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THE EFFECTS OF "ORDER" AND "DISORDER" ON HUMAN COGNITIVE PERCEPTION IN NAVIGATING THROUGH URBAN ENVIRONMENTS

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Abstract

This paper investigates how “order”, “structure”, and “disorder” of street layouts are perceived when navigating through an urban environment. It builds on the assumption that a mixture of “order” and “disorder” might be a key factor for the quality of understanding within an urban context and that an “ordered” environment tends to be more intelligible when broken up by an irregularity occasionally. Knowledge about urban layouts can be accrued by the traveller in different ways: From static viewpoints, from top-down maps, and in travelling through the scenery. Cognitive processes that are involved in organising information about the structure of the built environment are known to simplify and schematise information. Such a “mental map” creates an image of the city, helps in memorising it and facilitates wayfinding tasks. Wayfinding experiments and investigations into the configuration of street networks have so far supported the understanding of movement behaviour and given insight from different perspectives on an urban environment. This paper will attempt to relate two aspects - configurational and sequential experiences of navigation (along a route) - to each other in using a methodological framework that allows for comparison of quantitative measurements and findings from both fields of research. The centre of attention will be the perception of “order”, “structure” and “disorder” from both perspectives: From “above” and from “along within” an urban environment. A virtual movement experiment with pre-chosen routes through six city samples is expected to provide meaningful empirical data with view on the perception of both configurational (view from above) and sequential (moving through scenery) embodiments of “order” and “disorder”, thereby introducing a methodological approach that applies string code computation in the spirit of probabilistic information theory.

Key Words

order/disorder, spatial perception, cognitive mapping, types of knowledge, information theory

List of Illustrations

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"The mind constructs narratives from what would otherwise be chaos."
(Tversky, 2004: 1)

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Introduction

The aim of this paper is to apply concepts of "order" and "disorder" to the act of navigating through a built environment. It is drawn from the hypothesis that "order" or "disorder" can affect one's perception - and therefore one's knowledge - of the environment when moving along a given path.

It is postulated that navigation through space increases spatial understanding (see Gibson: 1966), and that the amount and quality of information that is gained accounts for the level of that understanding. This will be tested against the assumption that a mixture of "order" and "disorder" might be a key factor for the quality of understanding within an urban context and that an "ordered" environment tends to be more intelligible when broken up by an irregularity occasionally.

Navigation through urban environments is also known to be predominantly dependant on visual perception of the moving subject. The parts of the streetscape one can see will determine the probability and ease of a choice taken at decision points (or "turns"). The experience of moving through a street system can therefore vary from being an easy cognitive task to creating mazelike confusion.

Such phenomena of wayfinding and orientation in built environments have been investigated mainly in the fields of psychology and cognitive sciences. The origins of spatial cognition started from two fields, applied in architecture and geography, and theoretical psychology. Within psychological research, the notion "cognitive map" emerged from Tolman's paper "Cognitive Maps in Rats and Men".

People's memory for distance and direction has been investigated by researchers for factors that promote encoding and retrieval of information. According to Gibson, human beings move to achieve understanding rather than cognising an environment in order to be able to move through it.

Perception within a built environment has been mostly related to built forms, landmarks and other physical features (e.g. by Lynch, 1960), but not so much is known about the character of the information that is (and how it is) retrieved from the fabric structure of the street network.

The relevance of studying individual and collective behaviour in navigation is apparent: Spatial cognition determines action. It is dependant on perception and memory, both of which are feeding back on each other in a two-way process. The perception of "order", "structure" and "disorder" in an urban environment can be derived from different perspectives on it and from within it, which might cause different levels of legibility through the cognitive process, as is

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suggested in this paper: When looking top-down on a map for instance, a geometric “order” might be assigned to the urban pattern which is eventually perceived in a different way than a situational perceived “order” when standing in, or moving through a “3D-scene” based on the same block pattern. On the basis of this idea, the methodological approach in this paper is structured as follows:

Step 1: Top-down figure-ground plans of six different block patterns, cut out from distinct city environments, are analysed and compared to each other with “Depthmap” Visual Graph Analysis.

Step 2: Isovist analysis is applied in order to examine locomotion-relevant properties of space. While focussing on visibility/occlusion of edges, route strings will be extracted, fractionised in a barcode manner and scrutinised for their expression of orderliness. This could be extended to extreme pattern reductions like “binary codes”.

Step 3: 3D models were used for an empirical study, where fly-through movies, simulating routes through the environment samples, were sent to participants, accompanied by a questionnaire related to awareness of cognitive processes. This experiment is set up for testing the level of conscious perception of “structure” and “order” when moving through urban scenery without previous knowledge of the geometric layout of the street pattern. The reactions to these locomotion test flights will be compared to the “top-down plan” and “3D-scenery” analysis results retrieved form steps 1 and 2.

The relationship between “order” and “disorder” in a street layout is seen to be reflected in predictability (or probability) of a chosen route. The quantum of predictability will – throughout these three analytical steps - be scrutinised with respect to geometrical and topological measures of the samples, two aspects which are here assumed to form a duality in their impact of providing information about the grid for the moving subject. This duality works like a loop-back of new experiencing, half-knowledge of places, memorising, and information from physical and mental maps.

If order is expressed in regularities and repetitions, this paper suggests, then it can be perceived in moving about, e.g. by (consciously or unconsciously) “counting” the number of turns, thereby taking into account similarity and differences of turns, like left/right turn, sharp/slight turn (in terms of angles).

This paper, however, will predominantly deal with the question: How, and how precisely, does information assembled from situation-based experiences (from transitional, non-static views)

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in travelling build up an abstract overview knowledge that can then be referred to when one finds oneself in new situations of spatial experience? To what extent can changes of views, like approaching junctions and open spaces, be discerned as a rhythm? And how do rhythm and orderliness of a sequence of events (turns) and missed events (crossed junctions/no turn taken) on a journey through urban worlds affect the information retrieved in motion?

Interconnections with music that are made are derived from the idea that the art of architecture and the art of music seem to occupy the same territory in the brain. Inspired by Johann Wolfgang von Goethe’s dictum that “architecture is frozen music”, in this paper a similar idea will be kept at the back of the mind: If the experiencing of routes in three-dimensions and in real-time imposes a temporal order on static space, then a mental map that is built through cognising a route could be seen as the reverse; a sequence of static scenes, frozen in time.

Literature Review

In this chapter, theories related to this paper's problem definition and concepts containing relevant views on the nature of "order", "disorder" and "structure" are presented and reviewed from the perspectives of various fields of research. Ideas that can be found across a broad range of disciplines will be interlinked and contrasted with each other and set in relation to the focal research question in this paper. The aim is to set the research question into its theoretical context and to clarify notions and hypotheses that will set the grounds for engagement in and discussions on this specific topic throughout the following chapters.

Notions of "order" and "structure" are frequently used, and have been examined by philosophers, mathematicians, physicians, geographers, as well as researchers within the fields of medicine, psychology, cognitive sciences, information theory, and chaos theory. In architecture and urban design, geometric order and order in layouts are a fundamental thought to begin with in the creative process of building physical structures with functional and aesthetical qualities; however, order and structure with view on configurational properties in urban street layouts and their impact on an individual's perception when moving through an urban environment has not moved into the centre of the designer's attention yet. On theoretical grounds, and equipped with computational tools especially developed for the analysis of spatial configurations, Space Syntax researchers have settled a basis for thinking about these concepts and testing them.

Hanson (1989) raises three issues for the design of architectural and urban space, the first of which deals with the notions of structure and order in design and is therefore the main issue relating to the ideas in this paper. Structure and order, according to Hanson, are understood to be built on two different mechanisms. While order is the aspect that contributes to visual and conceptual clarity of an architectural or urban layout as immediately retrieved from a (physical or mental) map, structure is experienced through moving about a spatial system. Order is, therefore, static over time, consisting of geometrical elements that, in showing similarity of parts in relations to each other, are immediately available for perception and brought about by repetition, thereby forming a "Gestalt". Structure, on the other hand, is picked up as an arrangement of differences when moving about. An interesting distinction is also made with view to possibilities and effects of change to the layout or within the layout: structure is defined as the perceived differences which can be created within a spatial configuration. It is stated that structure has "continuity under transformation"; that "the mind can read structure, often without being able consciously to articulate it"; and that "the attempt to impose order on structure is a conscious, reflective, discriminating act". Principles of order are rather found in the regularities/repetitions/similarities which people normally pay attention to when looking at architecture, as for the geometrical patterns in artefacts. If order is expressed in regularities and repetitions, this paper suggests, it can be perceived in moving about, e.g. by (consciously or unconsciously) "counting" the number of turns, thereby taking into account similarity

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and differences of turns, like left/right turn, sharp/slight turn (in terms of angles). This isolated sequence of a single path, perceived in real time, contributes to the creation of a mental map. The cumulative effect of several single sequences as experienced on different paths through the same environment then amounts to the formation of an overall picture of the layout and the possible geometry of its parts. Along these lines, Hanson also points out that the configuration of a spatial system cannot be apprehended without relating parts of the picture to a whole. However, experiencing space as related discontinuities would require relating the local scale of the directly perceived information of immediate scenery to the global scale of the whole - simultaneously existing - configuration. To solve the initial problem of retrieving visual logic from a certain point within a configuration without being simultaneously at every point in the system, Hanson suggests: "An alternative way forward may be to raise the principles of structure to a level where of conscious thought, so that both structure and order can be used to reinforce each other so that the visual and the functional aspects of urban form together construct a spatial aesthetic." (ibid: 398). The level of conscious perception of structure and order when moving through urban sceneries will be tested in the empirical part of this study, comparing observers' abilities to grasp order geometrically and the picture that is built in mind (mental map) without previous knowledge of the objectively existing map.

In his 1960 book "The Image of the City", Kevin Lynch presents the results of his study (based on three American cities as examples: Boston, Jersey City and Los Angeles) on how people perceive and organise spatial information as they navigate through cities. His experiment included questionnaire surveys and interviews, along with the drawing of sketch maps. In his theoretic description of the city's visual perception based on objective criteria he introduced innovative concepts of "place legibility" and "imageability". Legibility (the ease with which city layouts are understood) is dependent on mental representations of a city. Lynch defines the representations of what a city contains as a network of five elements: paths, edges, districts, nodes and landmarks1. These elements also contribute to imageability if they are "meaningful, distinct, and not confusing". Lynch sees a two-way process in "building the image" between the observer and the environment: "The environment suggests distinctions and relations, and the observer [...] selects, organizes, and endows with meaning what he sees" (ibid: 6). He therefore suggests that well-designed paths rely on the clarity of direction, that is, paths that don not contain ambiguous or confusing turns. The implication of these conditions is ease of learning, understanding and remembering patterns. An ordered environment would thus provide a frame of reference (a global frame) that helps with organising information (picked up from the local surroundings) and taking up resulting actions supported by this information. The city image according to Lynch is analysed into the component's identity, structure and meaning. The ideal city image would then be "open-ended, adaptable to change, allowing the individual to continue to investigate and organize reality: there should be blank spaces

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where he can extend the drawing for himself” (ibid: 6). Related scientific fields that also investigate the “memorable city”, like environmental psychology and spatial cognition, have picked up on his work, using virtual environment setups and exploring how gradual alterations in the geometry of these elements in the layouts of cities can change the level of legibility and imageability – an undertaking that would not be possible to test in real world environments. The geometry of layouts has predominantly been investigated with a view on the angles between elements and the synchronisation of mechanisms when moving between them, based on visual cues. It appears, however, that no comparison has been done so far between the geometric characteristics of the plan layout as seen from above and the experience of turns along the move. Also, how information about block geometry is inscribed in the appearance of building edges and in which way they support the choice of direction in moving has not been tackled in depth by researchers yet. This, however, is part of the empirical analysis in this paper. Lynch’s study revealed that paths can be distinguished by a regular, cumulative change in quality (a “gradient”) in one direction, and that subjects tended to impose regularities on the experienced environment, in trying to “organize paths into geometrical networks, disregarding curves and non-perpendicular intersections” (ibid: 61). The experiment in this paper will be designed to test differences in perception by sending participants through a virtual movement experiment where one and the same city environment with its characteristic (ir)regularities is traversed along different routes. The results of the empirical study will be analysed with view on the organisation of paths in mind, e.g. “barcodes” that indicate turns, and city maps showing a range of possible routes taken. These route maps will be subject for identification after participants have been taken along predetermined journeys through a virtual environment in tailored fly-through animations.

It is a philosophical angle of vision that Foucault takes in “The Order of Things” (1969), where he draws from fields like literature and linguistics, biology, and arts. The ways in which we choose to order information and thoughts, is central in this book. According to Foucault, order is based on categorisation and the desire of organisation. It therefore strongly depends on the relation between the whole and its parts. Order and its significance can change based on these relationships. Through division of the whole into parts, understanding and organisation of information enables us to compare their relationships: “One cannot know the order of things in their isolated nature, but by discovering which is the simplest, then which is the next simplest, one can progress inevitably to the most complex things of all.” (ibid: 59). Foucault thereby explains a general science of order by two main ordering natures. While simple natures can be dealt with by using algebra (mathesis – a science of equality, attributions and judgements), complex representations can be analysed with a system of signs (taxinomia – a science of identities and differences, of articulations and classifications). Mathesis, or the science of calculable order, serves to define identities and differences in empirical analyses. Taxinomia “establishes the

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table of visible differences; genesis presupposes a progressive series; the first treats of signs in their spatial simultaneity, as a syntax; the second divides them up into an analogon of time, as a chronology”. (ibid: 82). Genesis, or the analysis of constitutions of orders, is therefore based on finding resemblances between things that are grasped progressively. Foucault understands that by establishing a “mathematics of order” based on identity and difference, all information can be broken down to “ones” and “zeros”. This supports the idea presented in this paper that, although visual environmental order is perceived in real time - chronologically and progressively - along a path, the information retrieved is then simplified, broken down into bits, and stored in measurable parts. These (locally retrieved) parts are further - and together with bits retrieved and stored from other paths - put together to a whole (global) picture, or mental map, of the surroundings. Therefore, this paper suggests, that a simplified and schematised mental map can be analysed in analogy to a mathesis – a calculable order. With this “analytic of imagination” in mind, it would then be possible to analyse and transform a chain of information bits, accrued from a linear time of representation, into a visual syntax that is inherent in simultaneously existing space.

In Touloumis’ paper about “Issues of Inscription of Temporal Experience” (2005) in architecture and landscape, an attempt of transcription of syntax and structure between architecture and poetry is made. Here, rhythm is recognised as a common feature in poetry and architecture. Since rhythm consists of sections of time that can be perceived by the senses, it can be seen as a subdivision of a span in analogy to metric distance. Touloumis draws a comparison with the dactyl metre: “Metre defines the relationship between weak and strong parts while the form is determined by rhythm. Rhythm defines not only the inner form of the metre but the way of its grouping as well.” It can be deduced that, if metric distance is analogue to the metre, spatially experienced rhythm can be attributed to the grouping of metric distances or intervals. That is, a sequence of intervals (consisting of built mass passed over time) alternating with gaps (open spaces passed) could be ascribed a rhythm that is made of chains of “positive” and “negative” mass, or abstracted “ones” and “zeros”. Touloumis even states that rhythm is “superior to the medium through which it is manifested”. The transmission of a rhythm, derived from the sequence of built forms and void spaces, might therefore be understood to be superior to the built form and its metric dimension itself. The memorising of an order through grouping of shapes of scenarios, and recognition of the rhythm of a linear spatial pattern (along a path), could thus be seen as the primary factor in spatial pattern recognition. Another interesting remark made by Touloumis is that points of turn can be realised as rhythm. Not only would the occurrence of a junction (gap) between building blocks contribute to the rhythm accordingly, but also the event of a turn. Based on this idea, the concept of turns as events (and not taken turns as missed events) will be introduced in the experimental part of this study.

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Thiel (1997) introduces an analytical approach for describing human experience of environments over time. He views the environment from the point of experience that changes as one moves through it, in opposition to the above view so often taken by designers and planners and he devises a system for notations which is based on a theory that can be seen closely related to music and dance. Acknowledging time as the fundamental characteristic of a given path, the notion "trajectory" is used which combines the notion of path (direction and distance) with time. According to Thiel, a path is characterised by events, whereby the "concept of event means a perceptible change in any environmental parameter, as experienced along a given path". A variety of notations are suggested that allow measurement of the complexity experienced objectively, e.g. regarding the anatomy of space, space connections or space-sequence notation. Inspired by Thiel's notations, the extraction and translation of turn events into "barcodes" is being introduced in this paper. A measurement of real time passed as metric relation between events, however, was abandoned for the encryption in "barcodes" and their string notation in the experiment and in the analysis. This approach was taken in order to enable an interpretation of perceptional features uncoupled from their relationship to metric distance.

Within the field of cognitive psychology, Tversky has done a vast amount of work in the realm of spatial mental representations, categories, and spatial cognition. Many of her ideas in these fields of research are related to this paper's topic and can be found scattered across the wide range of Tversky's papers, which therefore will be "cross-reviewed" in this paragraph. In her paper "Levels and Structure of Spatial Knowledge", Tversky distinguishes between "overview knowledge" needed for travelling without external cognitive aids (e.g. maps) at a global level, "views knowledge" that is "critical to the choice highlighted" along the route, especially at choice points, and "actions knowledge" at the finest local level needed for decision on the next steps. According to Tversky, these are levels of information with different mental representations. While the approaches taken for characterisations of cognitive maps as positioned by researchers are diverging and ranging from comparisons to a map on paper, to abstract mental models and cognitive collages, it seems, however, commonly acknowledged that the information that is represented is simplified and schematised, i.e. much of the information is omitted so that only parts of the information are represented. In her paper "Navigating by Mind and by Body" (2003b) Tversky ascribes errors throughout the process of schematisation being "inherent to the construction of mental spaces and to using them to make judgements in limited capacity working memory". All these relations might contribute to a distortion of spatial information. Some crucial observations about distortions and simplifications are made, which the methodology in this paper draws from:

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i) “Elements located relative to each other are remembered as more aligned relative to a reference frame than they actually are”; ii) “Distance judgements for routes are judged longer when the route has many turns or landmarks or intersections.”; iii) “Curves are often remembered as straighter than they actually are”/”directions get straightened in memory”; iv) “Angles of intersections are schematised to 90 degrees”; v) “Regions are remembered more symmetric than they actually are”; vi) “Cognitive maps schematise the two-dimensional horizontal slice of the world. By contrast, views schematise vertical slices of the world”; vii) “Changes in details and objects often go unnoticed, provided the general configuration remains the same”; viii) “Scenes that are organised are remembered better than scenes that are unorganised”.

Tversky also picks up on the difference of styles in descriptions of environments and declares:
(i) The view from a single viewpoint (at eye level) uses a relative frame of reference; (ii) the route description (changing viewpoints related to left, right, front, back, from travelling within the environment) an intrinsic frame of reference; and (iii) a survey description (extrinsic, from above) uses an absolute frame of reference. Not only are landmarks thought to be of relevance for helping in orientating oneself, but also changes of directions, which can be seen as segments of transition. However, the impact of landmarks on perception is separated out in this paper. The research method chosen here explicitly excludes landmarks and instead focuses on changes of direction only. (Throughout the empirical experiment, building heights are kept equal, at a constant height of 12m, to avoid the effect of orientation aided by landmarks.) Furthermore, Tversky refers to experiments where participants were asked to give route descriptions (verbally and with sketch maps) and, in strikingly strong similarity, reorientations tended to be memorised as turns at intersections, and in giving directions, the angle of turn was unspecified. Both of these showed that a substantial part of schematisation is owing to the redundancy effect of turns at intersections, thereby distorting the estimation of distances and building block shape geometry from the “real” measures, and as they are retrieved from 2-dimensional maps. In “On Bodies and Events” (2002) and “Event Structure in Perception and Cognition” (2001a), Tversky relates structures of bodies to structures of events, which are both made up by parts that can be decomposed into beginning, middle and end. While events are structured in time, bodies are structured in space. Both are continuous, however, as Tversky states, are fractionised and ordered into processable units and categories. “The human mind has a gift for bringing order to chaos.” (2001a: 3). In “Narratives of Space, Time, and Life” (2004), Tversky describes the way how chaos is structured in the human mind as a narrative of spatial language: “Out of the stream of sensation, the mind carves objects in space and actions in time, and configures objects into scenes and actions into events.” This is equivalent to a dualism between configurational and linear aspects of space, a survey perspective of omnipresent space, and a linear route perspective building a narrative along the temporal order of space. The methodology in this paper relates to these perpectives by implementing a twofold approach of perceptional

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differences between “from-the-top-view” of maps and “along-the-scenery” sequential strings.

A philosophical distinction between moving “along” a line or “across” a plane is also made by anthropologist Ingold. In his paper “Up, Across and Along” (2005) he claims that, in modern times, wayfaring - or continuous travelling - has been replaced by destination-oriented transport. A line actually drawn on paper, or virtually as a gesture, is described as a line that goes “for a walk” (thereby quoting Klee’s dictum about the freely developed line), as opposed to a line comprising of a “series of appointments”. In this sequenced line, cut up into segments, Ingold sees a predetermination of where every connecting line segment will lead to: the next destination dot. All movement is imagined to be wound up in the dot (the “moment”), whereas the connecting lines only constitute a chain of segments between dots. It is an assembly of lines that, through the way they connect, create – or “construct” - a higher order of connections. In analogy, one could also imagine that environments are built as assemblies of connected elements rather than coherent lines, especially when considering that orientation in a street network is predominantly based on views and visual clues. Transposing this concept onto this paper’s problem definition, how elements in the environment are assembled and structured in our mind, dots could be replaced by junctions and the line connectors by the street segments between junctions. The assembly of connectors - the street segments - would then accordingly establish the system that creates a higher order when moving from dot to dot (junction to junction). Having arrived at a junction, the most relevant, order generating aspect of perception would be directionality towards the next destination point along the route ahead. Or, as Ingold observes: “Whereas the active line on a walk is dynamic, the line that connects adjacent points in series is, according to Klee, “the quintessence of the static”. If the former takes us on a journey that has no obvious beginning or end, the latter presents us with an array of interconnected destinations that can, as on a route-map, be viewed all at once”. This might be the equivalent idea of a cognitive map constructed in the mind of the “from-point-to-point” traveller, which is then organised as hierarchical order of line segment sequences representing possible routes (sequences of connectors) in an “overview” mental map.

Investigations into wayfinding and directional choices that are taken by travellers have been done by Conroy-Dalton in her PhD dissertation “Spatial Navigation in Immersive Virtual Environments” (2001) and have been summarised in her published paper “The Secret is to Follow your Nose. Route Path Selection and Angularity” (2003). The underlying hypothesis was that actions at road junctions result in route linearity. This was tested in measuring angular deviations from a straight line, which appeared to show that “people follow their noses”, i.e. they follow “as straight a route as possible provided that the choice approximates the direction of their final destination”. In contrast to this paper’s approach, where people are confronted with a virtual pre-chosen route and asked about perception and retrieval of information, participants

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in Conroy-Dalton’s virtual simulation world navigated actively and immersively through a modelled urban environment containing a variety of urban block shapes. Routes were broken down into a sequence of chronologically ordered route choice nodes while each node (road junctions) was given an individual alphabetical character. Therefore the number of different characters was equal to the length of the string when building a sequence of labelled junctions that came to lie along the journey determined by the traveller’s choice. The difference to the string retrieval in this paper is (as will be explained in detail in the chapter about the research methodology), that here the number of characters is limited to four: [L], [R], [O], and [o]. These can occur repeatedly in one route string, and the “choice” is here not the actual choice of the test subjects, but pre-determined. While Dalton’s experiment setup was using a completely “invented” environment with created geometrical block shapes, the virtual environment used in this study is based on real city maps; however, building heights have been unified. Thus, both setups provided virtual environments that are not built on previous knowledge of the particular movement experiment.

Different types of spatial knowledge have been established by researchers (from geography to cognitive sciences), that define different approaches for examination of their impact on spatial comprehension. Golledge (1992) mentions three types in his paper: declarative, procedural and configurational knowledge. While declarative knowledge consists of the “inventory of pieces of information contained in long-term memory”, procedural knowledge relates to the linking of pieces of information into ordered strings, and survey or configurational knowledge is described as awareness of “configurational properties or layout characteristics of spatial features”. These features, he claims, are usually not directly sensed (and would relate to a “world” knowledge which will be part of the methodology in this paper), but integrated into a comprehensive system of spatial knowledge as piecemeal information. Segments and turns are elements used for ordering huge amounts of information into sequences; this serves as a way of classifying environmental information and simplifying it, which is known as the “chunking hypothesis”. Both configurational knowledge (in “worlds” seen from above) and procedural knowledge (along “routes” when moving through the real world) will in this paper be brought into a relation that makes them comparable, aided by a methodological approach that uses differences and similarities in perception derived from both types of knowledge. Golledge’s idea that “information learned from routes could readily be integrated into a configurational knowledge structure” is a crucial question that will be examined in this paper, in comparing how individuals might sense their environment from different viewpoints: configurational (spatial analysis from six city sample maps), procedural (string computation of turn events along routes) and perceptional (virtual movement experiment in the empirical part of the study).

The methodology chosen for testing this multilayered sensing on the basis of spatial analysis,

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string computation and the empirical experiment setup is explained in the following chapter, thereby building on the theoretical ideas and assumptions as they have been described in this literature review.

