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Using a computerized data collection method to explore sketch map drawing sequence

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Using a Computerized Data Collection Method to Explore Sketch Map Drawing Sequence

By

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Abstract

Cognitive mapping has attracted immense interest from many fields, creating collaborative and cross-disciplinary research. The study of cognitive maps enjoyed almost two decades of growth, until its decline in the early 1980s. By the 1990s, the new cross-disciplinary exchange with computer science and information technology has renewed interest in the field, which may be the next wave of cognitive mapping research explosion. This study will, through the development of an innovative tool and an in depth analysis of cognitive maps, namely, sequence, search for links between sequence and other variables, namely sketch map type classification, sketch map drawing processes and differences between female and male sketch maps.

The methodological tool, namely MMAPIT, was a different approach from past studies to collect sketch maps. MMAPIT was a combination of hardware (Tablet PC) and software that allowed subjects to draw their sketch map directly on the tablet and recorded the drawing process in audio and video format. The drawing process was transcribed producing the sequence or order each element was drawn.

The sequence data not only generated new ways of examining sketch maps, they also produced results worthy of note because of the new methodology used and the pairing of unlikely results. There were four major findings from this study, namely the fish tail graphical pattern, six ways to draw sketch maps, division of the landmark element into subgroups, and differences found between female and male produced sketch maps. The fish tail is a pattern resulting from the graphical presentation of the proportion of elements drawn at each sequence. This pattern showed the increase of landmarks and the decrease of paths throughout the graph. A second use of sequence was a method to classify sketch maps into map types including sequential, spatial and hybrid maps. Sequences were also input into a software, namely ClustalW, to cluster groups of subjects with similar sequence strings. This method not only classified map types but also revealed that sketch maps can be drawn through recalling elements in six different ways. These six drawing methods all started with paths, suggesting their importance as a framework for sketch map building. The recall order of elements is part of a larger study in psychology termed sequential spatial memory. In addition, this study also found gender differences; females drew more landmarks while males drew more paths.

This study has only uncovered the beginning of the sequence puzzle. A larger sample population, cross-disciplinary work and investigation on links between sketch map sequence and memory are required to further our understanding of peoples' perception of the environment and how that is reflected in the multilayered sketch maps. This understanding can lead to modelling peoples' sketch maps followed by predicting travel behaviours.

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Chapter 1

INTRODUCTION

Human beings have relied on drawings as a communicative tool prior to the creation of language. These pictures include cave drawings, petroglyphs and maps (Gelb 1963; Taylor et al. 1992). Although drawings were collected from different cultures at various historical times, they were strikingly similar. Taylor et al. (1992) observed that the prevalent commonalities between pictorial representations and the underlying systematicity reflect universal cognitive predilections. In this thesis, the drawing under investigation is the sketch map. A sketch map is a hard copy that captures space and time in a static form through the sequence of drawing. It has been used as a communicative method between people, such as giving directions or organizing spatial information. The recall sequence of spatial elements is known in psychology as spatial sequential memory. In this thesis, sequence is used to define different ways of recalling spatial image and elements. This sets the platform for future research on people's spatial intelligence and travel behaviour by examining sequence and sequential spatial recall. The main objective in this thesis is to explore the universal cognitive predilection with sequence of sketch map creation. A review of sketch map history is introduced below followed by thesis objectives.

In the early 1900s, Trowbridge (1913) introduced the term 'imaginary map' from his study of 'civilized men'. An imaginary map is essentially a map held in one's head that assists people in their navigation. Three decades later, Tolman's (1948) term 'cognitive map" became widely accepted and succeeded the 'imaginary map' concept. Gould (1974) refined Tolman's concept further by using a ranking method to elicit preference of place in the United States of America, coining the concept of a 'mental map.' The terms 'mental map' and 'cognitive map' are widely used in the literature, however, there are different opinions on these two concepts. The variation in definitions is a result of the multidisciplinary nature of the cognitive mapping field (Kitchin 1994). Some researchers use the terms interchangeably while others make a distinction between the two. In this thesis they are treated synonymously.

The study of cognitive mapping was at its height from the 1960s to the 1980s. It was a prosperous period of research where various methods and techniques were experimented within an interdisciplinary forum. The research attracted attention from numerous fields including geography, planning and psychology. Geographers used sketch maps, a cognitive map that is drawn on hard copy, usually paper, to study differences between real world elements and their cognitive representation. Psychologists developed theories to explain why and how people saw the environment they represented on sketch maps. Planners attempted to apply cognitive mapping approaches to the design of city landscapes.

The theories, applications, methodologies and knowledge resulting from this research on cognitive maps collectively formed a significant contribution to the spatial cognition literature. However, as quickly as this research area was ignited by Lynch (1960) through his influential book entitled "The Image of the City", it waned as rapidly in the 1980s. Lynch was influential because of his innovative methodology and imageability findings with the use of interviews and sketch maps. In this context, imageability is defined by Lynch (1960) as "quality in a physical object which gives it a high probability of evoking a strong image in any given observer. It is that shape, color, or arrangement which facilitates that making of vividly identified, powerfully structured, highly useful mental images of the environment" (pg. 9). He also examined macro concepts including the development of five elements of urban images, namely paths, landmarks, nodes, edges/boundaries and districts.

Many studies from the 1960s to the late 1970s used the sketch map as a tool to collect cognitive maps while others compared the sketch maps to the real world or hard copy maps. By the 1980s, research in cognitive mapping slowed substantially. By the 1990s, momentum in cognitive mapping revived but the focus shifted to creating innovative methodologies to collect new datasets, which were then used to generate new spatial knowledge. Researchers who participated in this latter research concentrated on developing models based on rules captured from past cognitive mapping studies to simulate how people view their environment (Kearney et al. 1997; Banai 1999) and to predict how people make travelling decisions (Singh 1996; Kuipers et al. 2003). Sketch maps, once a popular tool in the past, have been over shadowed by the current direction of cognitive mapping, which has forgone the simpler methods to collect information and replaced them with more sophisticated technology. Nevertheless, sketch maps have been used in some recent studies, although no longer as the sole method (Everitt 1998; Cinderby 1999; Bell 2000). Everitt (1998) and Cinderby (1999) used sketch maps along with interviews to identify the environmental perceptions of Manitoba, Canada and Northern Cape, South Africa respectively. In a different approach, Bell (2000) explored wayfinding through sketch maps, complemented with memory tests.

By studying and revisiting the topic of cognitive maps, in particular sketch maps, the goal of this study is to research on gaps in the literature and examine research possibilities that were missed in this field during its period of prominence. Although the literature on cognitive maps contains research and findings ranging from metric distortions between sketch maps and actual maps, peoples' environmental perception, and environmental learning theories, there is a paucity of published work on new methodologies to collect environmental sketch maps and on the sequential process of sketch map creation. In this context, the sequence of sketch map creation is defined as the order that each element in a sketch map is drawn (Lynch 1960). Lynch (1960) was the pioneer of the concept of map sequencing, as he believed that it might be important to learn about element interrelatedness and the perception of urban space. However, there has been limited research on this topic, and no apparent research has attempted to make the links between the sequence of elements and the resulting patterns with urban perception.

Sequence is unique in that it combines space and time. When a subject draws their sketch map, the underlying cognitive process is a recall of their movements through space and time in an ordered manner. The process of recall is studied in cognitive psychology and termed as sequential spatial memory. Thus the traditional ways of examining sketch maps do not show how the image of a city is acquired, stored and recalled. Rather, the sketch maps must be seen in a three dimensional representation through space, time and sequence. Through past sketch mapping studies, research has extracted information including spatial perception, distortions of real space and hierarchical organization of elements. Yet few researchers noticed sequence that is embedded within the process of sketch map drawing. Sequence is set of data stemming directly from sketch maps that needs to be explored as it relates to larger concepts of memory and performance in memory related tasks, both spatial and non-spatial.

The paucity in sequence research is strongly linked to past sketch map collection methods. Sketch maps have been analyzed with many methods, but typically only on paper. A new way to examine sketch map is to analyze them within a Geographic Information System (GIS) environment. Although this approach is not prominent, a few researchers have used GIS technology to study sketch maps through community participatory studies (Weiner et al. 1995; Tagg et al. 1996; Cinderby 1999; Cinderby 2004). Kwan et al. (1998) have also stressed the importance of integrating sketch maps into a GIS environment for the benefit of transportation studies. An innovative way to examine sketch maps is addressed in this thesis, through a tool called **M**ental **M**ap **A**cquisition **P**roject using **I**nnovative **T**echnology (MMAPIT). The name describes a research project that uses innovative technology to collect mental maps. In this research, the most important function of MMAPIT is its ability to collect sequence data.

1.1 Statement of Research Problem and Research Objectives

Lynch's (1960) work has opened many possibilities of research because sketch maps reveal urban perception, urban structure, activity space and the potential to model our activity space within the urban environment. This study is part of a larger study that investigates travel behaviour and modelling such movements, of which only a small part will be investigated in this thesis derived from two objectives. The first objective is to develop a methodological tool that can preserve the quality of drawn sketch maps and collect sequence data. Second, is to investigate the order that elements are recalled while drawing a sketch map. This is accomplished by analysing the sequence of sketch map creation.

1.2 THESIS OUTLINE

The thesis is divided into six chapters. Chapter Two provides a literature review on past cognitive mapping studies, with a focus on methodology. It serves as a framework to unify two concepts of the thesis. First, to develop a new methodology that addresses the limitations and builds on the strengths of past methodologies. Second, to learn whether sequence, which can be derived from the new methodology, provides researchers with new insights on the sketch map creation process.

Chapter Three describes the methodology, which, itself, is built from the methodological foundation of other researchers and the research gaps identified in Chapter Two. This chapter discusses the initial testing of equipment, selection of software and subjects, survey design and specific technological issues encountered in the research process.

Chapter Four describes the results, which are divided into two sections. The first section is a stringent evaluation of the methodological tool developed for this study (MMAPIT). The second section analyzes the quantitative data produced from qualitative verbal data.

Chapter Five discusses and interprets the data and results obtained from MMAPIT. This is followed by Chapter Six which concludes the thesis. This chapter suggests future research analyses, directions and improvements to the methodology. Finally it reviews and summarizes the methodology and major sequence findings and evaluates whether the objectives of the study were met.

Chapter 2

LITERATURE REVIEW

This chapter reviews the origin and direction of cognition mapping research. The first part of the chapter explores past cognitive mapping research. The second part is a review of sequence and element interrelatedness in sketch maps. This is followed by a discussion of the past methodological approaches used to collect sketch maps. The final component of this chapter presents a set of hypotheses stemming from research discussed and the objectives stated in Chapter 1.

2.1 PAST AND PRESENT OF COGNITIVE MAPPING RESEARCH

The initial concept of a cognitive map started with the idea of an 'orientation inside the head', as discussed by Trowbridge (1913). He hypothesized that 'civilized' people and creatures of lower order had different navigation methods, coining the concept an 'imaginary map'. Trowbridge (1913) concluded that there were seven types of imaginary maps and that the function of the imaginary map was to locate landmarks relative to a person's home.

The term imaginary map was succeeded by Tolman's (1948) concept of a 'cognitive map'. This concept arose from Tolman's experiment on the wayfinding behaviour of rats to locate food sources. He found that rats used trial and error to locate the best route to access food in a new maze that contained more routes to choose from than a maze that they had grown accustomed to. These findings led Tolman to speculate that human beings may also possess a similar cognitive map used for navigation in the physical environment.

Another term was adopted by behavioural geographers, namely a 'mental map', made popular when Gould (1963) first presented the idea, followed by a more concise definition by Gould et al. (1974). Gould asked subjects to rank places for different types of desirability, including but not limited to place of residence and national security. Gould (1974) suggested that people form mental maps of their environment. A mental map by definition is a visual display of mapped spatial preferences.

The three terms, imaginary map, cognitive map and mental map all suggest that our internal knowledge and representation of the external environment are retained in map form or, at least, resemble actual maps (Cadwallader 1979). However, this view has been questioned by some researchers (Downs et al. 1973c; Hart et al. 1973). The root of the divided views are explained by Downs et al. (1973) as stemming from the term 'map' which is used in cognitive map and actual or topographic maps but does not necessarily mean the two are the same. The term was used to show the functional rather than physical similarities between a cognitive and topographic map.

The process surrounding the study of cognitive maps is defined as cognitive mapping. Downs et al. (1973a) define cognitive mapping as:

> 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. The product of this process at any point in time can be considered as a cognitive map (pp. 9-10).

When the extraction of information from a cognitive map is done through drawing, this is called a sketch map. It has also been referred to as a 'manual map' (Rothwell 1975), however this term did not pick up in popularity.

Since the inception and acceptance of cognitive mapping, the research has expanded, bridging subjects such as geography, cartography, psychology, urban planning, anthropology, sociology and architecture (Moore et al. 1976; MacEachren 1992). Cognitive maps are of interest to these subjects for many reasons. Tuan (1975) lists five comprehensive reasons for its acceptance in geography:

- cognitive maps make it possible to give directions to a stranger
- cognitive maps make it possible to rehearse behaviour in the mind before going on the road
- cognitive maps are mnemonic devices that help us remember events, people and things based on their true or assigned location
- cognitive maps are an organization and storage of knowledge
- cognitive maps are imaginary worlds.

Cognitive mapping research has since expanded in many directions, falling into two research strategies, identified by Stea et al. (1970). The first strategy was a holistic approach that examined the overall system, identifying and describing elements, in an attempt to isolate interactions between elements. "On this level, a major concern is the establishment of purely functional relationships between, for example socioeconomic status variables and the cognition of different segments of the environment" (Stea et al. 1970, pg. 7). Representative research of this type usually employed sketch maps, where the analyses were qualitative (e.g. Ladd 1970, Appleyard 1970 and Rowntree 1997).

The second strategy was "a searching attempt to analyze the system interaction which has been isolated previously" (Stea et al. 1970, pg. 7). The focus of the second strategy was on the interactions between sets of variables that are within a set of system parameters. For example, knowledge of relationships and parameters can be used to create models to predict how people code information. Almost a prerequisite in the second strategy is the use of quantitative methods. Research that demonstrates this strategy includes Lee (1970), Kuipers (1978), Thorndyke et al. (1982), Moar et al. (1983), Lloyd (1989), MacEachren (1992), Kuipers et al. (2003).

Kuipers (1978) developed a model which simulated human common-sense knowledge of large-scale space named TOUR. This model was further developed and enhanced by Kuipers et al. (2003). The foundation of the enhanced model is a wayfinding 'skeleton' composed of 'major' paths. Logical rules were used to predict human wayfinding, one of which demonstrates a positive-feedback system where paths that are used frequently tend to be used more frequently (Kuipers et al. 2003).

