

THE UNIVERSITY OF HULL

THE COGNITIVE REPRESENTATION  
OF THE LARGE-SCALE ENVIRONMENT

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## Abstract

This thesis is concerned with the processes involved in the acquisition and use of cognitive representations of the large-scale environment, or 'cognitive mapping'. The first half of the thesis reviews relevant literature in three main sections. Firstly, the historical roots of the subject are described in chapters on early investigations of wayfinding and orientation, theoretical models of behaviour incorporating the concept of subjective knowledge and multi-disciplinary studies of environmental images. Secondly, studies of group differences in cognitive mapping and initial theoretical frameworks are reviewed. Finally, the current state of research evidence is assessed in relation to four research areas. These concern methodological issues, the structure of internal representations, the process of acquiring new representations and individual differences in cognitive mapping.

The remainder of the thesis reports and discusses four experimental studies of issues which were judged to be inadequately researched on the basis of the literature review. The first compared the utility of free-hand sketch-mapping and three-dimensional modelling with educated, adult subjects. The second investigated the rate of acquisition of cognitive maps, particularly during the first days of environmental experience; using a structured mapping task. Objective accuracy, subjective ratings of accuracy and recall order were examined in relation to building usage and spatial experience. The third experiment compared artificial map learning with spatial relations ability, visual imagery ratings and everyday map usage. Additionally, the effect upon learning of stimulus mode (map or verbal list), response mode and stimulus-response mode

compatibility was measured. The final experiment compared performance upon the 'real-life' mapping task of the second study with the map learning and spatial ability measures used in the third study.

Evidence was found that cognitive mapping, spatial ability and attitudes to navigational problems are positively related. It was concluded that future work should emphasize the process of cognitive mapping and the relationship between map form and practical needs.

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## General Introduction

This thesis is concerned with the process by which people acquire cognitive representations of the environments which they inhabit. This process is more commonly known as 'cognitive mapping', with the resulting representations being known as 'cognitive maps'. In order to avoid any misinterpretation of these terms, the definition provided by Downs and Stea (1973) should be noted, namely:

"Cognitive mapping is a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment."

(Downs and Stea, 1973, p.9).

As such, the phrase 'cognitive map' does not imply that the representation is map-like in structure, only that the information of which it consists can function like a map; it can be used to guide the possessor's spatial behaviour.

The purpose of the thesis is two-fold: to trace the development of cognitive mapping research and to report experimental investigations of a number of issues which emerge from the review.

The psychological investigation of cognitive mapping has evolved from a great diversity of sources. Although in retrospect it can be seen that many of the initial research areas were closely inter-linked, the early work was generally conducted with reference to only a small sub-section of the pertinent literature. This was almost certainly a consequence of the multi-disciplinary nature of cognitive mapping work prior to the 1970's. Researchers tended to cite only publications within their own academic disciplines or closely-related disciplines. It is noteworthy that one of the most influential papers written during

this period was one which drew upon material from a variety of sources and addressed its conclusions to a wide range of issues (Boulding, 1956).

Despite the heterogeneity of this early work, it is possible to attempt a broad categorisation; grouping together studies from several academic disciplines. Much of the very earliest research which is pertinent to cognitive mapping concerned wayfinding and orientation. Such research was conducted by psychologists, educational researchers and geographers; mainly during the first half of this century (Chapter 1). Probably the first experimental analysis of errors in wayfinding belongs in this category (Trowbridge, 1913). This report also incorporated one of the first conceptualizations of an internal representation; termed by the author an 'imaginary map'. Trowbridge's study was followed by several independent investigations of wayfinding phenomena, mainly concerned with compass orientation; evidence being sought for an innate 'sense of direction'. Apart from these studies, most of the early work on wayfinding was done in relation to two specific topics. These were the possibility of improving children's competence in orientation by means of special tuition and assessment of the sensory and navigational capacity of blind people.

In parallel with the early studies of wayfinding, researchers from a number of disciplines were developing theoretical ideas which emphasized the importance of subjective conceptualizations of the physical environment (Chapter 2). Within Psychology, these included the European Gestalt School of the 1930's, as well as individual theoretical contributions by Bartlett (1932), Tolman (1948, 1952) and Piaget (1954). The single most important paper by an economist concerned with subjective knowledge was that by Boulding (1956), as noted above. Another discipline which was gradually coming to realise the importance

of subjective environmental knowledge was Geography; papers by Wright (1947), Kirk (1951) and Lowenthal (1961) being worthy of note.

During the 1960's, these original theoretical ideas were followed-up by empirical studies mainly within the disciplines of Geography and Urban Design. It was the latter discipline which provided probably the most important contribution to the recent history of cognitive mapping research: namely, Lynch's book 'The Image of the City', published in 1960. Lynch's work was the impetus behind the many urban imagery studies of the 1960's (Chapter 3).

At the end of the 1960's cognitive mapping came to be accepted as a research area in its own right; as a sub-field of 'Environmental Psychology' (Chapter 4). The early years of research in this new interdisciplinary area were distinguished by numerous studies of group differences in cognitive mapping performance. These examined the importance of factors such as social class, age, sex and transport methods upon cognitive mapping.

The period from 1973 to 1976 was marked by an increase in attention to theoretical matters. During this period cognitive mapping research gradually widened to include theoretical and experimental analysis of the process of cognitive mapping, rather than being predominantly 'product-centred', as in the 1960's (Chapter 5). Up to the mid-1970's, interest in the development of cognitive maps had been almost exclusively concerned with ontogenetic development; that is, how cognitive representations of the large-scale environment develop during childhood. This area of research was comprehensively reviewed by Hart and Moore in 1973. Two years later, Siegel and White (1975) produced a lengthy review of all developmental work on cognitive mapping. In contrast to Hart and Moore, the later reviewers devoted a substantial section to microgenetic development; that is, to the way in which people acquire

cognitive maps of novel topographical areas. This difference highlights the change in emphasis towards microgenetic development which was occurring during the mid-1970's.

It was possible to identify a number of distinct (though related) issues by 1975; issues which have continued to dominate cognitive mapping research up to the present date. A lengthy paper by Beck and Wood (1976) included sections related to each of these issues (Chapter 6).

The final four review chapters of this thesis are devoted to the four main issues with which cognitive mapping researchers are faced. Given that researchers intend to study cognitive mapping by empirical means, the issue which must be logically considered first is that of methodology. The crucial question here is what type of task should be used to elicit evidence of the hypothesized internal representations.

Most early studies of urban imagery adopted an uncritical approach to eliciting cognitive representations; mainly using sketch-mapping techniques. As the number of studies increased, a wider range of subjects were tested and some researchers, notably Spencer (1973), began to express dissatisfaction with the technique. Spencer's main concern was that the sketch-mapping task was too difficult and unfamiliar for disadvantaged subject groups. Subsequent researchers have expressed more fundamental doubts about sketch-mapping and similar tasks which require people to produce two or three-dimensional representations (known collectively as 'direct mapping' tasks). Chapter 7 reviews the available evidence as to whether or not such tasks lead to distortions in the internal representations. Recent research findings are then considered which cast some doubt upon the relative utility of possible alternative techniques. The general conclusion reached is that the utility of any technique can only be judged within a specific context; taking into account the particular research focus, measurement requirements and subject characteristics.

Chapter 8 considers perhaps the most fundamental question facing cognitive mapping researchers; namely, how is the hypothesized internal representation structurally organized? This question is clearly within the domain of cognitive psychology and is consequently the one which has received most attention in recent years from research psychologists. The acquisition of internal representations of the environment provides an example of cognitive processing which has very high ecological validity (see Chapter 4). As such, it is likely to become of increasing importance in cognitive psychology, given the gradual move towards studying 'real-world' knowledge (e.g. Neisser, 1976).

Despite the methodological problems, researchers have produced evidence of the extent to which cognitive maps reflect the geometric properties of the objective environments which they represent. Numerous studies have found that cognitive maps contain simplifications and distortions of objective topography. In general, it seems that established cognitive maps consist of topological networks; with known places being linked by known routes. The links tend to be simplified into straight lines; with angles between links frequently being recalled as  $90^{\circ}$  turns. Research has also shown that cognitive maps for different scales of environment are hierarchically linked; the networks of a smaller-scale constituting the points of a larger scale representation. This system allows relationships to be inferred from the relative positions of their superordinate units. This system is generally an efficient way of storing a large amount of information but it can lead to erroneous judgements in some cases.

Chapter 8 also considers how the structure of a cognitive map changes during the course of microgenetic learning. When a map is acquired as a result of practical experience, the sequence of learning appears to go from egocentric point-link fragments to an integrated topological network.

Greater experience may then lead to the representations gradually acquiring Euclidean properties. However, some investigations have shown that where knowledge of an area is learned partially or primarily from maps or plans, the representations may possess Euclidean properties from the earliest stages.

Microgenesis is examined at greater length in Chapter 9, reviewing those studies which have required people to perform mapping tasks at various stages of acquiring cognitive maps. The first attempts to examine microgenesis concentrated their analyses on the type of structural changes mentioned above. That is, they looked for evidence of a transition from early sequential mapping (places linked by routes) to eventual spatial mapping (integrated networks of places and routes, approaching Euclidean accuracy). However, the use of simple sketch-mapping tasks for this purpose has proved to be fraught with difficulties, limiting the validity of these studies. It is possible that useful information may be derived from future studies of this type, if certain methodological changes are made; such as monitoring the process by which people produce the sketch-maps, rather than limiting analysis to the end products.

The majority of microgenetic studies reviewed in Chapter 9 have attempted to answer two main questions. Firstly, what type of environmental features are learned and how are these related to the learner's life-style? Secondly, how quickly do such representations develop and does the rate of knowledge acquisition change over time? Unfortunately, most of these studies have methodological inadequacies which limit the utility of their results. In this context, the major source of difficulty has been the type of subjects used. These have often been tourists, a group whose spatial experience and behavioural objectives are likely to differ radically from those of new residents to an area.



A few studies have avoided the main methodological pitfalls and have provided some preliminary evidence concerning the two questions noted above. In the first case, it appears that the environmental knowledge people acquire is largely determined by their individual needs. The evidence on rates of learning indicates that people can rapidly acquire a basic representation of a new environment; within the first few days of active navigation. This representation may consist of an arrangement of only those places which are crucial to the individual's needs, accurate at an ordinal level of measurement. Further learning may then increase the number of places and paths known, as well as 'fine-tuning' the information which is already known. This evidence is in accord with the models of cognitive mapping put forward by earlier theorists, such as Siegel and White (1975; see Chapter 5).

Another weakness of past research was highlighted by Chapter 9; namely, that the tendency to analyse data at a group level may have obscured crucial relationships between subject attributes and environmental learning. The final review chapter (Chapter 10) considers those subject characteristics which have been put forward as potential correlates of environmental learning. These can be put into the three broad categories of environmental experience, specific cognitive abilities and self-assessment of cognitive mapping ability. The general conclusion in the first category is that cognitive mapping of a specific area is enhanced by greater mobility and active travel experience within that area. This conclusion supports the mobility-based interpretation of group differences in mapping performance which was put forward in Chapter 4 of this thesis. It also seems that the distortions of reality to be found in cognitive maps may bear understandable relations to the forms of spatial behaviour which led to their development.

These findings, if proved to be reliable, have important implications in that they suggest the form of cognitive maps may be predictable from knowledge of people's spatial behaviour. If this is the case, then it should be possible to enhance people's representations by exposing them to greater spatial experience, especially in ways designed to offset potential distortions. Ironically, this possibility was actually put forward in a pedagogical context as early as 1916 (Freeman, 1916; see Chapter 1).

Despite the above discussion of the potential enhancement of cognitive mapping by spatial experience, it is commonly accepted that people differ in their aptitude for orientational and way-finding activities. The second and third categories of subject characteristics considered in Chapter 10 refer to two aspects of these individual differences. On the limited evidence available, it seems that performance on psychometric tests of spatial relations ability may be related to cognitive mapping ability. Additionally, map learning ability (at least when tested by direct map recall) seems to be partially dependent upon visual memory ability. These findings are of both practical and theoretical importance. At a practical level, they imply that psychometric tests can be found which will predict cognitive mapping performance to some degree. This would enable individuals to be identified who would be particularly adept at cognitive mapping tasks. Conversely, individuals who are found to lack such ability could be selected for remedial training, tailored to make use of those cognitive abilities which they do have (or possibly to improve their performance on the cognitive mapping related abilities).

At a theoretical level, the correlation between psychometric tests and cognitive mapping performance supports the models of mapping processes which have been put forward. That is, it suggests that people do, in fact,

use cognitive processes such as spatial manipulation of sensory information when they acquire a representation of a new area. It also implies that cognitive mapping tasks may be justifiably used as ecologically valid examples of cognitive processing tasks.

The final category of characteristics considered in Chapter 10 refers to the subjective experience of cognitive mapping. Again, the evidence reviewed is not extensive; but that which is available indicates that people are fairly accurate at judging their own potential expertise on a wide range of 'everyday' cognitive mapping tasks. Also, people who judge themselves to be good at such tasks, claim to be more likely to use secondary sources of information (e.g. maps, guides) and to seek out active navigational experience of novel places. This suggests a way in which small differences in basic cognitive ability may be exacerbated in everyday behaviour. That is, the poor self-assessment may discourage people from seeking out the spatial experience which could improve their cognitive representations.

In the light of the literature review, it will be seen that a number of issues have yet to be adequately investigated. The remainder of the thesis will report and discuss four empirical investigations of several of these issues. The subject pool sampled in the studies will be undergraduate students from one university. It could be said that exclusive use of this category will limit the generality of the experimental findings. To some extent, this criticism must be accepted. However, for present purposes, the use of this subject pool avoids several pitfalls which have flawed earlier studies. These subjects will be relatively homogeneous in terms of educational and experiential background, and will presumably be adequately familiar with maps and plans; so that the mapping tasks will not present great problems. Also, while they will all be of above-average I.Q., they should provide a wide

span of spatial ability; since they have not been selected on this basis. Additionally, it will be possible when necessary, to choose groups who will have had very similar experience of a convenient sized area (i.e. their campus). Places in the relevant area will be of similar functional significance to all subjects, so that pooling the data will be less likely to obscure any correlations between functional significance and cognitive mapping.

Chapter 9, as described earlier, reviewed those studies concerning the microgenesis of new cognitive maps. Some tentative evidence was found that the acquisition of environmental information could be directly related to the person's spatial experience; both building usage and patterns of movement. Also, it appears from the evidence that a large part of such information is acquired during the first days of experiencing the area. However, the evidence for these conclusions was very limited. In consequence, a study of microgenetic learning was carried out to supplement the research evidence and is reported in Chapters 12 and 14.

The review of methodological issues led to the choice of a direct mapping technique for the microgenetic study. However, it was not known whether or not a three-dimensional modelling task would prove more useful than a sketch-mapping task. In order to resolve this problem, Experiment I was carried out (see Chapter 11). The results of this study indicated that given certain refinements, a sketch-mapping task would be adequate for the required purpose.

Chapter 12 reports the main microgenetic study (Experiment IIa), examining building knowledge acquisition by new students on the university campus; comparing performance levels during the first week with those which are ultimately achieved. Equally, differential levels of building knowledge are analysed in relation to building use. The order in which the building positions were recalled is examined in relation to patterns

of spatial behaviour and research evidence on subjective organization in free recall. A 'repeated measures' version of the main study is also reported (Experiment IIb) for comparative purposes.

The second major issue to be examined in the empirical studies is the possibility of a correlation between psychometric tests of spatial relations ability and cognitive mapping performance. In addition to the work reviewed in Chapter 10, a spatial relations test used in Experiment I was found to correlate with certain indices of performance on the cognitive mapping tasks. Experiment III was therefore designed to examine the spatial relations ability-cognitive mapping relationship in greater detail (see Chapter 13). The cognitive mapping task used in this experiment was a simple spatial learning test; judged to be a valid index of everyday cognitive mapping ability. A contrived task was used, rather than a test of 'real-life' learning, to ensure that superior performance was not the indirect result of greater exposure to the experimental area. As well as the main relationship, Experiment III assesses the relationship between cognitive mapping performance and several subjective measures. These are vividness of visual imagery, efficiency at everyday spatial tasks and customary use of maps. These measures were chosen for study as a result of the research findings outlined earlier and reviewed in detail in Chapter 10.

The use of a simple spatial learning task in Experiment III enabled the experiment to examine an associated set of questions. These concern the relative efficiency of spatial information in graphic and verbal forms. Experiment III therefore uses a four-group design, where half the subjects learn a route map and half, an equivalent list of instructions. Half of each group recall the information in the same form as their stimulus and half in the alternative form. Chapter 13 reviews evidence from cognitive psychology research which indicates that graphic stimuli

and stimulus-recall compatibility should produce the best recall scores.

The final study of the thesis (Experiment IV; see Chapter 14) is a follow-up study to Experiments II and III, designed to clarify and extend the results of the earlier work. Each subject performs the 'graphic stimulus-graphic recall' task and the spatial relations test from Experiment III and the cognitive mapping task from Experiment II. Correlations are then determined between each set of data. The subjects used in this study are similar in background/experience to those of Experiment II, but they have had twice as long 'on campus' as the most experienced group in the earlier study. Consequently, their cognitive mapping performance (on the campus-mapping task) provides a useful comparison group for the earlier study.

The final chapter (Chapter 15) discusses the overall findings of the experimental work in relation to previous research. The three main areas of methodology, microgenesis and individual differences are discussed, as well as the issue of stimulus-recall compatibility raised in Experiment III. The final chapter also includes recommendations for future experimental work which could be performed as a follow-up to Experiments I to IV.

The Origins of Cognitive Mapping Research

## Chapter 1

### Wayfinding and Orientation

#### 1.1 Trowbridge's Concept of the 'Imaginary Map'

There has always been a great deal of interest in people's capacity to find their way around the environment. Much of this curiosity resulted from the anthropological reports of early explorers; describing astonishing feats of orientation among primitive tribes as well as disturbing instances of disorientation (see review by Lynch, 1960). Given this general interest in human way-finding, it is not surprising that empirical investigations of the ability were being published by the turn of the century. This material has been well-reviewed by Howard and Templeton (1966).

Perhaps the most-cited of these early studies was that by Trowbridge (1913). The first section of his paper concerned basic methods of orientation. He distinguished between 'domicentric' and 'egocentric' orientation. The former involved the judgement of position by reference to the user's home and was said to be characteristic of animals, birds, children and primitive people. In contrast, the latter involved no link with the user's home but instead, utilised an objective frame of reference based upon compass-point directions. This method had to be learned and was therefore only employed by 'civilised Man'.

The remainder of Trowbridge's paper concerned his concept of the 'imaginary map'. A person was said to possess such a representation if he customarily thought of distant places in other than their true directions. Trowbridge ascribed the vague feelings of disorientation which some people experience when emerging from large buildings to the action of 'imaginary maps'. He presented some experimental evidence that the latter phenomenon was associated with possession of an



'imaginary map'. His technique for assessing 'imaginary maps' was to give each person a circle drawn on paper. The centre of the circle was labelled as the city in which the experiment was taking place. The person was asked to mark the directions to the North Pole and to distant cities around the circle. This general technique is still being used in present-day research (e.g. Kozlowski and Bryant, 1977).

Trowbridge's 'imaginary map' may be seen as the forerunner of the cognitive map. It was formulated to describe the way in which people thought of the world, as was the cognitive map. However, Trowbridge's model differed from its modern counterpart in three main ways. Firstly, the 'imaginary map' was only said to contain directional material; no mention being made of distances, structure or appearance. Secondly, it was defined as "entirely imaginary, and erroneous" whereas a cognitive map is thought of as containing information which varies in accuracy from totally illusory to almost exact. Finally, Trowbridge claimed that an 'imaginary map' described how a person habitually thought of the world, with the explicit assumption that the accurate information was also known. In contrast, a cognitive map has been defined as:

"...an abstraction which refers to a cross-section, at one point in time, of the environment as people believe it to be."

(Downs and Stea, 1973, p.XIV).

Following Trowbridge's work, a variety of researchers concerned themselves with the faculty of human orientation. The studies published before 1960 can be discussed under three main headings:- the pedagogic treatment of orientation, environmental navigation by the blind and the psychological investigation of human orientation.

## 1.2 The Teaching of Spatial Orientation

Numerous early writers had testified to the inability of children to use directional concepts accurately (Gulliver, 1908; Ridgeley, 1922;

Howe, 1931). Trowbridge (1913) blamed the development of 'imaginary maps' upon inadequate early tuition and advocated the use of special techniques to train children in orientational matters. This precipitated several papers describing novel methods for assessing and teaching orientation. Most of these studies were reviewed by Howard and Templeton (1966) and by Hart and Moore (1973). Briefly, the studies showed that giving children factual information (e.g. the direction of the sun at various times of day) improved their performance. It was thought important to seat children in a special manner with compass directions prominently displayed in the classroom and maps correctly aligned with them. An extensive study by Lord (1941) found that children who sat facing North in their classrooms did better than other children on every orientation task.

One noteworthy publication not reviewed by Howard and Templeton was that by Freeman (1916). This article included a broad range of suggestions for improving the teaching of geography. Freeman asserted that the fundamental geographical concept was the 'spatial imagination', or the ability to represent cognitively the spatial properties of the large-scale environment. The advantage of this ability was that it permitted the simultaneous experience of spatial relationships beyond the limits of sight. Freeman advocated the use of aerial views of the local environment to facilitate the development of the 'spatial imagination'. Recent work by Stea and Blaut (1973) has supported this suggestion, by showing that very young children are able to identify environmental features from aerial photographs.

Freeman stressed the importance of drawing maps of the known locality, as a means of learning the principles of symbolic representation and to facilitate progress towards abstract map-use. He suggested that when group excursions were used, a mapping task should be incorporated,

so that every child and not just the group leader would be forced to take note of the directions and distances travelled. In so doing, Freeman anticipated much later findings about the importance of active navigation in the environmental learning process (e.g. Appleyard, 1969; Maurer and Baxter, 1972: see Chapter 4).

In conclusion, Freeman was probably the earliest researcher to consider at length the cognitive representation of the large-scale environment. By presenting the 'spatial imagination' as a storehouse for functionally map-like information, Freeman was approaching the modern concept of a 'cognitive map'. However, like other researchers during this period, he put unwarranted emphasis upon compass orientation and underrated the importance of landmark and route information.

### 1.3 Environmental Navigation by the Blind

#### (i) The Navigational Techniques of the Blind

Much of the research which has been conducted upon the perceptual abilities of the visually handicapped is of relevance to cognitive mapping research. In particular, the questions of which sensory channels substitute for vision in the task of environmental navigation and how the 'cognitive maps' of the blind differ from those of the sighted are of interest.

Most of the research into the navigational techniques of the blind has been published since 1940. One exception was the book by Villey (1930), entitled 'The World of the Blind'. In an early chapter, Villey discussed possible explanations for 'obstacle sensation'; that is, the ability which blind people have to determine the presence of obstacles in their immediate surroundings. He concluded that this is commonly achieved by the use of auditory information, with the proviso that the deaf-blind

may substitute olfaction or facial pressure in its place. In a later chapter, Villey used 'obstacle sensation' as one of his three main classes of orientational technique. The other two classes of techniques which he claimed were used by the blind were 'substitution of the senses' and 'muscular memory'. The phrase 'substitution of the senses' was used to embrace all forms of sensory perception other than the auditory feedback used in 'obstacle sensation'. 'Muscular memory' was said to operate by enabling a blind person to move over a certain distance and then halt at the required destination, without recourse to conscious memory (e.g. when ascending a flight of stairs or traversing a room).

Villey highlighted the importance of prior knowledge of an environment in determining the utility of particular orientational techniques. It was explained that 'obstacle sensation' cannot provide knowledge of a novel environment equivalent to that obtained visually; in a new environment it supplies only general information such as the presence of walls or doorways. However, in a familiar environment in which particular objects are anticipated, it can provide sufficient information for safe navigation. Efficient navigation was therefore said to involve the use of particular techniques to supplement prior knowledge (see also later discussion).

(ii) Experimental Studies of Blind Orientation

Writers from ancient times onwards had theorized upon the nature of blind people's space perception (see von Senden, 1960). However, it was not until the 1940's that psychological investigation commenced. The first aspect of blind orientation to be experimentally examined was 'obstacle sensation' (also known as 'facial vision'). After discounting theories of a 'sixth sense', Dallenbach and his co-workers were able to

provide evidence of what Villey (1930) had asserted earlier; namely, that subtle changes in echo pitch are sufficient to indicate the presence of an obstacle (Dallenbach, Supa and Cotzin, 1944; Worchel and Dallenbach, 1947).

In the 1950's, the interests of empirical researchers expanded to include the more general orientational ability of the blind. One aspect to be examined was the ability to relocate a position in space by following a route not previously used. Worchel (1951) compared the performance of young blind people with an equivalent group of blind-folded sighted subjects. The latter group achieved the best scores and Worchel concluded that this was due to their ability to convert kinaesthetic information into visual images. However, doubts have been raised about the validity of Worchel's results. The experimental setting, an open-air, isolated concrete area, eliminated almost all the orientational cues normally available to a blind person; in particular, the auditory feedback normally obtained by echoes from nearby walls or large objects. The dangers of generalising from artificial settings is shown by comparing Worchel's results with those obtained by Juurmaa (1965). Here, the position-relocation task was performed in a large hallway and blind subjects were found to be superior to blind-folded sighted subjects.

One study which used an ecologically valid setting to examine blind orientation was that by McReynolds and Worchel (1954). Subjects were asked to point to various nearby and distant places, and were also asked for the directions between various pairs of cities. Subjects were most accurate at pointing to local places and to the cardinal compass directions and were least accurate at giving the direction between two distant places. The (blind-folded) partially-blind and the totally-blind performed equally well, as did the adventitiously-blind and the congenitally-blind. The researchers concluded that in their experimental

setting, visual imagery was not necessary for geographical orientation. The researchers also obtained introspective reports of everyday navigational techniques used by their subjects. A wide range of cues were mentioned, largely in accord with Villey's (1930) classification. This abundance of cues rationalises the finding that the possibility of using visual imagery did not appear advantageous. However, it should be noted that all these subjects would have been highly-trained and well-practiced in the use of non-visual navigation. The researchers suggested that in the early stages of learning, or when performing complex tasks, one process (vision) might be superior to another.

(iii) The Environmental Schemata of the Blind

The conclusions of McReynolds and Worchel imply that a blind person will be at the greatest disadvantage (in comparison to a sighted person) when attempting to navigate an unfamiliar environment; since the latter constitutes a highly complex task. Also, the work of Villey (1930) emphasized the crucial nature of prior knowledge of an environment in facilitating efficient navigation by blind people.

It was to highlight this situation that a much later writer Foulke (1971) wrote 'The Perceptual Basis for Mobility'. He performed a comparative analysis of the information which may be acquired by blind and by sighted individuals when moving through an environment for the first time and during repeated traversals. The paper was written with a view to refining mobility training and improving the design of prosthetic devices. However, it also constitutes a useful general exposition on the nature of cognitive representations of the large-scale environment.

Foulke used the word 'schema' to label his concept of an organised cognitive representation, as had several other writers (e.g. Bartlett, 1932;

Piaget, 1954; see Chapter 2). Discussing the nature of an environmental schema in relation to blind mobility led Foulke to emphasize the functional utility of such a representation. This provided a valuable early contrast to the 'city image' research of Lynch (1960) and his followers (see Chapter 3), which emphasized the form of the representation, rather than its function. Indeed, Foulke's description of the development of a schema made explicit its utility for the individual:

".....The selection of information for inclusion in the schema is governed by the individual's needs, and these needs are determined by the nature of his interactions with the environment. The functional significance of this schema is that it greatly reduces the amount of information about a terrain that must be obtained to interact with it successfully ..."

(Foulke, 1971, p.3).

It can be seen from the above discussion that much of the work upon the spatial abilities of the blind is of direct relevance to psychological studies of cognitive mapping. Indeed, the questions about sighted people's schemata which Foulke (1971) put forward contained the essentials of much of the recent work on cognitive mapping. That is, they referred to the structure of schemata (see Chapter 8), the time-period for acquiring a useful schema and the order in which environmental features and spatial relationships are learned (see Chapter 9).

#### 1.4 The Psychological Study of Human Orientation

During the first half of the present century a number of isolated, psychological investigations of particular aspects of human orientation were carried out. Howard and Templeton (1966) provided the most comprehensive review of this diverse material, though Hart and Moore (1973) covered the work on frames of reference and ontogenetic development.

One of the first issues to be examined was the question of whether Man possessed an innate awareness of magnetic direction. This possibility had been considered at least as far back as Darwin (1859) but little evidence had been gathered for such a faculty. Howard and Templeton concluded from their review that there was no good evidence for such a magnetic sense. It is noteworthy that this controversy has been revived recently by the work of Baker (1981). Baker professes to have obtained evidence of a magnetic direction sense in humans. However, doubts have been raised regarding the validity of Baker's experimental design and several research projects in the U.S.A. have failed to replicate his results.

Howard and Templeton reviewed a few studies which examined the way in which people tend to align maps of their local environment. Two basic methods were found; one which took the person's own orientation into account and another which related map orientation to the actual orientation of the environment. The reviewers posed two important questions in relation to this finding. Firstly, did these individual differences reflect different abilities, or simply personal preference? Secondly, if people did differ in their ability to use a particular orientational method, was this the result of basic cognitive processing differences or simply differing experience? It is only in recent years that researchers have begun to investigate these questions experimentally (see Chapter 10).

An investigation of direction judgements carried out by Ryan and Ryan (1940) formed a useful follow-up to the study by Trowbridge (1913). In addition to either pointing to or stating various distances, subjects were asked to give introspective reports of their problem-solving methods. It was found that an individual calculated the direction to a far distant place in a series of steps; taking into account his orientation at the



small-scale in relation to each successively larger-scale environmental unit. Such a process would be anticipated by the present-day concept of hierarchically-organised spatial representations (see Chapter 8). Ryan and Ryan grouped the subjective methods into a small number of categories, including 'imaginal travelling', 'maps and air-views' and 'orientation deduced from (or held in) verbal formulae'. It would have been interesting if the researchers had attempted to relate the introspective reports to details of how each subject had originally learned each piece of information (see Chapter 8).

One psychological analysis of human way-finding which was not reviewed by Howard and Templeton was by Griffin (1948). Although at a purely speculative level (no empirical evidence being reported), his discussion formed an insightful analysis of the nature and function of 'schemata' as navigational aids. He stressed the need for functionally-efficient (rather than geographically-accurate) schemata and described the types of distortion and simplification of information which have since become important issues in cognitive mapping research (see Chapters 5, 6 and 8). He listed a number of factors likely to influence the efficiency of learning a new environment, including individual differences in 'sense of direction', amount of practice and mode of travel. All these possibilities have been confirmed by subsequent research (see Chapters 5, 6 and 10).

In short, many of the current topics and findings in cognitive mapping research were anticipated by isolated publications prior to 1960. However, in the absence of an organised research field, these papers remained unco-ordinated and obscure until the 1970's.

### 1.5 Spatial Orientation Research in the U.S.S.R.

During the period when the previously-reviewed work was being performed in the West, a parallel series of investigations was being conducted by Soviet researchers. As might be expected, access to reports of this research is somewhat limited, so that a detailed examination of the results will not be included in the present review. It is fortunate that one extensive review of the Soviet work has been written by Shemyakin (1962). From Shemyakin's review, it can be seen that Soviet researchers were concentrating upon the same general areas as Western researchers during this era. These were the ontogenesis of spatial knowledge, methods for teaching orientation and the spatial knowledge of the blind. In the last context, a further review is available. Zemtsova (1969) contains mainly work on perception of small-scale space but some research upon large-scale knowledge is included.

The research findings and theoretical discussion described by Shemyakin is largely in accord with the Western work reviewed previously. However, it seems that Soviet researchers were somewhat in advance of Western ones in their conceptualization of environmental representations. The emphasis upon the process of representing the environment, the stress upon 'active' modes of experience and the linking of representational form with practical needs were all characteristic of Western research a decade later. In addition, Shemyakin was one of the first writers to distinguish between sequential and spatial methods of representing an area. He concluded that route-mapping was the developmental predecessor of survey-mapping, both in ontogenesis and microgenesis. This conclusion is still considered valid today, at least where knowledge derived solely from practical experience at the topographical scale is concerned. Shemyakin distinguished between representations at different environmental

scales and noted the increased use of verbal labelling and survey-type knowledge at the largest scales (inter-urban, world 'maps').

Overall, the Soviet research formed a useful supplement to Western research during early development in the cognitive mapping field.



## Chapter 2

### Subjective Knowledge of the Environment

#### 2.1 Introduction

During the middle years of the present century, researchers from several social sciences became dissatisfied with the models of human behaviour which had been adopted by their disciplines. In all cases it was assumed that behaviour could be explained by evaluating the objective environmental influences acting upon a person. The dissenting researchers felt that such a theoretical framework was inadequate because it failed to take into account the different ways in which people interpreted the same objective environment. The researchers felt that it was this subjective interpretation which was crucial in determining behaviour, rather than the objective parameters which were currently being studied. The growth of this viewpoint may be seen in three main academic disciplines: psychology, economics and geography.

#### 2.2 Psychology

The way in which the objective or 'real' world is experienced by human beings was considered to be a major aspect of nineteenth century psychology. Both the Introspectionist Psychology of Wundt (1907) and the Functional Psychology of James (1890) took subjective experience as their central issue. Galton published the results of a questionnaire study of visual imagery as early as 1883. However, from the early years of the twentieth century onwards, the Behaviourist School founded by Watson (1913) sought to eliminate from investigation any phenomena which could not be objectively measured. As a consequence, U.S. and British experimental research into subjective experience was greatly diminished

until the 1960's; with a few noteworthy exceptions, such as Bartlett (1932) and Tolman (1948).

(i) Gestalt Psychology: the 'Behavioural Environment and the 'Life-space'

The revival of interest in subjective experience may be attributed to the work of the European 'Gestalt' school of psychologists. The work of Koffka (1935) and Lewin (1936) has been of particular importance; though it should be noted that many of their ideas were influenced by and in turn influenced, the ideas of the U.S. researcher Tolman (1932, 1948). Koffka (1935) described the 'behavioural environment' as the intervening construct between behaviour and the geographical environment. Using this framework, a person's interaction with his environment could be assessed in two ways. The first of these would be his objective behaviour in the geographical environment and the second, his subjectively-defined behaviour in his behavioural environment. 'A man standing in a large stone building' would exemplify the former; whereas 'a man praying in his local church' might be an alternative subjective description. Koffka believed that in order to understand or to predict behaviour, psychologists would have to consider that behaviour within the 'behavioural environment' of the person concerned.

The need to incorporate subjective experience into any explanation of behaviour was most extensively argued by Lewin (1936, 1951). Lewin believed that a person's behaviour was only to be understood by examining his 'life-space'; this being an hypothetical field consisting of the person and the environment as understood by him. The 'life-space' was conceived of as the psychological equivalent of a mathematical field, composed of a large number of forces acting upon a person. These forces could originate from either the person or his environment (social and physical - as represented in his life-space).

Lewin's work was of great importance in two main ways. Firstly, it emphasized the role of subjective interpretations of the environment in influencing behaviour. A person's behaviour was said to be determined by his cognitive structuring of the environment, rather than by objective aspects of the environment alone. Secondly, it highlighted the need to consider the social and physical context within which any observed behaviour took place. This concern was shared by other 'field' theorists and led to a greater emphasis upon making psychological experiments more representative of 'real-life' situations (cf. Brunswik, 1956; Chapter 4).

(ii) Tolman's 'Cognitive Maps'

It is likely that the theoretical ideas of Lewin and Koffka were the main impetus behind Tolman's origination of the 'cognitive map' concept. Tolman's experimental background was in animal learning studies, in particular maze learning in rats. Even so, the theory which he put forward to account for the results of his experiments had considerable relevance to human psychology. The human implications were discussed in more detail in his later writing (Tolman, 1952); though he did devote the final section of his 1948 'cognitive maps' paper to the implications of his theory for human behaviour.

In analysing the animal learning experiments, Tolman (1948) made two related assertions. Firstly, that complex cognitive processing of environmental stimuli took place before a rat learned to navigate a maze successfully. Secondly, that this processing involved the assimilation of environmental information into a 'cognitive map', incorporating details of routes and the positioning of particular items. While these assertions were contrary to the 'stimulus-response connection' theories of the Behaviourists, they were clearly in accord with Lewin's concept

of the 'life-space'. Those aspects of the rat's environment which it had learned about could be said to have become part of its 'life-space'.

In later writings, Tolman (1952) expanded upon his concept of a specific 'cognitive map' of an environment, to include a person's generalized knowledge of his total environment. He formulated the concepts of 'behaviour spaces' and 'belief value matrices' to account for people's behaviour; concepts which together were quite similar to Lewin's 'life-space'. A person's 'behaviour space' was said by Tolman to include his total spatial knowledge of the environment, at one point in time. His 'belief value matrices' were said to consist of his learned evaluations and conceptualisations of the objects in his behaviour space.

In retrospect, it can be seen that Tolman's work formed a link between the psychologists concerned with subjective knowledge and the multi-disciplinary researchers concerned with way-finding and orientation. However, it was not until the early 1970's and the development of 'environmental psychology' that this link was fully acknowledged (see Downs and Stea, 1973).

### (iii) Bartlett's Memory 'Schemata'

One British psychologist who found it necessary to postulate that people interpret the objective world in different ways was Bartlett (1932). He judged his early work on remembering, within the framework of the objective, experimental tradition, to be unsatisfactory. He saw that using simplified 'nonsense' material, chosen to minimise differences in subjective meaning, would not draw upon those processes used in 'everyday' remembering. Conversely, if 'everyday' learning material was used, then it could not be assumed that each person was being

presented with equally meaningful material. Despite the latter drawback, Bartlett used meaningful visual and verbal material, and formulated a theory of remembering from his experimental results.

In Bartlett's view, remembering was an act of construction, rather than the recall of individually-stored, invariant memory traces. In recalling, he said that a person drew upon 'organized settings' of past experiences, or 'schemata' (Bartlett adopted the word from the work of Head (1920), the physiologist). The results of Bartlett's recall experiments showed evidence of distortion, simplification and elaboration of material in line with the subject's personal interests. These effects were said to be the result of the schemata-based memory process, whereby the material remembered was that which was readily accepted by the person's schemata. The outstanding details recalled by a person would be those which were highly valued as a result of his own interests.

Bartlett's model of memory is largely in accord with the work of subsequent writers, who have also developed models of cognitive processing which depend upon internal structures such as 'schemata' (e.g. Neisser, 1976; see Chapter 5). It can be seen that the 'cognitive map' as described by Tolman (1948) and others, is a specialized type of schema, a view which has been elaborated by Neisser (1976).



(iv) Piaget's Cognitive 'Schemata'

Piaget, the developmental psychologist, also utilised the concept of a 'schema' in his theories. However, since Piaget's work was predominantly concerned with fundamental spatial concepts and exclusively, with ontogenetic development, his work will not be reviewed in this thesis. His research has, in fact, been extensively reported and reviewed elsewhere. Those studies which have discussed the development of large-scale environmental representations ('topographical schemata' in Piaget's terminology) are by Piaget, Inhelder and Szeminska (1960) and by Piaget and Inhelder (1967). A detailed review of those aspects of Piaget's work that are relevant to cognitive mapping research has been provided by Hart and Moore (1973; see also Chapter 5).

2.3 Economics

Economic theory has traditionally been developed by assuming the validity of a simplified model of human behaviour. Several economists during the first half of the twentieth century began to examine psychological literature with the aim of developing a more sophisticated model of human behaviour. Initially, this strategy did not appear to be very profitable, since the psychological literature of the time was dominated by Psycho-analysis and Behaviourism (see Katona, 1951). However, the work of the Gestalt 'field' theorists did seem to have some relevance for economic theory. Its concentration upon 'molar' units of complex behaviour (see Tolman, 1932) and its emphasis upon subjective experience made the work of great significance to the problems being faced by the economists.

(i) Boulding's 'The Image'

Undoubtedly the most influential and far-reaching publication by an economist in the field of subjective knowledge has been Boulding's book 'The Image' (1956). The book began by asserting that a person's behaviour depends upon his subjective knowledge of the world around him. Boulding chose to refer to the totality of this knowledge, about the social and physical environment as 'the Image'. By using the term 'Image', Boulding was not implying anything about the form or structure of this knowledge; rather, he was simply using it to label an unspecified knowledge base, an internal representation of the objective world.

In Boulding's model, the acquisition of new information did not necessarily involve a straight-forward addition to the Image. New information could affect the Image in a number of ways. As well as simple addition, new information could clarify part of the Image, or conversely, make it more uncertain. The most dramatic potential effect of new information was termed 'revolutionary change'; whereby particularly important information would lead to a total re-structuring of part of the Image. A similar model of learning has been put forward by contemporary psychologists (see Rumelhart and Norman, 1978).

Like the psychological 'field' theorists (see earlier sections), Boulding believed that the Image would have both 'fact' and 'value' components. The 'value' component was conceived of as an hierarchy of scales, rating the worth of parts of the Image according to various criteria. These 'value' scales were said to be the crucial elements determining the effect of new information upon the Image. They would make parts of the Image far more stable and therefore, far more resistant to change than other parts. It follows from the existence of the value system, that people do not deal with 'facts' in any absolute sense;

since their acceptance of information is influenced by subjective evaluation. However, Boulding accepted that people share many aspects of their Images with each other, enabling them to interact successfully.

In the remainder of his book, Boulding explored the role of the 'Image' in such diverse fields as biology, economics and history, differentiating between public and personal images and emphasizing the role of language in the development of common images. However, it is the initial chapters of Boulding's book which have been most influential; wherein he described his general idea of the 'Image'. Not only are his ideas in accord with those of the psychological 'field' theorists but also, his work has much in common with cognitive psychologists' theories about knowledge structures (e.g. Neisser, 1976).

Two of the most important publications to result from the influence of Boulding's 'The Image' were 'Plans and the Structure of Behaviour' by Miller, Galanter and Pribram (1960) and 'The Image of the City' by Lynch (1960). The first of these was written by psychologists who believed that there was a need to supplement work on subjective knowledge with an analysis of how such knowledge is utilised to guide behaviour. They developed the notion of a plan as analogous to the program that guides the behaviour of a computer. The book by Lynch reported his work on urban imagery and was the impetus behind the whole area of urban imagery studies in the design profession (see Chapter 3).

#### 2.4 Geography

It has been mentioned above that Boulding's book 'The Image' was very influential in the multi-disciplinary development of subjective knowledge research; despite Boulding's own belief to the contrary (Boulding, 1973, p.xi). One discipline which has explicitly adopted

his concept of the environmental image is geography (see Gold, 1980, p.38).

A major article in which the influence of both Boulding's book and Lynch's book may be clearly observed is Lowenthal (1961). Lowenthal's paper marked the beginning and possibly potentiated the sudden growth of image studies in geography during the 1960's. Drawing on a wealth of material from numerous academic disciplines (anthropology, philosophy, sociology, psychology, geography) and from literary and travel sources, Lowenthal discussed the nature of environmental images and their relationship with the real world. Expanding upon many of the themes in Boulding's book, Lowenthal presented a convincing account of the importance of subjective knowledge in geography. He discussed the extent to which some images are the 'personal worlds' of individuals, some are common to a cultural group and others to an entire species. The roles of language and acquired knowledge in shaping images were also analysed; with the acquired knowledge being anything from formal science to the folk-lore and mythology of primitive societies. Drawing mainly upon psychological studies, Lowenthal outlined the ways in which physiological and psychological factors determine the extent and detail of individual images.

While Lowenthal may have provided geographers with the most cogently-argued and comprehensive case for accepting 'subjective imagery' as a legitimate study area, the origins of geographical interest in this area can be traced back to earlier theorists. The quotation with which Lowenthal began his paper came from a speech made by Wright in 1947, namely:

"The most fascinating terrae incognitae of all are those that lie within the minds and hearts of men."

(Wright, 1947, p.15).

Wright put forward the idea that since geographers had explored most of the earth's land-spaces, they should start to examine the subjective world; that is, the geographical environment as construed by Man. He advocated the incorporation of diverse sources of information to achieve an understanding of what he called 'terrae incognitae'. It can be seen that Lowenthal had followed the recommendations of Wright, both from the emphasis of his paper and from the diversity of his sources.

In the same year that Katona published his book on the relevance of psychological theory for economic behaviour, an historical geographer propounded an equivalent argument for his own discipline. Kirk (1951) distinguished between the objective and the behavioural environments, with the latter being a psycho-physical field of structured knowledge about the objective environment. Kirk emphasized that the acceptance and evaluation of any information about the objective environment would be mediated by socio-cultural values, which would vary over time as well as between groups of people. In this assertion, Kirk was partially anticipating the ideas to be put forward by Boulding some five years later. However, Kirk concentrated upon the group level of analysis, omitting the question of how individuals may differ in their 'behavioural environments'. Presumably, this omission was a consequence of the aggregative tradition within geography, in particular the geographical study of human spatial behaviour. Another problem with Kirk's theory stems from his use of geographical traditions; namely, his belief that the 'behavioural environment' formed the basis for rational decision-making. During the period when Kirk was formulating his theory, the assumption of rationality was accepted by human geographers in the same way as it was by economists (see previous discussion).

## Chapter 3

### Multi-disciplinary Image Studies

1960-1969

#### 3.1 Introduction

The period from 1960 to 1969 was marked by a rapid increase in the number of man-environment interaction studies carried out within individual disciplines; culminating in the development of the inter-disciplinary field of 'Environmental Psychology' at the end of the 1960's. A large proportion of these studies were directly concerned with environmental imagery.

In order to clarify any review of multi-disciplinary image studies, it may be useful to consider the three components of the environmental image which were proposed by Pocock and Hudson (1978). The 'designative' image is that which includes information as to the physical nature of the environment, describing the elements of an image and their spatial inter-relationships. The 'appraisive' image refers to how a person assesses the environment, including absolute evaluation, relative preference and affective responses. The final image component, according to Pocock and Hudson, was the 'prescriptive'. This was described as the predictions and inferences which give to the overall image:

".... a depth, continuity, pattern or meaning beyond that justified by experience of a particular scene alone.."

(Pocock and Hudson, 1978, p.30).

Any attempt to measure one of these components alone would be necessarily somewhat artificial; since the basic model of an 'image' is one in which the three components outlined above interact with one another (see Boulding, 1956; Lowenthal, 1961; Lynch, 1960). In spite of this, much of the research into environmental images has tended to concentrate upon either designative or appraisive aspects of the image.

The designative image has become the primary focus of cognitive psychologists who are interested in the cognitive processes underlying environmental learning. Recently, cognitive psychologists have begun to study the prescriptive component; modelling cognitive processes in terms of 'production rules', which people are thought to use in navigating their environments (e.g. Kuipers, 1978; Clayton and Woodyard, 1981). In contrast, the main concern of geographers, sociologists and urban designers has been the appraisive image. Their interest in the image resulted from its explanatory value; as an intervening variable between the environment and behaviour. This differential emphasis has been highlighted by the particular techniques of data collection and analysis which have been used.

The following review will show that those disciplines which performed most of the environmental image studies during the 1960's were not necessarily the ones which had put forward the need for a 'subjective approach' prior to that decade. For example, psychological research into large-scale environmental knowledge during the 1960's was severely restricted. Conversely, urban designers took their inspiration from other disciplines and carried out a large number of urban image studies.

### Research within Individual Disciplines

#### 3.2 Geography (see also Chapter 2)

Within geography, image studies have varied between those conducted primarily by geographers alone and those which have led to the establishment of interdisciplinary research projects. The first of these categories includes work on what is usually termed the 'natural environment' (as opposed to the 'built' or 'man-made' environment) and work on images of regions and countries. The second category is composed primarily of urban image studies.

(i) The Natural Environment

One approach to environmental imagery which probably gained its inspiration from the work of Wright (1947) and Lowenthal (1961) is the 'phenomenological' approach. The theoretical underpinnings of this approach are that it is necessary to examine the symbolic meaning of the environment and that the traditional positivistic methods of the physical sciences are inappropriate to such a task. Instead, the phenomenologists have studied literary and anthropological sources as a means of examining the differing ways in which particular cultures have endowed their environment with meaning (see Tuan, 1971; Mercer and Powell, 1972). In addition, historical geographers have followed the recommendations of Kirk (1951) and examined documentary evidence of images changing over time (e.g. Lewis, 1972).

In contrast to the phenomenological, non-empirical study of landscape, some geographers have undertaken to look at human responses to the landscape from an experimental standpoint. Their aim has been to provide information which can be of use to planners and landscapers. They have employed both behavioural observations and interview techniques to obtain preference information (see Gold, 1980).

As well as the landscape imagery studies outlined above, a substantial body of research has developed from early work upon human adaptation to flood plains (see review by Gold, 1980). These investigations have now covered the full range of major environmental hazards (see Burton, Kates and White, 1978).

(ii) Regional and World Images

Once the concept of an image had been introduced into geographical thinking, researchers began to consider how images of 'macro-spaces' (regions, countries, continents) might affect the types of spatial



behaviour customarily studied by geographers (mainly migration and relocation). Although there was no evidence of a direct causative link between image and behaviour, researchers thought it sufficiently likely to warrant empirical investigations (see Gould, 1966). The aggregative tradition within geography meant that the majority of studies used a group level of analysis; comparing images of different cultures, age groups and social classes.

Three main techniques have been used to study people's designative and appraisive images of macro-spaces. Perhaps the most extensively used technique has been that devised by Gould (1966): subjects have to rank order lists of places in order of preference (usually in terms of residential desirability) and then the aggregated results are converted into a score for each location. The scores are then plotted onto veridical maps of the relevant countries to give contoured 'preference surfaces'. A variation upon this technique uses free recall of place names to enable construction of so-called 'information surfaces'; giving a measure of designative rather than appraisive images. Another technique was devised by Cox and Zannaras (1970). This required subjects to take each of a list of places in turn and to give the names of three places (at the same scale) which they consider to be most similar to it. These data were then aggregated and factor analysis permitted the researchers to assess the nature of their subjects classification schemes. In contrast, Saarinen (1973) used a simple, free-hand sketch-mapping technique in his cross-cultural study of 'world views'.

While these techniques have undoubtedly provided much information of interest, each one of them has its own drawbacks. Saarinen's sketch-mapping has all the problems which have been considered at great length in relation to urban-scale mapping (see Chapters 5 and 8). Cox and Zannaras' technique places the responsibility for interpretation

upon the researchers to an extent which may be unacceptable. For example, if a group of people link 'New Hampshire' and 'New Jersey' together on a consistent basis, are they linking the states spatially (north-east U.S.A.), conceptually (New England), verbally (begin with 'New') or by all three links? Gould's technique is useful but very limited, in that it only examines one small aspect of people's possible spatial image (i.e. residence preference or place-name recall). Also, it brings with it a danger of conceptual simple-mindedness, wherein the artificial 'surfaces' become known as 'mental maps', when they do not actually have any 'mental' component, other than the source of the original data.

### (iii) Urban Imagery

As mentioned earlier, much of the urban imagery research conducted by geographers has tended towards inter-disciplinary topics and as such, will be reviewed in greater detail in subsequent sections and chapters. However, the range of topics and empirical techniques can be outlined.

Economic geographers have undertaken a number of investigations of retailing environments, examining the images of both consumers (Downs, 1970; Hudson, 1974) and retailers (Harrison and Sarre, 1975). These studies concentrated upon the appraisive aspects of the image, since it was thought that such responses would be more important in making decisions about spatial behaviour. Techniques such as 'semantic differential' scales and 'repertory grid' testing were used. In contrast, some geographers looked at designative aspects of environmental images, as potential sources of influence upon consumer behaviour. The main image component to be considered in this context has been 'cognitive distance'; with researchers examining how appraisive aspects of the retailing image might affect the cognised distance to the retailing centres from the subjects home (see Thompson, 1963). The investigation of cognitive

distance was generalized from the retailing environment to any form of inter- and intra-urban distance judgements. Much work has been done upon factors influencing distance judgements and on possible mathematical descriptions of the relationship between cognitive and objective distance (see review by Briggs, 1973).

The way in which social groups are distributed in the urban environment and the influence of the physical environment upon socio-spatial behaviour gradually came to the attention of geographers towards the late 1960's. Early geographical interest in the concept of 'social space' can be traced to the writing of Sorre in the 1940's and 1950's (see review by Buttner, 1969). However, geographers did not begin to follow up this initial interest until some twenty years later. Most of the early research in this area was carried out either by sociologists or by those concerned with town planning (see later sections and review by Lee, 1976). Even so, a few geographers did begin to conduct investigations of 'social space', notably Boal (1969, 1970). He compared the spatial behaviour of the two main religious sects in Belfast; finding that both patterns of residence and spatial activity served to maximise segregation. Strong boundaries were noted between areas and spatial behaviour patterns avoided crossing these physical boundaries.

During the 1960's and early 1970's there was a general movement within geography towards the production of research which would be of use in public planning and policy-making. As a result, a number of geographers undertook to examine images of urban environments within the 'city image' paradigm originated by Lynch (1960). Notable examples are Eyles' (1968) study of images of Highgate Village, London, Klein's (1967) study of images of Karlsruhe and Goodey's (1974) studies of images of Aberdeen, Hull and Birmingham.

### 3.3 Sociology

#### (i) Urban Ecology

The Chicago school of urban ecology, founded by Park (1916, 1925) was characterized by a strong interest in the effect of the urban environment upon human behaviour. This group of 'social ecologists' examined the way in which behaviour patterns, as related to particular social groups, were distributed throughout the urban environment. They examined how communities and social classes were spatially distributed and socially structured in distinct areas of the city (see Strauss, 1961). As well as the influence of the physical environment upon socio-spatial behaviour, some sociologists looked at the way in which cultural factors and social values influenced the importance of physical parameters (most notably Firey, 1947). Webber (1964) considered the differing physical ranges of social behaviour exhibited by the upper and lower social classes. The former were said to increasingly constitute 'non-place communities'; travelling over large areas to conduct their social lives. In contrast, Webber saw working-class communities as being strongly tied to their physical neighbourhoods, with regard to their everyday lives. The above-mentioned ideas served as the impetus for a large number of sociological surveys, mainly examining the socio-spatial behaviour of social groups (see review by Gold, 1980).

#### (ii) Subjective 'Social Worlds'

Underlying the notion of 'social worlds' was the belief that people held distinct images of the different areas within their city; these images serving to perpetuate the existing socio-spatial order. Strauss (1961) wrote that the 'orbits' or socio-spatial behaviour patterns of people in a social group were similar because they had similar spatial

representations of the city; particular places had the same 'symbolic function' to members of the group. This idea was examined empirically by Orleans (1973), in his cognitive mapping study of the images of Los Angeles held by different social groups (see later chapters).

Chombart de Lauwe (1952) extended the ideas of the geographer Sorre (see previous section) to take into account subjective views of 'social space'. Sorre had used 'social space' to describe the objective physical environments inhabited by particular social groups: de Lauwe saw the need to differentiate between subjective and objective 'social space'. The former was the physical area as perceived by members of the indigenous social group. In an investigation of the 'social spaces' of Paris, de Lauwe (1952) found that subjective and objective assessments were often disparate; the subjective limits of an area being distorted in accordance with the values and aspirations of the inhabitants (see review by Buttimer, 1969). The tendency to distort boundaries so as to include desirable regions has been supported by other research findings (e.g. Klein, 1967; Eyles, 1968).

In contrast to the number of sociological surveys of group-dependent socio-spatial behaviour, only a few sociologists looked at subjective images of local areas, as did de Lauwe. The few research projects which were carried out before 1970 have been reviewed by Lee (1976).

### 3.4 Psychology

Psychological investigations of large-scale environmental cognition were very sparse during the 1960's. The decline in popularity of the Gestalt school and the strong laboratory tradition of Anglo-American psychology meant that 'real-world' learning situations were rarely considered as viable research areas. Two important exceptions to this general rule may be discussed: the 'neighbourhood' research of Lee (1954, 1964, 1968) and the 'behaviour setting' research of Barker (1965, 1968).

(i) The Neighbourhood as a Socio-spatial Schema

Lee's investigation of 'neighbourhood' cognition, undertaken in 1954 (though not widely reported until 1964, 1968), had a seminal influence upon both applied and theoretical disciplines. It showed that 'neighbourhood' was a psychologically significant phenomenon, which could be examined by a direct mapping task. In so doing, it led to a greater willingness among planners to incorporate the public's viewpoint into new town development plans. As a consequence, many research projects were carried out, mainly in the late 1960's and early 1970's, with the aim of discovering how the general public cognised their local environment (see reviews by Spencer, 1973; Lee, 1976). In the realm of cognitive mapping theory, these local area studies focussed the attention of researchers upon methodological problems inherent in direct mapping tasks. This precipitated a more sophisticated approach to externalising cognitive representations, taking into account the differential capabilities of the subjects (see Spencer, 1973; Mercer, 1975).

The impetus behind Lee's study lay in the post-war boom in the use of the 'neighbourhood unit' design in town planning. Originated by Perry in 1929, this involved housing 6,000 to 10,000 people in a distinct physical area, with central facilities (e.g. school, hall), interspersed open spaces, peripheral shops and arterial boundary roads. Lee noted that there was very little empirical evidence to validate these radical planning decisions. There also appeared to be some confusion as to whether people conceived of a 'neighbourhood' as a group of people or as a physical area. Lee decided that the best way to investigate the salience of the neighbourhood concept was to ask people directly, i.e. to examine subjective representations.