Footnotes:

1 The five elements represented in cities, as defined by Lynch (1966):

Paths:	the streets, sidewalks, trails, and other channels in which people travel
Edges:	perceived boundaries such as walls, buildings, and shorelines
Districts:	relatively large sections of the city distinguished by some identity or character
Nodes:	focal points, intersections or loci
Landmarks:	readily identifiable objects which serve as reference points

Research Methodology

In this chapter, the methodology chosen for the research is described and discussed with view on its significance for the research question, its apparent limitations, and the restrictions that emerged when it was applied.

A range of city street patterns that are increasingly and gradually different from each other was chosen for analysis. A number of six city samples appeared to be suitable and representative for investigating different grades of orderliness and structure, from the very regular grid to strongly organic street patterns and various mixtures between the two extremes. The Nolli[1] maps of these six city samples were retrieved from Allan Jacob's book "Great Streets" (1993). The clear definition of the mass of building blocks (in black) versus street canons and open spaces (left white) in these maps, as well as their unitary scale (each map would cover an area of 1609 meters x 1609 meters = 1 square mile in reality), rendered them ideal as a basis for direct comparison of different urban figure-ground patterns. They were used in multiple ways: (i) For visibility graph and isovist analysis (in Depthmap); (ii) for axial graph analysis (in Depthmap)[2]; and (iii) as 2D basis for the production of 4D "fly-through" animations in the empirical survey with accompanying questionnaire.

1. Visibility Graph and Isovist Analysis

The concept of visibility graph analysis is rooted in Benedikt's (1979) isovist analysis. He proposed that a space, or an environment, is perceived as a collection of visible surfaces that are not occluded by physical boundaries such as walls and partitions and thereby defined an isovist at a given point in the floorplan as being the contour of equal visual area which comprises all the space visible from that point when looking around in 360 degrees. Quantifying the isovist areas, perimeters, and solid boundaries, can be used to compare the quality of different spaces. Processed maps consisting of these isovist fields give an idea of how people navigate through spaces, since navigation is dependent on what can be seen from a particular point. The isovist field maps are therefore expected to correspond with movement behaviour, and, as will be assumed in this paper, also correspond to perception of space that people experience when travelling along routes through an urban environment. Perception of space in isovist analysis reflects what can be seen by the locally situated, individual observer and therefore is supposed to predict field-dependent behaviour (locomotion). In analogy, it is suggested in this paper, that perception of order and structure can be seen in relation to properties of these fields of equal visibility ranges. For the chosen six city samples, isovist fields have been generated for all points along a route (two routes for each city sample=twelve routes in total), in order to show what can be seen from an assembly of chosen points along a route. These point isovists are generated from (the centre of) every selected point and represent a catchment area of visible space that stretches between building blocks. Two different routes through each of the 6 city samples might produce two rather different or rather similar catchment areas, in terms of distance and

Research Methodology (contd.)

shape. At the same time, they might “drag” different characteristics of basically the same street pattern into the centre view of the observer, thereby creating rather different, or rather similar, field properties that account for pattern perceptions of “disorder”, “structure” and/or “order”. While isovist field measures operate only locally, visibility graph analysis (VGA) gives local and global syntactic measures. For retrieving information about “order” and “disorder” from the space defined and constrained by building surfaces, the full extension of space in between the built mass/surfaces requires consideration; visibility graph measures provide degrees of resolution of points, “visual step depth” expressing the visual integration of every point within open convex spaces (each point in VGA is the centre point of a grid cell in a grid that is overlaid on the plan). Hypothetically, VGA therefore gives an approximation of people’s interaction with space; in turn, perception of the environment along a given route would be related to the local and global information available and be inherent in visual relationships of points. Catchment areas in VGA are represented in fluently gradual steps from all points in the system, and express the level of integration (from blue=least integrated to red=most integrated). The visual relationship of all occupiable spaces to other occupiable spaces in the continuous maps of “city worlds” will in this paper be compared with the catchment area of metric shortest path step depth based on the idea that “visual” steps are more meaningful for perception and decisions making at points of directional choice than “metric” steps are. Moreover, differences in what can be perceived as “structured” or “ordered” in these maps as viewed from above can be retrieved and compared to participant perceptions as described in the questionnaire responses (see in paragraph “Empirical Survey Study”) below.

2. Axial Graph Analysis
In analogy to visual graph analysis, axial graph analysis calculates measures of integration, however, not from single points, but along “lines of sight”: These are axial lines as defined by Hillier and Hanson (1984) which have been found to correlate well with the number of pedestrians walking along these axial lines. (Pedestrian movement flow statistics are retrieved through observational methods). In this paper, however, axial maps have not been generated for correlation with movement behaviour observed, but for looking at perceptional data and different levels of “intelligibility” in the six “city worlds”, which is expressed in the relation between axial integration and connectivity measures within an urban street system. Intelligibility is a measure that is seen to incorporate characteristics of “structure” in “worlds” since the degree of ease with which a street system is understood, is seen to be analogically intrinsic in what is perceived as “structure”. In paragraph “Worlds and routes” below, will be explained in which way this analytical step complements the whole methodological approach in combination with responses from the empirical survey study.

Research Methodology (contd.)

3. Empirical Survey Study

The empirical part of the study is expected to corroborate, or to disprove hypotheses and findings from the analytic steps 1 and 2. Whereas in steps 1 and 2 it was attempted to find patterns of orderliness in 2D top geometrical relations of visual fields and simultaneous existing visual relations within the open spaces between building blocks along the route, in the empirical step the factor time is added as a fourth dimension. The experiment was set up in form of an online survey consisting of twelve samples with analogically structured question blocks for each sample, which was sent to a number of participants. The responses of 37 successfully completed surveys could be used for evaluation. In the beginning of each survey sample and question block, virtual fly-throughs were presented. They were based on Nolli maps of the six real city samples, with two pre-chosen routes through each sample, and prepared as multimedia files (short Quicktime movies). The accompanying questionnaire contained questions related to each of the routes taken in these movies with respect to perception of order, structure, rhythm, estimated speed, the length of intervals between junctions, number of turns taken, of junctions passed and of open spaces crossed (see a copy of the first of twelve sample-and-question blocks of the questionnaire in Appendix A). In opposition to other researchers' applied experiments on testing wayfinding behaviour and decision making of participants (i.e. in Conroy-Dalton's virtual movement experiment in her PhD thesis from 2001: "Spatial Navigation in Immersive Environments"), the approach in this survey focuses on comparing different features of spatial perception along a predetermined route through a given environment. The idea was to provide two routes through the same environment that, although the geometrical order seen from above stays the same, the systems can be experienced on very different levels of order when experiencing the routes in motion. The six samples were chosen to be – gradually - distinct from each other, on a range from one extreme to the other. The extremes are the strictest regular, rectangular grid and the irregular, multi-angular "organic" street pattern. The six city grids that were chosen for representation of what is expected to express a range of patterns, are listed below from what seem to be the most ordered (1=New York, Manhattan) to the most disordered (6=City of London) street patterns. Before the experiment was executed, it was estimated that the maps would offer the following main characteristics when seen top-down, as a figure-ground map:

1. New York (Manhattan): Strongly regular, orthogonal grid with slight interruption of a curved road.
2. San Francisco: Two rectangular, orthogonal grids meet at an angle.
3. Paris (L'Etoile): Geometric mosaic in a centred, star shaped super system.
4. Rome: Distorted grid and random pattern separated by a serpentine river.
5. Barcelona (Ramblas): Random street pattern, strongly different block sizes and surprising open spaces.
6. London (City of London): Most random, "organic" street pattern.

Research Methodology (contd.)

Screen shots of Quicktime movies that were presented in the virtual movemenent experiment:

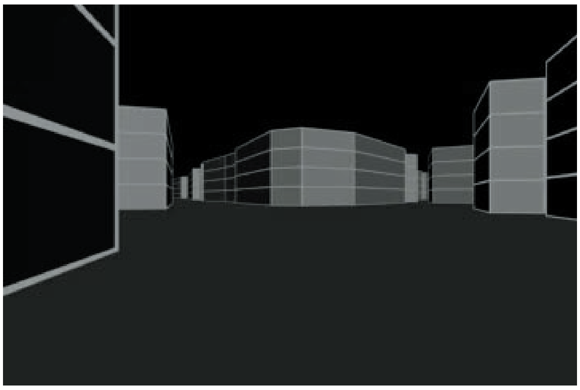


Fig. 1.1: London, route C

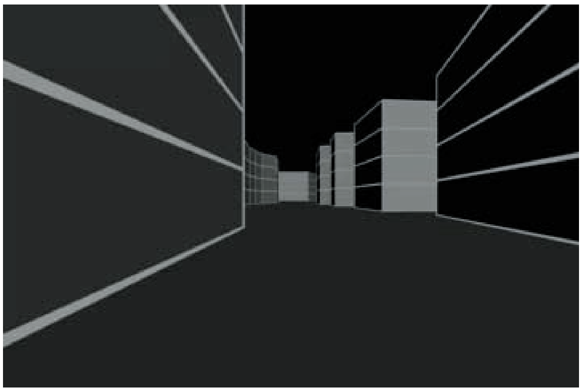


Fig. 1.2: Barcelona, route C

Fig. 1.3: Rome, route A

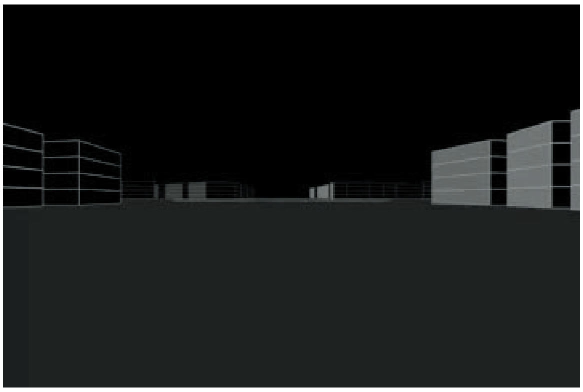


Fig. 1.4: Paris, route F

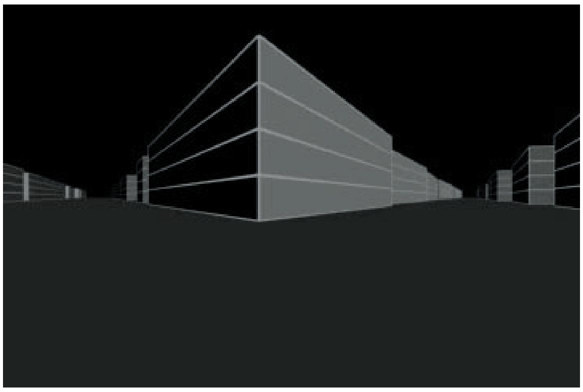


Fig. 1.5: San Francisco, route E

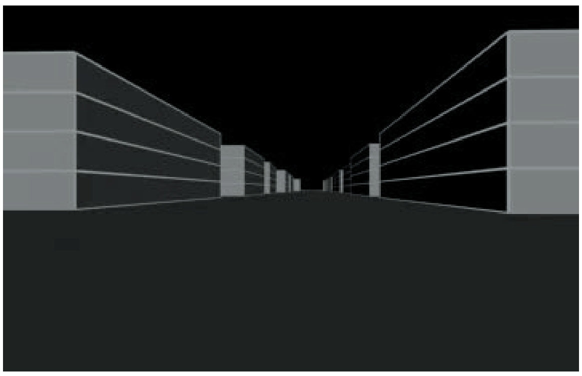


Fig. 1.6: New York, route E

Research Methodology (contd.)

For the movies, real building heights were ignored and kept constant at 12m (approximating four storeys on average), which is a building height that represents metropolitan urban settings and gives a feel of urbanity. The reason for choosing a unified block height was that - for testing hypotheses with respect to judgement about orderliness on a route in terms of turns and angularity only - the impact of landmarks on cognition and wayfinding needs to be excluded. Analysis would become too complex if orientation by means of landmarks would be considered alongside directional and rhythmical succession. Therefore, a virtually constructed environment based on a real street grid was deemed to be most appropriate. Building on theories about “events” and “structure” by Tversky (2001a)[3], and on her finding that the metric information stored in mental maps is not a “Euclidean” representation of space owing to distortions in the cognitive process, the notion “event” in this paper is used with the following concept in the back of mind: Events are structured in sequences; along a route through an urban environment these are sensibly categorised and assumed to “happen” in points where a directional choice has to be made. Thus, junctions and open spaces move into the centre of attention and are in this paper seen as events occurring in segments that define structure, rhythm, and order of a route. Categorisation of events is therefore suggested and has been used in this study as follows:

[L] event = left turn taken

[R] event = right turn taken

[O] event = open space crossed

[o] missed event = junction crossed without turn taken

“Barcodes” were generated according to the sequences of left/right turns, open spaces and solely crossed junctions, and presented in the survey. Turns taken or open spaces (like widenings at junctions or grand plazas) crossed are “events” that occur at places where the intensity level of spatial information is higher than along parts of the route where not so much new information is available, such as between junctions for instance. The informational content contained in such spaces is significant for the understanding of the street pattern, its connectivity (chances for change) and its orderliness as for a particular route within a network of possible routes. These generated barcode strings of events/non-events have been constructed by using four string characters: the characters standing for left turn [L], right turn [R], open space [O], and missed turn [o]. The twelve routes chosen were thus represented as “strings of events”; while all routes were kept at the same length (1660 meters). The strings, compiled from a particular route, are finite strings that contain up to four characters which mark potential events [L], [R], [O], and [o]. The length of each string is accordant with the quantitative number of potential events along the route, whereas the qualitative aspect of the string lies in the combination of the characters that occur along the route of possible events. Application of algorithms based

Research Methodology (contd.)

upon Kolgomorov’s approach will compute the complexity of the strings and therefore provide measures of complexity and information, which is quantification, determining the relationship between pattern packing and information content. Shannon introduced the probabilistic theory of information entropy in his 1948 paper “A Mathematical Theory of Communication”: The concept of entropy generally describes how much information there is in a signal or event. The measure of information entropy is usually expressed by the average number of bits needed for storage or communication. The number of bits needed to represent the result of an uncertain event is then given by its entropy. According to this, the computed entropy measures of route strings are interpreted as probability of the “uncertainty” that a route provides for the traveller and will be used for comparison with the traveller’s (here: survey participant’s) perception of uncertainty or clarity about a route taken.

4. Toward a Synthesis: Worlds and Routes

Although pattern descriptions for “routes” and “worlds” can be made in an isolated manner through the use of spatial and syntactical analysis as described above, the analytical procedures for “worlds” and “routes” can only be tackled with very different tools and therefore give measures that are not directly comparable with each other. The aspiration of this paper is to translate expressions of order and structure of both “worlds” and “routes” into a mediating system that provides an external framework for comparability (see Fig. 2). Instead of direct comparison of quantitative measures, for each subset (order in worlds / structure in worlds / order along routes / structure along routes), for each an appropriate quantitative measure is applied and correlated with percentages of responses retrieved from the empirical questionnaire results.

Four different attributes for inherent meaning of “structure” and “order” that were hypothesised on theoretical grounds, are brought into relation with empirically gathered figures that represent an averaged expression of human perception. While the conjecture is that “structure” within the synchronous “worlds” can be found in the relation between local and global information (intelligibility), “structure” along asynchronous routes is, however, expressed in the relation between redundant and total information (entropy) of string sequences. As described above, the strings have here been constructed predominantly from travellers’ impressions that - in a real-world situation - would lead to making choices about directional options at junctions. “Order” in routes could, however, be found in the total information measure of a string sequence.

In his tutorial paper on computing string complexity, information and entropy, Titchener gives guidance on measures that can be used for quantifying information content in finite strings. “If we write a series of characters on the page, we may view them as a parallel presentation of the symbols, where each carries equal status.” (Like “worlds” viewed spatially.) He goes on

Research Methodology (contd.)

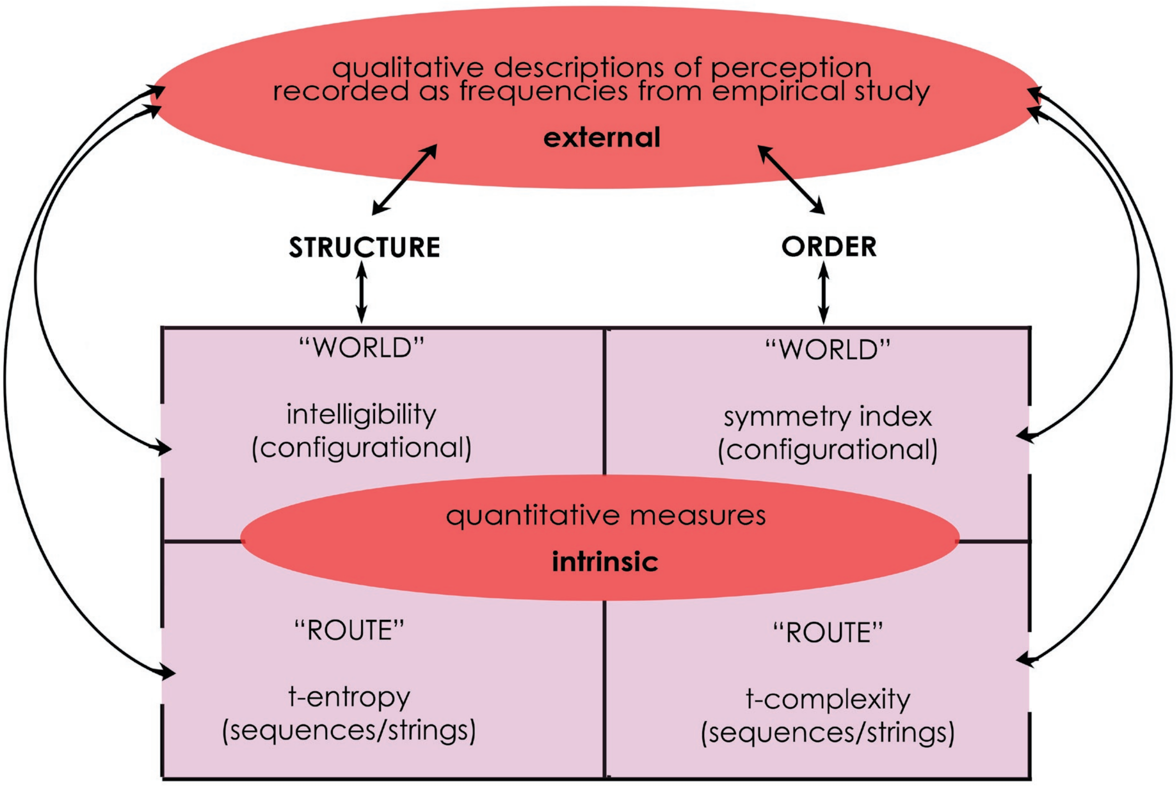


Fig. 2: Worlds-Routes / Order-Structure diagram illustrating the theoretical approach for correlating quantitative measures such as t-code measures of strings and spatial analysis tools (intrinsic) with measures retrieved from empirical study results (external)

saying “Or we may scan the symbols, giving precedence to the order in which the symbols are viewed.” (Like sequentially experienced elements along “routes”.) Since the repeating sequence of a single digit or letter (“LLLLLLL” or “OOOOOOO”) provides the extreme measure of the least uncertainty of serially communicated information, the measures retrieved for any more random sequence can be normalised with this “zero”-measure. Accordingly, the string measures were relativised in this paper’s methodology and such generated “normalised” measures used for correlation with other data.

All three aforementioned subsets could therefore be computed and measured. For “order” in “worlds”, the concept of symmetry index (Hillier, 1996) is suggested to be the equivalent basic measure for comparison. The current state of computability does not yet allow for testing the approach for “order” in “worlds” in this paper. The prospect and suggestion of implementing a configurational symmetry index, however, will be laid out in the discussion and conclusion chapters in this paper.

Research Methodology (contd.)

Footnotes

1 Giambattista Nolli (1701-1756) was an architect and surveyor who lived in Rome and devoted his life to documenting the architectural and urban foundations of the city. His 1748 map of Rome was detailed, accurate, ichnographic plan map of the city and eschewed the prevailing “bird’s-eye” perspective for an overhead view.

2 Depthmap is a computer program to perform visibility analysis of architectural and urban systems. This spatial network analysis software was developed by Turner, UCL, London. See also: Turner, A. 2001. “Depthmap: A Program to Perform Visibility Graph Analysis.” In: “Proceedings 3rd International Symposium on Space Syntax”, pp. 31.1–31.9.

3 Tversky (2001a: 3): “The ability to identify the parts of events and their relationships constitutes a distinct perceptual process, which we will call event structure perception. An event is defined to be a segment of time at a given location that is perceived by an observer to have a beginning and an end.”

London (The City) - “Routes”

Route A

Route C

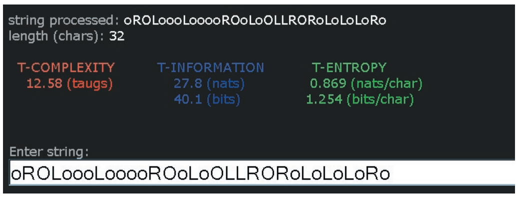


Fig. 3.1: Barcode and string computation
London, route A

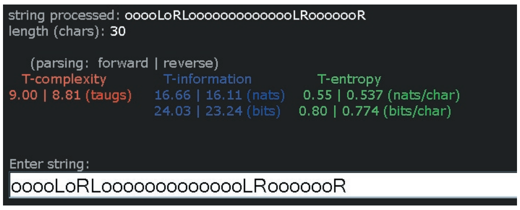


Fig. 3.2: Barcode and string computation
London, route C

Barcodes were transformed into strings and computer processed with “wtcalc”.
The absolute measures of information content of the route are shown as t-complexity, t-information and t-entropy.

London (The City)

Route A

Fig. 3 3
Route A: Isovist

Fig. 3.4
Route A: Visual step depth
colour range red=0 blue=12

Fig. 3.5
Route A: Visual step depth metric shortest path

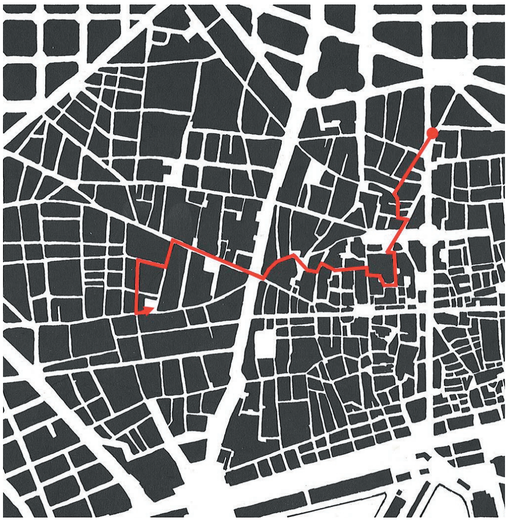
Route C

Fig. 3.6
Route C: Isovist

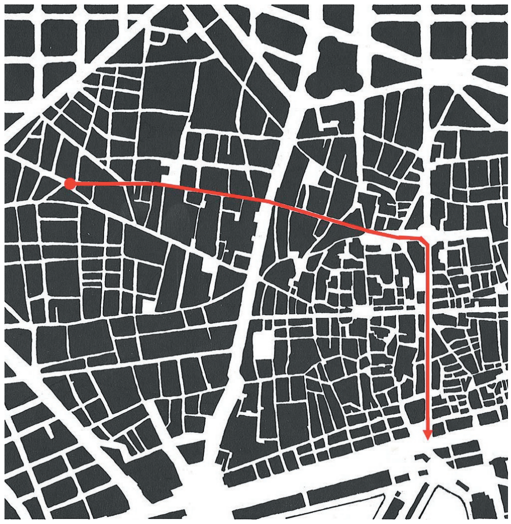
Fig. 3.7
Route C: Visual step depth
colour range red=0 blue=12

Fig. 3.8
Route C: Visual step depth metric shortest path
colour range red=0 blue=1500

Barcelona (Ramblas) - "Routes"



Route C



Route D

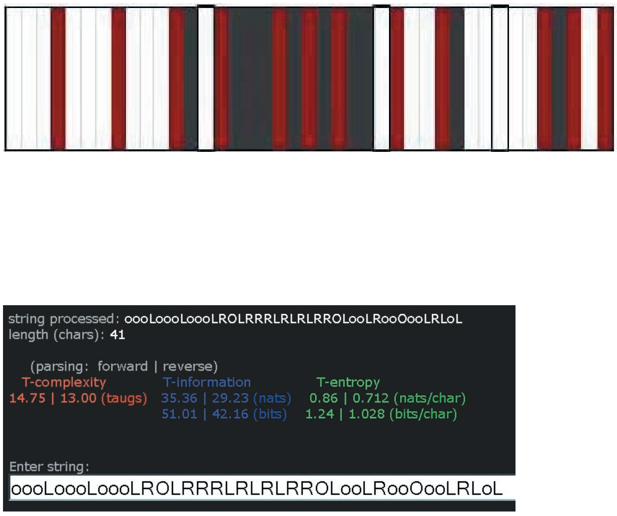


Fig. 4.1: Barcode and string computation
Barcelona, route C

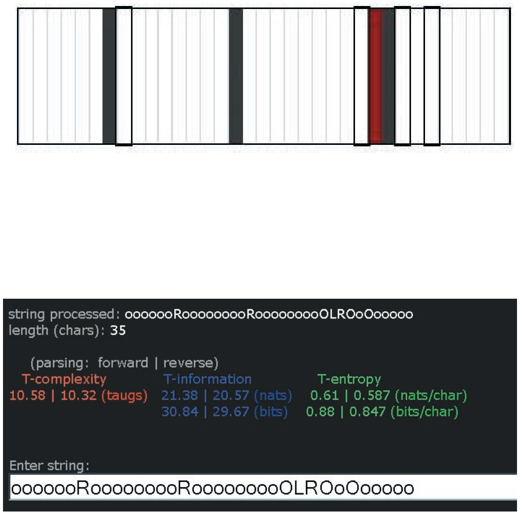


Fig. 4.2: Barcode and string computation
Barcelona, route D

Barcodes were transformed into strings and computer processed with "wtcalc".
The absolute measures of information content of the route are shown as t-complexity, t-information and t-entropy.