Another quantitative area of research is distortions. Thorndyke et al. (1982), Moar et al. (1983), Lloyd (1989) and MacEachren (1992) examined whether there were differences in environmental knowledge between subjects who learned of the environment through navigation or through a map. These researchers arrived at different conclusions. Thorndyke et al. (1982) found that subjects who learned landmarks through navigation performed better on distance estimation tasks and orientation judgments than subjects who learned from a map. Moar et al. (1983) found that angular and directional properties were misjudged on sketch maps, whether the source of knowledge was from real maps or direct experience with the area. However, Lloyd (1989) found that subjects who learned landmark locations from a map did not perform as well as subjects who learned them through navigation. MacEachren (1992) conducted a similar study to Lloyd (1989) and found similar patterns in navigation versus map learners.

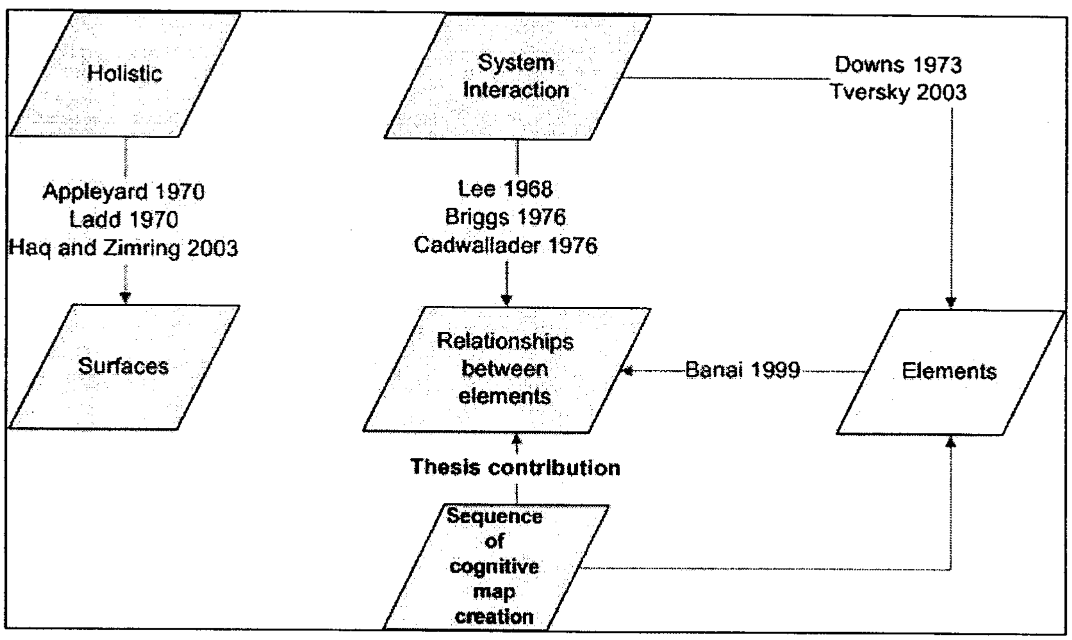
A related topic to sketch mapping is learning how people develop and acquire their knowledge of space. Montello (1998) revisited an older framework which he labelled the 'Dominant Framework'. A few authors, including Hart et al. (1973) as well as Siegel et al. (1975), have written about the interaction of landmarks, route knowledge and survey knowledge which form the basis of the Dominant Framework. Montello (1998) modified and expanded on the Dominant Framework to produce a new framework attempting to explain how people acquire their spatial information in a large-scale environment.

Although the two research strategies proposed by Stea et al. (1970) are different, they work in tandem with each other, as illustrated in Figure 2.1. The first strategy identifies general patterns or relationships between elements which are the foundation for research hypotheses. The second strategy tests the hypotheses and then models them. A few researchers have successfully bridged the two strategies, including Lynch (1960), Appleyard et al. (1964), Spencer (1973) and Rothwell (1975). Using both research strategies to examine sketch maps is particularly relevant to this research.

Stea et al. (1970) further identified three major research foci that fell under the two research strategies described above. These are elements (identifying the main elements and their interrelatedness), relationship between elements (metric distance of sketch map elements, orientation framework that relates the elements), and surfaces resulting from the relationship between elements (boundary of surface, do interrelationships between elements create a surface, the continuity/discontinuity of surface). During the classification of sketch mapping studies into the above categories, Stea et al. (1970) expected to find a maturing field of environmental perception, but were surprised to find only a "pubescent adolescent" (Stea et al. 1970, pg. 11).

Since Stea et al. (1970) paper, the direction has not changed much from what they described. Although researchers are now using new tools to visualize, analyze and model sketch maps, there is a research gap that has not yet been examined. This paucity in the literature concerning the sequence in which the elements are drawn is discussed later in the chapter. Figure 2.1 is a summary of past research conducted in the cognitive mapping field and where they fit into the strategies and foci. The two research strategies namely Holistic and System Interaction are shown to be linked directly to the three major foci, namely elements, relationship between elements and surfaces. A great deal of the cognitive mapping research discussed in the literature review fall into the Holistic and Surface research strategies while a smaller proportion fall into the System Interaction research strategy and its related foci groups. In particular, this study contributes to two research foci, namely elements and relationship between elements.

Figure 2. 1 Summary of Past Cognitive Mapping Researchers Organized by Research Themes



Modified from Rothwell (1975)

Figure 2.1 summarizes cognitive mapping research explored in the past and shows the research trends. These trends and major cognitive mapping research areas, namely sketch map research trends, sketch map distortion compared to actual maps, map type classification, map element interrelatedness, and sketch map sequencing are discussed in subsequent sections.

2.1.1 Sketch Map Research Trends

During the formative years of cognitive mapping research, there tended to be a focus on theoretical understanding and therefore less emphasis was placed on developing innovative methodologies to extract cognitive maps. Efforts were focused on theoretical understanding to improve knowledge of people's actions in and thoughts of space, but innovative creation of methodology suffered. The dearth of innovative techniques in the 1980s not only revived the use of methods developed in the past two decades but they were also accepted as given (Kitchin 2000). However, by the 1990s, there was a growing revival of interest in cognitive mapping research, from which new cross-disciplinary links between geography and psychology were renewed in addition to new links between geography with computer science and information systems (Kitchin 2000). A key focus of the newly developed interest in cognitive mapping was innovative methodologies and their role in generating new spatial knowledge from original datasets. The renewed interest can be credited to the growing spatial information technologies such as GIS.

2.1.2 Distortion in Sketch Maps

There have been many studies on distance distortion, all using different methodologies. However, there is no clear consensus on the level of distortion, what definite environmental factors contribute to distortions, or the best methodology to study this. Although much work has contributed to the literature on distance distortion, the distance estimates differ depending on the methodology used, making comparisons and identification of relationships between physical and cognitive distance difficult (Day 1976; Cadwallader 1979).

At the height of cognitive mapping research, different parts of cognitive maps were studied. First, distortions between map elements and ground objects were investigated in depth (Canter et al. 1975; Cadwallader 1976; Day 1976; Pocock 1978; Cadwallader 1979; Gale 1980; Tversky 1981; Lloyd et al. 1987; Lloyd 1989; Wakabayashi 1990; Tversky 1992; Wakabayashi 1994).

Canter et al. (1975) compared straight line distance estimates in Glasgow, Sydney and Tokyo and found that over- and under-estimation occurs in Tokyo (city of confusing image) and Glasgow ('legible' city). Tversky (1981) found alignment and rotation distortions in subjects' memories of location. From the sketch maps subjects produced, Tversky (1981) found that all subjects drew 60° intersections as if they were at 90° to each other, whereas thirty-five of the forty-five subjects drew 115° street intersection as 90°. Wakabayashi's (1994) work on sketch maps of Japanese cities also found alignment and rotation distortions confirming Tversky's (1981) findings. Furthering the findings of distortion, Tversky (1992) found three cognitive processes that cause systematic errors in spatial representation, namely categories or hierarchal organization, cognition perspective and cognitive reference points.

Much interest has been focused on the cognitive distance accuracy of map elements and ways to measure and make sense of map distance data (Pocock 1978; Säisä et al. 1986; Gärling et al. 1989; Lloyd 1989; Péruch et al. 1989). Most of these distortion studies were conducted under the assumption that metric information is imbedded in sketch maps. However, Cadwallader (1979) found that people do not represent physical space in mathematical ways on sketch maps. The study direction on sketch map metric distortion has shifted from mathematical comparison between sketch maps and ground elements to developing ways to evaluate and validate distortion-measuring techniques.

Although the subjects, locations, and variables used in these studies differ, there are some common findings between them. Péruch et al. (1989) found that subjects' estimations of travel distance exceeded those of straight-line distance from two locations, a similar finding to Säisä et al's (1986) study. Pocock (1978) reviewed factors within a city design that might cause inhabitants to over- or under-estimate distance, such as clear boundaries like a river or rail network.

2.1.3 Sketch Map Classification

In the 1970s a diversion in sketch map studies developed. The new research method used topological characteristics of sketch maps to classify them into categories. Ladd (1970) and

Appleyard (1970) independently developed sketch map classification systems. Ladd's (1970) classifications were not so much classifications but grouped sketch maps according to the degrees they resembled an actual map. Ladd (1970) developed four tiers ranging from a sketch map resembling a pictorial drawing to resembling a map with identifiable landmarks.

Sketch maps can be assigned to any classification by subjective observation. However, a more objective and satisfactory classification system was needed. This was provided by Appleyard (1970) who classified sketch maps drawn by subjects recruited from a steel town in Venezuela, in two ways, namely, 1) similarities between maps 2) accuracy of maps. As a result, Appleyard (1970) identified two major map types, namely sequential maps which are dominated by paths and spatial maps which are dominated by landmarks. Both map types were subdivided further by sequential or spatial characteristic into four subgroups. Appleyard (1970) found that the majority of map types drawn in his study belonged to the sequential map type (75% of total).

This research has been further explored by Pocock (1976b) who studied differences in sketch map types between visitors, tourists and residents in Durham, Britain. The results are similar to Appleyard's (1970), where the overall majority of map types were sequential, although the percentage is lower in this study. Pocock (1976) refined Appleyard's (1970) categorization by creating five subdivisions among sequential maps and six subdivisions among spatial maps. The results of the research by Appleyard (1970) and Pococok (1976) were replicated and confirmed by Wong (1979). Although the results are convincing, Murray et al. (1979) offer reasons for the dominance of sequential maps. Murray et al. (1979) noted that the spatial scale subjects were asked to draw at affects whether the map becomes a spatial or sequential map. Murray et al. (1979) found that 85% of sketch maps at the world and regional level were spatial maps, whereas 60% and 30% respectively of local and town maps were sequential maps and not surprisingly all sketched route maps were sequential.

Murray et al. (1979) used Pocock's (1976b) classification scheme but found it difficult to apply and generated different results. The low inter-rating reliability found by some authors, for instance Kitchin (1995), suggests that some classification schemes lack reliability Kitchin et al.

(2002). The lack of confidence in past classification methods lead to one of the hypotheses in this thesis that sequence can be a criterion to classify sketch maps.

2.1.4 Gender Differences in Sketch Maps

Many researchers have found differences between female and male performance on cognitive tasks. However, this section will only focus on the differences found by sketch mapping studies. Differences between female and male abilities were found in both sketch map appearance and retrieval strategies (Siegel 1981; McGuinness et al. 1983; Matthews 1984; Miller et al. 1986; Galea et al. 1993). A notable difference is that female subjects recalled more landmarks in the drawing than did male subjects. Instead, male subjects relied on orientation and direction, with the aid of paths, to create sketch maps (McGuinness et al. 1983; Galea et al. 1993). One explanation for this difference is rooted in human being's evolutionary past and the division of labour loosely known as hunter-gather. The hunting lifestyle required males to travel over a larger space away from home. The hunting and warfare lifestyle may have contributed to males' need for geometric relationships in space (Geary 1995). Females were responsible to collect and forage for food which would have required skills such as recognition and recall of landmarks as well as memory of objects' location (Eals et al. 1994).

Although many researchers found differences between female and male performance on sketch map drawing and cognitive tests, other studies did not (Newell et al. 1972; Kitchin 1996a; Kitchin et al. 2002). Newell et al. (1972) and Kitchin (1996) asked undergraduate students to draw a sketch map in addition to other cognitive tests. Neither study found differences between genders on spatial ability or geographic knowledge. Kitchin (1996) suggested that after the age of eighteen gender differences have little influence on the performance of cognitive tasks. Feingold (1988) explains that the lack of gender difference is due to a function of time such that differences observed in past studies maybe diminishing or disappearing over time. Other researchers admitted that there are gender differences but both genders perform well on different types of spatial tasks (Self et al. 1992).

The adaptability and evolutionary changes of people leads to the proposition that there is no quantitative difference between female and male produced sketch maps. The data collected from this study allows for tests of the hypothesis that there is no quantitative difference on sketch maps between genders.

2.1.5 Interrelatedness of Elements in Sketch Maps

The bulk of sketch map research is focused on the final product, in particular the metric relationship between real world and map elements, not only neglecting the process and sequence of creating the sketch maps, but also the relationship between elements in the map creation process. The literature of element interrelatedness is rudimentary, and has been the subject of study by a handful of researchers spread over decades. Lynch's (1960) research attracted Devlin (1976), Ladd (1970) and Wood (1976), who counted and compared the number of different elements on a sketch map. Lee (1968) calculated the proportion of landmarks per total elements drawn on a sketch map, further breaking down the classification into specific landmark types, namely areas, houses, shops and amenities. Ladd (1970) and Everitt (1998) described the general organization and observations from the number of elements drawn.

Denis (1997) found from two separate interviews that 35% of the total verbal description time was focused on linking landmarks to action (turn right at this landmark etc.), 39.7% to introduce landmarks and 9.8% describing landmarks. The values were very similar for both experiments. This shows that verbal route description is dominated by topological information rather than metric information such as distance between elements. From this study, Denis 1997 concludes that a good descriptive strategy is to utilize visible landmarks to give directions. This is supported by Allen et al. (1978) who concluded in their work that landmarks serve as organizing features. Data collected through an interview or discourse are important, as shown by Lynch (1960) who found that elements were less frequently sketched than mentioned such that elements of lowest frequencies in the interview were more likely to be excluded from the sketch map.

Not only were Lynch's five elements widely used by researchers to quantify sketch map elements, but their validity was also widely accepted. Nevertheless, some researchers questioned whether the five elements were as prominent on sketch maps of different cities and even modified the five elements down to three, specifically place, path and domain (Norberg-Schulz 1971). Pocock (1976a) replicated Lynch's (1960) study and found that the five Lynch elements did not transcend all towns, classes and cultures. Pocock (1976a) found that landmarks and paths were the most prominent element while district and node were so minimally recalled that it was grouped as a subcategory of 'area' and the term 'edge' was dropped. The only similarity between Pocock's (1976a) and Lynch's (1960) study is that the number of landmarks was greater than that of paths. Aragonés et al. (1985) further pursued Lynch's elements and found empirical support for them. Emerging from their research is that the edge category is ambiguous and not widely used by subjects to reconstruct their image of a city. The inconsistent representation and knowledge of elements is a proposition that element recall is dependent on the city of residence. The data collected with MMAPIT tests one of four hypotheses in this thesis. The null hypothesis states that subjects from urban and suburban residence have different sketch map creation sequence.