The study involved conducting over 200 interviews with female subjects, during which they were asked to delimit their neighbourhood on an objective base-map. The rest of the interview concerned shopping behaviour, club membership, location of friends' homes and details such as spouse's place of work. Approximately 75% were able to perform the map-drawing task. A number of observations and analyses were made upon the group data. The subjects appeared to consider 'neighbourhood' in terms of both social factors and physical space, these two being inextricably linked. Although neighbourhoods varied greatly between subjects, certain trends emerged. The most common size was around 75 acres; with the size being independent of population density. Three types of neighbourhood were differentiated; the 'social acquaintance', the 'homogeneous' and the 'unit'. The size and content of the maps were found to be significantly related to those aspects of socio-spatial behaviour which were assessed in the interviews. To enable comparison of neighbourhood sizes from different localities, Lee devised a 'neighbourhood quotient' (NhQ). This was the ratio of the number of elements in a person's 'schema' (this term was chosen after 1954 to describe the cognised area; in accord with Bartlett's (1932) usage) to the number of elements in the locality. The NhQ was therefore used as an index of 'social participation'. It was found to be related to social class, age, length of residence, place of husband's work and heterogeneity of social class.

These results enabled Lee to put forward practical recommendations as to the desirable parameters of prospective 'neighbourhood units'; the results of the study having confirmed the utility of this design in promoting a high level of social participation. Despite subsequent criticisms of the boundary-delineation task (see Spencer, 1973: discussion in Chapter 4), this study had a major influence on the development of neighbourhood cognition research.

(ii) Barker's 'Ecological Psychology'

The second major psychological contribution of the 1960's did not actually involve any direct examination of environmental cognition. Barker's 'ecological psychology' took naturally-occurring overt behaviour as its primary focus. However, Barker's research programme (begun in the early 1950's but most extensively reported in the 1960's) was probably a significant factor in the growth of an 'ecological movement' within U.S. psychology; meaning that 'cognitive mapping' was able to become an acceptable research area for psychologists from the late 1960's onwards.

The theoretical background from which Barker (1965, 1968) derived his inspiration was the work of Lewin (see Chapter 2). Barker believed, as had Lewin, that psychologists should examine 'real-life' behaviour at a 'molar' level of analysis (see Tolman, 1932). That is, in terms of meaningful units of behaviour rather than in terms of 'molecular' behaviour such as sensory or muscular responses. Barker saw the need for psychologists to obtain a 'natural history' of behaviour; since at that time it was not known how often the artificially-induced behaviour of the psychological laboratory occurred in the outside world. Barker was a strong advocate of psychologists adopting a 'transducer' role; observing and analysing natural 'experimenter-free' behaviour. As a means of analysing the behaviour which was observed in these observational studies, Barker developed a theory of 'behaviour settings'. Basically, a behaviour setting consisted of one or more regularly occurring activities (regardless of which individuals were present) in a specific locale.

Much of the research undertaken by Barker and his followers consisted of observing and analysing various behaviour settings, in terms of the behaviour episodes (units) which were found to occur in them. It was



shown that these settings had great power to coerce particular behaviour patterns from people; with behaviour being frequently found to vary more across settings within individuals than vice versa. Barker went on to analyse the effects of having greater or less than optimal numbers of people within a behaviour setting. (Typical behaviour settings which were analysed would be school drama performances, church services and baseball games).

As pointed out earlier, the importance of Barker's work to cognitive mapping research was that it emphasized the need to study everyday behaviour in its spatial context.

### 3.5 Urban Design

#### (i) Lynch's 'The Image of the City'

Lynch's book 'The Image of the City', published in 1960 is generally accepted as the most important single contribution to the development of cognitive mapping research. Although the research project which the book reported was quite modest (in terms of subject numbers), the technique which Lynch employed came to be emulated by many subsequent researchers; initially in the urban design profession and later in multi-disciplinary cognitive mapping studies.

Lynch's method of data collection involved an extended interview with each subject. Small groups of middle-class residents (15 to 30 per city) from each of Los Angeles, New Jersey and Boston were questioned about their cities. They had to describe both the city area and specific routes through it, discuss particular locations and most significantly, draw an outline sketch of the city centre. In order to analyse the data, Lynch devised a five-part classification of city elements:- landmarks, nodes, paths, edges and districts. Since Lynch was primarily concerned with the way in which different city designs affected people, he examined

the data for common elements. The overall 'public images' of each city were therefore illustrated by superimposing the frequently-named or drawn elements on an objective base-map. The size of each element was directly related to the proportion of subjects who included the element in their responses. Different maps were produced from the verbal and the sketched data. In some cases, the similarity between a person's verbal and graphic images was quite low; however, there was considerable similarity between the composite verbal and graphic images. Even so, the maps were found to have a higher threshold for element inclusion, in that the lesser-known items on the verbal image were not included on the graphic image.

Lynch discussed the implications of his results at great length. He observed that image-formation was a two-way process; the environment suggesting possible image structures and the person selecting and organising elements into a more or less coherent whole. The physical features and pattern of a city were therefore thought to be very important in determining the extent to which coherent images could be formed. Lynch developed two constructs so as to facilitate discussion of the physical nature of cities. These were 'legibility' and 'imageability'; the first being a measure of the ease with which an environment can be coherently organised by people and the second, that quality in an element which makes it likely to evoke a strong image. It was claimed that the imageability of an overall city was directly related to its legibility; in particular, an area with a regular street plan would be more likely to evoke a coherent image than would an irregular one. However, while regularity was an aid to the image-forming process, uniformity was not. Lynch stressed that distinctive visual elements in each part of a city would facilitate learning.

Clearly, Lynch's analysis of city imageability and legibility set forth recommendations for the design of new urban areas: however, as

Stringer (1975) pointed out, Lynch's work has been more influential in the evaluation of perception in existing cities than in the design process. Consequently, Lynch's analysis of city elements has been emphasized and re-examined, whereas his insightful analysis of the mapping process has received little attention.

Lynch noted that in addition to legibility, the coherence of an image would depend upon a subject's degree of familiarity with the area. He commented upon the enhanced recall of point elements at decision-points; thereby highlighting the orientational functions of elements. He provided an early analysis of navigating a city in terms of an unbroken sequence of these 'trigger cues'; an interpretation which has been repeatedly confirmed by subsequent work (see Chapters 5 and 8). The overall image of a large area was characterised as either a dynamic sequence of images, related to the experience of traversing the city or as a set of static map-like images, linked by generalities. This model is in accord with later work on models of image acquisition and their effect upon image form (see Chapter 9). Lynch also suggested that recall order in a mapping task might relate to order of image development; which has also been confirmed by later researchers (e.g. Milgram, 1976; Schouela, Steinberg, Leveton and Wapner, 1980).

Two further points raised by Lynch are worthy of note. He suggested that people would possess what he called 'shifting images', enabling them to orient themselves at whatever place, time or scale (e.g. street, city, country) was necessary; in short, they would possess an embedded hierarchy of images. Also, he believed that inter-subjective differences in mapping could be assessed in terms of the differential detail, abstractness and structuring of their mapping products. Both these ideas have been revived and expanded by later work (see Chapters 4, 5 and 8).

(ii) Urban Form and Visual Dominance

In the years following the publication of Lynch's book, several investigations of urban imagery were undertaken in order to confirm and generalize particular aspects of Lynch's work. De Jonge (1962) used a simplified version of Lynch's technique to study subjective knowledge of several Dutch cities. De Jonge found, as had Lynch, that mapping was easiest in areas with regular street patterns and distinctive point elements. Also, both Lynch and De Jonge found evidence that subjects simplify spatial information, eliminating slight irregularities of shape and direction. This process generally facilitated recall but could lead to disorientation in irregular areas (e.g. the five-sided Boston Common and gently curving streets). This 'good figure' tendency has been further investigated by Pocock (1975) and others (see Chapters 5, 6 and 8).

The importance of road travel in the formation of city images (at least in the U.S.) was reflected in two studies of highway cognition. Appleyard, Lynch and Myer (1964) examined their own experiences of highway travel with the aid of various recording techniques such as films, tape-recordings and sketches. They then tested their conclusions by interviewing a group of other travellers. Visual form was taken as the dominant factor and aesthetic value as the main consideration in the study. Their study was followed up by Carr and Schissler (1969) who investigated what people looked at during highway travel and what they recalled afterwards. The study tested the verbal and graphic recall of an urban highway trip; comparing passengers and drivers (new to the route) with regular commuters. In general, subjects recalled the same elements. Greater familiarity increased the number of elements recalled but not their relative importance. The items recalled were usually ones which had been fixated during the trip. However, there was a consistent difference between the memory and visual fixation relative orders for

the elements. Elements which were easy to name or verbally describe were more often recalled than fixated, whereas the reverse was true for elements which could not be easily named. While this effect may have been partially due to the verbal bias in the recall methods, the researchers viewed the effect as having implications for memory coding theory (cf. discussion in next section). Finally, a strong correlation was found between the exposure of an element ('time-in-view') and the probability of it being recalled. Together, Carr and Schissler's results supported Lynch's belief in the importance of physical, in particular visual, factors in image-formation.

(iii) Functional Importance of Elements

Despite the evidence that visual form was an important factor in determining the nature of urban images, a growing number of researchers during the 1960's began to question its primacy. Gulick (1963) concluded from his study of city images in Lebanon that 'imageability' resulted from the combination of distinctive visual form and significant social and behavioural associations. Sieverts (1967) studied young people's images of Berlin and concluded that apart from famous tourist attractions, architectural features were only important when associated with activity. Klein (1967) found a bias towards the inclusion of personally functional buildings in people's concepts of their 'city centre'. Steinitz (1968) examined the relationship between form and activity in images of central Boston. He showed that 'imageability' was dependent upon functional meaning but not the reverse. That is, some buildings were known for their associated activity without any knowledge of their physical nature; they might simply be known by a verbal tag such as 'Police Station'. When the form of a place was distinctive and congruent with the place's function (e.g. 'place of worship' with spire, stained-glass windows, etc.) then

recall was enhanced. However, if the visual form was not easily linked with the function, then recall of form attributes was suppressed in favour of verbal-functional attributes.

(iv) Visual and Verbal Memory for Spatial Elements

The results obtained by Steinitz imply that in learning a new area, the availability of a verbal tag (e.g. a functional description) might reduce the likelihood of a building's visual form being noted. This possibility is supported by the visual fixation and recall comparisons made by Carr and Schissler (1969; see previous discussion). These results may be profitably compared with a series of laboratory studies of visual and verbal memory. Pezdek and Evans (1979) examined the recall of objects on a visuo-spatial display, designed to simulate a real-world cognitive mapping task. Various experiments compared the recall of blocks with building photographs attached to them, blocks with verbal labels attached, blocks with both photographs and labels attached and unattached verbal labels. These items were arranged on a base-map to simulate an urban area. Recall and recognition of building names, picture recognition of building photographs and spatial location memory were assessed.

Overall picture recognition scores were poor and were lower in the 'photograph and label' condition than in the 'photograph only' condition. Verbal recall was unaffected by the presence of paired photographs; being equally high in all 'label' conditions. The researchers concluded that the verbal tag seemed to be the dominant aspect of the 'photograph and label' stimulus. Also, it was found that spatial location was more accurately recalled in the 'label' conditions than in the 'photograph only' condition. The researchers speculated from their results about building knowledge in the real-world. They said that knowing the functional name of a building might make it less likely that the physical

features would be encoded and stored: a possibility which was supported by the earlier 'city image' work of Steinitz.

The work of Pezdek and Evans is made particularly relevant to Steinitz's findings by virtue of the stimulus material description. The photographs were said to be visually but not functionally distinct whereas the labels were functionally distinct, for example 'hotel', 'school'. Therefore the subjects would be unlikely to invent functional labels from the photographs alone; nor would the photographs be 'distinctive and congruent' with the labelled functions, as in Steinitz (1968). As a consequence, Steinitz would have hypothesized that consideration of visual attributes would have been suppressed when labels were provided, but not otherwise. This is what was found by Pezdek and Evans. It might be hypothesized from Carr and Schissler's results (see earlier description) that visual attention to the photographs would be lessened by the presence of a name label. Pezdek and Evans provided slight evidence for such a situation by showing that instructions to remember visual details improved picture recognition scores without reducing verbal recall. This implied that subjects were adopting a strategy of non-attendance to visual details rather than being limited by their cognitive processing ability.

(v) 'City Image' Research after Lynch

The above discussion of 'city image' studies in the 1960's highlights the gradual shift in emphasis away from 'images as related to city structure' and towards 'images in relation to behaviour'. Researchers did not abandon the investigation of relationships between objective and subjective environments altogether but changed the focus of their studies. That is, they found that distinctive physical form alone did not influence recall probability whereas particular element structures (e.g. path

networks) seemed to have such an influence. In contrast to the reduced emphasis upon visual form, researchers began to find that behavioural associations (personal use, high levels of general activity, social symbol value and visibility from travel routes) were crucial factors in the formation of images.

In addition to the theoretical adaptations, researchers began to question the validity of Lynch's analytical techniques. Imagery studies carried out in other cities indicated that Lynch's five-part classification might not generalise to all environments. Many researchers found that only two or three of the five types of element were represented in their city; the types varying with city structure and size (see table in Kates, 1970, pp.654-5). De Jonge (1962) expressed doubts about the utility of displaying subjective elements on an objective base-map, as in Lynch's study. These drawbacks, in combination with further criticisms which became apparent in the early 1970's (see Chapters 4 and 6) led to a diminished interest in Lynchian 'public image' studies, at least among social scientists. Even so, a few researchers continued to perform 'public image' studies, stressing their utility in a planning context. Goodey (1974) reported studies in Birmingham, Hull and Aberdeen; finding further evidence for the importance of functional associations in image formation. In general, social scientists have adapted Lynch's basic technique in order to study group and individual differences in cognitive mapping (see next chapters).



Cognitive Mapping Studies (1969-1976)

## Chapter 4

### Early Cognitive Mapping Studies

1969-1973

#### 4.1 Introduction

The conclusions drawn from studies performed during the 1960's (see Chapter 3) brought the study of environmental imagery clearly within the limits of psychological inquiry. A gradual shift had occurred throughout the decade, from the city design-oriented studies of Lynch and his followers, to research which focussed upon the holders of the environmental images. Urban designers had found city images to be related to patterns of human activity (Gulick, 1963; Steinitz, 1968). Social scientists had noted group differences in the extent and content of local area images; these differences relating to factors such as personal values, age and social class (Eyles, 1968; Lee, 1968). Geographers had begun to investigate apparent illogicalities in people's behaviour, in terms of a 'subjective distance metric' (Thompson, 1963).

As was pointed out in earlier chapters, few psychologists undertook studies of environmental cognition prior to the end of the 1960's. Cognition at the environmental scale came to be treated as an issue of psychological interest with the emergence of 'environmental psychology' as a unified field of research. The latter had as its primary concern 'the psychological study of behaviour as it relates to the everyday physical environment' (Craik, 1966). The numerous potential research areas arising from an interest in Man's interaction with the environment were detailed in a lengthy paper by Craik (1970). What emerges from Craik's paper is the importance of one key question to environmental psychology; that is, 'how do people comprehend their environment?' It is the centrality of this question which lies behind the rapid growth of the sub-field of environmental cognition and in particular, 'cognitive mapping' studies.

It can be seen that not only were researchers from other disciplines beginning to look to psychology for research initiatives on environmental issues, but there was also a move within the discipline itself towards the study of 'real-life' behavioural phenomena. The work of Lewin has been described earlier (see Chapter 2). Brunswik (1956) had asserted that a meaningful theory of perception could only be obtained by observing how people perceive real-life phenomena in a normal environment; rather than basing theory upon experiments performed in perceptually impoverished laboratory settings. He used the phrase 'ecological cue validity' to describe the differential evaluation of environmental information in the perceptual process: a person 'believes' the environment to have the form which is implied by those cues to which he assigns the highest value. This process of environmental cue evaluation cannot logically be studied in an environment where the vast majority of cues which are customarily present have been artificially eliminated.

Following Brunswik, psychological research has evidenced the desire for 'ecological validity' in a variety of forms. At one extreme lies the 'ecological psychology' of Barker, whose work was discussed in Chapter 3. Briefly, Barker felt that any role played by the psychologist other than passive observer was undesirable and would destroy the natural patterns of behaviour which might otherwise be observed.

Despite the obvious utility of developing a 'natural history' of everyday human behaviour, most psychologists have not been so extreme as to completely reject the use of active experimentation in their research methodologies. Some of them have instead focussed upon the effects of differing environments upon people's cognitive processes. Two of these areas of research have been cross-cultural studies and investigations of perception in 'unusual' environments. One major area of cross-cultural study has been an assessment of variations in the susceptibility

to common visual illusions among people who have no experience of 'carpentered' Western environments (see Segall, Campbell and Herskovits, 1966). The investigation of perception in unfamiliar environments has covered a wide range of human habitats, from underwater to space travel (see Ross, 1974). A knowledge of the perceptual errors which occur in these settings is deemed to be one way of achieving a greater understanding of 'normal' perception.

Probably the largest section of those psychologists who have accepted the need for ecological validity are those who have begun to use traditional experimental methodology to study everyday behavioural phenomena. It is in this context that cognitive psychologists interested in memory processing turned to studying knowledge of the large-scale environment.

In summary, the psychological study of large-scale environmental representation developed from two main sources. Firstly, from multi-disciplinary investigations of environmental imagery; inevitably leaving a legacy of non-validated methods and diverse theoretical constructs. Secondly, from traditional experimental psychology, where researchers were beginning to expand their laboratory studies of perception and cognition to include 'cognitive mapping', as an ecologically valid example of cognitive processing.

#### 4.2 Stea's Concept of a 'Mental Map'

The diverse origins of environmental representation research made the development of a theoretical framework crucial to the future of the research area. That is, a coherent theoretical framework had to be formulated which would assimilate past research and enable a more directed programme of research to develop in the future. It was with this aim in mind that Stea (1969) produced a paper entitled 'The

measurement of mental maps: an experimental model for studying conceptual spaces'. Stea accepted that no physiological evidence was available for the existence of 'mental maps'. Instead, he put forward the model as a construct whose utility would be proven if people were found to behave as if such a 'map' existed.

According to Stea's model, conceptual space was a bounded one-, two- or three-dimensional space containing points, links between points and 'barriers' on some of the links. No particular scale of 'mental map' was focussed on, a 'point' could mean anything from a tree (at the local scale) to a country (at the global scale). Since the 'mental map' was accepted to be a hypothetical construct, it had to be operationally defined by Stea as the response elicited by a mapping task.

The central tenet of the paper was that externalized representations, whether obtained directly by sketching, or indirectly by deriving them from behavioural observations, possessed:

"...discernable and interesting metric characteristics."

Some of these characteristics were listed as:- absolute and relative location of points, interpoint distance (in terms of time and finance as well as miles) and size of an area. Stea noted the limited capacity of the human 'mapper' to process all the potentially available information provided by his environment. This necessitates the person making what Stea termed:

".....certain simplifications and adjustments, in accordance with his needs and experience in the conceptualization of these large and complex spaces."

Any such simplifications or adjustments will presumably be indicated by a lack of correspondence between the above-mentioned 'metric characteristics' and objective measures of the relevant geographical space.

In a discussion of certain elements of the model, Stea raised a number of issues which have since become important research topics within cognitive mapping. Perhaps the largest research area has developed from the question of how objective distance is represented in 'conceptual space'. While it is accepted that objective space is metric in nature, it is not known if its conceptual equivalent has these properties.

Stea reported an unpublished study (Buckman, 1966) which suggested that conceptual distances may be noncommutative; with distance towards a preferred location being perceived as shorter than distance away, that is towards a less-preferred location. At the time Stea's paper was written, a few other published articles were in fact available which supported the noncommutativity of subjective distance (Lee, 1962; Thompson, 1963). However, it is only since 1969 that subjective distance has been extensively investigated by environmental psychologists (see Canter and Tagg, 1975; MacEachren, 1980).

Stea also discussed two other hypothesized elements of conceptual space, both of which subsequently generated significant bodies of research literature, though to a lesser extent than subjective distance. These were the representation of interpoint direction and the representation of 'turns' (changes in bearing). In relation to the latter, Stea anticipated later findings (see Chapters 6 and 8) by noting the tendency of people to mentally represent angles in a simplified form, nearer to  $90^{\circ}$  than is actually the case. Two questions posed by Stea in this context are still not answered satisfactorily; namely, 'how does the familiarity of the subject with 'gridiron' cities affect his tendency to perpendicularize angles?' and 'how far does an angle have to deviate from  $90^{\circ}$  before it is no longer represented as such?'

Although Stea's (1969) paper expounded what was essentially a psychological model of conceptual space, it was not until the following year that he, in collaboration with Roger Downs produced a synopsis of the position of cognitive representation research specifically from a psychological viewpoint (Stea and Downs, 1970). The paper was written as an introduction to a special issue of 'Environment and Behavior' devoted entirely to papers on cognitive representation.

The paper began with a brief survey of the origins of psychological interest in cognitive representation at the environmental scale. In the course of this survey, the authors questioned the implications of concepts which were in current usage within environmental representation literature. In particular, the 'map' metaphor and the concept of an internal 'image'. Stea and Downs pointed out the potential hazards of an uncritical acceptance of such terminology. This was in contrast to Stea's (1969) earlier paper, which had not contained such a critique. They commented that the 'map' metaphor had led to a misguided notion that the internal representation consisted of a structure which was analogous to a graphic layout. Equally, the 'image' concept had led to an erroneous emphasis upon visual memory.

In the next section of their paper, the authors outlined what they saw as the areas in which research needed to be done and the methods by which such work should be carried out. They began by clarifying the purpose of studying cognitive representations; namely:

"..... The attempt to relate environmental behaviour to perception is the eventual object of the research ....."

A cognitive representation was therefore proposed as the intervening variable between the objective environment and the person's spatial behaviour. This explicit statement of the functional role of the cognitive representation permitted Stea and Downs to expand the focus

of research to include the process of 'cognitive mapping'. Previous researchers had mainly concentrated upon the form of well-established representations. In consequence, Stea and Downs pointed out the need to study the temporal nature of map formation and the covariation of the latter with "other features" (by which the authors meant subject or environmental variables).

It was in this paper that Stea and Downs made the distinction between two research strategies which were being used to study cognitive mapping. The first was holistic in nature, and was designed to identify any relationships between cognitive representations and subject or environmental variables. The second was an analytic strategy, designed to examine the quantitative details of such relationships. Most of the early city image studies would belong to the first category, since they requested general sketch-maps and then categorised what responses were obtained, noting any correlations with subject or environmental variables. Many of the most recent research projects exemplify the analytic strategy (see Chapters 7 to 10).

#### 4.3 Environment and Behavior (1970)

##### (i) Overview

The five papers introduced by Stea and Downs (1970) in 'Environment and Behavior' covered a wide range of research topics and methodologies. Downs (1970) used semantic differential scales to investigate how people conceptualized an urban shopping centre. This paper differs from most cognitive mapping studies, in that it only deals with the 'appraisive' or 'evaluative' component of the image rather than its 'designative' component (see discussion in Chapter 3).



The four remaining studies were presented by Stea and Downs (1970) as two pairs of contrasting papers; one pair (Lee; Lowrey) exemplifying the 'systems analysis' strategy and the other pair (Ladd; Appleyard) being more typical of the holistic, 'systems identification' type of research. Lee and Lowrey investigated the way in which distance was subjectively represented. Appleyard and Ladd both studied city images using sketch-mapping techniques; though Appleyard also collected verbal descriptions and 'trip' recall data, for comparison purposes. Appleyard looked at group differences in adult images of Ciudad Guyana, Venezuela; whereas Ladd's paper concerned the 'neighbourhood' knowledge of a group of lower-class, adolescent negroes.

(ii) Subjective Distance Estimation

Lee (1970) and Lowrey (1970) both used psychophysical techniques to investigate the subjective representation of objective distance, though Lee requested absolute distance estimates whereas Lowrey used a relative distance technique. Despite the similar range of locational types used by the two researchers, as well as the similarity in objective distances covered, they seemed to obtain contradictory results. Lowrey concluded from his analysis that people were generally very accurate; that is, their estimates were closely related to the corresponding objective distances. In contrast, Lee found an overall positive error, with the degree of overestimation being greater for places away from the city centre direction. The underlying reason for this discrepancy is not obvious. The type of psychophysical technique used might have affected the results, as might the method of data aggregation and analysis. Indeed, Elkington, McGlynn and Roberts (1976) suggested that the positive and negative distortions in Lowrey's work may have 'cancelled each other out', giving an inflated impression of the level of accuracy. Equally,

the discrepant results may have been caused by subtle differences in subject variables or the nature of the locations to which estimates were made.

The differential effect of direction (into versus away from a city centre) upon distance estimates which was found by Lee was equally difficult to interpret. Lee concluded that the most likely explanation was that the positive valence of the city centre led to a foreshortening of subjective distance in that direction. However, he discussed several other possible factors which might have contributed to the effect. Some degree of statistical support was available for two of these factors; these being differential familiarity for locations in either direction and a difference in the number of 'turns' in the typical origin-to-location routes. Subsequent research has lent support to the importance of the latter factor (see Chapter 8).

### (iii) City Images and the Role of Travel Mode

Appleyard's (1970) paper reported in detail the sketch-map data from his Venezuelan study. An earlier paper (Appleyard, 1969) had described his analysis of building knowledge in the relevant city, and had utilised all three types of data (sketch-map, verbal report and 'trip' recall). This had examined which building qualities were associated with a high probability of being recalled by subjects. Recall probability was shown to be positively correlated with such attributes as 'viewpoint significance' and 'visibility'. The attribute which showed the most systematic correlation with recall was 'use intensity', an index of the amount of activity associated with a building. This finding supports the research of Sieverts (1967) and others, which was reviewed in Chapter 3.

In analysing the sketch-map data, Appleyard (1970) made two important contributions to cognitive mapping research. The first of these was a methodological development: a classification scheme for the structure of city sketch-maps. Appleyard distinguished between two basic styles of map; the 'sequential', which uses routes as the major organising factor and the 'spatial', which emphasizes the absolute location of elements. This dichotomy is analogous to Shemyakin's (1962) distinction between 'route' and 'survey' maps. Within each style of mapping, Appleyard described four levels of structuring, to indicate the "extent, accuracy and coherence" of the sketch-maps. Appleyard classified 78% of the Venezuelan maps as sequential. Problems have arisen with the use of this system, both in terms of the validity of the stylistic dichotomy and in identifying the cause of differential use of the two styles. Canter (1977) has pointed out the probable influence of physical environmental form and task demands upon the type of sketch-maps produced (see also later chapters). Nevertheless, the typology proved useful in that it drew researchers' attention to the problems of assessing the structure and complexity of mapping products.

The second noteworthy aspect of Appleyard's study was his analysis of mapping differences in relation to customary mode of transport. The main ways in which people could travel through the city were by car or by bus; which could be described as 'active' and 'passive' modes, respectively. Eighty per cent of bus travellers were unable to produce a coherent map of the road system whereas all the car users could, even when educational or class differences had been taken into account (see later section). Appleyard attributed the poor mapping of bus travellers to qualities of the bus journeys, such as circuitous or disjointed routes and poor visibility from within the vehicles. Given Appleyard's account, journey quality does seem to be the most likely determinant of poor mapping. However, other contributory factors probably existed.

A study performed at the same time as Appleyard's, but not widely reviewed, suggests one factor which may have contributed to the transport differences. Howell (1969) obtained nearly 2,000 sketch-maps of Staten Island (U.S.A.), from both residents and commuters. A noticeable difference was exhibited between people who travelled around the island by active transport modes (walking and driving) and those who used passive modes (bus or train). When drawing maps, the former tended to lay great emphasis upon changes in direction. In contrast, the latter frequently depicted routes as straight lines, even when they were aware of the existence of bends or turns (see also Chapter 5). Such an effect was actually mentioned by Appleyard (1970) in his conclusions.

It is clear that the distortions typical of 'passive' transport users would cause problems when a graphic representation was being created. The drawbacks of using a graphic mode for externalising spatial knowledge which does not preserve vector information has since become a major issue in cognitive mapping research (see later chapters).

(iii) Neighbourhood Maps and Activity Ranges

The study performed by Ladd (1970) provided evidence of the role of a further factor which may have led to Appleyard's transport differences; namely, differential activity range. Ladd's original intention had been to assess the utility of sketch-map data in the study of neighbourhood concepts, from both theoretical and applied viewpoints. As a means of evaluating differential mapping performance, Ladd devised a four-group classification system for the sketch-maps. The lowest group were simply pictorial drawings; whereas the highest were completely map-like. Additional performance indices were obtained by measuring the extent of the sketches (geographical) and by counting the number of particular types or elements which had been drawn.

The results showed that there was no relationship between age or school grade level and mapping performance, but a small group of subjects appeared to experience considerable difficulties with the task. This prompted Ladd to recommend further investigation of the role of specific cognitive factors in mapping performance. This area has been investigated by a small number of subsequent research projects (see Chapters 5, 10 and 13).

A striking finding of Ladd's study was the wide variation in areas depicted by her subjects; differences not fully explained by the variety of home positions. Ladd noted that those subjects whose daily activities took them over a wider area, tended to draw larger neighbourhoods. Active interaction with the environment was therefore identified as having a major role in the cognitive mapping process, influencing the extent of a person's known neighbourhood. This relationship was confirmed by a number of 'neighbourhood perception' studies performed between 1967 and 1972 (reviewed in Spencer, 1973).

It therefore seems that the transport differences found by Appleyard may have been the indirect result of differences in spatial activity range. It is reasonable to assume that the greater mobility of car users would have led to them experiencing a wider area of the city than those who were limited to bus routes or walking. It also seems likely that activity range differences contributed to some of the other group differences in mapping which were found by Appleyard. He suggested that low mobility might have led to the poor mapping of female subjects. Also, he noted the restricted maps of newcomers; possibly a consequence of them having active experience of only a limited area of the city. Perhaps the most interesting difference, in that it cuts across educational or class boundaries, was that between occupational groups. Business executives and skilled workers produced accurate maps, whereas

housewives and professionals were relatively inaccurate. Again, this difference might be attributed to differential experience of the city area.

#### 4.4 Class Differences in Cognitive Mapping

One possibility raised by Appleyard was that the strong class-related mapping differences found in his study were partially dependent upon a "varying ability to conceptualise". However, in the years succeeding his 1970 paper, a number of other factors have been considered.

Maurer and Baxter (1972) used a series of tasks, including city and neighbourhood sketch-mapping, to examine racial differences in children's cognitive mapping. The most extreme differences were between white and black children, showing the former to be capable of drawing better city maps and larger neighbourhoods. As had Ladd, these researchers discussed the more extensive range of the better mapper's spatial activity and their generally higher mobility as possible explanatory variables. White children tended to have friends who lived further away than those of the black children. Also, the white children were more likely to travel to school by car. Since car-owners would probably have taken their children on trips around the city, they would have greater spatial activity ranges than other children.

The results of Maurer and Baxter's study therefore support the findings of Appleyard and Ladd, in that they highlight the differential mobility and territorial limits which are associated with differential mapping performance. It must be noted that while Maurer and Baxter's study professed to examine racial differences, the possibility of a correlation with socio-economic class was not eliminated. Given the information on comparative mobility, it seems that the differences might be adequately characterised as class differences, regardless of ethnic grouping.

Three studies, by Francescato and Mebane (1973) in Italy, Orleans (1973) in the U.S.A. and Goodchild (1974) in the U.K. provided further evidence of the existence of class differences in environmental representation. The study by Francescato and Mebane was designed to compare directly the images of two different physical environments, namely Milan and Rome. The comparison showed that the two cities were indeed represented in characteristic styles, with Rome being constructed mainly around landmarks and Milan around 'centres of activity'. As part of their investigation, the authors compared the maps of various age groups, socio-economic classes and of males and females. In general, the results showed the usual pattern, with the middle-classes, males and young adult subjects producing the best sketch-maps. The researchers were able to interpret the results by reference to mobility levels, as had the earlier researchers. However, a consistency in the type of subject who refused to attempt a sketch-map caused them to question the validity of the mapping technique. Older people and those in the lowest socio-economic class constituted the largest sub-groups in the 'refusal' category. This meant that those subjects who would have been at the lower end of the performance scale were not willing to produce a sketch-map.

The studies by Orleans and Goodchild showed similar effects to those of Francescato and Mebane. Orleans found clear differences in the size and accuracy of areas drawn by 'upper-' and 'lower-income bracket' subjects. He viewed his results as indicative of the differing scales of the 'social worlds' experienced by the upper and lower socio-economic classes. For lower-class subjects, both mapping accuracy and socio-spatial behaviour were closely linked to the mapper's home. As distance from the home increased, accuracy and social involvement declined rapidly. This was not the case with the higher income groups,

whose social involvement and mapping accuracy extended over a far larger physical area. Sociologists had already discussed the phenomenon of class-related socio-spatial behaviour and a similar effect had been noted in some neighbourhood studies (see Chapter 3).

Goodchild's mapping data was collected as one part of an exploratory study of class differences in attitudes to a local environment. He found that the middle-class group drew larger areas and included many more details than did the working-class group. He concluded that the difference was primarily due to the superior ability of the middle classes at conceptualizing their environment in a coherent fashion; as had Appleyard. However, Goodchild did admit that the differences may have resulted partly from the more circumscribed spatial behaviour of the working-class subjects. One detail of Goodchild's results adds further weight to this interpretation. Like Francescato and Mebane, Goodchild found that females produced more constricted maps; but additionally, that middle-class women produced maps with similar content but superior structuring to those of the working-class females. The variance in map content was smaller among females than among males. This is consistent with a spatial activity interpretation, since there would be less differences between the spatial ranges of the middle- and working-class women than between their male counterparts, given the range of occupations which the latter would hold.

Regarding the problem of subject refusal which was noted by Francescato and Mebane, Goodchild did not accept that there was any serious danger of bias. He claimed that the request for participation in the tasks would tend to be accepted by the lower-class subjects who were most interested in discussing the town's qualities. They would therefore be most similar to the middle class in attitudes, and any differences obtained would constitute an underestimate of the actual class differences.



#### 4.5 Problems of Sketch-mapping

Goodchild's appraisal of the effect of subject refusals was reasonable given his research aims: that is, to determine if there was any difference between the social classes in their conceptualization of their home town. Other shortcomings became apparent if the focus is changed to the levels of performance per se, rather than the relative performance. Goodchild claimed that his non-responders were less interested in describing what the town meant to them: this prompts the question of whether they were also less able to describe what the town meant. Any researcher interested in how a city was 'imaged' by its full range of inhabitants would have to consider the appropriateness of the chosen technique for each sub-group. Orleans discussed this matter in his paper and suggested a whole range of other techniques which could be employed, such as pre-drawn base-maps and pre-coded questions. Most of these possibilities have, in fact, been utilised since Orleans' paper (see later chapters) and his suggestions have been supported at length by Beck and Wood (1976).

The misgivings expressed by Orleans, regarding the universal utility of sketch-mapping, were experimentally investigated by Spencer (1973). Spencer's study was conducted with the aim of improving the role of public participation in urban planning. A predominantly working-class sample was tested (in Birmingham, U.K.), since Spencer believed it was necessary to determine what methods could be used to elicit the environmental imagery of even the most disadvantaged sections of society. This would enable a more representative 'public image' to be studied by planners. In addition to sketch-mapping, the study examined two other commonly-used methods of eliciting environmental imagery; verbal description and boundary delineation (i.e. of the 'neighbourhood') on an objective base-map. In common with Francescato and Mebane, Spencer

found that the refusal rate in the sketch-mapping task was greatest among the older, female and lower-class respondents. The desire to produce an assumed 'correct answer' was also very pronounced among this group. Spencer concluded that there were serious drawbacks to the use of sketch-mapping as a means of establishing the environmental images of the less-educated members of society.

All three methods were found to be inadequate in one way or another; some drawbacks were common to two or all three of the methods and others were peculiar to one method. The size of neighbourhood produced was found to be statistically related to the extent to which a subject experienced difficulty with the sketching or the verbal description tasks. Verbal description was therefore seen to be as dependent upon verbal skills as sketch-mapping was upon graphic skills. Since many of those people who would have problems with a graphic task will be similarly inexpert at a verbal level, the use of verbal description as an alternative to sketch-mapping must be viewed with some caution. An equivalent problem arose with the boundary-delineation task, in that subjects had to be capable of interpreting the symbolic language of the base-map in order to perform the task. Perhaps more serious was the fact that subjects were able to include items in their 'neighbourhoods' which they did not know and could not have actively depicted or described by the other two methods. Some subjects were said to have completed the boundary-drawing tasks:

"...with only slight regard for the consequences and implications of lines drawn."

Besides the problems uncovered regarding the validity of the individual methods, doubts were raised regarding their comparability. The size and content of neighbourhood areas was found to vary according to the mapping method employed. This fact caused Spencer to question

the conclusions drawn from comparisons between the results of different research projects, unless the same type of mapping had been employed throughout.

Despite the aforementioned inadequacies of the cognitive mapping methods, a significant relationship was found between the size of neighbourhood depicted and the subjects' spatial behaviour patterns. The last finding suggested that attempts to elicit the cognitive representations of 'domi-centred space' should not be totally abandoned. However, if the representations of the inarticulate or graphically unskilled were to be assessed, then it would be necessary to adapt or replace the traditional cognitive mapping tasks to make them compatible with the subjects' capabilities. Equally, if the psychological significance of mapped elements was of interest, then mapping tasks would have to be supplemented by other techniques, such as repertory grid or semantic differential testing. Spencer pointed out, as had Ladd (1970), that inclusion of an element on a sketch or in a bounded area would not indicate the level of personal or social significance which the mapper attached to it. Verbal techniques would be needed to provide evidence of evaluative responses. An alternative means of augmenting cognitive mapping data was independently put forward by Orleans, Goodchild and Spencer. They recommended that direct behavioural measures should be obtained from the subjects in order to assess the significance of the mapped area in the subject's actual spatial behaviour.

#### 4.6 Conclusions

It is apparent that the psychological investigation of cognitive mapping questions became well-established within the first few years of the 1970's. This view is supported by the fact that a comprehensive book of readings was published in 1973, edited by Downs and Stea. Several papers describing new experimental work were published for the first time in this volume (e.g. Orleans, Francescato and Mebane), as well as a variety of reprinted articles (e.g. Tolman, 1948; Griffin, 1948) which had not previously been drawn together under a collective heading. The introductory sections by the editors constituted a more extensive discussion of the points raised in their earlier paper (Stea and Downs, 1970). They provided an overall view of the cognitive mapping research area, suggesting phenomena to be accounted for and questions to be answered by subsequent research and theoretical developments. They also provided the useful definition of cognitive mapping which was quoted in the introduction to the present thesis.

Chapter 5Initial Theoretical Frameworks(1973-1975)5.1 Hart and Moore's Developmental Model

The transition from product-centred studies of urban imagery to process-oriented analyses of cognitive mapping precipitated several attempts to derive developmental theories of the mapping process. Theoretical analyses attempted to characterise two basic processes; one, the way in which the ability to form environmental representations develops in the child (ontogenetic development) and two, the way in which an adult develops a specific representation of a new environment (microgenetic development). Until the middle 1970's, by far the most extensively considered of the two was ontogenetic development. Hart and Moore (1973) comprehensively reviewed the early theory and empirical evidence concerning ontogenetic development, providing their own theoretical framework. They found that a useful way of analysing the available literature on the cognition of large-scale space was to highlight parallels with the stages of development of fundamental concepts of space which have been hypothesized by Piaget (e.g. Piaget and Inhelder, 1967) and Werner (1948). They took the type of 'reference system' used by a child to relate himself to his environment as being indicative of his stage of development. They showed how the available literature (mainly the pre-1960 orientation studies reported in Chapter 1 and the work of Piaget, Inhelder and Szeminska, 1960) indicated that there existed three basic types of reference system. These were termed 'egocentric', 'fixed' and 'co-ordinated' and evidence was given that the three occur as ontogenetic stages, parallel to the

stages of fundamental spatial cognition. Additionally, in discussing Shemyakin's (1962) distinction between 'route' and 'survey' mapping, they concluded that the ability to form route-representations was a developmental predecessor of the ability to form survey-representations.

Hart and Moore devoted a final section of their review to what they called the 'scant literature' on the microgenetic development of large-scale spatial representations. The discussion was limited to representations arising from active exploration and did not consider the possible effects of secondary information sources, such as maps. Again, the available literature was predominantly pre-1960; an indication of the lack of attention paid to cognitive factors in the 'city image' work performed in the 1960's. However, one or two studies from the latter end of that period were reviewed in the context of microgenetic learning, notably Appleyard (1970). Hart and Moore reached the tentative conclusion that, as in ontogenesis, route-representations appeared to be developmental predecessors of survey-representations. The latter was said to result from the interlinking of many 'route-maps'. Given that they were only discussing representations arising from first-hand experience, this is essentially the conclusion reached by later theorists (c.f. Siegel and White, 1975; Moar, 1979; Byrne, 1979).

The theoretical standpoint described in Hart and Moore's review was expanded and supplemented by empirical evidence in a number of papers by the second author (Moore 1972, 1973a, 1973b, 1974). In order to discuss differences in spatial representations in the widest range of contexts, Moore employed a definition of 'development' derived from the theories of Piaget and Werner, i.e.:

".....qualitative changes, differences, or variations in the organization of behaviour such that developmentally more advanced behaviour is more differentiated than lower forms of behaviour and hierarchically integrates lower stages and the behaviours associated with them."

(Moore, 1974, p.185).

This permitted him to refer to developmental differences between and within individuals at a particular point in time, as well as within an individual over a period of time (as would be the case in ontogenetic or microgenetic development).

The theoretical background and evidence which was reviewed in Hart and Moore (1973) led Moore to postulate three levels of spatial representation, as follows:-

- 1 : Undifferentiated egocentric.
- 2 : Differentiated and partially co-ordinated into fixed subgroups.
- 3 : Abstractly co-ordinated and hierarchically integrated.

The levels were chosen so as to incorporate the factors of abstraction, complexity, differentiation and reference system. These were the factors which Piaget and Inhelder (1967) and Werner (1948) claimed would alter as a result of development. If Moore could show that people consistently represented environments at one 'level' he would have provided evidence for a stylistic interpretation of the different representations. Conversely, if he found evidence for within-individual differences in 'level' across different environments (or the same environment over time), then he would be able to support the developmental standpoint.

Another derivative of developmental theory used by Moore involves the cognitive capabilities associated with different levels of representation. It is claimed that a person with one level of representation will be capable of performing certain cognitive operations on the information represented therein; further, that these will include

all the operations of which he would be capable at any lower level of representation. Therefore, a higher level of representation would be associated with a higher success rate on certain cognitive tasks. From parallels with Piagetian theory, Moore chose "associativity" and "reversibility" (finding more than one connecting sequence between end points and reversing a known sequence) as tasks which should be more likely to be achieved at his 'Level 3' than at the lower levels, if the developmental model was valid. Additionally, Moore hypothesized that the cognitive operations would be more often achieved in relation to a familiar, rather than an unfamiliar environment, with a correspondingly higher level of representation.

Moore tested the above hypotheses in a series of experiments (reported in Moore, 1973 and 1974) using high school students aged 15 to 19 years. 'Level of representation' was determined by having judges sort subjects' sketch-maps of particular areas into one of three levels; this the judges were able to do with a high level of reliability. Subjects rated familiarity of city areas on a five-point scale. The results supported the developmental model, in that consistent relationships were found between level of sketch-map representation, performance on cognitive spatial tasks and subjective familiarity of areas of the city. Moore did not find any significant relationship between level of representation and either age or general intellectual aptitude. However, he did find both a tendency for males to draw the city at a higher level than females and for the older children to produce significantly more complex, accurate sketch-maps. At a later date, Moore (1975) interpreted the latter findings as being a reflection of the greater active experience of the city possessed by the older, in particular older male, subjects. This is in accord with both his own model of representation resulting from man-environment interaction and also, with earlier interpretation



of research findings (c.f. Appleyard, 1970; Maurer and Baxter, 1972; Orleans, 1973). Greater active experience was consistently associated with more competent cognitive representations. Further support for this view was provided by Andrews (1973) who also found that high school seniors were more accurate than younger students when mapping their city. This difference only occurred when subjects lived within seven miles of the city. This gives the 'differential experience' interpretation more credibility, in preference to any general cognitive factors, since the latter should not be affected by place of residence.

## 5.2 Siegel and White (1975)

### (i) Introduction

In a lengthy paper published in 1975, two developmental psychologists, Siegel and White, addressed themselves to much the same area as had Hart and Moore (1973). However, the scope and emphasis of their 1975 paper was somewhat different. Whereas Hart and Moore had concentrated on ontogenetic development of spatial representations, reviewing both the literature on large- and on small-scale space, Siegel and White concentrated on large-scale space in the full range of developmental contexts. Siegel and White took as their basic tenet the view that:

"Spatial knowledge arises from the integration of successive perceptual experiences."

From a review of philosophical and neurological writing, they argued that people are neurologically predisposed to create this type of mental construction. Siegel and White began their discussion of cognitive representations of the large-scale environment ('macrospatial cognition') by describing the generally accepted qualities of such internalized models. They noted that the representations were incomplete, distorted, fragmented and multi-modal, as had Downs and Stea (1973). It was

emphasized that the representations were not necessarily 'map-like', but they did permit their owner to act as if he possessed a map, that is, they acted as a way-finding guide. The second commonly-accepted function of spatial representations, that of providing a frame of reference, was also mentioned, though not in any detail. Siegel and White clearly viewed way-finding as the principal function of the representation and directed the remainder of their paper accordingly.

(ii) 'Main Sequence'

The remaining sections of their review consisted of process descriptions of microgenesis and ontogenesis with an intervening discussion on the parallels between diverse developmental processes. An overview of evidence from work on perception, cognition, learning and recovery from cerebral injury led Siegel and White to propose a common progression within the various developmental contexts. They termed this progression a 'Main Sequence'. Though necessarily at a very speculative level, they believed that such a formulation could prove useful for interpretative and hypothesis-generating purposes in future research work. Essentially the same motives had led Hart and Moore (1973) to highlight developmental parallels, as noted earlier. The 'Main Sequence' postulated by Siegel and White involved the acquisition of associations between cognitive items, gradually developing into interlinked knowledge structures and eventually into a single organized structure. These cognitive structures would then become individual units in further 'Main Sequences'.

The discussion of the microgenesis of an adult's spatial representation of a new terrain provided perhaps the clearest example of Siegel and White's 'Main Sequence'. Landmarks, routes and configurations

were taken as being the three basic elements of spatial representations. The first two were said to be the minimal requirements for a representation to function as a way-finding guide. However, brief evidence was provided to support the existence of configurational knowledge, both from the cognitive mapping literature (e.g. Shemyakin, 1962) and from work on the effects of different types of cerebral injury upon the ability to use both route and configuration knowledge. Siegel and White argued that configurational knowledge could arise as a result of the integration of many routes; this being the 'Main Sequence', where routes represent the associational links between landmarks and configurations, the cognitive structures. They noted that such 'survey knowledge' would probably require long-term repeated experience for its development. It is unfortunate that the authors did not mention what later authors (e.g. Thorndyke, 1980) have emphasized; that survey knowledge is most commonly acquired through the use of secondary information such as maps or plans, thereby short-cutting the proposed 'Main Sequence'. Studies by Moar (1979) and Thorndyke and Hayes-Roth (1978) have shown the different levels of knowledge acquired by map-use and direct experience in large buildings. The abundance of maps and plans in Western society means that in many real-life learning situations, literate individuals are unlikely to follow the 'Main Sequence' proposed by Siegel and White. Survey knowledge could be acquired at any point in the learning process, not only when a large number of interlinked routes have been learnt. In the case of very large-scale survey knowledge, it is unlikely that it could be acquired through any means other than secondary information (e.g. an outline 'map' of a country or continent).

Despite the aforementioned limitations of Siegel and White's model of microgenesis, it did incorporate one of the first attempts to explain the psychological mechanisms utilised in the learning process. They

suggested that route knowledge might develop via a paired-associate learning system; a route being punctuated by a series of landmarks, each of which evokes an appropriate action decision, taking the person on to the next landmark. In this way the person would gradually progress from their starting-point to the required destination. Siegel and White even suggested a physiological mechanism to account for landmark learning. They believed that landmark memory would consist of 'recognition-in-context'; whereby a stimulus in a particular context would elicit multi-modal memory traces, especially motor decisions. The physiological mechanism which they thought might be operating to create such a memory link was that proposed by Livingston (1967), termed "Now Print". Herein a biologically meaningful event would act as a catalyst, causing the nervous system to 'take a photograph' of itself at that point. While landmarks signifying choice-points would clearly be the most crucial elements in such a representation, Siegel and White noted that some locations would be learned between these landmarks. The intermediate landmarks would then act as course-maintaining guides, to signify that the person was staying on the correct route.

### (iii) Implications of the Model

It can be seen that the route-learning process described above provides a partial explanation for the differential knowledge exhibited by people using 'active' and 'passive' transport modes. As noted earlier, Howell (1969) found that the former showed changes of direction as important occurrences on their sketch-maps, whereas the latter frequently depicted routes as straight lines. Changes in direction and associated landmarks would constitute highly important elements in the route representation of someone who had to walk or drive. In contrast, the passive traveller would simply need to recognise the starting-point and

terminus of his route; the remainder could be safely ignored. Appleyard (1969, p.138) noted the enhanced recall of some navigationally important buildings, despite their being "physically and functionally insignificant".

One important conclusion of this route-learning model is that the resulting representations will be essentially topological; that is, they will not conserve Euclidean directions and distances. Inter-landmark stretches will be 'empty space' and other than course-maintaining landmarks, learning between decision points will be incidental and initially negligible. However, Siegel and White did go on to suggest how a representation could gradually acquire some degree of Euclidean accuracy, given repeated experience in the relevant environment.

#### (iv) Scaling of Topological Networks

They proposed that approximate 'scaling' of a route would develop as a result of the existence of regular course-maintaining and decision-point markers. That is, a person would employ the heuristic that accurate navigation would have necessitated the existence of landmarks at a regular minimum distance from each other. Therefore, he would assume that a route which he represented as having six landmarks would be approximately twice the length of a route having three landmarks. From such a situation, it is possible to make predictions as to the probable effect of extreme numbers of one or both of the types of landmark (course-maintaining or decision-point). Numerous researchers have found that if two routes of the same total length vary in the number of turns they possess, the route with more corners will be estimated as longer than the other (Lee, 1970; Byrne, 1979; Sadalla and Magel, 1980). Further research by Staplin and Sadalla (1981) has indicated that the crucial factor in the last result is the ability to retrieve landmark information. That is, estimated route distance showed a greater

relationship to landmark recall scores than to recognition scores. This is clearly in accord with Siegel and White's model, whereby distance estimates are derived by noting the number of landmarks on a route-representation, necessitating active recall.

Overall, Siegel and White proposed that increased experience of an environment would lead to a dual transformation of the initial route-representations used for navigation. Topological information would gradually develop Euclidean components and known routes would become interlinked and enmeshed into a survey representation. It can be seen that this model is consonant with that of Moore (1974); with Moore's third stage of microgenesis, the "abstractly co-ordinated and hierarchically integrated" representation being equivalent to Siegel and White's 'survey representation'. However, the latter appears to provide greater potential for experimental analysis. While Moore could only categorize overall representations into three types, Siegel and White's conceptualization permitted a much wider range of analyses. Overall structure could still be assessed but in addition, individual landmark knowledge, distance and direction estimation could all be evaluated. Subsequent work by other authors has adapted and elaborated Siegel and White's work, but the basic model has proved to be a useful and acceptable one within cognitive mapping research.

The two main adaptations to the model have concerned the role of secondary information and the observation that Euclidean representations do not inevitably develop as a result of repeated practical experience. As discussed in the previous section, survey knowledge is most often acquired from secondary information sources, which means that Siegel and White's model of microgenetic development will not be followed (see also Chapter 8). The idea that many representations never develop

Euclidean components has been put forward by Byrne (see Chapter 8). He has noted that for most practical purposes, topological networks provide an adequate navigational aid.

(v) Ontogenetic Development

In a final section of their paper, Siegel and White discussed the ontogenetic development of cognitive representations. They showed how their 'Main Sequence' could be successfully applied to the available research findings about children's environmental learning; given the proviso that certain details would differ as a consequence of physical and psychological immaturity. This limited correspondence between the equivalent levels of organization in different versions of the 'Main Sequence' led Siegel and White to term the latter a 'state' sequence. They emphasized that, unlike a developmental sequence of 'stages', the 'Main Sequence' could only be partially prescriptive of the actual systems of organization in any particular context. They suggested that the balance of sensory information embedded in landmark ('recognition in context') memory would be different in young children's representations; emphasizing motor and affective components, but including less interpretative data than would adults'. They noted, as had Hart and Moore (1973), that survey representation would be delayed until an objective frame of reference was ontogenetically available. Also, the information-processing capacity of a child at a particular age would limit the extent to which it could become simultaneously aware of information acquired successively; the latter being a prerequisite of the most highly structured survey representations.

(vi) The Role of Activity

Throughout both their discussions of ontogenetic and microgenetic development, Siegel and White stressed the importance of physical activity in the process of forming spatial representations. In this way, they were integrating their ideas with previous cognitive mapping research, which observed the link between mapping performance and spatial activity patterns (see earlier discussion), as well as with traditional psychological studies of spatial learning, such as Held and Rekohs (1963). Active exploration in the environment, rather than passive movement, is apparently of major importance in the process of forming spatial representations. Siegel and White mentioned a number of studies which linked children's scores on spatial representation tasks to their activity range and stated that the cumulative evidence:

".....seems to indicate that the development and utilization of spatial representations is greatly facilitated (and may well be dependent upon) locomoting in the environment....."

(1975, p.38)

On the other hand, they were quick to point out that though such representations may be dependent upon practical activity, they are likely to contain a large visual component, at least in normally sighted people. This is intuitively obvious when one conceives of a major task of cognitive mapping as being, in Siegel and White's words: "...the derivation of simultaneity out of successivity..." (1975, p.46). The chief advantage of vision over other modalities is that it allows the immediate apprehension of a large space, greatly facilitating such an organising process.



### 5.3 Neisser's 'Orienting Schemata'

One theorist who observed the interdependent nature of vision and locomotion in the cognitive mapping process was Neisser (1976). He viewed 'cognitive maps', or 'orienting schemata' as a specific variety of the cognitive structures which he believed to be the basis of all perceptual activity. That is, he suggested that each perceptual act is directed by, and acts upon, a cognitive structure which he called a 'perceptual schema'. A schema would have the dual function of directing spatial behaviour and assimilating new spatial information for future use. Neisser emphasized that the perceptual process would be cyclical in nature, with the schemata continuously interacting with, and being altered by, the real environment. Additionally, schemata for specific aspects of stimulus displays would be embedded within schemata for the whole displays, rather than being successive stages in the perceptual process. In this way, a person would perceive, for example, an office, a desk and a wooden surface at the same moment, each schema providing anticipations and receiving confirming information at once (e.g. 'has four walls, ceiling, floor', 'flat top, four legs and chair by it' and 'polished, dark brown, supports objects on it').

Cognitive maps were therefore seen as perceptual schemata pertaining to the large-scale environment. Cognitive maps of smaller geographical areas would be embedded in cognitive maps of larger regions. Also, perceptual schemata for specific landmarks would be embedded within the cognitive maps of small areas, in a hierarchical fashion. Each level of schema would anticipate, accept and accommodate its own level of information. Given this model of the cognitive mapping process, Neisser clearly agrees with Siegel and White upon the importance of vision and locomotion. Vision provides the most extensive source of environmental information and this information is greatly enhanced by movement of the

viewer in the environment. The active exploration of an environment permits a person to discover the spatial relations between various elements, by observing the effect of his own movements upon the visual display. In addition, it is clear that at the large-scale of cognitive mapping, the range of spatial exploration will determine the potential extent of spatial information in a person's cognitive map; though again, the effect of secondary information sources must be noted.

Neisser concentrated his discussion upon sensory information gained from vision, since in normal-sighted individuals this will constitute the major source of environmental information. However, the principles of his model of cognitive mapping could equally well apply to non-visual modes, such as the auditory and haptic senses; though the potential for information and feedback would be very much smaller than that of vision. Both the quality and quantity of sensory information would be severely limited; the result of which can be seen from the impoverished cognitive maps of the blind (c.f. Foulke, 1971).

It can be seen that the theoretical approaches of Siegel and White (1975) and Neisser (1976) complement each other to provide a useful model of the cognitive mapping process. Cognitive mapping is seen as the process whereby sensory information, gained by experience of the environment, is assimilated into a cognitive structure, which in turn serves to anticipate and guide further spatial behaviour. Initial learning may consist of landmark recognition and associated recall of previous actions. Following this, continued exploration of the environment may result in a cognitive structure which includes numerous interlinked routes (sequences of landmark-action pairs) and varying degrees of configurational knowledge. The latter type of knowledge will occur more often when secondary information sources have been used, as will knowledge which maintains Euclidean geometric principles.