Barcelona (Ramblas)

Route C

Fig. 4.3
Route C: Isovist

Fig. 4.4
Route C: Visual step depth
colour range red=0 blue=12

Fig. 4.5
Route C: Visual step depth metric shortest path
colour range red=0 blue=1500

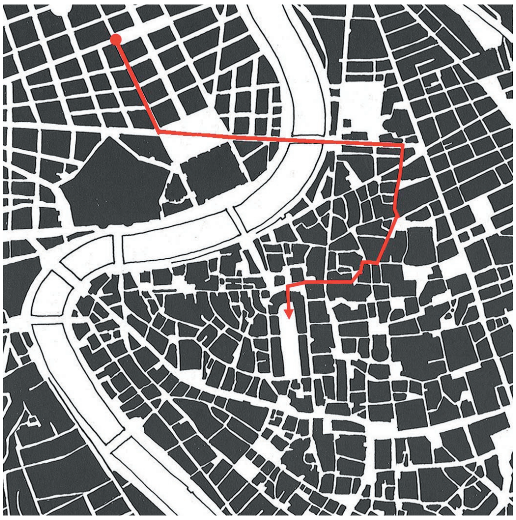
Route D

Fig. 4.6
Route D: Isovist

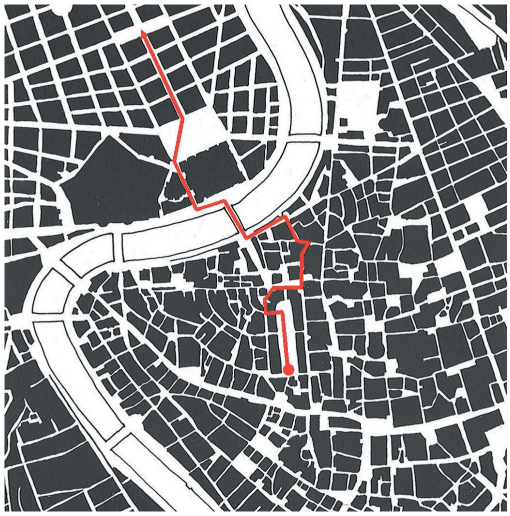
Fig. 4.7
Route D: Visual step depth
colour range red=0 blue=12

Fig. 4.8
Route D: Visual step depth metric shortest path
colour range red=0 blue=1500

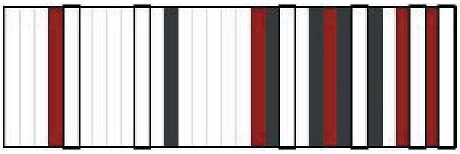
Rome - “Routes”

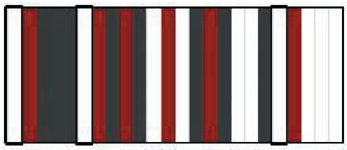


Route A



Route D





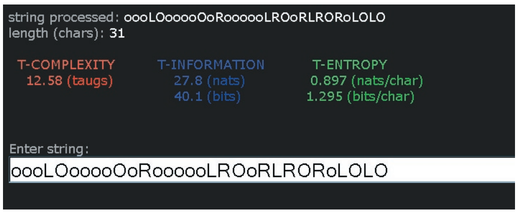


Fig. 5.1: Barcode and string computation
Rome, route A

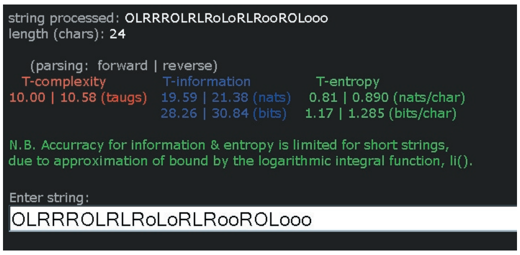


Fig. 5.2: Barcode and string computation
Rome, route D

Barcodes were transformed into strings and computer processed with “wtcalc”.
The absolute measures of information content of the route are shown as t-complexity, t-information and t-entropy.

Rome

Route A

Fig. 5.3
Route A: Isovist

Fig. 5.4
Route A: Visual step depth
colour range red=0 blue=12

Fig. 5.5
Route A: Visual step depth angular
colour range red=0 blue=1500

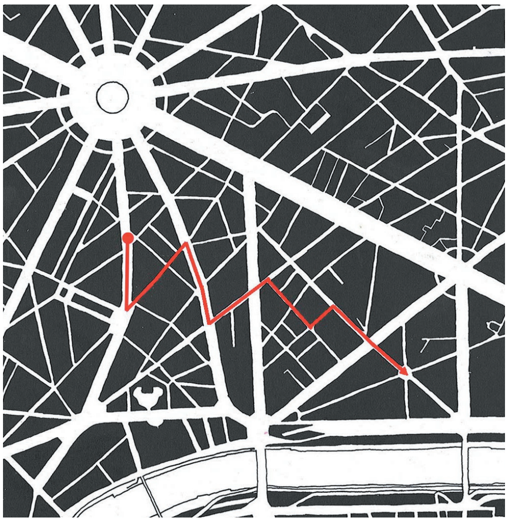
Route D

Fig. 5.6
Route D: Isovist

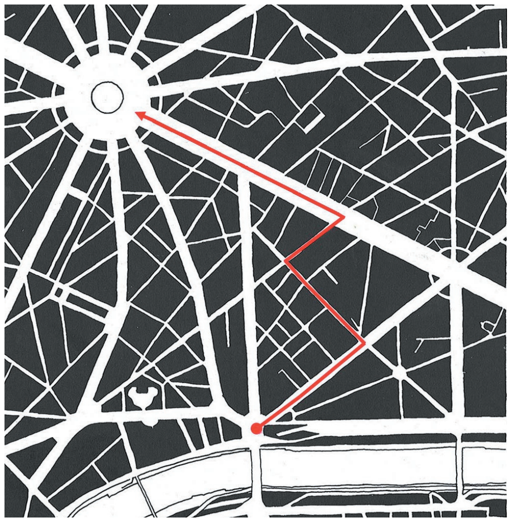
Fig. 5.7
Route D: Visual step depth
colour range red=0 blue=12

Fig. 5.8
Route D: Visual step depth metric shortest path
colour range red=0 blue=1500

Paris (L’Etoile) - “Routes”



Route B



Route F

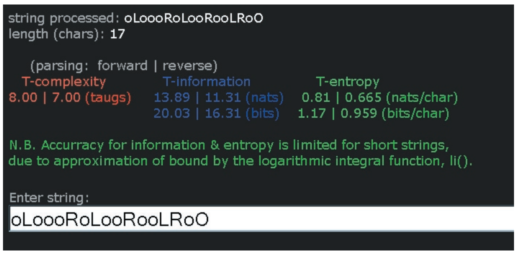


Fig. 6.1: Barcode and string computation
Paris, route B

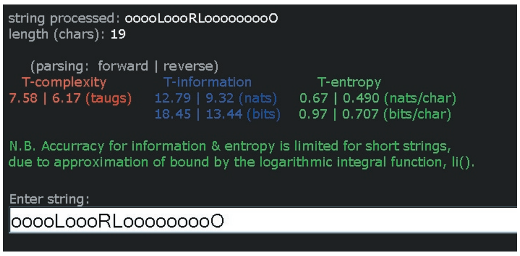


Fig. 6.2: Barcode and string computation
Paris, route F

Barcodes were transformed into strings and computer processed with “wtcalc”.
The absolute measures of information content of the route are shown as t-complexity, t-information and t-entropy.

Paris (L’Etoile)

Route B

Fig. 6.3
Route B: Isovist

Fig. 6.4
Route B: Visual step depth
colour range red=0 blue=12

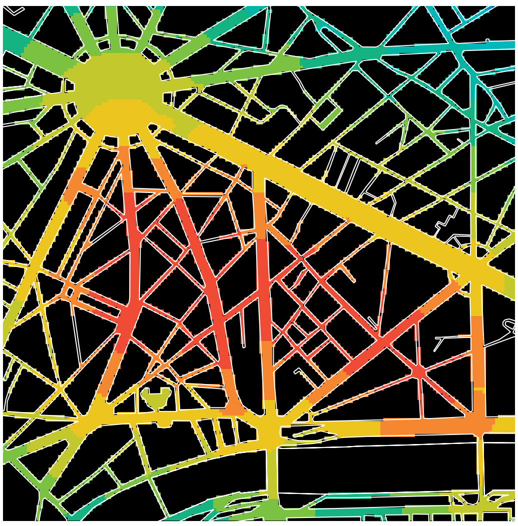


Fig. 6.5
Route b: Visual step depth metric shortest path
colour range red=0 blue=1500

Route F

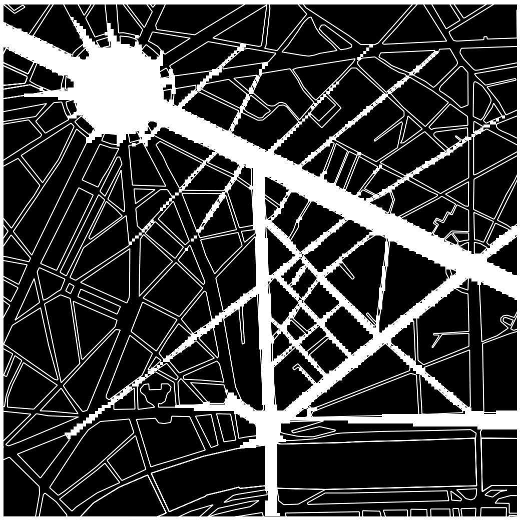


Fig. 6.6
Route F: Isovist

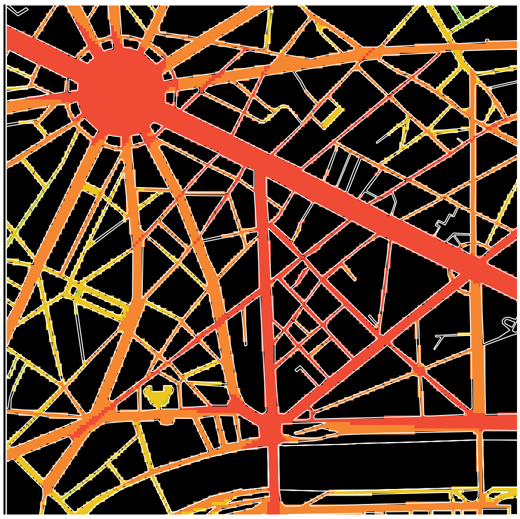


Fig. 6.7
Route F: Visual step depth
colour range red=0 blue=12

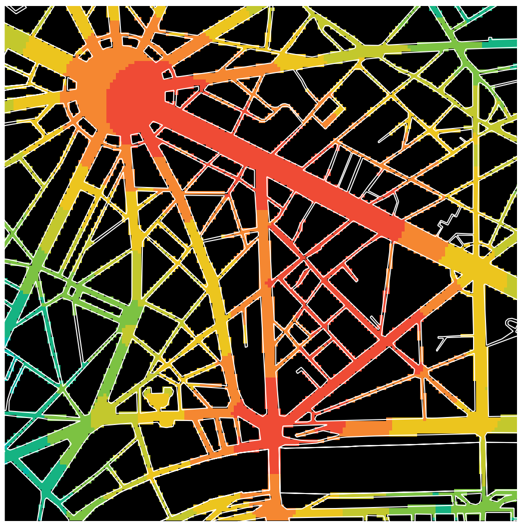
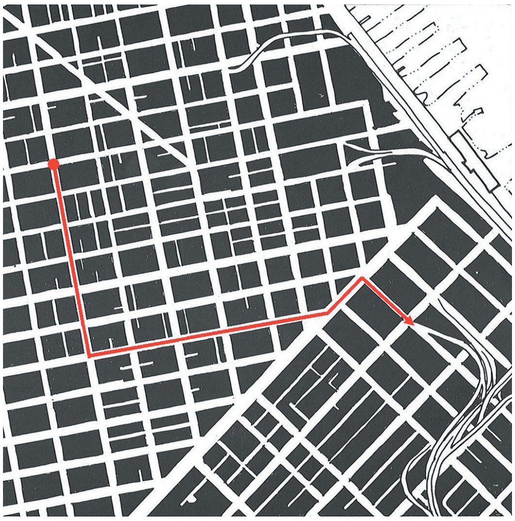


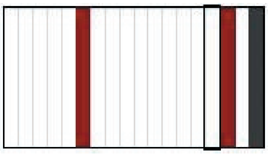
Fig. 6.8
Route F: Visual step depth metric shortets path
colour range red=0 blue=1500

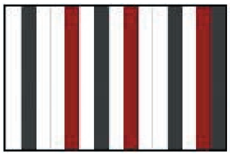
San Francisco - “Routes”



Route D

Route E





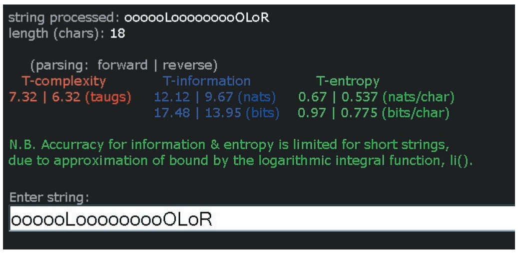


Fig. 7.1: Barcode and string computation
San Francisco, route D

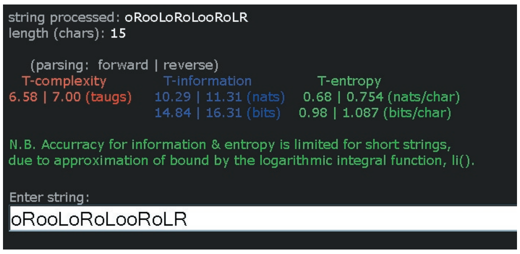


Fig. 7.1: Barcode and string computation
San Francisco, route E

Barcodes were transformed into strings and computer processed with “wtcalc”.
The absolute measures of information content of the route are shown as t-complexity, t-information and t-entropy.

San Francisco

Route D

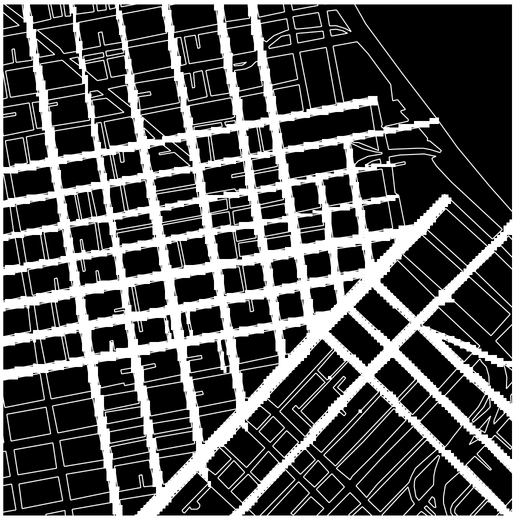


Fig. 7.3
Route D: Isovist

Fig. 7.4
Route D: Visual step depth
colour range red=0 blue=12

Fig. 7.5
Route D: Visual step depth metric shortest path
colour range red=0 blue=1500

Route E

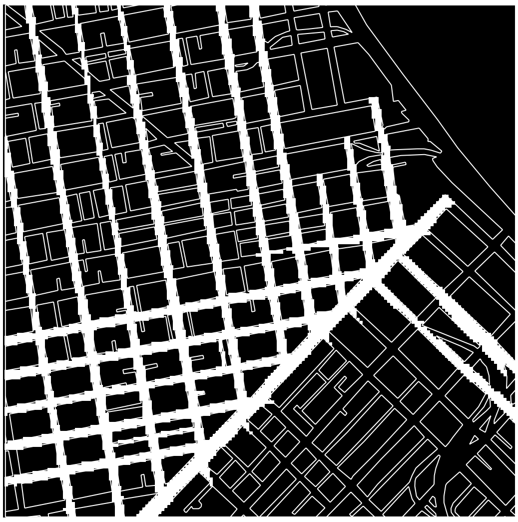


Fig. 7.6
Route E: Isovist

Fig. 7.7
Route E: Visual step depth
colour range red=0 blue=12

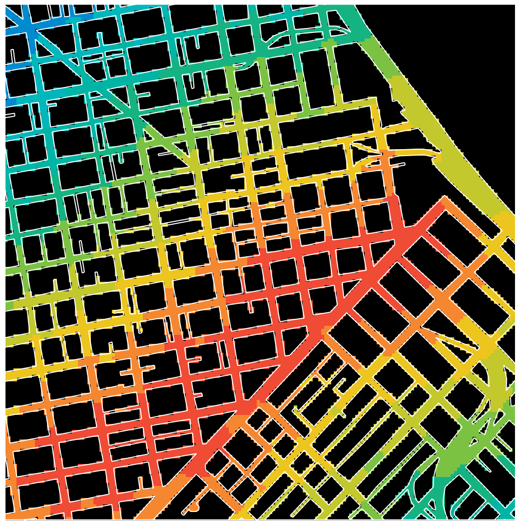
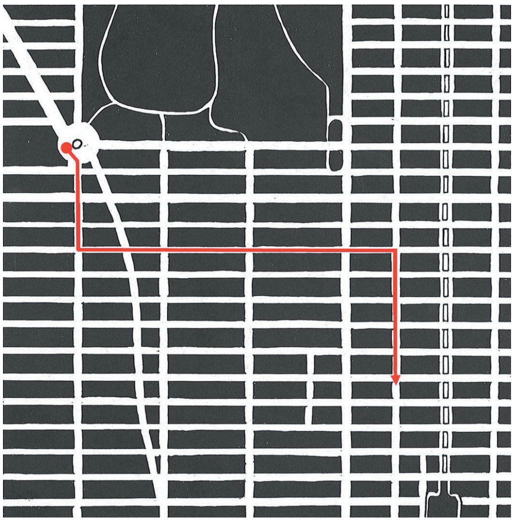
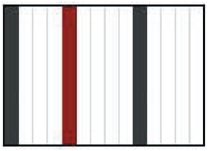


Fig. 7.8
Route E: Visual step depth metric shortest path
colour range red=0 blue=1500

New York (Midtown Manhattan) - "Routes"

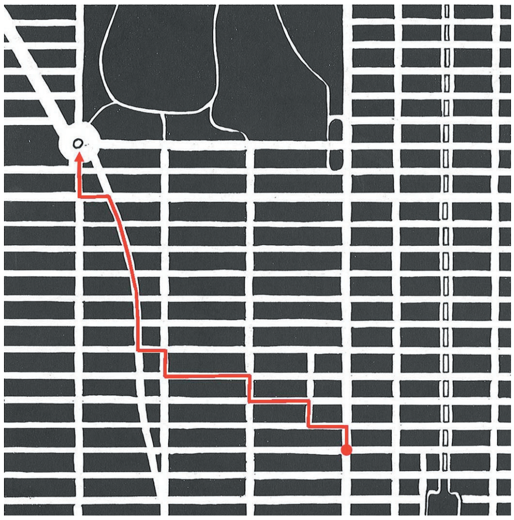


Route B

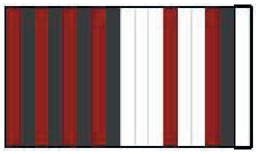


```
string processed: RoooLooooRoooo
length (chars): 14

T-COMPLEXITY      T-INFORMATION      T-ENTROPY
5.00 (taugs)      6.7 (nats)         0.4 (nats/char)
                  9.7 (bits)         0.6 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Enter string:
RoooLooooRoooo
```

Fig. 8.1: Barcode and string computation
New York, route B



Route E



```
string processed: LRLRLRLRoooLooLRO
length (chars): 17

(parsing: forward | reverse)
T-complexity           T-information                 T-entropy
8.00 | 8.58 (taugs)    13.89 | 15.49 (nats)     0.81 | 0.911 (nats/char)
                       20.03 | 22.34 (bits)     1.17 | 1.314 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Enter string:
LRLRLRLRoooLooLRO
```

Fig. 8.2: Barcode and string computation
New York, route E

Barcodes were transformed into strings and computer processed with "wtcalc".
The absolute measures of information content of the route are shown as t-complexity, t-information and t-entropy.

New York (Midtown Manhattan)

Route B

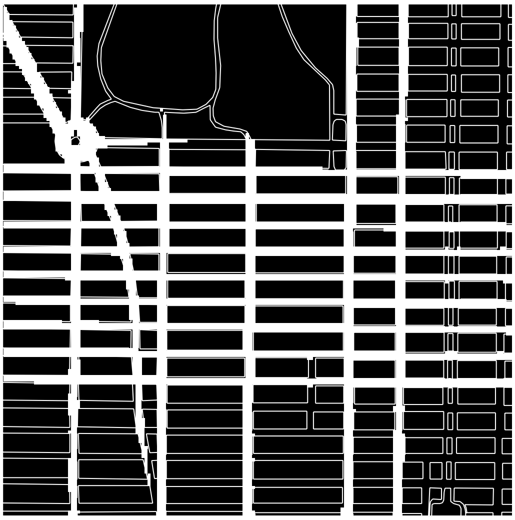


Fig. 8.3
Route B: Isovist

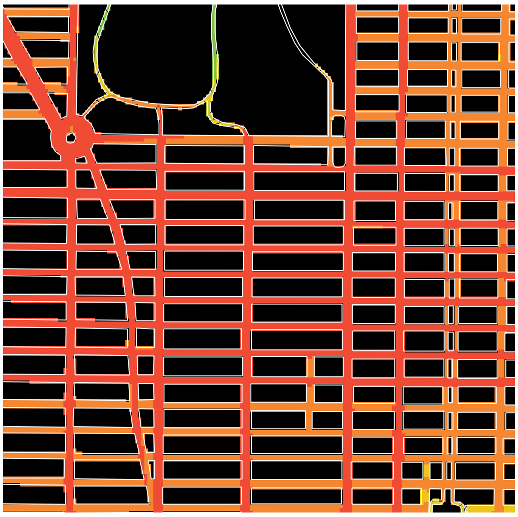


Fig. 8.4
Route B: Visual step depth
colour range red=0 blue=12

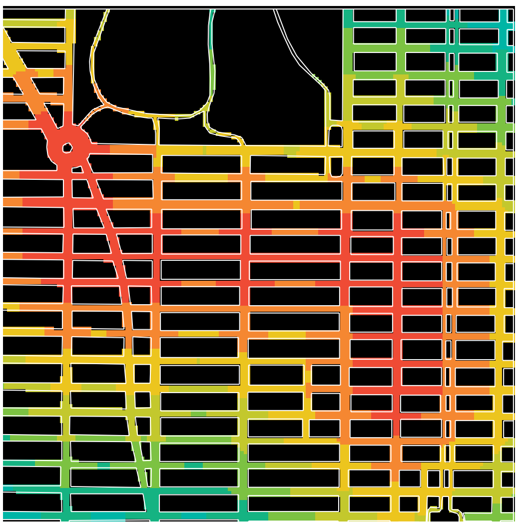


Fig. 8.5
Route B: Visual step depth metric shortest path
colour range red=0 blue=1500

Route E

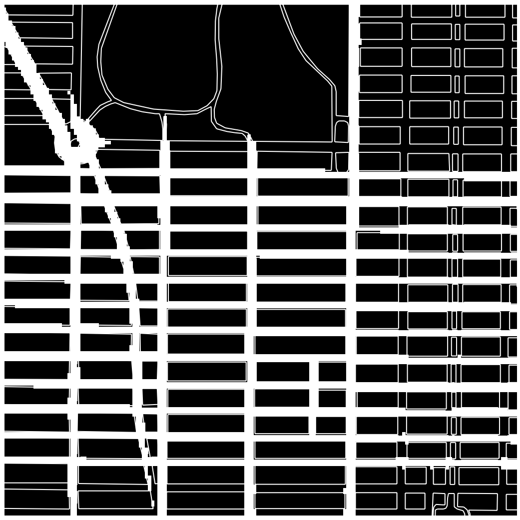


Fig. 8.6
Route E: Isovist

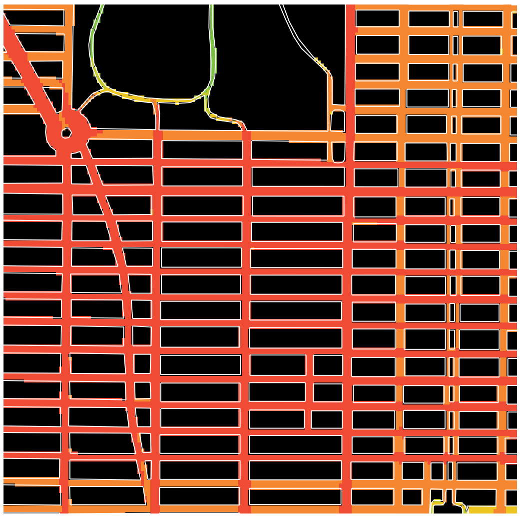


Fig. 8.7
Route E: Visual step depth
colour range red=0 blue=12

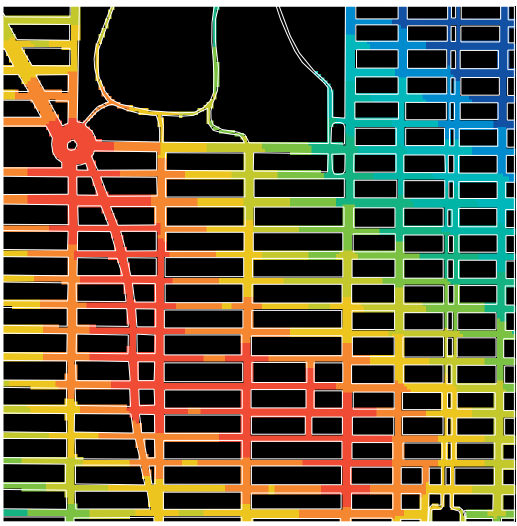


Fig. 8.8
Route E: Visual step depth metric shortets path
colour range red=0 blue=1500

