urban neighbourhoods have identifiable, spatial characteristics. This was explored by Dalton in his paper, *Configuration and Neighbourhood or is Place Measurable?*. In this paper, the author takes a theoretical rather than experimental approach to the problem by presenting a new method of spatial analysis that Dalton terms, 'point intelligibility mapping'. This takes the concept of 'intelligibility' from Hillier (Hillier, 1996) and takes the radical step of calculating the intelligibility of a point in space rather than an area or district. Dalton's findings are that known and defined neighbourhoods appear to consist of a set of axial lines with similar point intelligibility values, suggesting that the concept of neighbourhood is more than a pure social or cultural construct. Dalton concludes his presentation and paper by illustrating this new method as applied to an area of Boston used by Lynch (Lynch, 1960) in his cognitive mapping experiments.

In one of the few papers concerned with the layout of building interiors, Wineman, Peponis and Conroy Dalton presented their paper, *Exploring, Engaging, Understanding in Museums*. This work was based on a series of observations made of visitors to a pair of travelling science exhibitions. And in particular, they focussed their analysis on patterns of accessibility through the space of the exhibition, connections or separations among spaces or exhibition elements, sequencing and grouping of elements and go on to suggest how these might combine to shape both our perceptions and our understanding of the exhibition content. This paper suggests that these observed patterns of movement form the basis of visitor understanding and that these effects can be deliberately controlled and elaborated through a closer examination of the influence of the visual and perceptual properties of an exhibition.

Another paper that was both concerned with building layout and with the resultant effect on navigation was by Hölscher, Brösamle and Vrachliotis in their paper *Challenges in Multi-level Wayfinding: a case-study with space syntax techniques.* Hölscher et al. reanalyse one of their previous experiments on wayfinding in complex multi-level buildings with the help of space syntax measures. The paper is another example of active collaboration of cognitive researchers with a trained architect, G. Vrachliotis. The authors show that measures like integration and step-depths capture important architectural deficits of the building with respect to its navigability, substantiating earlier qualitative findings. Furthermore, they develop a set of new aggregate spatial measures for routes in a building and link these to human path choice strategies and differences in spatial knowledge.

The final building-level paper presented at the workshop was *Lighting Within the Social Dimension of Space: a case study at the Royal Festival Hall, London* by Antonakaki which investigates the role of light within the social dimension of space

and the influence that lighting may have on visitors' overt behaviour. It attempts to make a link between behavioural, qualitative and configurational issues of the built environment. The author performed an intervention study and was able to show that active variation of the lighting situation in the entrance area of a large theatre, identifying clear changes in the local patterns of movement as well as in visitor interactions. The paper calls attention to the fact that our behaviour in an architectural space is not only determined by its factual geometry, but to an important extent also by the perceptual qualities that can be modulated by adequate lighting design.

The paper *The Ingredients of an Exosomatic Cognitive Map: Isovists, Agents and Axial Lines* by Turner investigates the potential correspondence between the axial map, a key tool in Space Syntax analysis, and the cognitive map as a mental representation of space. The paper combines evidence from a series of experiments with perceptually driven agents inhabiting a simulated space. The paper connects ideas of direct perception and affordances with a notion of a spatial representation that resides outside of the agent itself, hence an *exosomatic* property. From a cognitive science perspective on representational issues this position is clearly controversial and this paper will clearly stimulate the debate about the relative roles of perceptual qualities and spatial memory for human movement in built environments.

Finally, extended abstracts of three poster presentations are included in this volume: Nenci and Troffa presented a poster on *Integrating space Syntax in Wayfinding Analysis*. Based on simulated movement in an urban environment the impact of metric distance on route choice is contrasted with the cognitive costs of choosing different routes through the system. The poster *Wayfinding and Navigation Processes in Piraiki Coast in the City of Piraeus* by Rafailaki compares the spatial memory and orientation of people highly familiar with this coastal area in Greece to visitors of the setting. The author argues that configurational properties of the space help to explain distortions in landmark memory as well as orientation difficulties. The poster *The Role of Space in the Emergence of Conceived Urban Areas* by Yang investigates another facet of the cognitive representation of urban areas: Named areas in a city are a prominent way of representing a complex city in a hierarchy of local regions and the author identifies spatial properties that correspond to the delineation of these urban areas.

It is clear from the descriptions of such a rich variety of papers, that not only are there numerous areas and degrees of overlap between these two groups but that collaborations between cognitive scientists, architects and the space syntax academic community appear to be rather fruitful. It is the hope of all of the workshop organisers that the Bremen 2006 workshop may serve as a springboard for future collaborations. Finally, we would like to take this opportunity to thank all of those who participated in this day, either as presenters or attendees.

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