Most recently, Banai (1999) studied the interrelatedness between pairs of Lynch elements, asking subjects to compare quantitatively and rank the elements they knew best on their university campus. Banai (1999) found that the importance of the elements to the legibility or perception of the campus in descending order are nodes, landmarks, paths and a tie between edges and districts. Although the studies are promising research, the study on interrelatedness between elements is as limited as the study on sequence, discussed below.

2.1.6 The Study of Sequences in Creating a Sketch Map

As described above, there has been extensive research on sketch maps with researchers creating, debunking, and confirming each other's findings. In particular, a wide range of research topics were initiated from Lynch's (1960) work, including but not limited to perception of the environment, element interrelatedness and pattern, public participation, creating sketch maps and sequence of elements. Of these topics, map element sequencing has received the least research attention in the published literature.

A summary of researchers who have studied sequencing, directly and indirectly is shown in Table 2.1. Lynch (1960) does not provide a definition of sequence but only refers to it as the "sequence of drawing" (Lynch 1960, pg. 155) and is optimistic that in future work on cognitive mapping "pattern and sequence considerations will be a primary direction" (Lynch 1960, pg. 159). After reviewing Lynch's (1960) work where sequence was mentioned, both in his sole authored work, and collaborative work with other researchers, Banerjee et al. (1977), there is no specific definition of what sequence means but it can be interpreted as the order in which subjects draw or verbally identify elements in their sketch map drawing. In this thesis, the term 'sequence' is used to describe the order in which each element is drawn on a sketch map.

Table 2. 1 Summary of Researchers who Conducted Research on Sketch Map and Sequence

Sequence research area	Method of data collection	Type of data collected	Example of researcher
Hierarchy	Listing of landmarks	Order of important landmarks	Stevens et al. 1978 Hirtle et al. 1985 Péruch et al. 1989
Sequence of elements drawn on sketch map	Pen/pencil and paper	Interviewer records sequence	Banerjee et al. 1977 Taylor et al. 1992
		Observational sequence	Lynch 1960
		Subject includes sequence while drawing	Wood 1973; 1976 Chase 1983
Sequence of elements captured from discourse	Verbal route description	Verbal recording (transcribed)	Denis 1997
Anchor Point theory	List of landmarks	Degree of knowledge of each landmark	Golledge 1978

It was not until a decade after Lynch's (1960) influential work on sketch map when Appleyard (1970) realized that the sketch map studies at the time did not investigate all variables stating "Maps picture spatial relationships which are very difficult to verbalize. That they do not usually indicate visual imagery, however, makes it important to devise other survey methods to fill out exactly how people structure their cities" (Appleyard 1970, p. 116). Appleyard (1970) suggested that sketch maps did not give a complete understanding of city structure, and noted that there was a need for survey methods designed to understand how people structure their city. The key idea here is that a different research angle must be applied to sketch maps, different from past research that focused on the final sketch map product, which is static. This new perspective was to examine the sketch map as it was being developed. Clearly, this suggests that the sequence should be examined. This need or gap for a new and innovative methodology is another niche that this thesis fulfils.

It is surprising that few researchers have made the link to study sequence and sketch maps. Two questions concern this absence of research, namely is there a literature void on the topic of sequence in sketch map creation? and, if a void exists, what are some reasons for this? Golledge (pers. comm., 2004) agreed that published material on sequence is lacking, and offers three reasons. First, researchers in the past lacked knowledge on experimental design and knowledge of survey methods, mainly a function of the academic immaturity of the research problem and simplicity of research methods in common use. Second, no recent research has been conducted based on the assumption that sequences are known and need no further research. Third, past experiments on sequences were observed or narrative and lacked rigorous documentation. Four, the concept of sequence has been trivialized thus receiving little research attention.

Nevertheless, since Lynch's (1960) initial research, a few researchers such as Wood (1973; 1976), asked their subjects to label each element as it was drawn on paper, in order to understand the sequence of the skeleton map construction. In another study, Banerjee et al. (1977) had the interviewers note the order in which elements were drawn. However, there was no discussion or analysis of sequence in either of these studies. Six years later, Chase (1983) studied novice and expert taxi drivers in Pittsburgh. He discussed briefly the sequence of drawing a sketch map, finding that the majority of taxi drivers drew a river first followed by streets and neighbourhoods. Even Cinderby (2004) who set up a camera to record the order of drawings did not discuss how this might be important.

Almost two decades later, Taylor et al. (1992) fulfilled Lynch's (1960) suggestion to study the sketch map sequence. Taylor et al. (1992) requested seventy undergraduate students to study one of three fictitious environments for five minutes. After this time, subjects were asked to sketch the map from memory and write a verbal description of the map. While subjects were sketching the map, the researcher recorded the order in which each element was drawn. An average recall distance for each pair of landmarks was calculated and input into a matrix then computed by ADDTREE (Sattath et al. 1977) which produced a hierarchy or tree from this. The horizontal path length represents the recall distances between places and the branches represent the degree of clustering (Kitchin et al. 2002). Taylor et al. (1992) found that the recall of landmarks followed in sequence from north to south of the fictitious environment. More surprising is the degree of similarity across subjects on the drawing sequence. This strongly suggests that recall of spatial elements and images occurs in a prescribed way. This technique has been studied in cognitive psychology and is termed sequential spatial memory. Human beings use this daily for information retrieval, for example recalling the alphabet or counting. Kosslyn et al. (1988) found that images are generated sequentially. The order of recall is similar to the sequence they were learned. Sequential memory has also been applied to language comprehension. Cataldo et al. (2000) found that children who comprehend language well had better memory for spatial and sequential location within text. If this finding is applied to sketch maps, then subjects with more developed sequential memory may have a better spatial sense of the environment.

Instead of using sketch maps, Denis (1997) examined sequence through discourse, where subjects were asked to describe a route. Denis (1997) found that each step along the route was reported in the order that the person sees it along the way. In particular, landmarks were given the most importance in the route description.

Although Golledge (1976) suggested ordering as an option to interpret sketch maps he also warned that there is the potential for misinterpretation in the sequence data. "For example, the subject may compile sketch and order things in terms of their perceived importance, size, or some other distinguishing characteristic. To interpret the ordering of elements in metric terms and to suggest that the ordering is based on their spatial proximity to the individual is misleading" (Golledge 1976, pg. 311). Unless the subject is egocentric and draws objects proximal to his/her reference point, metric interpretations based on sequence could be misconstrued (Golledge 1976).

In spite of the paucity of direct sketch map sequence research, there are studies that are closely related to sequencing, including hierarchy of elements (Stevens et al. 1978; Hirtle et al. 1985) and the anchor point theory (Golledge 1978). 'Hierarchy' in this paper is defined as the "reliable tendency of subjects to subdivide the environments and to draw or describe one set of features prior to another" (Taylor et al. 1992, pg. 494). The hierarchy of elements has been studied by a few key researchers including Golledge (1976), Hirtle et al. (1985) and (Stevens et al. 1978). Stevens et al. (1978) ran a series of tests to examine the errors resulting from inferential processes in spatial judgments. In one of the four experiments, undergraduate subjects were asked to indicate the direction between pairs of locations. One popular example was asking subjects the direction from San Diego, California to Reno, Nevada. Most subjects stated that Reno was northeast of San Diego but in fact it is northwest. Subjects may have inferred the relationship of the cities based on the relationship of the states, where Nevada is in fact northeast of California. The logic was that if Nevada is northeast of California, then Reno should also be northeast of San Diego. Based on similar city comparison errors, Stevens et al. explained this observation with a hypothesis that spatial information is hierarchically organized. Although the hierarchical organization is an efficient and economical way to store and save spatial information, the trade off is spatial distortion.

Hirtle et al. (1985) used free-recall data to generate hierarchical trees by using an algorithm called order tree algorithm. Subjects first cited a few anchor point landmarks, followed by less important landmarks. Hirtle et al. (1985) found clusters but the limitation was that the algorithm could have created hierarchies that never existed in the data (Hirtle et al. 1985).

Anchor point theory developed by Golledge (1978) illustrates the relationship between nodes and paths, showing that primary nodes and primary paths are linked in a hierarchical order. The resulting node-path skeletal network is filled in with more detail, creating a spread effect that develops into areal information such as neighbourhoods. The hierarchical order of cues (landmarks, paths etc) is divided into primary, secondary, tertiary levels and lower ordered nodes. The primary node represents the most well known cue, whereas the following levels reflect subjects' decreasing amount of spatial information, frequency of use and greater difficulty to recall (Golledge 1978). For example, an immigrant will place such places as home, work and grocery shopping centres in a hierarchical order where they function as anchor points. These primary level nodes are anchor points that set the behaviour space from which the immigrant can add more detail such as paths that links the primary anchor points. However, Golledge does not state the drawing sequence of the primary, secondary and tertiary nodes. Nevertheless, he proposes that anchor points are the foundation upon which the spatial hierarchy develops (Golledge et al. 1980).

The anchor point theory suggests that a subject will draw the elements they are most familiar with in the beginning of the sketch map. The data collected by MMAPIT and GeoLogger tests the hypothesis that the most frequented locations would be drawn first on a sketch map to serve as anchor points.

Closely related to the anchor point theory is the relationship between elements. Tversky et al. (1998) found that subjects described the environment in segments such that the background environments were drawn, followed by relevant landmarks which were placed within segments. Subjects used different perspectives to locate landmarks within the segments then interconnected these segments. The description of routes was constructed in the same hierarchical fashion. Tversky et al. (1998) also found that prominent or significant features were described first which is empirical data that supports Golledge's anchor point theory stated above. In addition to landmarks, paths were studied by Péruch et al. (1989) who identified a hierarchy in the organization of a street network. The levels they identified were organized into major highways, freeway segments and main roads which dominated over neighbourhood streets.

2.2 METHODOLOGICAL APPROACHES TO COLLECTING SKETCH MAPS

Sketch maps are created and used daily by people to give directions, or follow directions. The method of creation is usually with pen/pencil and paper. This section describes other methods of sketch map collection and their value in academic research. In addition, this section will compare similarities and differences between the two most popular methods of sketch map representation, namely sketch mapping and the nonmetric multidimensional scaling (MDS) method.

2.2.1 Sketch Map Methods and Applications

Cognitive mapping can be conducted in different ways, including psychophysical ratio scaling, psychophysical interval and ordinal scaling, mapping, reproduction and route choice (Golledge 1976; Richardson 1981; Montello 1991). However, the two most common practices are sketch mapping and distance estimation techniques (Brown et al. 1981).

The methodological processes of extracting sketch maps from subjects can be divided into four main groups, summarized in Table 2.2, namely drawing with pen/pencil and paper, interview with pen/pencil and paper drawing, addition of a field trip with the verbal and pen/pencil and paper drawing as well as using blocks to build a cognitive map. The first method of asking subjects to draw a sketch map has been widely used by researchers (Appleyard 1970; Devlin 1976; Wong 1979; Goldin et al. 1981; Hirtle et al. 1985). The simplest method is to ask subjects to sketch freely or to construct a map, usually by producing a map-like diagram on a piece of paper. The exact wording of the direction varies between researchers, but the common practice is to ask subjects to draw what they know about a given location. Depending on the research objectives, the researcher may require particular locations to be drawn on the map or allow subjects to draw freely. Any additional information verbalized by subjects about map components is typically not recorded during this process. The second method involves sketch mapping exercises with interviews which usually involves a tape recorder, or note taking verbatim by researcher conducting the interview (Lynch 1960; Appleyard et al. 1964; Lee 1968; Ladd 1970; Wood 1973; Everitt 1998).

Table 2. 2 Summary of Past Methodological Approaches used by Different Researchers to Collect Sketch Maps

Sketch map acquisition methods	Equipment	Output	Researcher Examples
Pen/pencil and paper	8.1/2 x 11 paper	Sketch map on paper	Appleyard 1970 Devlin 1976 Wong 1979 Goldin et al. (1981) Hirtle et al. 1985 Rowntree (1997)
Pen/pencil and paper Interview	Paper (paper size ranges from 8.1/2" x 11" or 14" x 22") Portable tape recorder	Sketch map on paper Verbal record of process (transcription)	Appleyard et al. 1964 Lee 1968 Ladd 1970 Rothwell 1975 Everitt 1998 Spencer 1973
Pen/pencil and paper Interview	Portable tape recorder	Sketch map on paper	Lynch 1960 Wood 1976
Field observations of subjects	Interview	Verbal record of process	Banerjee et al. 1977 Chase 1983
Building blocks to create a cognitive map	Small blocks 6 ft square board	A cognitive map display by blocks	Sherman et al. 1979

The importance of a verbal record is described by Denis (1997) as "the ubiquity of communication situations in which natural language is used to convey spatial knowledge justifies the development of research in this domain" (Denis 1997, pg. 410). Interviews are one way to complement the sketch maps and simultaneously accumulate information on the cognitive process (Ericsson et al. 1984). In addition, language adds another level of spatial information (Tversky 2000). The use of qualitative methodologies, both scientific and interpretative, is increasing amongst spatial knowledge investigations (Kitchin 2000).

The third technique builds on the first two, whereby subjects were taken on a field trip related to the area of their sketch map and were invited to talk about the environment along their journey (Banerjee et al. 1977). The fourth approach is a move away from the traditional sketch mapping collection method, where subjects were simply asked to create their cognitive map with blocks on a piece of cardboard (Sherman et al. 1979; Hirtle et al. 1985) to avoid differences in artistic talent. The subjects were permitted to reposition elements, making this method special because the map is both a stimulus as well as a response during the building process and a producing agent as well as product (Sherman et al. 1979).

Past methodologies used primitive methods to collect sketch maps due to a lack of technology, with exception of a tape recorder. There is, however, room to incorporate advanced technology to record simultaneously different types of data, such as verbal, sketch, and process of drawing. The computer offers a new opportunity for researchers to analyze data, through animations, sonifications, tactilizations and virtual reality, providing new ways to touch, feel and listen to data (Montello 2002). This opportunity was explored further in this study.

The various sketch map collection methods described above result in one common product, the sketch map. Sketch maps have been extensively used to investigate how people view their environment (Lynch 1960; Ladd 1967; Lee 1968; Pailhous 1969; Appleyard 1970; Spencer 1973; Rothwell 1975; Devlin 1976; Banerjee et al. 1977; Wong 1979; Rowntree 1997). As noted earlier, one of the most influential projects on environmental perception is Lynch's (1960) research. Lynch (1960) created five elements including paths, landmarks, nodes, edges and districts using sketch map data collected from his study. In addition, Lynch used sketch maps to examine urban imageability and how that contributes to city design, focusing on three American cities, namely Boston, Jersey City, and Los Angeles. This approach was adopted by others such as Banerjee et al (1977) who examined the perception of countries including Argentina, Australia, Mexico and Poland. Pailhous (1969) and Rowntree (1997) also used sketch maps as a tool to determine whether there were differences in perception of space due to demography. Pailhous (1969) found stark differences in the sketch maps drawn, due in particular to level of education, length of residence, gender, age and ethnicity. The study space employed by Rothwell (1975) is different from the above research as subjects were asked to draw a sketch map of their home floor plan. Lee (1968) and Spencer (1973) studied a broader scale, using sketch maps to examine the neighbourhood. Similarly, Devlin (1976) investigated the difference of sketch maps drawn by females who were new to the town of Idaho Falls, Idaho, then again how they faired three months later. Ladd (1967) and Wong (1979) studied sketch maps of ethnic groups specifically black youths and Chinese adults. Both researchers used sketch maps as a tool to solicit participation from community members and learn of their perception of neighbourhood. A comprehensive review of methods and their validity was explored by Montello (1991).