"Worlds" - Global Integration (Axial Graph Analysis)

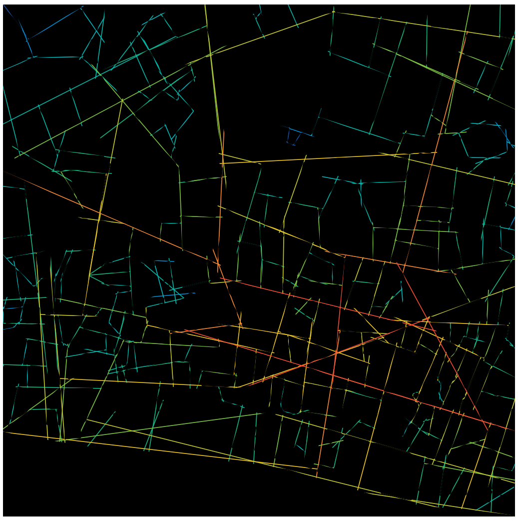


Fig. 9.1: London: Axial graph analysis
Axial map showing "Integration (HH)"

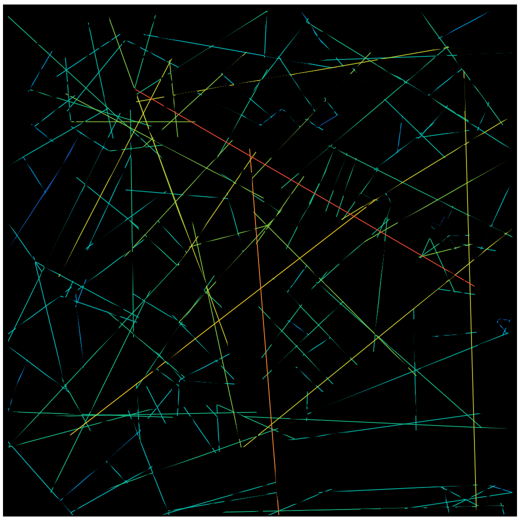


Fig. 9.4: Paris: Axial graph analysis
Axial map showing "Integration (HH)"

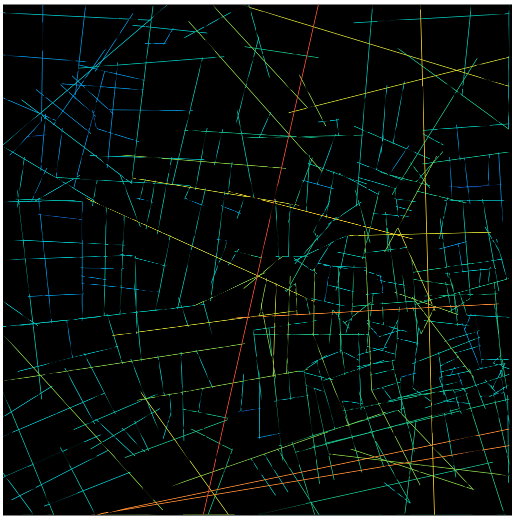


Fig. 9.2: Barcelona: Axial graph analysis
Axial map showing "Integration (HH)"

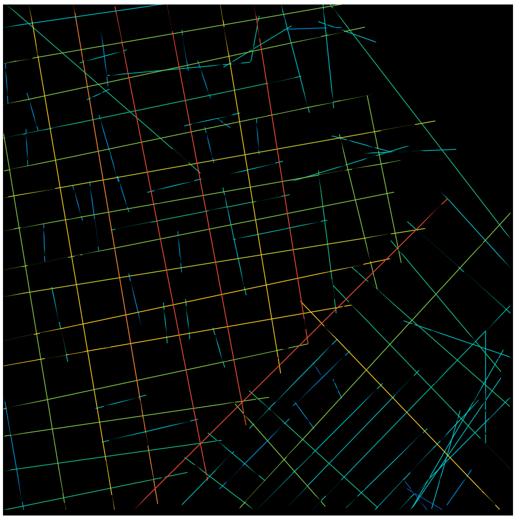


Fig. 9.5: San Francisco: Axial graph analysis
Axial map showing "Integration (HH)"

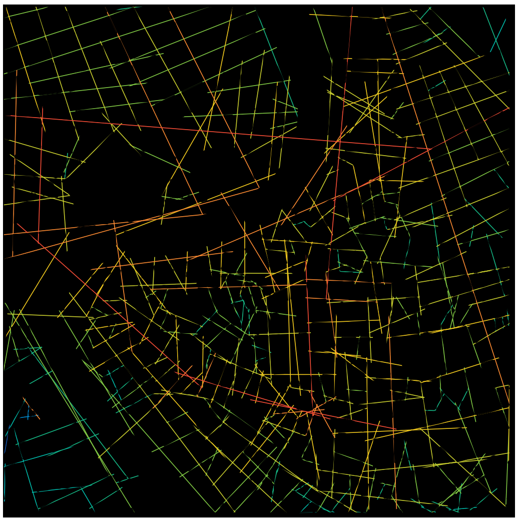


Fig. 9.3: Rome: Axial graph analysis
Axial map showing "Integration (HH)"

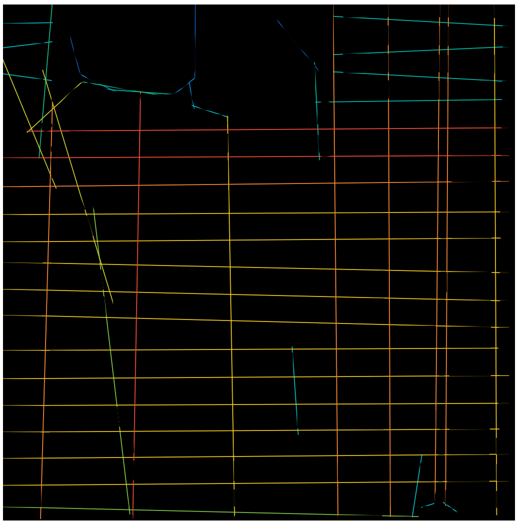


Fig. 9.6: New York: Axial graph analysis
Axial map showing "Integration (HH)"

"Worlds" - Connectivity (Axial Graph Analysis)

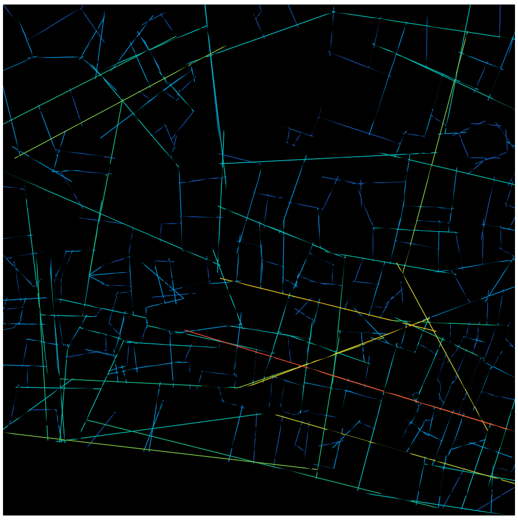


Fig. 10.1: London: Axial graph analysis
Axial map showing "Connectivity"

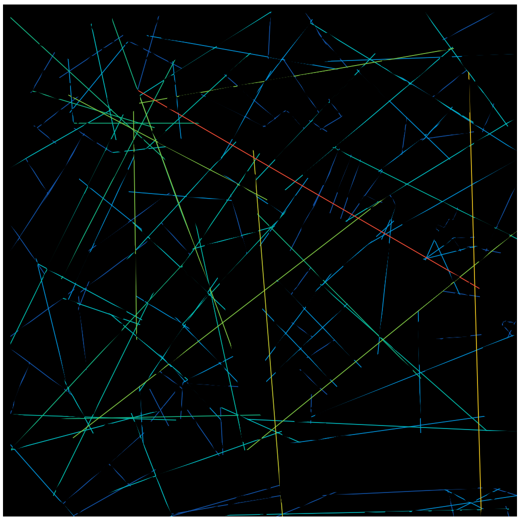


Fig. 10.4: Paris: Axial graph analysis
Axial map showing "Connectivity"

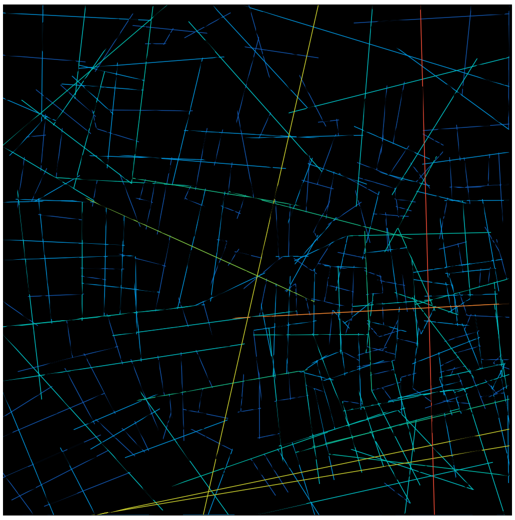


Fig. 10.2: Barcelona: Axial graph analysis
Axial map showing "Connectivity"

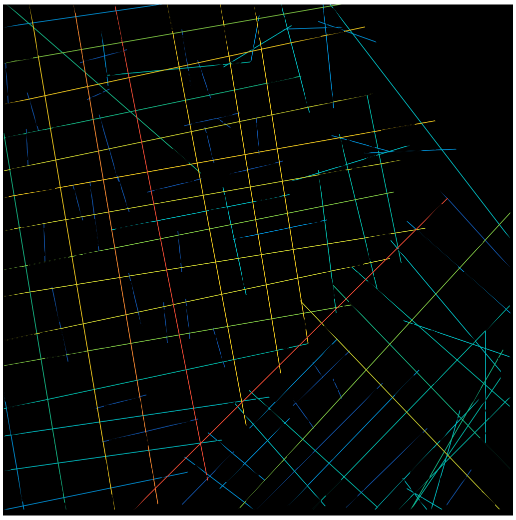


Fig. 10.5: San Francisco: Axial graph analysis
Axial map showing "Connectivity"

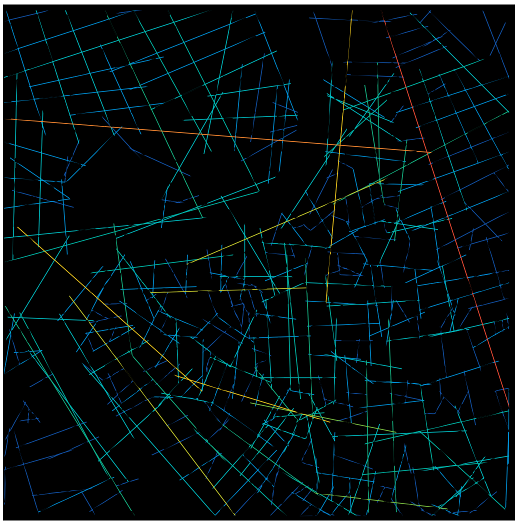


Fig. 10.3: Rome: Axial graph analysis
Axial map showing "Connectivity"

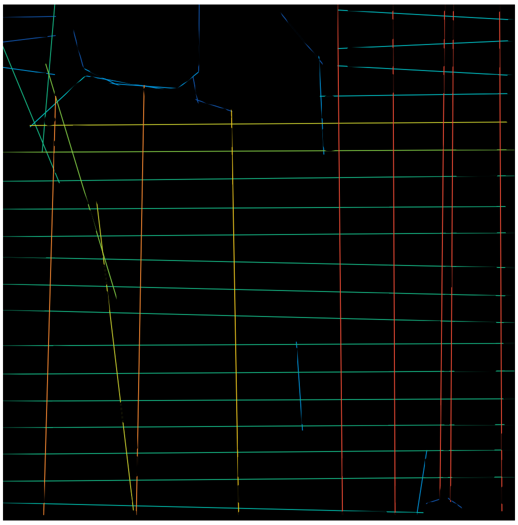


Fig. 10.6: New York: Axial graph analysis
Axial map showing "Connectivity"

“Worlds” - Intelligibility

Syntactical Measures from Axial Graph Analysis

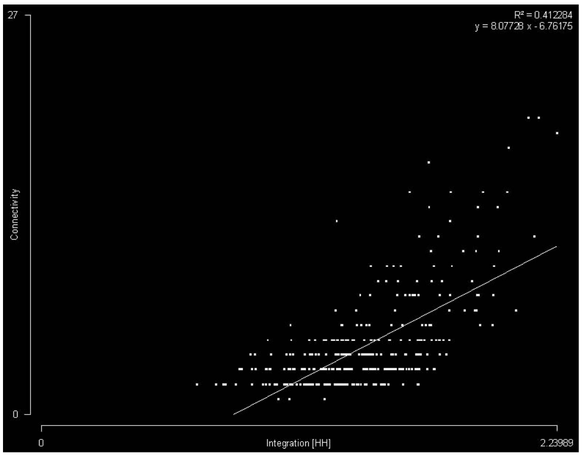


Fig. 11.1: London: Axial graph analysis
Scattergram showing “intelligibility”
R-squared=0.41

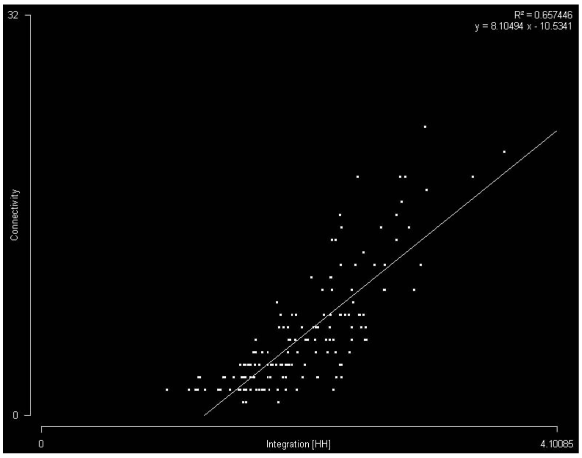


Fig. 11.4: Paris: Axial graph analysis
Scattergram showing “intelligibility”
R-squared=0.66

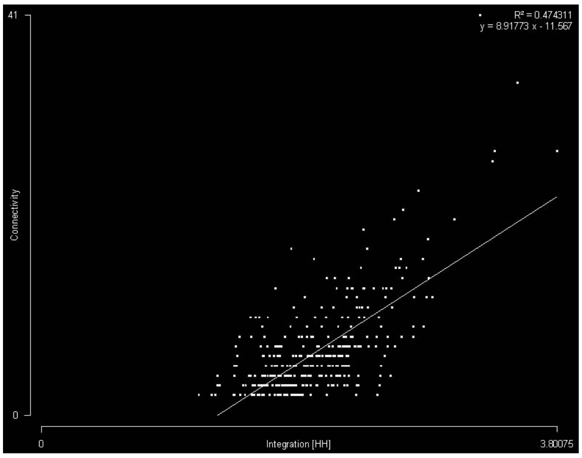


Fig. 11.2: Barcelona: Axial graph analysis
Scattergram showing “intelligibility”
R-squared=0.47

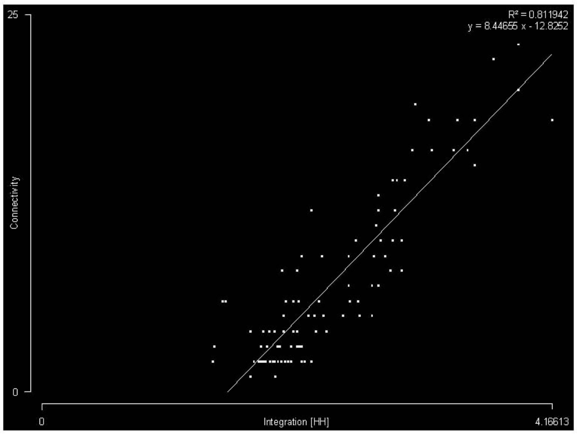


Fig.11.5: San Francisco: Axial graph analysis
Scattergram showing “intelligibility”
R-squared=0.81

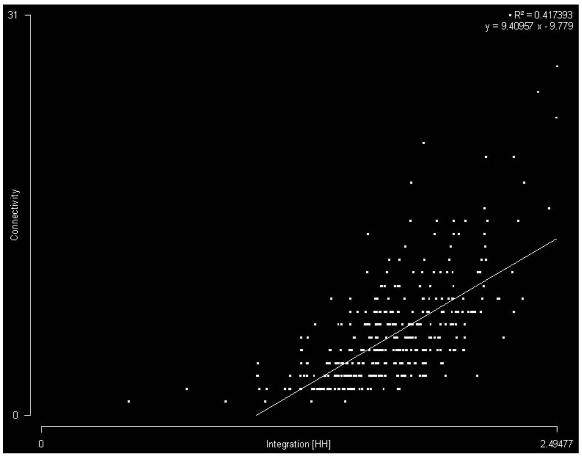


Fig. 11.3: Rome: Axial graph analysis
Scattergram showing “intelligibility”
R-squared=0.42

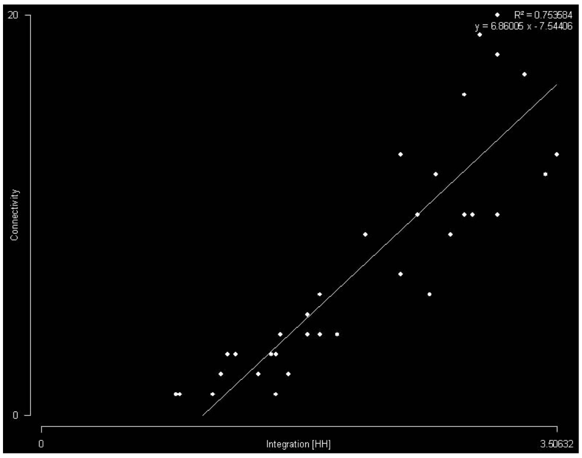


Fig. 11.6: New York: Axial graph analysis
Scattergram showing “intelligibility”
R-squared=0.75

Statistical Evaluation and Findings

This chapter presents findings from visibility graph and axial graph analysis, statistical evaluation of the data retrieved from the virtual movement experiment, and string computation of the "barcodes" that were extracted from defined route characteristics, as explained in the previous chapter about the applied research methodology.

1. Visibility Graph Analysis (Figs. 3.3-3.8, 4.3-4.8, 5.3-5.8, 6.3-6.8, 7.3-7.8, 8.3-8.8) revealed that a city can offer very different visual cues about an underlying street pattern depending on the path chosen for travelling through the urban environment. The isovist fields showing the areas of vision that are "drawn in" along all points on a path show that such visual "catchment areas" do not always differ only according to the delineation of the route (which would amount to the metric step depth). Some of them pick up structurally differing catchment areas, as for the more random, irregular patterns that could be found in the City of London, Barcelona, the "organically" laid out part of Rome, and Paris. In contrast to this, the more grid-like a street layout in these six city samples appears the more similarity across isovists seems to occur for different routes (New York, San Francisco, and the grid-like quarter northwest of the river in Rome). Generally speaking, organic patterns (London, Barcelona, the part of Rome east of the river) showed very differing visual fields being drawn into sight along two different routes. While the diagonal road that breaks two orthogonal systems at an angle manages to connect them with one visual step along both routes (San Francisco), the grand boulevard in Paris only comes into full apprehension where the route itself is running along this line (route F). Owing to the limited number of city samples, this might have to be attributed to the trait of organic street layouts: They usually consist of narrower streets than plan-grids do, and therefore naturally lack potential of offering views into adjacent street connectors. The comparison of visual integration step depth and visual metric step would naturally be expected to show that the metric step depth map approximates the contour of the path course (as an extended field around the path course). The metric step is therefore different from the more global visual picture, which - as for the selected six city samples - stays very similar and consistent in the more orthogonal grids. However, Paris and San Francisco, which are systems that are "broken" by a diagonal axis, are more dependent on the particular paths taken with regard to the selection of streets that can be easily grasped in only one visual step.

2. Axial analysis was applied in order to find the "intelligibility"[1] for each of the city systems which would then serve as comparative measure for results from the virtual movement experiment with view on "structure" and how it is perceived in "worlds", i.e. the configurational layout of a city. The relation between global integration and connectivity expresses the "intelligibility" of a system of lines (representing the longest lines of sight available), which can be seen in the scattergrams in Figs. 11.1-11.6. A ranking order of city samples with view on intelligibility has been established from the r-squared values[2]. Since the r-squared values show the degree that

Statistical Evaluation and Findings (contd.)

the two measures of global integration and connectivity correspond to each other, the ranking order from the highest r-squared value, and therefore most intelligible city, down to the least intelligible city, would be as follows:

Intelligibility for the 6 city samples:

1) San Francisco: r-squared = 0.81
2) New York: r-squared = 0.75
3) Paris: r-squared = 0.66
4) Barcelona: r-squared = 0.47
5) Rome: r-squared = 0.42
6) London: r-squared = 0.41

These values express the intelligibility of a street system, that is, the ease of understanding of the global street pattern. They will be correlated with statistical data that resulted from the questionnaire of the virtual movement experiment.

3. Participants’ responses from the questionnaire (a sample questionnaire representing one out of twelve sample and question blocks from the online survey experiment is illustrated in Appendix A) were investigated with particular interest in the frequency of answer choices in guessing wrong or right maps, barcodes, the number of turns taken, the rhythm of intervals, to what extent the built environment along a route was perceived as ordered, structured, coherent, eventful, confusing, interesting, unusual, regular, repetitive, etc. It also served for comparison of verbal descriptions that were queried. Apart from one sample (London, route A), the majority of participants guessed the right barcode and the right route map from six presented barcodes and six presented maps after having watched the fly-through moving image. The route map for New York, route E, was even chosen correctly by 37 out of 37 participants.

Most questions concerning number ranges of turns taken, junctions passed, and open spaces crossed were also estimated by the highest percentage of participants. The only exceptions were: London, route A, where 32 percent estimated having taken fewer turns (8-9), while only 10 percent were right in guessing a number of 10+ turns that were actually taken along the route. For Rome (route A), 30 percent thought that they took 5-6 turns although there were 10 turns. Similarly, in New York, route E, nearly every second participant estimated having taken fewer turns (8-9), than the actual 11; moreover, 46 percent estimated having crossed 10+ junctions without turning instead of actually only 6 “missed” turns. Along route F in Paris, however, only a third of participants thought that they crossed 8-9 junctions straight ahead, while there were in fact 16 junctions crossed without turning. From these statistics, it appears that generally a rather smaller number of directional changes were recognised than were in fact made. Stronger

Statistical Evaluation and Findings (contd.)

discrepancies in the amplitude of wrong guesses could be found in junctions crossed straight ahead, which suggests that the moving subject - when walking straight ahead - is paying less attention to the number of possible turns that could have been taken than to the number of directional changes that are made. As long as one “follows his or her nose” (see Conroy-Dalton, 2003), information that could potentially be retrieved by “counting” passed junctions, is instead neglected. This conforms to Conroy-Dalton’s hypothesis that “the most popular routes from a sample (as calculated string-matching techniques) also appeared to be more linear” (ibid: 107), which is furthermore along the lines of her finding that “the reason that participants selected straighter routes was in an attempt to avoid complexity” (ibid: 126). From the reverse view of perception along a route that is taken in a “passive” way (i.e. without the potential of choice and decision making), the conjecture about the minimising process of informational content in building the mental map seems to be validated through the fact that following a straight line (even passively) is not resisted, but rather supported through neglect of “missed” directional information.

From verbal descriptions of the travel experiences in the experiments was found that the more turns approximate an angle of 90 degrees, the more they are mentally categorised as turns. One of the participants, who seemed to be consciously aware of this assumption, described it as “hard to assess whether one really takes a turn or follows the natural course of a route”.

Opinions about whether it was estimated that the route taken in the fly-throughs was running through a city based on a fairly organic street pattern, or a fairly regular grid, on a relatively symmetric, or a relatively asymmetric street layout, overall matched for the two different routes chosen from a common city sample. At the extreme, route B through New York was assumed to be an orthogonal regular grid by all 37 participants, as well as all participants assessing the street layout to be symmetric. Diverging perception was found in responses for Barcelona, where route C was estimated by more than 94 percent to be organic and asymmetric, while route D divided people with exactly 50 percent for each pair of categories “organic” versus “regular grid” and “symmetric” versus “asymmetric” layout.