#### 5.4 Pocock (1975)

##### (i) Group Differences in Images of Durham

It follows from such a process, that the amount and the spatial extent of a person's experience, combined with his behavioural objectives, are likely to exert substantial influence upon the form of his representation. This theoretical construct lay behind a research project conducted upon images of Durham by Pocock (1975). He compared the 'city images' possessed by residents, visitors to the city (for educational classes) and summer tourists. These groups completed a questionnaire, designed to assess their verbal 'image' of the city and were also asked to draw a free-hand sketch-map. The verbally obtained information referred mainly to symbolic or affective categories of recall, which, while pertaining to physical elements, was not essentially spatial in organization. These results showed that visual components were overwhelmingly dominant, but some mention was made of aural images by three-quarters of all subjects.

The mental map data allowed Pocock to raise several research issues but also led him to question earlier work in the area. It is unfortunate that the effect of familiarity which might have been inferred from the difference between the three groups was confounded by the diverse behavioural objectives underlying their interactions with the city. Comparisons between persons with different lengths of residence in the city and between tourists and newly-arrived residents might help to separate out the two potential effects.

Pocock did, in fact, obtain measurement differences between the three groups, as well as between the sexes and socio-economic classes. In classifying the so-called 'mental maps' Pocock utilised Appleyard's (1970) scheme, but saw fit to question its universality. It became

necessary for Pocock to devise a modified version of the scheme, to compensate for the difference in the basic shape of the city (compared to Ciudad Guyana, Venezuela - used by Appleyard) and what Pocock termed: "culture, scale and instructional set". Even so, the sequential/spatial dichotomy and complexity scale did make possible a discussion of the causality of several group differences. One such difference was that tourist maps were more 'spatial' in style than were the maps of the other groups. This is initially counter-intuitive, given the foregoing models of microgenetic development (Moore, 1974; Siegel and White, 1975). Tourists were perhaps the least familiar group and yet they produced the most highly developed (supposedly) style of representation. One possible explanation for this enigma, suggested by Pocock, was the nature of tourist attractions. As Pocock pointed out, this particular city is renowned for its buildings rather than its street scenes, so that the emphasis upon routes usually found in early representations would be less likely to occur in a tourist population. Such a situation would not be expected among the residents or visitors, as their activity patterns and behavioural objectives would be quite different. Firstly, routes would be important from a functional standpoint, rather than from aesthetic considerations; secondly, the activity pattern of a city resident would tend to be of a repetitive nature (for example, home to work or shops) and less exploratory than that of the tourist. The latter would lead to over-learning of a few routes and knowledge of a limited range of locations. Perhaps the most important factor might lie in the differential use of secondary information sources. Tourists, by nature, are more likely to consult maps, plans and guide-books, which as noted earlier, would give them a greater awareness of configurational details within the city.

A second variation between the groups was the level of complexity; the tourists giving the lowest proportion of the most sophisticated maps. This gives further credence to the argument that the mapping differences resulted from differing behavioural objectives. The fact that tourists were relative newcomers to the city was shown by the low levels of complexity on their maps; the type of elements which they emphasized reflected their behavioural objectives within the city. In contrast, residents who gave low scores on verbal measures of 'attachment' and 'attraction' to Durham were found to produce low complexity sequential maps. The negative sentiments may have acted indirectly by lowering the level and extent of interaction with the city to the minimum required by the residents' daily life. This would result in simple representations of a few routes, but little knowledge (or interest) in the general shape of the whole city, hence giving sequential representations only. Restricted activity patterns may also have led to the predominance of sequential representations among female and elderly subjects, with lack of opportunity to explore, rather than lack of inclination, being the relevant variable in these cases.

When the maps were grouped only in terms of complexity rather than separated into styles, the most sophisticated representations were obtained from the young, the middle-classes and male subjects. Pocock pointed out that the age factor was confounded by the disproportionate number of active subjects in the younger group; so that age was doubtless inversely related to familiarity and not directly related, as might be expected. The result that residents of less than ten years standing produced more sophisticated maps than those of more than ten years was similarly confounded by an excess of middle-class subjects in the first group. The major significant variable in this section was, in fact, socio-economic class, two-thirds of the middle-class subjects produced

'complex' maps whereas only a quarter of working-class subjects did likewise. These results are in accord with work reviewed earlier (Orleans, 1973; Goodchild, 1974); but again, it is not possible to determine which of the potential variables (i.e. spatial activity patterns, behavioural objectives, cognitive capabilities and graphic skills) were of significance.

(ii) Orientation Errors and 'Good Figure Tendency'

Pocock also analysed the maps from the standpoint of orientation errors and what he termed 'good figure tendency'. In the first of these analyses, he noticed the low proportion of conventional ('North up') map orientations; this category being larger among the spatial maps than the sequential. Separating out the different orientations enabled Pocock to link them convincingly to their owners' practical experience of the city. This was mainly in terms of typical entry point; for example, many more northern residents produced south-facing orientations than those who lived in the southern suburbs. In contrast, the latter group produced a correspondingly higher proportion of conventional orientations. The tendency to produce south-facing orientations would presumably be lessened by knowledge of the overall shape of the city and its relationship to the surrounding country. It is therefore understandable that spatial map sketchers gave a larger proportion of conventional maps: sequential maps, probably derived from personal route experience, would tend to show more egocentric frames.

Pocock looked at the tendency of subjects to depict shapes, lines and patterns as being nearer to the Gestalt ideal (symmetric, parallel, rectilinear, closed, etc.) than they actually were; terming this the 'good figure tendency'. At least 60% of the sketches were shown to exhibit some degree of 'gft', according to Pocock's analysis. Examination

of the maps showed an 'unequivocal trend' towards greater 'gft' in the more complex maps. There was a direct relationship between complexity and 'gft' among the spatial maps, but no such relationship in the sequential category. Pocock suggested that this difference may have been due to 'spatial' sketchers being more likely to construct their maps around the more 'gft'-prone elements, such as the river. However, since 'gft' was also greater among males than females and increased with familiarity, there seems to be a deeper reason behind such a process. Pocock summarized the results of this section by saying that 'gft' was more likely if the respondent was male, middle-class and familiar with the city. Judging from the rest of the mapping results, 'gft' could equally well be characterized as being associated with more complex, especially spatial, maps. It seems that the process involved in the 'gft' is integrally linked with the cognitive mapping task; possibly meaning that successful mapping of an area cannot be achieved in the absence of 'good-figure' adaptation of the available stimulus material.

Initially, the last finding appears to be inconsistent with Follini (1966), who claimed that the tendency towards 'good figure' would be found to diminish with increasing competence or familiarity. This does not, in actuality, constitute a serious conflict, since the potential stimulus information in an environmental setting is immeasurably more complex than in the shape perception experiments considered by Follini. At the topographic level, the task is to achieve an understanding of the general structure and content of the whole: to reach Follini's next stage of competence, that of appreciating the distinctive irregularities of each stimulus element, would be virtually impossible. Such a task would entail 'perfect' cognitive mapping, which is theoretically conceivable but practically impossible. It would entail not only 'photographic' memory traces, but also an infallible method of externalizing such images.

## 5.5 The Role of Specific Cognitive Factors

It can be seen that what Pocock termed the 'good figure tendency' involves the derivation of basic geometric forms which most closely approximate aspects of a complex stimulus array. While it is not possible to state at what point this effect occurs, clearly, at some point it will be necessary for the mapper to perform cognitive manipulations of complex environmental information. Since Pocock's work, several researchers have found evidence that indicates that the 'good figure tendency' occurs when information is encoded and stored (Byrne, 1979; Chase and Chi, 1981; see Chapters 6 and 8). From Pocock (1975), it seems that level of cognitive mapping sophistication may be correlated with the ability to perform these cognitive manipulations.

Several researchers (Appleyard, 1970; Ladd, 1970; Goodchild, 1974) had suggested that differential performance on their mapping tasks may have been a result of a varying ability to conceptualise the environment; however, few had included experimental analysis of this possibility. Two studies which did examine the correlation between performance on standard tests of specific cognitive abilities and cognitive mapping skills were by Bycroft (1974) and Moore (1975). Bycroft looked at the relationship between the sketch-map sophistication of a group of young children and their scores on a number of tests of cognitive ability. The sketch-maps were assessed by a modified version of Appleyard's taxonomy; cognitive ability by a number of standard tests. The highest correlation was found between cognitive mapping scores and a test of the ability to manipulate cognitive spatial information (the 'Shapes and Toys Test'; Watt, 1951). However, significant correlations were also found between cognitive mapping and tests of reasoning ability, so that general cognitive functioning, rather than specific cognitive abilities, may have been crucial. This question prompted Moore to



assess the cognitive abilities of the subjects who took part in his study of the development of cognitive representations (as discussed earlier; Moore, 1973 and 1974). He assessed their general cognitive ability by five tests of verbal reasoning and numerical ability and their specific spatial ability by the 'Spatial Relations Test', taken from the 'Differential Aptitude Test' battery (Bennett, Seashore and Wesman, 1951). This last test evaluated a person's ability to manipulate cognitive representations of spatial information. Moore found that the 'Spatial Relations Test' alone was significantly correlated with mapping performance. It can be concluded from these results that by the mid-1970's there was tentative evidence for the involvement of general spatial ability in the cognitive mapping process.

#### 5.6 The Validity of a 'Stylistic' Interpretation of Mapping

Another issue to emerge from Pocock's study is that of the validity of a stylistic interpretation of mapping products. Pocock was able to employ Appleyard's taxonomy (1970), but found it necessary to adapt it to take into account the influence of the basic city shape upon mapping products. This influence was discussed by Canter (1977), as was the effect of 'instructional set' upon mapping; the latter being thought capable of biasing the mapper to produce either predominantly spatial or sequential maps. Consideration of Pocock's work and that of other researchers indicates the potential influence of differing behavioural objectives and secondary information sources upon the style of map produced. Adherents to a 'personal style' interpretation of mapping products would therefore have to show that differences in 'style' were independent of type or amount of experience in the environment being mapped. The work of Moore (1974) actually supports the opposite

conclusion; that the type of map produced is related to the level of familiarity with the environment. Further to this interpretation, Canter has shown how Appleyard's taxonomy (four levels of complexity in each of 'spatial' and 'sequential' styles) may be better characterized as constituting a single sequence of eight levels of complexity, with each 'sequential' level being classed as less complex than its equivalent 'spatial' level.

In short, though Appleyard's taxonomy proved useful for initial examination of differences in cognitive mapping, the validity of employing a 'personal style' interpretation of the differences appears to be questionable. A developmental model, associating cognitive mapping performance with environmental experience and cognitive functioning, seems to provide a viable alternative.

## Chapter 6

### Beck and Wood (1976)

#### 6.1 Introduction

##### (i) General

It appears that by 1976, the areas of research had emerged which were to dominate cognitive mapping studies up to the present day. These areas can be categorized as follows:

- (1) Methodological studies criticising and comparing existing and newly developed techniques for externalizing cognitive representations (Spencer, 1973).
- (2) Studies of the processes whereby cognitive representations are formed, in relation to the experience of the subjects; with both quantity (i.e. the microgenetic development of new representations) and quality (e.g. geographical range, travel mode and objectives of subjects) of experience being studied (Howell, 1969; Appleyard, 1970; Maurer and Baxter, 1972).
- (3) Studies of the extent to which subject characteristics (e.g. specific cognitive abilities, age, sex, I.Q.) may account for individual differences in performance upon tasks designed to assess cognitive mapping skills (Ladd, 1970; Moore, 1975).
- (4) Studies of the structure of 'cognitive maps', attempting to uncover the principles governing internal transformation and storage of spatial information, with an emphasis upon the form of the physical environment (Follini, 1966; Pocock, 1975).

In the early stages of research into environmental cognition, (i.e. 1960 - c.1973), studies were mainly concerned with 'public images' - i.e. those aspects of subjective environmental images which were shared by members of a relevant social group. As such, they tended to employ sketch-mapping or verbal elicitation techniques without any consideration of their validity. However, by 1976, the shift in interest to the individual 'cognitive map' led to a situation where almost every paper included some discussion of methodological issues, whatever the primary focus of the research.

(ii) Beck and Wood

A major paper published in 1976 by Beck and Wood, containing both theoretical and experimental material (though the experimental work was more thoroughly documented elsewhere - Wood, 1973; Beck, Paris and Wood, 1975), epitomised this dual-focus approach. The authors set out to develop theoretical constructs which would contribute to an understanding of the cognitive processes involved in large-scale spatial learning. They attempted this by first acknowledging that 'cognitive mapping' is a process which involves both the transformation of environmental information into some unspecified cognitive form and the subsequent use of this 'knowledge' to solve environmental problems. As such, they were able to note that variables of interest can be grouped according to whether they refer to qualities of the subject, the environment, the subject's experience of that environment or the type of elicitation method used to study such learning.

## 6.2 Subject Characteristics and Cognitive Mapping

The first experimental report constituted an investigation of the relationship between a wide range of subject characteristics and performance upon a set of sketch-mapping tasks. Each task required the subjects to represent a different type of knowledge about their home town (Montreal, Canada). In this way, Beck and Wood were putting into practice their own belief in the utility of map-drawing as a means of communicating environmental knowledge. They advocated the separate elicitation of various types of information as the most efficient means of evaluating the multiple "layers" of which they believed the 'cognitive map' to be composed.

Although details of the analysis carried out upon the four types of sketch-maps were not included in this paper, the authors did make a useful distinction between performance as measured by the amount of detail produced (i.e. content) and performance as measured by the spatial accuracy of such details. Most earlier studies had in fact concentrated chiefly upon content (see Chapters 3 and 4) as a performance index. This was no doubt largely due to the research emphasis of the era, but additionally, the free-hand sketch-mapping technique did not facilitate quantitative assessment of accuracy. It is significant that prior to this date, the only noteworthy attempt to examine accuracy in graphic recall did not use free-hand sketch-mapping. This was by Stea and Taphanel (1974) who followed the innovative example of Battro, Ellis, Freeman and Matalon (1972), by using a 3-D modelling task to elicit the 'cognitive maps' of a group of adults (see Chapter 11).

In making the content/accuracy distinction clear, Beck and Wood opened the way to future investigations of content and accuracy as independent measures, which could be separately related to subject variables or even compared with each other. It was not known if people

who produced highly detailed 'maps' were also highly accurate, or if the two measures were unrelated. A third possibility was that the measures were inversely related, subjects employing a form of 'trade-off' between the two.

The results of the Montreal study indicated that a number of personal characteristics are correlated with high performance, on both content and accuracy scales. The important factors appeared to be long-term residence, 'active' travel mode, high mobility and good orientation ability (self-assessed). These results support earlier findings (e.g. Appleyard, 1969; Ladd, 1970; Siegel and White, 1975) as to the importance of active exploration in the development of complex cognitive maps of an area. They also found that general experience with maps was correlated with performance on their sketch-mapping tasks. This was a possibility raised by Orleans (1973) and others as an explanation of low-mapping performance by less-educated subjects (despite their being able to find their own way around the relevant environment).

Beck and Wood also found some variables which were correlated with content but not accuracy. These were the subjects' self-estimates of particular environmental knowledge, objective short-term memory for graphic material and self-estimates of memory ability. The authors concluded that:

"We appear to be dealing with different cognitive mechanisms in the processing of content and spatial veridicality."

It should be recalled at this point that Moore (1975) found that 'level of representation' (a cognitive mapping measure more akin to accuracy than content; since it indicates the complexity of the map structuring, rather than what is included) was correlated with a measure of spatial relations ability: however, it showed no such

correlation with any of the verbal measures of intelligence assessed by Moore. It is questionable what pattern of correlations would have emerged had Moore assessed mapping ability by a verbal (rather than graphic) index.

Together, these results highlight the dangers, noted by past writers (e.g. Spencer, 1973), of directly comparing verbal and graphic products of mapping tasks. Subjects may perform at a high level on one type of task but appear much less knowledgeable when tested by the alternative type. It must also be noted that this discrepancy may be quite independent of educational level, being dependent upon specific cognitive abilities which may vary greatly between subjects, with any given educational level.

### 6.3 Experiential Variables in Microgenesis

At this point, Beck and Wood outlined their conclusions as to the role of experiential variables in the development of cognitive maps over a microgenetic time-scale. They based their conclusions upon the results of a microgenetic learning study of a group of adolescents who were touring London, Paris and Rome over a 35-day period. One of Beck and Wood's research interests lay in the design of teaching methods aimed at improving people's ability to interpret and organize new spatial information. As a consequence, subjects in this study were initially taught 'ENVIRONMENTAL A', a mapping language devised by the authors to facilitate the representation of environmental knowledge. This also incorporated the principle of dealing separately with each 'type' of information, in a series of 'map layers'. In this case, the recall maps which subjects were asked to produce of the cities were drawn on a series of overlaid transparencies. They were asked to begin with a node-link 'skeleton', then a district map and finally, a number

of overlaid 'attribute maps'. The 'attribute maps' enabled subjects to indicate more of their evaluative responses and memories than would be possible on a combined sketch-map.

Observations made by the authors during the tours, combined with measures obtained from the sketch-maps, allowed them to extract three potential sources of variance in cognitive mapping performance, resultant upon the subjects' experience. Beck and Wood concluded that, especially in the early stages of learning, the temporal sequence in which the environment is experienced may exert an inordinate influence upon its cognised form. As a result, an environment experienced in spatially-fragmented temporal sequences would be less accurately mapped than one in which temporal sequences of experience were co-ordinated with spatial parameters.

A second factor which emerged from the authors' observations was the role of secondary information (e.g. maps, guide-books) at all stages of experience, i.e. before, during and after experience. Beck and Wood pointed out that the integration of such information with direct experience was a process which had not been investigated and they speculated that individual differences in mapping ability might be paralleled by similar differences in ability to integrate multiple sources of information. Beck and Wood's investigation indicated that good mappers use a wide variety of sources of information.

The third experiential source of variance in mapping performance which the authors discussed, was the role of representational activity during 'trips' around the environment which was to be mapped. By this they were referring to a situation wherein subjects periodically obtained some reminder of significant places experienced on the tours (e.g. postcards, photographs, etc.). It can be seen that this factor may be of particular importance when studying a tourist population and



might conceivably lead to a high level of content-recall for landmarks so represented.

The consideration of experiential factors in cognitive mapping brought to the fore a major problem inherent in naturalistic experiments. That is, in order to be non-intrusive, the 'experimenter' must necessarily sacrifice the right to control the precise nature of each subject's environmental experience. Even when subjects were all taking part in the same guided tours, some subjects would have been better able than others to obtain potentially available information. In most natural learning situations, subjects will follow idiosyncratic spatial activity patterns, which the experimenter may not be able to monitor comprehensively. These limitations must be considered when the decision is being made as to whether a naturalistic or a controlled laboratory study should be utilised to study a particular aspect of cognitive mapping. The precise focus of the study will determine which variables are of paramount importance and therefore, which methods must be used.

#### 6.4 Environmental Variables in Cognitive Mapping

Consideration of a subject's experience in an environment naturally led Beck and Wood to examine how attributes of the geographic field itself might relate to mapping performance. In doing this, they were following in the tradition of Lynch (1960) and other urban-design workers (e.g. De Jonge, 1962; Gulick, 1963), who also focussed their studies upon environmental variables: however, Beck and Wood extended such work by interpreting stimulus parameters within a psychological framework. They used an information-processing approach to assess which factors in an environment might affect the level of representation that could be achieved. In this way, they were characterizing the mapping process as one which primarily involves the pick-up and use of

functionally-important information by the subject, as a means of environmental navigation. This characterization is aligned with that of experimental psychology and supercedes the aesthetic/appreciative motives which were assumed to underly the development of urban images, as studied by urban designers (e.g. Lynch, 1960; Carr and Schissler, 1963). However, within their conceptual framework, Beck and Wood did note the possible influence of 'affect loadings' upon the perceived size of a particular element; namely, an element in an environment with a similar affect loading will be overestimated and vice versa. The authors therefore pointed out the necessity of taking account of such a source of variance in representations.

The issue of subject attitude influence is one which was also raised by Pocock (1975), who found that low scores on 'attraction' and 'attachment' to the mapped environment were related to poor mapping performance (see earlier discussion). Similar suggestions may be made in relation to Beck and Wood's work as were applied to Pocock's finding: that the emphasis of a representation may be related to the level of experience which a subject has of the constituent elements. In the case of Beck and Wood's claims, it may be that a liked place is emphasized in a liked environment because it is one which is well-known or highly-frequented by the subject; indeed, it may be the one which causes the whole environment to be liked. Equally, a disliked place in a disliked area may be the first one known (and disliked!) by the subject; with the consequence that the remainder of the environment is avoided and therefore not learned by the subject. This would imply that attitude was a mediating variable, with knowledge/experience being the actual factor which determined the element emphasis upon the elicited representation. Howell (1969) also found a positive relationship between residents' attitudes to Staten Island and the quality of their sketch-

maps. People who admitted to being unable 'to identify with' the area and said they had little local involvement performed poorly on the sketch-mapping task. The best maps (having the highest content and accuracy) were drawn by people who were interested in the island. In addition, those who drew the best maps were found to have combined information from direct experience and from commercial map information. Hence, Howell's results also supported Beck and Wood's claim that good mappers were well able to integrate information derived from multiple sources.

The other field-constructs discussed by Beck and Wood were clearly within the framework of a representation developed via an information-processing system. The level of 'redundancy' or replication of orientational information was claimed to affect mapping potential; with an excess of information (assuming the subject can interpret such information) leading to better performance. It was also speculated that the density of environmental information available in a person's surroundings might affect the type of representation formed; notably, that a sudden change in density might precipitate a corresponding change in scale or form of representation.

Two environmental features which were deemed to cause problems for the would-be mapper were large, amorphous elements and route intersections. In the former case, the difficulty in achieving an accurate representation lay in the fact that direct experience could only furnish piecemeal information regarding the relevant physical parameters. The element (such as a river or park) would never be perceived as a whole and the overall shape would therefore be difficult to establish and co-ordinate with the rest of the person's 'cognitive map' - unless, of course, secondary information sources, such as a map were consulted. Even then, the irregular contours of a natural feature

would not be easily stored in memory, without the processes of simplification (c.f. Pocock, 1975) possibly rendering crucial aspects of the information inaccurate.

The inaccuracies arising from simplification processes at the storage level were also raised in relation to the mapping of intersections. They referred mainly to the tendency for angles to be represented as either  $45^{\circ}$  or  $90^{\circ}$ , whichever was the nearest to the true value. This phenomenon had been experimentally investigated by Pocock (1973). He chose subjects who would have been highly qualified to sketch certain road intersections (geography undergraduates in a well-known area) in order to ensure that any distortions obtained would not be attributable to lack of skill. Despite this design, subjects showed a clear tendency to simplify road intersections and to align roads with cardinal compass directions. Pocock therefore attributed such effects to the cognitive system operating when the environmental information was stored. Additional experimental confirmation of the tendency to simplify angles has been found by Byrne (1979). Chase and Chi (1981) have shown how U.S. subjects may even simplify  $45^{\circ}$  into  $90^{\circ}$  angles. It may be recalled that Stea (1969) had observed this phenomenon and questioned how far it was dependent upon the subjects being familiar with grid-iron street patterns. A cross-cultural comparison might indicate to what extent past experience affects the degree of distortion which is exhibited. Canter (1977), in discussing Pocock's results, questioned whether any sketching task, however adept the subject group, could unequivocally show that a cognitive process was leading to simplifications, rather than them being a sketching by-product:

"....perhaps brought about by the use of a set of simple stereotypic patterns to convey spatial information...."

Canter then evaluated evidence from non-graphic 'mapping' tasks

(Canter and Tagg, 1975), and drew the conclusion that the distortions are, in fact, a result of cognitive processing at the storage stage.

Beck and Wood pre-supposed Canter's conclusion, by assuming that cognitive storage processes, aimed at minimising the memory load, produce the simplification of angular information. Indeed, they pointed out that an intersection is a place at which there is an overload of information - making storage 'economy measures' particularly important.

Beck and Wood suggested that the above-mentioned features (intersections and large, natural elements) might be differentially represented in terms of content and veridicality. Both types would possibly be well-represented on a 'content' index, but poorly so on measures of accuracy. In the case of large, natural areas, their content memorability would be a result of their size and singularity, as well as their functional significance. Intersections would be recalled for their functional significance and their unusually high information load. Both types of feature would be poorly-represented in terms of accuracy, for the reasons given above. By highlighting this potential content-accuracy differential, the authors were implicitly recommending separate and complementary assessments of knowledge as 'content' and knowledge as 'veridicality' - an issue they had raised earlier, in their discussion of subject variables.

#### 6.5 The Choice of Elicitation Technique

The final class of constructs considered in Beck and Wood's discussion were those pertaining to the experimental task itself. They first described the operations which must take place between perceptual information being recalled and it being included in an elicited 'map'. These were listed as:-

- (1) rotation of perceptual information into the plane required for mapping;
  - (2) co-ordinated scaling down of information, involving generalization of finer details;
  - (3) symbolizing the spatial elements and attaching verbal labels;
  - (4) consciously forming a mental representation of the element/group of elements prior to externalization,
- and finally,
- (5) producing the 'map'.

The authors stressed that in their opinion, these operations were not carried out in a single sequence, but were overlapped and interwoven in a feedback loop of map production, observation of the product, correction of perceived inaccuracies, retrieval and inclusion of further information.

The complexity of this group of operations made it clear to the authors that the nature of the elicitation task may crucially affect the results of any investigation of cognitive mapping. They limited their discussion of task demands to those directly related to their own techniques; namely, the advantages of base-maps and the use of a 'mapping language' over the free-form sketching task used by the previous researchers. The chief advantage of base-map usage was seen as being its ability to reduce initial gross errors, which would otherwise mean that the subject was working from an erroneous base - possibly leading to an underestimate of his/her overall spatial knowledge. However, Beck and Wood mentioned one drawback to the use of a base-map, that is, as the level of detail in the base-map increases (giving a decrease in the potential for initial scaling errors), there is a contingent decrease in the amount of subjective information which is transmitted by the subject during the task. As the authors noted, it is important

that an experimenter is clear which aspects of the subject's knowledge base he is attempting to 'tap'. Beck and Wood considered their 'layering' technique, as used in 'ENVIRONMENTAL A', to be a sensible compromise. This permits the subject to indicate his concept of the basic frame-work of the area, without biasing his view with new information: whilst reducing any accumulation of errors by separating out the different types of elements onto transparent overlays.

At several times in their paper, Beck and Wood observed that a person is able to use the part of his 'map' which he has already drawn as a source of 'new information' to aid his subsequent organization of the material. Despite this observation, they did not go on to discuss whether graphic (2-D) tasks can therefore ever be considered to be a useful elicitation technique. This is doubtless due to the fact that the paper was written as a defence of sketch-mapping as an investigation tool. Nevertheless, this did become one of the main controversies debated by cognitive mapping researchers during the subsequent years (e.g. Sherman, Croxton and Giavanatto, 1979; Baird, 1979). However, at the time when Beck and Wood were writing, graphic techniques were still predominantly viewed as being a useful tool for investigating cognitive mapping. As Canter (1977) stated:

"...because of the efficiency, variety and summarising qualities of sketch maps they present a valuable means of exploring conceptual systems."

Lynch put the case even more strongly in his 'Foreword' to Moore and Gollidge's (1976) book 'Environmental knowing: Concepts and Theories':

"...The graphic languages are excellent for communicating multiple relations between things at one glance, in a single complex pattern."

Indeed, Lynch went on to describe a wide variety of means whereby sketches can be analysed (e.g. emphasis, distortions, bias of detail, gaps, connections) and asserted that, even at a low level of skill, much

spatial knowledge can be communicated by graphic means. He also stressed the frequently unappreciated fact that whichever elicitation technique is used, a subject's performance will be to some extent dependent upon his skill in using the relevant modality. Subjects may be unskilled in many other 'languages' besides the graphic. This fact was illustrated by Spencer (1973) who found that limited verbal skill was as great a handicap to describing an area as limited graphic skill was to sketching the same area.

In view of this, Lynch stated that training in any 'language' will improve a subject's ability to communicate via that medium. On the other hand, he also asserted that any language (even a specially designed mapping language such as 'ENVIRONMENTAL A') can only uncover part of an overall environmental image, and that any attempt to ascertain the totality of such an 'image' must use a variety of techniques. In this, he focusses attention not only upon the end-product of a mapping task, but also upon the sequence and manner in which it was produced. Lynch was presumably looking to the sequence in which a 'map' was drawn in the hope that it might reflect some aspects of the process by which the internal representation was originally organized. A similar notion was also put forward by Canter (1977) who suggested that the drawing sequence might parallel the acquisition process in terms of the level of complexity observed at various stages.

Lynch's demand that a wide variety of techniques be used to characterise all the aspects of an environmental image, may set an impractically high standard for any one study. As an alternative recommendation, it is reasonable to claim that Lynch was implicitly supporting Beck and Wood's opinion that researchers should clarify what aspect of an environmental image they aim to study with a particular technique. Beck and Wood had stated such a view when



discussing the utility of base-maps; but the same may be said for any study. Whichever technique is used, it will only highlight a subset of the store of environmental information possessed by a subject: it is therefore important that this area be made explicit if valid conclusions are to be drawn from the study.

## 6.6 Conclusions

In summary, Beck and Wood's work was important for both its methodological and its theoretical considerations. From a methodological standpoint, the utility of a structured graphic 'mapping' task was demonstrated; indicating that at least some of the strongly stated disadvantages of graphic methods can be eliminated by the introduction of some form of structure to the task.

At a theoretical level they provided a useful analysis of the types of variable which must be studied if an understanding of the mapping process is to be achieved. They provided experimental evidence of the importance of two of these types; namely, the psychological characteristics which may affect mapping ability and the experience which a 'mapper' has of the environment to be mapped. In the first case, these were variables hinted at but not studied directly before this time. Study of the second type, experiential variables, was an inevitable result of the new emphasis upon process in cognitive mapping. Indeed, by the end of their paper, Beck and Wood were able to characterise their model of the cognitive processes involved in learning an environment. Their conclusions were in agreement with most other researchers, emphasizing the dual purpose of 'cognitive maps', e.g.:

"....to the extent that the mental map is an organization of past experience, it is also not merely a data base on which to move through the environment, but most critically a program organizing the search for, selection, and creation of future geographic information." (p.236)

The mapping process therefore, is seen as both facilitating navigation and providing a frame of reference for absorbing new environmental information.

Essentially, they were proposing an interactional-constructivist model of environmental cognition, similar to that being put forward at the same time by other cognitive mapping researchers (Moore, 1974; Siegel and White, 1975). Like other proponents of this model of cognitive mapping, they lent support to Neisser's (1976) cyclical model of schemata development (see earlier discussion). Neisser stated that the schema (cognitive organisation of knowledge) is constantly being adapted by new information which results from its use. In Beck and Wood's case, this is said to occur when an external 'map' is being produced, since they consider the construction of a 2-D representation as being the major task of someone attempting to utilise his environmental knowledge. Other researchers widened the issue to state that the cyclical 'image-action-new information-altered image' system can occur without the person having ever produced an external map or 're-representation'.

Unfortunately, Beck and Wood used the phrase 'mental maps' (which they defined as "sketch products created by experimental subjects") throughout their paper, when presumably they must have been referring to the hypothesized internal organisation of knowledge. Otherwise, the quotation above would imply that no-one could navigate an environment unless they first drew a sketch of how they believed the area to look. Clearly, this confusion of internal representations and external 'map' products must be avoided if lucid discussion is to take place on these issues.

The Present State of Research

## Chapter 7

### Methodological Issues

#### 7.1 Introduction

A number of major issues have been identified (see 'General Introduction' and 6.1) which have dominated cognitive mapping research from the mid-1970's to the present day. This chapter and the following three chapters will review the most recent evidence pertaining to each of these issues.

The foremost issue facing cognitive mapping researchers is one of methodology. If valid investigations are to be carried out into the development and structure of cognitive maps, then acceptable methods of eliciting and analysing these internal representations must be found. Previous chapters have described the misgivings raised in relation to the widespread use of free-hand sketch-mapping, particularly with disadvantaged subject groups (see 4.5). One experimental attempt to alleviate the problems of sketch-mapping, by using base-maps and a special mapping language was described in Chapter 6 (Beck and Wood, 1976).

The remainder of this chapter will review the available research findings pertaining to a more fundamental question: namely, are researchers justified in using any elicitation technique which necessitates the production of a two-dimensional array by the subject? In order to answer this question, it will be necessary to evaluate the utility of alternative techniques for eliciting the spatial aspects of environmental representations, or what has been termed the 'designative image' (see 3.1).

## 7.2 The Validity of 'Direct Mapping' Techniques

Those few recent studies which have been primarily concerned with methodology have examined the validity of what are collectively known as 'direct mapping' techniques. This term covers any technique for eliciting cognitive representations which entails the subject placing elements in a two-dimensional array; with the assumption that the arrangement will be directly analogous to the actual spatial dispositions of the relevant elements. Sketch-mapping is the most familiar technique, but three-dimensional modelling and computer-based arrangements are fundamentally similar techniques. All these variants of direct mapping necessitate each map element being placed so that it bears the correct spatial relationship to every other element.

The method most commonly used as an alternative to direct mapping is that of distance estimation. Here subjects are required to compare the distances between pairs of points. Again, a number of variations upon this basic technique have been employed. One variant simply involves arranging all possible pairs of elements, such that they subjectively range from the pair which are closest together to the pair which are furthest apart. Another involves using a scale which has a standard distance between two well-known elements already marked on it. The subject marks his estimate of the distance between each two target elements in relation to this standard. A third type of task actually requires the subject to assign a number to each pair of elements to represent the distance between them (either on a standard scale e.g. 1 to 100 or on a metric scale e.g. metres). Once inter-item distances are obtained these can be analysed by either determining the power function which best fits the estimated-actual distance relationship, or by employing a non-metric form of 'multi-dimensional scaling' (cf. Kruskal, 1964). The latter technique produces the two-dimensional spatial layout which best fits the rank-orderings of inter-point distances.

Distance estimation became commonly-used as a method of eliciting spatial representations as a consequence of criticisms being levelled at free-hand sketch-mapping. The seemingly less complex task of estimating relative or absolute distances between pairs of points was seen as a useful means of circumventing the numerous disadvantages of sketching tasks. The objections raised in relation to sketching fell into two main groups; those which apply only to unstructured sketching tasks and those which apply equally well to any direct mapping technique. The first group of problems have been gradually alleviated over the course of cognitive mapping research by the development of modified types of sketch-mapping. The dependence upon graphic ability and the problems of choosing an appropriate scale were lessened by the introduction of structured mapping techniques, such as that used by Beck and Wood (1976). Some researchers eliminated the graphic component completely; by using a three-dimensional modelling task (e.g. Stea and Taphanel, 1974).

The second group of problems thought to affect sketch-mapping were more fundamental to the two-dimensional nature of the task and as such, could be said to affect any variant of direct mapping. Sketch-mapping was said to constitute too difficult a task for the naive subject, in that it forced him to consider the position of each element which he placed, in relation to every other element on the map. In so doing, the subject was said to create new information for his internal representation, by virtue of the geometric constraints of the map product. That is, by creating constellations of elements with the aid of known angles and distances, previously unknown spatial information would be inadvertently made explicit as a result of Euclidean geometric principles. The subject's spatial representation would therefore be elaborated as it was being externalised.

One recent study which claimed to provide tentative evidence of the above effect was performed by Sherman, Croxton and Giavanatto (1979). They compared a three-dimensional modelling task with a distance estimation task for the same set of buildings. One group of subjects performed only the distance estimation task (DE1) while a second group modelled the area before completing the distance estimation task (DE2). Distance measures were taken from the 3-D models in order that the two techniques could be directly compared. A multi-dimensional scaling (MDS) procedure was used to 'fit' the sets of distance estimation to the objective map. In this way, north-south and east-west dimensional weightings were obtained to show the two-dimensional distortions in the data. The ratio of each pair of weightings provided an index of the 'shape' of each spatial configuration. Sherman, et.al. pointed out that overall, the ratios indicated a greater similarity between the models and DE2's than between the models and DE1's. Also, there was a low correspondence between the two sets of distance estimates. The researchers took this as tentative evidence that performing a direct mapping task had altered the subjects' representations. They did, however, admit that subject differences may have led to their results; the between and within subject design possibly biasing the results towards the effects found.

Aside from possible subject differences, a number of extraneous factors might have contributed to the results shown by Sherman, et.al.. One of these was that the researchers tested people from three residential areas, all of whom did not follow the same pattern of results. One group showed the reverse pattern to the one highlighted by the researchers (i.e. their results showed a greater similarity between DE1 and modelling than between modelling and DE2). A second group showed a DE2 result which was exactly halfway between DE1 and modelling. Only one group

actually showed the highlighted effect. The differing spatial experience of the three residential groups may have confounded any methodological effects (c.f. Holahan, 1978).

The modelling task itself may also have created problems, in that the large size of the base necessitated a perspective view while modelling. The researchers commented that this may have caused subjects to foreshorten distances in the positions furthest from where they were standing while mapping. If subjects predominantly stood so they viewed the arrangement as they customarily did when entering the campus, this would have led to characteristic distortions from each residential group. It is noteworthy that the group whose results showed the strongest difference between DE1 and modelling (with the models exhibiting a foreshortening in the north-south dimension) were those whose customary campus approach was 'North up'. Since the latter is the traditional orientation for maps, there would presumably have been an increased likelihood of subjects creating their models from that viewpoint. Other residential groups may have moved between 'North up' and their own customary approaches, so lessening any overall pattern in the distortions. While it is true that the foreshortening effect in the 'North up' group was reflected in their later distance estimates (implying that modelling had affected their representations), this does not necessarily mean that a modelling, or any other form of direct mapping task would invariably give rise to such changes. The elimination of the abovementioned idiosyncrasies of the modelling task may have also eliminated any differences between it and distance estimation, in terms of accuracy and distortions.



### 7.3 Problems of MDS and Distance Estimation

Given the previously discussed confounding factors, the evidence that mapping alters cognitive representations, as provided by Sherman, et.al., appears to be of limited value. On the other hand, evidence of a more substantial nature has accumulated that MDS-derived configurations based on distance judgements may not be adequate representations of a person's subjective knowledge. MacKay (1976) examined the accuracy of MDS solutions of inter-city distance information based upon either hand-drawn maps or pair-wise distance estimation. Accuracy was assessed both objectively (against a veridical map) and subjectively, with subjects assessing their own maps after a ten week delay. MDS solutions were derived from hand-drawn map distances, rather than taking the hand-drawn arrangements per se, so that the pair-wise data would not be differentially affected by the efficacy of the MDS technique. The only difference between the two conditions was therefore the source from which the distance estimates were obtained. MacKay found that hand-drawn maps produced objectively more accurate layouts than the card-sorting task. In addition, subjects rated their own sketch-derived layouts as more accurate than their own 'pair-wise' layouts.

One study completed at about the same time as that by MacKay, but not reported until later, drew similar conclusions about the relative utility of direct and pair-wise mapping techniques (Baird, Merrill and Tannenbaum, 1979). Using a computer terminal, subjects performed a direct mapping task and a distance judgement task. In the former, they positioned building names on a 2-D matrix display and in the latter, they provided a numerical estimate (on a standard 0-100 scale) of the distance between each possible pair of buildings. A 2-D display was generated to match the distance judgements by the use of an MDS technique.

Baird, et.al., like MacKay, found that subjects judged their own 'direct' layouts to be more accurate than their own distance judgement/MDS layouts.

One discrepancy between the results obtained by MacKay and those of Baird, et.al. was that the people tested by the latter did not have any strong preference for an 'objective' map in comparison to their direct maps, as MacKay's had done. This was probably because the accuracy levels for a small campus map would be far higher than for a map of the U.S.A., so that any differences between the direct map and the objective map would be less noticeable to a subject. Indeed, when Baird, et. al. assessed the objective accuracy of the mapping products, they found both of them (direct and distance judgement/MDS) to be highly accurate.

The results obtained by Baird, et. al. were somewhat perplexing; while two types of spatial layouts were shown to be equally accurate, subjective judgement consistently favoured one of them, the direct map. Baird explained this (in Merrill and Baird, 1979) in terms of the different procedures that are employed by subjects and by MDS to form a two-dimensional map. While a person is producing a two-dimensional layout, he appears to position each new element in relation to all the other elements already positioned, sometimes adjusting the other elements so as to maximise the overall accuracy of the layout. As MacKay (1976) suggested, this procedure might incorporate knowledge of angular relationships as well as distance information. In this way, the person would resolve any conflicts which accrued during the course of the mapping session by using his full range of spatial knowledge. The MDS technique, in contrast, is limited to resolving only those inequalities which can be derived from the distance judgements. Baird speculated that his subjects were using subtle spatial cues, as described above, as grounds for rejecting the MDS-produced maps. On the basis of this

limitation, Baird concluded that the direct mapping technique provided the more useful tool for examining cognitive representations of the spatial environment.

#### 7.4 Conclusions

In conclusion, there appear to be several important points which can be gleaned from the above discussion. In the first place, none of the commonly-used techniques for eliciting cognitive representations can claim to be infallible. Whichever technique is employed, some degree of distortion and bias will probably contaminate the data so obtained. The extent to which any technique adversely affects the form and content of the data may depend upon several factors. Subject characteristics such as educational background, specific cognitive abilities and travel experience are all likely to influence the suitability of a mapping technique. Equally important is the realisation that a particular method can only elicit a partial representation; so the suitability of a technique will also depend upon the specific theoretical focus of an experimental study.

It therefore seems that the decision as to the type of elicitation technique to be used must be made by the individual researcher, taking into account the abovementioned factors. As far as methodology is concerned, researchers may now have to view appropriateness as a desirable goal, rather than absolute superiority.

For the purposes of the empirical studies to be reported in this thesis, it was decided that a direct mapping technique would be acceptable. This can be justified by considering the outline of the intended empirical studies provided in the 'General Introduction'. The subject population would have an educational and experiential background which should enable them to carry out a direct mapping task

without undue difficulty. The studies were intended to examine experiential and cognitive correlates of overall accuracy in depicting spatial layouts. The focus of the studies is therefore on individual differences in elicited spatial accuracy, rather than on the form of the underlying cognitive structures per se. Given this fact, and in the light of the discussion in 7.3, it seems that a direct mapping method may actually be preferable to the use of distance estimation. A direct mapping task will enable a subject to utilise any spatial information s/he has to produce a spatial array.

## Chapter 8

### The Structure of Cognitive Maps

#### 8.1 Introduction

As noted in the 'General Introduction', the structure of internal spatial representations has become the subject of much research attention within cognitive psychology. Cognitive mapping has been recognised as a convenient 'real-life' example of cognitive information processing. This chapter will review the findings of such experimental studies, in relation to earlier conceptualizations of cognitive mapping, such as that by Siegel and White (1975). The studies have been concerned with two related issues. Firstly, they sought to ascertain the geometric properties of cognitive representations in relation to the external reality which was being represented. Secondly, they concerned the changes which might commonly occur in such geometric properties as a consequence of increased spatial knowledge.

#### 8.2 The Geometric Properties of Cognitive Maps

##### (i) Distortions

As discussed in Chapter 6, several authors had commented upon, or obtained evidence of, the tendency for angular information to be represented in a simplified form: people recalling junctions as right angles when they were actually acute or obtuse. Recent studies by Byrne (1979) and Chase and Chi (1981) have provided further evidence of this phenomenon. Byrne (1979) also provided evidence of another previously documented phenomenon, the so-called 'turns effect'. That is, a route having many turns along it is commonly recalled as being longer than a less convoluted path of the same objective length. This effect has also been reported by Staplin and Sadalla (1981) in an

elaborately controlled study. They also showed that intersections along a route act in the same way as turns, their number being directly related to the degree of overestimation. A third study reported by Staplin and Sadalla indicated that the crucial variable determining the overestimation was the ability to recall actively the information about turns or intersections (c.f. Chapter 6).

The above-mentioned findings are consonant with the 'topological network' model of spatial representation. This model was described in greatest detail by Siegel and White (1975); though it had been put forward as a possibility by earlier theorists, such as Rand (1969). Herein, an urban environment is characterized as a network of nodes, representing specific locations; inter-connected by links, representing roads or other types of pathway. Such a representation need only be topological, since a route and destination are necessary for accurate navigation, but knowledge of Euclidean distance is not. However, approximate scaling was said to develop as a by-product of the need for 'course-maintaining' landmarks along a route. The need for these markers to exist at minimum distances apart (in order to re-assure the person that he is still 'on course') suggests an explanation for the 'turns-' or 'intersections effect'. The more places a person could recall along a route, the longer he would judge it to be. Such a model of spatial representations was postulated by Byrne (1979) as an explanation for his experimental findings on the 'turns effect' and angular simplification.

In general, researchers agree that an individual gaining active experience of a route will learn a simplified form of the available information. The start, destination and decision-points along the route (mainly where changes in bearing have to be made) will always be learned. In addition, where long stretches of route exist with no need to change course, a person will tend to learn particular 'markers'

which will serve as reassurance that he is still on the required route. As Byrne (1979) observed, while these representations will not necessarily encode vector information, the number of places remembered along a route will be, on average, proportional to its objective length.

The results of a study by MacEachren (1980) seemed to show that his subjects were using travel time as a basis for their distance estimates, rather than objective distance, as would be expected from the model described above. He found that in an urban environment, U.S. car users gave subjective distance estimates which were closely related to both travel time and to a measure of 'stimulus-centred factors' (the number of intersections, turns, traffic lights and objective distance). Cognitive distance was noticeably less correlated with objective distance alone. However, upon closer examination, the findings may have been the result of subjects applying their customary mapping processes to an abnormal (inner city) environment. The environmental complexity and traffic density in an inner city area will mean that the number of potential 'nodes' on a traveller's representation will be far higher than for an equivalent size area in a suburban or rural setting. This will tend to reduce the degree of relationship between the number of nodes recalled and the objective distance. Also, many of the nodes recalled by car users will be those which necessitate time delays, for example traffic lights or crossroads. Such time delays will enhance the likelihood of these nodes being recalled and will mean that summing the nodes will produce a closer approximation to travel time than objective distance. Indeed, MacEachren found a correlation coefficient of 0.98 between objective measures of travel time and number of 'stimulus-centred factors'. In this way, using the normal heuristic for judging objective distance in an abnormal environment will give representations apparently based upon travel time. Since a cognitive

measure of distance which reflects travel time rather than mileage will have greater utility to car users, people are unlikely to find their representations inadequate for everyday problem solving, at least within an inner city area. MacEachren noted that at the intercity scale, petrol costs would be likely to re-establish the importance of objective distance.

(ii) Hierarchical Nature

Another hypothesized quality of spatial representations which has received attention in recent years has been their hierarchical nature. Neisser (1976) described a person's representation of the spatial environment as an hierarchical system of landmark, route and network knowledge. Information which constituted a network at one spatial scale would be subsumed into a single node at a larger scale. For instance, a person's knowledge of the street network of his home town might form a single node, representing that town, in his cognitive representation of his county or country. Subsequent authors have expanded Neisser's model, describing a system of superordinate units, linked by generalized directional relationships (Stevens and Coupe, 1978; Chase and Chi, 1981). Each superordinate unit would be composed of a representation of smaller scale spatial information, wherein interpoint directional links would be explicitly stored. If links between small scale nodes in different superordinate units were required, the necessary information would have to be inferred from the generalized superordinate links. For example:-

1. Yorkshire lies North of Derbyshire;
- and 2. Leeds is in Yorkshire;
- and 3. Derby is in Derbyshire.

Therefore, Leeds must lie North of Derby.



This combination of stored information and inference-making clearly has the advantage of reducing the memory load required for efficient large-scale spatial learning. However, in certain circumstances, the system can lead to erroneous spatial judgements being made. A series of experiments by Stevens and Coupe (1978) have shown how such errors can occur using both 'real-life' knowledge and artificially simplified learning materials. People were asked to judge the direction between pairs of cities in North or Central America. In the cases where the cities had a different directional relationship to that which existed between their superordinate units (either countries or states), the inter-city judgements were distorted in the direction of the latter. The researchers' subsequent experiments with simplified map-learning tasks showed that even with straight boundaries between superordinate units, subjects consistently distorted the incongruous interpoint directions towards the direction between their superordinate units. Additionally, subjects had a high level of confidence in the accuracy of all their judgements, implying that inappropriate reasoning, rather than task difficulty was leading to the errors.

Chase and Chi (1981) discussed the theoretical considerations of such a system at greater length than did Stevens and Coupe (1978). An initial review of cognitive skills literature enabled Chase and Chi to show how the 'small-scale storage + large-scale inference' system may be observed in various areas of cognitive problem-solving and skilled task performance. A short experiment which involved sketching a small geographical area (university campus) provided further evidence for the potential errors which can occur with such a system. A  $45^{\circ}$  angle in the actual street network was distorted to  $90^{\circ}$  by three-quarters of the subjects. Chase and Chi were able to relate this and other distortions to a 'grid structure' imposed upon the subjects' cognitive

representations. Chase and Chi concluded that the 'knowledge plus inference' system had a high overall utility for everyday spatial navigation.

### 8.3 Developmental Changes in Cognitive Maps

#### (i) Introduction

Recent research and theoretical papers upon developmental changes in cognitive representations have sought to assess the significance of the method by which environmental information is acquired. In particular, the effect of secondary information such as street-maps and plans has been considered. As discussed in Chapter 5, this has meant that the earlier, simpler model of developmental changes has been both supported and adapted as a consequence of later work. Briefly, the developmental sequence described by Siegel and White (1975) among others, viewed representations as developing from route structures to inter-linked networks and also, from being topological in nature to possessing Euclidean properties.

#### (ii) Map-learning and Navigational Experience

Several recent research papers have shown that subjects who have learnt an area from a map show a different pattern of spatial problem-solving expertise to subjects who have learnt from actual navigation. Both Moar (1979) and Thorndyke and Hayes-Roth (1982) have investigated the differences between the knowledge of a large building as possessed by people who had worked in it and by people who had only studied a floor-plan. Both studies showed that distances along customary paths within the building were judged more accurately by people who had navigational experience of the building. Also, such people were better at orientational judgements requiring cognitive 'perspective changes'.

In contrast, map-learners were better at judging Euclidean (straight-line) distances between isolated points. However, when subjects had an increased level of navigational experience, the map-learners' superiority at Euclidean judgements disappeared. That is, the experiments provided evidence of the gradual qualitative shift from a topological to a Euclidean representation when an area is learned through direct experience.

In general, the most recent research supports the existence of a sequence of qualitative changes in spatial representations resulting from increased practical experience. Moar (1979) described the sequence as being from egocentric, through topological, to Euclidean. The differences between progressive stages of development were seen as being of degree, rather than kind. That is, at any stage, a representation might contain aspects of each of the three types of representation listed above. Increased experience would lead to an increase in higher-order components; the most accomplished directly-learned 'cognitive maps' approximating to accurate Euclidean representations. The effect of learning an area with the aid of a map was seen as being that a subject could develop a Euclidean representation from the offset. Additionally, such learning would not be initially tied to one or two routes but would be essentially two-dimensional from the start.

It can be seen from the above, that a representation which has been learned solely from a map will be most 'map-like' in its properties, having two-dimensional Euclidean properties and being dominated by a single perspective. The latter quality has been highlighted by Evans and Pezdek (1980). They utilized a 'mental rotation' task wherein subjects were required to judge the accuracy of triads of labelled points, in terms of the 'real-life' places which the points represented. When the subjects' knowledge was derived solely from maps (states or buildings in an unknown area), there was a linear function between

their reaction time in judging the triads and the number of degrees by which the triads had been rotated from the Cartesian standard. No such function existed when subjects had learned the information through direct experience (campus buildings). The researchers suggested that direct experience of the relevant area would be likely to involve multiple perspectives, rather than a single perspective, as might dominate a representation learned from a map.

Thorndyke and Hayes-Roth (1982) discussed the various cognitive transformations which would be needed in order to make different spatial judgements on the basis of map-learned or directly-learned 'cognitive maps'. It seems that the efficiency with which a person can make any particular judgement may depend upon both the source of the representation and the complexity of the necessary transformations. This theoretical framework may prove to be useful in resolving conflicts in earlier research findings. For example, in comparing sketch-mapping and pairwise distance judgements, MacKay (1976) found that sketching yielded the more objectively accurate information. In contrast, Baird, Merrill and Tannenbaum (1979) found that both methods led to highly accurate spatial representations. The source of this discrepancy may lie in the nature of the elements being represented. MacKay was testing knowledge of intercity distances over the U.S.A., whereas Baird, et. al. were looking at inter-building distances on a campus. It may be that MacKay's subjects were more adept at sketching than distance judging because sketching constituted the closest approximation to the form in which they had learned the information (U.S. maps): thereby necessitating minimal cognitive transformations. On the other hand, Baird, et. al.'s subjects would be equally adept at sketching a campus plan or estimating inter-building distances. The availability of objective campus plans and the probable high level of campus knowledge (and therefore an increased

likelihood of a Euclidean 'survey-type' representation) would facilitate the first task. The subjects' direct experience of the campus would have been largely composed of route travel between buildings. Since Moar (1979) and Thorndyke and Hayes-Roth (1982) found that direct experience facilitated route distance judgements, the estimation of inter-building distances along a straight route would be a simple recall task. Where the inter-building routes contained turns, subjects should also have little difficulty in calculating 'straight-line' distances, given their high level of campus knowledge.

Thorndyke (1981), reviewing the above material, has concluded that individuals will probably possess different types of knowledge about different sections of the environment, depending upon their level and type of experience, the geography of the area, the availability of maps and the person's motivation to learn.

## Chapter 9

### The Microgenesis of Cognitive Maps

#### 9.1 Introduction

Within the past decade, the process by which people acquire cognitive maps of new areas (microgenesis) has begun to be empirically examined by several groups of researchers (see Table 9.1). The two basic questions to be answered in this context are:

(i) What is learned about a new area?

and (ii) How quickly is a representation acquired?

The next section of this chapter (9.2) will highlight some of the inadequacies of initial attempts to study the microgenetic process. Difficulties in interpreting these studies stem from both the choice of subjects and the types of measures taken, as well as from the way in which the studies were conducted.

The following two sections (9.3 and 9.4) show how the consideration of an individual level of analysis by a few researchers led to a greater awareness of the functional nature of cognitive maps. That is, they uncovered the relationships between individual spatial needs and the content of acquired representations.

Section 9.5 discusses attempts to quantify elicited representations in terms of topological and Euclidean accuracy. Such measures are clearly necessary if the microgenetic learning process is to be examined.

One of the flaws in earlier microgenetic studies was that very few of them adequately assessed the earliest stages of knowledge acquisition. The final section of this chapter (9.6) reviews two studies which have included some assessment of the initial learning phase.

Table 9.1: Studies of the Microgenesis of Cognitive Representations

DATE	AUTHORS	SUBJECTS		ENVIRONMENT	LENGTH OF EXPERIENCE		Total No. of Tests	Repeated Measures
		NO.	TYPE		AT FIRST TEST	AT FIRST TEST		Separate Groups
1976	DEVLIN	26	WIVES OF MILITARY PERSONNEL	TOWN (IDAHO FALLS, U.S.)	2.5 WEEKS	3 MONTHS	2	R.M.
1977	PEARCE	72	TOURISTS	TOWN (OXFORD, U.K.)	2 DAYS	6 DAYS	2	S.G.
1977	SIEGEL and SCHADLER	30	SCHOOL-CHILDREN AGED $\approx$ 5.5 yrs.	CLASSROOM (U.S.)	1 TO 2 MONTHS	8 MONTHS	2	S.G.
1979	HERMAN, KAIL and SIEGEL	66	STUDENTS	CAMPUS (PITTSBURGH, U.S.)	3 WEEKS	6 MONTHS	3	S.G.
1980	SCHOUELA, STEINBERG, LEVETON and WAPNER	40	STUDENTS	CAMPUS (CLARK UNIVERSITY, WORCESTER, U.S.)	1 TO 3 DAYS	6 MONTHS	6	R.M.
1981	EVANS, MARRERO and BUTLER	34	STUDENTS	CAMPUS or CITY (N=20 - U.C.I., U.S.; N=14 - BORDEAUX, FRANCE)	"WITHIN FIRST 2 WEEKS"	10.5 MONTHS	2	R.M.
1981	SPENCER and WEETMAN	30	STUDENTS	CAMPUS and CITY (SHEFFIELD, U.K.)	2 DAYS	11 WEEKS	3	R.M.

## 9.2 Early Microgenetic Studies

### (i) Cross-sectional Studies

The earliest evidence of the effects of increased familiarity were provided by cross-sectional studies (Appleyard, 1970; Pocock, 1975: c.f. Chapters 4 and 5). These studies compared the mapping performance of groups of subjects who had spent different lengths of time in the experimental area. Appleyard (1970) did not perform any detailed analysis of this variable since it was confounded by differences in mobility, transport mode and intellectual ability; all variables which he found to affect mapping performance. He did, however, describe one or two noteworthy findings. Those subjects with more experience of the city were more likely to draw 'spatial' maps than were the newcomers, whose representations were largely confined to 'sequential' maps. Newcomers also drew maps which were more restricted in extent than people who had lived in the city for longer: however, the areas which were drawn by newcomers, were drawn more accurately. The last finding was thought by Appleyard to show that their level of interest and concern with the area was probably higher.

Pocock (1975) performed some detailed analysis of his 'levels of familiarity' groups. Unfortunately, his design was confounded by differences in the motives and spatial behaviour of his three groups. He used residents, visitors (to the city for regular classes) and tourists as his three groups. The main difference which he found between groups was that tourists produced low level spatial maps but residents mainly drew high level sequential maps. While the level of organization difference was in the expected direction, the stylistic differences ran counter to theoretical expectations. The latter anomaly has been interpreted in terms of the groups' differing aims and use of secondary sources (see discussion in Chapter 5).