The product of a sketch map does not offer much information about what the subject knows. As Lynch (1960) found, there may be little similarity between a sketch map and interview of the same subject. Lynch's (1960) solution was to analyze subjects' sketch maps cumulatively, instead of individually. To achieve this, a composite map was created to reflect the details in each individual map. A few researchers followed after Lynch (1960) and analyzed the composite sketch map of all subjects (Francescato et al. 1973; Orleans 1973).

2.2.2 Comparing Two Methods: Sketch Mapping and Nonmetric Multidimensional Scaling (MDS)

Researchers have attempted to show the effectiveness of sketch maps compared to other methods that were developed at the same time (MacKay 1976; Baird et al. 1979; Magana et al. 1981; Richardson 1981; Buttenfield 1986). This is particularly important because there are so many ways to create a sketch map, as presented above. Naturally there are questions on the credibility of sketch maps because they are far from accurate when compared to cartographic maps or aerial maps (Downs et al. 1973b).

McKay (1976) was the first to examine the credibility of sketch maps compared with locational maps derived from nonmetric multidimensional scaling (MDS) techniques. Sketch mapping and MDS are clearly different methods used in an attempt to collect the same data. While sketch mapping exercises require subjects to draw a map, MDS requires subjects to estimate distances between pairs of locations in space. The values are input for analysis in a matrix form. The distances can reflect proximity, similarity, correlation, or other characteristics (Golledge 1978). While there are clear differences in approach, the two methods have produced similar results. MacKay (1976) and Buttenfield (1986) agree that sketch maps produced consistent placement of landmark over MDS because subjects received immediate feedback as they saw the progress of the sketch map but MDS was an abstract *ex post facto* interpretation of the environment. Baird et al. (1979) found that both MDS and sketch mapping on a computer were representative of the environment due to the similarity of the results they produced. Magana et al. (1981) had similar findings as other researchers. In general, Magna et al. (1981) found that constrained and unconstrained MDS and sketch maps were equally accurate for measuring geographic knowledge.

MDS is one of many distance measuring techniques in the field of cognitive mapping. A general criticism is the lack of research in the validity and reliability of these measures (Kitchin et al. 2002). Sketch mapping on the other hand has been tested for its reliability. The use and research of sketch maps is based on the assumption that there is reliability in this tool. Specifically, when a person draws a sketch map twice, the two products should not differ significantly. Blades (1990) asked subjects to draw a route they were familiar with, the asked the same subjects to draw the same route one week later. Blades (1990) found a high correlation between elements drawn on the first sketch map and on the second sketch map. The high degree of similarity suggests that sketch mapping is a reliable technique.

Further studies were conducted to determine how stimuli or reference points affected the sketch mapping and MDS methods respectively (Day 1976; MacKay 1976; Holyoak et al. 1982). Day (1976) found that the location of the first few points, whether they were reference points given to subject or points drawn by subject, would restrict the development of a sketch map. Holyoak et al. (1982) research supports Day's (1976) work that reference points distort distance and location judgment.

2.2.3 Integrating Sketch Maps in a Geographic Information System (GIS) Environment

In reviewing the literature of sketch map studies, it is obvious that very few studies have attempted to integrate sketch maps into a GIS environment, although attempts have been led by a few researchers. An early contribution was by Rothwell (1975) who asked subjects to sketch a floor plan of their home, then digitized the sketch maps to obtain XY coordinates for each wall intersection. Twenty years later, Weiner et al. (1995) developed sketch maps for a community in

Kiepersol, South Africa. These were digitized before integrating them into a GIS environment. The work of Weiner et al. (1995; 1996) and Harris et al. (2002) are unique, not only because they were the first to integrate sketch maps into GIS but that their use of sketch maps settled social conflicts. For example, the detailed sketch maps drawn by South African farmers proved the unreliability of government maps which portrayed false information. This brought attention to the deeper roots of apartheid discrimination, enforced by the law, government and local white farmers. Their work on sketch maps and GIS became important in a new field called public participatory GIS (PPGIS).

Tagg et al. (1996) also used GIS to conduct public participation interviews in Namibia, but went a step further by incorporating Global Positioning System (GPS) points into the study. The local community was asked to prepare a sketch map of each district, including segregation of important resources and resource areas, district boundaries and their patrol routes. In addition, GPS points of landmarks such as windmills and villages were collected. A basemap was prepared by digitizing features from topographic maps, sketch maps, satellite images, GPS points, information knowledge of village resident and authorities. In the same year, Singh (1996) developed prototypes to study sketch maps in a GIS. Using scripts, Singh (1996) was able to model Lynch's five elements in a GIS. The success of integrating Lynch's (1960) design concepts to GIS led Singh (1996) to argue for urban planners to use GIS.

Cinderby (1999) discusses a particularly innovative way to integrate sketch maps into a GIS and the benefits of this work. Cinderby (1999) not only integrated individual sketch maps into a GIS, he overlaid many individual sketch maps or group sketch maps, similar to the composite sketch map method used by Lynch (1960). This new method to analyze sketch maps identified the individual perceptions of the environment when viewed together as a group.

The few attempts at integrating sketch maps into GIS has prompted Kwan et al. (1998)to suggest for more research on representing sketch maps in a GIS environment. Kwan et al. (1998) explain that there are two purposes to this, first, to develop a recording process that collects information of people's sketch maps in a form usable by a GIS and second, to represent and incorporate sketch maps into a GIS since they do not necessarily register or scale properly with a basemap. Incorporating sketch maps into a GIS environment is fitting because sketch maps are multilayered, much like the internalized structure of a GIS database (Golledge et al. 1997), containing data that are coded and symbolized. The data collection tool, MMAPIT, developed in this study has been able to satisfy these two requirements.

2.3 Development of a Sound Methodological Tool

Methodology is crucial in any study because it provides the operational glue that binds data, analysis and the resulting conclusions. The three components, namely methodology, data and conclusions form an interrelated cycle where each component affects the other. Kitchin (1996b) studied whether conclusions can be influenced by the method of data collection and analysis by testing 279 first year undergraduate geography students on their spatial knowledge. Thirteen tests from four methods, namely graphing, partially graphic and reconstruction, uni-to-multidimensional and recognition method were administered. A few major findings resulted from this study. First, Kitchin (1996) concluded that the collection method affects the results as all thirteen tests produced varying results. Second, all tests introduced inherent bias into the analysis, therefore there was no superior test. Third, bias due to given reference points can be corrected and controlled.

Kitchin's (1996) study is important as it questions the popular techniques of the past and draws attention to the significance of the method and analysis design, since different methods designed to collect the same data produce different results. Kitchin (1996; 2000) concluded that the analysis design is of central importance to the type of results produced, stating that "test and analysis design are of critical importance, with different tests designed to measure the same knowledge producing significantly different results" (Kitchin 2000, pg. 15).

The MMAPIT tool plays a central role in the methodology and analysis design. Not only is MMAPIT a new tool, it has the potential to collect different datasets compared to past studies, thus allowing for new analyses and results to be explored. The expected analyses techniques and results are detailed in the hypotheses below which were derived from gaps or questionable results found in the Literature Review.

2.4 HYPOTHESES

The following hypotheses are explored in this study:

1. The sequence of sketch map creation can be a criterion with which to classify sketch map types
2. Elements that are more frequently used will be drawn first in the sketch map
3. The sequence of sketch map creation is different between subjects living in urban and suburban space
4. There is no quantitative difference between overall female and male sketch map elements.

2.5 CHAPTER SUMMARY

This chapter has given an overview of past approaches, research and methodology in the field of mental mapping. Although the work of mental mapping has been extensive, it is clear from this discussion that the direction of the field has concentrated in a few research areas. These areas include sketch map distortions compared to actual maps, use of sketch maps to understand human acquisition of environmental information, and the perception of the environment as well as the examination of typological features of sketch maps. The consequence of such focused research is that potential research areas are completely missed or ignored. For example, the sequence of sketch map creation and the interrelatedness of elements are two such research areas that have been neglected.

Since the cognitive mapping research declined in the early 1980s, there have been few methodologies developed and even fewer involving technology. In the next chapter, as an effort to resurrect innovation and interest in cognitive mapping methodologies, the MMAPIT approach is explained in detail. The description of MMAPIT is followed by an explanation of the data collection process which includes sketch maps, GPS traces and sketch map sequence strings.

Chapter 3

METHODOLOGY

This chapter first presents an overview of the methodological development. Next, the three study sites, namely Toronto, Scarborough, and Markham/Richmond Hill/Vaughan (MRV), all located in southern Ontario, Canada are described. In 2001, Toronto, post local area amalgamation, had an estimated population of 2,481,495. Scarborough, prior to the amalgamation and becoming part of Toronto, had an estimated population of 593,295. The average estimated population for MRV is 174,221 (Statistics Canada 2004).

Following the study site description, the chapter provides an overview of the MMAPIT tool and its components. Pre-tests of software and determination of appropriate reference points are discussed prior to the application of MMAPIT. A detailed description of the data collection process is followed by the data preparation process, including correcting the format, and giving a field heading to each GPS column followed by transcribing verbal data. The last part of the chapter details the steps to integrate data into a GIS environment.

3.1 Methodological Overview

The MMAPIT tool was built on a combination of sketch map methods (sketch map and verbal record) used by previous researchers (Lynch 1960; Banerjee et al. 1977; Everitt 1998), as well as a new way to examine sketch maps including the recording of sketch map drawing process. This change in data collection method not only allows collection of a different dataset from past studies, but it also allows several unique analytical opportunities to be established. Although MMAPIT attempts to integrate strengths and avert some of the limitations of past studies, it still has inherent bias, as noted by Kitchin (1996). For example, the nature of the tool does not eliminate such bias as scale which results from subjects' difficulty in visualizing map scale (Day 1976; Evans 1980), and subjects' discomfort from feeling overwhelmed, especially when there is no obvious end or constraint to the exercise (Day 1976). Nevertheless, MMAPIT, as a new methodology to collect sketch maps offers the potential for generation of new data and results never before collected by other methods. Moreover, it allows the sequence of sketch map drawing to be investigated more rigorously.

The MMAPIT tool was supported in part by a larger study funded by a Social Sciences and Humanities Research Council (SSHRC) grant held by Dr. S.T Doherty. The larger project seeks to understand human decision-making processes in travel behaviour and to model with rules that govern such actions. However, this study is a small part of the larger study and will focus specifically on the development of the MMAPIT tool and sequence in sketch map creation. In this study, MMAPIT attempts to 1) incorporates sketch maps into a GIS environment 2) provides another avenue to collect sketch maps 3) collects sequence of elements as they are drawn by recording the process of sketch map development 4) serves as an innovative tool in an exploratory study. Three further characteristics are important in terms of MMAPIT design and approach, namely the preservation of past methodological success, improvements to past methodological limitations and collecting a different dataset from past cognitive mapping studies. The first requirement lists indicators relating to the strengths of past methodologies that are retained in MMAPIT. These indicators are namely quality of sketch maps, ergonomic pen/pencil and paper feeling, visual display of sketch map as an immediate feedback to subjects and readability of maps for research. The most important indicator is the quality of sketch maps. Although the collection process differs slightly from past studies, it is expected that MMAPIT can produce sketch maps of similar quality compared to the products created with a pen/pencil and paper. The second indicator is to make subjects, as much as possible, feel as if they are using the traditional method of pen/pencil and paper method. The ergonomic and comfortable feel of MMAPIT is important for subjects to accept it as a substitute for pen/pencil and paper. The third indicator is that subjects must receive feedback, by seeing their sketch map as they are drawn, without lag time. The last indicator comes back full circle and is related to the first indicator. The importance of sketch map quality is crucial because subjects and researchers must be able to examine and make sense of them.

As described above, MMAPIT must be able to preserve quality aspects of previous methods. There are four limitations that MMAPIT seeks to lower, namely distortion, scale, increasing size of drawing surface and less cluster from labelling. Distortion is inevitable and displayed by all subjects. In Toronto, the distortion was so obvious that two reference points had to be rotated to make the direction easier for subjects to perceive. In turn, reference points in general, were used to indicate and control scale. The purpose was to give subjects an idea of distance and area estimation. Third, the size of the drawing surface was flexible, and not limited to the drawing screen size of 7.5" x 10". If subjects wanted to extend their drawing surface, they could use 'scroll' buttons to increase either the length or width of the drawing area. In addition to more drawing space, instead of the cumbersome task of writing labels on screen, MMAPIT can record each subject's verbalized name of each element, as it is drawn. It can be difficult to discern what the illustrated elements are on sketch maps, particularly when labels are absent. However, too many labels can clutter the map, leaving little room for other elements to be drawn. In this study, both verbal data and map elements were captured by a video software, without compromising each other.

The third requirement highlights the advantages MMAPIT has over past methods, emphasizing its innovativeness and usefulness. The four advantages include capturing sequence of map creation, collection of verbal data that matches in real time with the sketch map drawing process, immediate addition of sketch maps to a GIS environment, and moving away from the traditional pen/pencil and paper methodology. The most important feature is the ability to capture effortlessly the sequence of sketch map drawing by recoding the whole process followed by subjects on screen. Due to the video recording and sound recording, any verbal comments made about elements will match in real time to the drawing process. The third advantage is the ability to export immediately the sketch map into a GIS environment without digitizing. The lack of digitizing is only one of many indications that MMAPIT is a tool that is moving away from the traditional pen/pencil and paper method. The continued enhancements of new technology add possibilities for future designs like this one.

The hardware that comprises the MMAPIT environment includes a notebook computer called Tablet PC, which is part of a new generation of computers. It has a wireless pen that allows subjects to draw or write directly on the computer screen, which itself can be folded to form a flat drawing surface such that the screen serves as a drawing tablet. The screen dimension is 7.5" x 10", close in size to a piece of letter size paper of 8.5"x11". This form of notebook was chosen because it has the capability to emulate the feeling of drawing with a pen on paper. In addition, it collects digital sketch map data in an easy manner and moves away from the traditional pen/pencil and paper method of past sketch map collection approaches, which are difficult to assemble, collect and analyze.

The first software component of MMAPIT is a video capture package called Camtasia Studio produced by TechSmith (TechSmith 2003). It records, as video, all activities that occur on the computer screen in the form of an audio-video interleave format (.avi format), while capturing sound or voices produced respectively by the computer or subjects, as well as a timer to show the recording duration. The audio-verbal record and visual- video components comprise the qualitative data used in this research.