Verbal, qualitative descriptions of the rhythm that people perceived along the pre-chosen routes demonstrated that indeed one and the same city area can be perceived very differently depending on the journey through it. Barcelona received along route D descriptions like “train rails rhythm”, “hypnotic”, “sinuous”, while route C was associated with “like being involved in a car chase”, “crazed”, “pulsating”. London was experienced as “syncopated”, “bumpy”, “jazzy”, “cardiac”, “dysrhythmic” (route A), and in contrast also as “spooky”, “dreamy”, “dense rhythm” (route C). Rome, however, along both routes, was identified as consisting of two distinct parts, where a minimum of two distinct patterns was recognised: “The first section of

Statistical Evaluation and Findings (contd.)

the route was linear and ordered; the second section was more organic; the following sections were more linear again”, “consisting of two or three sub-areas of totally different characters” (route A) and “discontinuous”, a “historical centre going into a more modern district” (route D). New York was also assessed similarly along two different routes, although not for its different parts or sub-areas, but in terms of its “mechanistic”, “clockwork” ticking, “a-b-a-b-…”-dictated rhythm (in spite of the fact that route B consisted of long straight lines and very few turns); the mechanistic stop-and-go apprehension was therefore apparently retrieved through an awareness of theoretically possible, but practically skipped turns along the path.

Footnotes

1 Intelligibility measures - on a scale from 0 to 1 - the information that can be inferred about a complex relational system from the locally available visual information. As described by Hillier (1996), it represents “the relation between what cannot be seen and what is available”.

2 The r-squared value can be interpreted as the proportion of the variance in the y-axis attributable to the variance in the x-axis.

Discussion

Findings from the applied spatial analysis, the empirical study and from string computation as presented in the previous chapters are subsequently going to be discussed and interpreted. It is sought to bring them into meaningful relation with the hypothesis that had initially been posed, and to the theories as mounted in the literature review chapter.

Referring back to the earlier discussion of concepts, it can be recollected that order, according to Hanson, is immediately available to perception, based on its nature of repetition, similarity of elements and apparent "Gestalt". Order has also been attributed to be static over time, which raises the question which elements are perceived as repetitive when moving along a route. In deviation from the common allegation that architectural features of buildings and their metric dimension are the main components that define orderliness in a city environment, it has been attempted to identify measures that can be treated independently from the metric extension of built mass, namely the negative, complementing elements made of open space between buildings, which comes to junctions and open spaces along routes. In the analysis, these spaces for potential actions or events have been accounted for in terms of their emergence only, without consideration of the distance between them. Therefore, changes in direction (turns[1]) were categorised into four possible events that featured as four characters in string sequences. It was suggested that events along a route carry properties and information that can be translated into a notation of sequences. Computation of such extracted strings delivered measures for complexity and entropy of sequences.

While t-complexity is by definition the basic measure of "production steps to construct the string"[2] it was expected to be the equivalent expression of the simple most form of congregation of elements that is perceived as calculable order in judging equality of elements. The correlation of t-complexity measures with percentages of questionnaire responses for concepts like structure, coherency and order delivered significant r-squared values (Figs. 12.1-12.3). The conjecture that survey responses for "order" would correlate best with t-complexity measures can not be confirmed: It does not feature with more significant values than correlations with perceptions of "coherency" along a route do for instance.

Structure, however, was declared to be "picked up as arrangement of differences when moving about" and to have "continuity under transformation". Along the lines of the string code measure for order, the relevant expression for structure in sequential information appears to be t-entropy, which is closely related to Shannon's entropy measure. It delineates the shape of distribution of information bits and thereby approximates the probability of order in the appearance of single elements. Again, the scattergrams in Figs. 12.4-12.6 show good correlations with responses for all concepts "ordered", "structured", and "coherent"; however, none of these concepts is significantly ahead of others when looking at the r-squared values.

Discussion (contd.)

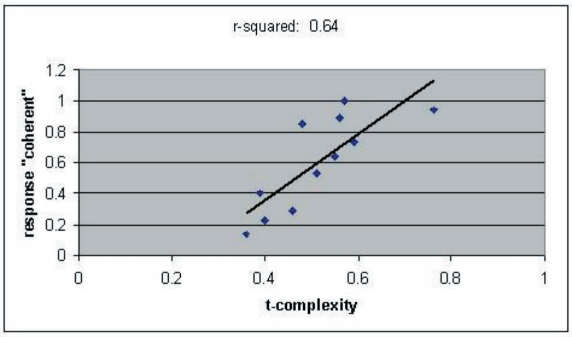


Fig. 12.1: Scattergram showing correlation between the normalised t-complexity measure and responses for "coherent"

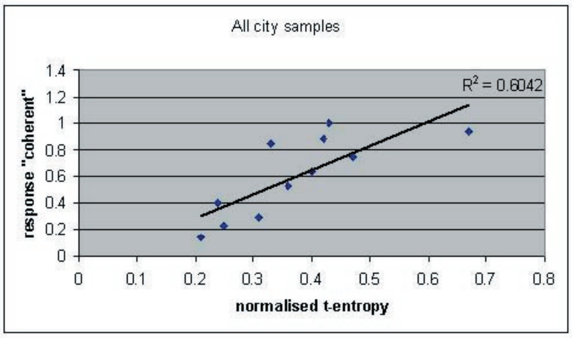


Fig. 12.4: Scattergram showing correlation between the normalised t-entropy measure and responses for "coherent"

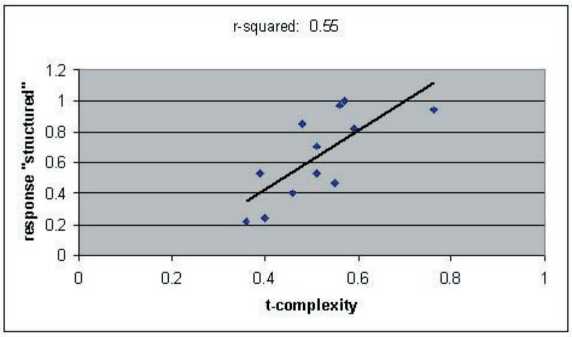


Fig. 12.2: Scattergram showing correlation between the normalised t-complexity measure and responses for "structured"

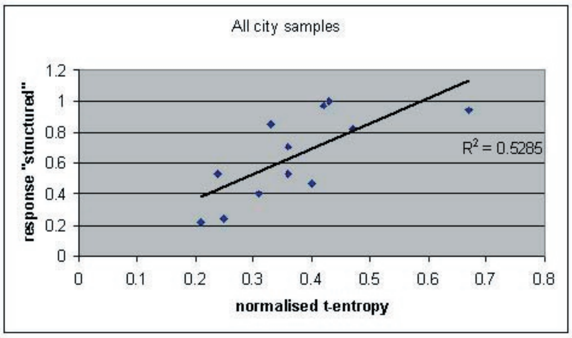


Fig. 12.5: Scattergram showing correlation between the normalised t-entropy measure and responses for "structured"

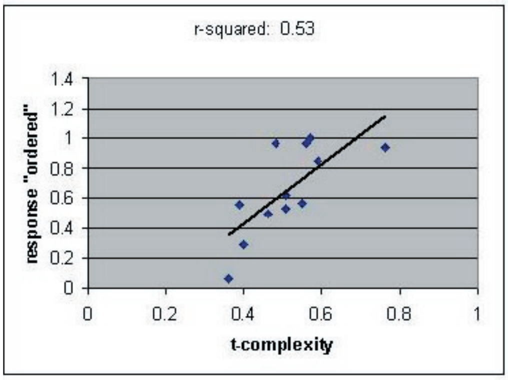


Fig. 12.3: Scattergram showing correlation between the normalised t-complexity measure and responses for "ordered"

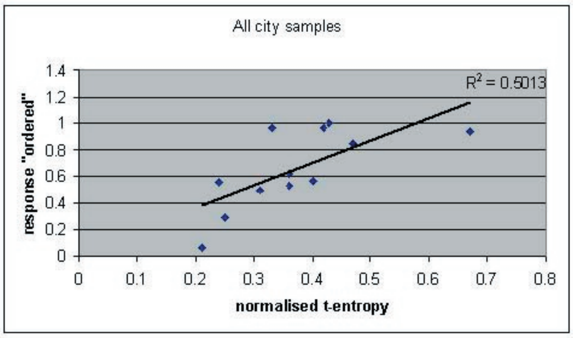


Fig. 12.6: Scattergram showing correlation between the normalised t-entropy measure and responses for "ordered"

Discussion (contd.)

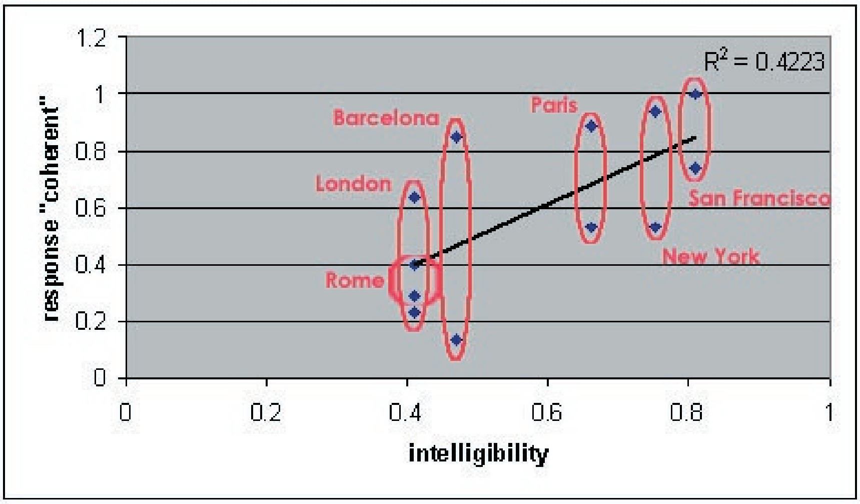


Fig. 12.7: Scattergram showing correlation between syntactical measure "intelligibility" in "worlds" and the percentage of questionnaire responses for "coherent"

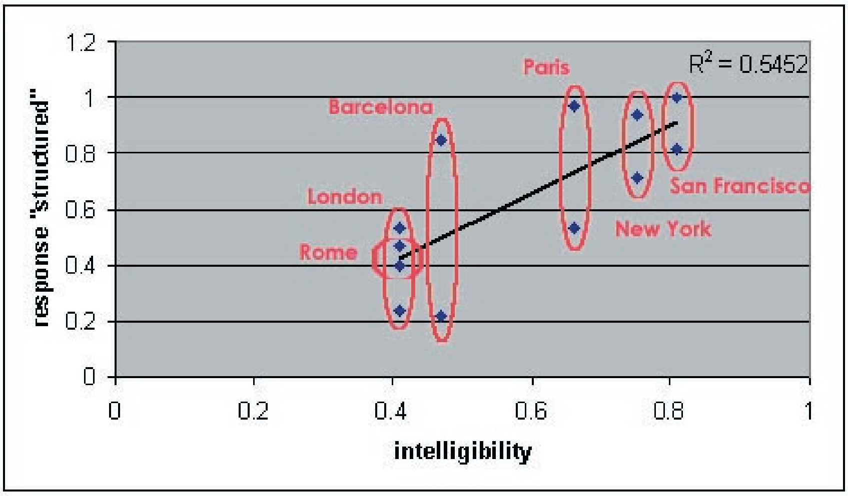


Fig. 12.8: Scattergram showing correlation between syntactical measure "intelligibility" in "worlds" and the percentage of questionnaire responses for "structured"

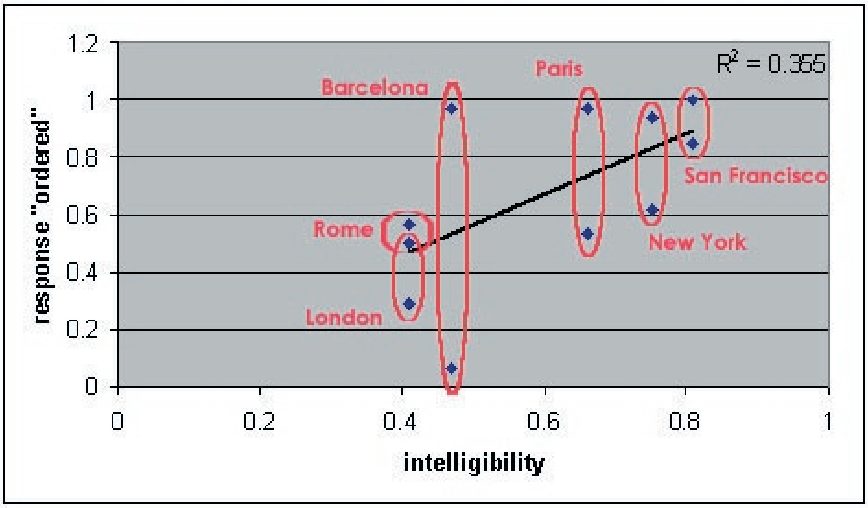


Fig. 12.9: Scattergram showing correlation between syntactical measure "intelligibility" in "worlds" and the percentage of questionnaire responses for "ordered"

Discussion (contd.)

Fairly significant is also the correlation of intelligibility of all sample worlds with responses that appraised an environment perceived in motion as structured, which purveys an r-squared of 0.55. This suggests a relatively strong dependency between “intelligibility” and “structure”, which attests the initial conjecture being expedient.

In general, there is a limitation to the computation of string codes which has to be considered in assessing the measures retrieved from string calculations: Short strings give slightly distorted results[3] owing to approximations in the calculation process.

More closely inspection of single routes of cities and their relation to the regression line in the overall scattergram of all cities - when looking for “structure” in “worlds” - revealed that the two routes through Barcelona significantly diverge from each other and from the regression line, whereas the two routes through Rome are most significantly approximating each other and the regression line. This accords to the verbal descriptions retrieved in open ending questions of the questionnaire, where Barcelona (with its seemingly continuously random street pattern when seen from above) was described as very contrasting for the two routes, while Rome (being split into a grid-like part and an “organic” part of the city) received fairly concordant recognition of being made up of two distinct patterns. Overall, this suggests that configurational aspects of a street layout show similarities with the perceptual recognition of route experiences when looking at the overall statistical data (which is a construct of collective perceptional data, although an urban environment is normally experienced by individuals and through a series of routes).

The hypothesis that “order” in “worlds” could be found in the relation between empirically obtained statistics and a configurational symmetry index as devised by Hillier could not be applied as a testable concept owing to the fact that no computational tools have been developed for the symmetry index yet.

Footnotes

1 For the construction of “barcodes” and strings, turns were rated as such where directional changes would occur in an equivalent of an axial map. This corresponds with the principle of longest lines of sight that can be drawn between building surfaces on the figure-ground map.

2 For more definitions of t-code measurements, see: http://tcode.auckland.ac.nz/tutorial.html

3 Computation of strings with less than 25 characters gave the following warning: “Accuracy for information and entropy is limited for short strings, due to approximation of bound by the logarithmic integral function, li().

Conclusion

This paper aimed at opening new ways for investigation into the role of “order” and “structure” in navigating through urban environments. It thereby focussed on the effects of concepts such as order, structure, disorder, and coherency on an individual’s perception when moving through an urban setting. The methodology chosen provided an external frame of empirical data retrieved from a virtual movement experiment that was brought into relation with configurational analysis of the urban patterns of the six city samples used, and with a new approach of extracting information about directional changes along routes. Normalised string complexity and string entropy measures for “barcodes” that were constructed from directional route characteristics, were applied throughout all samples and brought into relation with statistical data retrieved from the empirical experiment, thereby representing levels of perceptional awareness of individuals.

Focal questions posed in this paper were thus: Is “order”, “structure” or “disorder” of an urban layout as a simultaneously existing network of streets and open spaces perceivable when moving through the scenery, along a given path? Can one even measure how “interesting”, “coherent” or “efficient” a route is?

In order to come closer to a methodology for testing these principles, a conjecture has been developed which acted on the assumption that there are existing relationships between “structure” in worlds and configurational “intelligibility”, between “structure” along routes and string entropy, between “order” along routes and string complexity, and between “order” in worlds and a configurational symmetry index as described by Hillier (1996: 89-145).

The correlations that were looked at, including measures retrieved from spatial configurational analysis and from string computation, and empirical data that represents phenomena of spatial cognitive perception, appeared to be meaningful to a degree of such significance so that it can be suggested that further exploration into the adaptability of this methodology should be undertaken. More tailored investigations into methods employing string computation and further work into computation of a configurational symmetry index would have gone beyond the scope of this paper; they form, however, an interesting and challenging task for future research.

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Appendix A - Survey Questionnaire (Sample 1 of 12 only)

Bartlett School of Architecture

MSc AAS (Advanced Architectural Studies)

Virtual Movement Experiment

Hello

The following experiment forms the experiential part of my master thesis, which deals with the perception of orderliness and rhythm that occurs when moving through urban environments.

You will be asked to watch 12 short movie clips, each of them less than 90 seconds long. After each movie clip, you should answer some questions (most of them in the form of multiple choice questions), related to perception of order and rhythm when moving along the route.

The total time for the survey will be approximately 25-40 minutes, depending on the speed of your decision making. Basically, you should try to answer spontaneously according to your immediate reactions and feelings.

The building blocks in the movies are kept neutral in terms of shape, façade structure and building height. The virtual environment will therefore appear very abstract and "unreal" to you. This is intentional.

Let me also point out that none of your answers are "wrong", even if you didn't guess the objectively "right" one presented at the end of each section. This is nothing like an “intelligence test”, but a representation of what is subjectively perceived with a minimum of information provided. All that counts is that you read the questions thoroughly and give answers according to what you truly feel or what you estimate.

Your personal details will be treated confidential and data kept anonymous for analysis and evaluation.

Please note that you can’t go back a step in survey questions. You can watch each movie only once before answering the related questions. Go sure that you press the "send survey" button that will appear after the very last question to save the data!

Now sit back and relax - the experiment starts here!

Personal Information

Age:

○ -15 ○ 16-29 ○ 30-44 ○ 45-59 ○ 60-74 ○ 75+

Gender:

○ Female ○ Male

The data will be used and kept anonymous and there will be no publishing without consent. I would be grateful if you could confirm the following:

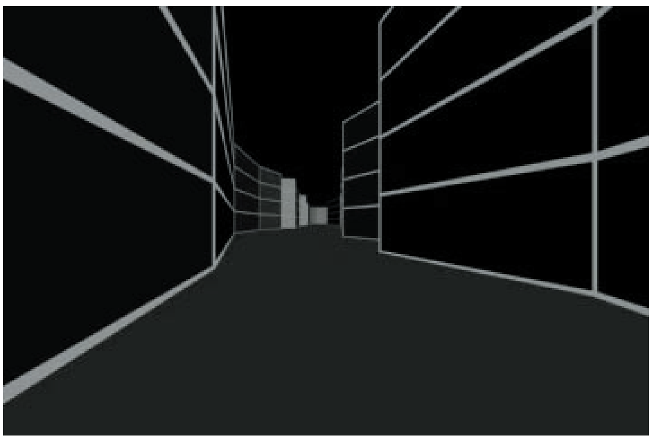
	Yes	No
May I use your questionnaire material in my master thesis?	○	○

The first movie should start playing after you pressed the "next" button.
If it doesn't start automatically, just click in the black window or on the middle of the screen and the movie will start immediately.

While watching, please pay attention to the route that you are virtually moving through, to the "orderliness" or "rhythm" of building blocks, to the number and quality of junctions you are crossing, to the occurence of open spaces, and to changes of direction that you are taking along the journey.

After having watched the movie to the end (each movie is less than 90 seconds), please move on to answer the following questions.

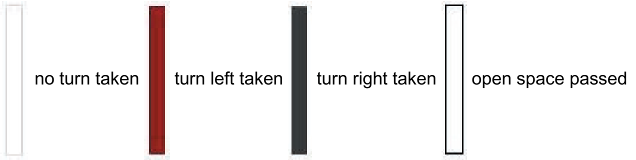
Sample 1 of 12

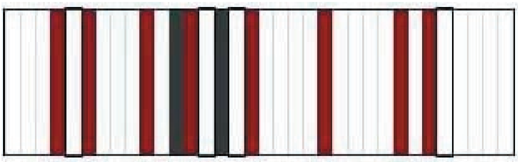


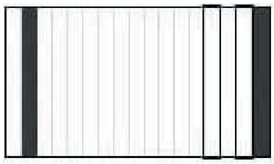
Appendix A (contd.) - Survey Questionnaire (Sample 1 of 12 only)

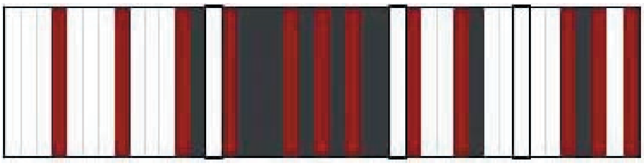
Based on your intuition, please choose from these 6 "barcode strings" the one that you associate most with the rhythm that you have just experienced along the route in this movie clip.

The single strips making up the barcodes indicate events as:

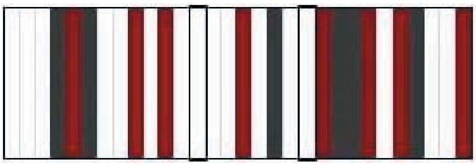


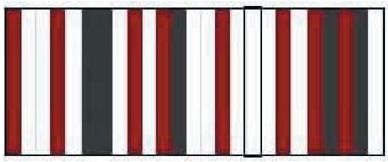
○ 

○ 

○ 

○ 

○ 

○ 

Appendix A (contd.) - Survey Questionnaire (Sample 1 of 12 only)

Please assess if you feel that the route through this environment was overall more...

interesting ○	monotonous ○
continuous ○	interrupted ○
coherent ○	fragmented ○
repetitive ○	alternating ○
efficient / linear ○	inefficient / meandering ○
structured ○	disarranged ○
rhythmic / regular ○	arhythmic / erratic ○
confusing / disorganised ○	clear / unambiguous ○
ordered ○	chaotic ○
unusual / place with identity ○	usual / common place ○
eventful ○	uneventful ○

Would you assume that the route which you moved along is based on...

a simple, approximately orthogonal street grid? ○ ○ a complex, more "organic" street layout?

Would you assume that the route which you moved along is based on...

a more symmetric street layout? ○ ○ a more asymmetric street layout?

	Yes	No
Do you think you moved at constant speed?	○	○

Please estimate...

	1-4	5-6	7	8-9	10+
how many changes of directions you made along the whole route:	○	○	○	○	○
how many junctions you crossed over along the whole route - without making a change of direction:	○	○	○	○	○
how many open spaces you passed or crossed over along the whole route:	○	○	○	○	○

Appendix A (contd.) - Survey Questionnaire (Sample 1 of 12 only)

Would you estimate that the route was made up of...

- ○ many short intervals between turns?
- ○ many short intervals and a few long intervals between turns?
- ○ an equal mixture of short and long intervals between turns?
- ○ a few short intervals and many long intervals between turns?
- ○ a few long intervals between turns?
- ○ Other

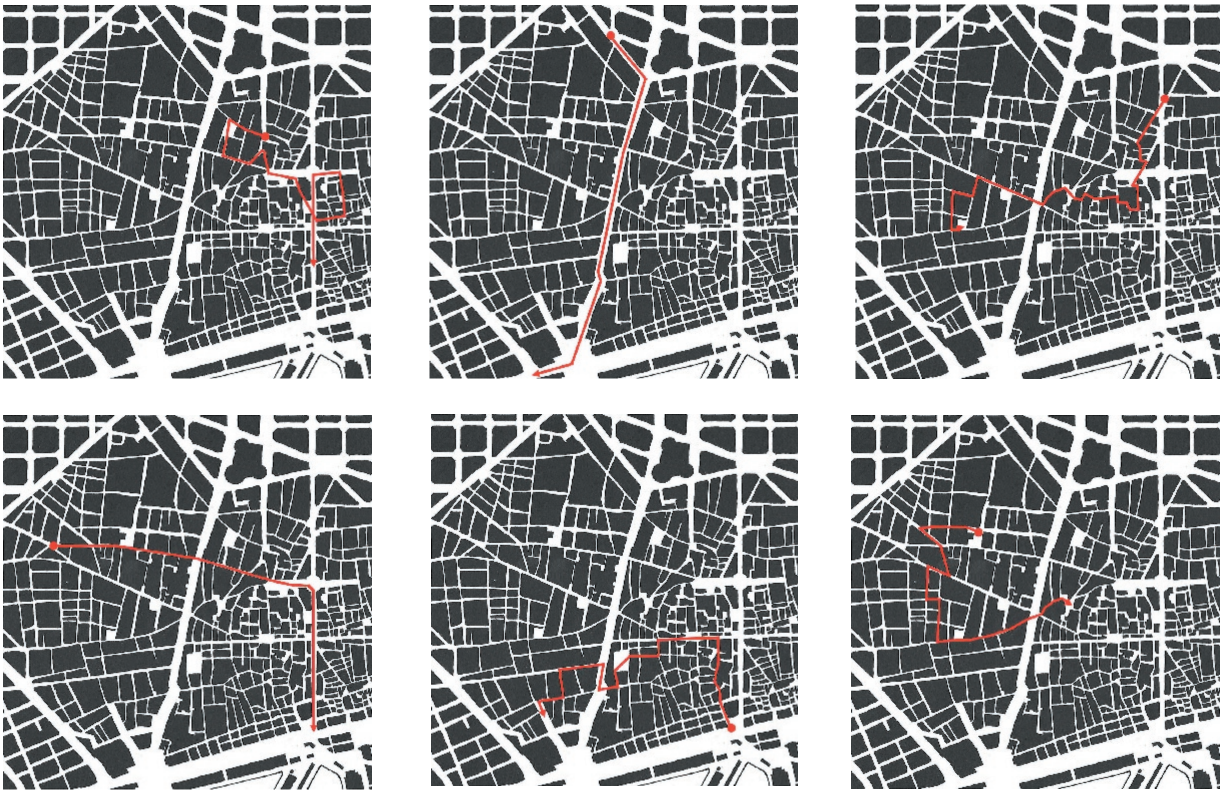
Please make notes below if this was experienced differently in different sections of the route, and describe briefly - in your own words - in which part of the route mainly short, or mainly long intervals, appeared.