(ii) Tourist Studies

The alternative to cross-sectional studies, the longitudinal design (possibly a more direct method of studying microgenesis), was not extensively utilised until most recent years. Follini (1966) had used such a technique but as the environmental scale of her study was a single room (with blind-folded subjects, so that the necessarily piecemeal perception of the room using the tactual sense might be said to model the visual perception of a much larger environment e.g. a city), the validity of generalising any results to 'everyday' cognitive mapping may be questionable.

The study by Beck and Wood (1976) concentrated on the city scale, in the tradition of Lynch (1960) and his followers. Unfortunately, certain idiosyncrasies of Beck and Wood's study mean that it is of limited use as an investigation of 'everyday' environmental learning. In an attempt to obviate the problems of free-hand sketching as a means of testing spatial knowledge, Beck and Wood developed a mapping language known as 'ENVIRONMENTAL A'. Their subjects were taught this language prior to experiencing the experimental environment. As described in Chapter 6, the mapping system required users to draw a point-line skeleton first and then an areal map on an overlaid transparency. Finally, a series of 'attribute' overlays were filled in by the user, employing a detailed set of pictograms and labels. Subjects were given detailed instructions how to carry out the mapping task, such as where to start the point-line skeleton and what to consider at each stage. Subjects were asked to practice the technique by mapping their home environment prior to the experiment proper.

The problem with using this system to study microgenetic learning is that subjects may approach their environmental experience differently to untutored people, being primed as to the information which will be

needed to complete a mapping task. This means that the mapping products may be more informative because subjects have been stimulated to acquire more information, not simply that they are more adept at externalising what they know. Wood and Beck (1976) acknowledged this criticism, but countered it with the fact that any communication requires the use of a language system, and that it is better to have 'literate' than 'illiterate' subjects. However, this is not the point at issue in the context of microgenetic learning. What is crucial is that researchers do not affect the normal learning process which they are assessing. It is not clear whether Beck and Wood's system fulfils this requirement.

Two more factors in the design of Beck and Wood's study adversely affected its research utility. Firstly, as in the case of one of Pocock's (1975) groups, Beck and Wood's subjects were tourists; U.S. teenagers on a guided tour of European cities. The behaviour patterns and attentional set of such people would therefore be very different to that of new residents in the same area. Any comparison of the number and proportion of elements represented on mapping products with those from a residential group may be of limited validity. Secondly, the time-scale of the study was very small. While the first maps were drawn reasonably early (3 days), the final maps were drawn after only 6 days. Given that the environments being mapped were major cities such as London and Rome, it is likely that subjects' knowledge would have developed much more in succeeding weeks. Practical considerations obviously necessitated the early termination of the environmental experience in this study. In mitigation, given that the subjects were tourists, their learning rate might have been much faster than that of new residents. An investigation of new residents would probably require a much longer time-scale.

The study by Pearce (1977) unfortunately suffered from the last two drawbacks discussed above. The subjects were tourists and the second and final mapping session was after only six days. Pearce actually suggested that an improved design would include a longer time to the final mapping task. In addition, the mapping task designed by Pearce provided subjects with a prompt list of possible types of elements, as well as an example of a city 'cognitive map'. These aids were deliberately chosen to include all the Lynchian types of elements (e.g. landmarks, districts). However, since subjects were only given the recall aids at the time of mapping (and separate groups were utilised for the first and second mapping sessions), their learning of the spatial environment would not have been affected, as that of Beck and Wood's subjects might have been. The main finding of Pearce's study was that there was a significant increase in the number of landmarks, paths and districts over the experimental period; their relative proportions being unchanged. This result substantiated the result of an informal, single-subject study by Canter (1977), where a steady increase in point and link knowledge was found. In addition, Pearce found a significant increase in orientational accuracy over his experimental period.

### 9.3 Functional Landmarks

One study which did not have any of the above-mentioned drawbacks was that by Devlin (1976). Twenty-six women took part in this study, completing free-hand sketch-maps 2½ weeks and 3 months after moving into a new home town. The sketch-maps were analysed in terms of landmarks, routes and overall structure. Devlin noted that by the first mapping session, subjects had already acquired a high level of knowledge of the town. No radical changes in structure were observed

at the second mapping session; rather, more detail was included within the framework of each subject's initial map. As in Pearce (1977) and Canter (1977), the relative proportions of the different types of elements remained the same.

The major contribution made by Devlin's study can be said to lie in her analysis of the role of landmarks in the process of cognitive mapping. In the introduction to her research report, Devlin set out the reasons for her assessment of landmarks as:

"....presumably critical perceptual experiences in the formation of a cognitive map."

Landmarks were seen as important perceptual markers in cognitive representations at all levels of competence. In the initial stages of learning, landmarks and paths which are punctuated by landmarks, may be the only form of cognitive representation possessed. At a high level of competence, wherein a person possesses an integrated network representing a topographical district, landmarks may still be important in the role of navigational markers. In this case, a landmark may be used to "stand for" a more complex area, for orientational purposes. This consideration helps to explain Lynch's (1960, p.49) claim that people who know a city best tend to navigate by means of small landmarks.

Devlin concluded her introduction by outlining four factors which would influence the learning of particular buildings. These were visual distinctiveness, the frequency with which a building was experienced, whether it had ever constituted a goal for the person and if it constituted a potential goal. Given this theoretical stance, the main analysis of Devlin's study concerned landmarks. Personal knowledge of the subjects in the study enabled Devlin to comment upon the extent to which recalled places were functionally important. A

four-part classification of landmarks was adopted to assist in the analysis. The types were:-

- 1) physically and perceptually prominent;
- 2) functional (shared) and perceptually prominent;
- 3) functional (shared);
- 4) functional (personal).

A subject's home was taken as the primary example of category 4). The majority of landmarks on the maps were found to belong to the functional categories. The buildings recalled by the greatest number of people belonged to the 'functional (shared) and perceptually prominent' category; these buildings also showed the greatest increases in 'frequency of inclusion' from the first to the second mapping session. Of the total numbers of different landmarks recalled by subjects at each mapping session, approximately half belonged to the 'functional (personal)' category.

#### 9.4 Individual Level of Analysis

What is clear from Devlin's analysis is that earlier studies of city imagery, by concentrating upon pooled data, may have missed one of the most important factors determining recall of particular environmental elements. The functional significance of an element to an individual, however physically humble that element may be, may to a large extent determine its inclusion in his cognitive map. Devlin made an important observation upon the changing role of functional landmarks. That is, an element which becomes part of a cognitive map by virtue of the person having visited it (as a 'goal') can later be used as an orientational landmark in planning another route (as a 'subgoal'). This is in addition to elements which are used as orientational markers from the offset (i.e. have no 'internal'

functional significance to the person). By relating the cognitive representation to the practical needs of the person, Devlin can be said to have provided a means to judge the relative importance of potential environmental elements. In opposition to an 'imageability' approach to cognitive mapping, Devlin's approach would make functionally significant but physically uninteresting buildings of greater importance than functionally non-significant but physically singular ('imageable') buildings. This model is in accord with earlier findings (see Chapters 3 and 4) that buildings are more often recalled when connected with high levels of activity or decision points along travel routes. It is also consistent with the model of cognitive representations of the large-scale environment put forward by Siegel and White (1975) and others (see Chapters 5 and 8).

The fact that so many of the landmarks in Devlin's study were of the 'functional (personal)' category must indicate the limitations of using group data when analysing the nature of environmental images. Where subjects in a group follow grossly different spatial behaviour patterns, the elements they recall may be correspondingly diverse. A system of frequency counting would therefore overemphasize common elements but underemphasize personally functional landmarks. Two approaches can be used to lessen this drawback; one being to choose the most homogeneous subject group possible (as far as spatial behaviour and building use is concerned) and the other to analyse cognitive mapping products at an individual level.

One study which attempted to relate the form of individual cognitive representations to personal behaviour was that by Holahan and Dobrowolny (1978). This study attempted to relate distortions in the cognitive representations of a campus area to individual variations in spatial activity patterns. Collective and individual spatial behaviour were

assessed by direct observation and questioning respectively. Distortions and differential emphases in drawn sketch-maps were found to bear a systematic relationship to the behavioural data (see discussion in Chapter 10). Unfortunately, Holahan and Dobrowolny did not collect any data upon building use; the analysis being limited to outdoor behaviour. Such an approach may have proved useful in providing further evidence to support Devlin's work.

### 9.5 Assessment of Accuracy

One limitation of Devlin's method of data analysis was that it only took the content of the sketch-maps into account. The sketch-maps were evaluated only in terms of the presence or absence of particular elements. No attempt was made to assess the accuracy of the layouts; apart from a brief mention of the common orientational errors and how these were reduced at the second mapping session. Given the unstructured nature of the mapping task, accuracy measurements would have been limited to 'relative accuracy'; that is, the accuracy with which elements are spatially inter-related. No objective referent would be available from which to assess 'absolute accuracy' (c.f. Stea and Taphanel, 1974).

One microgenetic study which assessed mapping accuracy from data similar to that of Devlin was Evans, Marrero and Butler (1981). They used an unstructured mapping task to look at the increase in particular types of elements and in accuracy with increased temporal experience. Both ordinal and Euclidean accuracy were assessed. Ordinal accuracy was measured by a method taken from Siegel and Schadler (1977) who had examined the microgenesis of children's knowledge of their classroom layout. Landmarks were first grouped in spatial 'clusters', according to their objective positions. A score was calculated for both intra-cluster and inter-cluster accuracy. These were obtained by summing

the number of correct horizontal and correct vertical relationships between pairs of landmarks; the totals being adjusted for maximum possible scores. Euclidean accuracy was assessed by performing multi-dimensional scaling upon the most frequently-included landmarks and then correlating these with M.D.S. solutions of the objective landmark positions. The results of the study were similar to those found by Siegel and Schadler (1977; wherein Euclidean accuracy was assessed by direct measurement, since subjects were provided with an objective framework for their classroom perimeter), namely, that Euclidean accuracy improved with time whereas ordinal accuracy did not. This finding supports the model of developmental changes in the structure of cognitive representations which was proposed by Siegel and White (1975), Byrne (1979) and others (see Chapters 5 and 8). Ordinal accuracy would develop first, in the sense of knowing the relative positions of landmarks and their interconnections. Euclidean accuracy, in the sense of correct angles and distances would develop more slowly, by what Evans, et. al. termed 'fine tuning'.

The notion that people rapidly acquire basic configurational knowledge of the main elements of an area and then 'fine tune' this representation at a more gradual rate has been further supported by Herman, Kail and Siegel (1979). They employed an entirely non-graphic set of tasks to assess the microgenesis of spatial knowledge of a college campus. Noting the drawbacks of sketch-mapping (see Chapter 7), these researchers chose a combination of verbal recall, visual recognition and M.D.S. solutions of 'crows-flight' distance comparisons, to assess landmark, route and configurational knowledge. Three groups of subjects were used, with three weeks, three months or six months experience of the campus. It was found that landmark and route knowledge increased from three weeks to three months but not thereafter,



and that configurational knowledge increased from three weeks to six months (analysis was not possible on the three month data). Like Devlin (1976), Herman, et.al. commented upon the high level of configurational accuracy which had already been achieved by the first test session.

## 9.6 The Initial Learning Period

### (i) Introduction

It is apparent from the experimental findings discussed above that cognitive representations of a novel environment may become quite well-established within the first few weeks of environmental experience. It therefore seems reasonable to assume that cognitive representations will be at their most labile during those few weeks; so that any microgenetic study should include at least one test session during this period. Few studies have incorporated a mapping test so early in the learning period; Devlin's (1976) subjects had a minimum of 2½ weeks experience, Herman, et. al. began testing at 3 weeks and Evans, et. al. merely said that the first mapping session was "within the first two weeks". The imprecision of the last-mentioned timing could have led to a wide variation in performance levels for the first test session. However, since Evans, et. al. did not provide any details of variance in their results, this cannot be confirmed.

It may be recalled at this point that Beck and Wood (1976) and Pearce (1977) did test their subjects within the first few days of environmental experience. However, the practical limitations of their investigations meant that the maximum experience any subjects had was one week. Given the other problems with these two studies, such as the subjects being tourists (see earlier discussion), their findings cannot be directly compared with longer term investigations of 'everyday' environmental learning, such as Devlin (1976).

(ii) Spencer and Weetman (1981)

Two studies have been reported which looked at the microgenesis of 'everyday' environmental learning and included mapping tests within the first few days of experience. Spencer and Weetman (1981) examined the growth of campus, city and route knowledge in a group of 30 new students. Subjects were asked to draw a series of sketch-maps after 2 days, 2 weeks and 11 weeks in the city. The route knowledge which was tested was the usual journey from their place of residence (the same for all) to the campus. Maps were analysed in three ways; the style (spatial/sequential), the level of organization (high/medium/low; according to Murray and Spencer (1979) ) and the numbers of landmarks, paths and districts.

The data analysis showed that the route knowledge was always drawn sequentially, the campus knowledge was almost always drawn spatially and the city maps changed from being approximately two-thirds sequential at the first test to almost equally sequential and spatial at the final test. Spencer and Weetman claimed that these results did not support the view that spatial representations develop from initially sequential knowledge. They pointed out that some people drew spatial maps from the start and others always drew sequential maps; two people even switched from spatial to sequential. In addition, subjects had been asked at the first mapping session to sketch a map of their previous home town: these maps were found to relate strongly to the experimental maps in terms of style.

There are several problems which can be seen in regard to Spencer and Weetman's interpretation of their results, both in terms of methodology and analysis. The researchers chose their subjects to be as homogeneous as possible; matching them on age, education, length of experience, place of residence and place of work. However, it is

unlikely that their spatial experience of the city was precisely the same, or that their use of maps was equivalent. Subjects had been told to use the maps provided by the University in the normal way, not to try to improve their future mapping performance. The researchers did test a control group, at the third mapping session (who had not been tested before) but only reported that their (the experimental group) "...overall performance fell within the range of these controls". More precise details of the distribution of mapping styles and levels would have been useful. Subjects were not asked for any information about their spatial behaviour or map usage; this too might have been enlightening. The results also showed a sex difference in mapping style, females drawing more sequential maps than males; this difference may also have borne some understandable relationship to spatial behaviour and map usage. No details of sex differences in level of organization were given, so these cannot be interpreted as support for differential levels of city experience.

The low level of transfer from sequential to spatial city mapping over the course of the experiment may have been the result of several factors in operation. Firstly, the initial response may have 'set' the subjects mapping to a particular style (it may also have affected the way they drew their home town map in the first mapping session; or the converse, if the home town map was drawn first). Secondly, given the size and complexity of the city being mapped (Sheffield, U.K.), an integrated 'spatial' map might not be expected to develop until the subjects had much longer than 11 weeks experience. The use of previous home-town maps to show how the subjects represent a well-learned area may also be misleading. All the subjects were 18 years old, implying that their previous home town was known from an adolescent perspective. Brown and Broadway (1981) have studied adolescent images of home-towns

and found that accuracy of cognitive maps was strongly related to size of home-town, frequency of car use and gender. In effect, the limited spatial range of school-age children may mean that beyond the local (home and school) area, their knowledge of the town they live in is likely to be severely limited. It is noteworthy that only 7 of Spencer and Weetman's 30 subjects drew their previous home-town at a 'high' level of organization. Thirdly, the use of secondary sources may have allowed spatial maps to be drawn from the start, so that the sequential to spatial development (characteristic of knowledge acquired through direct experience only) would be less likely to be highlighted.

A final problem with the stylistic analysis of Spencer and Weetman's data is that no observations were made of the way in which the maps were produced. It is possible that subjects may have judged themselves incapable of producing an overall street network of the city and therefore limited themselves to indicating certain streets and how known areas of the city inter-relate. Such a map could be drawn by a sequential process, 'mentally travelling' known routes in order to judge the position of known areas. Even so, the end-product would be classified as 'spatial'. Subjects in this study were even allowed second attempts, so that initial, sequentially-produced maps may have been discarded. Only by monitoring the recall process could such interpretative difficulties be alleviated.

(iii) Schouela, Steinberg, Leveton and Wapner (1980)

The other microgenetic study of everyday environmental learning which included a mapping test within the first few days was by Schouela, et. al. (1980). This study was designed with two aims in mind. Firstly, to look for evidence that the development of cognitive representations of the large-scale environment follows the 'orthogenetic principle'

(cf. Hart and Moore, 1973); that is, they become increasingly differentiated and integrated. Secondly, to examine the process by which information about the spatial environment is cognitively organised; in particular, the use of a stable, functionally-defined 'anchor-point' throughout the learning period. The basic method of the study was similar to that of Spencer and Weetman (1981), namely, a 'repeated measures', sketch-mapping test of the growth of campus images in a group of new students. Seventeen subjects drew maps on a total of 6 occasions, from "1-3 days" to "24 weeks" after arrival. In addition, two groups (of 12 and 11 subjects) were tested from the second and third test occasions onwards. These people provided controls for the effect of 'repeated measures' in the main group. Subjects were asked to sketch the campus, numbering the elements in the order in which they were included. Upon completion they were asked to give reasons for their choice of starting-point and to describe their method of producing the sketch-map.

The data analysis was both quantitative and qualitative. The quantitative analyses assessed the number of buildings, the number of correctly-shaped buildings, the number of streets and finally, an index of the amount of distortion in the relative building positions. The last of these was similar to Evans, et. al.'s 'index of relative accuracy'. The index took into account the number of times each building was in the correct relationship to lines joining all other possible pairs of buildings. For each map, the total number of incorrect relationships was divided by the maximum possible, so that the resultant index would decrease as accuracy increased. These four quantitative measures were used to indicate the degree of 'differentiation and integration' at each test session. The results were analysed for the group as a whole and significant increases were found in the first three measures over the 24 weeks; a corresponding significant decrease was found in the distortion index.

The first maps of the repeated measures control groups were analysed in comparison to the equivalent mapping session data from the main group in order to assess the effect of 'heightened awareness'. No significant differences were found on any measure. The first mapping sessions of each of the three subject groups (main group + 2 control groups) were analysed (1-3 days, 1 week, 3 weeks) in order to simulate a 'separate groups' study. The 'number of buildings' measure showed a significant increase in this analysis but the other three did not, though all but the distortion index showed mean differences in the expected direction over the three-week period. Schouela, et. al. did not attempt to interpret this anomaly; three possible factors may be outlined. Firstly, though the 'heightened awareness' hypothesis was not confirmed statistically, there may have been a non-significant effect upon the main group's scores. This would have enhanced any increment due to 'time on campus' to give a statistically significant overall increase in the separate measures group. Without this non-significant 'heightened awareness' factor, the separate groups analysis would not show a significant improvement due to 'time on campus'. Secondly, the separate groups analysis only covered 3 weeks, whereas the main analysis covered 24 weeks; this curtailment may have diminished the chances of finding a significant improvement. Thirdly, a separate groups design would introduce the problem of 'individual differences' in cognitive mapping into the data, so that group variations in mapping ability may have obscured any main effect.

Schouela, et. al. examined the choice of starting-points and the verbal reports to discover if subjects were using a consistent 'anchor-point' and to obtain some insight into the process of creating the sketch-maps. They found that by far the most common starting-point was the subject's place of residence (on campus), this occurring on

over half of all the maps drawn. From the verbal reports, the researchers identified three ways in which the starting-points could have been functionally important to the mappers. These were as the person's place of residence, as a centrally-placed landmark and as a place associated with 'personal environmental transactions'. The first and third belong to Devlin's 'functional (personal)' category, whereas the second is a clear example of an orientationally functional landmark (not necessarily of any 'internal' function for the mapper). Six of the 17 subjects used the same starting-point throughout and almost all the rest used the same starting-point for 5 of the 6 mapping sessions. Unfortunately, Schouela, et. al. gave no further information as to when these last subjects changed starting-point or which places they used. If the changeover was after the first mapping session (within the first week), this would be further support for the view that cognitive representations are at their most labile in this initial period.

The subjective reports upon the process of creating the maps enabled the researchers to classify three main strategies, all of which employed the map's starting-point in a central organizing role. These strategies were as follows:-

- (a) Beginning at X and 'mentally travelling' a route, adding other places as they would be encountered;
  - (b) Beginning at X and adding other places, by working spatially outwards (regardless of routes);
- and (c) As (b), but dividing the campus into sub-regions which are completed separately.

Schouela, et. al. attempted to compare their findings as to the importance of an anchor-point with more general memory research findings. Unfortunately, the examples which they cited, such as recency and primacy effects and the von Restorff phenomenon in the recall of

serially-learnt nonsense syllables may not provide the most worthwhile comparisons. Such examples refer mainly to the enhanced recall of particular items, rather than to the role of these items in organising the recall of the rest of the material. The 'anchor-point' as used by Schouela, et. al. seems to compare more easily with Devlin's analysis of the factors influencing the recall of landmarks. The anchor-points chosen by Schouela, et. al.'s subjects could all be evaluated as being one or more of (a) visually distinct; (b) frequently-experienced; (c) used as a goal; (d) used as a sub-goal (navigational aid).

Schouela, et. al. might profitably have made comparisons with general memory research in terms of the overall principles of subjective organisation of learning material (in the present case, the campus 'elements'). The recall orders and subjective reports enabled them to produce the above-listed three recall strategies. These findings could have been compared to the work of Tulving (1966) among others, who has looked at the degree of consistency with which randomly-presented items are recalled together (see discussion in Chapter 12). This may have led Schouela, et.al. to raise questions regarding the correlation between the use of particular strategies and recall efficiency or upon the relative importance of functional and spatial associations in determining recall orders.



## Chapter 10

### Individual Differences in Cognitive Mapping

#### 10.1 Introduction

It has long been established that there exist gross differences between people in their orientational ability (see Chapter 1). Nevertheless, the direct investigation of individual differences is one of the least extensive areas of cognitive mapping research. One study which did look at a wide range of personal characteristics in relation to mapping performance was that by Beck and Wood (1976), which was described in Chapter 6. To recapitulate, they found that five main factors related to both the content and accuracy of several sketch-maps drawn by each subject. These were:-

- 1) long-term residence;
- 2) active travel mode;
- 3) high mobility;
- 4) good orientational ability (self-assessed);
- 5) general experience with maps.

Additionally, three more factors were found to relate to content but not accuracy; namely:-

- 6) self-estimates of particular environmental knowledge;
- 7) objective short-term memory for graphic material;
- 8) self-estimates of memory ability.

It is possible to divide the factors identified by Beck and Wood into three broad categories, as follows:

- i) spatial experience;
- ii) specific cognitive abilities;
- iii) self-assessment of ability at cognitive mapping and orientational tasks.

Research conducted mainly during the past decade has confirmed that each of these categories relates to objective cognitive mapping performance. This chapter will review the findings within each category.

## 10.2 Spatial Experience

The microgenetic studies reviewed in the last chapter provide considerable support for the existence of a positive relationship between long-term residence and enhanced cognitive mapping performance. Also, research reviewed in Chapters 4 and 6 has confirmed that active travel modes are associated with superior cognitive mapping (e.g. Howell, 1969; Appleyard, 1970).

In addition to travel mode, some studies have shown that amount of travel, both local and regional, relates to mapping performance (e.g. Maurer and Baxter, 1972; see Chapter 4). Brown and Broadway (1981) looked at distance estimation in adolescents and found that low mobility was associated with inaccurate task performance. Murray and Spencer (1979) found that geographical mobility was related to the complexity and organization with which sketch-maps of varying scales were drawn (local to world). However, caution must be exercised in interpreting the latter study, in that mobility level may have been confounded with both educational level and map experience (the three mobility levels were groups of airline pilots, students and coal-miners). Finally, Devlin (1976) suggested that a high level of geographical mobility may have enhanced her subjects' (wives of military personnel) efficiency at mapping. She assumed that this would operate by predisposing them to locate and remember places of functional importance upon entering each environment.

Length of residence, travel mode and level of mobility are factors which describe, in quantitative and qualitative terms, the nature of a person's actual experience of his spatial environment. As outlined above, these factors have been shown to influence the efficiency of performance on cognitive mapping tasks. It therefore seems reasonable to suggest that individual differences in the form and content of cognitive maps may show some relationship to differences in patterns of spatial activity. This was the theoretical stance which led Holahan and Dobrowolny (1978) to compare sketch-mapping with 'behavioural mapping' (cf. Ittelson, Rivlin and Proshansky, 1970). The latter information was assessed at the individual and the collective level. At the individual level, subjects were asked to mark on their sketch-maps the places where they would go to:- 1) sit 2) socialise and 3) meet most people, as well as the point where they typically entered the campus area. The overall answers to the first three questions were verified by the collective mapping. A random selection of sub-areas on the campus were observed repeatedly over the course of a month (for two hour periods) by observers who counted the number of individuals:- 1) sitting 2) socialising and 3) present (overall frequency of use).

Unstructured sketch-maps were collected from each subject and were analysed in four ways. 'Border zones' were determined which showed the areas mapped by various proportions of subjects; the largest being that which was surrounded by the objective campus perimeter. 'Frequency zones' were calculated which reflected the percentage of subjects who drew the buildings enclosed in those areas. 'Size exaggeration' scores were calculated for each subject, in reference to the areas covered by the four main pathways through the campus. Finally, a 'centrifugal distortion score' was calculated for each subject, which showed how far the subjective campus centre deviated from the objective centre.

A strong statistical relationship was found between the border and frequency zones and the indices of spatial usage, with the less well-represented zones being less often used. This relationship was obtained when the individual self-reports were pooled, as well as when the observed collective behaviour was analysed. Size exaggeration scores were compared between subjects who did and did not use each of the pathways. Two of these showed statistically significant positive relationships between use and exaggeration (a third was non-significant but in the same direction and the fourth pathway was not used by enough people to permit analysis). The centrifugal distortion was shown to be greater for subjects who entered the campus peripherally (via the campus bus-stop) than for subjects who lived in central campus accommodation. It would have been interesting to know if the displacement of the 'peripheral' subjects' map centres was generally towards the point-of-entry; however, no such analysis was reported.

Holahan and Dobrowolny concluded that their integration of cognitive and behavioural mapping had proved to be a useful strategy. That is, it had highlighted systematic relationships between various features of cognitive maps and aspects of group and individual spatial activity patterns. It therefore seems that any future investigations of group differences in 'real-life' cognitive mapping should take differences of spatial activity patterns into account. Such differences may have been a salient factor in many of the studies conducted prior to the mid-1970's, when broad group differences such as social class and age were being examined. Some of the researchers did, in fact, raise such a possibility (e.g. Ladd, 1970; Orleans, 1973).

### 10.3 Specific Cognitive Abilities

#### (i) Visuo-spatial Imagery

In their study of geographical mobility levels (see 10.2), Murray and Spencer (1979) hypothesized that performance on a sketch-mapping task might be to some extent dependent upon a person's ability to form visual images of his environment. A second group of students were asked to draw sketch-maps of their campus, which were analysed to give scores for complexity, elaboration and organization, as in Murray and Spencer's main study. At a later date, the same subjects completed a 'self-rating' questionnaire, designed to assess the ease with which the person could:

"...evince or manipulate various visual mental images...."

(Murray and Spencer, 1979, p.390).

A non-significant positive correlation coefficient was obtained between the sketch-mapping and visual imagery scores. Murray and Spencer concluded that although there was evidence for a weak 'general image-strength factor' in their mapping task, cognitive mapping performance seemed to be independent of the ability to call up visual images of specific objects or scenes.

It should be recalled at this point that some evidence has been obtained of a significant correlation between the ability to manipulate visuo-spatial images and cognitive mapping performance (Bycroft, 1974; Moore, 1975; see Chapter 5). This being so, Murray and Spencer's low correlation appears to be somewhat contradictory. A possible resolution of this conflict can be found in the 'mainstream' psychological literature on visual imagery and memory ability. Baddeley (1976) reviewed evidence of the role of visual imagery in relation to visual memory ability. He concluded that tests of spatial visualization, but

not subjective ratings of visual imagery, have been shown to correlate with visual memory performance. Baddeley suggested two possible explanations for this anomaly. The first was that imagery experiences cannot be inter-subjectively standardized. The second was that the efficiency of visual memory may depend only upon the quality of the underlying stored information and not upon any subjectively-experienced epiphenomena. This distinction has also been made by Paivio (1971) and others.

In a later discussion of visuo-spatial imagery, Baddeley provided a third possible explanation of the anomaly outlined above. He distinguished between the concreteness of the image, essentially visual in nature, and the 'control process', by which the imagery is utilised by its possessor to perform a task. Reporting a series of unpublished experiments by Baddeley and Lieberman, he was able to show that the imagery system used in task performance was essentially spatial. It would therefore follow that performance on a cognitive mapping task (having a strong spatial component) would be better predicted by a test of spatial manipulations ability than by a test of visual (but not essentially spatial) imagery.

(ii) Visual Memory and Map Learning

One experiment which looked at the relationship between visual memory ability and map-learning was Thorndyke and Stasz (1980). Map-learning was chosen as an example of a complex task requiring the acquisition of both verbal and visuo-spatial information. The task clearly has 'ecological validity' and may be seen as one aspect of general cognitive mapping (namely, the ability to utilise secondary sources of information). This experiment utilised the results of an earlier study, which was also reported in Thorndyke and Stasz (1980).

The earlier study examined the procedures used by a small group of subjects to learn a pair of maps. Examination of verbal protocols enabled the researchers to describe two sets of procedures (or 'techniques'), one set being related to high performance ('effective procedures') and a second set which was uncorrelated with performance ('neutral procedures'). Examples of effective procedures were 'partitioning' (directing attention to sub-areas of the map) and 'pattern encoding' (learning a description of a shape). Examples of neutral procedures were 'rehearsal' (repeating names of elements) and 'mnemonics' (to recall names with aid of retrieval cues such as initial letters).

The second experiment used three groups of subjects to examine the effect of training subjects to use the aforementioned procedures. After assessing their baseline map-learning performance, the three groups were given differential training programmes, namely:-

- 1) effective procedures;
- 2) neutral procedures;
- 3) no procedures (subjects given general advice on concentration, etc.).

'Visual memory' was thought by the researchers to be a potential source of variation in map-learning performance, so this was also assessed. The test which they used required each subject to:

"....remember the configuration, location and orientation of spatial information in a complex display....."

(Thorndyke and Stasz, 1980, p.159).

In view of the foregoing discussion of visuo-spatial imagery, this task appears to be an appropriate measure of the basic cognitive ability, being essentially spatial. Even so, it lacks any necessity to transform or manipulate the spatial material, an ability which has

been found to correlate with cognitive mapping. However, it must be recalled that the map-learning task also lacks such a component, requiring only the direct recall of a two-dimensional display. If a 'direct experience' learning task had been used by Thorndyke and Stasz (such as having subjects walk around a novel environment and then sketch the layout), then it may be suggested that their test of visual memory would have been unlikely to show any correlation with performance. As mentioned earlier, Beck and Wood (1976) found that short-term memory for purely visual displays related to content recall but not accuracy. A test of essentially spatial recall might have correlated with accuracy (as in Moore, 1975).

The results of the study were quite clear. Visual memory ability was strongly correlated with both pre- and post-training map recall. Training group differences were obtained for the 'spatial attribute' scores but not for the 'verbal attribute' scores. In respect of the latter finding, the researchers pointed out that they had found much lower individual differences in 'verbal' recall scores than in 'spatial' recall scores. They assigned this fact to the educational background of their subjects, which emphasized verbal learning. In addition, the 'effective procedures' were predominantly directed towards spatial learning rather than verbal learning.

In addition to the strong correlation between visual memory scores and map recall, an interesting relationship was found between visual memory and effective procedure training. The success of training in the procedures was dependent upon a subject's visual memory ability. Low ability subjects were less likely to use the effective procedures when they had been trained and derived less benefit from such procedures when they did use them. It therefore appears that a complex learning task such as memorizing a map may be partially dependent upon an underlying basic cognitive ability.



#### 10.4 Subjective Assessment of Cognitive Mapping Ability

##### (i) Introduction

Beck and Wood (1976) found two types of subjective judgements concerning cognitive mapping which related to mapping performance. These were the subjective assessment of 'orientational ability' (meaning general way-finding ability) and the subjective evaluation of environmental knowledge. Evidence to support the second was obtained by Thorndyke and Stasz (1980) who found that efficient map-learners were superior at assessing their state of learning, of "Knowing what they know".

##### (ii) 'Sense of Direction' and Spatial Orientation Ability

Kozlowski and Bryant (1977) examined the accuracy of subjective assessments of orientational ability. They began by noting that people will readily assess their ability to find their way around their environment and will ascribe their success or failure to having a good or a poor 'sense of direction'. The researchers concluded that a subjective assessment of cognitive mapping ability (or 'spatial orientation ability') could be obtained by asking people to rate their 'sense of direction'. The question then arose as to what degree of relationship existed between self-rated 'sense of direction' and performance upon cognitive mapping tasks.

In a series of experiments, Kozlowski and Bryant compared 'sense of direction' (self-rated on a seven point scale) to a variety of other objectively-measured and subjectively-experienced aspects of cognitive mapping. For the first two experiments subjects completed questionnaires which contained all the mapping tasks and subjective-report items. Subjects had to complete several mapping tasks, involving:-

- 1) pointing to unseen goals (both local and distal);
- 2) completing a local area map (attempting to represent both distance and direction accurately);
- 3) local distance estimation (using a ratio-estimation procedure);
- 4) time estimation (for walking between local places).

The local pointing tasks were accomplished by marking the directions between given places on a display which had a key direction marked on it. The distal directions were simply drawn on the page, relative to 'North'.

The results showed a significant relationship between self-assessment and orientation performance. Good 'sense of direction' subjects were better at pointing to nearby cities though not to North. Distance estimation from the maps did not relate to 'sense of direction', nor did the direct estimations of distance or of time. Kozlowski and Bryant attributed this lack of correlation to the restricted range of performance levels. All subjects estimated time and distance quite accurately for the well-known local area being used. Self-assessments of time and distance estimation ability did, however, correlate highly with direction estimation (as well as with each other).

In addition to the main results, other self-report data showed that good 'sense of direction' subjects were better at a wide range of day-to-day orientational tasks. These included giving directions, reading maps and exploring new routes. Also, they were less likely to feel anxious when lost. These results support Beck and Wood's (1976) findings which were discussed earlier.

(iii) 'Sense of Direction' and Spatial Learning in a Novel Environment

The third experiment conducted by Kozlowski and Bryant (1977) examined the relationship between 'sense of direction' and spatial learning in a novel environment. Two groups of subjects, having self-assessed good and poor 'sense of direction' took part. Subjects in small groups were led through a maze of underground tunnels a number of times. Before and between trials they completed questionnaires assessing time, distance and direction estimations for the maze. Subjects were told at the outset that the experiment concerned time estimation. Subjects also had to assess their motivation levels, attention and learning strategies.

Since subjects were unaware of the distance and direction questions until after Trial 1, this data could be used as a measure of incidental learning. No difference was found between 'good' and 'poor' subjects for Trial 1 on any measure. However, performance diverged in the later trials. 'Good' subjects did not improve immediately, but did so after repeated trials; implying that repeated experience is necessary for superior performance as well as a deliberate attempt. 'Poor' subjects did not improve at all. No differences were found in self-rated psychological attitudes, both groups appeared to be trying to learn the maze, with similar strategies and motivational levels.

### 10.5 Conclusions

Taken together, the results of the experiments into individual differences permit the formulation of a tentative profile of good cognitive mappers. They would have a positive attitude to the process of learning about their spatial environment, which would lead them to gain greater spatial and temporal experience of an area than their

less-skilled counterparts. They would utilise a wide range of secondary information (maps, guides) and would integrate this information with their directly-acquired knowledge. In addition, they would possess the basic cognitive abilities required for them to learn and transform environmental information so acquired.

The Experimental Studies

## Introduction to Experiments

The preceding four chapters of this thesis reviewed recent experimental findings in four main areas of cognitive mapping research. These concerned the choice of elicitation technique, the structure of the internal representations, the microgenetic development of these representations and individual differences in cognitive mapping ability. As was described in the 'General Introduction', several questions may be formulated which have yet to be adequately answered. The remainder of the thesis will report and discuss four empirical investigations of questions arising from the findings reviewed in Chapters 7, 9 and 10.

Chapter 7 reviewed research work which assessed the merits of various techniques for eliciting internal representations. It was concluded that for present purposes, a 'direct mapping' technique (where the subject creates a two-dimensional array of spatial elements) would be preferable to an 'indirect mapping' technique (where the relative positions of places are calculated from inter-place distance estimates made by the subject). Experiment I (Chapter 11) was designed to investigate if a three-dimensional modelling technique would be preferable to the more common two-dimensional sketch-mapping technique. Evidence is reviewed that modelling can be advantageous when poorly-educated, disadvantaged people are being studied; Experiment I examined whether or not such advantages were also apparent for the highly-educated subject groups to be used in the present studies.

The results of this experiment indicated that the modelling technique did not seem to have any intrinsic advantages over sketch-mapping once certain drawbacks of sketching are alleviated. This involves the provision of an appropriate scale, the chance to re-position items and the elimination of the need to produce graphically elaborate

plans. It was therefore decided that subjects in subsequent experiments should be provided with a base-map overlaid with a grid and be permitted to erase and re-draw their initial plans.

Experiment I also incorporated a test of 'spatial relations ability' into its design; so that the possibility of correlations between cognitive mapping performance and psychometric spatial ability could be examined. Chapters 5 and 10 reviewed tentative evidence that such relationships existed. Experiment I provided evidence that spatial ability scores were positively related to the consistency with which subjects scaled their plans.

The studies reviewed in Chapters 9 and 10 suggested three questions which Experiment IIa (Chapter 12) was designed to answer. Firstly, does environmental learning in a new area occur at a faster rate during the first few days of practical experience? Secondly, is there evidence of a relationship between people's spatial behaviour (building use and movement within the area) and their knowledge levels or their cognitive linking of places? Finally, do people assess their 'state of knowledge' more accurately as their actual level of knowledge increases?

Experiment IIa used the same topographical area as Experiment I, and also a similar but more homogeneous (in terms of length of experience and building usage) subject group. The experiment used a structured mapping task which required people to draw the positions of a set of buildings on a base-map in any order they wished. Also, to indicate their confidence in the accuracy of each placement. The buildings were chosen from the results of Experiment I, to include a subset which were well-known by the subjects in Experiment I, and a subset which were not.

The results showed that learning took place at a high rate during the early days, particularly for functionally important buildings. Buildings which were less functional were learned more slowly. Evidence

of spatial links in the recall order increased during the first week. It was found that accuracy of self-assessments increased as knowledge increased.

Experiment IIb was performed to clarify the results of Experiment IIa by using a repeated measures design. This showed an equivalent pattern of results to the main study over the experimental period.

Experiment III (Chapter 13) was primarily designed to investigate possible correlates of individual differences in cognitive mapping. From Experiment I, it seems that cognitive mapping ability may be related to specific visuo-spatial ability. Chapter 10 reviewed evidence that cognitive mapping ability might be correlated with subjective assessment of general orientational ability, as well as with attitudes to everyday orientational tasks and map use. Experiment III therefore included questionnaire assessment of the above-mentioned subjective factors and a standard test of spatial relations ability. Additionally, it was thought useful to assess not only the ability to manipulate spatial information but also, the strength of 'static' visual imagery. Accordingly, a questionnaire assessing the vividness of visual imagery was included.

Since it is difficult to ensure that all subjects have had an equivalent exposure to a particular environment, cognitive mapping ability was assessed by a simple spatial learning task. This task enabled the examination of how the overt form of stimulus material affects learning and how learning differs between situations where recall is required in the same mode, or in a different mode, to the stimulus. Evidence is reviewed which suggests that graphic stimuli would yield higher scores than verbal stimuli, and that stimulus-response compatibility would yield higher scores than cross-model conditions. A four-group design was therefore used, with equivalent



route information being presented either as a map or as a list, and recall being required in the same or the alternative mode.

The recall levels were examined separately for node (place label) and link (directional) information. It can be seen that there is at least a logical distinction between the identity and the position of items in a spatial array. It therefore seemed reasonable to hypothesize that these two measures might be differentially affected by both the subject's cognitive abilities and the stimulus form. Significant learning differences and correlations were obtained in Experiment III, largely in accordance with the hypotheses derived from previous research.

One problem with Experiment III was the existence of a ceiling effect in the scores for the map stimulus-map response condition and in the spatial relations test. Experiment IV (Chapter 14) was conducted to clarify the relationships between spatial learning and spatial relations ability. The subjects used in this final study were similar to those used in Experiment IIa but they had spent twice as long 'on campus' as the final group in the earlier experiment. For this reason, the 'real-life' cognitive mapping task was incorporated into Experiment IV, so that the conclusion that knowledge levels had reached a plateau by the end of Experiment IIa could be tested. Also, this enabled 'real-life' cognitive mapping performance to be compared with performance on the artificial spatial learning task and the spatial relations test.

The results of Experiment IV confirmed that ceiling levels of knowledge had been reached by the end of Experiment IIa. Significant relationships were found between performance on the three types of spatial task.

## Chapter 11

### Experiment I

#### A Comparison of Free-hand Sketch-mapping and Three-dimensional Modelling as Techniques for the Elicitation of Cognitive Maps

Summer 1979

### 11.1 Introduction

The present study was designed as a methodological comparison of two graphic techniques for eliciting cognitive maps of a well-known environment. A subsidiary aim was to assess the relationship (if any) between spatial relations ability and mapping ability as indicated by the mapping tasks.

#### Problems of Sketch-mapping

Early investigations of environmental representations, following the innovative example of Lynch (1960), utilised a free-hand sketch-mapping technique to elicit what Lynch termed 'city images' (see Chapter 3). The relationship between objective and subjective environments was the primary concern, so analysis was predominantly at the group level. In order to enhance the probability of obtaining stable 'public images', the early researchers chose homogeneous groups of middle-class subjects. It was not until researchers expanded their investigations to include a wider cross-section of the public, that the disadvantages of the sketch-mapping technique became apparent (see Chapter 4).

The main conclusion that was drawn from the later studies was that sketch-mapping constituted too difficult a task for people who were unfamiliar with maps or generally less educated. As a consequence, the maps drawn by these people frequently under-estimated their actual

levels of environmental knowledge. A large proportion of the most disadvantaged groups refused to attempt the sketch-mapping task. Allied to this difficulty is the fact first noticed by Lynch (1960), that there is a higher 'threshold' to the level of knowledge required if an element is to be included on a map than if it is to be included in a verbal description. This is probably another indication of low confidence levels. It implies that lesser-known elements may be omitted from free-hand sketch-maps; a possibility which limits the utility of the technique as a means of studying the process of acquisition in cognitive mapping. Stea and Taphanel (1974) listed the above-mentioned difficulties and added to them the problem of quantitative analysis of location. This referred to the difficulty encountered when attempting to assess the accuracy with which elements were placed; either in relation to each other (relative accuracy) or in relation to an objective map of the same scale (absolute accuracy).

A final problem with free-hand sketch-mapping is that errors are effectively permanent, in the sense that subjects are unable or unwilling to correct earlier parts of their sketches when subsequent drawing highlights their inaccuracy. As Beck and Wood (1976) stated, initial scaling errors can force the rest of the sketch into an erroneous form and in so doing, invalidate the locational data which might be obtained from such a map.

### Three-dimensional Modelling

It was to eliminate such problems that some researchers took to using a three-dimensional (3-D) modelling task as an alternative means of eliciting cognitive maps. This technique had been used successfully with young children ('toy modelling' - cf. Piaget, Inhelder and Szeminska, 1960; Stea and Kasnitz, 1969; Stea and Blaut, 1973) but has only been

considered as a means of measuring adult knowledge in recent years. The first study using this approach was by Battro, Ellis, Fremont and Matalon (1972). They had students of architecture produce 3-D models of an urban street network using small wooden blocks. The researchers noted the advantages of their technique when compared with sketching, in terms of its superior quantifiability. They found systematic distortions in the dimensions of the models, despite the fact that their subjects were highly trained in the observation and representation of the built environment. All subjects over-estimated the width of streets which they had been required to explore, but under-estimated the street lengths, the building heights and the width of streets crossing the main streets. The researchers concluded that adults develop a 'practical' model of urban space, which takes account of topological but not metric properties. This conclusion is in accord with later models of urban spatial representation (Siegel and White, 1975; Byrne, 1979; see Chapters 5 and 8).

Stea and Taphanel (1974) followed on from Battro's study and from their own work upon children's images by measuring the representations of two groups of adults, in California and Mexico. They asked subjects to arrange wooden landmark miniatures upon a base-map of their home-town. The Californian data were analysed so as to permit the researchers to distinguish between 'locational' (absolute) accuracy and 'relational' accuracy (the latter being with reference to certain key landmarks). Many subjects were found to have poor locational accuracy, but of these, a large proportion had good relational accuracy. The two performance indices were then utilised in a study of group differences in the Mexican sample. As hypothesized by Stea and Taphanel, there were social class and sex differences in the two measures. These differences were thought to be mediated by educational level, with locational accuracy being greatest among the more highly educated (middle-class, male) subjects.

The work of Battro, et.al. and Stea and Taphanel seems to show that 3-D modelling could be a viable alternative to sketching as a means of graphically externalising spatial knowledge. As Stea and Taphanel commented, model-making has "...a certain intrinsic appeal..." to adults, which minimises both the problems of subject refusal and higher inclusion thresholds which are associated with sketch-mapping. Since the modelling task only involves the arrangement of blocks or similar items, the dependence upon graphic ability and general map familiarity is also reduced. Modelling also has the advantage of enabling the subject to adjust the position of elements whenever he wishes to do so. In this way, the subject is likely to consider the final product to be an accurate representation of the area as he believes it to be.

Two further advantages of 3-D modelling concern data analysis. Firstly, as was pointed out by Battro, et.al., it is far simpler to quantify the accuracy of a model built from uniform blocks than that of a free-hand sketch-map. Secondly, while avoiding the pitfalls of sketching, 3-D modelling retains the potential for analysis in most of the ways which would be appropriate for sketch-maps. The latter were listed by Lynch (1976) and included assessment of the sequence of production, variance in detail (emphasis and omissions), total structure and scale distortions.

In view of these issues, it was thought necessary to compare the utility of 3-D modelling and free-hand sketch-mapping in an experimentally controlled setting. The main purpose of the present study will be to evaluate the relative utility of the two techniques when a group of well-educated, adult subjects are being tested.

## Spatial Ability and Cognitive Mapping

During the early 1970's a number of researchers conjectured upon the existence of a relationship between cognitive mapping performance and specific cognitive abilities. Appleyard (1970) claimed that the better performance of his 'educated group' could be explained by their greater ability to conceptualize and their superior skill in abstracting and inferring information from personal experience. Ladd (1970) thought that the performance of her subjects was probably influenced by their ability "...to conceptualize and represent spatial relations...." (see review in Chapter 4).

A few researchers have attempted to assess the hypothesized relationship directly. Bycroft (1974) found a high correlation between sketch-map sophistication and the ability to manipulate cognitive spatial information. However, significant correlations were also found between sketch-mapping and tests of reasoning ability, suggesting that general cognitive functioning may have been crucial. Moore (1975) investigated the latter possibility by assessing the relationship between 'level of representation' and scores on a variety of cognitive ability measures (standard tests of verbal reasoning, numerical ability and spatial relations ability). Moore found that only one of the tests was related to 'level of representation' in cognitive mapping; this being the 'Spatial Relations Test' (from the Differential Aptitude Test Battery devised by Bennett, Seashore and Wesman, 1951). It was shown that 25% of the variance in Spatial Relations scores could be explained by 'level of representation' (see review in Chapter 5).

It was therefore considered useful to incorporate completion of the 'Spatial Relations Test' into the design of the present study. The study will aim to elucidate the relationship between spatial relations ability and cognitive mapping performance, using more detailed performance measures than were used by Moore (1975).

### Specific Methodological Issues

Since this study is an attempt to compare comprehensively the two types of direct mapping task, it is desirable that they be made as similar as possible in all but the key factors. For this reason, the modelling task will involve a range of materials, so that subjects can easily represent any type of element they wish, as they could in a sketching task. This will make a comparison of 'map' and 'model' content more meaningful. If the modelling materials were restricted to blocks, this would bias subjects towards including buildings and omitting elements such as paths or vegetation.

The study will also incorporate a comparison of the levels of accuracy achieved with the two techniques. A frequently-made claim concerning sketching is that subjects have difficulty choosing an appropriate scale with which to begin their 'map'. It is possible that the scaling problem may be alleviated when subjects are provided with a ready-made scale unit, in the form of a modelling block. To maximise the possible utility of this factor, no assistance will be given in choosing a suitable scale. The tasks will therefore be unstructured; that is, no preprinted base-map will be used.

Not only is the final product of a mapping task of interest, but also the way in which the map or model is produced. Lynch (1960) recommended that his experimenters took notes upon the order in which elements were drawn, as potential evidence of the relative importance of particular elements. Canter (1977) re-iterated Lynch's words and pointed out the utility of videotape recording equipment for this purpose. All the sketching and modelling attempts in the present study will therefore be recorded using videotape equipment. A permanent record of the growth of each map or model will greatly facilitate the accurate analysis of recall order.

Summary

To recapitulate, the present study has two main aims:-

- 1) to make a detailed comparison of three-dimensional modelling with free-hand sketch-mapping as techniques for the elicitation of spatial representations. This will involve analyses in terms of:-

- i. content;

- ii. accuracy (position and scaling);

- and iii. recall order;

- 2) to examine the relationship between mapping competence and ability to manipulate cognitively spatial images.

The study will test two main hypotheses. The first of these is that three-dimensional modelling will yield higher scores than will free-hand sketch-mapping on both content and accuracy measures of elicited representations. Stea and Taphanel (1974), as reviewed earlier, concluded that modelling was seen as a less threatening task than sketch-mapping, so that subjects would be willing to include places of which they were unsure, when they would not do so on a sketch-map. Hence, a higher content score is hypothesized for modelling. Stea and Taphanel also claimed that since modelling reduced the reliance upon drawing skill and enabled elements to be repeatedly re-positioned, the end-product would be more likely to be seen as accurate by the subject. Hence, a higher accuracy level may be hypothesized for modelling, since it is said to reduce unwanted sources of error. Stea and Taphanel's subjects were poorly-educated adults; the present study will investigate whether modelling has the same advantages when the spatial knowledge of well-educated subjects is being assessed.

The second main hypothesis is derived from the findings of Moore (1975; see Chapter 5 and above section). Moore found that of a variety of cognitive ability measures, a test of spatial relations ability was



the only one which was correlated with the judged 'level of representation' (an index of spatial complexity) of sketch-maps. The present study will separately assess the extent to which spatial relations ability is correlated with measures of content and accuracy. It is hypothesized that a significant correlation will be found between spatial relations ability and the accuracy measures, since the latter most obviously relies upon the cognitive manipulation of spatial information. It is less clear if measures of content will bear any relation to spatial ability, since these may only involve verbal memory for place-names.

## 11.2 Method

### Subjects (see Appendix 1)

The sample consisted of eight male and eight female university students (mean age = 21.875 years, range 20-29 years). The time that they had spent on the campus ranged from one to five years (mean = 2.875 years) and all but two of the subjects lived in accommodation "off campus". The subjects were paid £1 each for their services.

### Materials/Apparatus

The task materials were chosen with the aim of ensuring that the tasks were as similar as possible in all but the factors which are essential to sketching or to 3-D modelling. For this reason, subjects in the sketching conditions were provided with a 30 cm ruler and an eraser in addition to the drawing card and pencils. This was to ensure that their sketching performance was not limited by the inability to draw straight lines or to erase erroneous parts of the 'maps'. Both maps and models were produced on a base of thin white card, approximately 55 x 75 cm. In the modelling task, the card was pinned to a block of soft-board so as to provide a firm base and to facilitate the positioning of mapping pins.

As explained earlier, a range of materials were provided for the modelling task, from which subjects were free to choose whatever they needed. The standard set of materials with which each subject was provided was as follows:-

70 wooden blocks - 30 at 5.0 x 2.5 x 2.0 cm

20 at 2.5 x 2.5 x 2.0 cm

20 at 1.5 x 2.5 x 2.0 cm

Several large sheets of black card

" " " " green "

Small coloured counters

Mapping pins

Scissors, pencils.

The block sizes were chosen so that an optimum arrangement on the base-card would give an accurate scale-model of the main campus area. All the materials were chosen to produce unambiguous images when video-taped, e.g. black and green card gave a clear contrast on black and white film.

The 'Spatial Relations Test' (SRT) question forms and answer sheets were taken from the 'Differential Aptitude Tests', second edition (Bennett, Seashore and Wesman, 1951).

### Experimental Design

The study was primarily designed to assess the utility of sketching and modelling as techniques for eliciting spatial representations of a campus area. In addition, it was thought useful to compare initial and later attempts to represent an area and to evaluate the relative utility of sketching and modelling in each of these cases. A four-group design was therefore adopted; four subjects performed the modelling task first and then the sketching task, four followed the reverse sequence, four performed the modelling task twice and four the sketching task twice. This design permitted both within- and between-subject comparisons of the sketching and the modelling tasks (see Table 11.1).

Equal numbers of males and females were assigned to each group. It was not possible for all subjects to be tested at the same time of day, so morning and afternoon test sessions were counterbalanced across the groups.

Table 11.1 : Experimental Design

		Second Task	
		Sketching	Modelling
First Task	Sketching	4 Subjects	4 Subjects
	Modelling	4 Subjects	4 Subjects

Free recall

All subjects followed the same basic procedure: they performed the first task, then completed the SRT and finally performed the second task. The SRT provided an adequate time-delay before the second task; as was necessary to lessen short-term retention of the details from the first task. Any tendency to "mentally rehearse" the task during the time-gap would be made improbable by the intensive nature of the SRT.

The instructions for sketching and modelling (see Appendix 2) were composed to as to be as similar as possible, the only difference being the section where the technique details were given. The instructions were also left as basic as possible, in order to discover what interpretation the subjects would put upon the task requirements. They were asked to draw a map/plan or to make a model of the University campus and to include as many details as possible, labelling items by writing on the base-card. No guidelines were given as to the type of element required, so that comparisons of 'content' could be made between modelling and sketching, and in relation to accuracy or practice. Equally, no guidance was given regarding the limits or size of the area required, so that the efficiency with which the maps or models were scaled could be assessed. In keeping with the unstructured nature of the modelling and mapping tasks, no limit was put upon the time allowed for producing the representations.

It was decided to record the verbal comments made by subjects during task performance; this being useful for two purposes. Firstly, it provided an accurate check upon what the subject was attempting to represent at each stage of the task and therefore facilitated the recording of order and content details. Secondly, it provided evidence about the strategies being adopted and the methods of recall being utilised during task performance.

### Prompted Recall

Despite the 'free recall' form of the tasks, it was thought desirable to maximise the environmental knowledge which was eventually elicited from the subjects. This was achieved by adding a 'prompted recall' section at the end of the second task. A list of elements was read to the subject who was asked if he knew the identity of each item and if so, to indicate its position on his map or model. In this way, partially-known elements could be elicited, which subjects might not otherwise have had the confidence to include. The 'prompted recall' list consisted of any items from the experimenter's checklist which were not spontaneously included by the particular subject in his representation. These included all the buildings on the campus, plus external staircases, walkways, car-parks, bicycle-racks, lawns and paths.

## Procedure

Subjects were individually tested on a day convenient to them. The overall span of the study was 51 days. The subjects worked in a large teaching room, sitting at a table arranged in front of the video-camera while performing the sketching/modelling tasks. A microphone was placed on the table in front of the subject. Subjects were asked to move to another table in order to complete the SRT, so as not to be distracted by the experimenter re-arranging the materials.

The basic sequence followed by every subject was as follows (written instructions were given for each stage of the experiment; see Appendix 2):-

1. Complete 'Subject Details' (regarding age, sex, years at University, etc.; see Appendix 3);
2. Perform 'First Task' (sketching or modelling according to group);
3. Complete SRT (30-minute time limit);
4. Perform 'Second Task';
5. Perform 'Prompted Recall Task';
6. Write 'Comments' on sheet provided.

The experimenter was seated in front of the subject, to one side of the video-camera, throughout the tasks. This enabled the control of the video equipment and the keeping of a written record of the subject's behaviour. The prompted recall section was not video-recorded, since the elements were read to the subject one at a time, making an order analysis meaningless. Several subjects were not capable of scaling their representations down to a size which would fit on the base-card. In these cases, if the subject requested more base-card to attach to the initial one, this was provided.

Following the completion of each 3-D modelling task, the experimenter made a permanent record of the final arrangement of items by drawing around them on the base-card (labelling the items unambiguously, if the subject had not done so).

## Data Analysis

The quantitative analysis of the sketching and modelling tasks concentrated upon three basic measures; these being content, accuracy and sequence of element inclusion. The first two were used to evaluate the final maps or models, whereas the last concerned the way in which the representations were produced.

## Content

The details on the base-cards, the experimenter's written records and the videotape recordings were used to make comprehensive records of the elements included by each subject. The items were then categorised as either buildings or non-building elements. In the cases where one physical building served two or more distinct functions, it was scored in accordance with the number of labels; for example, "Lib. + Educ. Lib." was counted as two buildings, whereas the same physical shape labelled as "Lib." was counted as one building.

Checklists were made for the first and second tasks, regardless of task type (i.e. sketching or modelling). The number of buildings and non-building elements in each map or model were noted. The number of extra buildings recalled on the second task was noted for each subject; this being termed the 'change score'. Change scores were not calculated for non-building elements since there was a very large variance in these scores.