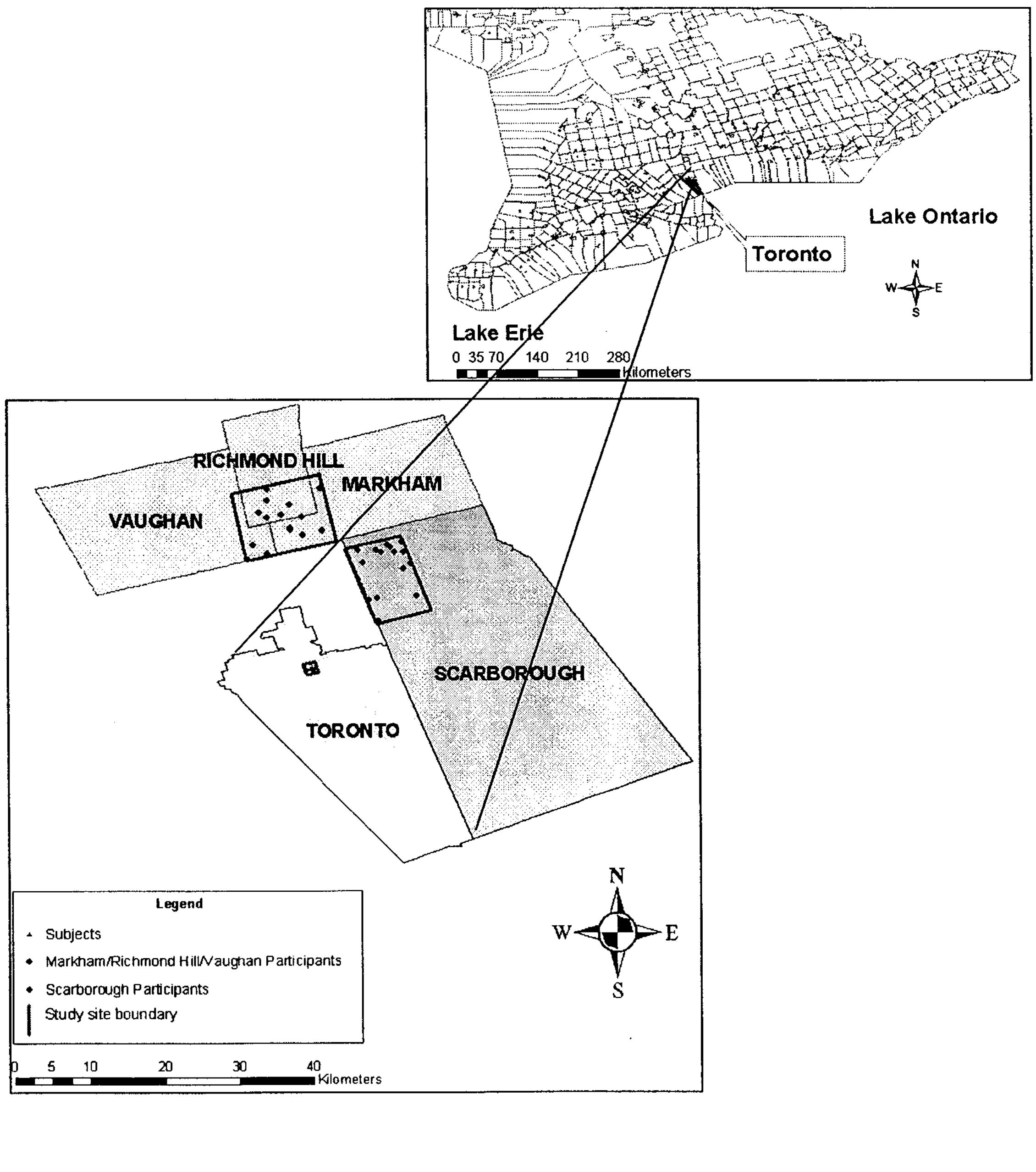
The second software component of MMAPIT is a drawing package, namely Corel Draw 9, produced by Corel Inc. Subjects use this software to draw their sketch map. This drawing package was selected from many for various reasons (explored further in section 3.2.4). One of the main reasons was the option to customize the interface. The goal of the customization process was to replicate the interface of simple drawing packages, by removing icons, easing the apparent complexity for both novice and expert computer users.

3.2 Pre- and Post Data Collection Processes

3.2.1 Study sites

Three study sites were selected for this study, namely the cities/towns of Toronto, Scarborough and MRV (Figure 3.1). According to the Organization for Economic Co-operation and Development (OECD) Toronto is classified as an urban centre, Scarborough, which was a separate city prior to amalgamation, is now a part of greater Toronto and Markham/Richmond Hill/Vaughan is a suburban/intermediate centre (Beshiri 2003). Difference city types were chosen to test the hypothesis that sequence in sketch map creation is dependent on city of residence.

Figure 3. 1 Location of the Three Study Sites and the 4x4 city Block Boundary from which Subjects were Recruited



The three study sites are characterized by different neighbourhood composition and urban planning. For example, Scarborough is characterized mainly by houses and some condominiums, as well as large plazas or 'generic big box malls' Unique shops are not readily visible and instead franchise stores are more evident. In MRV, the landscape is more typical of Scarborough than Toronto. There are many condominiums, large houses clustered into residential neighbourhoods, and newly developed areas. This is a reflection of classical suburban/edge development versus a classical older downtown exhibited by Toronto. Toronto is much more dense, although plagued by condominium development, it has older houses and unique, specialty stores. Toronto's mix use planning, different from the other two cities, creates dense areas of diverse land use, ranging from shopping to residential use.

The area covered by each study site is generally four city blocks by four city blocks. The size of a city block varies somewhat between areas, with an increase from the urban to suburban areas. Hence, the suburban study site in MRV spans three town boundaries, whereas Toronto spans two kilometres in length.

The boundaries of the study sites are shown in Figure 3.1. Toronto is bounded north to south by Isabella Street to Dundas Street and east to west by Sherbourne Street to Bay Street. Scarborough is bounded north to south by Finch Avenue to Eglinton Avenue and east to west by Victoria Park Avenue to McCowan Avenue. MRV is bounded north to south by Major Mackenzie Avenue to Steeles Avenue and east to west by Bathurst Street to Woodbine Avenue.

The three cities differ vastly, highlighted as one moves from Toronto to MRV. Statistically, Toronto is the most populated of the three cities and is also the most dense. In terms of income, MRV has the highest average income, followed by Toronto and trailed by Scarborough. The higher income in MRV may also be the reason why home ownership is the highest, and rental the lowest of all cities (Table 3.1).

Table 3. 1 Summary of Demographic Profile of the Three Study Sites

Demographic category	Toronto	Scarborough	Markham/Richmond Hill/Vaughan*
Total population	4,682,897	593,297	174,222
Area (square Km)	5,902.7	187.70	195.6
Total minority population	1,712,530	353, 165	6,770
Minority as a percentage of total population	36.6	59.5	38.9
Average income (15 years and over)	25,593	21,272	27,710
Employment rate	64.7	59.1	66.73
Unemployment rate	5.9	7.7	4.8
Number of owned dwellings	1,033,460	121,010	45,40
% of total population	22.1	20.4	26.1
Number of rented dwellings	601,80	73,15	6,16
% of total population	13.9	12.3	3.6

Source: Statistics Canada (2004)
* Value is average of three cities

3.2.2 Description of Subjects

A total of forty-five subjects participated in this study, with fifteen subjects from each study site. To ensure that a representative sample was used, subjects were randomly selected from a larger participant pool from a joint Wilfrid Laurier University/University of Toronto transportation study during the months of July to November 2003. The subjects fulfilled the following six criteria, namely 19 years or older, lived at current residence for a minimum of 2 years, employed full time, live within the boundaries of one of the three study sites but must work outside of the confines and be in city of residence during the week that the GPS device was carried.

The demographic profiles of subjects from the three study sites are similar except for average age and income (Table 3.2). In terms of residence length, 73% of Scarborough residents lived in the city for more than 5 years, whereas the remaining subjects were relatively new, only having lived between 2 to 4 years. Interestingly, the numbers are reversed for Toronto and MRV residents. In Toronto and MRV, 40% and 60% respectively, residents were long term, whereas the remaining 60% and 40% of the subjects had lived in the city for 2 to 4 years.

The data calculated for each site shows that average income is higher respectively in MRV and Scarborough than Toronto. The average age of subjects in Toronto and Scarborough is similar, 28 and 25 respectively whereas the average age of subjects in MRV is approximately 15 years older than the first two sample sites. Gender is split virtually down the middle where Toronto has seven females and eight males, Scarborough and MRV have eight males and seven females.

Table 3. 2 Summary of Subject Demographic Data by City of Residence (45 subjects)

Criterion	Toronto	Scarborough	MRV	Ontario*
Age	28	25	42	37
Average Income	$30 000	$40 000	$50 000	$32,865
Gender (F/M)	7/8	8/7	8/7	5,832,990/5,577,060
Average number of map use in the last month	1	0	4	
Long term* resident (5 + years)	6	11	9	
Intermediate resident (2 years to 4 years)	9	4	6	

Source: Statistics Canada (2004)
*Definition of long term and intermediate term residence acquired from Golledge et al. (1973)

Overall, the average age of the sample (32 years) and income ($40 000) is not that different from the equivalent values for the Ontario population as obtained from Statistics Canada for the same year (37 and $32 865 respectively). City by city, compared to the Ontario population, the average age of Toronto and Scarborough subjects are substantially younger by 12 years. Conversely, MRV subjects are closer to the average age. As for income, Toronto subjects earned close to the provincial average, where Scarborough and MRV subjects earned a great deal more than the Ontario average income.

3.2.3 Drawing Software

The use of Corel Draw 9 was determined after a process of stringent pre-testing, where three different types of drawing packages were examined. The ideal drawing package had to be user-friendly and intuitive for the subjects, as well as customizable so the researcher could make appropriate modifications. Subjects who participated in the pre-test were interviewed only for the purpose of determining the most appropriate drawing software package and had no further involvement with the project. Twenty subjects were recruited through emails sent to friends, family, and co-workers.

The three drawing software packages examined included a professional drawing package (Corel Draw 9), a low-end drawing package (Paint) and a pseudo-drawing package (Microsoft PowerPoint). A professional drawing package is specifically created for advanced graphic designs and has a wide range of drawing options. The software is targeted to professionals or avid users as there are more specialized functions available. A low-end drawing package is one with limited drawing functions and capabilities that include sufficient functions and options for intermediate users to create graphics. A pseudo drawing package is one that has other primary functions aside from drawing, however it has limited but simple drawing tools.

3.2.4 Drawing Package Pre-Test

Evaluation of the drawing software packages consumed approximately 13 hours, as each of the twenty subjects were individually interviewed for approximately 30 to 40 minutes. The basic commands of each drawing package were explained in detail before the subject started to draw. Each subject was asked to draw a sketch map of their neighbourhood in 5 minutes, each time using a different software package. The order of software presentation was kept consistent among all subjects, in order to reduce effects of learning differences caused by order of software presentation. Paint was presented first, followed by Corel Draw, with PowerPoint last. The interview was followed by personal questions including their age, computer literacy/comfort level, and their preference ranking of each drawing software package.

The purpose of asking personal questions was to evaluate and amend the types of questions and to review the layout efficiency of the database (interface, order of questions, drop-down list versus entering data) used by interviewer to record information at the actual interviews (explained in Section 3.2.5). After the personal questions, subjects were asked to rank (1 = least preference, 10 = greatest preference) each of the three drawing packages in terms of ease of use, overall feel of the software, preference for one software over the others, and other comments. The results from the pre-test are shown in Table 3.3.

Table 3. 3 Pre-test Preference Results to Select Software for Research Use (20 volunteers)

	Age	Computer literacy	Corel Draw (Overall)	Corel Draw (Ease of use)	Paint (Overall)	Paint (Ease of use)	MS PowerPoint (Overall)	MS PowerPoint (Ease of use)
Average	25	7.89	7.66	7.89	7.42	8.00	5.74	5.74
Minimum	18	1	6	6	5	6	2	1
Maximum	55	10	10	9	10	10	9	9

The most popular drawing package was Paint followed closely by Corel Draw 9, with MS PowerPoint ranked third. Paint is on all computers that run on Windows hence it is likely that subjects have had prior exposure to, or have even used the software. Corel Draw 9 was ranked second, which was surprising since only one out of twenty subjects had ever used the program. MS PowerPoint was ranked third as its drawing commands are not intuitive, nor is it as straightforward to use compared to the other two software packages.

Although the overall preference for Paint ranked slightly higher than Corel Draw 9, Corel Draw 9 was selected based on several factors. First, the interface of Corel Draw 9 can be customized to even out a lot of its complexity. Second, there are important but advanced functions such as rotation to rotate the Toronto reference points (explained in Section 3.3.1), which Paint lacks. Third, and, most importantly, the output generated from Corel Draw 9 can be read by a GIS package, which creates an attribute table, showing the order drawn with a row for each element. This, as suggested in Chapter Two, is of primary importance in understanding element sequencing.

3.2.5 Pre-test Questions

The second task involved the collection of demographic data, at the end of the sketch mapping exercise. During the course of the question period, the interviewer recorded answers directly into database forms on the notebook computer. Useful insight on the phrasing of questions, which questions to delete or retain, and design of data table for efficient information input were gained from the pre-test.

3.2.6 Reference Points

Reference points are important in cognitive mapping studies because they impose on subjects spatial constraints. Second, reference points introduce a concept of scale to the drawing area (Kuipers 1978; Golledge et al. 2003). In this study, a reference point pre-test was performed to identify the two best known or recognized points for each study site. For this pre-test, five visible landmarks were chosen from a city map based on their size, land use and distance from each other. The selected reference points for each study area are shown in Table 3.4.

Table 3. 4 Five Reference Points for each Study Site used in Pre-test to Select for the Two Most Familiar Locations

Toronto	Scarborough	Markham/Richmond Hill
Allan Garden	Bridalwood Mall	Buttonville Airport
Eaton Centre	General Hospital	First Markham Place
Maple Leaf Gardens	Scarborough Town Centre	HillCrest Mall
Ryerson University	Centennial College	Central Hospital
Wellesley Subway Station	Victoria Park Ave/Hwy 401	Yonge St./Hwy 7

Another group of subjects was recruited through friends and family who reside in one of the three study sites. From this, fifteen subjects were recruited from each of the three study sites solely for this pre-test. Correspondence with subjects was via email. Subjects were asked to identify and rank the five reference points based on familiarity (1 = most well known, 5 = least well known). They were asked to disclose their age and length at current residence.

Results of reference point prominence were generated by dividing the number of subjects who selected a particular reference point by the total number of subjects, calculated for each ranking level. For example, in a sample of twenty subjects, if fourteen subjects selected the Eaton Centre as the most well known reference point, four selected it as their second choice, two selected it as their third choice, the rankings would be calculated as shown below:

First rank: 70% (14/20*100)

70% of subjects chose Eaton Centre as the most well known reference point in Toronto

Second rank: 20% (4/20*100)

20% of subjects chose Eaton Centre as the second most well known reference point in Toronto

Third rank: 10% (2/20*100)

10% of subjects chose Eaton Centre as the third most well known reference point in Toronto

The two reference points for Toronto were chosen based on the reference point ranking results in Table 3.5. In Toronto, the two best known landmarks were the Eaton Centre and Wellesley Subway Station.