Find a name or adjective for the kind of “rhythm” that moving past the building blocks made you feel.

In the movie, you were taken along a route through a virtual city environment that is based on street patterns of a real city.

The maps below show the figure-ground pattern of the building blocks in this real city.
In these maps, 6 different routes are marked, indicating starting points (solid circle) and termination points (arrowhead).

Please choose the route that you assume you were taken along in the movie:



Congratulations: You chose the right route!
The route was based on a map of Barcelona (Ramblas).

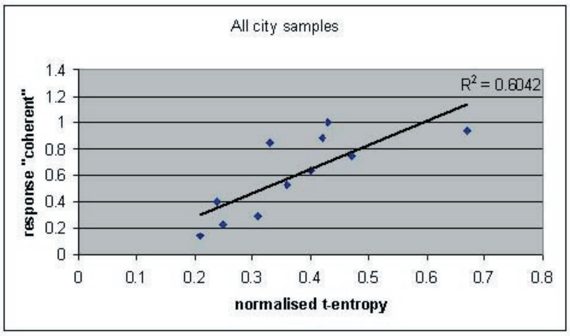
Now try the next one!

The route was based on a map of Barcelona (Ramblas).
Your guess was not quite right this time. The right answer for the route would've been:

Appendix B1

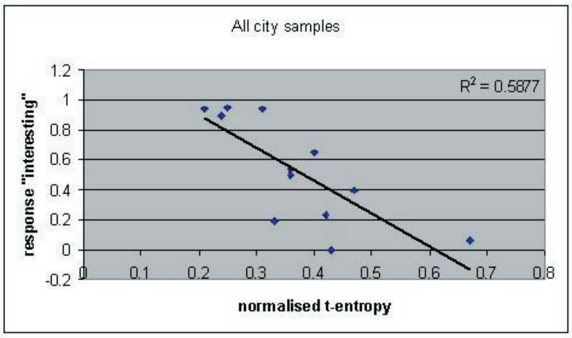
“Structure” in Routes (t-entropy) - all city samples

“Coherent”



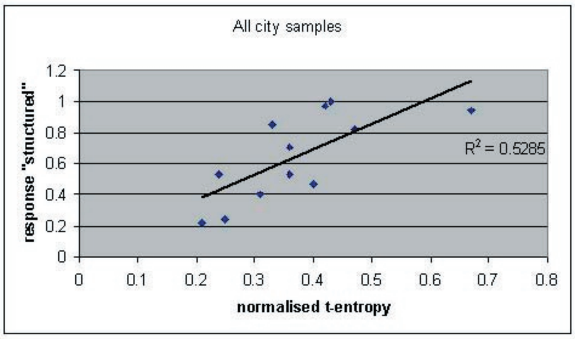
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “coherent”

“Interesting”



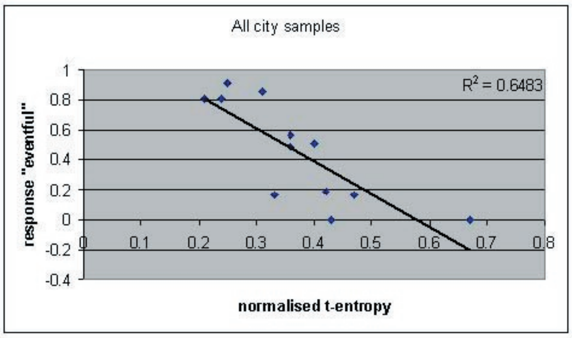
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “interesting”

“Structured”



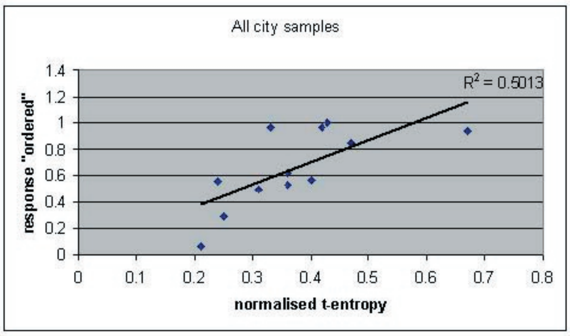
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “structured”

“Eventful”



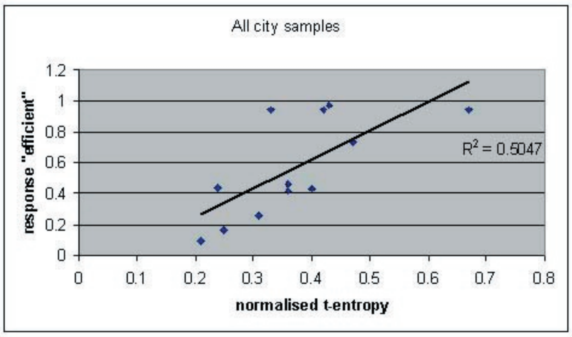
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “eventful”

“Ordered”



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “ordered”

“Efficient”



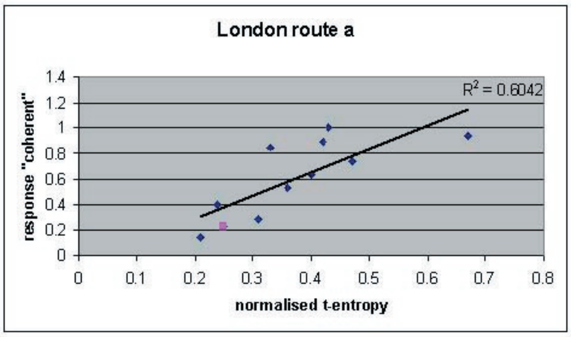
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “efficient”

Appendix B1 (contd.) - Structure in Routes

"Structure" in Routes (t-entropy) - London

Route A

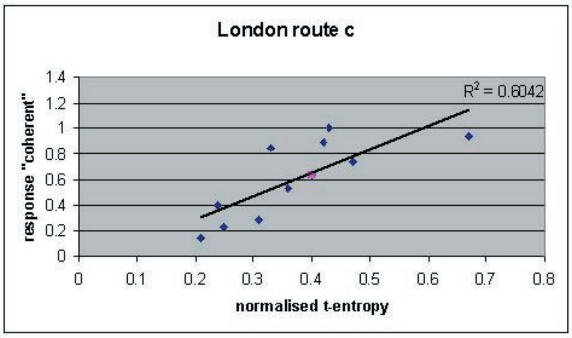
"Coherent"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

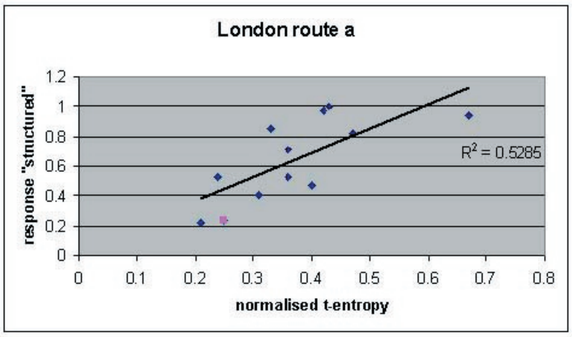
Route C

"Coherent"



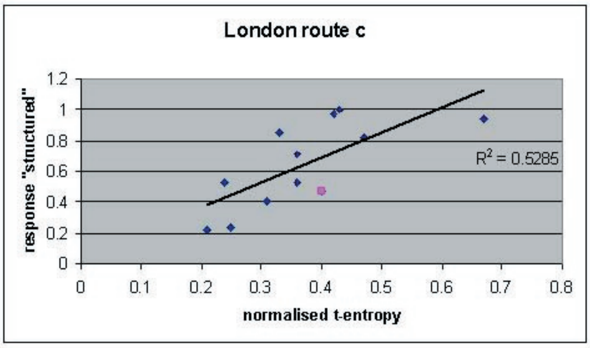
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



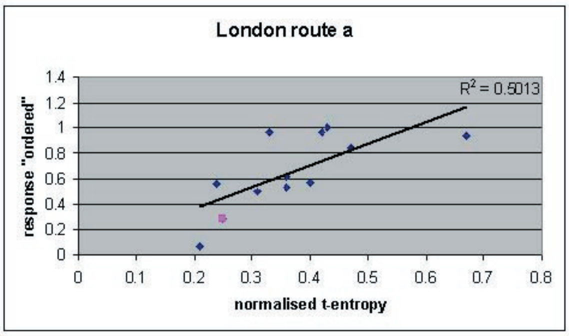
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Structured"



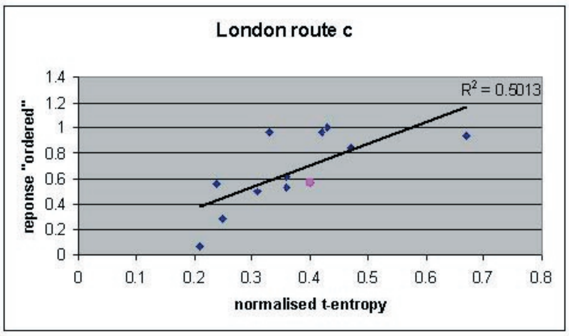
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"



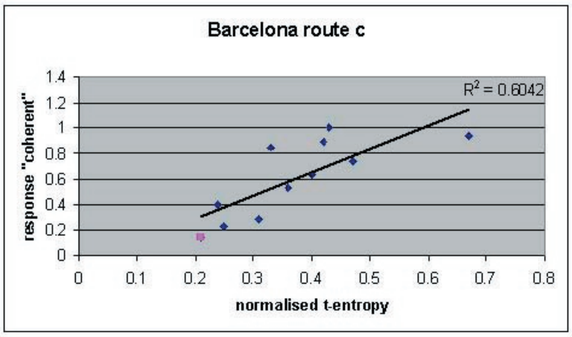
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

Appendix B1 (contd.) - Structure in Routes

"Structure" in Routes (t-entropy) - Barcelona

Route C

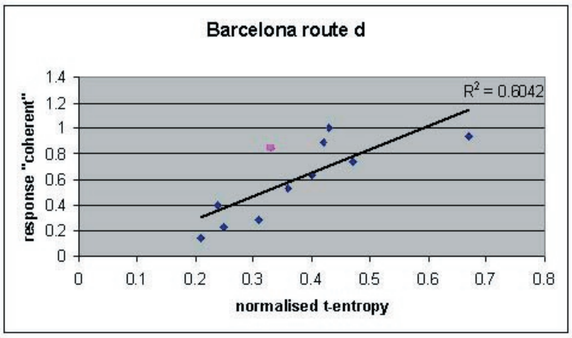
"Coherent"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

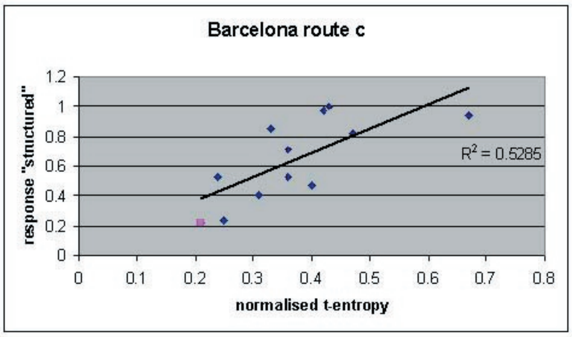
Route D

"Coherent"



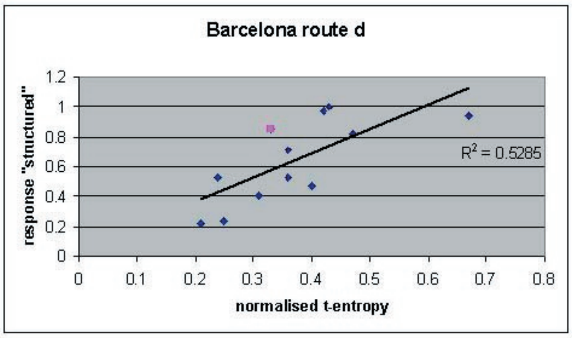
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



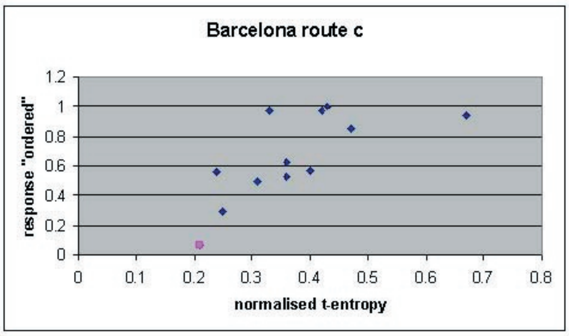
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Structured"



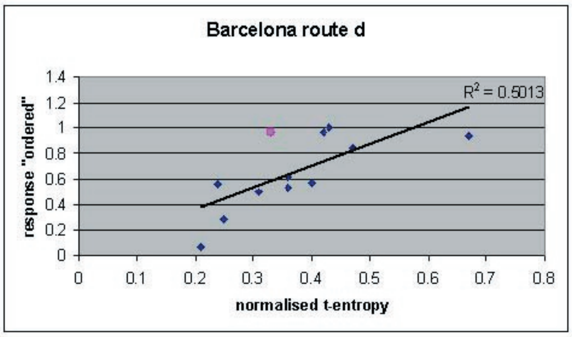
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"



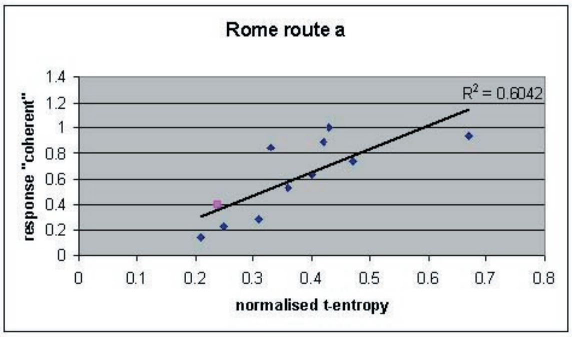
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

Appendix B1 (contd.) - Structure in Routes

“Structure” in Routes (t-entropy) - Rome

Route A

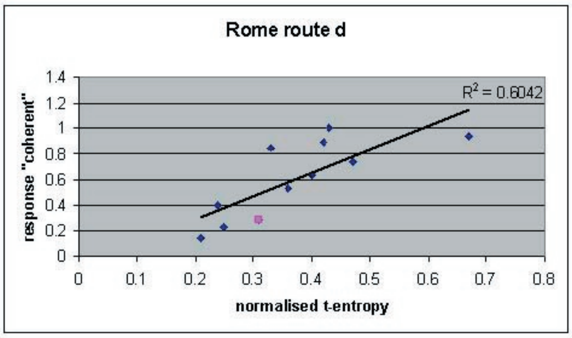
“Coherent”



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “coherent”

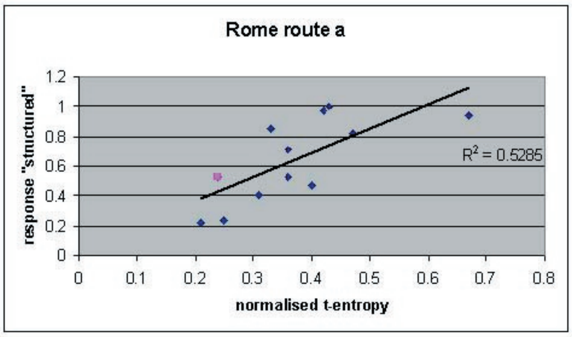
Route D

“Coherent”



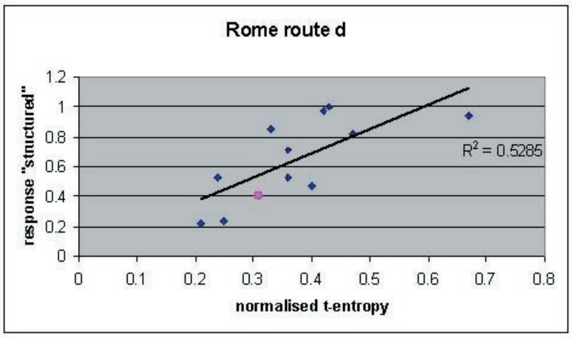
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “coherent”

“Structured”



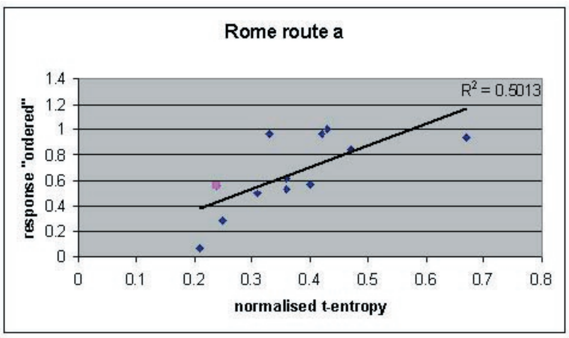
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “structured”

“Structured”



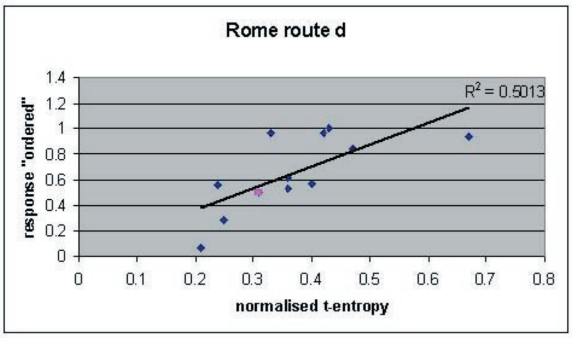
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “structured”

“Ordered”



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “ordered”

“Ordered”



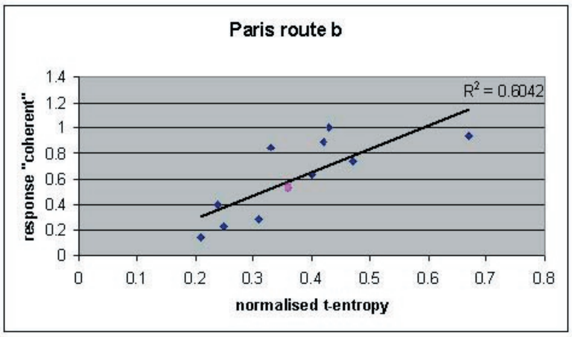
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “ordered”

Appendix B1 (contd.) - Structure in Routes

“Structure” in Routes (t-entropy) - Paris

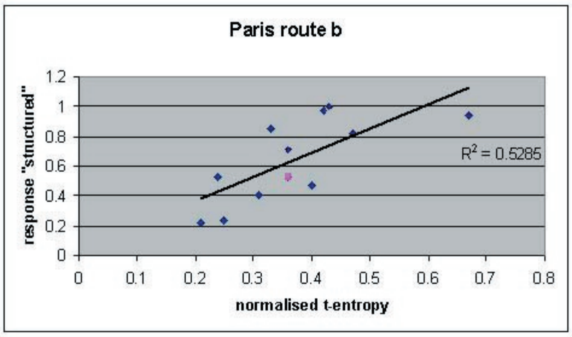
Route B

“Coherent”



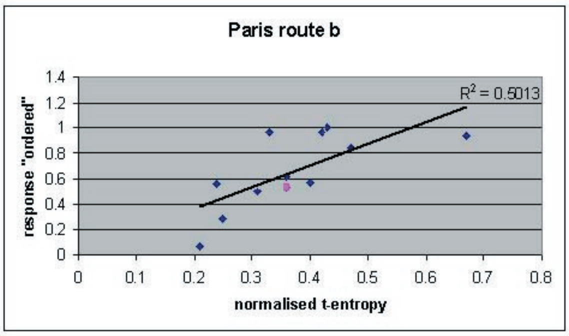
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “coherent”

“Structured”



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “structured”

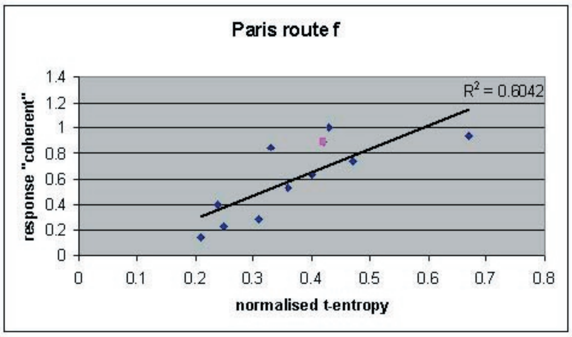
“Ordered”



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “ordered”

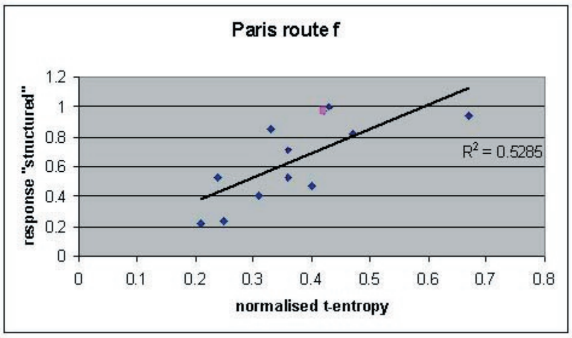
Route F

“Coherent”



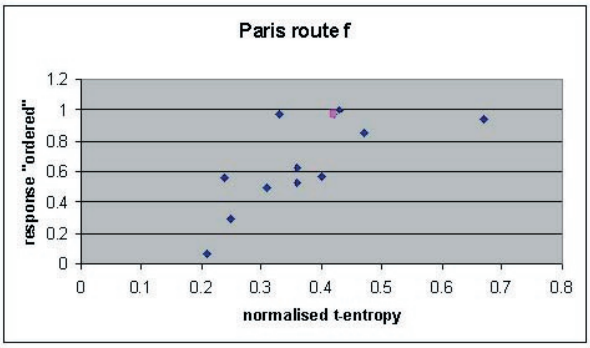
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “coherent”

“Structured”



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “structured”

“Ordered”



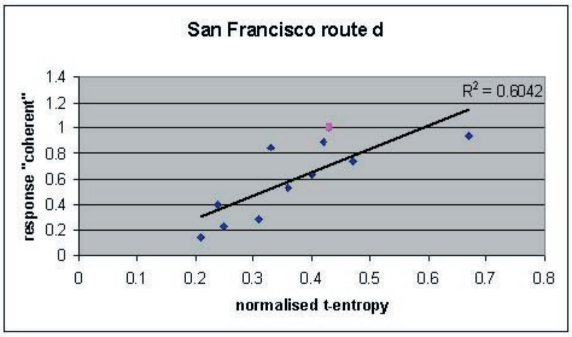
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for “ordered”

Appendix B1 (contd.) - Structure in Routes

"Structure" in Routes (t-entropy) - San Francisco

Route D

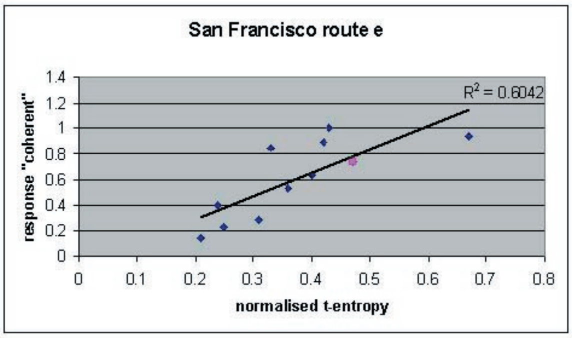
"Coherent"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

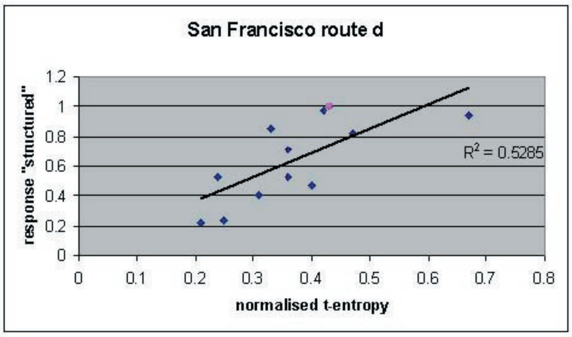
Route E

"Coherent"



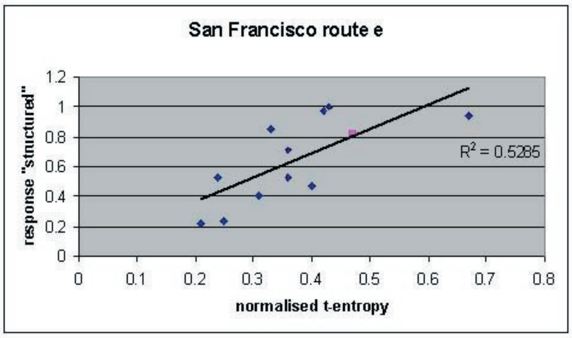
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



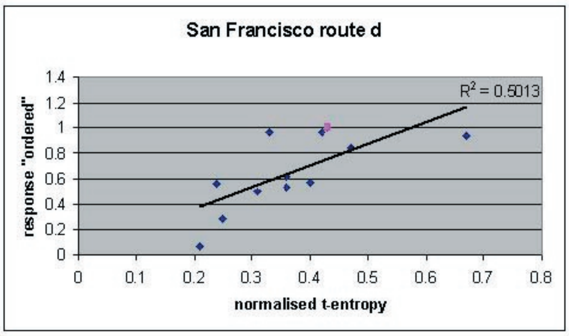
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Structured"