## Accuracy

Stea and Taphanel (1974) distinguished between 'locational' and 'relational' accuracy, the former referring to absolute geographical accuracy and the latter to accuracy of element inter-relationships. It is apparent that 'locational' accuracy can only be measured when subjects represent their knowledge on an objective base-map, which enables 'correct' geographical position to be specified.

In the present study, subjects were not given any objective base-positions and so accuracy had to be assessed in terms of the relative distances between buildings. It was observed that all 32 representations (16 x 2 attempts per subject) showed one building ('Admin.') in the S.W. corner of the campus; that being its correct position in relation to the rest of the campus. By taking the centre of this building as the origin (0,0) of a Cartesian co-ordinate system, it was possible to describe the position of any building as  $(x_i, y_i)$ ; where  $x_i$  and  $y_i$  are the horizontal and vertical displacements, in millimetres, of building  $i$  from 'Admin.'.

Measurements were taken from the central point of eight buildings, these being chosen so as to cover each geographical quadrant of the actual campus area and also to have been included on at least 90% of representations. These data were tabulated separately for the first and second task performances (regardless of male/female and sketch/model categories). Within the 'first task' data there were 12 empty cells (six horizontal and six vertical) caused by three subjects omitting a total of six buildings from their representations. These cells were replaced with approximate values calculated using a procedure recommended by Winer (1970). This involved calculating the row, column and overall means for the tabulated data and substituting the relevant sum (row mean + column mean - overall mean) into each empty cell (see also 'Method' section in Chapter 12).



A set of 'true' (x,y) readings were then obtained in the above manner from an objective ground-plan of the area, so that the degree of error in a subject's representation could be ascertained. However, before any direct comparison could be made between the subjective and the true positions, it was necessary to 'scale down' the former, so as to make them equivalent in magnitude to the objective plan. This was done using the following procedure:-

The basic scaling procedure was carried out using a computer program 'MAPS' (see Appendix 4) with the following four sets of data:-

- i. first task - horizontal (H1)
- ii. " " - vertical (V1)
- iii. second task - horizontal (H2)
- iv. " " - vertical (V2)

Each set of data was treated in the following manner:-

The eight relevant 'true' distances ( $t_1$  to  $t_8$ ; for the eight buildings whose accuracy was being assessed, taken from the objective ground-plan) were summed to produce TSUM.

Then, for each subject:

their eight distances ( $SB_1$  to  $SB_8$ ) were summed to produce SBSUM and a scaling factor, equivalent to the ratio of the two distance sums was produced -

$$SF = SBSUM/TSUM.$$

A root mean square error score (RMSE) was then calculated as follows:

$$RMSE = \sqrt{\sum_{i=1}^8 \frac{SB_i}{SF} - t_i^2 / 8}$$

(where  $i =$  buildings 1 to 8).

In this way, four RMSE's and four SF's (one for each of H1, V1, H2 and V2) were obtained for each of the 16 subjects. A measure of each subject's ability to co-ordinate horizontal and vertical scales was produced by calculating the ratio of horizontal S.F. to vertical S.F. for the first and second tasks separately;

$$\text{i.e. SFR1} = \text{first task SF ratio} = \frac{\text{SF (H1)}}{\text{SF (V1)}} \text{ for each subject.}$$

(Perfect co-ordination would give a ratio = 1 ).

Thus, each subject's accuracy was assessed in two ways. Firstly, in terms of building knowledge, as measured by the root mean square of the deviations between the 'true' and subjective positions of a group of buildings. These were measured separately for horizontal and vertical dimensions. Secondly, in terms of the ratio of the horizontal and vertical mean scale (as calculated above) produced by the subject. All measures were calculated separately for the first and second tasks, giving a total of six measures per subject;

i.e. RMSE for H1, V1, H2 and V2; and SFR1 and SFR2.

### Sequence

The videotape recordings were used to number each subject's element checklists (for the first task and the second task) according to the sequence in which they were included on the maps or models. It was apparent from the completed tables that a group of twelve prominent buildings were included by almost all subjects. The sequence in which these buildings were represented by each subject on each of his/her mapping attempts was extracted from the element orderings. Any building missed out by a subject was given the lowest rank (i.e. 12). These data were then tabulated for the first and the second tasks, so that the degree of similarity between subjects in their sequences of representation could be assessed.

### 11.3 Results

Analysis of the data concentrated upon four measures and their inter-relationships. The measures were as follows:- content, accuracy and recall order obtained from the two attempts to represent the campus area, and spatial relations ability, obtained from the 'Differential Aptitude Test' as described in the 'Method' section.

#### Comparison of Sketch-mapping and 3-D Modelling

##### Content

Content analysis was performed separately upon building and non-building elements, as described in the 'Data Analysis' section. The means and standard deviations of the number of elements in each category were calculated across all subjects. Separate analyses were performed on the first and second tasks. The results are shown in Table 11.2.

Table 11.2 : Number of Elements Represented.

	TASK	MEAN	S.D.
Buildings	First	17.125	2.421
	Second	18.688	2.952
Non-Building Elements	First	16.312	11.190
	Second	17.125	10.301

The building scores showed a small mean increase from the first to the second attempt to represent the area; this proved to be significant ( $A = 0.2736$ ,  $p < 0.05$ , 1-tailed). The results in Table 11.2 indicate that there was no significant increment in mean number of non-building elements from the first to the second attempts to represent the area.

Also, that further analysis of the non-building element scores was not feasible due to the high level of variance exhibited.

In order to uncover any differences between sketch-mapping and modelling, the building scores were subdivided and the two recall techniques compared. Table 11.3 shows that there was no difference between techniques on the first task and a slight advantage (non-significant) for sketching on the second task.

The 'prompted recall' section of the procedure proved to be difficult to administer systematically. The experimenter was often unable to identify which buildings were already included on a subject's plan, until the plans and video-tapes were analysed in detail. Therefore, at the end of the experimental procedure, a limited number of elements were read to the subject. Every subject was able to include at least one further building element (range 1 to 9 buildings, mean = 3.3) and up to 30 non-building elements (e.g. lawns, bicycle-racks, stairways).

Table 11.3 : Mean Number of Buildings Produced by Sketch-mapping and Modelling.

	First Task	Second Task
Sketch-mapping	17.125	19.250
Modelling	17.125	18.125

An examination of the building 'change scores' in each of the four groups revealed that all subjects who modelled first increased their scores, as did three of the four subjects in the sketch → sketch group. In contrast, none of the sketch → model group produced an increment in building scores from the first to the second tasks (three produced a decrement and one remained stable). The mean 'change scores' for the four groups are shown in Table 11.4.

Table 11.4 : Mean 'Change Scores' for Building Elements

		SECOND TASK		
		Sketch-mapping	Modelling	
FIRST TASK	Sketch-mapping	+3.000	-2.250	+0.375
	Modelling	+3.000	+2.500	+2.750
		+3.000	+0.125	+1.507

### Accuracy

Accuracy levels were analysed by producing six sets of rankings from the six accuracy measures (these being the 'RMS horizontal errors', 'RMS vertical errors' and 'S.F. ratios' for each of the first task and the second task). The scale-factor ratios were ranked by using the formula:-

$$\text{error} = \left| 1 - \text{S.F.} \right|$$
 where S.F. was calculated as in the 'Data Analysis' section. A perfect S.F. ratio (= 1) would therefore give an error =  $\emptyset$ .

To compare the levels of accuracy achieved by sketch-mapping and modelling, the six sets of accuracy rankings were grouped according to which mapping technique a subject had been asked to use. The mean ranks for each technique were then determined within each accuracy measure (see Tables 11.5 a), b) and c) ). In order to test the statistical significance of the accuracy differential between sketch-mapping and modelling, Mann-Whitney 'U' tests were carried out on each of the six measures. The probability levels of the 'U' values obtained are shown in Tables 11.5 a), b) and c).

Table 11.5 : Mean Ranked Accuracy for Sketch-mapping and Modelling.

a) Horizontal RMS Errors

	FIRST TASK	SECOND TASK
Sketch-mapping	9.062	7.750
Modelling	7.938	9.250
p value (1-tailed)	0.360	0.287

b) Vertical RMS Errors

	FIRST TASK	SECOND TASK
Sketch-mapping	6.875	10.750
Modelling	10.125	6.250
p value (1-tailed)	0.097	0.032

c) S.F. Ratios

	FIRST TASK	SECOND TASK
Sketch-mapping	6.625	10.625
Modelling	10.375	6.375
p value (1-tailed)	0.064	0.041

These results showed that there was a statistically significant ( $p < 0.05$ ) difference on the second task between the vertical RMS errors obtained by sketch-mapping and those obtained by modelling, with modelling producing the more accurate representations. A similar result was found in the S.F. ratio measure, with modelling producing significantly more accurate representations than sketch-mapping on the second task. There were no significant differences between the techniques on any of the first task measures or on the second task horizontal RMS errors.

## Recall Orders

Recall orders were initially analysed so as to uncover any similarity between subjects in their pattern of map construction. The data were divided in two different ways; firstly, into two subsets - [first task] and [second task] and secondly, into four subsets - [first task/sketch-mapping], [first task/modelling], [second task/sketch-mapping] and [second task/modelling]. These comparisons were designed to show if the level of inter-subject similarity in recall order was affected by the amount of practice which subjects had had and the type of mapping technique used.

Total ranks within subsets were obtained for each building (in the set of 12 which were chosen in the manner described in the 'Data Analysis' section) and a Kendall's coefficient of concordance was calculated for each group. The results of the two types of grouping are shown in Tables 11.6 a) and b).

Table 11.6 a) : Levels of Concordance for First and Second Tasks.

TASK	W	$X^2$	d.f.	P
First	0.528	92.93	11	<0.001
Second	0.194	34.18	11	<0.001

Table 11.6 b) : Levels of Concordance for Sketch-mapping and Modelling

TASK	TECHNIQUE	W	$X^2$	P
First	Sketch-mapping	0.5473	48.165	<0.001
	Modelling	0.5249	46.188	<0.001
Second	Sketch-mapping	0.0948	8.341	n.s.
	Modelling	0.3765	33.130	<0.001

From Table 11.6 a) it can be seen that there was a strong association between the orders in which all subjects constructed their 'maps' on both their first and their second attempts ( $p < 0.001$ ). However, from the reduction in the value of  $W$  at the second task, it may be claimed that the tendency to follow a common recall sequence is more pronounced among subjects who have not had an opportunity to practice the task beforehand.

Table 11.6 b) shows that the level of concordance was highly significant within both sketch-mapping and modelling subsets in the first task and for modelling subjects in the second task. However, the concordance coefficient between subjects who sketched their second attempt showed that no common sequence was utilised by this subset.

The reduction in concordance levels at the second task was further examined by calculating the level of consistency in recall order exhibited by each subject across the two task attempts. Spearman correlation coefficients were calculated for each subject. The direction and significance levels are shown in Table 11.7.

Table 11.7 : Within-Subject Recall Order Consistency  
(First task to Second task)

$r_s$ Value =	1.0	0.701	0.504	0.0	-0.504	-0.701	-1.0
Probability level	$p < 0.01$	$p < 0.05$	n.s.	n.s.	$p < 0.05$	$p < 0.01$	
Number of subjects	8	2	2	0	1	3	



The subjects showed a generally high level of similarity between their first and second mapping sequences; only two subjects giving non-significant coefficients. Four subjects gave significant negative correlations, implying that they had reversed their original mapping sequences. Three of these four subjects were in the [second task/sketching] subset; a fact which would have given rise to the non-significant concordance coefficient for that group.

The mean recall sequence (across all subjects) for the first task was compared with that for the second task. This was to see if there was any change in the common pattern of position recall between the first and the second task attempts. The Spearman correlation coefficient which was obtained was highly significant ( $r_s = 0.972$ ). This showed that the general recall pattern remained the same throughout the experiment (i.e. after subjects had practiced the task).

Finally, the mean recall sequence for all subjects (see Table 11.8) on the first task (i.e. first attempt to represent the campus) was compared with the actual layout of the twelve buildings on the campus (see Figure 11.1). It can be seen that there was clear evidence of spatial links between buildings which were consistently recalled in close sequence.

Figure 11.1 : Mean Recall Order for Twelve Common Buildings in First Task (Sketch-mapping and Modelling Data Combined).

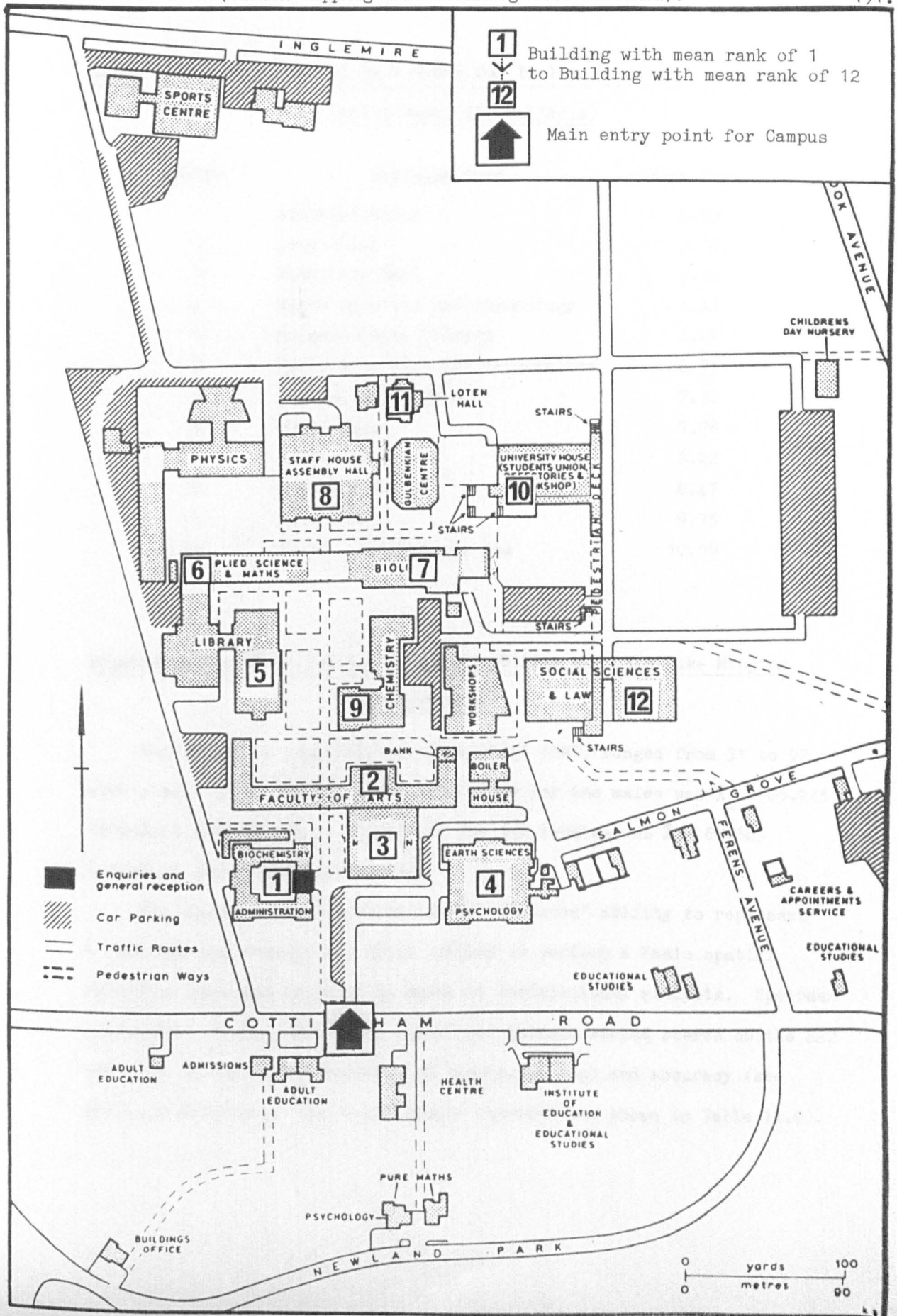


Table 11.8 : Mean Recall Rank Order for Twelve Buildings

(First Task, All Subjects)

<u>Number</u>	<u>Building Name</u>	<u>Mean Rank</u>
1	Administration	2.63
2	Arts Block	3.38
3	Middleton Hall	3.94
4	Earth Sciences and Psychology	4.44
5	Brynmor Jones Library	4.69
6	Applied Science and Mathematics	6.75
7	Biological Sciences	7.38
8	Staff House	7.78
9	Chemistry	8.22
10	Students Union	8.47
11	Loten Hall	9.75
12	Social Sciences and Law	10.59

Relationship between Spatial Relations Ability and Cognitive MappingPerformance

Scores on the 'Spatial Relations Test' (SRT) ranged from 31 to 97 with a mean of  $\bar{X} = 65.375$ . The mean score for the males was  $\bar{X}_m = 65.125$  (standard deviation  $\sigma_m = 25.26$ ) and for the females was  $\bar{X}_f = 65.625$  (standard deviation  $\sigma_f = 17.68$ ).

The degree of relationship between subjects' ability to represent a familiar environment and their ability to perform a basic spatial relations task was assessed by means of correlational analysis. Spearman correlation coefficients were calculated between ranked scores on the SRT and each of the ranked measures of mapping content and accuracy (see previous sections). The coefficients obtained are shown in Table 11.9).

Table 11.9 : Spearman Rank Correlation Coefficients between SRT scores and Cognitive Mapping Performance

Measures of Cognitive Mapping	$r_s$ with SRT scores	
	First Task	Second Task
Content	0.357	0.169
Accuracy:- Horizontal RMS errors	0.230	0.012
Vertical RMS errors	-0.015	0.090
S.F. Ratios	0.434*	0.494*

\* $p < 0.05$  (N=16, 1-tailed)

As can be seen from Table 11.9, neither the content nor any of the RMS position error scores were significantly correlated with scores on the S.R.T. In contrast, the ability to co-ordinate the horizontal and vertical dimensions of the maps or models (the S.F. ratio scores) was significantly correlated ( $p < 0.05$  with scores on the SRT).

#### Relationship Between Content and Accuracy Measures

The relationship between the level of accuracy with which a subject mapped the campus area and the total amount of detail they included was assessed. Spearman correlation coefficients showed that only one pair of content-accuracy measures were significantly related, these being content and horizontal RMS error scores on the second task (see Table 11.10).

Table 11.10 : Spearman Rank Correlation Coefficients Between  
Content and Accuracy Scores

ACCURACY CONTENT	Horizontal RMS Errors	Vertical RMS Errors	S.F. Ratios
First Task	0.2037	0.2375	-0.1669
Second Task	0.6316 *	-0.1537	0.2040

\*  $p < 0.01$  (N=16, 1-tailed)

## 11.4 Discussion

### A Comparison of Free-hand Sketch-mapping and Three-dimensional Modelling

The primary aim of the present study was to compare the utility of 3-D modelling and free-hand sketch-mapping as techniques for studying the environmental knowledge of 'educated' subjects. The two quantitative methods of assessing performance involved noting which elements were represented ('content') and where, in relation to the overall plan, certain key elements were positioned ('accuracy').

#### Content

In order to clarify the analysis of content, the elements were divided into two categories; one including all the building elements and the second, all the other elements. A preliminary analysis of these categories revealed that there was a slight increase in the mean number of buildings produced at the second attempt to represent the campus area. This performance increment was not present in the non-building category. The variance in the two sets of scores showed that there was a difference in the relative uniformity of the two category scores, across subjects. The building category had a fairly small variance; the content charts showing that subjects were producing a common core of buildings plus a number of other buildings idiosyncratic to sub-groups of the sample. This led to a situation where, of the 41 buildings which were included on at least one 'map', 15 to 20 were common to most subjects and the rest were included by only 2 or 3 subjects. The higher level of recall for the second task shows the typical 'reminiscence effect' found in free recall tasks of this type (Baddeley, 1976,. The 'prompted recall' section after the second task revealed that subjects who had omitted any of the common group of

buildings could position them when given the name of each building. This suggests that the necessary information is available but relatively inaccessible.

The non-building category exhibited a different pattern of scores on the two mapping attempts. A very wide range of scores was produced; from 1 to 44 elements on the first task. Since it is very unlikely that of two subjects with three years experience of an area, one could only recall the position of one non-building element whereas the other could recall the position of 44, another explanation must be sought. The comments of some subjects pointed towards the most likely underlying reason for the high variance. These people said that they were unsure of how much detail to include; an indication that the open-ended instructions constituted ambiguous task demands. A brief 'prompted recall' section for the non-building elements showed that subjective interpretation of task demands, rather than knowledge limits, had determined spontaneous responses. A comprehensive 'prompted recall' section was not possible, since the total range of potential elements could not be specified beforehand.

These considerations prevented any further statistical analysis of the non-building scores. However, it was possible to look at the differences in building scores between the four testing groups (i.e. 'sketch → model', 'sketch → sketch', 'model → model', 'model → sketch'). This analysis showed that there were no significant differences between sketch-mapping and modelling on either the first or the second mapping attempt. When performance upon the second attempt was considered for the four groups it appeared that 'sketch → model' yielded the lowest mean building score, implying that negative transfer had occurred from the sketch-mapping to the modelling task. The 'change scores' (second task score minus first task score), a simple measure of the size and

direction of each subject's performance change, illustrated the above point more clearly. Eleven of the 12 subjects in groups 'sketch → sketch', 'model → sketch' and 'model → model' improved their scores on the second task whereas none of the 4 in the 'sketch → model' group did so (three decreased and one was unchanged).

The results of the content analysis highlight two main points. Firstly, there is a common group of elements that appear in all the subjects' representations of the area. Secondly, subjects are not able to interpret an instruction to map an area as an unambiguous task demand. The superiority of 3-D modelling which was found by Stea and Taphanel (1974) was not exhibited in the content scores of the present subject sample (i.e. well-educated people mapping a familiar environment). On the contrary, where an initial sketch had been drawn, the change to 3-D modelling upon a repeated attempt to map seemed detrimental to performance. It appears that the advantages of 3-D modelling may be limited to cases where subjects would be likely to find sketch-mapping an excessively difficult task, such as when studying a poorly-educated group of people.

### Accuracy

The comparison of accuracy levels achieved by sketch-mapping and modelling gave different results at the first and the second attempts to represent the campus area. When subjects were making their first attempt to represent the area, sketch-mapping and modelling led to equivalent levels of accuracy. That is, there were no significant differences in mean ranking for the two techniques, on any of the three indices of accuracy (horizontal RMSE, vertical RMSE and SF ratios). In contrast, at the second attempt, two of the three indices showed modelling to be associated with a higher level of accuracy than sketch-mapping.



At first sight these findings seem to run counter to the results that might have been predicted from Stea and Taphanel's (1974) findings. They emphasized the role of a modelling technique in increasing a subject's confidence regarding the task. Such an effect would presumably be most noticeable at the first attempt, whereas enhanced scores for modelling were only found at the second attempt in the present study. The crucial difference between Stea and Taphanel's work and the present study was probably the nature of the subject group. Stea and Taphanel were examining the cognitive representations of a predominantly uneducated community for whom sketch-mapping would have constituted an excessively difficult and unfamiliar task: this would not have been the case in the present study. In this group, modelling would be a less familiar task than sketch-mapping, given their educational background. Comments made by the subjects showed that as many people felt hindered by the modelling materials as felt they were preferable to sketch-mapping. This would have offset any initial advantage of one technique over the other.

The results of the second attempts at representing the campus suggest that different factors may operate once subjects have had an opportunity to construct an initial arrangement of the basic elements. When second attempts were produced by modelling, their horizontal and vertical mean scales were significantly closer to each other than when sketch-mapping was used. This implies that the use of modelling materials does alleviate the scaling problem which is often experienced by subjects in free-hand sketch-mapping tasks. It is not obvious whether the advantage lies in the ease with which elements in a model can be moved about in relation to each other, or in that the building unit (smallest block) acts as a standard in both dimensions, enabling more consistent scaling to be produced.

The fact that RMS errors in the vertical dimension followed the same pattern as scale-factor ratios, whereas those in the horizontal direction revealed no difference between sketch-mapping and modelling accuracy requires further explanation. To do this it must be noted that RMS errors and scale-factors were not determined independently of one another. The scale-factor of a plan reflected the mean length of the item displacements in one dimension. The accuracy of each item position was then assessed once its displacement was adjusted by the scale-factor. Therefore, a large position error could be due to a lack of position knowledge or an inconsistent use of scale. Since the scale-factor ratio is another index of the consistency of scaling (between dimensions, rather than within), it might be anticipated that a large RMS error would be associated with an inaccurate scale-factor ratio.

Accepting this interpretation, it is left to explain why the horizontal RMS errors did not follow the same pattern (modelling scores superior to sketching on second attempts) as S.F. ratios. Several inter-related factors may have limited the scope for variable accuracy or scaling consistency in the horizontal dimension. The shape of the campus area meant that the north-south direction was predominant, giving more scope for variable accuracy in the vertical dimension. The shape of the base-card was such that most subjects took the width of the paper as equivalent to the width (east-west) of the campus. It is possible that having a reference distance of this type reduced the scope for error in the horizontal dimension. Unfortunately, this choice of reference distance was the source of the main scaling problem experienced by the subjects. If the width of the base-card defined the horizontal limits of the campus, then several of the vertical displacements would be off the top end of the base-card. Therefore, the subjects initially chose too large a scale to allow the accurate representation of the vertical

distances on the campus. Most subjects began their plans at the southern border of the area and worked northwards. This frequently led to them having to re-adjust the whole layout of the map southwards, in order to fit in later elements. Alternatively, subjects would gradually decrease the vertical scale as they placed the more northerly elements; this foreshortening effect leading to higher error scores (i.e. scale variability) in the vertical dimension. It may be that the use of standard modelling elements reduced this foreshortening of the vertical dimension by concentrating the subject's attention upon the size and shape of buildings and by increasing their willingness to re-position earlier elements (only possible in sketching by the lengthy process of erasing and re-drawing).

In summary, the use of 3-D modelling has been seen to give a slight advantage over free-hand sketch-mapping, in terms of the accuracy of the plans so produced. However, further consideration of the results and the nature of the tasks indicated that the superiority of modelling was probably due to it facilitating accurate scaling. Providing subjects with an appropriate scale for their plans, in the form of a base-map, should minimise any advantage of modelling over sketch-mapping, at least with an educated subject group.

#### The Relationship between Spatial Relations Ability and Cognitive Mapping Performance

The results obtained from the analysis of the relationship between spatial relations ability and mapping accuracy yielded a pair of contrasting findings. There was a positive correlation between the spatial relations test scores (SRT) and the ability of subjects to adopt similar mean scales in the horizontal and vertical dimensions. This result is what may have been anticipated, given the nature of the SRT.

This is a test of the ability to manipulate cognitive spatial images, which will of necessity involve the comparison of angles and distances which are displaced in two dimensions. Any attempt to co-ordinate the scaling of distances in the vertical and horizontal dimensions of a graphic representation will clearly involve similar processes.

In contrast, there was no significant degree of correlation between SRT and the RMS position errors in either dimension. To interpret this result, it is necessary to recall the way in which scale-factors and position errors were calculated. As noted earlier the two are not obtained through independent channels; the values of the position errors depend upon the degree to which the plan is 'scaled down' in an attempt to equate the general magnitude with that of the objective reference plan (see also 'Data Analysis'). A large position error could therefore occur as a result of either an inconsistent choice of scale or a lack of knowledge as to the true location of that building. This being so, the negative finding of the present study does not eliminate the possibility that if scaling problems were alleviated, a correlation might be found between SRT and actual building knowledge. Equally, if the degree of correlation between SRT and ability to maintain an efficient choice of scale were of interest, then a design would have to be adopted which equalised building knowledge across subjects, as far as possible.

Another problem arising from the open-ended free recall design was the limited range of buildings which could be included in the evaluation of accuracy. Since an equivalent index had to be drawn from each subject, only buildings which were spontaneously included by all subjects could be utilised. It is likely that these were also the best known buildings, so that performance was being assessed on a truncated range of accuracy. It could be that differential performance which is related to spatial ability would only be apparent when low familiarity building knowledge

was assessed. That is, all subjects however poor their spatial ability, might be able to recall the position of their most frequented buildings: differential performance only being exhibited at a lower level of environmental usage. This limitation could be overcome by the use of a forced recall procedure in which subjects would have to recall the positions of a predetermined standard group of elements. The buildings group could be chosen by the experimenter to include those which may be less well-learned by the subjects, so as to expand the range of accuracy which they are likely to exhibit.

Together, these considerations imply that a comparison of different peoples' knowledge of the interpositions of environmental elements can best be made by providing them each with a base-map and a standard set of elements which they are required to represent on the map.

Although it was hypothesized that SRT scores would be correlated with performance on the spatial components of the mapping task, it was not known whether they would be correlated with those aspects of environmental knowledge which lacked an essentially-spatial component (see also Chapter 6). The results of the present study showed the 'content' measure to be not significantly correlated with SRT performance. As 'content' is simply a measure of the number of elements present (regardless of position) it is essentially a measure of verbal label knowledge. The result therefore supports the view that non-spatial measures of environmental knowledge will not correlate with performance on tests of basic spatial manipulations ability.

One drawback of the content measure in the present study is that although essentially non-spatial, it is confounded by the fact that an item may not be included if no spatial information is known about it. That is, a subject will omit a building he knows by name unless he has at least a minimal notion of where it should be placed. This situation

might have been responsible for the fairly high (though statistically non-significant) correlation found between SRT and content on the first attempt at representing the campus. Only by eliminating the spatial component, as would be achieved by requesting a simple listing of building names, could a comprehensive measure of verbal knowledge be obtained.

#### The Relationship between Content and Accuracy Measures

The finding that some accuracy but not content measures of learning in the cognitive mapping task correlated with SRT performance is in accord with the conclusions of Beck and Wood (1976). They believed that different cognitive mechanisms were used in the processing of content and spatial veridicality (see also Chapter 6). Indeed, the present study revealed a generally low level of correlation between subjects' ranked accuracy and ranked content scores; suggesting that the two constitute independent indices of performance. The one significant correlation which was obtained (between horizontal accuracy and content on the second attempts), may have been artefactual. Given the limitation upon the horizontal axis due to the card width, increasing the number of buildings positioned may have simplified the task of correctly placing the buildings. Subjects placing several buildings in the correct sequential order on the horizontal axis are likely to produce smaller distance errors if the total width is limited, than if they can extend the inter-building gaps indefinitely.

The lack of correlation between content and accuracy may at first sight seem surprising, since both are supposedly measures of mapping competence and could therefore be expected to follow a similar pattern. But, a number of studies have shown that the identity and position of items in a spatial array are partially independent (e.g. Henderson, 1972;

Wetherall, 1978). The fact that they were not correlated highlights the need for careful choice of performance measures and for caution in the interpretation of results and when making generalizations on the basis of such results. It has been accepted that 'cognitive mapping' consists of "...a series of processes...." (Downs and Stea, 1973) but the possibility of a person performing well on one of these processes and poorly on another has not been emphasized enough. Lynch (1976) was one of the few researchers to point out such a need. The use of a unitary ('good' versus 'poor' cognitive mapper) measure of performance may even have obscured crucial variables and hindered the development of any real understanding of how people navigate their environments. It is necessary to look more closely at which processes particular subjects or groups of subjects are able to perform and to attempt to relate them to other measures of cognitive abilities or experiential factors. The question also emerges as to how far a person can compensate for his lack of ability in one area by making extra use of his skills in another e.g. a person with a poor spatial memory may learn complex spatial layouts by means of a long series of 'Left at X'-type sequences - thereby utilising a good verbal memory.

### Recall Orders

Analysis of the degree of concordance between subjects in their order of recalling the major buildings revealed a strong similarity on their first attempt and a less strong similarity on their second. Further individual correlations between each subject's first and second orderings revealed the cause of the lower overall concordance on the second attempt. Ten of the sixteen subjects produced first and second attempts which were positively correlated; of the remaining six subjects, four exhibited significant negative correlations. These four people were

effectively using the same sequence on both occasions, but were working through it backwards on the second attempt. The comments made by some subjects confirmed this impression. In this way, the overall concordance coefficient would be considerably reduced, giving the impression that use of a common sequence had diminished.

An impression of the general common sequence of mapping the area was derived from the total rank orderings for each building, across subjects. This showed the existence of spatial links between buildings which were ranked adjacently. Subjects were to a great extent recalling places in the order in which they would be passed when walking along the campus pathways from the main entrance. Two issues arise as a result of this finding. The subjects employed in the present study were all very familiar with the campus; it is important to know at what point such a spatially-linked recall sequence emerges in the subject's behaviour. It may be that spatial linking is apparent from the earliest stages of environmental learning, or that it becomes evident only after repeated interaction with the environment. The second issue concerns a point raised in relation to accuracy analysis; namely, that the free recall design limited the analysis to buildings included by all subjects, probably the best-known ones. In the same way, recall orders could not be analysed for the full range of buildings. It is therefore questionable as to where in the recall sequence the lesser-known buildings would be placed. A systematic investigation of complete recall sequences would necessitate a forced recall pattern as recommended for the study of spatial relations ability-mapping accuracy links.

The separate analyses of sketch-mapping and modelling revealed that it was subjects who sketched their second attempts who were largely responsible for the reduced concordance coefficient for the second task.



Three of the four significant negative correlations ('reversals') were from people who sketched their second attempts. Given the low number of cases involved in each condition, it is not possible to draw any firm conclusions as to the cause of this discrepancy.

## 11.5 Conclusions

### The Relative Utility of Sketch-mapping and 3-D Modelling

#### (i) Content

There was no overall difference between sketch-mapping and modelling in the number of elements recalled. This was true for building elements and for the total number of other items. If a previous attempt to map had used sketch-mapping, then modelling appeared to produce a decrement in building recall. A common group of buildings were recalled by all subjects, regardless of mapping technique. The number of non-building elements recalled appeared to be dependent upon the subjects' interpretation of the task instructions.

#### (ii) Accuracy

The use of 3-D modelling did not enhance the accuracy of the subjects' first attempts to represent the experimental area. However, once all the subjects had been given the opportunity to make an initial arrangement, modelling was associated with superior scaling consistency (i.e. at the second mapping attempt).

#### (iii) Recall Orders

There was no difference between sketch-mapping and modelling in the orders in which subjects produced their representations. These recall orders were highly consistent (both within and between subjects) and reflected the spatial experience of the subjects.

#### (iv) General

With an educated, adult sample, 3-D modelling does not seem to have any intrinsic advantages over sketch-mapping as a means of externalising cognitive maps. The apparent drawbacks of sketch-mapping, such as

difficulties with scaling, line-drawing and re-adjusting items can easily be alleviated by modifying the task demands.

Content and accuracy scores appeared to constitute independent measures of cognitive mapping performance.

#### Spatial Relations Ability and Cognitive Mapping Performance

There was a significant correlation between scores on the S.R.T. and ability to co-ordinate horizontal and vertical scales in the mapping task. No such relationship existed between S.R.T. and content scores or S.R.T. and errors in building position, once the mean scale had been taken into account. The interpretation of the latter finding was complicated by the fact that the mean scale and position error measurements could not be made independently of one another.

It was recommended that further work in this area should ensure that subjects are provided with a suitable scale to alleviate the confounding of the scaling/accuracy measures. Also, that a 'forced recall' design should be used so as to enable the correlation between SRT and mapping to be assessed over the full range of building knowledge.

## Chapter 12

### Experiment IIa

#### The Microgenetic Development of Spatial Knowledge: Building Position Knowledge and Subjective Organization in Relation to Spatial Experience

Autumn 1979

#### 12.1 Introduction

This experiment was designed to investigate the rate of acquisition of spatial knowledge about a real environment; in particular, during the first few days of environmental experience. Additionally, it was sought to assess the generality of results obtained in Experiment I, which showed consistency between subjects in the buildings which were accurately known and in the order in which such buildings were recalled. The present study was designed to assess at what stage in the acquisition process any such consistencies would develop. Also, to examine the relationship between objective and subjective assessments of spatial knowledge, and the order in which places were recalled in a mapping task.

#### Cognitive Mapping in a Novel Environment

The process by which an individual acquires a spatial representation of a new environment has been relatively neglected within cognitive mapping research until the last few years. The recent investigations of this microgenetic learning process were reviewed in Chapter 9. It was concluded from the evidence reviewed, that there had not been any adequate assessment of the earliest stages of cognitive map acquisition, in an 'everyday' learning situation. For example, Herman, Kail and Siegel (1979) compared the spatial knowledge of three groups of college freshmen for their campus, after 3 weeks, 3 months and 6 months respectively.

It was found that landmark, route and configurational knowledge were "quite accurate" after 3 weeks, became "more finely tuned" up to 3 months, but did not improve significantly during the subsequent 3 months. It therefore seems necessary to investigate the early weeks of the learning period, and in particular the initial days of environmental experience, when cognitive maps might be at their most labile.

One drawback of Herman, et. al.'s study was that only buildings which were likely to have been used by the subjects were included in the tasks. There was no assessment of incidental learning of those buildings which were not frequented by the subjects. Also, knowledge of building locations was not analysed on an individual basis, so it was not possible to look for differential learning rates. Earlier researchers into urban imagery and cognitive mapping considered what qualities of buildings would affect the likelihood of them forming part of a person's mental representation of an urban area. Initially, researchers from Lynch (1960) onwards concentrated upon physical parameters such as were described by Lynch's concept of 'imageability' (see Chapter 3). However, evidence rapidly accumulated to suggest that the functional significance of a building was of major importance in determining the likelihood of recall (see Chapters 3, 4 and 9). In particular, Devlin (1976; see Chapter 9) noted the importance of assessing functional importance and building knowledge on an individual basis.

Devlin's argument was that by using a group level of analysis, previous researchers had eliminated any evidence of relationships between individual spatial knowledge and idiosyncratic spatial activity. Clearly, when an individual level of analysis is impractical, the use of a more homogeneous group (in terms of building usage) may increase the likelihood of a relationship being found between functional significance and spatial knowledge. The present study therefore used a group of subjects with a highly similar pattern of building usage.

Experiment I (see Chapter 11) assessed subjects with well-established representations of the same area as the present study. A clear distinction was found between two categories of buildings; one category having buildings with a high likelihood of being 'known' by a subject, and the other with a low likelihood. The present study will investigate if newcomers to the area show this distinction, and whether or not differential learning rates are exhibited for the two building types.

#### Recall Order as Evidence of Subjective Organization

It was found in Experiment I that there was a high degree of consistency, both between and within subjects, in the order in which buildings were recalled in the mapping task. Examination of these consistent orders indicated that subjects were recalling buildings in a spatially-linked pattern, reflecting their personal experience of the area. It therefore seemed that the recall order results were providing evidence of a form of subjective organization based upon actual spatial experience.

Early memory researchers investigated the cognitive organization of new material by analysing word order in free recall tasks. Bousfield (1953) found that when using a randomly ordered stimulus list, composed of four taxonomic categories of nouns, repeated free recall trials produced a consistent new order of words, with a clustering of items from within each category. Consistent ordering has also been found when the test material lacked overall common categories, such results being interpreted in terms of the strength of associative bonds between the items. Jenkins and Russell (1952, 1958) showed that clustering could be predicted from free association norms for pairs of list items. Deese (1959) developed this work by demonstrating that the probability of two items being adjacent in the recall order was correlated with the inter-

item level of association. A study by Marshall (1967) showed that categorical clustering enhanced recall scores over and above the level that would be predicted from a 'level of association' approach to free recall. Tulving (1962) proposed the term "subjective organization" to refer to the phenomenon whereby words are recalled in a consistent order, despite a randomized input on each trial. Tulving measured subjective organization in a way which could be applied to test material without the assumption of objective associational or categorical inter-item relations. He counted the number of times that any two items were recalled consecutively over the series of trials, in comparison to the number of such pairings which would be expected by chance. It has been generally found (Tulving, 1966) that there is a positive correlation between amount of subjective organization and recall scores.

The utility of a map-like mental organization has been recognized since ancient times in terms of mnemonic devices such as the 'Method of Loci' (Yates, 1966). Psychological research in this area has focussed upon the evidence for this form of mental organization as a means of learning the spatial environment. This began with Tolman (1948; see also Chapter 2) asserting that a spatial environment is learned by a process of mentally working-over and elaborating incoming stimulation:

".....into a tentative, cognitive-like map of the environment" (1948).

Evidence of the facilitating effect of a map-like mental 'framework' upon learning has been reported by Reynolds (1966, 1968). It was found that verbal learning of paired-associates was enhanced by prior familiarization with related material embedded in a schematic map. More precisely, the map structure contained the stimulus words printed beside pictures related to the associated response words. Controlled comparisons in the 1968 study indicated that it was the integration of the verbal-visual pairings into a 'meaningful and organized whole' which facilitated recall, rather than the verbal-visual pairings per se.

From this, it appears that a map-like cognitive structure, based on personal experience, may constitute a particularly efficient form of subjective organization for spatial learning purposes. As in Experiment I, the present study will be designed to permit subjects to generate their own order of building position recall, so that the evidence for cognitive linking may be evaluated. The study will also attempt to determine at what stage in the environmental learning process subjects start to recall buildings in a consistent order; also, to assess whether or not the level of consistency increases as accuracy increases. The latter would be consistent with the findings of Tulving and others (see above).

#### Subjective and Objective Assessments of Accuracy

It has been claimed by Beck and Wood (1976; see Chapter 6) that people are capable of estimating the content of their knowledge of an environment, but not its accuracy. As a means of testing this claim, subjects in the present study will be required to rate their confidence in the accuracy of each of the locations that they draw. Thorndyke and Stasz (1980) found that 'good mappers' were more accurate than 'poor mappers' at assessing their current state of learning, so that a good performance on a mapping task would be associated with a more accurate self-assessment of mapping accuracy (see also Chapter 10). This seems to indicate that confidence ratings will be more closely related to accuracy of recall as familiarity with the environment increases.

#### Methodological Issues

The decision as to which type of cognitive mapping task to use in the present study was made on the basis of a review of the literature and the conclusions of Experiment I (see Chapter 11). It was concluded



from a review of recent methodological studies that the choice of mapping task should be made upon the basis of the theoretical focus of the study to be undertaken and the type of subjects to be tested. The main focus of the present study is upon group differences in objective and subjective mapping accuracy, and in order of position recall during mapping. The relative accuracy with which groups of educated, adult subjects are able to depict the spatial layout of the major buildings in a local area is to be assessed. Given these factors, the evidence suggests that a direct mapping technique (i.e. depicting the layout in a small-scale, two-dimensional representation) would be the most appropriate technique. The conclusions drawn from Experiment I (see Chapter 11) suggest that with subjects such as the ones to be used in the present study, a sketch-mapping task may be adequate, provided that certain problems are alleviated. These problems concern the choice of a suitable scale, the confounding of performance by drawing ability and the need to standardise the degree of detail required. The first two problems will therefore be lessened by requiring the subjects to draw the required buildings (with size and shape being irrelevant) onto a base-map of the local road pattern, overlaid by a grid. The latter will be provided as a drawing aid.

The problem of standardising the degree of detail which subjects will attempt to include will be solved by using a 'forced recall' technique. Subjects will be given a standard list of building names and will be required to indicate the position of each on a base-map. Since the recall of building positions will be the main focus of the study, rather than the recall of building names, this procedure should be satisfactory. As well as facilitating data analysis, the 'forced recall' technique will increase the likelihood of partial knowledge being elicited. It was found that in the 'free recall' technique used in Experiment I, subjects were apt to omit poorly-known buildings through lack of

confidence, even though they were able to position the buildings when prompted. Quantitative analyses of individual differences in accuracy and recall order were necessarily limited to elements included by all subjects. This meant that 'low familiarity' buildings had to be excluded from such analyses. The present study will attempt to perform such analyses over the range of building familiarity.

### Summary

To summarise, the major hypotheses of the present study are that:-

- 1) there will be evidence of environmental learning during the experimental period, the majority of which will have occurred during the first week of environmental experience;
- 2) there will be significant differences between the level of recall for the two groups of buildings chosen from the previous study (Experiment I), and such differential recall will be related to the functional and spatial importance of the buildings;
- 3) there will be a preferred order of building position recall, and use of this order will become more consistent over time, approaching that found in Experiment I;
- 4) the rank order of building position recall will be related to the functional or spatial properties of the buildings;
- 5) increased environmental knowledge will be marked by an increase in the correlation between subjects' self-assessments of performance and objective measures of accuracy.

## 12.2 Method

### Subjects

The sample consisted of four groups, each containing five male and five female, first-year university students. All subjects followed the same academic course, so their building use and spatial activity patterns would have been as similar as was possible in a study of 'real-life' learning. The experiment was timed so that the four groups had been exposed to the relevant topographical area for differing lengths of time. The approximate number of days 'on campus' for each of the groups was as follows:-

<u>Group</u>	<u>Number of days</u>
D1	2
D2	4
D3	6
D4	50 (i.e. 10 weeks, with weekends spent 'off campus').

All the subjects were unpaid volunteers.

### Materials: (see Appendix 5)

A three-page answer booklet, as follows:-

1) 'Subject Details' - a questionnaire requesting age, sex, mathematical and geographical qualifications, as well as details of familiarity with the campus area, prior to the date set as Day 1 for the purposes of this experiment (that being the first day when subjects would have spent any length of time in the area). 'Familiarity' was measured both in terms of first-hand experience and use of secondary sources, such as maps and photographs.

2) 'Instructions' - this page consisted of a paragraph of task instructions and a buildings list. The task instructions began with a brief rationale for the study, followed by details of how to perform the task and the fact that a maximum of 15 minutes was to be allowed for its completion.

The buildings list contained 16 building names; half of the answer booklets had the buildings in alphabetical order and half in reverse alphabetical order. This was to counter-balance any effect of the presented order upon the position recall orders. Use of the two types of booklet was balanced over each day. In front of the building names there was a column of spaces, in which subjects could record their chosen position recall order (i.e. drawing order). After each building name was a 5-point scale, so subjects could record their confidence rating of the accuracy with which a building was positioned.

The list of buildings was composed of eight 'well-known' and eight 'poorly-known' buildings, determined from the results of Experiment I, which had investigated stable, long-term campus representations (see Chapter 11). The buildings were also chosen to cover the maximum area within the campus boundaries. When all 16 buildings were ordered alphabetically, the mean ranks for the two categories of buildings were equal.

3) 'Base-map' - this was approximately 21 cm x 29 cm (A4) and showed all the roads in the campus area, overlaid by a 1 cm square grid; the latter being provided primarily as a drawing aid. The direction of North was drawn on the lower left corner of the grid. The names of the four public roads were printed alongside the lines but the campus routes were unlabelled, since they do not have names.

## Procedure

Subjects were group-tested, either in a room just off the campus boundary (D1, D2, D3) or in a central campus lecture theatre (D4), in accordance with practical constraints at the time.

Subjects were asked to complete the questionnaire and then to read the task instructions. The task involved reading through the printed list, then choosing one building at a time (in whichever order the subject wished) and carrying out the following sequence:-

1. drawing the position of the building on the base-map;
2. numbering the building (on the list and on the map) according to its position in the recall order (i.e. 1 for the first building drawn to 16 for the last);
3. rating personal confidence in the accuracy of the building's position on the relevant scale.

It was emphasized to subjects that the size and shape of the buildings was not of relevance, since error measurements were to be taken from the geometric centre of the drawn buildings. They were also asked to limit their confidence ratings to one of the 5 points marked on each scale, rather than the intervening spaces, so as to facilitate data analysis.

Subjects were then given 15 minutes to perform the task.

## Data Analysis

Three sets of data were collected from each response booklet; namely, recall orders, confidence ratings and objective error scores for the 16 buildings. Error measurements were made by first marking the intersection of diagonals upon rectangular building sketches and the approximate geometric centre upon irregular figures. A transparent template with the correct centre locations marked on it was then placed over each map. This enabled the straight-line distance between each veridical and elicited building centre to be measured (to the nearest mm); producing a set of 16 error scores for each subject.

The data were tabulated and 'empty cells', resulting from a subject's refusal to respond to a particular building, were filled by one of two methods. The recall orderings were completed by assigning the final rank to an omitted building. The confidence rating and error score 'empty cells' were filled by means of a formula recommended by Winer (1970). This entailed calculating the row ( $\bar{r}$ , buildings) and column ( $\bar{c}$ , subjects) means for the data tables, as well as the overall means ( $\bar{x}$ ). The value to be ascribed to any cell  $x(r_i, c_j)$  was then given by the following formula:-

$$x(i,j) = \bar{r}_i + \bar{c}_j - \bar{x}$$

A computer program 'CELFIL' ( see Appendix 6) was devised to calculate and substitute the required figures into each data matrix.

The various subtotals and means necessary for the data analysis were then calculated from the amended tables.

### 12.3 Results

#### Changes in the Level of Recall

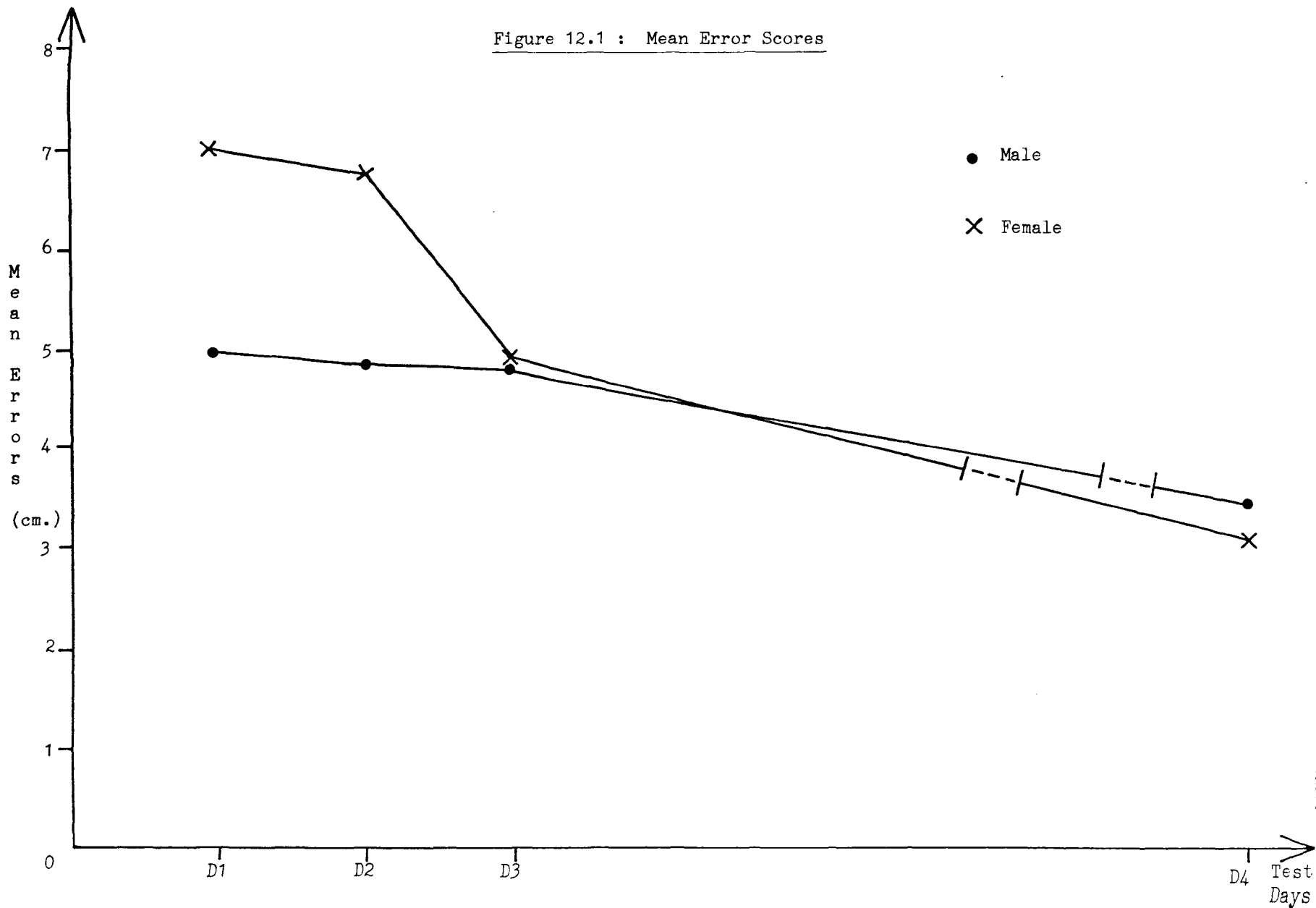
##### Error Scores

Examination of the mean error scores (see Figure 12.1) for each of the four test days indicated that learning (as measured by a reduction in error scores) had taken place over the experimental period. A three-way analysis of variance of the error scores (with day of testing, sex and buildings as the three factors) was performed to test for the presence of any statistically significant differences within the data. The improvement over the four days proved to be significant at the  $p < 0.01$  level (see Table 12.1).

Table 12.1 : Summary Table of 3-Way ANOVA of Error Scores

<u>Source</u>	<u>d.f.</u>	<u>S.S.</u>	<u>V.E.</u>	<u>F</u>	<u>p</u>
<u>Between Ss</u>					
Days (D)	3	764.845	254.948	4.499	<0.01
Sex (Sx)	1	138.125	138.125	2.438	n.s.
D x Sx	3	184.321	61.440	1.084	n.s.
Ss within Gps	32	1813.084	56.659		
<u>Within Ss</u>					
Buildings (Bldg)	15	2377.560	158.504	13.688	<0.01
Bldg x D	45	595.701	13.238	1.143	n.s.
Bldg x Sx	15	105.394	7.026	<1	n.s.
Bldg x D x Sx	45	394.424	8.765	<1	n.s.
Ss within Gps x Bldg	<u>480</u>	<u>5558.132</u>	11.579		
	639	11931.586			

Figure 12.1 : Mean Error Scores





### Confidence Ratings

The mean confidence ratings decreased slightly from D1 to D2, then increased again up to D4 (see Figure 12.2). A three-way analysis of variance, comparing mean confidence ratings on the four test occasions, showed that the increase was statistically significant at the  $p < 0.05$  level (see Table 12.2).

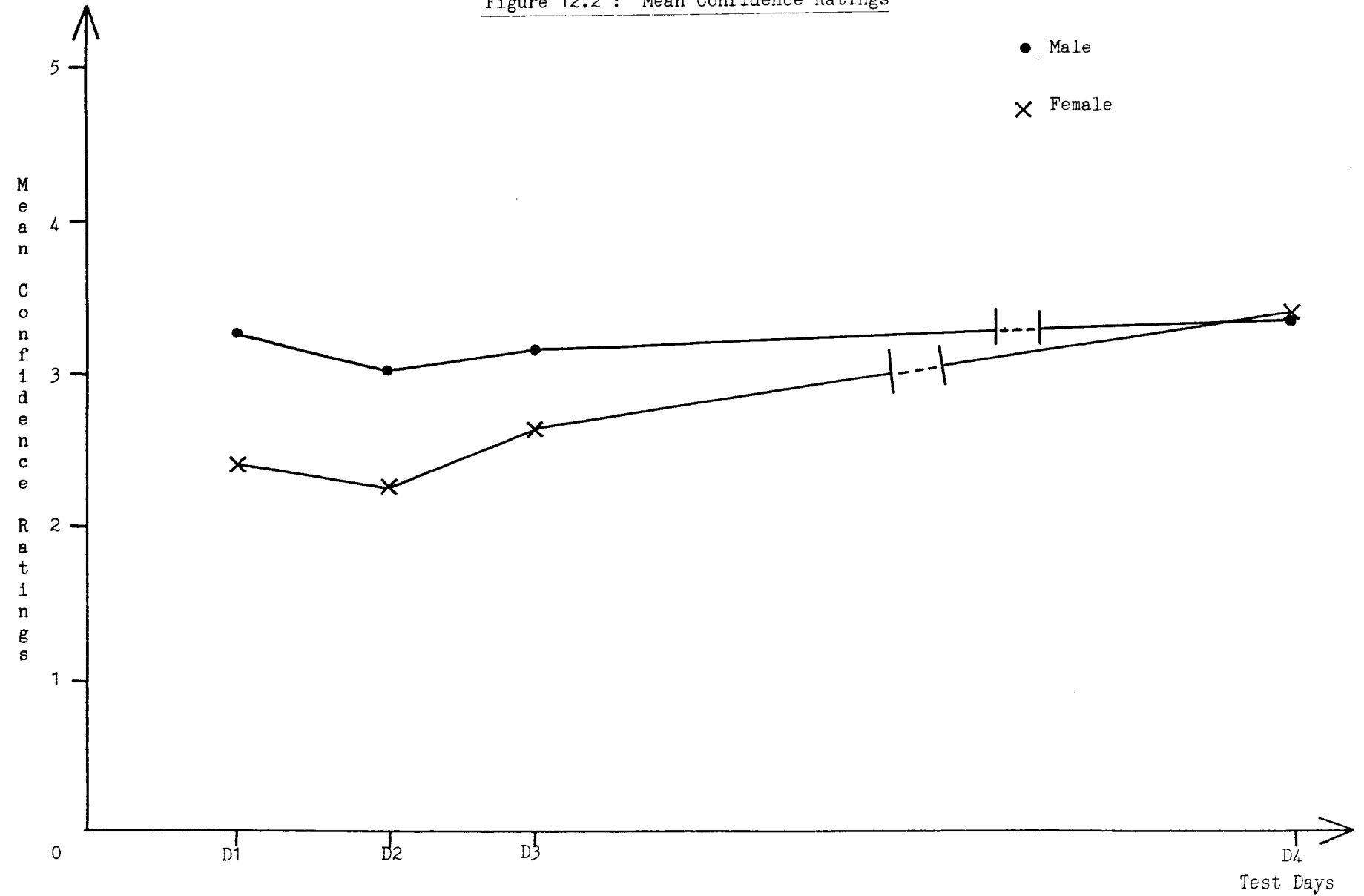
### Relationship between Error Scores and Confidence Ratings

Since both objective accuracy (reciprocal of error scores) and subjective confidence levels rose during the course of the study, Pearson correlation coefficients were computed for each day to measure the level of association between the two. R values of -0.660, -0.794, -0.714 and -0.789 were obtained for D1, D2, D3 and D4 respectively. These values were all significant at the  $p < 0.01$  level (df = 14, two-tailed). The negative sign showed that confidence was negatively correlated with error scores, and therefore, positively correlated with objective accuracy.