Table 3. 5 Results of Potential Toronto Reference Points

Landmark/Rank	1st	2nd	3rd	4th	5th
Allen Garden	13.33%	13.33%	13.33%	6.67%	53.33%
Eaton Centre	86.67%	0.00%	6.67%	6.67%	0.00%
Maple Leaf Garden	0.00%	33.33%	33.33%	26.67%	6.67%
Ryerson University	0.00%	6.67%	20.00%	40.00%	33.33%
Wellesley Station	0.00%	46.67%	26.67%	20.00%	6.67%
Total	100%	100%	100%	100%	100%

The results of Scarborough reference point ranking are displayed in Table 3.6. The two reference points for Scarborough were chosen based on these rankings. In Scarborough, the two best known reference points were Scarborough Town Shopping Centre and Centennial College. Although Bridalwood Mall and Centennial College have the same rating, Centennial College was chosen to prevent sole use of shopping centres as anchor points. In addition, the location of Centennial College is far enough from Scarborough Town Shopping Centre to give subjects a good sense of scale.

Table 3. 6 Results of Potential Scarborough Reference Points

Landmark/Rank	1st	2nd	3rd	4th	5th
Bridalwood Mall	13.33%	26.67%	20.00%	6.67%	26.67%
Centennial College	6.67%	26.67%	20.00%	26.67%	20.00%
Scarborough General Hospital	0.00%	13.33%	26.67%	40.00%	20.00%
Scarborough Town Centre	66.67%	26.67%	6.67%	0.00%	6.67%
Victoria/401	13.33%	6.67%	26.67%	26.67%	26.67%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

The results of reference point ranking for MRV are displayed in Table 3.7. In MRV, the two best known reference points were First Markham Place and Hill Crest Mall. More subjects rated Hill Crest Mall in third to fifth place than Buttonville Airport, an indication that subjects know Hill Crest Mall better than Buttonville Airport.

Table 3. 7 Results of Potential MRV Reference Points

Landmark/Rank	1st	2nd	3rd	4th	5th
Buttonville Airport	20.00%	40.00%	20.00%	13.33%	6.67%
First Markham Place	60.00%	13.33%	0.00%	0.00%	26.67%
Hill Crest Mall	0.00%	40.00%	26.67%	26.67%	6.67%
York Central Hospital	0.00%	6.67%	20.00%	13.33%	60.00%
Yonge/407	20.00%	0.00%	33.33%	46.67%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

The two final reference points selected for each study site were incorporated in the template for the final interviews. This is discussed in the following section.

3.2.7 Template Creation

Two templates were created for this study. The first served to create a standard drawing interface and the second to deduce longitude and latitude coordinates (in decimal degrees) required for a world file (.wld) in a GIS environment.

Template 1 comprises the standard drawing surface presented to subjects. This template was created to show the two reference points for each study site. The reference points were first created in AutoCAD 2002, a specialized drafting package that can integrate reference geographic coordinates. In this study, latitude and longitude coordinates in decimal degrees were used as the reference coordinates. The addition of real world coordinates is significant to this study because they allow sketch maps to be digitally overlaid on each other and on to other georeferenced layers when the anchor or reference points are geocoded (assigned real world coordinates).

Two steps were required to obtain the latitude and longitude values for each reference point. First, the postal code of each reference point was found on the Canada Post website (Canada

Post 2004). These postal codes were then computed in a geocoding software called GeoPinpoint, produced by DMTI Spatial, which converts all postal codes to latitude and longitude (X, Y) coordinates in decimal degrees. Second, a template was created in AutoCAD 2002 by drawing two circles representing the two reference points. When the first circle was drawn, a command was typed into the program which elicited a space to input the X, Y coordinates for that reference point. The same step was repeated for the second circle. This file was saved in a drawing exchange (.dxf) format because this format can be read by both Corel Draw and the GIS package. These steps were repeated two more times to create three customized templates, one for each study site, with the two reference points discussed in Section 3.2.6.

Template 2 was created similarly to Template 1. After the two reference points were drawn on screen in AutoCAD 2002, a box was drawn around them to serve as a border. Since there are two circles with latitude and longitude coordinates, the software derives coordinates for the four corners of the border through triangulation of the two existing anchor points. This produced six anchor points comprising of the two reference points and the four corners of the border. Since Template 2 was used to create a world file (to be discussed in Section 3.5.1), the accuracy of overlaying sketch maps over other georeferenced layers increases with more known reference points.

The limitation of this technique is the time consumption. Another way to generate anchor points is to locate them on a DMTI road network and digitize directly on-screen. This would have maintained the same level of accuracy and takes less time.

3.3 Acquisition of Sketch Maps and GPS Traces

The data collection was divided into two main components. The first was the collection of sketch maps, followed by the collection of GPS traces of travel behaviour.

Each interview began by presenting the subject with two identical consent forms, one to sign and provide to the interviewer and the other for the subject's record. An identification code for each subject was immediately created to protect their identity. This identification code was created by using the date of interview (ddmmyy) followed by the first four letters of the subject's surname. For example, if a subject by the last name of Reeves was interviewed on Nov. 10, 2003, the code would be 10112003Reev. This coding approach was selected over straight forward numerical assignment because this system allows the researcher to quickly identity the subject, recall their characteristic qualities (i.e. gender, city of residence etc) and the date the interview took place.

The sketch maps were collected during an interview with each subject. All interviews took place at a subject's home or work place, taking approximately 1 hour and 15 minutes, including 15 minutes for practice. The interview consisted of three parts. The first part asked subjects to sketch a map of their neighbourhood on the tablet PC screen. The template they were given to draw on depended on their residence because each study site had a different set of reference points. The sketch mapping exercise was followed by the identification of the paths and landmarks that the subject used between two to six times or seven and greater times a week. There is no frequency class of one, based on the assumption that subjects must have travelled along a path or seen a landmark, during the length of their residence, at least once in order to draw it and know of its location. Second, a frequency class of one would possibly prompt the subject to include many landmarks and paths that were not significantly used. The first two tasks took approximately 50 minutes. The second part sought to collect demographic data, taking about 15 minutes. The third part of the interview comprised answers to a verbal question, lasting an average of 5 minutes. At the end of the interview, each subject was presented with their choice of a $20 gift certificate or ten Toronto Transit Commission (TTC) tokens.

After the sketch map and accessory data collection, each subject was asked to collect GPS traces by wearing a GPS logger which sends and receives signals from up to twelve satellites orbiting the earth. The subject was instructed to carry the GPS logger from the time they left their home each day until they returned home for a continuous and consecutive four day period from Thursday to Sunday. When the subject travelled outdoors they were advised to wear the

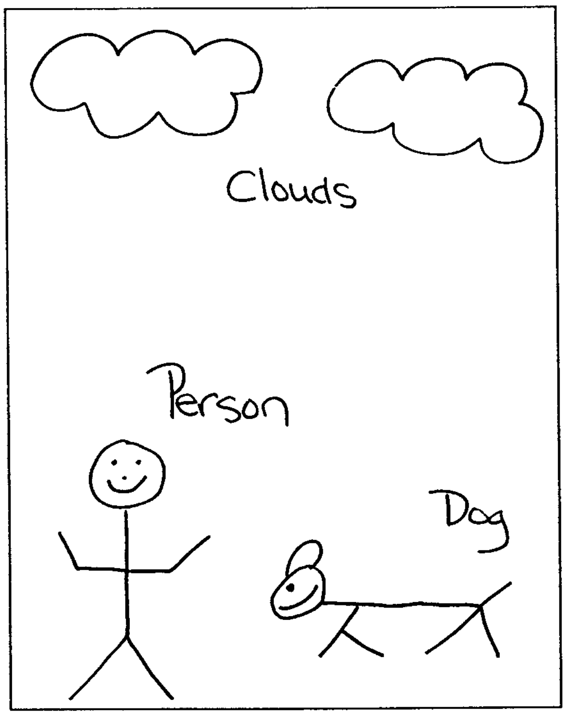
GPS across the shoulders for maximum signal transfer with satellites, but in the car, the signals could be detected if the GPS logger was placed on top of the dashboard adjacent to the windshield. When the subject was in a closed area not accessible to the outside environment, such as the TTC subway, no satellite signals communication was possible. However, when they were at home, they were asked to place the GPS at a window to allow for continual data collection of their geographic location. This served two practical purposes. The first is to condition subjects to place the GPS logger close to a window at all times. The second reason is to have a complete dataset showing their activity space even when they are stationary.

3.3.1 Acquisition of Sketch Maps

The subjects were first introduced to the Corel Draw 9 drawing package. The first 15 minutes of the interview was dedicated to three goals, namely demonstration of the four drawing commands, practice time, and recreating a prepared diagram. The four commands left on screen were freehand (draw), pick (select to delete), zoom (in and out), and cut (erase). All other Corel Draw commands and functions were removed from screen. This was followed by practice time for free exploration on the drawing template. The final practice was the recreation of a diagram after the subject had announced comfort with the tool. For this task, the subject was presented with a picture that included two clouds, a person, and a dog, each with a label (Figure 3.2). Each subject was asked to reconstruct the diagram with the wireless pen on the tablet PC. The purpose was to ensure that a variety of geometric shapes that were common in past sketch map research were practiced, such as curved lines, straight lines and writing. Once the subject was completely comfortable with the wireless pen and the drawing software, the sketch map drawing exercise began.

For Toronto subjects only, at the time of sketch map creation, reference points were rotated by 341° to display them as being aligned vertically from top to bottom, rather than the actual slanted angle. This was performed as subjects from the first two interviews drew the sketch maps as if north was at the top of the computer, even though the reference points were slanted to true north. This observation indicated that subjects ignored the angled reference points and in their head placed them vertically and drew from that perception. To prevent subject confusion, the two reference points were rotated to appear aligned, going from top to bottom of screen. Once the subject completed the sketch map, the two reference points and consequently the whole sketch map were returned to their true north position using basic geometric rotation features in Corel Draw 9.

Figure 3. 2 Practice Diagram for Subjects to Recreate before Drawing the Sketch Map



Each subject was instructed as follows: "From memory, sketch a map of the area you live in, showing whatever you think is important. Say out loud the names of everything you draw and where possible, explain why you are drawing them. You have as much as 30 minutes to draw the map." The time of 30 minutes is quite standard in past studies (Saarinen et al. 1995). Drawing tips and conventions for depicting paths and landmarks were explained before the exercise commenced. These instructions were placed beside the subject for their reference at any time during the interview (Figure 3.3). Note that Figure 3.3 has unintentionally created a bias towards the Lynch elements by suggesting subjects to draw paths and landmarks, and displaying examples of them. This bias may have confounded the results, in particular the high recall counts of paths and landmarks.

Figure 3. 3 Instruction Sheet and Drawing Tips for Subject Reference

TASK

From memory, sketch a map of the area you live in, showing whatever you think is important. Describe the names of all paths and landmarks by saying them out loud or writing on the screen. You have as much as 30 minutes to draw the map, so take your time.

Drawing Tips

1. To draw use the Free hand tool:

2. To draw a landmark of any kind, make sure it is a "closed" shape as in the following:

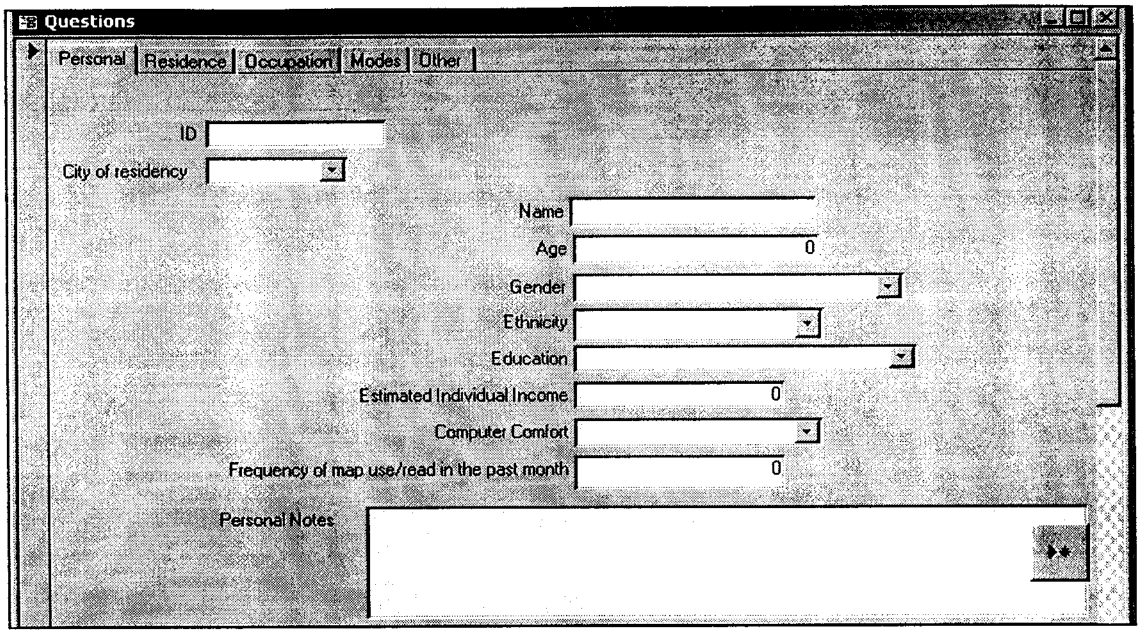
To draw a path of any kind, use single lines:

Once the subject declared that s/he had completed the sketch map or the 30 minute time limit had passed, the sketch mapping exercise was concluded. Both the drawing and video were saved. The sketch map was saved in both native Corel Draw (.cdr) format and Autodesk exchange (.dxf) format. The sketch maps were saved in the Corel Draw format to allow for future addition of colour or text deletion if required. The .dxf format allowed for immediate importation into a GIS package.

The next step was to ask the subject to "Classify all the paths and landmarks drawn into frequency of usage. The first classification is paths travelled on and landmarks visited two to six times a week, the second classification is seven and more times a week". The subject was asked to identify each path and landmark that fell into each classification, then to estimate the frequency of use. The definition of frequency of use differed between a path and a landmark. The frequency of path use was defined as the number of times the subject travelled along the path in a week. The frequency of landmark use was defined as the number of times the subject noticed the landmark. One visitation to a landmark is defined by having entered and exited that landmark. As the subject gave the frequency number of a path or landmark, the interviewer would select the named element, frequently asking subject to assist in finding that particular element since most were not labelled. The interviewer did not need to record manually the exact frequency number because it was recorded by the audio-visual software as the subject said the frequency but each named element was selected for colour coding purposes. The colour green represents two to six times a week and red was used to represent use of seven and greater times a week. The same procedure was used for all elements recalled with a frequency number, even elements that subjects did not draw. Instead of colour coding these, the subject simply named the path or landmark and verbalized the frequency of use in a week. This became part of the verbal record stored in the video.