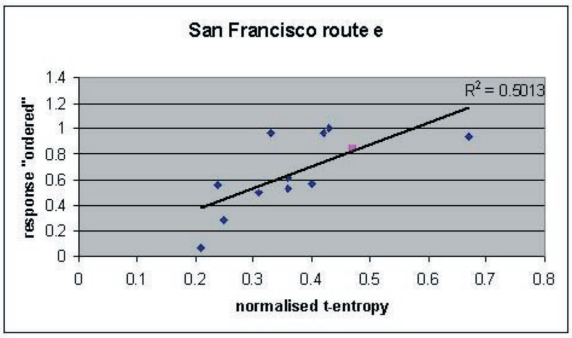
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"



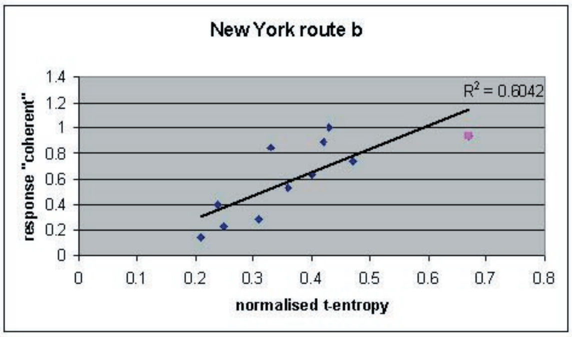
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

Appendix B1 (contd.) - Structure in Routes

"Structure" in Routes (t-entropy) - New York

Route B

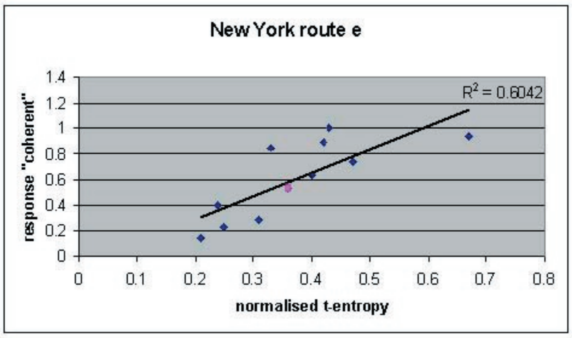
"Coherent"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

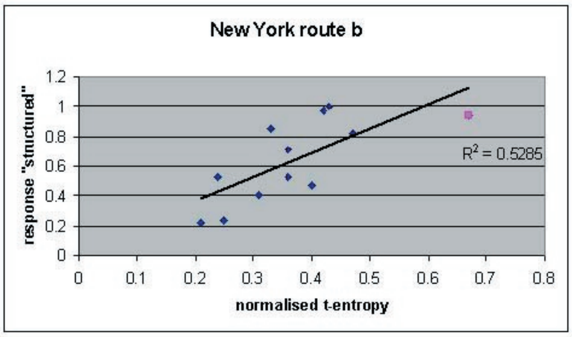
Route E

"Coherent"



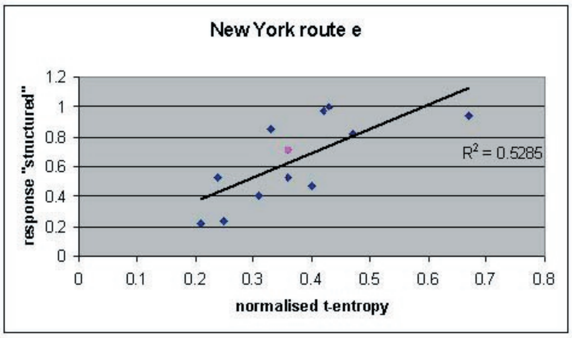
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



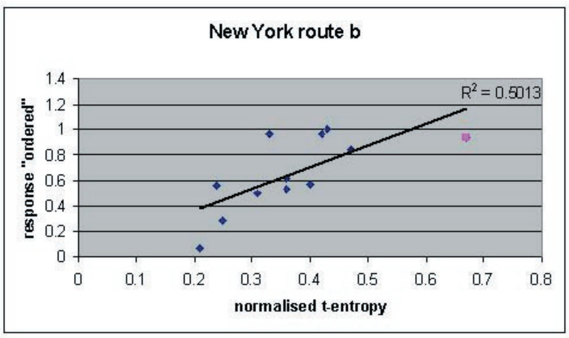
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Structured"



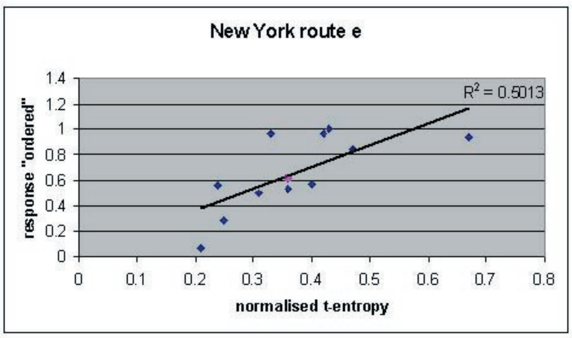
Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"

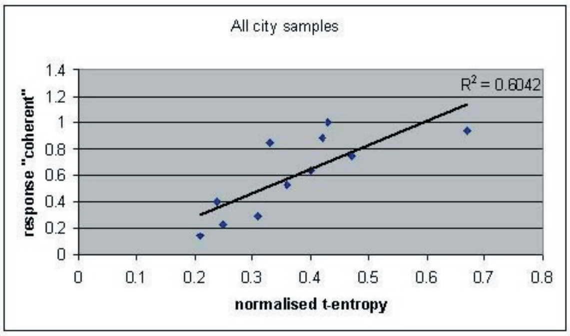


Scattergram showing correlation between t-entropy of route strings and the percentage of questionnaire responses for "ordered"

Appendix B2

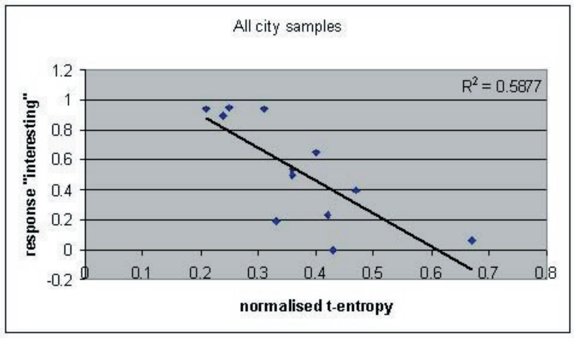
“Order” in Routes (t-complexity) - all city samples

“Coherent”



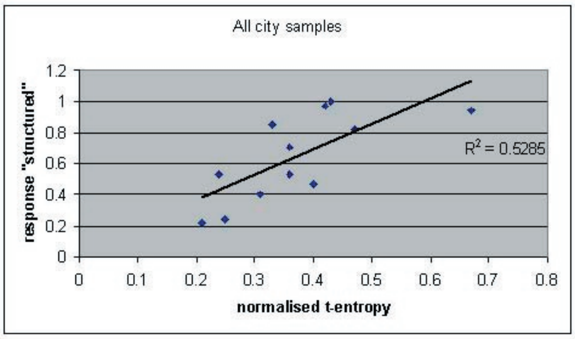
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “coherent”

“Interesting”



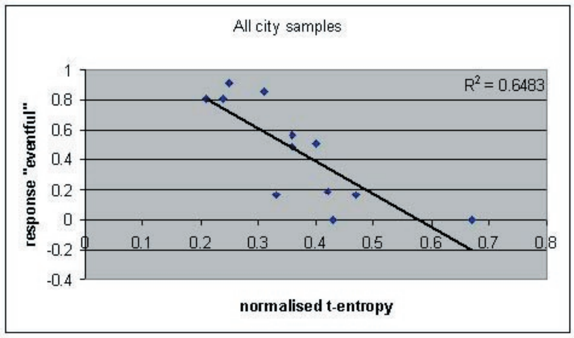
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “interesting”

“Structured”



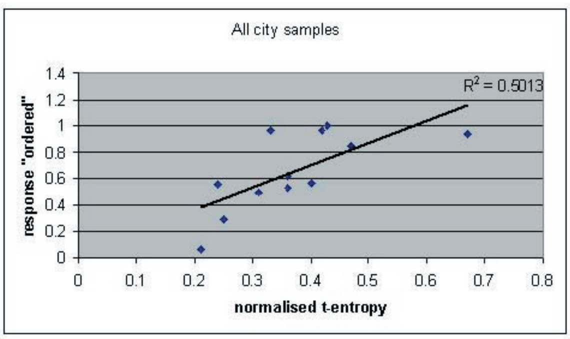
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “structured”

“Eventful”



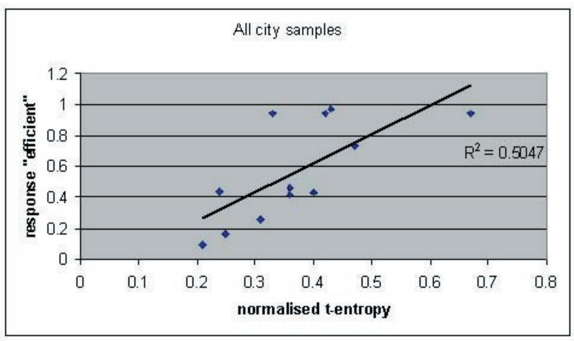
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “eventful”

“Ordered”



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “ordered”

“Efficient”



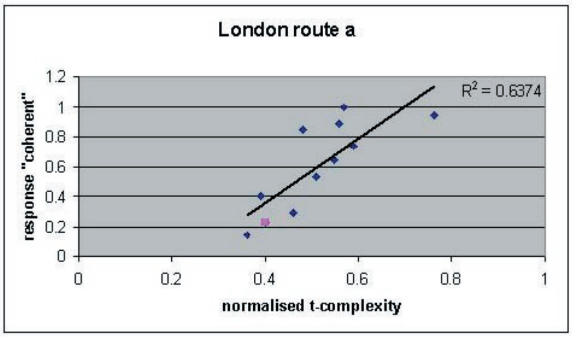
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “efficient”

Appendix B2 (contd.) - Order in Routes

“Order” in Routes (t-complexity) - London

Route A

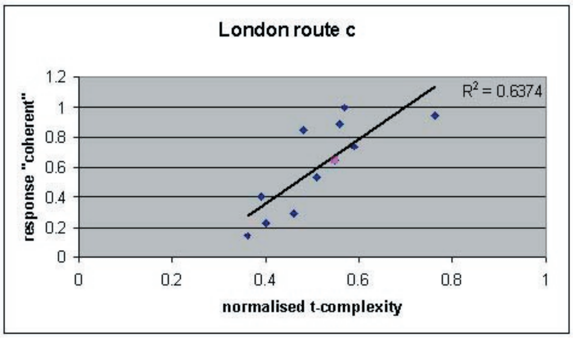
“Coherent”



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “coherent”

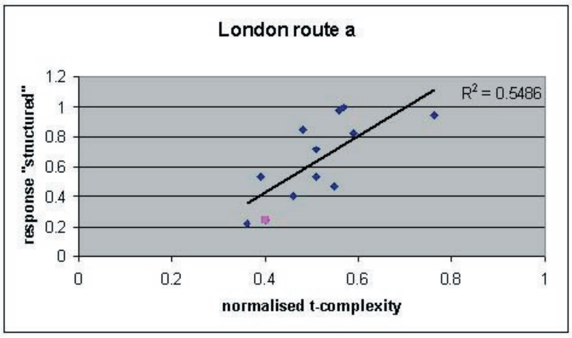
Route C

“Coherent”



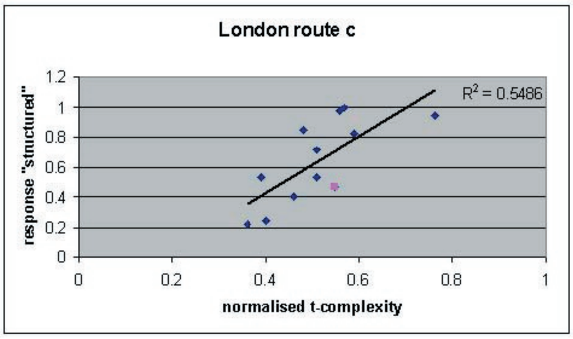
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “coherent”

“Structured”



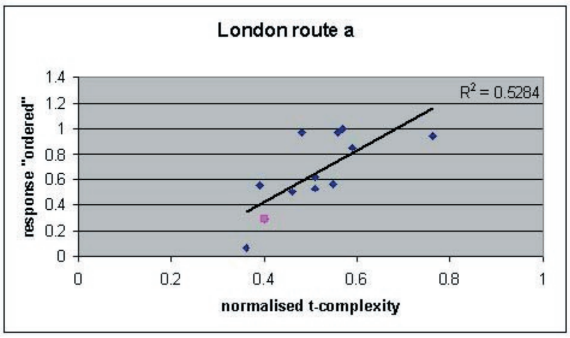
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “structured”

“Structured”



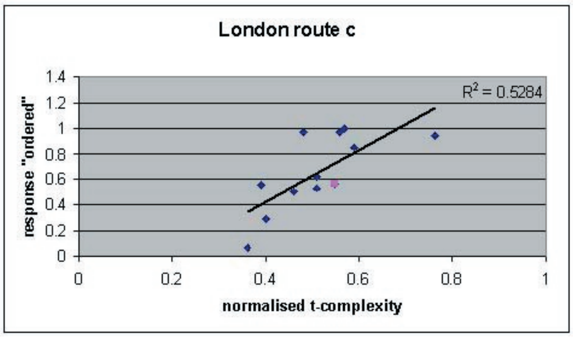
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “structured”

“Ordered”



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “ordered”

“Ordered”



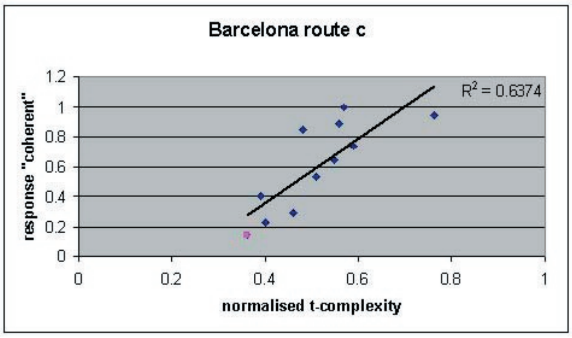
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for “ordered”

Appendix B2 (contd.) - Order in Routes

"Order" in Routes (t-complexity) - Barcelona

Route C

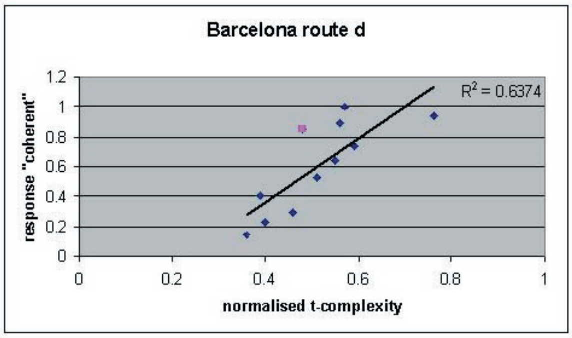
"Coherent"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

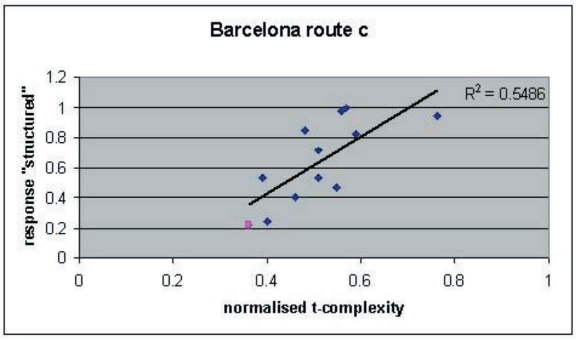
Route D

"Coherent"



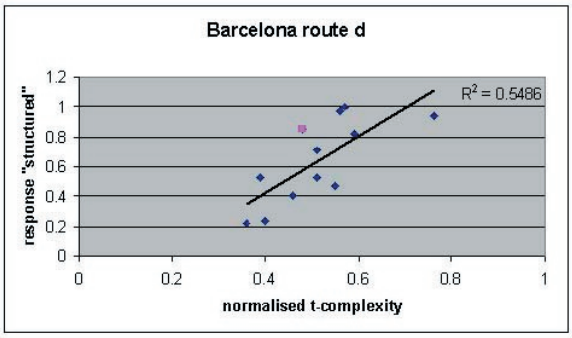
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



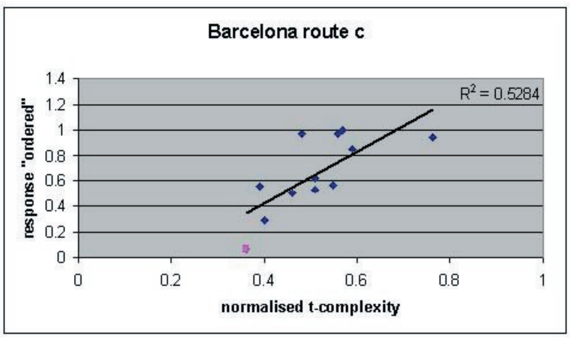
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Structured"



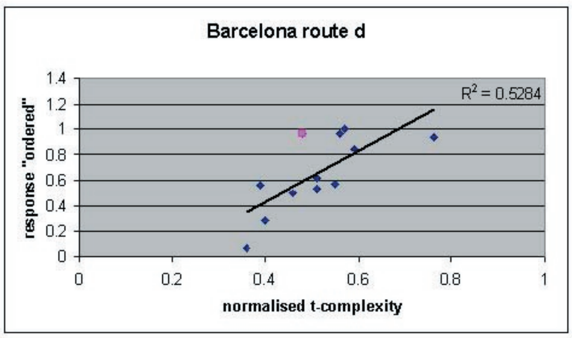
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"



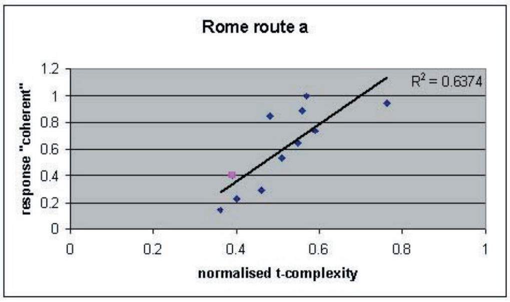
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

Appendix B2 (contd.) - Order in Routes

"Order" in Routes (t-complexity) - Rome

Route A

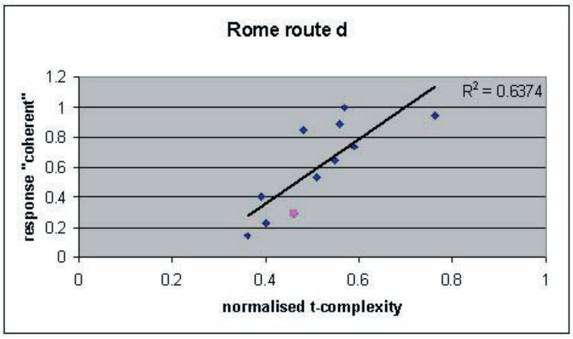
"Coherent"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

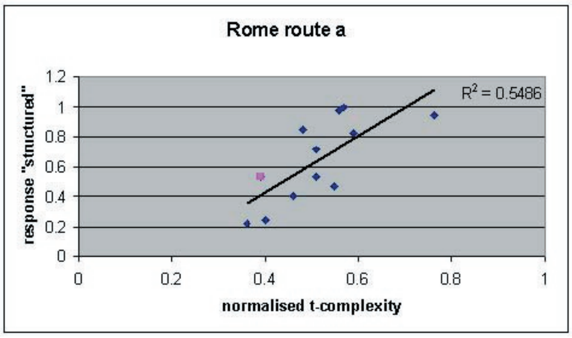
Route D

"Coherent"



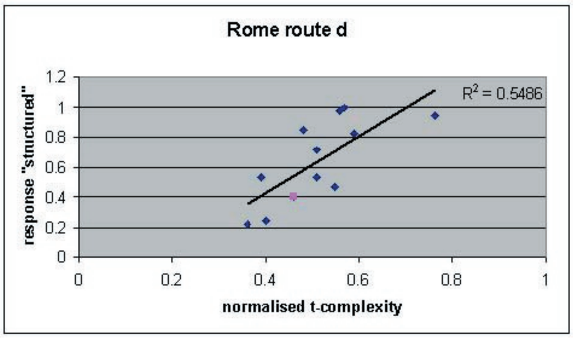
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



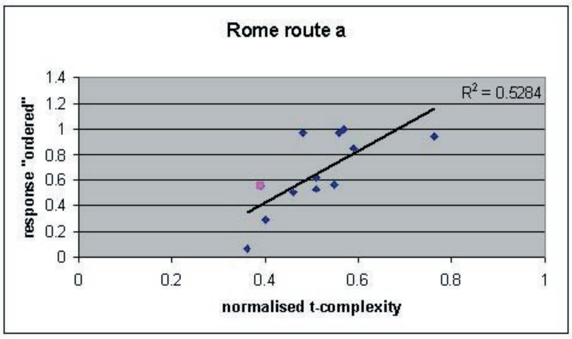
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Structured"



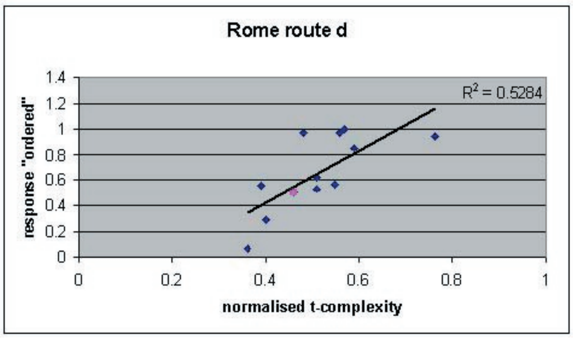
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"



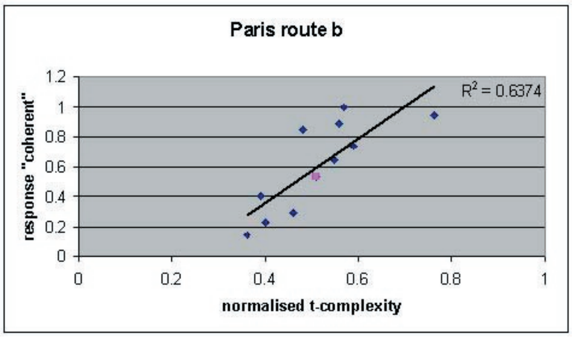
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

Appendix B2 (contd.) - Order in Routes

"Order" in Routes (t-complexity) - Paris

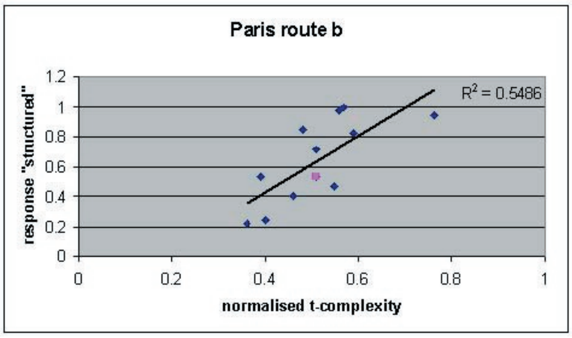
Route B

"Coherent"



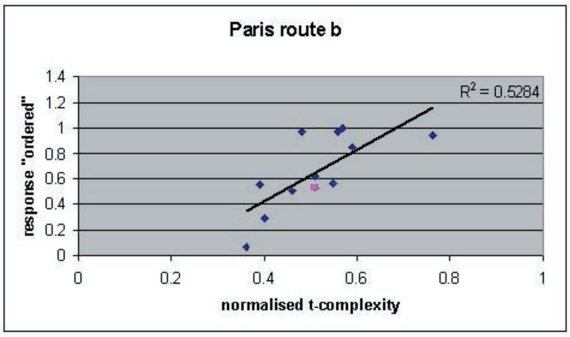
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

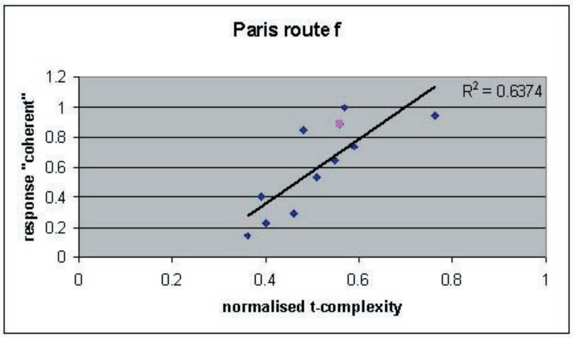
"Ordered"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

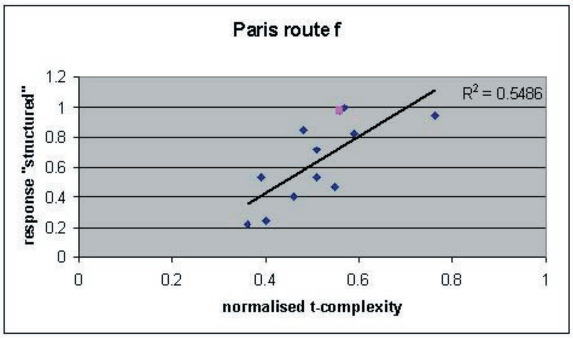
Route F

"Coherent"