Table 12.2 : Summary Table of 3-Way ANOVA of Confidence Ratings

<u>Source</u>	<u>d.f.</u>	<u>S.S.</u>	<u>V.E.</u>	<u>F</u>	<u>p</u>
<u>Between Ss</u>					
Days (D)	3	44.516	14.839	3.243	<0.05
Sex (Sx)	1	37.822	37.822	8.267	<0.01
D x Sx	3	17.814	5.938	1.298	n.s.
Ss within Gps	32	146.400	4.575		
<u>Within Ss</u>					
Buildings (Bldg)	15	613.377	40.892	44.493	<0.01
Bldg x D	45	67.801	1.507	1.639	<0.01
Bldg x Sx	15	4.766	0.318	<1	n.s.
Bldg x D x Sx	45	54.592	1.213	1.320	n.s.
Ss within Gps x Bldg	<u>480</u>	<u>441.150</u>	0.919		
	639	1428.238			

Figure 12.2 : Mean Confidence Ratings



### Sex Differences in Mapping Accuracy

Since equal numbers of males and females were tested on each day of the present study, it was possible to look for possible sex differences in objective and subjective mapping accuracy, over the course of the study.

The mean error scores for males and females (see Figure 12.1) appeared to show that different learning patterns were developing during the first week of experience (D1 to D3 inclusive). Male subjects produced a stable level of accuracy during this period. Females were less accurate than males during the first two test days (after two and four days 'on campus') but improved to the level of the males' accuracy by the third test day (after six days' experience). This equivalent level of performance was still present at the final test day (after ten weeks' experience). However, these differences were not large enough to achieve statistical significance (see Table 12.1).

The mean confidence ratings for males and females revealed a clear sex difference, with male subjects being more confident of their mapping accuracy (see Figure 12.2). This differential was apparent throughout all the first week of experience, though it had diminished somewhat by the third test day (D3, after six days' experience). However, when the final group were tested after ten weeks 'on campus', the confidence differential was no longer in evidence.

Unlike the objective accuracy measures, the sex differences in confidence ratings were large enough to achieve statistical significance ( $F = 8.267$ ,  $p < 0.01$ ,  $df = 1,32$ ), as can be seen in Table 12.2.

### Recall Orders

The variance of the mean ranks for the buildings indicated that subjects appeared to be largely following a common order when recalling

the positions. Some buildings were frequently drawn early in the sequence, producing a low mean rank and some were equally often drawn after most other buildings, giving a high mean rank. A Kendall's Coefficient of Concordance was calculated from the data gathered on each day, in order to discover if the inter-subject association level was statistically significant. These analyses yielded values of  $W = 0.443, 0.518, 0.730$  and  $0.457$  for D1, D2, D3 and D4 respectively. All these values were statistically significant ( $p < 0.01$ ). The level of concordance therefore rose throughout the first week, but then decreased again between the end of the first week and the tenth week of experience.

#### Relationship between Recall Order and Accuracy Measures

A comparison of the mean error scores and confidence ratings with their associated recall orders over the four test days suggested that their level of association might not be as great at the end of the experimental period as at the beginning. To test this possibility, Pearson correlation coefficients were calculated for each day between mean recall order and mean confidence ratings (see Table 12.3). The results showed that there was a consistently significant ( $p < 0.01$ ) positive correlation between recall orders and error scores, i.e. the most accurately positioned buildings were placed first. However, as was anticipated, the correlation fell slightly as familiarity increased.

The correlation between recall orders and confidence ratings was significant ( $p < 0.01$ ) throughout the experimental period, i.e. building positions about which subjects were most confident were consistently drawn first (giving low ranks and therefore, a negative correlation). However, this sequence of correlations did fall slightly from an initial peak of  $r = -0.971$  to a final  $r = -0.874$ .

Table 12.3 : Pearson Correlation Coefficients between Recall Orders and Accuracy Measures

'r' Between -	D1	D2	D3	D4
Error Scores and Recall Orders	0.679	0.791	0.678	0.627
Confidence Ratings and Recall Orders	-0.971	-0.940	-0.939	-0.874

( $p = 0.01$ ,  $r = 0.623$ ,  $df = 14$ , two-tailed).

Differential Building Accuracy

It was hypothesized that there would be differences in the accuracy of position recall for buildings in the 'well-known' and 'poorly-known' categories (I and II respectively) which were derived from the results of Experiment I. This hypothesis was tested by dividing the data tables according to the buildings dichotomy and calculating separate mean error scores, mean confidence ratings and mean recall positions in the two categories, for each test day (see Tables 12.4 a) to c) and Figures 12.3 and 12.4).

Table 12.4 a) : Mean Error Scores

Test Days Bldgs	D1	D2	D3	D4	Mean
Category I	4.443	4.327	3.366	2.210	3.586
Category II	7.592	7.334	6.432	4.299	6.414
Mean	6.017	5.830	4.899	3.255	5.000

Table 12.4 b) : Mean Confidence Ratings

Test Days Bldgs	D1	D2	D3	D4	Mean
Category I	3.609	3.566	3.947	4.090	3.803
Category II	2.083	1.694	1.826	2.591	2.048
Mean	2.846	2.630	2.886	3.349	2.926

Table 12.4 c) : Mean Recall Positions

Bldgs \ Test Days	D1	D2	D3	D4	Mean
	Category I	6.000	5.988	5.388	6.106
Category II	11.000	11.012	11.612	10.894	11.130
Mean	8.500	8.500	8.500	8.500	8.500

The results shown in Tables 12.4 a), b) and c) indicate that buildings in Category I were recalled more accurately, more confidently and sooner, than buildings in Category II. It may be seen from Figure 12.3 that the reduction in objective position errors over the test period was not confined to buildings in one category. Over the first week of environmental experience (i.e. D1 to D3), the increase in accuracy was very similar for the two building categories. However, between the end of the first week and the tenth week (i.e. D3 to D4), the accuracy increase was greater for the 'poorly-known', or Category II buildings. In the same way, the increase in confidence levels between the first and tenth week was greater for the Category II buildings (see Figure 12.4). It can be seen from Figure 12.4 that confidence levels increased only within Category I during the first week (i.e. D1 to D3).

In order to test the statistical significance of the building category differences, a two-way analysis of variance was performed with each of the three sets of data (mean errors, mean confidence ratings and mean recall rank for each building). In addition, the significance of the category difference was assessed within each test day (and of the test day differences within each category).

It can be seen from Table 12.5a) differences between mean error scores for the two building categories were statistically significant on each test day. Equally, significant reductions in error scores took

Figure 12.3 : Mean Errors for Building Categories I and II

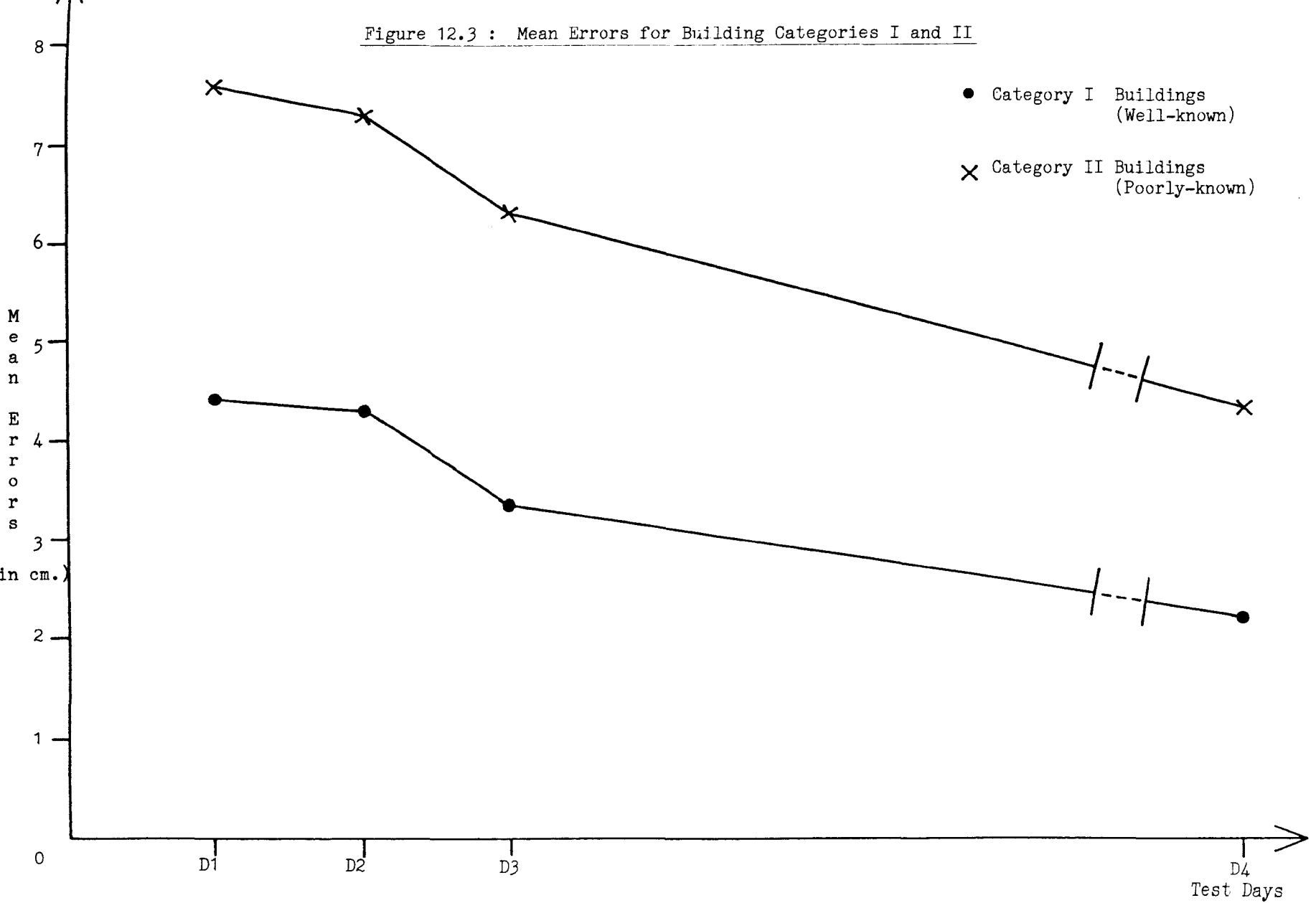
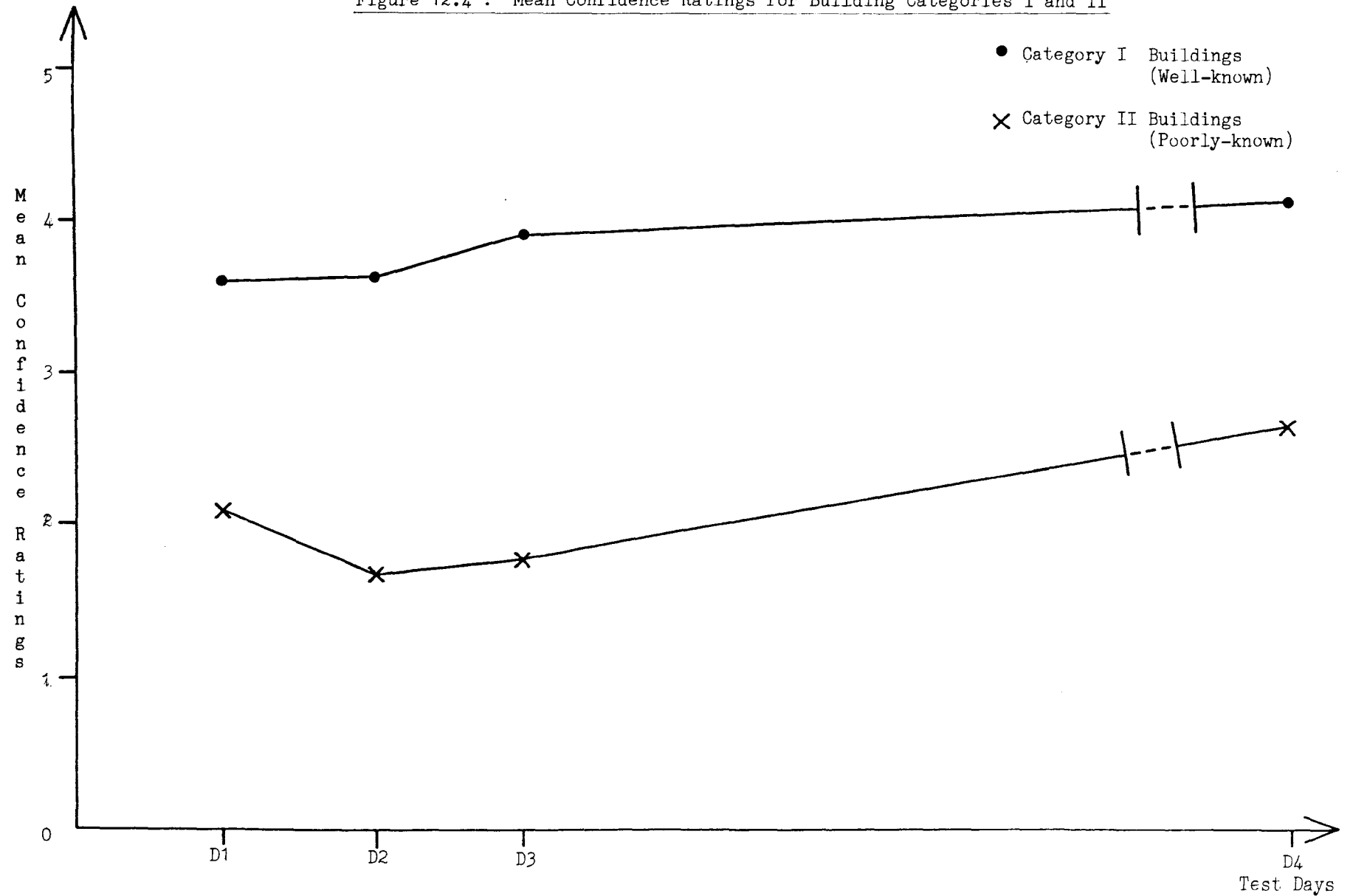


Figure 12.4 : Mean Confidence Ratings for Building Categories I and II





place over the test period within each building category. The category differences were also significant for the confidence ratings and the recall orders (see Tables 12.5 b) and 12.5 c). The increases in confidence levels shown in Figure 12.4 were also statistically significant (see Table 12.5 b) ).

Table 12.5 a) : Two-way ANOVA and Individual Comparisons of Mean Error Scores

<u>Source</u>	<u>F ratio</u>	<u>d.f.</u>	<u>p</u>
Building Categories (BC)	16.316	1,14	<0.01
Days (D)	18.921	3,42	<0.01
Interaction (BC x D)	<1	3,42	n.s.
BC on D1	13.354	1,56	<0.01
BC on D2	12.176	1,56	<0.01
BC on D3	12.658	1,56	<0.01
BC on D4	5.875	1,56	<0.05
Days in BCI	6.379	3,42	<0.01
Days in BCII	13.273	3,42	<0.01

Table 12.5 b) : Two-way ANOVA and Individual Comparisons of Mean Confidence Ratings

<u>Source</u>	<u>F ratio</u>	<u>d.f.</u>	<u>p</u>
Building Categories (BC)	55.326	1,14	<0.01
Days (D)	10.711	3,42	<0.01
Interaction (BC x D)	2.662	3,42	n.s.
BC on D1	28.876	1,56	<0.01
BC on D2	43.437	1,56	<0.01
BC on D3	55.836	1,56	<0.01
BC on D4	27.867	1,56	<0.01
Days in BCI	3.947	3,42	<0.05
Days in BCII	9.427	3,42	<0.01

Table 12.5 c) : Two-way ANOVA and Individual Comparisons of Mean Recall Positions

<u>Source</u>	<u>F ratio</u>	<u>d.f.</u>	<u>p</u>
Building Categories (BC)	29.712	1,14	<0.01
Days (D)	<1	3,42	n.s.
Interaction (BC x D)	1.245	3,42	n.s.
BC on D1	21.054	1,56	<0.01
BC on D2	21.265	1,56	<0.01
BC on D3	32.634	1,56	<0.01
BC on D4	19.302	1,56	<0.01
Days in BCI	<1	1,56	n.s.
Days in BCII	<1	1,56	n.s.

Changes in Preferred Order of Recall

It was hypothesized that as the level of environmental familiarity increased, the subjects would become more likely to recall the campus buildings in the order which was found in Experiment I; since the latter examined recall orders for buildings among long-term 'residents'. For the purpose of testing this hypothesis, it was necessary to use a set of buildings which were included by all subjects, in both Experiment I and the present study. A set of eight buildings were identified which formed part of every elicited representation, regardless of accuracy. These consisted largely, though not entirely, of buildings in 'Building Category I' in the present study. The mean rank order (recall position) for these eight buildings was then extracted from the overall recall orders for each day's representations. These sets of mean ranks were then themselves ranked, to produce five mean recall orders, one for each test day in the present study and one for Experiment I. The degree of similarity between these mean recall orders was then assessed by producing a Spearman non-parametric correlation matrix for the five mean rankings (see Table 12.6).

Table 12.6 : Spearman Correlation Matrix for Ranked Mean Ranks  
of the set of eight common buildings

$\rho$	D1	D2	D3	D4	Experiment I
D1		0.9524	-0.4392	0.0238	-0.1429
D2	0.9524		-0.4148	0.0476	0.0476
D3	-0.4392	-0.4148		0.7563	0.7319
D4	0.0238	0.0476	0.7563		0.5476
Experiment I	-0.1429	0.0476	0.7319	0.5476	

( $\rho = 0.6430$ ,  $p = 0.05$ ,  $n = 8$ , 1-tailed)

The coefficients so obtained showed that the orders of building recall on the first two days of the present study were not significantly correlated with the equivalent recall order produced in Experiment I. However, the third testing occasion (D3) produced a mean recall order which was significantly correlated ( $p < 0.05$ ) with that of Experiment I. The mean order from the final group tested in the present study (D4) was positively correlated with the Experiment I rank ordering, but not to a significant degree.

## 12.4 Discussion

### Environmental Learning Rates

The results of an analysis of variance test upon the error scores showed that significant learning took place over the experimental period. Examination of the mean error scores on each test day showed that this increase in spatial accuracy took place both during and after the first week, in approximately equal amounts. This finding has implications for Herman, Kail and Siegel's (1979) claim, that their subjects' representations were "quite accurate" at three weeks. It appears that if Herman, et. al. had tested subjects after only one week, they might have found a similarly accurate level of knowledge had developed.

Since it is likely that the absolute time required to reach a stable representation is dependent upon the intensity of environmental experience, these student representations will constitute an extremely fast rate of development; the students spending all of their days in a relatively compact topographical area. It is noticeable too, that the buildings in most frequent use were learned most quickly in the present study; implying that if Herman had included the buildings not frequented by his sample in the task, these would not have been represented 'quite accurately' after only three weeks.

### Differential Learning Patterns

The comparison of learning curves for building Categories I and II provided evidence that different buildings are learned at different rates. While the rate of learning (error score reduction) was similar during the course of the first week, accuracy increased far more in Category II than in Category I, during the interval from the end of the first week to the tenth week. This could be the result of three factors in operation; namely, the elimination of gross errors for one

or two buildings in Category II, a general improvement in the accuracy for Category II and finally, the fact that accuracy in Category I may have been reaching an asymptotic level. This last possible factor could be tested by a further trial, after a longer time had been spent in the area (see Experiment IV in Chapter 14).

The fact that the two categories of buildings were chosen from the results of Experiment I, seems to indicate that the categorisation would be stable over the entire range of subject experience levels, given a common building usage pattern. Examination of the buildings in the two groups shows a clear distinction on the grounds of frequency of use and functional importance to the subjects who were tested. Category I contains mainly general academic and recreational buildings; whereas Category II contains non-academic buildings and a number of science blocks unused by the subjects tested. It is noteworthy that the buildings most accurately placed in the first two days (e.g. Library, Sports Centre, Students' Union) were those which would have been visited most often.

There were two buildings which did not give error scores at the levels expected by virtue of their category membership. In these cases, the different experiences of subjects in Experiment I (on whose representations the categories were based) and the present study might elucidate the reasons for the discrepant results. The 'Wolfson Lab.', a Category II building, was relatively well-known by the end of the present study, in comparison to Experiment I. It may be noted that this building was not fully built until most of Experiment I subjects had been 'on campus' for a year or more. As such, it was not in existence until their representations would have had time to reach a stable level of development. On the other hand, it was fully built long before any of the subjects in the present study arrived.

The other building to yield an unexpected result was 'Staff House', which was relatively inaccurately placed during the first two test days, despite being in Category I. This building is one which is functionally important (for recreation and examinations) but is not highly frequented by the subject pool. Subjects on the first two days of testing would therefore be unfamiliar with the building name. The building is, however, clearly positioned at a major decision-point on the main campus route and it is possible that subjects would have been able to locate it, had the stimulus been a visual representation (e.g. photograph), rather than a verbal tag. This highlights the distinction between the internal and orientational functions of a building, either of which can lead to its inclusion in a cognitive representation.

Since the task in the present study initially involved recognition of verbal labels, it was biased against the recall of buildings which were used purely as orientational aids. In this sense, the task probably gave an underestimate of the influence of orientational information upon the form of subjective representations.

### Recall Orders

From the concordance coefficients, it appears that consistency between the subjects in the order in which they chose to draw the buildings increased during the test period, reaching a peak after a week and then lessened again. Initial competence seemed to be achieved by means of adopting a common recall order: a result which can be compared to Tulving's (1966) claim that there is a positive correlation between amount of subjective organization and recall scores.

After the first week, the use of the common recall order diminished somewhat; possibly because subjects were gradually developing idiosyncratic spatial behaviour patterns, in comparison to the stereotyped route and

building use of the first week. This could not be firmly established without more detailed 'behavioural mapping' measurements on an individual basis.

It will be recalled that analysis of the present study included a comparison of the mean recall orders on each test day with an equivalent set of results from subjects tested in Experiment I; the latter constituting a sample with well-established spatial knowledge of the area. The analysis showed that subjects in the present study did not produce recall sequences similar to those in Experiment I during the first two test days. However, on the third test day (after a week's environmental experience) the mean recall order was significantly correlated with that from Experiment I. As was noted in Chapter 11, the common recall order adopted by Experiment I subjects reflected the order in which buildings would have been encountered when traversing the area along the main paths.

Given that the evidence for spatial linking in recall orders only appeared after several days 'on campus', it is necessary to determine what lay behind the recall orders produced on the first two test days. The correlations between recall order and confidence ratings are of importance here. Throughout the present study, but particularly on the first test day, there was a remarkably high correlation between choice of recall order and subjective appraisal of knowledge. It therefore seems that initially, recall order is confidence-bound, with high confidence, well-known buildings (i.e. oft-frequented, functionally important) being drawn first. As the environmental representation develops, with buildings becoming cognitively 'linked' to spatial positions on a sequence, the tendency to produce all the best-known buildings first decreases.

The above analysis leads to the conclusion that as competence increases, what may be termed 'functional mapping' diminishes and 'sequential mapping' becomes more evident. At first sight, this seems to run counter to the customary view of sequential mapping as a developmental predecessor of a route-independent type of map, termed 'spatial' (Appleyard, 1970) or 'survey' map (Shemyakin, 1962; see earlier review). However, upon closer inspection, the discrepancy disappears. A 'functional map', as described above, is a simple, often grossly inaccurate representation of an area, containing only those elements known personally to the subject, in approximately the correct spatial relationship to each other. A 'spatial/survey map', which develops from sequential stages, is a complex, accurate representation of an area, which also emphasizes the spatial dispositions of the elements, without any apparent reliance upon a route. It should be noted that while 'spatial maps' generally result from several sequential maps becoming enmeshed into an integrated spatial network, in some circumstances 'spatial maps' can occur directly. This primarily occurs when an area is learnt from maps rather than solely from navigation, but can also occur when practical experience takes place at a large scale, e.g. aircraft pilots (see discussion in Chapter 8).

'Sequential mapping': storage or recall?

Since the evidence of sequential mapping was obtained within the framework of a recall task, it may be argued that the route-linked building series is only created at the time of recall and is not organized in such a manner in the cognitive representation. This would mean that a task such as the present study necessitated the cognitive manipulation of non-sequential material into the sequence which is then represented on the graphic base. This seems unlikely for a number of reasons:-



- 1) Experiments such as Reynolds (1968) show that it is the object-spatial organization at time of learning which aids recall;
- 2) The analogous mnemonic 'Method of Loci' succeeds in aiding recall by stressing the same object-place linking along a known route as the learning technique;
- 3) Where sequences are elicited from subjects who have learnt the material through practical experience, they are equivalent to the routes which have been followed by the person; which would not necessarily be the case if the sequences were first produced as a graphic recall aid.

From this, it seems that cognitive mapping involves the integration of new spatial information into the existing representation. Therefore, it seems likely that the efficiency with which a new cognitive map is acquired will depend upon at least two abilities. Firstly, the ability to perform cognitive manipulations with the primarily visual information obtained during environmental experience, or 'spatial relations ability'. Secondly, the ability to retain that information and retrieve it when necessary, or 'spatial memory'. Evidence for the importance of these abilities is assessed elsewhere in this thesis (see Chapters 10, 13 and 15).

One consideration to emerge from the above discussion is that, in order to study the process of cognitive mapping it is necessary to distinguish between 'map content' and 'map arrangement'. In other words, what is known and how that knowledge is mentally linked. It may be that the functional importance of buildings and the subject's spatial activity patterns may differentially affect these two map attributes.

### Objective and Subjective Accuracy Measures

The present study showed that there was a significant positive correlation between objective and subjective measures of mapping accuracy throughout the learning period. Additionally, it was found that the level of correlation increased as the subjects became more objectively accurate. This finding conflicts with Beck and Wood's (1976) conclusion, that subjects can estimate the content but not the accuracy of their cognitive maps. In contrast, it supports Thorndyke and Stasz (1980), who claimed that higher levels of competence were related to a more accurate subjective awareness of state of learning. It is difficult to interpret Beck and Wood's negative finding without engaging in a detailed analysis of their experimental work. However, one possibility is that the greater complexity of their mapping task (at the city-scale, rather than a small topographical area as in the present study) prevented subjects from reaching objective levels of accuracy to match their feelings of 'knowing' certain places.

### Sex Differences in Cognitive Mapping

It is widely accepted that there exist notable sex differences in cognitive functioning; particularly in the area of spatial ability, where adult males have been repeatedly found to perform at a superior level (see review by Fairweather, 1976). However, from an evaluation of positive and negative results, Fairweather concluded that:-

"The male advantage appears confined to tasks involving transformations of visual stimuli, and particularly in three dimensions....."

(1976, p.250).

Since the cognitive manipulations involved in forming an environmental image exemplify these very factors, it is possible that cognitive

mapping tasks will yield a similar performance differential to tests of spatial ability. Given that equal numbers of males and females were tested on each day of the present study, it seemed useful to analyse the obtained data in terms of possible sex differences.

Analysis of the error score variance revealed a non-significant sex difference in favour of the males. Observation of the mean error scores indicated that male accuracy was superior to female accuracy (though not at a statistically significant level), during the initial days of environmental experience. By the third test day (after a week) this tendency had disappeared.

In contrast, the difference between the sexes in mean confidence ratings (with males being more confident) was statistically significant. On the first two test days, this differential might have been simply an accurate awareness of state of knowledge; but if this were the case, by the third test day, this confidence differential should no longer have existed. The results suggest that the initial female performance deficit could be mediated by their expectancy level being lower, giving lower confidence which might have adversely affected their mapping ability. It may have been that such a situation resulted from sex-stereotyping, which holds that women are poor users of maps and equally poor wayfinders. This attitude has been found by previous researchers (Spencer, 1973; Pocock, 1975; see Chapters 4 and 5), where female subjects expressed extreme reticence at performing a map-drawing task and in many cases refused outright. However, in those studies, the subject populations probably yielded a superior male performance as a result of gross sex differences in educational background and environmental experience. It is noteworthy that such educational or experiential differences would have been at a minimum among the subjects used in the present study.

## Methodology

With regard to the utility of the mapping technique, no subject refused or was unable to complete the task and the data so obtained were suitable for analysis within the conceptual framework of the study. As such, the mapping technique can be evaluated as generally useful, but nevertheless, a number of problems must be considered. Firstly, although the experiment was meant to be forced spatial recall, a number of subjects still omitted certain buildings when they were unsure of the position. It might therefore be advantageous if subjects in future studies of this type were permitted to label guessed responses separately (e.g. by colour-coding), so that 'guesswork' would become an acceptable part of the task, rather than constituting a 'failure'.

Another problem with a name recognition-position recall task is that even though the position recall is subject-ordered, the spontaneity of building name recall is lost. If subjects were asked to produce a free-recall list of building names, without any need to also recall position, then maximum spontaneity of recall would be achieved. This list could then be utilised in the same way as the standard one was in the present study, each subject effectively providing his own recognition list. An additional probe list, similar to that used in Experiment I could also be provided afterwards, so as to maximise the amount of information elicited.

The grid and base-map materials were useful, in that they provided the subjects with the confidence necessary to perform the task and also enabled quantitative analysis to be carried out. On the other hand, the base-map prevents a subject from indicating his subjective idea of the shape of the area, and may also constrict his elicited building pattern into unnatural boundaries. These problems can be alleviated by using Beck and Wood's (1976) 'overlay' technique, where subjects

first draw their idea of the framework and then draw the building pattern on a separate sheet; should the cognitive representation of the framework be of primary interest.

The separate groups design was chosen with the aim of eliminating any distortion of the natural learning process due to the subjects' attention being drawn to their cognitive maps during an inter-test period. The separate groups design did yield useful results in terms of objective and subjective accuracy and recall sequences. However, it was clear that, particularly in the error scores, the high rate of individual differences may have partially obscured the actual pattern of learning.

## 12.5 Conclusions

### 1) Learning Rates

For high intensity experience, much of learning takes place within the first week, especially for highly frequented (functionally important) buildings. With lesser-known buildings, a considerable increase in accuracy takes place after the first week. An overall male superiority was not found, though there was a tendency towards greater male accuracy on Days 1 and 2.

### 2) Differential Learning Patterns

A clear difference was obtained in the accuracy and rate of learning of two categories of buildings, chosen from an earlier study (Experiment I) based on the same physical area. It was possible to distinguish between the two categories in terms of their functional importance to the subjects used.

### 3) Recall Orders

The development of initial competence was marked by an increase in concordance between the recall orders produced by the subjects. Whilst a core sequence remained common up to an asymptotic level of learning (as represented by the subjects in Experiment I), the high concordance reached by the end of week 1 diminished somewhat during later learning, possibly due to idiosyncratic spatial behaviour patterns. During week 1 subjects appeared to substitute a spatially-linked sequential mapping for their initial knowledge-dependent 'functional maps'.

#### 4) Confidence and Recall

As familiarity increases, subjects developed a more accurate awareness of their spatial knowledge. At the same time, the correlation between recall order and confidence rating was reduced; further evidence that supposed 'knowledge' was being overtaken by another factor (spatial-linking) as the main determinant of recall order.

#### 5) Methodology

Given a number of minor improvements, the experimental task provided a workable means of studying the microgenetic development of a cognitive representation. The large amount of individual differences between subjects created an obstacle to unequivocal result interpretation.

## Experiment IIb

### A Repeated Measures Comparison with Experiment IIa

#### 12.6 Introduction

The results of Experiment IIa produced some useful information regarding the rate at which various elements become organised into a coherent and accurate cognitive representation of a new environment. However, unequivocal conclusions were prevented by the high level of individual differences which were encountered. One way to solve this problem would be to retain the separate groups design and increase the number of subjects per group; but this was impracticable in the present study. The other solution would be to use a repeated measures design in order to reduce the level of individual differences within the data. The present study was therefore designed to take repeated measures from one group of subjects, in an attempt to show significant learning patterns similar to those found in Experiment IIa.

One drawback to the use of such a design is that repeated testing could be said to create an unnatural learning situation, where both future learning and subsequent mapping responses may be affected by the initial mapping task. Poulton (1973) has discussed at length the dangers of within-subject designs; stating that they generally constitute a learning situation, where later performance is facilitated by the initial 'practice'. It is therefore necessary to determine if such an effect occurs, and if so, for how long after the initial mapping task the effect remains in evidence. To this end, the present study was designed in conjunction with Experiment IIa.



The repeated measures group consisted of subjects who had first completed the task as members of one or other of the Experiment IIa groups which had been tested during their first week of environmental experience (groups D1, D2 and D3; tested after 2, 4 and 6 days). The data produced by these subjects constituted the repeated measures group initial task performance (RM1). The second task performance (RM2) was timed to coincide with the final testing day of Experiment IIa (D4; after 10 weeks). In this way, the effect of prior testing could be assessed by comparing the second attempt of the repeated measures group with an initial attempt of another group who had an equivalent length of environmental experience.

## 12.7 Method

### Subjects

The repeated measures and D4 (Experiment IIa) groups were obtained by group-testing the available subject pool after approximately ten weeks 'on campus'. Ten of these subjects (5 male and 5 female) had not been tested before and therefore they constituted the D4 group. A further 17 subjects (10 male and 7 female) were identified as having performed the task on one or other of the test days during the first week (i.e. were subjects in D1, D2 or D3): these subjects constituted the repeated measures group. The latter group were unaware at the time of their initial task completion that a second attempt was to be requested in the future.

### Materials

As used in Experiment IIa.

### Procedure

Since this study was essentially an extension of Experiment IIa, the procedure was basically the same as that described earlier, with an additional question necessitated by the group-testing situation.

Subjects were asked:

"Is this the first or second time you have tried this task?"

They were asked to reply by writing on the top corner of the first page of the task booklet. Subjects were then given a brief rationale for the task, as follows:

"I'm interested in the amount of environmental learning that takes place within the first week of moving into a new environment. In order to do this I must have some measure of the ceiling level that is eventually reached."

Following this, subjects were instructed as in Experiment IIa and completed the task in the same manner.

After data collection, the repeated measures group (those who answered "second time") were matched to their initial forms by means of the 'subject questionnaire' on the front page (since the task was completed anonymously). Data from the initial task analysis were therefore termed 'RM1' and from the second attempt 'RM2'.

## 12.8 Results

### Error Scores

Examination of the mean error scores for males and females in the RM1 and RM2 group revealed no evidence of a sex difference, as can be seen from Table 12.7. For this reason, the data from the two sexes were pooled for the subsequent analysis.

Table 12.7 : Mean Error Scores for Males and Females in Repeated Measures Group

	RM1 (2 to 6 days)	RM2 (10 weeks)
Males	4.907	3.059
Females	5.043	3.410
	4.963	3.204

The mean error scores on the first (RM1) and second (RM2) attempts at the mapping task appeared to show evidence of learning over the experimental period, as can be seen from Table 12.7. A two-way analysis of variance was performed on the error scores, with number of attempts and buildings as the two factors. The improvement in accuracy (decrease in error scores) was significant ( $F = 12.769 (1,16) p < 0.01$ ), as was the difference between buildings ( $F = 11.078 (15,240) p < 0.01$ ). In addition, the interaction between attempts and buildings ( $F = 2.558 (15,240) p < 0.01$ ) was also significant.

### Differential Building Knowledge

The mean error scores for individual buildings on each of the trials seemed to show the same pattern as that which was found in Experiment IIa. The buildings again fell into two main categories, those about which all

subjects were accurate and those which the subjects did not appear to know. The building group categorization used in Experiment IIa (high versus low hypothesized accuracy) was applied to the repeated measures data. This division yielded building category means which were equivalent to those found in Experiment IIa (see Tables 12.8 a) and b)).

From this it can be concluded that the repeated measures group comprised a representative sample of Experiment IIa groups D1 to D3. Equally, the differential mean scores for the building categories in RM2 showed that the 'buildings effect' persisted when subjects were given a second opportunity to represent the area. The lower mean scores for RM1 compared to the mean of D1, D2 and D3 scores, can be accounted for by noting the distribution of female subjects in RM1. The seven females were comprised of 1, 2 and 4 subjects from D1, D2 and D3 respectively. Since the relatively high female errors which affected the separate groups mean were largely in D1 and D2, these were somewhat under-represented in RM1.

Table 12.8 : Mean Error Scores for Building Categories I and II

a) Repeated Measures Group

Tests \ Bldgs	RM1	RM2
Category I	3.529	2.095
Category II	6.397	4.313
	4.963	3.204

b) Separate Groups (Experiment IIa)

Tests \ Bldgs	D1+D2+D3 3	D4
Category I	4.045	2.210
Category II	7.119	4.299
	5.582	3.255

The building category means for RM2 were very similar to those obtained from D4, except that building category I was represented slightly more accurately by RM2 (see Tables 12.8 a) and b)). Over the whole building range there did not appear to be any consistent difference between

RM2 and D4, this impression being supported by the result of an analysis of variance, which showed that the difference between the RM2 and D4 mean scores was non-significant ( $F < 1$ ).

#### Recall Orders and Confidence Ratings

The findings of Experiment IIa regarding recall orders and confidence ratings were supported by the results obtained from the repeated measures group. The extent to which subjects produced the buildings in a common recall order on each of the two test occasions was assessed by computing a coefficient of concordance, as was done in Experiment IIa. The coefficient obtained for RM1 ( $W = 0.533$ ) was equivalent to a level somewhere between D1 to D3 on the separate group testing ( $W = 0.4433$  to  $W = 0.7298$ ). Equally, the coefficient for RM2 ( $W = 0.488$ ) was similar to that obtained from D4 ( $W = 0.4567$ ).

Mean rank orderings and confidence ratings for building categories I and II were calculated from the repeated measures data. These mean values conformed closely to the pattern of results obtained in Experiment IIa (see Tables 12.9 a), b) and Table 12.10 a), b)). Category I buildings were consistently recalled before Category II and were judged to be accurate with a higher degree of confidence than those of Category II.

Table 12.9 : Mean Rank Orderings for Building Categories I and II

a) Repeated Measures Group

Tests \ Bldgs	RM1	RM2
Category I	5.949	5.690
Category II	11.051	11.310
	8.500	8.500

b) Separate Groups

Tests \ Bldgs	D1+D2+D3 3	D4
Category I	5.792	6.106
Category II	11.208	10.894
	8.500	8.500

Table 12.10 : Mean Confidence Ratings for Buildings Categories I and II

a) Repeated Measures Group

Tests Bldgs	RM1	RM2
Category I	3.658	4.010
Category II	1.914	2.577
	2.786	3.294

b) Separate Groups

Tests Bldgs	D1+D2+D3 3	D4
Category I	3.707	4.090
Category II	1.868	2.591
	2.787	3.340

## 12.9 Discussion

The results from the repeated measures group showed that significant learning took place during the course of the ten-week experimental period and that the increment was similar in amount to that which was found in Experiment IIa, using a separate groups design. In addition, the repeated measures group exhibited an increase in confidence of the same magnitude as that which was found in Experiment IIa. These findings imply that the results of the separate groups design were a genuine reflection of the learning process occurring in the sample, rather than chance variation due to a high level of individual differences in mapping ability.

Not only were the objective and subjective measures of learning similar, but also the levels of intra-group agreement upon recall order. The within-group concordance of subject-generated rank ordering fell slightly over the experimental period. As was discussed in relation to Experiment IIa, this may be due to a divergence in the spatial behaviour patterns of the subjects during the course of the experimental period.

Application of the dichotomy between 'well-known buildings' (Category I) and 'poorly-known buildings' (Category II) which was developed from Experiment I again produced consistently high and low scores on both measures of accuracy and mean recall positions. This procedure was as effective with the repeated measures data as with the separate group. It seems then, that it is possible to predict which elements of a topographical area are likely to be learned by newcomers and which are not. As was discussed in Experiment IIa, an examination of the types of buildings in the two categories indicates that functional importance seems to be of primary significance as a determinant of knowledge levels. In the present study, where name recognition was required, function in terms of internal use appeared to be of paramount importance: if a study utilised visual recognition, then function in



terms of orientational utility might be the most important factor in determining the level of learning exhibited in the task. In other words, buildings used as navigational landmarks during movement through the environment may be known for their visual appearance only, their names remaining unknown. It is implicit in this assertion that any one mapping task cannot be said to measure all aspects of spatial knowledge possessed by subjects; but rather, some component of that knowledge.

The lack of any significant differences between the second mapping attempt of the repeated measures group and the first attempt of the equivalent separate group has implications for both methodology and theory. Firstly, it demonstrates that a design of this kind can be used to measure environmental learning without the natural learning sequence being unduly affected by repeated mapping activity. No evidence was found that repeated testing precipitated active learning attempts (by focussing the subject's attention upon his own state of knowledge) or caused subjects to become increasingly skilled at the mapping task itself. However, it must also be noted that the present study utilised an approximately nine-week interval between testing; so it is possible that prior testing did affect the sample, but that such an effect had gradually diminished over the inter-trial period. This means that the effect of using a shorter interval would have to be ascertained before utilising this design to study environmental learning in a brief period, for instance the initial days of environmental experience.

At a theoretical level, the discovery that prior completion of a task did not affect subsequent performance upon the same task is somewhat enigmatic. The most apt interpretation would be clarified by the results of the study suggested above. If taking repeated measures over a short interval leads to an increased learning rate, then it implies that prior testing does enhance mapping performance but that forgetting over a longer period causes the erosion of such an effect. However, if no such

effect is found, then it would seem that mapping performance could only be improved by an increase in the spatial knowledge which it is designed to tap: maximum efficiency at using the structured graphic technique being attained upon the first testing session.

Also, if repeated testing did not enhance rate of learning, then it would imply that mapping activity was not encouraging subjects to learn actively more during subsequent exposure to the relevant locale. This runs counter to Follini (1966), who studied the microgenetic development of a room representation, when inter-trial periods were occupied by either representational (verbal or graphic) activity or an irrelevant task. From the results of subsequent verbal measures of spatial conceptualization of the room, Follini claimed that:

".....the person who represents space has a more highly organized, more articulate, more ordered and integrated view of space than does the person not engaging in representational activity....."

(1966, p.132).

This facilitating effect of mapping upon the development of spatial conceptualization may have been dependent upon factors in Follini's study which distinguish it from the present study. The experiment involved ten sequences of a 30-second learning trial followed by a mapping task, within a single testing session. This design would cause subjects to focus completely upon the task of learning the spatial details and to utilize each learning trial to 'correct' the previous mapping attempts. The time-scale involved would reduce any tendency to forget information as might occur in a real environmental learning situation. In the latter case, environmental competence would develop as a by-product of the need to navigate the environment; it would not be the primary aim of the subjects. It appears then, that the degree of facilitation produced by mapping activity may be moderated by the nature of the learning situation.

In conclusion, the present study has served two purposes. It has shown that the results derived from Experiment IIa give a valid picture of the microgenetic development of cognitive representations of a novel environment. The study has also indicated that repeated mapping trials do not necessarily lead to an abnormal rate of spatial knowledge acquisition, at least when there is an inter-trial interval of several weeks and when the intervening environmental experience is not explicitly directed towards spatial learning. That is, subjects were unaware that they would be asked to perform the task again and therefore, would have been less likely to have paid undue attention to their environment during the inter-test period.

## Chapter 13

### Experiment III

#### Spatial Learning Performance in Relation to Spatial Ability, Subjective Factors and Stimulus-Recall Mode Factors

October 1980

#### 13.1 Introduction

The present study was designed to assess the degree of relationship which existed between spatial learning performance and a number of individual characteristics. The latter included both specific cognitive abilities and self-rated mapping skills. In addition, the spatial learning task was used to compare the levels of recall achieved when using equivalent visual and verbal stimulus materials. Finally, the effect upon performance of recalling the spatial information in a different form to the original stimulus was assessed.

#### Individual Differences in Cognitive Mapping Ability

A number of recent studies have provided evidence of a link between basic cognitive abilities and performance upon cognitive mapping tasks. Bycroft (1974) found a relationship between children's sketch-map sophistication and a test of the ability to manipulate cognitive representations of shape. Moore (1975) performed a similar study with adults and also found a significant correlation, not mediated by general I.Q. or educational level (see also Chapter 5). Experiment I (see Chapter 11) yielded a significant correlation between a spatial relations test and one of the measures of cognitive mapping accuracy.

There is less consistent evidence for the role of simple visual imagery ability in cognitive mapping. That is, the extent to which a person is capable of experiencing a static visual image, without any need to manipulate the said image (see review in Chapter 10). Thorndyke and Stasz (1980) found a strong relationship between scores on a map-learning task and visual memory ability. However, the latter was an objective test of the ability to recall a visuo-spatial scene, not an assessment of the subjective experience of visual imagery. Murray and Spencer (1979) compared sketch-mapping performance and a test of the subjective experience of visual imagery. A non-significant positive correlation was found, but the researchers concluded that visual imagery was not an important factor in cognitive mapping.

It seems important to examine further the degree of relationship which exists between cognitive mapping ability and visual imagery and spatial relations ability. The present study will therefore include such an examination.

As well as specific cognitive abilities, a number of other individual characteristics have been found to be associated with superior cognitive mapping ability. These characteristics have been assessed by Beck and Wood (1976) and Kozlowski and Bryant (1977), mainly by the use of self-rating questionnaires. As reviewed in Chapters 6 and 10, these characteristics include:- high general map use, a positive attitude to maps, a good 'sense of direction' and confidence when in unfamiliar surroundings. A self-rating questionnaire will therefore be included in the present study, with items devised to assess the above characteristics. Scores on this questionnaire can then be correlated with cognitive mapping performance.

### Choice of Cognitive Mapping Task

It has been shown by previous research that superior cognitive mapping may result from people having had greater experience of an environment, both directly and through the use of secondary information (see Chapter 10). From the findings of Kozlowski and Bryant (1977; see above), superior mappers may seek out a greater level of environmental experience than inferior mappers, despite their having the same opportunities.

This being so, a study which attempts to compare cognitive mapping performance with individual differences in other factors must attempt to eliminate this experience differential. For this reason, an artificial task was used in the present study, so that exposure to the stimulus could be equalised. The stimulus materials were chosen so as to ensure that the task was an ecologically valid example of cognitive mapping. Since learning the details of routes is a recurrent aspect of everyday cognitive mapping, this was tested in the present study.

The actual stimulus materials were taken from a study by Owen and Mutch (unpublished). These researchers compared two forms of route representation; a schematized map and an equivalent verbal listing. Both forms of the route were employed in the present study, for reasons explained below (see next section). Using the 'serialism-holism' distinction originated by Pask (1976), Owen and Mutch compared performance on the map and list conditions in relation to the subject's customary approach to everyday tasks. They had subjects complete a questionnaire designed to assess the extent to which they carried out everyday tasks in a 'holist' or a 'serialist' fashion. 'Holists' were found to learn the map far more quickly than the list whereas 'serialists' did equally well on both (better than the 'holists' on the list and worse on the map). An adapted version of the questionnaire used by Owen and Mutch will be included in the present study, in an attempt to confirm this result.

## Visual and Verbal Memory

It is generally accepted within cognitive psychology that visual imagery can, and does play an important part in many learning situations (see reviews by Holt, 1964; Paivio, 1971; Marks, 1972; Sheehan, 1972). Some theorists, notably Pylyshyn (1973), have claimed that the so-called 'visual imagery' effects could be adequately explained within a propositional framework. However, it has been claimed that recent evidence may be best explained by recourse to visual imagery (e.g. Kosslyn and Pomerantz, 1977).

Further than this, a number of studies have provided evidence that visual and verbal memory systems may operate somewhat independently. Sanders and Schroots (1969) found that memory span could be increased by using materials from two different modalities, i.e. verbal strings (consonants) and visual strings (light positions). Brooks (1968) showed that the extent to which a secondary task interfered with the performance of a main task was dependent upon the modes of the two tasks. Where the secondary task mode was the same as that of the main task, interference was greater than in cross-modal cases. That is, a verbal response impaired memory for sentences more than memory for block diagrams.

Similarly, Den Heyer and Barrett (1971) found that memory for the positions and the identity of letters on a spatial array were differentially affected by verbal and visual tasks between stimulus display and recall. The position information was most affected by the visual task and vice versa. Bahrack and Boucher (1968) found that the likelihood of recalling an object's name and the likelihood of recognising its drawing were statistically independent. Bahrack and Bahrack (1971) showed that this independence was not due to the different methods by which memory had been accessed; that is, they found that visual recognition was independent of verbal recognition, as well as of verbal recall. Henderson

(1972) reported three experiments concerning identity and spatial position information. The experiments showed that performance on these two measures of learning improved at different rates; that performance on one could be traded against performance on the other and that partial statistical independence could be demonstrated for the two measures. More recently, Wetherall (1978) tested the ability of drivers to navigate a route which had been previously learned either from a map or from a list of verbal instructions. Those who learned the list were successful, whereas map-learners were unable to drive over the correct route. Wetherall concluded that the problem might have been partly due to:

"....competition between the map and the driving task for a spatial memory system...."

On the basis of further laboratory studies, he stated that:

"....there appear to be separate storage formats for spatial and "linear" information...."

Assuming that verbal and visuo-spatial memory can be utilised as separate memory codes, the question arises as to which form is the most efficient for any particular task. Paivio, Rogers and Smythe (1968) found that free recall of pictures was superior to free recall of lists of words which named the pictures. Using a recognition procedure, Shepard (1967) found that picture stimuli yielded higher scores than equivalent descriptive sentences. Furthermore, Standing (1973) showed that the superior recognition of pictures could be incremented by using particularly vivid stimuli. The creation of vivid visual images to characterize verbal materials is in fact the basis of many mnemonic techniques. The extent to which this strategy improves recall has been shown to depend upon the nature of the learning materials. Paivio and his colleagues (Paivio and Csapo, 1969; Ernest and Paivio, 1971; see review by Paivio, 1972) concluded from the results of various paired-associate learning tasks that the effectiveness of visual and verbal codes was influenced by the position of the materials on a concrete-



abstractness continuum. In other words, the utility of a visual coding system is dependent upon the ease with which the information can be characterized visually. From this, it would seem that visual memory would be particularly useful for the learning of spatial mapping information, given the ease with which such material can be displayed in a graphic form. Consequently, a stimulus mode which was visual in nature should facilitate spatial learning over and above the level achievable by a verbal description.

Murphy & Hutchinson (1982) showed overall learning of graphic displays to be very similar whether the display itself was used as a stimulus or the elements were described in a verbal sequence. However, they did find that more errors were made in the verbal condition. They concluded that the advantage of the visual condition lay in the fact that subjects were better able to use Gestalt properties of the displays as recall aids. The present study will therefore incorporate a comparison of spatial learning from visuo-spatial and verbal displays.

#### Stimulus-Response Compatibility

Early studies of cognitive mapping, from Lynch (1960) onwards, used the free-hand sketch-map as a means of externalising environmental knowledge. Unfortunately, this technique proved to have several drawbacks both in terms of its suitability for certain subject groups and its quantifiability (see Chapters 4 and 6). These difficulties have caused many researchers to abandon the use of graphic techniques completely and to rely upon methods such as distance estimation or verbal recall. On the other hand, some researchers have continued to support the use of graphic techniques in preference to numerical or verbal techniques (see Chapter 7). In particular, Lynch (1976) detailed the advantages to be derived from the use of sketch-mapping. In so doing,

he stated that:

"...the graphic languages are excellent for communicating multiple relations between things at one glance, in a single complex pattern."

(Lynch, 1976, p.VI).

If this statement is accepted, then it follows that the graphic response mode will provide a more useful method of recalling spatial information than will non-graphic modes such as verbal listing. The present study will evaluate the relative efficiency of graphic and non-graphic responses in a route-learning task.

One factor which is likely to influence the appropriateness of a response mode is the type of stimulus material experienced by the subject. It is possible that the production of a mapping response from a totally different type of stimulus will present an additional problem to the subject. Murphy and Atkinson (1982) found that subjects were generally able to derive a graphic response from a verbal stimulus description. However, subjects made more errors when recalling from the verbal stimulus condition than they did when both stimulus and response were in graphic form. Unfortunately, their design did not include a group who learned and recalled the verbal description of the display. It is therefore not known if this condition would have led to a higher score than the verbal stimulus-graphic response group. A number of earlier investigations found that subjects could use a variety of encoding strategies (visual, verbal, abstract-semantic) when learning visual or verbal material (e.g. Tversky, 1969; Frost, 1971). Also, the encoding strategy was found to be under subjective control to some extent, and could be manipulated by the demands of the experimental conditions (e.g. Tversky, 1969; Klatzky and Stoy, 1974, 1978).

Given that cognitive mapping studies often involve an elicitation task which uses a different mode to the learning experience (e.g. map-drawing from navigational experience or distance estimation from map-learned material), it is clearly important to assess the effect of stimulus-response compatibility upon performance. For this reason the route-learning task will include four conditions, as follows:-

1. verbal stimulus - verbal response;
2. graphic " - " "
3. verbal " - graphic "
4. graphic " - " "

Appropriate group comparisons will be made to determine the effect of stimulus mode, response mode and stimulus-response compatibility upon learning scores.

### Summary

In summary, the hypotheses to be tested by the present study are as follows:-

1. There will be a positive correlation between performance upon the spatial learning task and the following measures:-
  - (i) spatial relations scores (MPFB);
  - (ii) visual imagery scores (VVIQ);
  - (iii) frequency of / confidence in map use;
  - (iv) confidence in unfamiliar surroundings;
2. Scores on the 'Serialism-holism' questionnaire (where a high score indicates 'holism') will be positively correlated with performance in the 'map' learning conditions;
3. Overall levels of spatial learning will be greater for map stimuli than for equivalent list stimuli;

4. Map response conditions will be associated with higher scores than will list response conditions;
5. a) Cross-modal (stimulus → recall) conditions will exhibit lower recall scores than will corresponding same-mode conditions, i.e.
  - (i) list → list scores > list → map scores and
  - (ii) map → map scores > map → list scores;
- b) Any learning decrement shown in the cross-modal condition which demands a list response will be greater than any decrement shown in the cross-modal condition demanding a map response.

## 13.2 Method

### Subjects

A total of 64 undergraduates were tested; 50 in one test session and 14 in small groups. The design necessitated subjects being divided into four treatment groups, with equal numbers of males and females in each group. The groups were as follows:-

<u>Group</u>	<u>Stimulus Mode</u>	<u>Recall Mode</u>	<u>Number of Subjects</u>
LL	List	List	16
ML	Map	List	16
LM	List	Map	16
MM	Map	Map	16

### Materials (see Appendix 7)

Each subject was given an 11-page booklet containing all the appropriate learning materials (according to group membership), answer pages and questionnaires. Interleaved blank pages were used to ensure that subjects were only exposed to the stimulus materials for the requisite length of time.

The stimulus map was taken from Mutch (1980) and was known as the Killman-Kenealy Map (1979). The map represented a route and consisted of 20 distinct elements. The elements were of two types, either named locations (nodes, e.g. 'church', 'library') of which there were 11 or decision-point directions (links, e.g. 'left at ...', 'veer right ...') which led from one node to the next.

The stimulus list was a verbal equivalent to the stimulus map, containing the 20 elements embedded in a 19-point set of route instructions.

Practical considerations meant that only half the subjects could perform the spatial ability test at once, so the remainder of each booklet took one of two forms:-

1. <u>MPFB</u>	2. SHQ
SHQ	MUQ
MUQ	<u>VVIQ</u>
VVIQ	MPFB

Subjects were allowed 15 minutes to answer the first 48 items in the 'Minnesota Paper Form Board' Test (MPFB, Likert and Quasha, 1941). The final 16 items of the standard 64-item test were not used, in order to equate the time limit with that required to complete the three questionnaires. This enabled the two forms of test sequence to be run concurrently, with all subjects transferring to a new section at one point.

The 'Serialism-Holism' Questionnaire (SHQ, adapted from Mutch, 1980) was designed to assess the subjects customary method of tackling a variety of tasks.

The 'Map Use' Questionnaire (MUQ) was designed for the present study, to assess the subjects confidence and subjective ability in everyday navigational problems, both with and without maps.

The 'Vividness of Visual Imagery' Questionnaire (VVIQ, Marks, 1972) required 5-point ratings of the vividness of a variety of imagined scenes.

Procedure

Subjects were given the following instructions for the initial task:

"Describe how you would explain to someone who did not know the campus, how to get from this lecture theatre/laboratory/room [as appropriate] to the Students' Union. You may give your answer as written instructions, a sketch-map or a mixture of the two, whichever you prefer."

These instructions were printed on an overhead projector slide for presentation to the group of 50 subjects and were read aloud to the smaller groups. Subjects were given as long as was necessary to complete the task, up to a maximum of 5 minutes (no-one needed longer).