The second part of the interview was designed to collect personal information and was organized to follow the sketch mapping exercise so that subjects were more comfortable with the interviewer and more at ease to answer personal questions. The personal questions were recorded directly into a database table via the form shown in Figure 3.4. There were five sections of questions: Personal, Residence, Occupation, Modes, and other.

Figure 3. 4 Form used to Collect Demographic Data



Personal questions inquired about each individual's personal information, including an identification code, city of residence, name, age, gender, ethnicity, highest level of completed education, estimated personal income for the year, level of computer comfort, number of times a map was read in the past month. The second section was to identify the subject's residential history by inquiring about the length of time and major intersection of the current to the past five residential locations. The third section sought to establish interrelations on the subject's occupational history by inquiring about the length of time and major intersection of the current to the past five occupation locations. The fourth section was to identify the frequency use of eight different travel modes including automobile as driver and passenger, public transit, bicycle, foot, motorcycle, scooter, and rollerblade. The last section included miscellaneous information including the type of gift certificate desired, time to pick up GPS logger to be used in phase two of the data collection, postal code of residence, largest and closest intersection to residence, comments on the drawing methodology and its possible influence on the sketch map creation. Of forty-five subjects, only one refused to answer a particular question. In this case, it was their age.

The last question in the interview is asking subjects to "Describe everything you see en route from home to work". The subject's verbalization was recorded by the video software. The purpose of this question was to compare the order people recall elements on their sketch map and the order they recall it verbally, as if they are walking through the neighbourhood.

3.3.2 Acquisition of Global Positioning System (GPS) Traces

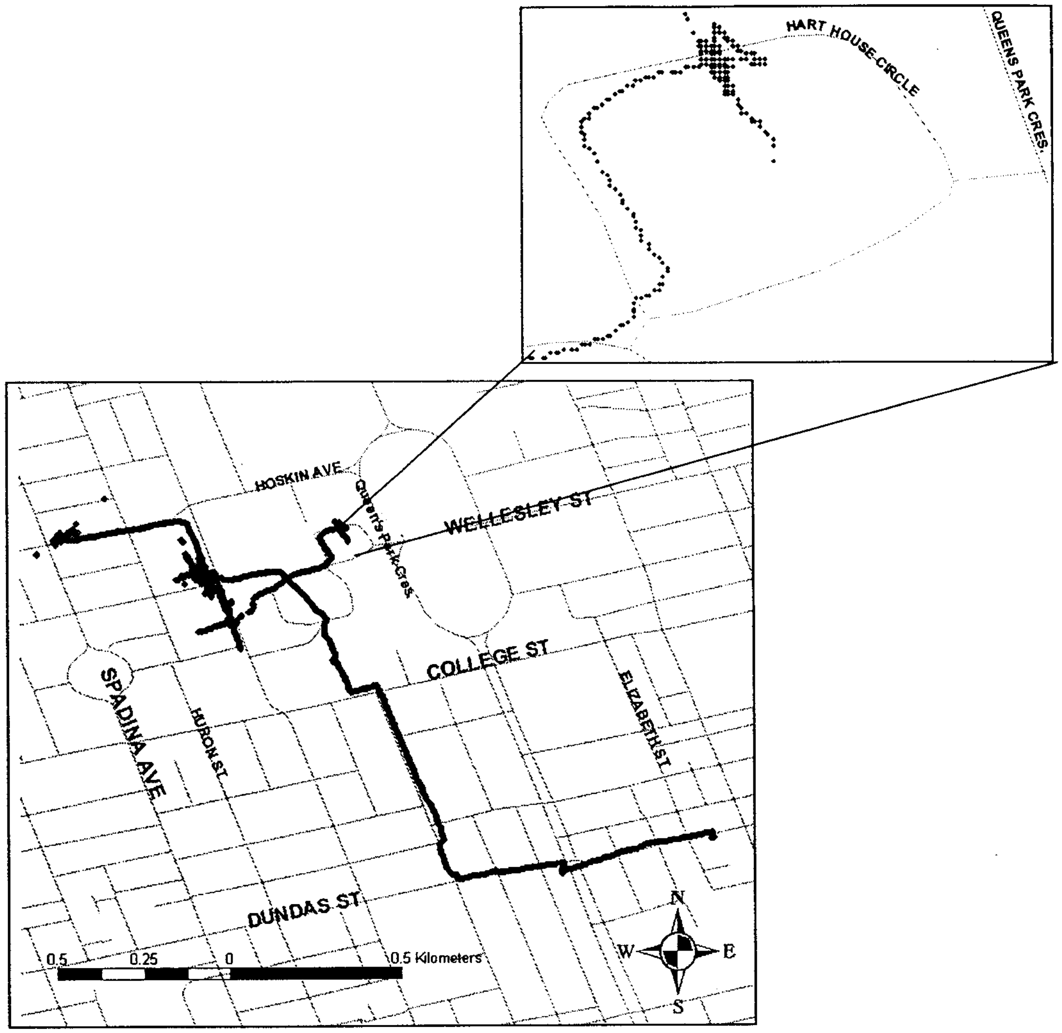
The collection of GPS traces followed the sketch map exercise. This in cognitive mapping research is a new method that allows comparison of "cognitive space" and "action space". An action space is a concept describing an individual's total interactions and responses to their environment (Golledge et al. 1997).

A GPS trace is a visual display of second-by-second GPS coordinates collected by the GPS logger. Figure 3.5 illustrates the GPS trace overlaid over a segment of the street network for the city of Toronto. This subject was travelling within downtown Toronto.

The specific GPS logger used is produced by GeoStats and is best described as a customized personal GPS with three components, accumulatively called a "GeoLogger" (see Figure 3.6). The system comprises a receptor for satellite signals and a memory box to store the data. There are two battery sources, a large 7.2V customized battery that powers the GPS and store purchased 9v battery for the memory box. The GPS GeoLogger was given to the subject immediately after the interview and, as noted earlier, they were asked to carry it on a daily basis for four consecutive days, from Thursday to Sunday. A list of instructions was given to complement the verbal instructions by the interviewer. The written instructions included the following:

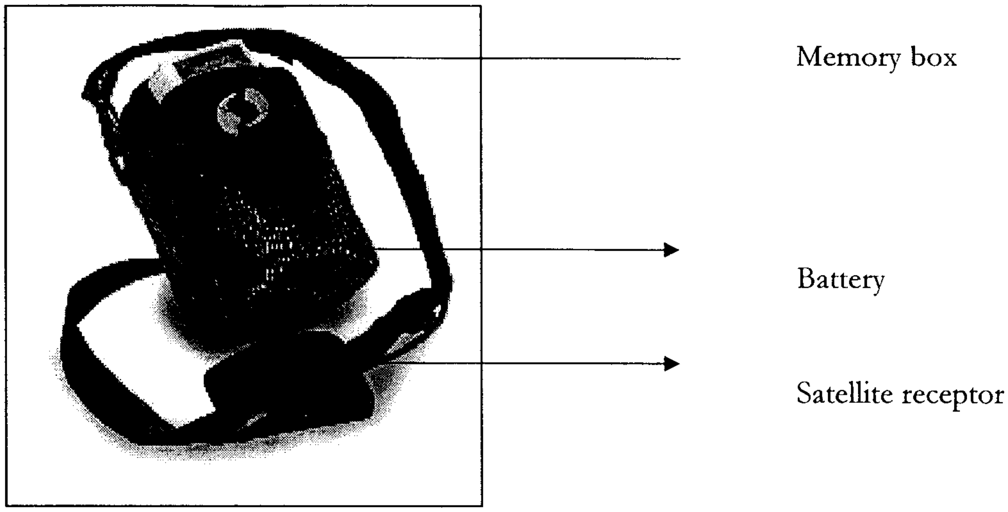
- If travelling in a vehicle, place the unit on a dashboard (if secured), seat beside you, or other location that provides the GPS device as clear a view of the sky as possible
- When inside a building for long periods of time (e.g. home, office) you can set the GeoLogger aside but please remember to put it back on when you leave the building for any reason
- Be sure that the GPS antenna located on top of the shoulder strap is facing upward
- Be sure that the red light on the GeoLogger is flashing at all times

Figure 3. 5 Example of One Day GPS Trace Overlaid on Street Network in ArcGIS 8.0*



* The GPS trace has been modified slightly to protect subject anonymity

Figure 3. 6 Personal GPS "GeoLogger"



Source: GeoStats (2003)

3.4 PREPARING, CODING AND ANALYZING COLLECTED DATA

3.4.1 GPS Data Preparation

Two steps were required before the GPS data were usable. First, the data had to be downloaded using the GeoStats GeoLogger software. The data consisted of second-by-second GPS points, including all the attributes shown in Table 3.8, as an example dataset. The second step involved data preparation that included three stages. First, the latitude and longitude values received the same number of decimal digits because the GIS package used for this study only project X, Y coordinates that have the same number of decimal places. Second, all longitude values for the western hemisphere was assigned a negative sign in front of the number, since the measurement starts from Greenwich, England but are measured positively in a clockwise direction from 0^{o}. Third, a heading was given to each of the thirteen columns.

The first column displays the row number of each GPS point. The second row shows the validity of the data where A = valid data. The third and fifth columns show the latitude and longitude coordinates in decimal degrees, each having the same number of decimal places in both columns. Columns four and six show the acronym of direction, using the conventional compass system. The seventh column shows the time each GPS point was collected and the date is shown in column eight. Column nine shows the speed in miles/hour or Kilometres/hour. The tenth column displays the heading, in degrees ranging from 000 to 359. Altitude in column eleven is empty unless the subject is travelling along a gradient. Column twelve shows the Horizontal Dilution of Precision (HDOP), an indicator of satellite clustering in space. The higher the number, the farther apart the satellites are, giving more accurate signals and information. The last column shows the number of satellites that the GPS is able to establish communication with. The greater the number of satellites, the more accurate is the GPS readings. The prepared GPS data were then able to be added into a GIS environment.

Table 3. 8 GPS Data Points in Database Table, after Preparation

Record#	Valid	Latitude	North	Longitude	West	Time	Date	Speed	Heading	Altitude	HDOP	Satellites
1	A	43.63097	NS	-79.41838	W	143838	120803	0	0		3.5	2
2	A	43.63092	NS	-79.41853	W	143839	120803	0	0		3.5	3
3	A	43.63088	NS	-79.41863	W	143840	120803	0	0		3.5	3
4	A	43.63088	NS	-79.41865	W	143841	120803	0	0		3.5	3
5	A	43.63087	NS	-79.41863	W	143842	120803	0	0		3.5	3
6	A	43.63088	NS	-79.41858	W	143843	120803	0	252		3.5	3
7	A	43.63085	NS	-79.41858	W	143844	120803	1.2	252		3.5	3
8	A	43.63083	NS	-79.41862	W	143845	120803	1.5	252		3.5	3
9	A	43.63082	NS	-79.41863	W	143846	120803	2.6	252		3.5	3
10	A	43.63082	NS	-79.41895	W	143847	120803	3.7	252		3.5	3
11	A	43.63073	NS	-79.41895	W	143848	120803	4.5	252		3.5	3
12	A	43.63073	NS	-79.41903	W	143849	120803	4.5	252		3.5	3
13	A	43.63072	NS	-79.41905	W	143850	120803	4.5	252		3.5	3
14	A	43.63071	NS	-79.41905	W	143851	120803	5.3	252		3.5	3
15	A	43.63071	NS	-79.41903	W	143852	120803	4.5	252		3.5	3
16	A	43.63070	NS	-79.41903	W	143853	120803	5.3	252		3.5	3
17	A	43.63069	NS	-79.41902	W	143854	120803	4.0	252		3.5	3
18	A	43.63069	NS	-79.41902	W	143855	120803	3.7	252		3.5	3
19	A	43.63068	NS	-79.41902	W	143856	120803	4.5	252		3.5	3
20	A	43.63068	NS	-79.41900	W	143857	120803	1.2	252		3.5	3

3.4.2 Transforming Qualitative Data to Quantitative Data

Recording of a sketch map alone was not enough to fulfil the basic thesis objectives. Hence, a verbal record was also obtained from subjects, which greatly enhanced the sketch mapping process. Tversky et al. (1998) as well as Ericsson (1984) stressed the importance of language as a tool to learn spatial knowledge. In this study, language is regarded not only as a method for subjects to 'talk' through their knowledge, but also as a device for the researcher to learn about a subject's spatial knowledge through the process of verbalization. Verbal communication is also a practical technique to reduce the burden of subjects having to write everything on their sketch map. This technique mirrors other studies conducted by researchers including Lynch (1960), Banerjee et al. (1977), and Chase (1983), who used verbal data to supplement the sketch mapping process.

Before any sense could be made of the verbal record, three steps were required to convert recorded verbal data into useable information. The first step was to transcribe the verbal record from each subject using a word processor. Transcription was a crucial step as any error(s) in the verbal record would affect the accuracy of subsequent steps, and compound errors in succeeding analysis processes. The transcription process was labourious, as noted by Elliott (1996) who described the process of transcription as labour intensive and time consuming, since the researcher or person transcribing must interpret and make meaning of what they hear. The typical time to transcribe one interview was between two to three times the length of the actual interview. Several obstacles lengthened the transcription time, for example the recording volume was too low and information was not audible; words were mumbled or poorly pronounced and were difficult to cross-check and understand; subjects stopped often to think for a lengthy period of time; subjects back-tracked to correct errors, and the person transcribing needed to replay the interview; some subjects spoke too fast, making it difficult to type at the same speed or to capture everything that was said.

All verbal data that alluded to or explicitly mentioned Lynch's five image elements were colour coded as follows, red = path, green = landmark, blue = node, pink = district, orange = boundary. This step took an average of 30 minutes per verbal record. Next, each element was added to a database table, in the sequence it was drawn. Each database table became the attribute table corresponding to the sketch map elements in the GIS. Additional information was added to the database including Personal ID, element code (1 = path, 2 = landmark, 3 = node, 4 = district, 5 = boundary), element group, element group code, total number of elements, time required to complete sketch map, frequency of element use per week, standardized order, element name taken verbatim from subject's verbal record during the sketch map creation and other derived variables. These data are displayed in Table 3.9 and explained in Table 3.10.