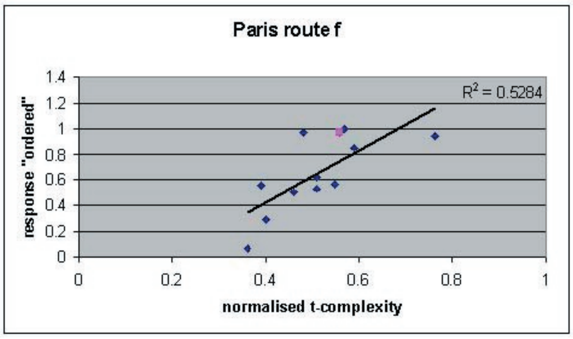
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



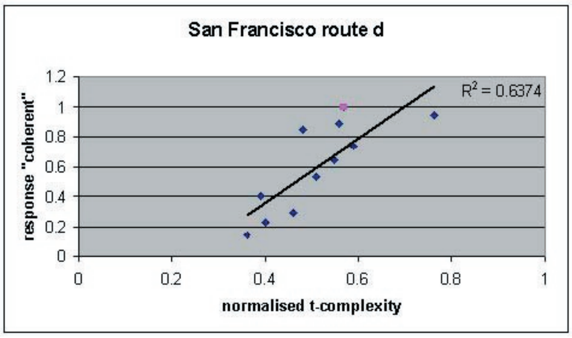
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

Appendix B2 (contd.) - Order in Routes

"Order" in Routes (t-complexity) - San Francisco

Route D

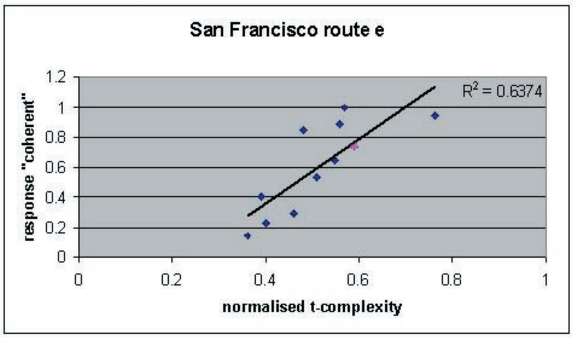
"Coherent"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

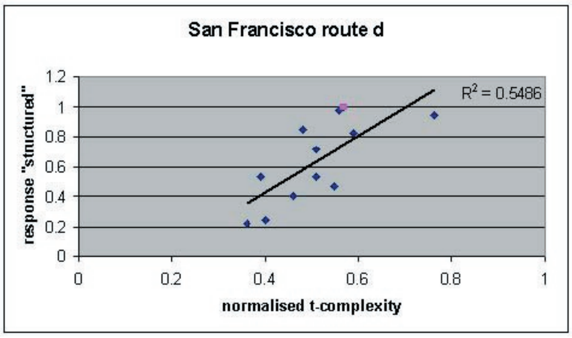
Route E

"Coherent"



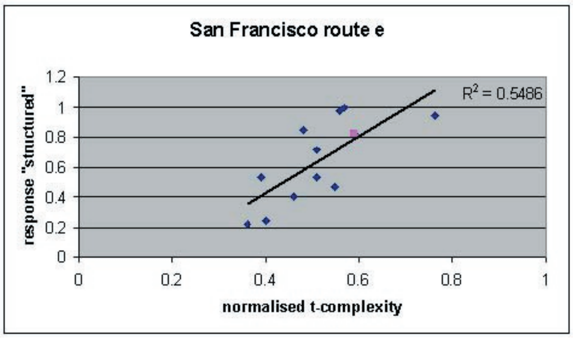
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



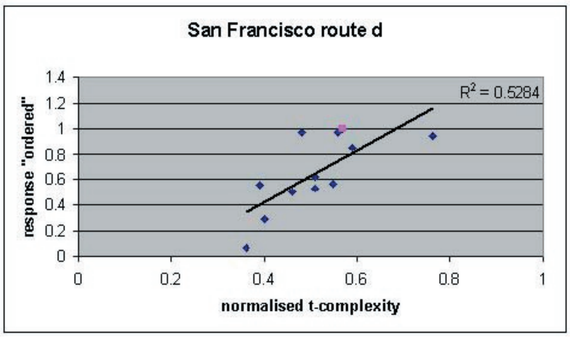
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Structured"



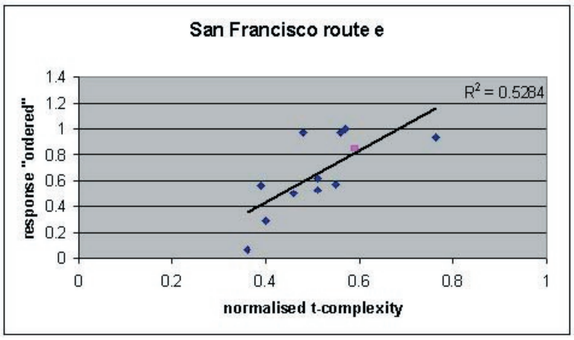
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Ordered"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

"Ordered"



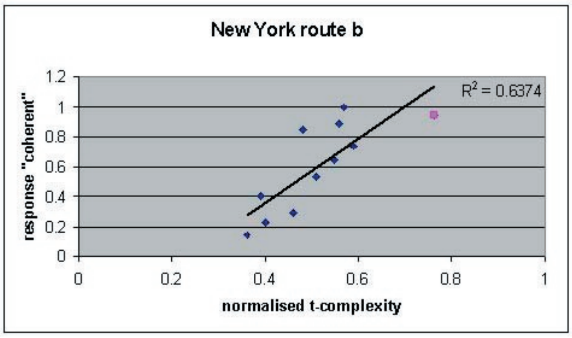
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

Appendix B2 (contd.) - Order in Routes

"Order" in Routes (t-complexity) - New York

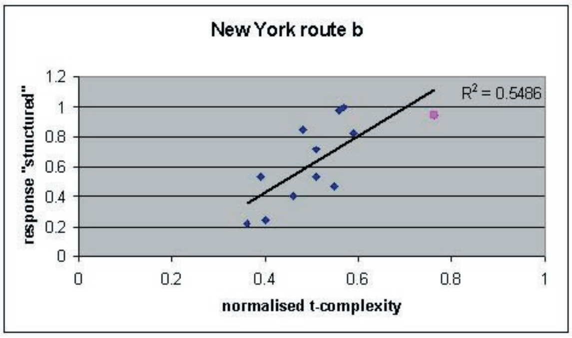
Route B

"Coherent"



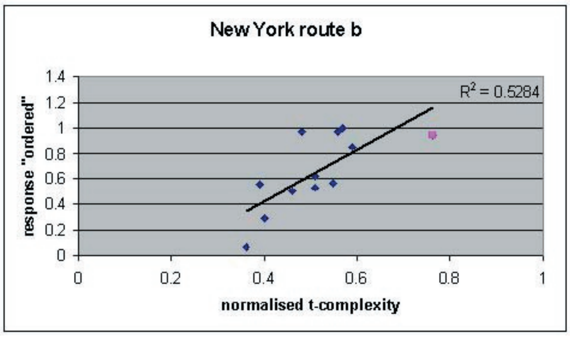
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

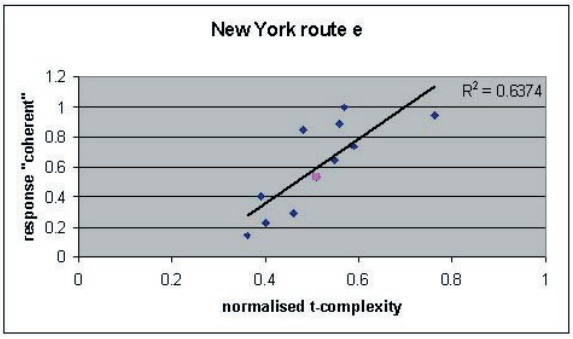
"Ordered"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

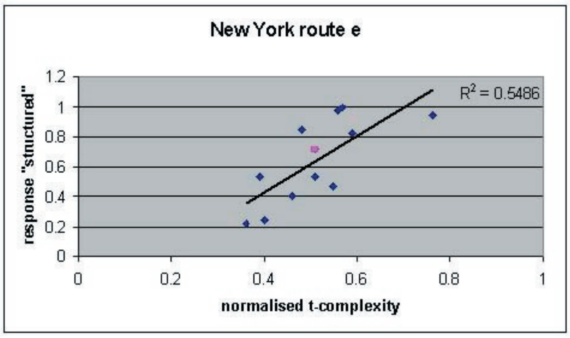
Route E

"Coherent"



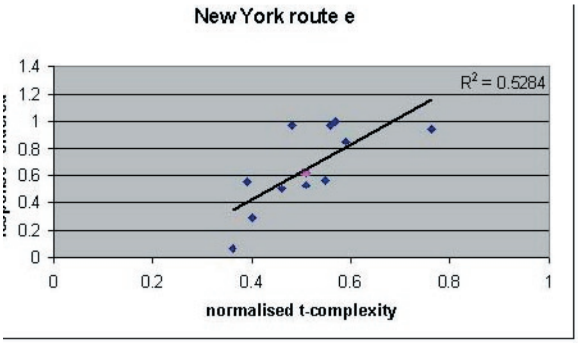
Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "coherent"

"Structured"



Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "structured"

"Ordered"

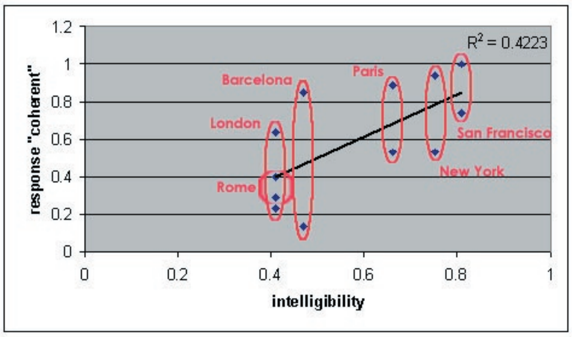


Scattergram showing correlation between t-complexity of route strings and the percentage of questionnaire responses for "ordered"

Appendix C

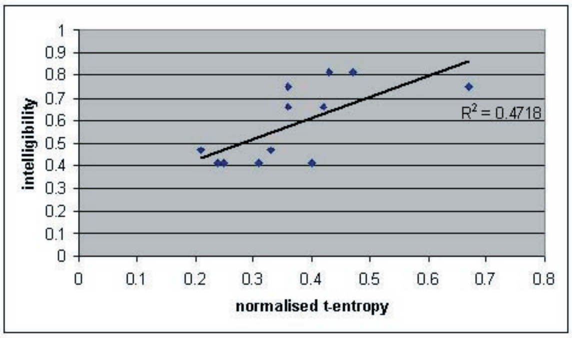
“Structure” in Worlds (intelligibility) - all city samples

“Coherent”



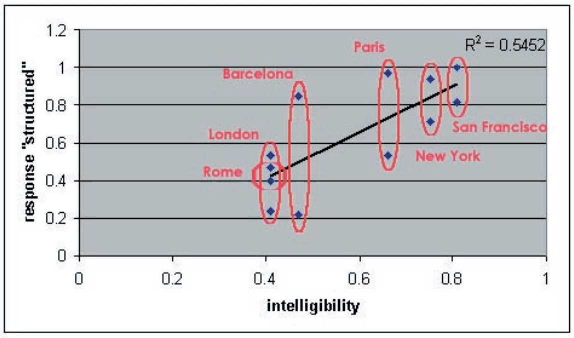
Scattergram showing correlation between syntactical measure “intelligibility” in “worlds” and the percentage of questionnaire responses for “coherent”

T-Entropy



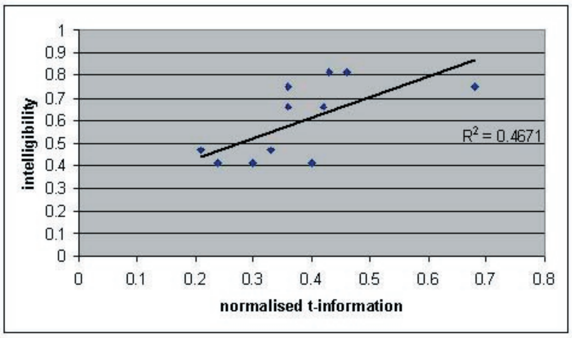
Scattergram showing correlation between syntactical measure “intelligibility” in “worlds” and the t-entropy measure from string computation

“Structured”



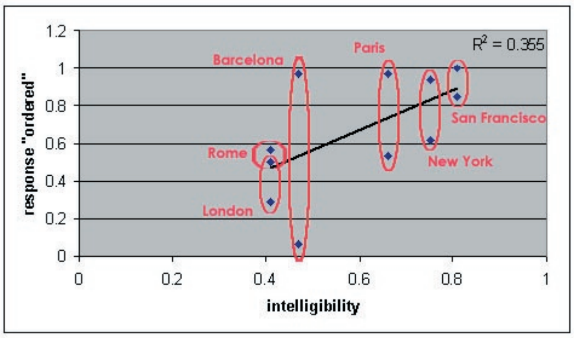
Scattergram showing correlation between syntactical measure “intelligibility” in “worlds” and the percentage of questionnaire responses for “structured”

T-Information



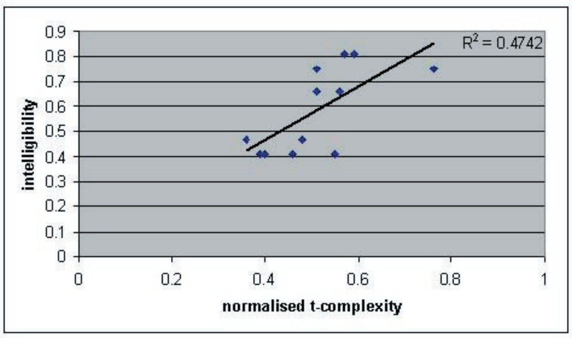
Scattergram showing correlation between syntactical measure “intelligibility” in “worlds” and the t-information measure from string computation

“Ordered”



Scattergram showing correlation between syntactical measure “intelligibility” in “worlds” and the percentage of questionnaire responses for “ordered”

T-Complexity



Scattergram showing correlation between syntactical measure “intelligibility” in “worlds” and the t-complexity measure from string computation

Appendix D - String Computation with T-Calc

http://130.216.197.3/cgi-bin/wtcalc?textline=0000 and http://tcode.auckland.ac.nz/tutorial.html
Courtesy of Dr Mark Titchener

LONDON

London route A (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **oROLoooLooooROoLoOLLRORoLoLoLoRo**
length (chars): 32

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
12.58 (taugs)	27.8 (nats)	0.869 (nats/char)
12.58 (taugs)	40.1 (bits)	1.254 (bits/char)

London route A (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **RLLRLLLRRLLLR**
length (chars): 13

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
5.58 | 5.00 (taugs)	8.0 | 6.7 (nats)	0.6 | 0.5 (nats/char)
5.58 | 5.00 (taugs)	11.5 | 9.7 (bits)	0.8 | 0.7 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

London route C (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **ooooLoRLooooooooooooLRooooooR**
length (chars): 30

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
9.00 | 8.81 (taugs)	16.66 | 16.11 (nats)	0.55 | 0.537 (nats/char)
9.00 | 8.81 (taugs)	24.03 | 23.24 (bits)	0.80 | 0.774 (bits/char)

London route C (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRLLRR**
length (chars): 6

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
3.58 | 3.00 (taugs)	4.2 | 3.3 (nats)	0.7 | 0.5 (nats/char)
3.58 | 3.00 (taugs)	6.1 | 4.8 (bits)	1.0 | 0.8 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Appendix D (contd.) - String Computation with T-Calc
http://130.216.197.3/cgi-bin/wtcalc?textline=0000 and http://tcode.auckland.ac.nz/tutorial.html
Courtesy of Dr Mark Titchener

BARCELONA

Barcelona route C (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **oooLoooLoooLROLRRRLRLRLRROLooLRooOooLRLoL**
length (chars): 41

```
   (parsing:  forward | reverse)
  T-complexity          T-information            T-entropy
14.75 | 13.00 (taugs)   35.36 | 29.23 (nats)    0.86 | 0.712 (nats/char)
14.75 | 13.00 (taugs)   51.01 | 42.16 (bits)    1.24 | 1.028 (bits/char)
```

Barcelona route C (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LLLRLRRRLRLRLRRLLRLRLL**
length (chars): 22

```
   (parsing:  forward | reverse)
  T-complexity          T-information            T-entropy
7.58 | 8.00 (taugs)     12.79 | 13.89 (nats)    0.58 | 0.631 (nats/char)
7.58 | 8.00 (taugs)     18.45 | 20.03 (bits)    0.83 | 0.910 (bits/char)
```

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Barcelona route D (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **ooooooRooooooooRooooooooOLROoOooooo**
length (chars): 35

```
   (parsing:  forward | reverse)
  T-complexity          T-information            T-entropy
10.58 | 10.32 (taugs)   21.38 | 20.57 (nats)    0.61 | 0.587 (nats/char)
10.58 | 10.32 (taugs)   30.84 | 29.67 (bits)    0.88 | 0.847 (bits/char)
```

Barcelona route D (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **RRLR**
length (chars): 4

```
   (parsing:  forward | reverse)
  T-complexity          T-information            T-entropy
2.00 | 2.58 (taugs)     2.1 | 2.8 (nats)        0.5 | 0.7 (nats/char)
2.00 | 2.58 (taugs)     3.0 | 4.0 (bits)  0.7 | 1.0 (bits/char)
```

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Appendix D (contd.) - String Computation with T-Calc

http://130.216.197.3/cgi-bin/wtcalc?textline=0000 and http://tcode.auckland.ac.nz/tutorial.html
Courtesy of Dr Mark Titchener

ROME

Rome route A (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **oooLOooooOoRoooooLROoRLRORoLOLO**
length (chars): 31

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
12.58 (taugs)	27.8 (nats)	0.897 (nats/char)
12.58 (taugs)	40.1 (bits)	1.295 (bits/char)

Rome route A (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRLRRLRRLL**
length (chars): 10

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
5.00 | 4.58 (taugs)	6.7 | 5.9 (nats)	0.6 | 0.5 (nats/char)
5.00 | 4.58 (taugs)	9.7 | 8.6 (bits)	0.9 | 0.8 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Rome route D (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **OLRRROLRLRoLoRLRooROLooo**
length (chars): 24

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
10.00 | 10.58 (taugs)	19.59 | 21.38 (nats)	0.81 | 0.890 (nats/char)
10.00 | 10.58 (taugs)	28.26 | 30.84 (bits)	1.17 | 1.285 (bits/char)

Rome route D (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRRRLRLRLRLRRL**
length (chars): 14

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
6.00 | 5.58 (taugs)	8.9 | 8.0 (nats)	0.6 | 0.5 (nats/char)
6.00 | 5.58 (taugs)	12.8 | 11.5 (bits)	0.9 | 0.8 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Appendix D (contd.) - String Computation with T-Calc

http://130.216.197.3/cgi-bin/wtcalc?textline=0000 and http://tcode.auckland.ac.nz/tutorial.html
Courtesy of Dr Mark Titchener

PARIS

Paris route B (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **oLoooRoLooRooLRoO**
length (chars): 17

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
8.00 | 7.00 (taugs)	13.89 | 11.31 (nats)	0.81 | 0.665 (nats/char)
8.00 | 7.00 (taugs)	20.03 | 16.31 (bits)	1.17 | 0.959 (bits/char)

Paris route B (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRLRLR**
length (chars): 6

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
2.58 (taugs)	2.8 (nats)	0.4 (nats/char)
2.58 (taugs)	4.0 (bits)	0.6 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Paris route F (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **ooooLoooRLooooooooO**
length (chars): 19

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
7.58 | 6.17 (taugs)	12.79 | 9.32 (nats)	0.67 | 0.490 (nats/char)
7.58 | 6.17 (taugs)	18.45 | 13.44 (bits)	0.97 | 0.707 (bits/char)

Paris route F (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRL**
length (chars): 3

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
2.00 (taugs)	2.1 (nats)	0.7 (nats/char)
2.00 (taugs)	3.0 (bits)	1.0 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Appendix D (contd.) - String Computation with T-Calc

http://130.216.197.3/cgi-bin/wtcalc?textline=0000 and http://tcode.auckland.ac.nz/tutorial.html
Courtesy of Dr Mark Titchener

SAN FRANCISCO

San Francisco route D (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **oooooLoooooooooOLoR**
length (chars): 18

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
7.32 | 6.32 (taugs)	12.12 | 9.67 (nats)	0.67 | 0.537 (nats/char)
7.32 | 6.32 (taugs)	17.48 | 13.95 (bits)	0.97 | 0.775 (bits/char)

San Francisco route D (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LLR**
length (chars): 3

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
2.00 | 1.58 (taugs)	2.1 | 1.7 (nats)	0.7 | 0.5 (nats/char)
2.00 | 1.58 (taugs)	3.0 | 2.4 (bits)	1.0 | 0.8 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

San Francisco route E (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **oRooLoRoLooRoLR**
length (chars): 15

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
6.58 | 7.00 (taugs)	10.29 | 11.31 (nats)	0.68 | 0.754 (nats/char)
6.58 | 7.00 (taugs)	14.84 | 16.31 (bits)	0.98 | 1.087 (bits/char)

San Francisco route E (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **RLRLRLR**
length (chars): 7

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
3.58 (taugs)	4.2 (nats)	0.6 (nats/char)
3.58 (taugs)	6.1 (bits)	0.8 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Appendix D (contd.) - String Computation with T-Calc

http://130.216.197.3/cgi-bin/wtcalc?textline=0000 and http://tcode.auckland.ac.nz/tutorial.html
Courtesy of Dr Mark Titchener

NEW YORK

New York route B (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **RoooLooooRoooo**
length (chars): 14

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
5.00 (taugs)	6.7 (nats)	0.4 (nats/char)
5.00 (taugs)	9.7 (bits)	0.6 (bits/char)

New York route B (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **RLR**
length (chars): 3

T-COMPLEXITY	T-INFORMATION	T-ENTROPY
2.00 (taugs)	2.1 (nats)	0.7 (nats/char)
2.00 (taugs)	3.0 (bits)	1.0 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

New York route E (string):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRLRLRLRoooLooLRO**
length (chars): 17

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
8.00 | 8.58 (taugs)	13.89 | 15.49 (nats)	0.81 | 0.911 (nats/char)
8.00 | 8.58 (taugs)	20.03 | 22.34 (bits)	1.17 | 1.314 (bits/char)

New York route E (string, contracted):
Computing string T-COMPLEXITY, T-INFORMATION & T-ENTROPY

string processed: **LRLRLRLRLLR**
length (chars): 11

(parsing: forward | reverse)

T-complexity	T-information	T-entropy
4.00 | 3.91 (taugs)	4.9 | 4.7 (nats)	0.4 | 0.4 (nats/char)
4.00 | 3.91 (taugs)	7.0 | 6.8 (bits)	0.6 | 0.6 (bits/char)

N.B. Accurracy for information & entropy is limited for short strings,
due to approximation of bound by the logarithmic integral function, li().

Appendix E

city	route	sample no	junctions total	turns taken	no turn taken	right turns	left turns	double turns	triple+ turns	open spaces
London	a	2	32	13	19	5	8	2	2	4
London	b	none	33	7	26	4	3	0	2	0
London	c	7	30	6	24	3	3	2	0	0
London	d	none	25	9	16	4	5	0	2	2
London	e	none	36	6	30	2	4	1	1	1
London	f	none	35	10	25	6	4	2	0	2
Barcelona	a	none	34	22	19	10	12	3	2	3
Barcelona	b	none	17	2	15	2	0	1	0	2
Barcelona	c	9	41	10	24	2	8	0	2	4
Barcelona	d	1	35	4	31	3	1	1	0	0
Barcelona	e	none	30	14	16	6	8	2	1	2
Barcelona	f	none	28	13	15	5	8	4	1	1
Rome	a	3	31	10	21	5	5	3	0	6
Rome	b	none	27	14	13	8	6	1	1	4
Rome	c	none	32	20	12	12	8	2	1	2
Rome	d	8	24	14	10	8	6	1	1	3
Rome	e	none	33	13	20	8	5	2	1	11
Rome	f	none	34	14	20	6	8	2	1	6
Paris	a	none	20	6	14	5	1	0	1	2
Paris	b	6	17	6	11	3	3	0	0	1
Paris	c	none	13	6	7	2	4	3	0	0
Paris	d	none	21	7	14	4	3	1	0	1
Paris	e	none	15	8	7	3	5	1	0	1
Paris	f	11	19	3	16	1	2	0	0	1
San Francisco	a	none	23	6	17	3	3	2	0	1
San Francisco	b	none	23	14	9	7	7	4	0	1
San Francisco	c	none	20	6	14	1	5	0	1	1
San Francisco	d	4	18	3	15	1	2	1	0	1
San Francisco	e	12	15	7	8	4	3	0	0	0
San Francisco	f	none	19	11	8	6	5	3	1	1
New York	a	none	14	6	8	0	6	0	1	0
New York	b	10	14	3	11	2	1	0	0	0
New York	c	none	14	8	6	4	4	0	0	0
New York	d	none	13	5	8	4	1	0	1	0
New York	e	5	17	11	6	5	6	1	0	1
New York	f	none	15	8	7	4	4	0	0	0

Table of all six routes in all of the six sample cities. The routes that are highlighted in purple were the ones presented in the online survey experiment. They were also used for correlation with string computation measures, syntactical measures from axial graph analysis, and statistical data from the survey responses.