Following this, they were asked to read their task instructions and were given 5 minutes to learn the stimulus material. When they had turned the stimulus page out of sight, they were asked to carry out the recall instructions printed on the next page. A maximum of 5 minutes were allowed for the recall.

At this point the groups received different instructions. Groups LL and MM were given copies of the MPFB test papers and the general question format was explained to them. Groups ML and LM were told to fill in all the questionnaires in the booklet. After 15 minutes the two sets of instructions were interchanged.

Data Analysis (see Appendix 7)Map Recall

The number of correct nodes and links shown on each subject's map were assessed separately. A node was judged to be correct if it was accurately positioned in relation to the shape of the map and/or between the appropriate adjacent nodes. Also, the nodes had to have an unambiguous label (e.g. 'sports' was correct for 'sports ground' but a cross '+' symbol could have meant either a memorial or a church). Each subject was therefore given a 'node' score from a maximum of 11. A link was judged to be correct if it gave the correct directional change in relation to adjacent links. Where a turn was not a simple right-angle (acute or obtuse) and the subject had erroneously drawn it as such, a half-mark was allotted. The subjects 'link' score was therefore from a maximum of 9.

List Recall

Node and link scores were obtained from the list recall data in a similar fashion to the map recall data. One point on the 'node' scale was given for each unambiguous place label correctly positioned between adjacent nodes (and/or links). One point on the 'link' scale was given for each correctly described left or right turn. Half a point was given when an appropriate modifier (e.g. 'sharp left') was omitted.

MPFB Test

The standard scoring system for the MPFB was employed, with a correction for guessing. This permitted a maximum score of 48.



### 'Serialism-Holism' Questionnaire

The six questions were each of the form 'In situation A either X or Y is your typical behaviour'. A 'holism' score was obtained by allotting a score of 1 to the holist-type alternative in each question and a score of 0 to the serialist-type alternative. The six scores were summed for a subject, giving a maximum holism index of 6 and a minimum of 0 (equivalent to maximum serialism).

### 'Map Use' Questionnaire

No overall consistent scoring system could be devised for this questionnaire, since the items were so diverse in nature. However, as a general rule, a low score was given when the subject indicated high frequency or confidence in map use. Other questions, such as the items pertaining to verbal instructions or anxiety in new surroundings, did not easily fall into this pattern and an arbitrary system had to be adopted. This procedure was satisfactory, since the items were to be analysed separately, rather than being summed to give an overall index of map use. The initial task performed by subjects (campus directions) was labelled as question 11 of the map use questionnaire for the purpose of analysis. The individual item scoring system is listed in Appendix 7.

### 'Vividness of Visual Imagery' Questionnaire

Overall visual imagery scores were obtained by summing the individual subjective ratings for the 16 items. Since the rating system ranged from 1 for maximum vividness to 5 for minimum (i.e. no image at all), VVIQ scores could range from 16 for the person with the most vivid visual imagery to 80 for the person with no visual imagery.

### 13.3 Results

Separate analyses of the node and link data were performed for the spatial learning task. This was to highlight any differences between the two types of stimulus material in their sensitivity to particular task demands. The same analyses were performed on both sets of data. Mean scores were calculated for each of the conditions and three-way analyses of variance were performed to assess the significance of any mean differences.

#### Node Scores

Table 13.1 : Mean Number of Nodes Recalled (standard deviation in parentheses)

		RESPONSE MODE		
		LIST	MAP	
STIMULUS MODE	LIST	9.31 (1.74)	8.50 (2.10)	8.90
	MAP	9.88 (1.71)	10.38 (1.20)	10.13
		9.60	9.44	9.51

Table 13.2 : Summary Table of 3-Way ANOVA of Node Scores

<u>Source</u>	<u>d.f.</u>	<u>S.S.</u>	<u>V.E.</u>	<u>F.</u>	<u>p</u>
<u>Between Ss</u>					
Stimulus (A)	1	23.766	23.766	7.78	<0.01
Response (B)	1	0.391	0.391	<1	n.s.
Sex (C)	1	1.891	1.891	<1	n.s.
A x B	1	6.891	6.891	2.26	n.s.
A x C	1	0.016	0.016	<1	n.s.
B x C	1	3.516	3.516	1.15	n.s.
A x B x C	1				
Subjects within Gps	<u>56</u>	<u>171.125</u>	3.056		
TOTAL	63	207.984			

From Table 13.1, it can be seen that mean node scores were higher when a map stimulus was used than when a list stimulus was used. This difference was shown to be statistically significant (see Table 13.2). Table 13.2 indicates that response mode had no overall effect upon node scores. However, the mean node scores (see Table 13.1) indicated the existence of an interaction between response and stimulus modes. A map response to a map stimulus gave the highest node scores; a map response to a list stimulus gave the lowest node scores. This interaction was shown to be statistically nonsignificant (see Table 13.2).

Examinations of the standard deviations of the node scores in the four conditions showed that there was a reduced level of variance in the map stimulus-map response condition. The mean node score in this group (10.38; maximum 11) indicated that the reduced variance was the result of a 'ceiling effect'. The reduction in variance would jeopardise the validity of any correlations calculated between the MM node scores and other variables.

### Link Scores

Table 13.3 : Mean Number of Links Recalled (standard deviation in parentheses)

		RESPONSE MODE		
		LIST	MAP	
STIMULUS MODE	LIST	6.25 (1.92)	6.00 (2.03)	6.12
	MAP	6.38 (1.63)	8.47 (1.07)	7.42
		6.32	7.24	6.78

Table 13.4 : Summary Table of 3-Way ANOVA of Link Scores

<u>Source</u>	<u>d.f.</u>	<u>S.S.</u>	<u>V.E.</u>	<u>F.</u>	<u>p</u>
<u>Between Ss</u>					
Stimulus (A)	1	26.910	26.910	8.75	<0.01
Response (B)	1	13.600	13.600	4.42	<0.05
Sex (C)	1	0.100	0.100	<1	n.s.
A x B	1	21.970	21.970	7.16	<0.01
A x C	1	0.000	0.000	<1	n.s.
B x C	1	2.070	2.070	<1	n.s.
A x B x C	1	0.035	0.035	<1	n.s.
Subjects within Gps	<u>56</u>	<u>172.281</u>	3.076		
	63	236.965			

Table 13.3 shows that mean link scores were higher when a map stimulus was used than when subjects were given a list. Additionally, the mean link score was higher when subjects recalled the material in the form of a map than when a list was required. A three-way analysis of variance (see Table 13.4) showed that the effects of stimulus and response modes were statistically significant. However, the ANOVA indicated that there was a significant interaction between stimulus and response modes. The interaction can be interpreted by reference to the mean link scores shown in Table 13.3. The mean link score for the map stimulus-map response group was much higher than for the other three conditions, which yielded similar mean scores. This implies that the superiority of a map stimulus only occurred when a map response was required; if a list response was used, the performance level fell to that of the list stimulus conditions. The pattern of the interaction was the same as that which was found (though non-significantly) in the node scores. The highest scores were found with a map response to a map stimulus and the lowest scores with a map response to list stimulus.

The list response conditions were between these extremes. A specific comparison of the LL and MM groups proved to be highly significant ( $F = 12.8, p < 0.01, d.f. = 1, 56$ ).

As in the node scores, the MM group showed a reduced variance compared to the other three groups, associated with a high mean score (8.47; maximum 9.0). Again, this 'ceiling effect' would affect the validity of correlation coefficients between the relevant node scores and other variables.

#### Relationship Between Spatial Learning Scores and Other Measures of Spatial Ability

It was hypothesized that there would be a positive correlation between scores on the spatial learning task and each of a number of spatial ability indices, both objective and self-rated. For this reason, each subject completed a shortened form of the MPFB test, the VVIQ and two questionnaires wherein subjects rated their spatial behaviour and ability (see 'Method' section). One questionnaire referred to customary styles of solving everyday problems and the other to general map usage and travel behaviour.

#### Minnesota Paper Form Board Test

The mean score obtained on this test was 37.812 with a standard deviation of 7.248. Since the maximum possible score was 48, this indicated that the distribution was slightly skewed, many subjects gaining their maximum marks.

The relationship between MPFB scores and spatial learning scores was assessed by calculating Pearson correlation coefficients between the two scores. This was done for node and link scores, both within test conditions and over all conditions (using within group residuals).

Table 13.5 : Pearson Correlation Coefficients between Spatial Learning Scores and MPFB Scores

a) <u>Nodes</u> N = 16 within cells		Response Mode		<u>Within Group Residual</u> (N = 64)
		List	Map	
Stimulus Mode	List	0.202	0.283	0.339*
	Map	0.510*	0.458*	

\* p<0.05,  
1-tailed.

b) <u>Links</u>		Response Mode		<u>Within Group Residual</u> (N = 64)
		List	Map	
Stimulus Mode	List	0.083	-0.039	0.124
	Map	0.326	0.130	

As can be seen from Table 13.5, there was a significant positive correlation ( $p < 0.05$ ) between the MPFB scores and the node scores in each of the map stimulus conditions, but not in the list stimulus conditions. The within condition residual was significantly correlated with MPFB scores for nodes only. None of the conditions yielded significant correlations between link scores and MPFB scores.

#### 'Vividness of Visual Imagery' Questionnaire

The mean score obtained from the VVIQ was 36.844 with a standard deviation of 9.360. Since it was possible that the VVIQ was measuring a similar ability to the MPFB, a Pearson correlation coefficient was calculated between the two. This indicated that they were relatively independent measures ( $r = -0.196$ ,  $N = 64$ ,  $p = 0.061$ ). Pearson correlation coefficients were therefore calculated between VVIQ scores and spatial learning scores, in the same manner as the MPFB scores.

Table 13.6 : Pearson Correlation Coefficients between Spatial Learning Scores and VVIQ Scores

a) <u>Nodes</u>		Response Mode		<u>Within Group Residuals</u> (N = 64)
		List	Map	
Stimulus Mode	List	-0.361	0.059	= -0.149
	Map	-0.053	-0.574**	

\*\* p<0.01,  
1-tailed

b) <u>Links</u>		Response Mode		<u>Within Group Residuals</u> (N = 64)
		List	Map	
Stimulus Mode	List	-0.446*	-0.116	= -0.199
	Map	-0.192	-0.250	

\* p<0.05,  
1-tailed

In order to interpret the correlations between spatial learning scores and the vividness of visual imagery, it is necessary to recall that a high score on the VVIQ indicates low visual imagery. Hence a strong positive correlation between the two scores would be signified by a high negative coefficient. No overall relationship was found, across the four conditions, for nodes or links (i.e. within condition residuals were not significantly correlated with VVIQ). As shown in Table 13.6, coefficients were generally negative, indicating positive relationships between spatial learning and VVIQ scores. Only two of the conditions yielded statistically significant correlations between VVIQ and spatial learning, these being node scores in the map stimulus-map response condition ( $p < 0.01$ ) and link scores in the list stimulus-list response group ( $p < 0.05$ ).

### 'Serialism-Holism' Questionnaire

The 'serialism-holism' questionnaire was first analysed by means of a Principal Components Analysis which yielded three main factors. The three factors which loaded most highly on each of these factors were then correlated with node and link scores, within test conditions. However, this analysis did not yield any meaningful results, so the details will not be reported further.

### 'Map Use' Questionnaire

Examination of the 'map use' questionnaire items, together with a Principal Components Analysis of the data lead to the identification of three main factors:- MUQ1, MUQ2 and MUQ3.

MUQ1 was produced from items 1, 4, 6, 7, 8 and 9 (see Appendix 7) and referred to a subject's self-rated ability at everyday orientational tasks;

MUQ2 was produced from items 2 and 11 and referred to the tendency of a subject to use a map;

MUQ3 was produced from items 3, 5 and 10 and referred to a subject's anxiety in new surroundings.

Correlational analysis was then performed in order to assess the relationship between scores on the spatial learning task and these three MUQ factors. The correlation coefficients are shown in Table 13.7.



Table 13.7 : Pearson Correlation Coefficients between Spatial Learning Scores and MUQ factors

MUQ2	MUQ3	NODES <sup>†</sup>	LINKS <sup>†</sup>	
-0.0417	-0.2092	-0.1435	-0.3312*	MUQ1
	-0.0382	0.0060	-0.0836	MUQ2
		0.2270*	0.2182*	MUQ3
			0.5210*	NODES <sup>†</sup>

\*  $p < 0.05$ , 1-tailed

† Within group residuals,  $N = 64$

Before interpreting the correlation coefficients in Table 13.7, it is necessary to note that a high score on MUQ1 is indicative of low confidence, whereas high scores on MUQ2 and MUQ3 are indicative of high map use and lack of anxiety respectively.

It can be seen that the correlation between MUQ1 and link scores ( $r = -0.3312$ ,  $p < 0.05$ , 1-tailed) confirmed the hypothesized relationship between self-rated ability to perform orientational tasks and objective recall of spatial information. However, no such relationship was found between self-rated ability and the recall of item names in a spatial array ( $r = -0.1435$ ,  $p > 0.05$ ). No significant correlation coefficients were found between MUQ2 and node or link scores; indicating that this index of map use was not related to objective spatial learning performance.

Significant correlation coefficients were obtained between MUQ3 and node scores ( $r = 0.2270$ ,  $p < 0.05$ , 1-tailed) and between MUQ3 and link scores ( $r = 0.2182$ ,  $p < 0.05$ , 1-tailed). These showed that self-rated ability to cope with novel surroundings was related to objective performance on an artificial map-learning task, as measured by place-name recall and recall of spatial inter-relationships.

## 13.4 Discussion

### Spatial Learning Task

The results of the spatial learning task provided varying degrees of support for the experimental hypotheses. The map stimulus was found to be associated with significantly greater spatial learning than was the list stimulus, whether node or link scores were used as an index of learning. This provided evidence for the superiority of a graphic display as a means of presenting spatial information which has to be learned. As mentioned earlier, Murphy & Hutchinson (1982) concluded from their study that the superiority of a graphic display was due to the ability of subjects to use the Gestalt properties of the stimulus as recall aids. Some indication of the importance of this factor in the present study may be gleaned from the recall data in the map stimulus-list response condition. Five of the sixteen subjects in the group drew the graphic display on some part of their recall page, in addition to listing the route details. It seems reasonable to assume that they drew the shape of the route before listing the details, though no evidence is available to support this assumption. If this were the case, subjects would only need to recall the direction of movement (in addition to the 'shape' of the route) in order to enable them to derive the links. It is possible that the remaining subjects were performing an equivalent cognitive operation on an internal representation of the route display.

The overall effect of response mode upon recall efficiency was less clear than that of stimulus mode. The node scores showed no difference between list and map forms of response. The link scores did show such a difference but the effect interacted with stimulus mode. The mapping response was only associated with a high level of performance in the map stimulus conditions; indicating that stimulus-response compatibility

was important, rather than response mode per se. It had been hypothesized that cross-modal conditions would be associated with lower scores than corresponding same mode conditions: this was confirmed with map stimulus groups but not with list stimulus groups. In other words, the need to recall map-learned material in the form of a list adversely affected performance but the need to recall list-learned material in the form of a map had no such effect. This confirmed the hypothesis concerning the asymmetric nature of performance decrements in cross-modal conditions. It had been expected that converting spatial information into a graphic form would not be as difficult as converting it into a verbal form. The essentially two-dimensional nature of a graphic display lends itself to the presentation of spatial information.

The fact that the node scores did not produce the expected pattern of interaction requires some explanation. One possibility is that since nodes are less 'spatial' than links, they are less likely to be affected by the need to convert them from one mode to another. As was discussed in Experiment IIa, evidence has accumulated that verbal items are more easily recalled when they are embedded in a map-like structure at the learning stage (e.g. Reynolds, 1966, 1968). Such a principle lies behind the efficacy of the 'Method of Loci' mnemonic system (see Yates, 1966). It is also reflected in the superiority of the map stimulus conditions to the list stimulus conditions. However, unlike links, nodes would not need to be converted to a radically different form in the cross-modal conditions; they would remain as verbal labels in a fixed sequence. Cross-modal conditions would therefore not have such a detrimental effect upon node scores as upon link scores.

One problem with the interpretation of the spatial learning task was the existence of a 'ceiling effect' in some of the conditions. The complexity of the stimulus material was such that many subjects were

is presented visually, the easiest learning method may be to learn the 'shape' of the route and then learn the items at each point along it. The utility of this method is shown by it being the basis of mnemonic devices (see discussion in previous section). It follows that individuals who are more adept at encoding spatial information ('shape') will have more time to learn the nodes and will have a more reliable mnemonic base on which to 'peg' the verbal information. Thus it seems that superior spatial memory may be reflected in enhanced node scores.

Support for this possibility is provided by the MPFB-node score correlations within the four experimental conditions. Node scores were significantly related to MPFB scores in the conditions where the spatial links were displayed visually, but not when they were verbally described.

Despite the tentative explanation given above, it must be recalled that 'ceiling effects' existed in several of the sets of scores obtained in this experiment. That is, many subjects scored very highly on the spatial learning task, particularly in the map stimulus-map response category. Additionally, the overall distribution of MPFB scores was skewed slightly towards the high scores. This situation could have obscured the nature of the genuine correlation between spatial learning scores and MPFB scores. It is not possible to speculate what degree of correlation would exist between less restricted scales. Permitting a wider range of scores at the top end of each scale could have led to higher correlation coefficients; confirming that there existed a strong relationship between spatial learning and spatial relations ability (as measured by the MPFB). On the other hand, increasing the range of high scores might lead to a very low correlation. That is, at the lower end of both scales, the two measures would be highly correlated, but above a certain cut-off point, there would be no relationship between the two. This would be interpreted as meaning that a minimum level of spatial

able to recall either all the nodes or all the links (or all of both) in certain conditions. Fortunately, examination of the mean scores indicates that eradication of the ceiling effect, by means of increasing the stimulus complexity, would serve to exaggerate the effects which have been found, rather than altering their direction. The only condition leading to a ceiling effect upon the link scores was the map stimulus-map response group, so that the asymmetric interaction between stimulus and response conditions would have increased if that group's scores had been higher. Similarly, both the map stimulus groups had mean node scores approaching the maximum, so that increasing their potential values would have increased the stimulus mode effect.

The Relationship between Spatial Learning and other Measures of Spatial Ability.

Minnesota Paper Form Board Test

A positive correlation was hypothesized between scores on the MPFB, which is a standard test of spatial relations ability, and scores on the spatial learning task which was employed in the present study. When the effects due to stimulus and response conditions were eliminated (by using 'within-group residuals'), the node scores confirmed the hypothesized relationship. In contrast, the residual link scores were not significantly related to MPFB scores. Since the links are essentially spatial in nature but the nodes are not, the reverse situation might have been anticipated; that is, link scores being correlated with MPFB, but not node scores. In order to attempt to explain this anomaly, it is necessary to consider the nature of the spatial learning task in more detail. The information which had to be learned by the subjects consisted of a series of verbal tags connected by spatial links. When this material

relations ability is needed to perform the spatial learning task adequately, but beyond that point, it has no effect upon performance levels.

The actual relationship between MPFB scores and spatial learning ability would therefore be clarified by increasing the range of scores on both scales. In the case of the spatial learning task, this could be achieved by either increasing the complexity of the learning material or by reducing the time allowed. The skewed distribution of the MPFB scale was probably a result of shortening the test length and the time allowed for completion in the same proportion, when the items were progressively more difficult. Also, the subjects were of above-average intellectual ability. Hence, either the full test should be used or the subject group should be changed.

#### 'Vividness of Visual Imagery' Questionnaire

This questionnaire is a measure of the degree to which a person can experience a strong 'mental picture' of a scene or object. For this reason it was thought likely that scores on the VVIQ would relate to performance on the spatial learning task; particularly when the material was presented in a visual form. No evidence for a VVIQ-spatial learning relationship was found across the subject group as a whole. However, within the 'same-mode' conditions, certain relationships were found. In the map-map condition, node scores were significantly correlated with VVIQ. A similar relationship between link scores and VVIQ may have been obscured by a strong 'ceiling effect' in that condition (in the link scores). In the list-list condition (where no 'ceiling effects' were obtained), the link scores were significantly related to VVIQ and the node scores showed a non-significant tendency towards such a relationship.

Together, these findings imply that visual imagery ability is important for the recall of both visually-presented material and verbal material describing essentially spatial information. This supports the work of cognitive psychologists which was reviewed earlier (see section 13.1). The fact that link scores were strongly related to visual imagery than were node scores also follows from previous research. That is, Paivio (1968; see section 13.1) concluded that the effectiveness of visual imagery would depend upon the ease with which material could be characterized visually. It is clear that links are suitable for visual recall (at least when connected into an overall route 'shape'). It is also possible that the choice of nodes for the present study (e.g. 'pub', 'church', 'school') may have allowed subjects to use strong visual images to aid their recall. This possibility could be tested by comparing the correlations of the present study with those of a similar task, using abstract verbal items as nodes, e.g. nonsense syllables.

The essential difference between tests of 'static' visual imagery and of the ability to manipulate images has been discussed in Chapter 10. Since the VVIQ is a measure of 'static' visual imagery, it may only be important when material has to be recalled in the same form as it was learned. This was the case with the study by Thorndyke and Stasz (1980) who found that visual memory ability was an important component of map-learning ability (see also section 13.1 and Chapter 10). If the learning task demanded more complex cognitive manipulations, the importance of simple visual imagery might be lessened (as in Murray and Spencer, 1979; see Chapter 10). The difference between the correlation coefficients in the 'same-mode' and the 'cross-mode' conditions in the present study support this view. The 'same-mode' conditions yielded the high coefficients described above whereas the cross-modal conditions produced uniformly low correlations between the spatial learning scores and the VVIQ.

### 'Map Use' Questionnaire

It was hypothesized that scores on the spatial learning task would relate to subjective efficiency at using maps and self-rated anxiety in novel surroundings. These hypotheses were tested by assessing the degree of correlation between spatial learning scores and responses to the 'map use' questionnaire. The pattern of responses revealed three main factors in the questionnaire, corresponding to subjective confidence in map use, frequency of map use and anxiety in new surroundings. Correlational analysis confirmed that subjects who performed best on the spatial learning task also had most confidence about everyday mapping tasks and were least anxious when in novel surroundings. These findings confirm the results of studies by Beck and Wood (1976) and Kozlowski and Bryant (1977), which were discussed earlier (see section 13.1).

One 'map use' questionnaire factor was not significantly correlated with any of the other measures in the study. However, this seems likely to be a result of it being an inadequate index of what it was first thought to measure; that is, 'tendency to make use of a map'. The factor was derived from the responses to two questions. One of these asked if being allowed to draw a map would facilitate giving verbal directions. The other one asked for directions to a location (well-known to all subjects) and noted whether subjects chose to draw a map. It is possible that an adequate index of everyday map use would require more extensive questions; assessing the subjects' everyday use of printed maps, in the way that previous researchers did. This being so, the present non-significant finding cannot be said to provide sufficient grounds for rejecting the hypothesis that frequency of map use relates to performance on spatial learning tasks.

Unlike Beck and Wood (1976) and Kozlowski and Bryant (1977), the present study used an artificial map-learning task to assess objective



ability. The reasons for this choice were outlined earlier (see 'Introduction'). The artificial task was judged to be an ecologically-valid aspect of cognitive mapping. Despite this, it would be useful to know if performance on this task was related to cognitive mapping tests of 'real-life' knowledge, as used by previous researchers.

### 13.5 Conclusions

#### The Relationship Between Spatial Learning and Other Measures of Spatial Ability

The present study provided tentative evidence for the existence of a positive relationship between spatial learning ability and specific ability to manipulate cognitive images. It was found that self-rated visual imagery ability was positively related to spatial learning when the recall mode was the same as the stimulus mode. Performance on the spatial learning task was also found to be positively related to self-rated efficiency at orientational tasks and confidence in unfamiliar surroundings.

#### The Effects of Stimulus and Response Modes

The results of the present study revealed that better route learning occurred when stimulus material was presented in map form than when an equivalent verbal list was used. No such overall difference was found between map and list recall modes. The effects of stimulus and response modes were found to interact. The superiority of a map stimulus was only apparent when a map response was required: if a list response was demanded, performance was equivalent to that in list stimulus conditions.

#### General Methodology

The spatial learning task used in the present study was apparently too simple for the subject group tested: future research should therefore increase the stimulus complexity or reduce the permitted learning time. The full MPFB test should also be employed in future research, since the present shortened version led to an unwanted 'ceiling effect' in the scores. It is necessary to discover if performance on artificial spatial learning tasks is directly related to 'real-life' cognitive mapping performance.

Chapter 14Experiment IVThe Relationship between Spatial Ability,  
Artificial Spatial Learning and  
'Real-life' Cognitive MappingSpring 198214.1 Introduction

This experiment was designed to answer several questions raised by Experiments II and III. The questions concerned the relationship between a test of spatial relations ability, an artificial map-learning task and a cognitive mapping task measuring actual spatial knowledge. In addition, it was sought to verify conclusions formed after a previous study which used the cognitive mapping task.

Adaptation of Experiment III

One of the aims of Experiment III had been to measure the correlation between performance on a spatial learning task and spatial relations ability, as measured by the Minnesota Paper Form Board Test (Likert and Quasha, 1941). However, problems arose with the interpretation of the correlations so obtained. It transpired that a 'ceiling effect' occurred in both the MPFB scores and some of the spatial learning scores, limiting the variance in both sets of data and hence restricting the correlation coefficients. The situation occurred with the MPFB test because practical considerations had led to only a subsection of the test items being used. The time limit was reduced by a quarter and the last quarter of the test items were omitted. Unfortunately, the fact that the questions were progressive in nature, combined with the high calibre of subjects, produced a truncated range of scores. Many subjects achieved maximum

or at least very high scores. It was therefore necessary to repeat the study using the complete MPFB test, so as to assess the complete range of spatial relations ability in the subject group.

Experiment III had utilised the spatial learning task in four different forms, employing combinations of map or list stimuli and map or list recall demands. The route details in the map and the list stimuli were equivalent, but the map had the advantage of providing subjects with a visual 'Gestalt' to aid their recall. This resulted in subjects gaining generally very high scores in the map stimulus conditions, at least when a straightforward graphic recall was required. The condition in which subjects had to transform the material, by recalling it in the form of a verbal string of route details, produced lower scores. This was most noticeable for the 'link' scores (the route details between landmarks) where no 'ceiling effect' occurred, but did not affect the 'node' scores (the landmarks) in the same way. Even so, for the purposes of the present study, it was thought desirable to avoid these complications, by having all subjects do the 'map stimulus-map response' condition. However, this was the condition which produced the most severe ceiling effects in both node and link scores, so the stimulus materials had to be made more complex. A similar map to the one used in Experiment III was designed, except that the number of nodes and links were increased to 16 and 15 respectively. This was tested on a pilot group of 7 subjects for a 3-minute learning period. One subject succeeded in recalling the full details of the map. Also, some of the subjects commented that the general direction of travel (south-west to north-east) disrupted their learning attempts. Therefore, a final map was designed, with 18 nodes and 17 links, the route beginning at the top of the stimulus page and progressing downwards.

## Artificial and 'Real-life' Cognitive Mapping Tasks

Evidence reviewed in Experiment III (e.g. Beck and Wood, 1976; Thorndyke and Stasz, 1980) suggested that there is a direct relationship between people's performance on contrived laboratory tests of spatial learning and their ability to cope with everyday navigational problems. In addition, Kozlowski and Bryant (1977) found that there was a positive relationship between performance on cognitive mapping tasks, which tested knowledge of a real environment and personal ratings of ability in everyday orientation tasks. From these, the question emerges as to whether performance on artificial spatial learning tasks relates to that on cognitive mapping tasks, testing actual knowledge of a real environment. Accordingly, a test of 'real-world' environmental knowledge was incorporated into the present study. Since the available subject pool had appropriate environmental experience, the cognitive mapping task from Experiment II was utilised.

### Follow-up to Experiment II

Experiment II had examined the microgenetic changes which took place in subjects' ability to produce a structured plan of an environment with which they were becoming familiar. Objective positional accuracy (inversely related to 'error scores'), subjective assessment of accuracy ('confidence ratings') and recall sequences were measured. Four separate groups were tested; after two, four and six days and ten weeks of experience in an initially novel environment. All subjects had been asked to use a standard set of buildings in their plans, which were drawn onto an objective base-map. These buildings had been chosen on the basis of a 'free-recall' study (Experiment I) of the same topographical area. It was hypothesized on the basis of Experiment I that the buildings could be divided into two categories of eight buildings; the

members of one of these categories being generally more accurately and confidently placed than the members of the second. In addition, the buildings in the best-known categories would be generally drawn prior to those in the second categories when a free order of recall was permitted. These results were confirmed by Experiment II and the present study attempted to replicate these findings with a new group of subjects.

One of the aims of Experiment II had been to show that there was a significant increase in accuracy over the ten-week period of the study, with a substantial proportion of this increase occurring in the first week of environmental experience. This was confirmed for the 'well-known' category of buildings; the accuracy with which they were represented was assumed to be reaching an asymptotic level by week 10. A much larger proportion of the increase in accuracy of 'less well-known' building representation occurred after the first week of environmental experience. It was therefore not known if this trend towards increased accuracy in representation of building position would have continued after the final week 10 task completion. Experiment IV therefore provided an opportunity to assess whether the accuracy found after ten weeks represented an ultimate, stable level of performance or if further improvement may have occurred. Subjects in the present study had approximately twenty weeks experience of the relevant environment at the time of Experiment IV. Their behavioural objectives while in the area and their overall spatial activity patterns were also likely to have been very similar to the groups of subjects tested in Experiment II.

Summary

In summary, the aims of Experiment IV were two-fold:

- 1) to assess the correlations between performance upon three different spatial-oriented tests; these being
  - i. spatial relations ability (MPFB test),
  - ii. a spatial learning task
  - and iii. a 'cognitive mapping' test of actual knowledge;
- 2) to verify the findings of Experiment II in relation to differential learning patterns and asymptotic levels of accuracy and confidence.

## 14.2 Method

### Subjects

The subjects consisted of 6 male and 10 female first-year university undergraduates. All subjects had spent two terms (20 weeks) 'on campus' and none had completed any of the three experimental tasks prior to taking part in the present study.

### Materials (see Appendix 8)

Each subject received a five-page answer booklet containing a stimulus map for the spatial learning task, a blank map recall page, an MPFB answer sheet, a cognitive mapping task instruction page and a base-map.

### Stimulus Map

As described in section 14.1, the stimulus map for the spatial learning task consisted of a route map containing 18 nodes and 17 links. The nodes were 18 different verbal labels, naming typical town-map elements (e.g. 'Infirmary', 'school', 'Hotel'). The position of each node was marked by a small square. Each link was represented by a straight line, with all the turns being right-angles. Arrows marked the direction of travel and the 'start' and 'finish' nodes were also labelled.

### Cognitive Mapping Task Instructions

Apart from a few minor alterations to the instructions, the task requirements were the same as those used in Experiment II. The base-map (with superimposed grid), buildings list and associated confidence scales and spaces for numbering the recall sequence were all identical



to those used in Experiment II. As in the latter study, half the subjects had the buildings list in alphabetical order and half in reverse alphabetical order, to counter-balance any effect of presented order upon recall order. The instructions were almost the same, except that additional emphasis was put upon the demand that subjects should attempt to draw every building from the list on the base-map. Data analysis had been complicated in Experiment II by several subjects omitting buildings which they did not know. It was made explicit in the present instructions that a guess could be indicated by marking the 'Low' end of the 'confidence scale'. In addition, subjects were requested to number both the list of buildings and the map elements with their own recall order. This was to ensure that the identity of drawn buildings could be ascertained in all cases.

### Procedure

All subjects were tested in one group and followed the same procedure. The map-learning task was done first, with subjects being given three minutes to learn the route details. Immediately after the learning period, subjects were asked to perform some arithmetic calculations which were written on a blackboard. They were asked to write the solutions on a corner of their recall page until 30 seconds had been allowed; at which point they could begin to recall the map. This procedure was to eliminate any short-term retention of map details. Subjects were given as long as was necessary to recall the map, which was never more than 5 minutes.

The MPFB test was completed after the map-learning task. Subjects were given the standard 20 minutes to try to answer all 64 items.

The cognitive mapping task was performed last, with the experimenter making sure that all the subjects fully understood the task instructions prior to beginning the 15-minute completion period.



## 14.3 Results

The Relationship Between Cognitive Mapping, Spatial Learning and  
Spatial Relations Ability

The extent to which scores on the cognitive mapping task, the spatial learning task and the MPFB test were correlated was assessed by computing Pearson correlation coefficients between the seven performance measures (see Table 14.1).

Table 14.1 : Pearson Correlation Coefficients between Cognitive Mapping  
Scores, Spatial Learning Scores and MPFB Scores

Confidence Rating Bldg Category II	Error Score Bldg Category I	Error Score Bldg Category II	MPFB	Nodes	Links	
0.006	-0.049	0.262	0.513*	0.628**	0.021	Confidence Rating Bldg Category I
	-0.221	-0.564*	0.016	0.013	-0.053	Confidence Rating Bldg Category II
		0.617**	-0.513*	-0.146	-0.454*	Error Score Bldg Category I
			-0.160	0.190	-0.288	Error Score Bldg Category II
				0.468*	0.038	MPFB
					0.022	Nodes

\*  $p < 0.05$ , 1-tailed

\*\*  $p < 0.01$ , 1-tailed

Scores on the MPFB test were found to be significantly correlated with both subjective (confidence rating  $r = 0.513$ ,  $p < 0.05$ ) and objective (error scores  $r = -0.513$ ,  $p < 0.05$ ) measures of accuracy at positioning Category I buildings. MPFB scores were also found to be significantly correlated with node scores on the spatial learning task ( $r = 0.468$ ,  $p < 0.05$ ). Node scores were found to be significantly correlated with subjective (confidence rating  $r = 0.628$ ,  $p < 0.01$ ) but not with objective (error scores  $r = -0.146$ ,  $p > 0.05$ ) measures of accuracy at positioning Category I buildings.

Link scores on the spatial learning task were found to correlate with only one other measure, this being objective accuracy (error scores  $r = -0.454$ ,  $p < 0.05$ ) for positioning Category I buildings. Unfortunately, a noticeable 'ceiling effect' occurred in the link scores (maximum score = 17, mean = 14.6875, s.d. = 3.3807) which jeopardises the validity of the correlations between link scores and other measures.

In addition to the between-test results, two significant correlations occurred within the cognitive mapping task. Error scores for Category I buildings and for Category II buildings were found to be correlated ( $r = 0.6165$ ,  $p < 0.01$ ). The confidence ratings for the two categories of buildings were not correlated. Within Category II buildings, confidence ratings and error scores were significantly correlated ( $r = -0.5636$ ,  $p < 0.05$ ), but not within Category I buildings.

#### Cognitive Mapping Task: A Comparison of Experiments IIa and IV

Mean cognitive mapping scores were obtained from the data collected in the present study. These consisted of error scores, confidence ratings and recall orders. Two of each of these mean scores were calculated; one for each of the two building categories which were defined in Experiment IIa. These results were then compared with those obtained in

Experiment IIa, in order to determine if a stable level of performance had been reached by the end of the latter experiment (see also Chapter 12). Both sets of results are presented in Tables 14.2 a), b) and c). It can be seen that the results of the present study confirm that a stable level of cognitive mapping performance had been achieved by the end of Experiment IIa. That is, subjects who had approximately 20 weeks experience of an area did not perform the cognitive mapping task in a different way to those who had approximately 10 weeks experience.

Table 14.2 a) : Mean Error Scores for Building Categories I and II

Experiment		IIa				IV
Time spent 'on campus'		2 days	4 days	6 days	10 weeks	20 weeks
Mean Error Scores	Building Category I	4.443	4.327	3.366	2.210	2.045
	Building Category II	7.592	7.334	6.432	4.299	4.720

Table 14.2 b) : Mean Confidence Ratings for Building Categories I and II

Experiment		IIa				IV
Time spent 'on campus'		2 days	4 days	6 days	10 weeks	20 weeks
Mean Confidence Ratings	Building Category I	3.609	3.566	3.947	4.090	3.855
	Building Category II	2.083	1.694	1.826	2.591	2.244

Table 14.2 c) : Mean Recall Orders for Building Categories I and II

Experiment		IIa				IV
Time spent 'on campus'		2 days	4 days	6 days	10 weeks	20 weeks
Mean Recall Orders	Building Category I	6.000	5.988	5.388	6.106	5.383
	Building Category II	11.000	11.012	11.612	10.894	11.617

The level of consistency between subjects in their choice of recall order was assessed by calculating a Kendall's coefficient of concordance for the present study. This proved to be highly significant ( $W = 0.5276$ ,  $X^2 = 126.6$ , d.f. = 15,  $p < 0.001$ ) indicating that subjects were following a common sequence in recalling the building positions.

#### 14.4 Discussion

##### The Relationship between Cognitive Mapping, Spatial Learning and Spatial Relations Ability

The present study was designed to assess whether or not performance in a test of 'real-life' cognitive mapping was related to performance in artificial tests of spatial ability. Spatial ability was measured by a map-learning task and a standard test of spatial relations ability (the MPFB test; see 'Method'). Several statistically significant correlations were found between performance indices on these tests.

##### (i) MPFB and Cognitive Mapping

It was found that performance upon the MPFB was positively related to levels of objective accuracy (negatively related to error measures) and subjective confidence in positioning 'well-known' (Category I) buildings on the cognitive mapping task. This finding confirms the suggestion made in Experiment I (Chapter 11) that if the problem of scaling a graphic representation could be alleviated, then spatial relations ability would be found to correlate with mapping accuracy.

A major problem in the interpretation of this correlation was described in Chapter 13. Briefly, the superior mapping of the high spatial ability subjects might be the result of greater environmental experience, precipitated by a positive attitude to everyday spatial tasks. To some extent, this possibility must be considered; at least in terms of the tendency to explore different paths through the relevant area. However, it should be noted that the spatial experience of the present sample with regard to Category I buildings was largely controlled by factors external to the subjects themselves. That is, all subjects had the same length of experience in the area and during that time, their use of Category I buildings would have been necessarily very similar.

So it is probable that any gross differences in cognitive mapping performance were dependent not upon the experience which subjects had of the environment, but upon the information which they had acquired and organised during that experience.

It may seem that the results for Category II buildings refute an hypothesis made in the discussion of Experiment I (Chapter 11). It was suggested that the use of a 'forced recall' design (necessitating position recall across the full range of building knowledge, rather than allowing a subject to include only buildings of which he is very confident) would increase the likelihood of a correlation being found between spatial relations ability and mapping accuracy. In this experiment it was found that low-level knowledge was not related to performance on the spatial relations test. A possible reason for this anomaly can be found by analysing the intended meaning of 'low-level building knowledge'. This refers to incidental knowledge which people might have of rarely-used buildings. If comparisons are to be made between subjects regarding this type of knowledge (as in the MPFB-error score correlation), it is clear that the level of experience ought to be equalised between subjects. That is, in a natural learning situation, particular subjects may have had cause to learn the position of a building which is generally unknown to the rest of the group. Such irregular background experience could confound any pattern of correlation which might otherwise appear between mapping accuracy and specific cognitive abilities.

In the present study, the buildings in Category II are generally representative of low-level knowledge. Overall comparisons between the two building categories revealed highly significant learning differences. However, it is likely that the imposition of this standard categorisation will have meant that some subjects had more experience of particular



Category II buildings than had others. The lack of correlation between mapping accuracy and spatial relations ability may therefore reflect an inadequate definition of 'low-level knowledge' in the present study.

(ii) MPPFB and Spatial Learning

The present study revealed a statistically significant positive correlation between MPPFB scores and node scores on the spatial learning task but no such correlation between MPPFB and link scores. These results are equivalent to those found in the 'map stimulus-map response' condition in Experiment III (Chapter 13).

The present study was carried out to discover the relationship between MPPFB scores and spatial learning scores when the 'ceiling effects' found in Experiment II were eliminated. The use of a more complex map stimulus than in Experiment III prevented the appearance of a 'ceiling effect' in the node scores but not in the link scores. This supports the idea that node learning performance was dependent upon the speed and efficiency with which the link structure was learned. The latter would then have formed a basis on which to learn the nodes; in the manner of the 'Method of Loci' mnemonic device (see also Chapter 13). If this was the case, then the use of a more complex map would produce a reduction in mean node recall while maintaining the high link recall scores.

It therefore seems that specific spatial relations ability and the ability to memorise a route map are related. This finding is somewhat surprising in that the spatial learning task did not involve any spatial manipulation; the material being recalled in the same form that it was presented. A positive correlation with static visual imagery ability would have been understandable; as was found in Experiment III and the study by Thorndyke and Stasz (1980). However, the fact that spatial

relations ability and spatial learning performance were related implies that there is a factor common to both, possibly concerning the quality of spatial memory traces or the efficiency with which 'control processes' operate when performing spatial tasks (as discussed by Baddeley, 1976; see also Chapter 10).

(iii) Spatial Learning and Cognitive Mapping

The coefficients calculated between the spatial learning task and the cognitive mapping task showed that there were two significant correlations concerning Category I buildings. Node scores were related to confidence ratings for the 'well-known' buildings and link scores were related to the objective accuracy (error scores) with which these were positioned. It therefore seems that there is some evidence that performance upon contrived laboratory tests of spatial learning is related to the efficiency with which people perform tasks that are designed to indicate their spatial knowledge of a real environment.

Several points need to be made about the correlation coefficients which were obtained. As noted earlier, the link scores were subject to a 'ceiling effect', so the results which were obtained must be treated with caution. It is possible that if the range of the link scores had been extended, they may have been found to correlate with subjective (confidence ratings) as well as objective accuracy. Indeed, link scores may also have correlated with the accuracy measures for Category II buildings. However, the spatial relations ability (MPFB) - cognitive mapping correlations showed that the superior performance of 'high ability' (on MPFB) subjects was limited to Category I building knowledge (see earlier section). From this it may be hypothesized that only Category I knowledge would correlate with scores on the spatial learning task.

The above hypothesis assumes that the factor which led to the association between spatial relations ability and spatial learning, also underlies the spatial learning-cognitive mapping correlation. In other words, some basic cognitive factor may be partially responsible for the level of performance on spatial learning tests, spatial relations tests and those parts of cognitive mapping tests designed to measure 'high level' knowledge. The only result within the present study which opposes this interpretation is the non-significant correlation between node scores and error scores for Category I buildings. An explanation for this lack of correlation is not immediately apparent. As discussed in Chapter 13 (see section on 'VVIQ') the nature of the nodes used in these spatial learning tests (i.e. Experiments III and IV) may have permitted non-spatial strategies for remembering the material. This would have lessened the dependence of node scores upon the existence of a well-learned link structure. Subjects whose poor spatial abilities would have caused them to do badly on the spatial learning test might thereby have achieved good scores.

Despite the 'ceiling effect' in the link scores, a significant correlation was found between them and error scores for Category I buildings. This means that the subjects who failed to learn the relatively simple visuo-spatial link structure (map shape) were generally the same people who positioned the major buildings inaccurately.

#### (iv) Cognitive Mapping

Within the cognitive mapping task, two significant correlations were found. The error scores for building Categories I and II were significantly correlated. In general then, subjects were consistently accurate, or inaccurate, at positioning all the buildings. This implies that a 'good' or a 'poor' mapper can be identified for the full range of

environmental knowledge. It also supports the possibility raised earlier (see section (i) ) that the low correlation between MPFB and Category II buildings was due to differences in background spatial experience contaminating the accuracy levels. That is, if the 'over-learned' Category I buildings showed an MPFB-error score relationship and people were consistently good or bad throughout the knowledge range, then an MPFB-error score relationship would be expected for Category II buildings also.

The other significant correlation within the cognitive mapping task was between confidence ratings and error scores for Category II buildings. No such relationship existed for Category I buildings. The lack of correlation in Category I might have been anticipated from the small variance in confidence ratings. Almost all confidence ratings for Category I buildings were within the top three (from a range of five) points on the scale; meaning that the correlation with error scores was made on a truncated range. As discussed earlier, the Category II buildings produced a wider range of accuracy, both subjective and objective; this being reflected in the significant correlation between the two. This finding has implications for Beck and Wood's (1976) claim that people can estimate the content of their 'cognitive maps', but not the accuracy. The present study shows that subjects may be able to provide some information as to the accuracy of their mapping products. The negative finding by Beck and Wood may have been the consequence of using a 'free recall' design. That is, subjects were not forced to represent elements of which they had little knowledge; possibly leading to data comparable to Category I buildings in the present study.

The Microgenesis of Building Knowledge

The mean 'cognitive mapping task' scores obtained in the present study support the conclusions reached in Experiment IIa. Subjects with twenty weeks experience of the campus were not significantly better at representing the area than subjects who had ten weeks experience, implying that an asymptotic level of performance had been reached by the ten week stage. Both objective (error scores) and subjective (confidence ratings) measures of positional accuracy remained stable. The slight differences which did occur between the mean scores for the two sets of subjects were mainly in the direction of the more experienced having less accuracy. This was probably the result of differences in the subjects' experience of particular buildings on the campus. Although the two groups of subjects were very similar, the functional importance of at least one building had changed during the two-year period between the two experiments. The 'R.S.A.' building (in Category II) ceased to function in the capacity for which it was labelled, before the subjects in Experiment IV first arrived in the area. Consequently, a reduced level of accuracy would be expected from the subjects tested at the later date (Experiment IV), despite their having greater experience of the area. The mean error scores for the 'R.S.A.' confirmed this expectation.

The 'recall order' results for the present study were also comparable to those found in Experiment II, supporting the reliability of the earlier findings. A significant degree of consistency was found between subjects in the orders in which they drew the positions of the buildings. The level of consistency was lower than that which was found at the end of the first week (in Experiment II, group D6), as was the level found after ten weeks (in Experiment II, group D50). In addition, the mean recall ranks for the two building categories exhibited the expected relationship: the Category I buildings generally being positioned prior to those in Category II.

## 14.5 Conclusions

### The Relationship between Cognitive Mapping, Spatial Learning and Spatial Relations Ability

It can be concluded from the present study that spatial relations ability, map-learning ability and everyday cognitive mapping ability are inter-related.

- (i) Evidence was found that spatial relations ability was correlated with accuracy at depicting the spatial layout of functionally-important buildings. The lack of correlation with poorly-known, functionally-unimportant buildings was thought to be the result of experiential differences between subjects.
- (ii) Spatial relations ability was also found to be correlated with performance on the map-learning task. Unfortunately, the problem of a ceiling effect in the link scores (which formed the 'shape' of the map) was not eliminated in the present study. This was thought to be due to the learning strategy adopted by the subjects.
- (iii) Some evidence was found that cognitive mapping and map-learning were related. However, the results of this analysis were less clear than in the other sections. It seemed possible that subjects may have adopted non-spatial strategies for learning the 'nodes' of the map stimulus.

### The Cognitive Mapping Task

- (i) Within the cognitive mapping task, evidence was found that people may be consistently good or bad at depicting building positions across the complete range of building familiarity. Also, that people may be able to assess the accuracy of their building knowledge to some extent.

- (ii) The cognitive mapping scores obtained in the present study confirm the conclusions reached in relation to Experiment II (Chapter 12). Error scores, confidence ratings and recall patterns for the present subjects (with twenty weeks' experience) were very similar to those achieved by the end of Experiment II (with ten weeks' experience). It therefore seems that cognitive mapping knowledge had stabilised after ten weeks' experience of the campus area.

## Chapter 15

### General Discussion and Conclusions

#### 15.1 Methodology

##### (i) The Choice of a Direct Mapping Technique

The review of methodological problems in Chapter 7 concluded that none of the currently available techniques for the elicitation of cognitive maps are devoid of drawbacks. This being so, the particular technique employed in any study should be chosen to suit the specific aims of that study. Attention should be paid to such variables as the aspect of knowledge being examined, the type of data analysis to be performed and the subject pool being sampled.

The cognitive mapping studies in this thesis were designed to assess knowledge of the spatial configuration of elements in a small topographical area. It should be recalled that recent work reviewed in Chapter 7 has shown that the subjectively-judged accuracy of 2-D configurations was higher when layouts were produced directly by each subject than when they were created by multi-dimensional scaling (from distance judgements). It was mainly for this reason that direct mapping techniques were chosen for the present studies. However, it was also thought important to re-assess the utility of sketch-mapping as an elicitation technique; given the strong criticisms which have been made of it in the last decade (see review in Chapters 4 and 7).

##### (ii) The Relative Utility of Sketch-mapping and Three-dimensional Modelling

The two main types of direct mapping technique to be used in cognitive mapping studies have been sketch-mapping and 3-D modelling.



It has been shown by Stea and Taphanel (1974; see Chapter 11) that 3-D modelling may have several advantages over free-hand sketch-mapping, when the cognitive mapping of less-educated people or young children is being studied. However, no evidence was available that these advantages exist when more educated subjects are tested. It therefore seemed necessary to compare the utility of these two elicitation techniques with a group of educated, adult subjects.

Experiment I (see Chapter 11) was designed as an exploratory, open-ended comparison of free-hand sketch-mapping with 3-D modelling. The experimental materials were chosen so as to ensure that the two techniques differed in only their essential qualities. Also, the instructions for both tasks were kept to the minimum, differing on only the essential details. The simplicity of the instructions allowed subjects to make their own interpretation of the task demands. Much of the early work on cognitive mapping (see Chapters 3 and 4) used very basic instructions and it is not known if the differences so obtained were confounded by differences in the subjects' understanding of the task. Subjects in Experiment I were therefore simply asked to make a map or model (as appropriate) of their university campus, including as many details as possible and labelling items. Comparative performance was assessed by measuring both the content and the accuracy of the spatial layouts. The design of the study necessitated each subject producing two campus representations. This permitted both between and within subject comparisons of the sketch-maps and models. It also enabled a comparison of first and second attempts, regardless of the technique used.

The results of the technique comparisons did not reveal any gross differences in performance as measured by content or by accuracy. No statistically significant differences were found at all for the content scores. The only difference between the accuracy of sketch-maps and

models was found when the subjects' second attempts were examined. In this case, modelling did seem to facilitate consistent scaling in the horizontal and vertical dimensions of their spatial layouts. At a subjective level, there was no overall preference for one technique over the other. Comments made by subjects were equally balanced between those who claimed that 3-D modelling was easier than sketch-mapping and those who felt hindered by the modelling materials.

It therefore seems that earlier findings regarding the advantages of 3-D modelling over sketch-mapping do not apply to the assessment of cognitive mapping in educated, adult subjects. Greater confidence was not noted for the modelling task; in terms of willingness to co-operate (no 'subject refusals' were encountered for either task), subjective assessment of task difficulty or the amount of detail elicited. The problem of reliance upon general map familiarity was not applicable to the group tested in Experiment I, who would all be familiar with maps and plans. Dependence upon graphic ability may have been a greater problem for the sketch-mappers than the modellers. However, it appeared that the main problems of the campus tasks were those of arranging the elements and deciding upon a suitable scale; rather than producing elaborate graphic or modelled displays. In these cases, the two techniques were probably equally difficult. Additionally, two sketch-mapping problems (those of not drawing straight lines and being unable to remove erroneous elements) were alleviated in Experiment I by providing the subject with a ruler and an eraser.

Thus, the only evidence from Experiment I that 3-D modelling might be advantageous was the enhanced scaling consistency on the second tasks. This being so, it seems that for educated subjects, sketch-mapping could be made equal in utility to 3-D modelling, by simplifying the scaling process. This could be achieved by providing some reference distances

on an appropriate scale. While this procedure would still be open to the criticism that subjects may not be able to use the scale provided, it would at least avoid grossly inappropriate initial scale choices. The utility of providing the subject with an appropriately-scaled base-map was highlighted by Beck and Wood (1976; see Chapter 6).

(iii) Task Instructions

The 'basic' instructions for the cognitive mapping tasks enabled assessment of the extent to which different subjects interpreted the task demands similarly. Some degree of consistency was found, in that all subjects included a basic group of major campus buildings. However, clear evidence was found for the ambiguity of the task demands, when non-building elements were assessed. Very high variance was found in these scores; some subjects produced simple representations composed of only the main buildings and one or two paths and other subjects painstakingly represented every building, path, tree, lawn, etc. The 'prompted recall' section indicated that the detail produced on many of the representations did not exhaust the subject's total knowledge; despite the task instructions asking for 'as much detail as possible'. This was further supported by the comments of subjects, who expressed uncertainty as to the amount of detail required.

It may be concluded from the above that subjects should not be simply asked to 'draw a map' or 'make a model' of an area, if it is wished to characterise their overall knowledge. Since subjects vary in their interpretation of the level of detail required, it would not be possible to draw conclusions regarding the limits of their knowledge from the responses to such a request. However, if the study is to focus upon the representation of particular common elements, which are likely to be spontaneously produced by all subjects, then such instructions would be sufficient.

The drawback to providing subjects with more detailed instructions as to what should be mapped is that it reduces the amount of information transmitted by a subject in the experimental task. If the detail in a cognitive map is of primary interest, then the most useful method may be to use a two-stage task; the first stage using simple instructions to assess spontaneous representations and the second stage being an exhaustive 'prompted recall' stage. If more detailed recall instructions were to be given in a one-stage study, then the types of elements required could be listed generically (e.g. 'houses, roads, trees') or specifically (e.g. 'Building X, Building Y'). A generic listing may be preferable in that it at least shows which elements are spontaneously included within each given category. A specific listing may be required if a standard performance index is to be derived from the maps or models. That is, between-subject comparisons of mean position accuracy, recall order or size exaggeration would require data obtained from a standard set of elements. It would therefore be necessary to elicit mapping attempts for each of these elements from each subject. The lack of such a 'forced recall' procedure led to a restriction upon the accuracy and recall order data which could be analysed in Experiment I (see also Chapter 11).

(iv) The Process of Externalising a Cognitive Map

In addition to the content and accuracy measures in Experiment I, the order in which people included each element was monitored. Permanent records of each subject's sequence of element inclusion were obtained from video-tapes of the task performances. Initial examination of these records indicated that there were often spatial and functional links between adjacent items in the recall orderings. It was thought useful to compare recall orders between and within subjects; to look for

similarities and discrepancies in the sequences. However, the free recall design of the study meant that subjects varied greatly in the total number of elements included. A standard set of recall orders therefore had to be derived by choosing a group of elements which were included on each representation. Twelve such elements were identified.

Between-subject concordance coefficients and within-subject correlation coefficients (the latter assessing consistency between first and second task attempts) were calculated from the 'twelve element' orders. These showed a high degree of similarity between subjects in the order that they included the twelve buildings on their first task attempts. The second mapping attempts yielded a lower concordance level, but examination of each subject's 'first versus second attempt' correlation coefficient revealed that this was due to several 'reversals' in the sequences. That is, when representing the environment a second time, some subjects deliberately chose to reverse the sequence used in their first attempts. An impression of the common recall sequence was obtained by ranking the total ranks, across subjects, for the twelve buildings. This common sequence showed evidence of spatial links between buildings ranked next to each other. In addition, the direction of most recall sequences (apart from the 'reversals') reflected the spatial experience of most subjects. The representations usually began at the southern perimeter, the point at which subjects would enter the campus during their initial experience (cf. Schouela, Steinberg, Leveton and Wapner, 1980; see also Chapter 9). The sequence then followed the main walking route through the campus.

It can be concluded that examination of the process of completing a cognitive mapping task may provide important evidence of cognitive organization. The main problem which was found in the recall order analysis of Experiment I was the limited range of elements for which

any systematic analysis could be performed. It is not known where in the recall sequences the more idiosyncratic building elements would have occurred. Analysis of the complete recall orderings may have revealed more convincing evidence of spatial or functional links. Alternatively, it may have been found that only the major buildings were recalled in a spatially-linked fashion; as if to form a 'framework', upon which the less-important buildings would then be added. It therefore seems necessary to look at recall orderings in a situation where all subjects are obliged to include less important elements in their externalised cognitive maps of an area.

The examination of recall orders might have been a useful addition to many of the early cognitive mapping studies. Although Lynch (1960) recommended that notes be taken of the order of mapping, few researchers did so until the last few years. In particular, studies such as Appleyard (1970) and Goodchild (1974) which attempted to assess 'styles' of sketch-mapping, might have benefitted from having recall order data to examine. The classification of sketch-maps into 'spatial' or 'sequential' often proved problematic, and might have been facilitated by direct evidence of the way in which the representations were produced.

The use of an experimental design which demanded two 'cognitive maps' from subjects highlighted another possible problem in certain earlier studies. Although strong positive correlations were generally found between recall orders for first and second attempts, some subjects deliberately adopted different strategies at their second attempts. This indicates that initial and subsequent elicited representations are not necessarily comparable. The initial attempt may be used to recall and organise information into a 2-D representation, which can then be reproduced with far less intervening processing, at the second attempt. In consequence, the practice of some researchers (e.g. Spencer and

Weetman, 1981; see review in Chapter 9) of permitting initial 'throw-away' sketch-mapping attempts, with all structured analysis being based upon second attempts, may be ill-advised. Useful evidence of cognitive organization may have been discarded by this procedure.

In conclusion, any studies which profess to examine the underlying cognitive organization of spatial information through mapping tasks should monitor recall orders. In addition, they should pay particular attention to initial attempts to externalise such information, rather than limiting analysis to final mapping products. It has been shown that the use of video-tape recording is of great value in facilitating this type of data collection and analysis.

## 15.2 Microgenetic Development

### (i) The Purpose and Design of Experiment II

A review of past research into the microgenetic development of cognitive maps uncovered a number of inadequacies (see Chapter 9). There was found to be a need for investigation of the initial experience of a novel environment, comparing this early learning to that which can be achieved after long-term experience. It was found that few studies had examined the orders in which elicited representations were constructed and that even less had adequately analysed such data. Many researchers, from the 1960's onwards (see Chapters 3 and 4), had noted the enhanced recall of functionally important elements. However, only a few (notably Devlin (1976); see Chapter 9) had included any analysis of differential element knowledge in their studies. In addition, evidence was found in Experiment I that people may recall a very familiar area in a spatially-linked sequence. The question therefore arose as to when in the learning process such spatial linking becomes

evident. It was to further these areas of research that Experiment II was carried out (see Chapter 12).

The design of Experiment II was developed so as to incorporate the recommendations of Experiment I. A structured sketch-mapping task was used, subjects being provided with a grid-marked base-map. In this way, the main drawbacks of sketch-mapping (reliance upon graphic ability and scaling difficulties) were lessened, while still retaining its advantages. Also, sketch-mapping was a more practicable technique than 3-D modelling, given the need for assessing large numbers of subjects in a short period, which necessitated group-testing.

Given the main purpose of the experiment, to compare performance over a learning period, it was clearly necessary to obtain comparable data from each test session. A structured recall task, including 'forced recall' of a range of elements was therefore adopted. In accordance with the conclusions of Experiment I, these elements (campus buildings) were chosen so as to include places which would probably have been spontaneously included by all subjects and also, places which might have been drawn by only a few. Since the campus and subject population used in Experiment II was approximately the same as in Experiment I, the particular buildings were chosen from the recall data obtained in the earlier study. Provision was made for subjects to label the order in which they constructed their maps and they were also asked to indicate how confident they were of the accuracy of each building position. The recall orders were requested since it was not possible to video-tape each subject's task performance.

Experiment II tested campus knowledge after two, four and six days' experience and compared these levels with those reached after ten weeks. Following the completion of the study, it was thought valuable to test a further sample, with longer than ten weeks' experience. The subjects



used for Experiment IV (see Chapter 14) constituted an appropriate follow-up group, since they were highly comparable to the earlier subjects in terms of spatial experience but had twenty weeks' experience of the campus area.

(ii) The Time-scale of Cognitive Map Acquisition

The results of Experiment II showed a substantial increase in objective sketch-mapping accuracy during the first few days of exposure to the novel environment. A comparison of the performance increment during the first week with that which occurred over the subsequent nine weeks indicated that the subjects' cognitive maps were at their most labile during the initial phase of learning. Indeed, by the tenth week of environmental experience, performance had apparently reached an asymptotic level. That is, the group tested in Experiment IV, with twenty weeks' experience of the same area, were no more accurate than the ten week group.

It therefore seems that spatial knowledge acquisition may be most rapid in the initial stages of entering a new area, followed by a stage of less rapid learning, culminating in a stable cognitive map which is not enhanced by further experience. Clearly, the results of Experiments II and IV do not permit any statements to be made about the learning curve between the end of the first week and the tenth week, since no measures were taken during this period. However, it seems likely that there would be a gradual decline in the rate of knowledge acquisition, rather than any sudden change. Further research would be needed to confirm this hypothesis.

The discovery that microgenetic learning of a specific topographical area may reach an asymptotic level and then remain stable seems surprising at first sight. It might be assumed that accuracy levels would continue

to improve indefinitely with continued exposure to the area. Even so, the 'levelling off' of mapping accuracy might have been anticipated from the theoretical models of cognitive mapping which were reviewed earlier (see Chapters 5, 6 and 8). Siegel and White (1975) and Byrne (1979) described cognitive map acquisition by practical experience as resulting in a topologically accurate network representation, with some degree of scaling along the various links. The functional utility of this type of representation was said to be that it provided the information necessary for efficient navigation of an area, with the minimum memory load. Clearly, an exact Euclidean representation would not be needed to fulfil such a role. Therefore, the researchers would not have expected such a representation to develop.

Thus, the stabilization in accuracy which was found in Experiment II and IV could be in accordance with such a model. The levels of error among the most highly experienced subjects might indicate the existence of accurate network representations. Since the latter would be adequate for the navigational needs of the person, no further accuracy would be expected.

It should be noted that the actual time taken for a cognitive map to stabilize may be dependent upon the environmental scale. The time taken in Experiment II, approximately two to three months, might only apply to experience of a fairly small topographical area. The learning period could be much longer for larger intra-urban or urban areas. Some of the microgenetic studies reviewed in Chapter 9 found that significant improvements occurred in accuracy up to six months and beyond. The topographical areas being learned in these studies (e.g. Herman, Kail and Siegel, 1979) were larger and more complex than that tested in Experiment II.

The intensity and range of direct environmental experience are also likely to affect the rate at which an area is learned. If a cognitive map is learned through practical experience, then presumably, the frequency of experiencing an area will influence the absolute rate of knowledge acquisition. From the research reviewed in Chapters 4, 5 and 8, it seems that the practical navigational needs of a person would affect the form (extent, detail, organisation) of the eventual cognitive map, rather than the rate at which it was acquired. One proviso is that a change in the practical needs of the person, once a stable cognitive map has developed, will probably lead to renewed learning. This effect was noted by the present author in an analysis of the navigational techniques of two blind people (Smith, Note 1). One subject explained how he had only learned much of his existing spatial knowledge after some years of experiencing the relevant area, when he changed from using a guide-dog to 'white stick' navigation (i.e. from a 'passive' to an 'active' system; see Chapter 4).

Another potential source of variance in rate of cognitive map acquisition is the subject's I.Q. Most subjects used in microgenetic studies have been of above average I.Q. Consequently, it might be argued that a lower rate of acquisition would be found among less intellectually gifted people. Investigation of this hypothesis would be hampered by the high probability of intellectual differences being confounded by differences in experience with common techniques for externalising cognitive maps (see Chapter 4). The slight evidence which is currently available (e.g. Moore (1975); see Chapter 5) suggests that general I.Q. is not an important factor in cognitive mapping. However, there is some evidence that specific cognitive abilities may affect cognitive mapping (see Chapters 5 and 10). Even so, this evidence pertains to the form of cognitive maps, rather than

the rate or efficiency of acquisition. Further research is obviously necessary before the role of subject factors in rate of knowledge acquisition can be determined (see also Section 15.3).

(iii) Differential Building Knowledge

The results of Experiment II showed that both the asymptotic accuracy levels and the rate of improvement in accuracy varied greatly across the buildings used. To a large extent, these differences were predicted in advance by the building categorisation which was derived from the results of Experiment I. Equally, the subjects themselves were aware of how well they knew the positions of the buildings and their estimations became more accurate as learning increased. In short, there was a predictable and easily identifiable difference between those buildings which were well-known by subjects and those which were not.

Examination of the nature of the well-known and lesser-known buildings revealed a parallel distinction in terms of the functional utility of the buildings for the subjects tested. A direct relationship was found between the accuracy with which buildings were positioned and the extent to which the subjects would have used the buildings during the learning period. The results therefore supported the work of some early urban designers (see Chapter 3) and the more recent research by Devlin (1976). Devlin's study (see review in Chapter 9) highlighted the primacy of 'functional significance' in determining the content of cognitive maps.

One problem with the analysis of the Experiment II results is that most of the 'functionally significant' buildings were also 'physically and perceptually prominent'. The combination of functional and perceptual significance yielded the greatest frequency of recall in Devlin's study. However, perceptual prominence alone was not sufficient to lead to

learning. Thus, it is important to know if the 'well-known' buildings in Experiment II would have been recalled by subjects for whom the buildings were not functionally significant.

Some informal evidence collected by the present author (Note 2) suggests that non-academic users would represent the 'academic' details of the campus with less accuracy than the subjects in Experiments II and IV. Additionally, they would be likely to include many details and peripheral areas of the campus which were not included by the subjects in Experiment I. Obviously, there is a need for further investigation of the cognitive maps of different user groups in a common environment. Such research could take the form of a more systematic version of the informal study which was mentioned above; involving the examination of 'real-life' learning. Alternatively, an artificial learning study could be employed. This would involve exposing groups of subjects to a novel area; varying the functional significance of the buildings, but keeping all other factors constant.

The above discussion does not, of course, preclude the possibility of non-functional elements being learned by people. Devlin (1976) noted the tendency of her subjects to recall potentially functional places, such as hospitals and schools. Earlier researchers (e.g. Appleyard (1969); see Chapter 3) noted the importance of 'social symbol value' and 'visibility from travel routes' in determining recall probability. Although architectural features were generally low on the recall lists of Sieverts' (1967) subjects, he did note that famous tourist attractions were generally known. Milgram (1976) found that most Parisians were familiar with the Eiffel Tower, L'Arc de Triomphe, Notre Dame and Sacre Coeur, but beyond those, were surprisingly ignorant of many aspects of 'guide-book' Paris. This last finding suggests that factors such as 'social symbol value' play a relatively minor role in the acquisition of cognitive maps.

It is clear that aside from the functional significance of elements in terms of internal use, elements may be known because of their role in navigation. Many of these orientationally-functional elements will also be internally functional to a person. Devlin (1976; see Chapter 9) pointed out how particular places may be absorbed into the navigational routes of a person after initially being visited. That is, a place may change from being a 'goal' to being a 'sub-goal' on a route. This dual role of places would be anticipated from the network model of cognitive mapping put forward by several researchers (see Chapter 5 and 8).

In contrast to this dual function of some elements, other ones may be known solely for their orientational function. These will be elements which would be totally insignificant to the person, were it not for their strategic position on a navigational route, e.g. a group of trees, billboards or electricity pylons. As was discussed in Chapter 12, the results obtained in Experiment II may have under-estimated the importance of orientationally-functional elements by using a task which required initial recognition of the verbal labels for buildings. Orientationally-functional places may only be recognisable by visual cues. However, the need for orientational cues would probably have been low in the spatial area studied in Experiment II, due to its small scale and the high availability of internally-functional buildings. Elements known solely for their orientational function would be needed more at a larger urban scale.

Given people's propensity to recall buildings which have a significant internal function for them, it would seem sensible for environmental designers to facilitate accurate orientation by emphasizing such elements. Canter (1978) put forward this view, stating that signposting systems should be based upon the knowledge the potential user is likely to have.

(iv) Recall Orders

The cognitive mapping task used in Experiments II and IV required subjects to label the sequence in which they chose to construct a 2-D campus plan, from the given buildings list. This procedure enabled both comparisons between subjects (within and between test sessions) and analysis of inter-building links.

A high rate of agreement was found between subjects in their chosen 'recall orders' (position recall, rather than identity recall, since the latter was not needed due to the 'forced recall' design), within each test session. The extent of this agreement was found to reach a peak by the end of the first week of exposure to the campus and then to decrease somewhat to the level found in the long-term stable cognitive maps (after ten and twenty weeks). As noted in an earlier section, the time-scale must be somewhat approximate; given that no test sessions took place between the end of week one and week ten.

These results were shown to be compatible with a model of cognitive map acquisition which related the content and accuracy of cognitive maps to the building use and spatial experience of the subjects. In the first few days of environmental exposure, subjects recalled the buildings in order of decreasing subjective knowledge (i.e. there was an extremely high correlation between confidence ratings and recall orders). The significant concordance level at the first session would therefore have been due to similarities in building familiarity. However, a particularly high rate of concordance would not be expected upon this basis; since within any familiarity level, the order of recall would be largely random. That is, if several buildings were equally well-known, then there would be no reason why subjects should produce the same ordering of those buildings.

During the first week of campus experience, the subjects would have followed a fairly standard pattern of spatial activity. By the end of the week, this stereotyped behaviour was reflected in the very high rate of concordance between subjects in their recall orders. It was shown (by comparison with sequence data from Experiment I) that by the end of the first week, the order of positioning the major elements had approached a spatial adjacency sequence found in subjects with long-term experience. This sequence approximated the order in which the buildings would be passed when walking along the main route through the campus, from the main entrance. The initial stage of learning a new area by means of practical experience therefore seems to involve the acquisition of a unidirectional linked sequence of elements. This is what was described in the microgenetic theories of Siegel and White (1975), Byrne (1979) and others (see review chapters 5, 8 and 9).

Following the initial rise in concordance during the first week, there was a decline in the extent of inter-subject agreement in recall orders to the (still significant) level found in the 'long-term' mappers. This decline was matched by a slight reduction in the tendency to position buildings in order of decreasing confidence. These results were explained in terms of a gradual increase in idiosyncratic spatial behaviour, particularly with respect of 'low-level' knowledge.

Despite this reduction, subjects continued to position Category I ('well-known') buildings prior to Category II buildings, even up to the highest level of knowledge. It appears that the subjects were arranging the well-known buildings and then 'attaching' the lesser-known buildings to their well-known neighbours, by means of simple recall links (e.g. X is above Y and in line with Z). This two-stage strategy could be the result of the spatial demands of the mapping task. That is, since subjects knew that inter-positions were the main focus of the task,



they might choose to start by setting up reference points of which they were very confident. From the differential accuracy findings (see previous section), the inter-positions of Category I buildings may be known with the highest degree of accuracy, possibly including 'Euclidean' distance /angular information. These would therefore form a reliable frame-work upon which to 'attach' the elements which were known only by topological links.

This tentative explanation could be tested by comparing the results with a non-spatial recall method, e.g. free verbal recall. If the above explanation is accurate, the use of this technique should lead to an increase in the range of buildings which would be recalled in the spatially-linked sequence. This type of recall would be similar to that used in the 'Method of Loci' mnemonic technique.

In conclusion, Experiments I and II have demonstrated the utility of incorporating recall order analysis into cognitive mapping research. Clearly, the evidence discussed above could not have been derived from analysis of 'end products' alone. Examination of the way in which people carry out mapping tasks would also help to resolve the controversy surrounding the structure of cognitive mapping products. As discussed in Chapter 9, recall order data would indicate if apparently non-sequential materials had been produced in a sequential manner.

#### (v) Sex Differences

One aspect of the results of Experiments I and II which contradicted earlier findings was the lack of any clear sex differences in cognitive mapping performance. Previous research has usually found evidence of male superiority in the extent and accuracy of large-scale representations (see Chapter 4). This discrepancy can be seen to give further support to the spatial experience based model of cognitive mapping. That is,

in most earlier research, it was accepted that male subjects had greater experience of the area being 'mapped'. Also, their experience was more often 'active', whereas their female counterparts typically had 'passive' spatial experience; a factor which has been shown to influence the efficiency of cognitive map acquisition (see Chapters 4, 5 and 6).

In the present experiments, such experiential differences would have been minimised. Additionally, the results would not have been confounded by inequalities in educational background or general map-related experience. The results therefore support the idea that commonly-found sex differences in cognitive mapping are mediated by differences in spatial experience and educational background.

Although there were no objective sex differences in cognitive mapping, the results of Experiment II showed a higher level of confidence among the male subjects. It seems that stereo-typed expectations might therefore exist in groups where no objective sex differences exist.

It should also be noted that there were no sex differences in objectively-measured spatial relations ability in the present thesis. This specific cognitive ability is thought to be relevant to cognitive mapping performance (see later discussion) and might therefore have confounded earlier research findings.

### 15.3 Individual Differences in Cognitive Mapping

#### (i) Spatial Relations Ability and Cognitive Mapping

The primary purpose of Experiments III and IV was to investigate the possible link between spatial relations ability, as assessed by standard psychometric tests, and performance upon cognitive mapping tasks. In Experiment III, it was decided to assess cognitive mapping ability by using an artificial map-learning task. This was to ensure that all subjects had the same amount of exposure to the stimulus.

The map-learning task was devised as an ecologically-valid example of a cognitive mapping problem; that is, it demanded the acquisition of a schematic urban route. Unfortunately, 'ceiling effects' were found in a number of the scores from Experiment III. In Experiment IV, the map-learning task was made more complex, in an attempt to avoid these undesired effects. Additionally, performance on the 'real-life' cognitive mapping task devised for Experiment II was measured, the results being compared with the spatial relations and map-learning scores.

Evidence was found of a significant positive relationship between scores on the spatial relations test (the MPFB) and the node recall scores in the map-learning task. No such relationship was found with the link recall scores (the directional route segments between nodes). These two results were found in both Experiments III and IV (i.e. with or without a truncated range in the MPFB and node scores). Unfortunately, Experiment IV did not succeed in eliminating the 'ceiling effect' in the link scores, despite the considerable increase in the complexity of the learning material. A possible explanation for this last problem was outlined in Chapter 14. Briefly, the most efficient means of learning the visual map display might be to commit the route 'shape' to memory and then to 'attach' the verbal node tags to the points. In this case, an increase in the complexity of the map-learning task would lead to a reduction in node scores but not necessarily in link scores.

Thus, a consistency in performance was found between spatial relations ability and a contrived example of a cognitive mapping task. The correlations between these tasks and scores on the 'real-life' cognitive mapping task showed a similar consistency in the expected direction. That is, the subjects' accuracy and confidence at depicting the major elements of their familiar environment was directly related

to their scores on the spatial relations and map-learning tasks.

Experiments III and IV therefore support the research of Moore (1975) and others (see Chapters 5 and 10) who found a relationship between spatial relations ability and cognitive mapping ability. This tentative evidence clearly needs to be verified by further research. However, the potential role of spatial relations ability should be considered in future investigations of cognitive mapping. It is not possible to state whether or not the relationship found between spatial relations ability and cognitive mapping scores was partially (or totally) due to the nature of the mapping task. Further cognitive mapping studies including assessment of spatial relations ability should use non-graphic accuracy measures (e.g. distance estimation) in order to clarify this matter.

No relationship was found between spatial relations ability and the cognitive mapping of those environmental elements which were generally poorly-known by the subject population in question (i.e. 'Category II buildings'; see section 15.2 (iii) ). It was suggested (see Chapter 13) that any underlying relationship could have been confounded by individual differences in spatial experience of these lesser-known buildings. However, it is difficult to see how these inequalities could be eliminated in a natural learning situation. 'Behavioural mapping' of the type used by Holahan and Dobrowolny (1979; see Chapter 10) would not be practicable for a long-term study at an individual level of analysis. A system of subjective behaviour monitoring (e.g. keeping a diary of spatial behaviour) might be feasible; at least as a means of determining whether places had been visited or not. Even so, 'secondary experience', or knowledge acquired from other people or from printed sources could still go unrecorded. Also, long-term diary-keeping might well alter the natural learning situation, by drawing people's attention to their environment

unnecessarily. Tourist studies might provide one situation where such activities would be acceptable (e.g. Beck and Wood, 1976; see Chapter 6): however, these have their own drawbacks as microgenetic studies (see Chapter 9). In conclusion, the examination of correlates of low-level knowledge might be one area which necessitates the use of artificially-controlled learning.

(ii) Visual Imagery and Cognitive Mapping

The existence of 'visual imagery' has been the cause of much controversy in the cognitive psychology literature (see review in Chapter 13). Given that the map-learning task involved material particularly suited to visuo-spatial learning, it was thought useful to include an assessment of imagery ability into Experiment III. It should be recalled that Experiment III involved a four-group design, with half the subjects learning the material visually and half in an equivalent verbal form. Half of each stimulus group then recalled the material in a visual form (a map) and half in a verbal form (a list). This was primarily to examine the relative utility of the stimulus forms and the stimulus-response pairings (see Section 15.4). However, it also permitted the analysis of visual imagery within each of the four groups.

The results showed that the vividness of visual imagery was significantly related to learning scores, but only in the 'same mode' conditions. That is, if the task necessitated information being 'cognitively transformed' in any way, then the advantage of vivid visual imagery diminished. It was therefore concluded that 'static' visual imagery ability would probably be of little importance in 'real-life' cognitive mapping, which would of necessity include much cognitive transformation of environmental information. It seems likely that spatial relations ability would be of greater significance in the latter case.

This conclusion is in accord with previous research findings reviewed in Chapter 10. For example, Murray and Spencer (1979) found only a low correlation between a 'real-life' sketch-mapping task and a measure of visual imagery vividness. In contrast, Thorndyke and Stasz (1980) found a strong relationship between performance upon their artificial map-learning task and a test of 'static' visual memory.

### (iii) The Subjective Assessment of Cognitive Mapping Ability

It was shown in Chapter 1 that the notion of a 'sense of direction' has a long history, both in general usage and in academic literature. That is, it was thought that a person would display a consistent level of efficiency at orientation and way-finding, across a wide range of situations and throughout their lives. Kozlowski and Bryant (1977) noted that people will readily provide estimates of their own orientational ability. This being so, the researchers went on to investigate the accuracy of these self-estimates (see also Chapter 10). They found that subjects who claimed to have a good 'sense of direction' were indeed, better than others at a variety of cognitive mapping tasks. In addition, self-report data indicated that these subjects had a more positive attitude to map use, orientational tasks and environmental exploration. Similar results were found by Beck and Wood (1976; see Chapter 6).

The results of Experiment III support these earlier findings; showing that people are aware of their own cognitive mapping ability and that this ability is reflected in their attitudes to related everyday tasks. The question of causation therefore arises. Does someone have a poor 'sense of direction' because of a basic cognitive limitation, or simply because they avoid all experience of orientational tasks or map use? The findings discussed in this thesis suggest that experience, both of active navigation and of map use, may play a large part in determining

the extent and complexity of the cognitive maps achieved by a person. Thus it seems that individual differences in cognitive mapping ability are partially determined by general and specific spatial experience factors. The importance of these factors is perhaps most noticeable when the consequences of sex-role stereo-typing are considered (see Chapter 4 and section 15.2).

On the other hand, an increasing number of studies, including Experiments III and IV are beginning to find evidence of a relationship between cognitive mapping performance and basic spatial relations ability. So it seems that there may be a cognitively-determined limit upon the efficiency with which someone can learn to acquire spatial information about the large-scale environment. This view is supported by Thorndyke and Stasz (1980) who found that the success of training in effective map-learning procedures was dependent upon each subject's visual memory ability. The utility of training programmes in cognitive mapping tasks, as advocated in 1916 by Freeman (see Chapter 1), may therefore rest upon the relative importance of basic cognitive factors and experiential factors.

#### 15.4 Stimulus-Recall Compatibility in Cognitive Mapping

One of the main methodological problems of cognitive mapping research has been the decision as to what type of recall task to employ (see Chapter 7). A number of studies (reviewed in Chapter 8) found that the efficiency with which subjects were able to use different elicitation techniques was related to the way in which they acquired their spatial knowledge. In particular, there was a clear difference between people who had learned a topographical area through navigation and people who had learned it from a map (Moar, 1979; Evans and Pezdek, 1980; Thorndyke and Hayes-Roth, 1982). 'Navigation' subjects were better at

judging route distances and judging from different perspectives; whereas 'map' subjects were better at Euclidean ('straight-line') distances. This differential was most noticeable in the earlier stages of knowledge acquisition: after extended experience of the environment, 'navigation' subjects were able to make Euclidean judgements as well as 'map' subjects.

The implications of these findings have been discussed in terms of the hypothesized underlying structures of the subjects' cognitive representations (e.g. Moar, 1979). However, the results also have methodological implications. If a study is designed to compare elicitation techniques or to investigate the structure of cognitive maps, then obviously it will be necessary to use mapping techniques which some subjects may find difficult. On the other hand, if the research is designed to compare the performance of groups of subjects, then the mapping technique must be chosen so as to maximise the efficiency with which subjects are able to externalize their knowledge. Perhaps even more important, is to take possible methodological differences into account when comparing the results of different research programmes (cf. discussion of MacKay, 1976 and Baird, Merrill and Tannenbaum, 1979 in Chapter 8). For instance, if Thorndyke and Hayes-Roth (1982) had studied the microgenesis of building knowledge, then their conclusions regarding the rate and pattern of knowledge acquisition would have depended upon both their choice of subjects ('map-learners' or 'navigation') and their choice of technique (Euclidean distance estimation or route distance estimation).

Unfortunately, in many 'real-life' learning situations, it is not easy to specify the way in which spatial knowledge was acquired. At the urban and intra-urban levels, the majority of people will acquire their cognitive maps by a combination of modes; e.g. practical experience, printed maps and verbal information from other people. Even so, it may



still be useful for the researcher to be aware of the potential importance of this variable, so that appropriate decisions can be made when prior experience was clearly of one type or another.

During the 1970's, cognitive mapping research highlighted the inadequacies of free-hand sketch-mapping (see Chapters 4, 6 and 7); with the consequence that many researchers abandoned the use of graphic techniques completely. In the light of the above discussion, it may be that this policy could be problematic, particularly when subjects have acquired their knowledge primarily through maps (e.g. at the inter-continental scale). This view is supported by the results of the stimulus-recall mode comparisons in Experiment III (see Chapter 13). As was hypothesized from previous memory research, better learning was obtained from the map stimulus than from the list stimulus. However, the utility of the recall modes was found to interact with the type of stimulus experience. That is, the superiority of the map stimulus completely disappeared if non-graphic recall was demanded. It therefore seems that in some cases, researchers might do best to retain the graphic nature of the recall technique; concentrating instead on eliminating the undesirable components of the task (see previous discussion).

## 15.5 Conclusions

A number of conclusions can be drawn from the studies reported and the literature reviewed in the present thesis. These conclusions relate to a number of methodological and substantive issues in cognitive mapping research.

The choice of an elicitation task appears to be a question of relative utility; since no task has been shown to have absolute superiority in all situations. Factors such as the nature of the subjects' spatial experience, their educational background and the aims

of the research project will need to be considered. In particular, the utility of graphic recall has been found to depend upon the extent to which non-essential drawbacks (e.g. reliance upon drawing ability, scaling problems) of the task are eliminated, as well as the factors listed above. Experiment I showed that the superiority of 3-D modelling over sketch-mapping which was found by Stea and Taphanel (1974) may be limited to subjects on a low educational level.

It appears that one of the main problems of past cognitive mapping research is that insufficient attention was paid to the details of the elicitation task and data collection. Experiment I found that the type of instructions often given to subjects were not interpreted in a standard manner. The type of element and level of detail required may need to be specified in task instructions. In addition, it has been argued that analysis of the sequence in which cognitive mapping tasks are completed provides potentially crucial information for the researcher.

It was argued that previous research into the acquisition of new cognitive maps had paid insufficient attention to the first few days of learning. Accordingly, Experiment II studied this period in greater detail and found that this was when learning took place at the greatest rate. It was also found that there was a rapid acquisition of major elements and a more gradual acquisition of less important elements. An analysis of the type of buildings learned first, learned later or never learned indicated that functional significance was of paramount importance, rather than social, physical or aesthetic significance. A distinction was made between two types of functional significance; namely, internal use and orientational importance.

Recall order data showed a high general level of inter-subject consistency in the mapping sequences. This consistency increased over the first few days of environmental experience and then declined. The

mapping sequences used by subjects were interpretable in terms of spatial experience and building use. Initial competence in a new environment appeared to be attained by learning a spatial adjacency-based sequence of the major 'functional' elements. No sex differences were found in the experiments reported in this thesis; a finding which was thought to provide further support for experience-based mapping. That is, in the studies reviewed which found noticeable sex differences, these were usually correlated with clear differences in spatial experience.

Experiments III and IV supported previous research findings which had suggested that specific spatial relations ability might account for some of the performance differences found in cognitive mapping tasks. Self-rated visual imagery was found to correlate with performance on a map-learning task, though not when any cognitive transformation of the information was required. This supported previous judgements as to the limited relevance of 'static' visual imagery ability to everyday cognitive mapping, which will necessarily involve cognitive manipulation of the stimulus information. It was also found that people were capable of assessing their own cognitive mapping ability to some extent. These self-assessments were shown to relate to their attitudes to everyday navigational tasks.

In conclusion, the research findings in this thesis suggest that actual spatial experience is an important factor in the process of cognitive mapping. The structure of a cognitive map has been found to depend upon both the type and the amount of experience. The content of a cognitive map appears to be mainly determined by the practical needs of the holder. Where performance differences are found in spite of similarities in practical needs and spatial experience, it seems that the spatial relations ability of the individuals may be a relevant factor.

A recent review notes the findings of Kozlowski and Bryant (1977) and Thorndyke and Stasz (1980) with regard to the relationship between spatial ability and cognitive mapping performance (see Chapter 10) and concludes:

"These initial results are suggestive, and they underscore the potential utility of examining the relationship between the operations involved in learning and using representations of the environment and psychometric measures of spatial ability."

(Cooper and Regan, 1982).

It is hoped that the experimental work reported in this thesis may serve to supplement these initial studies.

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Appendix 1Subject Data - Experiment I

No.	Sex	Age	Years on campus	Geographical G.C.E.'s	Degree Course	SRT	Residence on/off campus	Experimental Condition
1	M	27	2	O	Theology	75	ON	S - S
2	F	21	4	-	Psych./Educ.	31	OFF	M - S
3	M	22	3	-	German	32	"	S - M
4	F	22	3	O,A	Psychology	65	"	M - M
5	M	21	3	O	Law	50	"	M - M
6	F	20	3	-	Theology	82	"	S - M
7	M	22	3	-	German	41	"	M - S
8	F	29	3	O	Psychology	70	"	S - S
9	F	20	3	-	English	70	"	S - M
10	M	20	2	O	French	93	"	M - M
11	F	21	3	O	Maths/Computer Studies	85	"	M - S
12	M	20	3	-	Law	41	"	S - S
13	F	22	3	-	German	44	"	S - S
14	M	20	1	O	German/Swedish	92	"	M - S
15	F	21	3	-	Theology	78	ON	M - M
16	M	22	5	-	Maths	97	OFF	S - M

Appendix 2INSTRUCTIONS TO SUBJECTSExperiment I - Summer 1979

## INSTRUCTIONS (SKETCHING)

Please will you use the paper provided to draw a map/plan of the University campus, including as many details as you can remember. Label as many items as you can and try to 'think aloud' as you work.

Have you any questions?

## INSTRUCTIONS (MODELLING)

Please will you use the apparatus provided to make a model of the University campus, including as many details as you can remember. If necessary, cut the coloured paper into strips or whatever shapes you need. Label as many items as you can (write on the paper base) and try to 'think aloud' as you work.

Have you any questions?

## INSTRUCTIONS (PROMPTED RECALL)

A list of items which you may be able to add to your map/model will now be read out one at a time. If you recognise the item say "yes", if not, say "no". Then try to add the item where you think it should fit.

Appendix 3

## SUBJECT DETAILS

AGE : \_\_\_\_

SEX : \_\_\_\_\_

Number of years spent at University : \_\_\_\_

Degree subject :

Do you have any Geographical qualifications (e.g. 'O-Level')? If so, what?

Place of residence during term-time?

Method of travelling to University from residence :-

Chiefly by car	<input type="checkbox"/>
" by bus	<input type="checkbox"/>
" on a bicycle	<input type="checkbox"/>
" on foot	<input type="checkbox"/>

Can you remember having seen any maps / models / photo.'s of the University?  
If so, give details.

## COMMENTS

What did you think of the tasks which you have just performed? Have you any comments to make about the relative difficulty of the first and second mapping / modelling tasks?

## Appendix 4

## MAPS Computer Program

```

10 DIM TRUE(4,8),OBS(4,8,16),ADJ(4,16)
15 DIM SF(4,16),SBSUM(4,16),TSUM(4)
20 OPEN "I",F1,"RESULTS"
30 FOR I=1 TO 4
40 FOR J=1 TO 8:INPUTF1,TRUE(I,J)
45 TSUM(I)=TSUM(I)+TRUE(I,J)
46 NEXT J
50 FOR K=1 TO 16
60 FOR J=1 TO 8
70 INPUTF1,OBS(I,J,K)
75 SBSUM(I,K)=SBSUM(I,K)+OBS(I,J,K)
80 NEXT J
85 SF(I,K)=SBSUM(I,K)/TSUM(I)
100 NEXT K,I
110 OPEN "O",F2,"SCALED"
200 FOR I=1 TO 4
210 FOR K=1 TO 16
220 FOR J=1 TO 8
230 E=OBS(I,J,K)/SF(I,K)-TRUE(I,J)
240 TOT =TOT+E^2
250 PRINTF2,USING" ffff.f";E;
260 NEXT J
265 TOT=SQR(TOT/8)
270 PRINTF2,USING" ffff.f";TOT;SF(I,K):TOT=0
280 NEXT K:PRINTF2,:NEXT I
290 CLOSE
500 OPEN "I",F2,"SCALED"
510 IF EOF(2) THEN CLOSE:END
520 LINE INPUTF2,A$:PRINT A$
530 GOTO 510

```

Have you visited the University before the start of this term (Saturday)?

If so, how often?

How long have you been?

How many times have you been?

Have you seen the University Computer Centre?

Did you look at the computer program?

Did you see any of the films?

Have you seen any other computer programs or films?

If so, which?

SUBJECT DETAILS

Age \_\_\_

Sex \_\_\_

Please could you indicate which, if any, of the following qualifications you hold:-

	'O' Level	'A' Level	Other (specify)
Mathematics			
Geography			

Did you attend the Freshers' Conference?

No \_\_\_\_\_

Yes - all of it \_\_\_\_\_

Yes - part (specify below) \_\_\_\_\_

Have you lived in Hull prior to commencing this course? \_\_\_\_\_

If so, for how long? \_\_\_\_\_

Have you visited the University before the start of this term (Saturday)? \_\_\_\_\_

If so, how often:-

Once (interview/open day) \_\_\_\_\_

More than once (explain below) \_\_\_\_\_

Have you seen the University Prospectus? \_\_\_\_\_

Did you look at the photographs? \_\_\_\_\_

Did you look at the maps? \_\_\_\_\_

Have you seen any other maps/photographs of the campus? \_\_\_\_\_

If so, which?

A5

INSTRUCTIONS

This is an investigation of the relationship between environmental knowledge and environmental experience. Please could you use the grid provided to draw a plan of the university campus. Include each of the buildings in the list provided; do not omit any that you do not know, make a calculated guess. After placing each building, mark a cross on the relevant 'confidence scale', in order to indicate how sure you are that the position of the item is correct. Draw the items to whatever size and shape you wish, there is no need to follow the grid pattern. It is not necessary to construct the plan in the given sequence; simply label the items 1 to 16 (in the space provided below) in the order that you draw them on the map. You have a maximum of 15 minutes to perform the task; please work silently, your comments will be requested after the task is finished.

Have you any questions?

ORDER	BUILDINGS	CONFIDENCE SCALE			
		LOW			HIGH
___	Administration	_____	_____	_____	_____
___	Applied Science & Maths	_____	_____	_____	_____
___	Biochemistry Huts	_____	_____	_____	_____
___	Boiler House	_____	_____	_____	_____
___	Brynmor Jones Library	_____	_____	_____	_____
___	Earth Sciences & Psychology	_____	_____	_____	_____
___	Middleton Hall	_____	_____	_____	_____
___	Nursery	_____	_____	_____	_____
___	Physics	_____	_____	_____	_____
___	Research Students Association	_____	_____	_____	_____
___	Sports Centre	_____	_____	_____	_____
___	Staff House	_____	_____	_____	_____
___	Social Sciences & Law	_____	_____	_____	_____
___	Students' Union	_____	_____	_____	_____
___	Wolfson Laboratory	_____	_____	_____	_____
___	Workshops	_____	_____	_____	_____

N.B. Please label your map buildings 1 to 16 - as above.

INGLEMIRE LANE

A5

364.

CRANBROOK AVENUE

SALMON GROVE

FEARNS AVENUE

COTTINGHAM ROAD



## CELFIL Computer Program

```

CELFIL;
"BEGIN" "INTEGER" N,Y,X,I,J;
"REAL" SUMT,SUMTOT,COLMTOT;
"ARRAY" DATA [1:16,1:30],B,SUMC,COLM[1:30],
      A,SUMR,SUMX[1:16];
"READ" N;

"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO" A[I]:=N;
"FOR" J:=1 "STEP" 1 "UNTIL" N "DO" B[J]:=16;
Y:=X:=0; SUMT:=SUMTOT:=COLMTOT:=0;
"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO"
"FOR" J:=1 "STEP" 1 "UNTIL" N "DO"
"BEGIN" "READ" DATA[I,J];
"IF" DATA[I,J]=0 "THEN"
"BEGIN" A[I]:=A[I]-1;
      B[J]:=B[J]-1;
      X:=X+1;
"END";
SUMR[I]:=SUMR[I]+DATA[I,J];
SUMC[J]:=SUMC[J]+DATA[I,J];
SUMT:=SUMT+DATA[I,J];
"END";
"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO"
SUMR[I]:=SUMR[I]/A[I];
"FOR" J:=1 "STEP" 1 "UNTIL" N "DO"
SUMC[J]:=SUMC[J]/B[J];
SUMT:=SUMT/((N*16)-X);
"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO"
"FOR" J:=1 "STEP" 1 "UNTIL" N "DO"
"BEGIN" "IF" DATA[I,J]=0 "THEN"
      DATA[I,J]:=SUMR[I]+SUMC[J]-SUMT;
"IF" DATA[I,J]<0 "THEN" DATA[I,J]:=0;

      "PRINT" SAMELINE, DATA[I,J];
Y:=Y+1;
"IF" Y=5 "THEN" "BEGIN" "PRINT" *'L';
      Y:=0; "END";

"END";
"PRINT" *'R50';

SUMTOT:=0;
"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO"
"BEGIN" "FOR" J:=1 "STEP" 1 "UNTIL" N "DO"
SUMX[I]:=SUMX[I]+DATA[I,J];
SUMTOT:=SUMTOT+SUMX[I];
"END";
COLMTOT:=0;
"FOR" J:=1 "STEP" 1 "UNTIL" N "DO"
"BEGIN" COLM[J]:=0;
"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO"
COLM[J]:=COLM[J]+DATA[I,J];
COLMTOT:=COLMTOT+COLM[J];
"END";
"PRINT" SAMELINE, *'L3' MEANS FOR EACH BUILDING, 1 TO 16 *'L2';
"FOR" I:=1 "STEP" 1 "UNTIL" 16 "DO"
"PRINT" SAMELINE, I, *'S4', SUMX[I]/N, *'L';
"PRINT" SAMELINE, *'S3' TOTAL = *'S2', SUMTOT, *'L4' SUBJECT SUMS=*'L2';
"FOR" J:=1 "STEP" 1 "UNTIL" N "DO"
"PRINT" COLM[J]/16;
"PRINT" SAMELINE, *'L2' TOTAL=, COLMTOT, *'L10';
"END";

```



Appendix 7Experiment III: Answer Booklet/Scoring System

Name ..... Group .....

MALE/FEMALE

Please produce your answer to the stated problem in the space below.

INITIAL TASK (Read out to subjects):-

"Describe how you would explain to someone who did not know the campus, how to get from this lecture theatre (or laboratory, as appropriate) to the Students' Union. You may give your answer as written instructions, a sketch-map, or a mixture of the two, whichever you prefer."

SCORING SYSTEM:-

Map only	- 1
Map + verbal instructions	- 2
Verbal list only	- 3

THIS WAS SCORED AS THE FINAL QUESTION IN THE MUQ

Experiment III    Task InstructionsList Stimulus

Overleaf is a list of instructions. When you are told to begin, turn the page and study them carefully. You will have five minutes to try to learn them. After that you will be told to turn to the next page and you will then have five minutes to recall the information.

Map Stimulus

Overleaf is a route map. When you are told to begin, turn the page and study it carefully. You will have five minutes to try to learn it. After that you will be told to turn to the next page and you will then have five minutes to recall the information.

Map Recall

Please recall what you have just learnt by drawing a map to represent the information.

List → List Recall

Please recall the list you have just learnt.

Map → List Recall

Please recall the information contained in the map by describing, in sequence, the route represented by it and the places on the route.



A7

1. Start at the Park Gate.
2. Proceed South.
3. Turn Left at the Church.
4. Proceed to the Pub.
5. Turn Right at the Pub.
6. Proceed to the Doctor's Surgery.
7. Turn Left.
8. Proceed to the Supermarket.
9. Turn Left again.
10. Continue to the Sports Centre.
11. Veer Right.
12. Carry straight on past the Memorial Hall.
13. When you reach the Restaurant ...
14. Turn sharp Left.
15. When you reach the Library ...
16. Turn Right.
17. Proceed to the Prison.
18. Turn Left.
19. Carry straight on to the Railway Station.

SERIALISM-HOLISM QUESTIONNAIRE

Please complete the following questionnaire. Make sure that you answer every question. Do not spend too long on each question. Indicate your answer by circling the appropriate letter or number on the right hand side of the page.

SCORING

- |  |      |   |
|--|------|---|
| 1. When starting on a new text book, do you  |      |   |
| (a) skim through it quickly to gain a general idea of the contents                                       | 1(a) | 1 |
| OR   |      |   |
| (b) start at the beginning and work straight through to the end?   | 1(b) | 0 |
| 2. If you are doing a crossword, do you  |      |   |
| (a) work through the list of clues in order  | 2(a) | 0 |
| OR   |      |   |
| (b) read quickly through the clues and select the one you can complete first?                            | 2(b) | 1 |
| 3. When shopping in a supermarket, do you  |      |   |
| (a) use a list   | 3(a) | 0 |
| OR   |      |   |
| (b) just take things from the shelves as you see them?   | 3(b) | 1 |
| 4. When choosing a novel from a library, do you  |      |   |
| (a) usually have a clear idea of the author/book you want  | 4(a) | 0 |
| OR   |      |   |
| (b) choose a book by browsing through the shelves?   | 4(b) | 1 |
| 5. On meeting a stranger for the first time do you   |      |   |
| (a) tend to form an immediate impression   | 5(a) | 1 |
| OR   |      |   |
| (b) reserve judgment till later?   | 5(b) | 0 |
| 6. When confronted with a new subject area (such as statistics) do you                                   |      |   |
| (a) like to master each successive step before progressing to the next one                               | 6(a) | 0 |
| OR   |      |   |
| (b) like to obtain a general overall impression of the subject before going back to fill in the details? | 6(b) | 1 |

(continued overleaf)

- 2 -

MAP USE QUESTIONNAIRE

7. If you were stopped in the street and asked to give directions to a place you knew which required explaining a sequence of five or six actions (e.g. turn left at second traffic lights), would you have

SCORING

	(a) given a competent set of verbal instructions without any difficulty	7(a)	1
OR	(b) given a competent set of verbal instructions after much hesitation and self-correction	7(b)	2
OR	(c) given a set of verbal instructions which were inefficient or inaccurate	7(c)	3
OR	(d) been unable to supply a set of verbal instructions?	7(d)	4
8.	Would you find it easier to give the above instructions if you were able to sketch a map of the routes?	8 YES	1
		8 NO	2
9.	If you had to travel by car from Hull to somewhere in the south of England, which of the following would you be most likely to do?		
	(a) Use a map to plan your route and as a guide on the journey	9(a)	1
OR	(b) use a map to plan your route and rely on road signs on the journey	9(b)	2
OR	(c) not use a map at all (e.g. ask a friend for instructions)?	9(c)	3
10.	When you use a map, do you		
	(a) usually rotate it so that 'up' corresponds to your direction of travel	10(a)	1
OR	(b) tend not to rotate the map?	10(b)	2

Assuming you lived five miles away from your place of work and travelled each day by car, would you

	(a) tend to always follow the same route to and from work	11(a)	3
OR	(b) try to vary the route occasionally	11(b)	2
OR	(c) try to vary the route as much as possible?	11(c)	1

(continued on next page)

- 3 -

MAP USE QUESTIONNAIRE continued

- |   |                      |   |                           |     |
|---|----------------------|---|---------------------------|-----|
| 12. Please rate how difficult/easy you find the following:-                                     | <u>Very<br/>Easy</u> |   | <u>Very<br/>Difficult</u> |     |
| i) planning a route before a journey from a map   | 1                    | 2 | 3                         | 4 5 |
| ii) keeping track of your progress on a map, during a journey                                   | 1                    | 2 | 3                         | 4 5 |
| iii) describing a route you know well, without using a map                                      | 1                    | 2 | 3                         | 4 5 |
| iv) describing a route you know well by drawing a map.  | 1                    | 2 | 3                         | 4 5 |
| 13. When you first go to a new town. how anxious are you about the possibility of getting lost? | <u>Very</u>          |   | <u>Not at all</u>         |     |
|   | 1                    | 2 | 3                         | 4 5 |

SCORING

AS

ANSWERED

VIVIDNESS OF VISUAL IMAGERY QUESTIONNAIRE

SCORING AS ANSWERED

14. For the next section of the questionnaire you are required to try to rate the vividness of your visual imagery. The items instruct you to imagine some object or situation. For each item circle the number (from 1 to 5) which best describes how vivid your image is. The numbers 1 to 5 should be used according to the following descriptions:

<u>Rating</u>	<u>Description</u>
1	'Perfectly clear and as vivid as normal vision'
2	'Clear and reasonably vivid'
3	'Moderately clear and vivid'
4	'Vague and dim'
5	'No image at all, you only "know" that you are thinking of the object'.

(continued overleaf)

- 4 -

For items 1-4, think of some relative or friend whom you frequently see (but who is not with you at present) and consider carefully the picture that comes before your mind's eye.

Item

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1. The exact contour of face, head, shoulders and body.   | 1 | 2 | 3 | 4 | 5 |
| 2. Characteristic poses of head, attitudes of body etc.   | 1 | 2 | 3 | 4 | 5 |
| 3. The precise carriage, length of step, etc. in walking. | 1 | 2 | 3 | 4 | 5 |
| 4. The different colours worn in some familiar clothes.   | 1 | 2 | 3 | 4 | 5 |

Visualise a rising sun. Consider carefully the picture that comes before your mind's eye.

Item

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| 5. The sun is rising above the horizon into a hazy sky. | 1 | 2 | 3 | 4 | 5 |
| 6. The sky clears and surrounds the sun with blueness.  | 1 | 2 | 3 | 4 | 5 |
| 7. Clouds. A storm blows up, with flashes of lightning. | 1 | 2 | 3 | 4 | 5 |
| 8. A rainbow appears                                    | 1 | 2 | 3 | 4 | 5 |

Think of the front of a shop which you often go to. Consider the picture that comes before your mind's eye.

Item

- |  |   |   |   |   |   |
|--|---|---|---|---|---|
| 9. The overall appearance of the shop from the opposite side of the road.                            | 1 | 2 | 3 | 4 | 5 |
| 10. A window display including colours, shapes and details of individual items for sale.             | 1 | 2 | 3 | 4 | 5 |
| 11. You are near the entrance. The colour, shape and details of the door.                            | 1 | 2 | 3 | 4 | 5 |
| 12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands. | 1 | 2 | 3 | 4 | 5 |

Finally, think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye.

Item

- |                                    |   |   |   |   |   |
|------------------------------------|---|---|---|---|---|
| 13. The contours of the landscape. | 1 | 2 | 3 | 4 | 5 |
|------------------------------------|---|---|---|---|---|

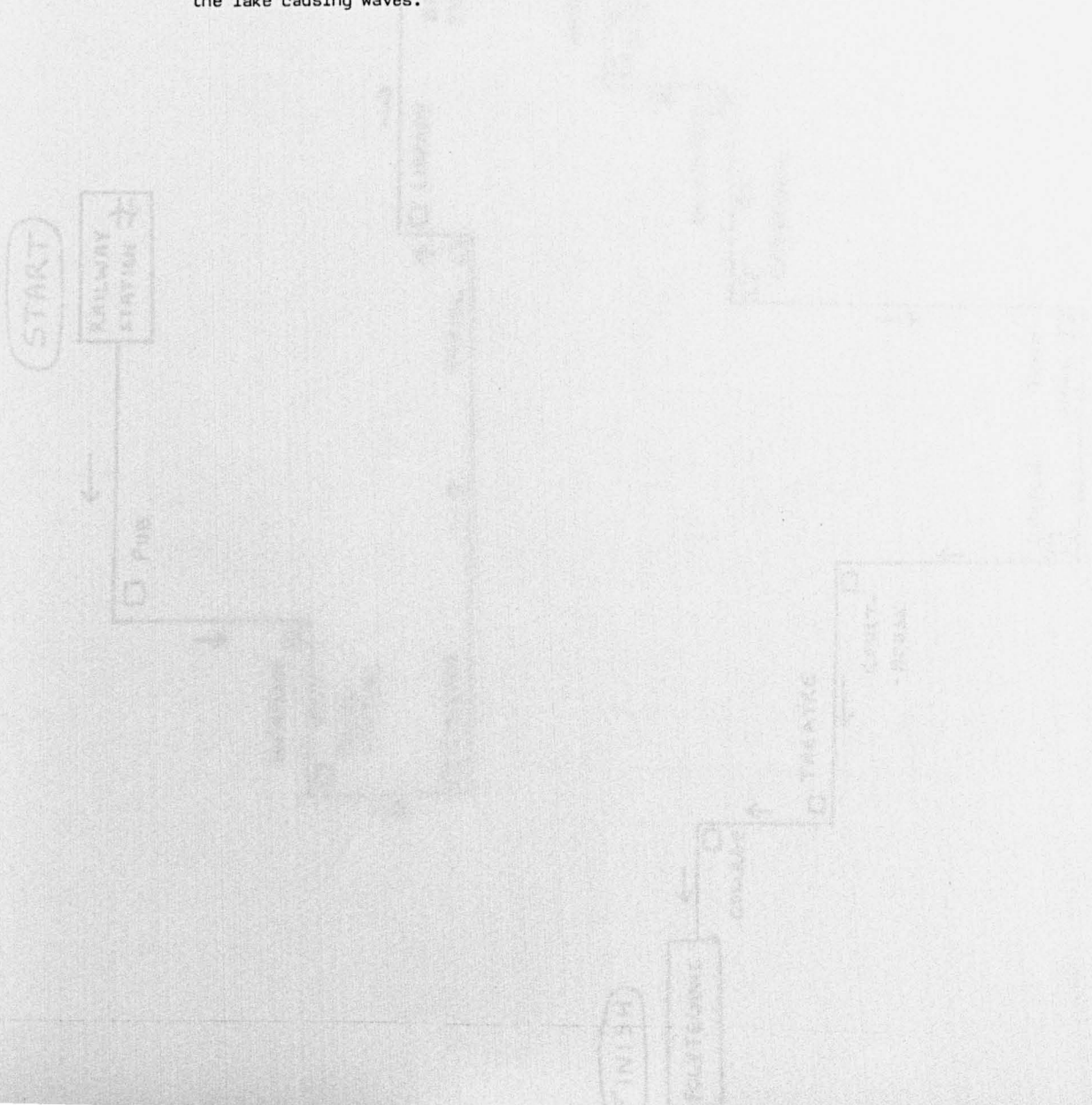
(continued on next page)



- 5 -

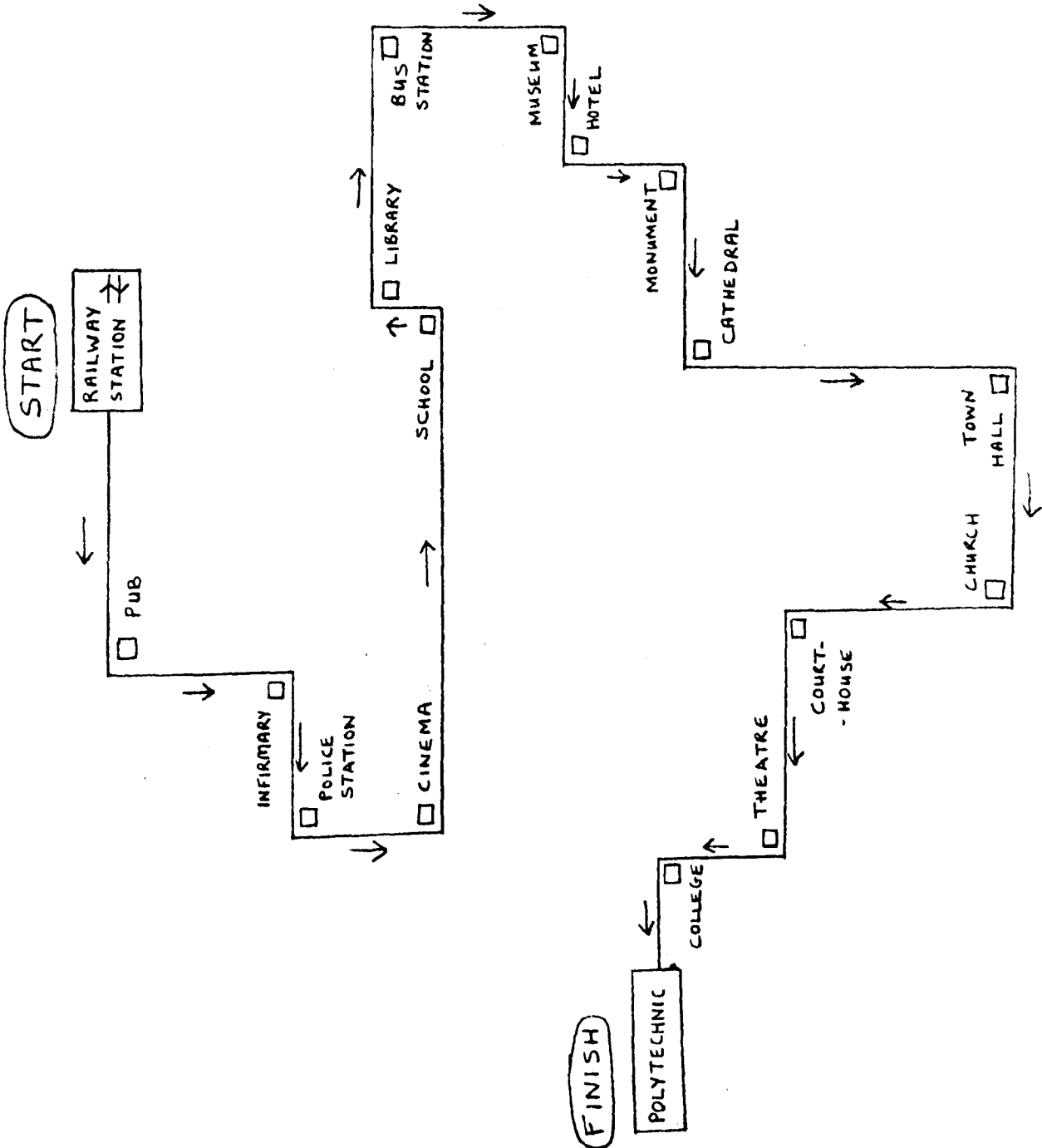
Item

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| 14. The colour and shape of the trees                               | 1 | 2 | 3 | 4 | 5 |
| 15. The colour and shape of the lake.                               | 1 | 2 | 3 | 4 | 5 |
| 16. A strong wind blows on the trees and on the lake causing waves. | 1 | 2 | 3 | 4 | 5 |



Appendix 8

Experiment IV: Answer Booklet



ANSWER SHEET FOR FORM TEST

NAME ..... CLASS ..... TODAY'S DATE .....

DO NOT WRITE ON THE QUESTION BOOKLET - WRITE YOUR ANSWERS IN THE BOXES BELOW

environmental knowledge and you could use the grid provided on the map. Include each of the five points on the map. You must calculate a guess. After you have calculated a guess, you must write one of the five points on the map in order to indicate how sure you are that your guess is correct. A guess would be correct if it is within the size of the area to whatever size you follow the grid pattern. Write your answer in the given sequence; places below and on your map. You have to do the task.

PRACTICE PAGE

Page 2

Page 3

Page 4

Page 5

- ORDER BUILDING
- Administration
- Applied Science/Maths
- Biochemistry Unit
- Boiler House
- Bryden Jones Library
- Earth Science/Physics
- Middleton Hall
- Nursery
- Physics
- Research Students
- Sports Centre
- Staff House
- Social Sciences/Law
- Students' Union
- Wolfe Laboratory
- Workshops

1	2	3	4
5	6	7	8

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

17	18	19	20
21	22	23	24
25	26	27	28
29	30	31	32

33	34	35	36
37	38	39	40
41	42	43	44
45	46	47	48

49	50	51	52
53	54	55	56
57	58	59	60
61	62	63	64

**INSTRUCTIONS**

This is an investigation of the relationship between environmental knowledge and environmental experience. Please could you use the grid provided to draw a plan of the university campus. Include each of the buildings in the list provided, it is very important that you do not omit any; if necessary make a calculated guess. After placing each building, mark a cross at one of the five points on the relevant 'confidence scale', in order to indicate how sure you are that the position of the item is correct (a guess would be indicated by low confidence). Draw the items to whatever size and shape you wish, there is no need to follow the grid pattern. It is not necessary to construct the plan in the given sequence; simply label the items 1 to 16 (in the spaces below and on your map) in the same order that you draw them on the map. You have a maximum of fifteen minutes to perform the task.

ORDER	BUILDING	CONFIDENCE SCALE	
		LOW	HIGH
—	Administration	— — — — —	
—	Applied Science/Maths	— — — — —	
—	Biochemistry Huts	— — — — —	
—	Boiler House	— — — — —	
—	Brynmor Jones Library	— — — — —	
—	Earth Sciences/Psychology	— — — — —	
—	Middleton Hall	— — — — —	
—	Nursery	— — — — —	
—	Physics	— — — — —	
—	Research Students Assoc.	— — — — —	
—	Sports Centre	— — — — —	
—	Staff House	— — — — —	
—	Social Sciences/Law	— — — — —	
—	Students' Union	— — — — —	
—	Wolfson Laboratory	— — — — —	
—	Workshops	— — — — —	

INGLEMIRE LANE

A8

378.

CANALBROOK AVENUE



SALMON GROVE

FARNS AVENUE

COTTINGHAM ROAD