Table 3. 9 Sketch Map Attribute Table upon Exportation in a GIS Environment

Record number	ID	Sequence	Element name	Element code	Element Type	Element Group	Total elements	Frequency of element use	Standardized order
1	23072003Reev	11	Wellesley station	3	Subway station	18	24	4	45.83
2	23072003Reev	12	Wellesley St.	1	Street	10	24	10	50.00
3	23072003Reev	13	Yonge St	1	Street	10	24	14	54.16
4	23072003Reev	14	Dundas St	1	Street	10	24	2	58.33
5	23072003Reev	15	Atrium on Bay	2	Shop-ping mall	20	24		62.45
6	23072003Reev	16	Gap	2	Clothing store	26	24		66.83
7	23072003Reev	17	Bay St	1	Street	10	24		70.23
8	23072003Reev	18	Side street	1	Street	10	24		75.00
9	23072003Reev	19	HMV	2	Music store	26	24		79.16
10	23072003Reev	20	Ryerson University	2	Univer-sity	58	24	5	53.33
11	23072003Reev	21	Electronic store	2	Electro-nic store	26	24		87.50
12	23072003Reev	22	Chinatown	4	Chinese stores	116	24	2	91.66
13	23072003Reev	23	Wilket Creek	5	Creek	103	24		95.83
14	23072003Reev	24	College Park	2	Shop-ping mall	20	24	2	100.00
15	28072003Reev	1	Police station	2	Police station	60	68		1.47
16	28072003Reev	2	Red Cross	2	Blood donation centre	99	68		2.94
17	28072003Reev	3	Tim Hortons	2	Coffee shop	70	68	5	4.41
18	28072003Reev	4	Starbucks	2	Coffee shop	70	68		5.88
19	28072003Reev	5	Little Italy	4	Italian stores	116	68		7.35
20	28072003Reev	6	Bay St./ Yonge St.	3	Street corner	16	68	2	8.82

Element groups were created in order to generalize and categorize the specific element names and the descriptions given by the forty-five subjects. There were a total of 118 specific element groups, which included all the different elements, ranging from consumer shops to educational institutions to community areas. These general categories were obtained by grouping similar elements together to form one element group. For example, a magazine store and a bookstore were grouped as 'bookstore'.

Table 3. 10 Summary of Database Table

Name of Column	Description of Column	Calculation Methods
ID Code	Identification code used to identify subject simultaneously maintaining confidentiality	Combination of interview date and last four digits of subject's last name e.g. 10112003Reev
Sequence	The numerical value of order each element was drawn on the sketch map	A numerical value is given to each element based on the verbal record
Element name	The name that is verbalized by the subject	The name is typed into database verbatim from verbal record
Element code	Numerical value representing each of the five elements	1 = path, 2 = landmark 3 = node, 4 = boundary 5 = district
Element type	Name of element	Name of element copied verbatim from verbal record e.g. 'Yonge St.'
Element group	Numerical value representing group of element type	Categorization of all element types into manageable groups
Total element	Total elements drawn by each subject	A count of all elements verbalized by each subject
Total time	Total time taken to draw sketch map	Total time is read from the video
Element use	Frequency use of each element	Every element that subject listed as having used 1-6 times or 7 and greater times a week
Standardized order	Percentage of sketch map process	Each sequence is standardized by dividing the sequence number by total number of sequence and multiplying by 100 (this is done for each subject)
City	Numerical value representing city of residence	1 = Toronto 2 = Scarborough 3 = MRV
Name	Name of subject	Full name given by subject
Demographic data	A collection of data including age, sex, income, highest level of education, ethnicity, comfort level with computer, frequency of map use, residential and work trajectory, frequency of modal travel	Information obtained at time of interview

3.4.3 Extracting Sequence from the Sketch Map Drawing Process

A unique possibility to examine the type of elements drawn as the drawing exercise proceeded from beginning to end is explored in this study. One way to graph the result could have been to examine the percentage of elements that were paths or landmarks at each sequence. The problem is that subjects' total number of elements or sequence varied from 24 to 243. Thus, comparing one subject's 50th step (their last step) to another subject's 50th step (only half way through) is not necessarily indicative of equivalent stages in the drawing process. To control for this, the standardized order was calculated. The percentage of each element type drawn was calculated using a standardized order that maintained comparability between the numerical order in which subjects drew elements.

The standardized order was calculated by converting each subject's total sequence count to range from 0% to 100%, where each sequence or step is represented by a percent, the percentage through the drawing exercise. This conversion was calculated by dividing each sequence order by the total number of sequence and multiplying by 100%, for each subject. For example, a subject with 50 elements has 50 drawing steps, one representing each element drawn. The first sequence represents 2% of the whole drawing process (1/50*100) while the 15th sequence represents 30% of the way through the drawing exercise.

Once all forty-five sketch maps were converted to fit the 0% to 100% standardized sequence, the next step was to calculate where along the standardized sequence the proportion of all elements were drawn. The percentage of each element type found at each standardized sequence was calculated by summing each element type and dividing by the total number of elements at every sequence. For example, from 2% to 3% of the way through the drawing exercise, if there were 30 paths, 10 landmarks, 4 nodes and 1 boundary, their percentage make up at that standardized sequence would comprise 66.7% paths, 22.2% landmarks, 8.8% nodes and 2.2% boundaries. This distributes all subjects' response along the same sequence continuum from 0% to 100%.

3.4.4 Voice Recording

Due to the importance of the verbal record, the MMAPIT tool had the capability to record verbal data spoken during the sketch mapping exercise. The stored data could be replayed to examine the sketch map creation process and assist in identifying map elements, to enhance both the qualitative and quantitative datasets.

Three types of qualitative data were derived from the verbal recording, namely the names of the elements drawn, why the elements were drawn, and a visual recording of the sketch map creation process. Quantitative data were derived from the qualitative verbal record, including demographic data and the frequency of element use (Table 3.10).

The verbal record provided the option to transform qualitative data into quantitative data or to analyze the qualitative data alone. However, the quantified dataset provides many more relationships between variables, and the ability to investigate the existence of patterns and relationships that may not have easily been discerned solely from the verbal data or sketch map.

3.4.5 Analyzing Sequence Data with a Unidimensional Sequence Alignment Method

Studying elements in the order that they were drawn is relatively new to sketch mapping. As noted in Chapter 2, Taylor et al. (1992)are the only researchers in a large literature who have rigorously examined the sequence of a sketch map, although their study was limited to the order that landmarks were drawn. In the present study, the sequence of drawing was examined for all five Lynch elements.

There were a few potential methods to cluster the sequence strings such as a statistical method called cluster analysis. Cluster analysis encompass factor analysis and multidimensional scaling. However, in this study, a process of unidimensional sequence alignment borrowed from biology was used because it could analyze data in nominal form. Unidimensional sequence alignment is a statistical technique that calculates the best match between sequence strings of nominal data which are then aligned to emphasize the similarities and differences along the sequence strings (EMBL-EBI 2004). Originally, this approach was developed to compare the sequence of amino acid strings in Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (Durbin et al. 1998).

The specific sequence in this study was derived from the colour-coded transcription, as described in Section 3.4.2. Starting at the beginning of the transcription, every element was recorded in short hand, as follows, P = path, L = landmark, N = node, B = boundary D = district. Hence, a sample sequence would appear as L P P L P D D B P P P D D P P L L L etc.

The sequence resembles that derived from a string of biological DNA or RNA which are analyzed and matched by running the sequence through software that matches clusters of identical sequence. There are some fundamental similarities and differences between DNA and sequence as examined in this study. DNA is built with four building blocks whereas the MMAPIT sequence string is built with the five Lynch elements. A DNA strand is composed of two complementary strands whereas the MMAPIT sequence has only one strand. Despite these basic substantial differences, it was decided to use DNA software to analyze sketch map sequences. Specifically, ClustalW DNA software, developed by the European Bioinformatics Institute (EMBL-EBI 2004), was chosen for this purpose because it has, in addition to the standard alignment output of results, a better graphic representation of the results than other alternatives. ClustalW is described as a general purpose multiple sequence alignment program for DNA or proteins. It produces biologically meaningful multiple sequence alignments of divergent sequences (EMBL-EBI 2004).

The cross-pollenization of geography and biological analytical techniques is innovative in this context as it bridges the qualitative and quantitative components of sketch map studies.

3.5 Integrating Data into a GIS Environment

Three types of data from MMAPIT could be incorporated into a GIS environment, namely the GPS traces, the sketch maps, and the verbal data that accompanied each sketch map. The next section describes in detail how these data were incorporated into the GIS.

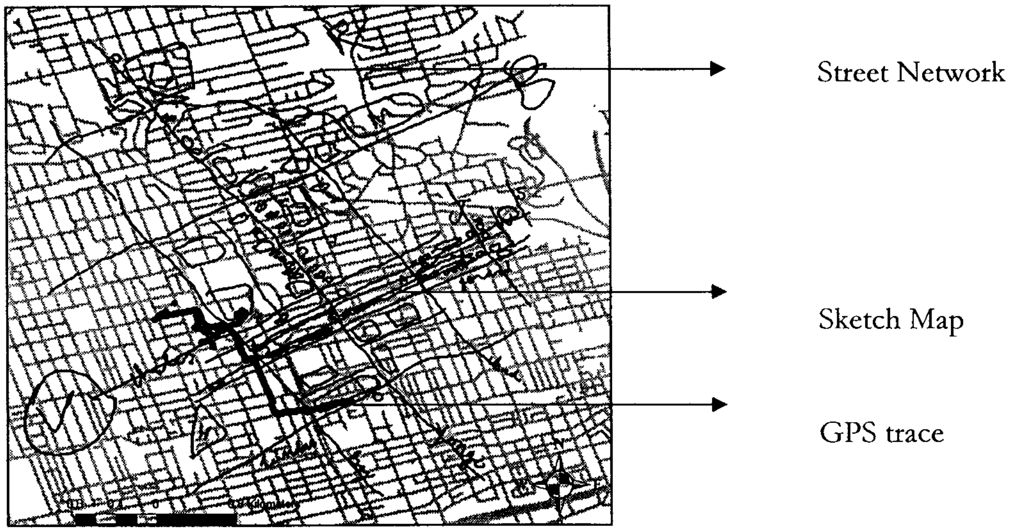
3.5.1 Integrating Sketch Maps with GPS Traces into a GIS

In order to integrate the digital sketch maps into a GIS environment, a 'world' file (.wld) and map projection had to be assigned. The geocoded reference points produced in AutoCAD lost their coordinate reference system information when exported from the drawing package to a GIS package. Hence, a world file was needed to perform the sketch-to-real world transformation, correcting for the lost spatial information. A world file is a simple text file containing georeferenced information. The format of the file contains a pair of X, Y coordinates representing the actual location of the reference points on the sketch map. A second pair of X, Y coordinates represents the new location in geographic space, where the reference points will be projected in the GIS package. The GIS package can apply the world file when it detects a file name with the same prefix as the drawing name in the same directory. For example, when the GIS package finds the sketch map 10112003Reev.dxf and a world file 10112003Reev.wld, it transforms the coordinates in the sketch maps according to those in the world file. Only one world file needs to be written and it must be based on the reference or anchor points discussed earlier.

Once the world file was created, a map projection had to be defined. The Universal Transverse Mercator (UTM) projection was selected because it distorts fewer characteristics than other projections for the study area and in fact, it is the projection used for all hard copy and digital base mapping in Canada. For this study, the North American Datum (NAD) 1983 and UTM zone 17N were used.

The GPS traces were by default collected in decimal degrees so once the GPS dataset was prepared (Section 3.4.1), it could be imported into a GIS environment. Figure 3.7 shows the overlaying of GPS trace and a sketch map over a street network.

Figure 3. 7 Overlay of Sketch Map on a GPS trace and Road Network in a GIS Environment



3.5.2 Building an Attribute Database Table in a GIS Environment with the Verbal Record

The process of building a database is time consuming because there is no simple method to add data into a GIS attribute table. In this study, data were directly entered into the attribute table in two stages. First, the video was reviewed for each subject and the sequence of each element drawn was listed on hard copy. This created a replicated version of the sketch map with sequence numbers and element information. The second stage was to add manually the elements from paper to the digital attribute table in the GIS package. This was accomplished by selecting each element on-screen then switching to the attribute table and adding the corresponding information. To ensure consistency in data cleaning, a set of data classification guidelines was created, as described below.

Attribute tables were populated with verbal data from the interviews. There were six classification categories, namely how to classify text/name, element/code, sequence, frequency, writing and checking for gaps in attribute table.

Under the 'text' field, appropriate phrases were recorded while under the 'name' field, the name of the element was coded. An effort was made to identify specific schools and streets even if the subject could not remember what they were called. Confirmation of unknown features was crosschecked with a hard copy map of each study site. However, if there was no way to identify a feature then 'unnamed element' was entered.

Under the 'element' field, the name of the Lynch element was recorded. Under the 'code' field the corresponding code number was added as follows, paths (code 1), landmarks (code 2), edges/boundary (code 3), districts (code 4), and nodes (code 5). For the purpose of data coding, the following definitions were used. A path (code 1) is any route used for transportation or perceived by the subject as a useable transportation route including roads, subway lines and walking trails.

A landmark is any single memorable building or feature in the environment, i.e. a possible destination or navigation cue, excluding a route. Landmarks serve as a point of reference, but observers do not enter them, they are external. Essentially anything discrete that could be represented by a point on a map is a landmark. A large feature, such as a park, a plaza or a road sign can also be a landmark as it is considered one entity.

The next element can be identified as an edge but more often referred to as a boundary. Lynch (1960) interpolated edges from common features that either separated discrete districts or which people did not travel beyond (for example, shore lines in Boston). Although subjects in the current research mentioned the Toronto waterfront and the Scarborough Bluffs, these are destinations rather than boundaries because subjects talked about visiting these areas for recreation rather than seeing them as a boundary or barrier. Perhaps the shore of Lake Ontario is not as visible as it is in Boston it has not become a commonly perceived edge. Equally, subjects indicated 'different' districts but did not indicate precisely where they started or ended.

Districts are generally homogeneous areas that contain many elements. For example, if a subject summarized his/her thoughts by saying "there are a lot of plazas along here" or "a lot of shops in here" without naming them specifically, the area was considered a retail district in their mind. Many discrete landmarks can be later summarized into a district, but if so, they should be coded individually as identified by the subject.

Nodes are points, and were identified as points of change and importance. More specifically, nodes are strategic points in the city that serve as intensive foci points. Subway stations are transportation nodes, although airports, because they are less frequently used, were only considered as landmarks. Subject's homes and places of work were marked as nodes because of the important changes in activities that occur there. Road junctions, crossings and intersections were also considered to be nodes.

The following classification is sequence, which refers to the order in which the elements were drawn on the sketch maps. The two reference points were always coded as 1 and 2 for each study site, as their presence almost certainly affects the order of other elements. As each subsequent element was drawn, it was numbered in the order drawn. If an element such as a street was later extended or a landmark erased and redrawn more correctly, the new feature retained its original numbering.

Frequencies of landmark- and path-use were requested at the end of each interview. Elements that were comprised of multiple rows were problematic, such as extensions of streets. If a certain street segment was indicated for a frequency value then only that segment of the entire element would receive the element value in the attribute table. However, the software often records a line segment in multiple records, making the precise section of a line segment very difficult to determine. Where this is the case, the frequency for a greater area than indicated is recorded. For example, often streets consist of two segments, a long line indicating the bulk of its length, and a second segment that is shorter at the end. If a subject said s/he only used the top half of the street 12 times a week, the entire street was coded (i.e. both segments, unless the tail was in the unused segment).

Subjects often wrote letters, words or number on their map as labels in order to identify elements. These were identified in the 'element' field as writing and the meaning of the writing was listed under the 'text' field. The rest of the fields for these entries were left blank or zero.

As a rule, once the database table for a map was completed, blank rows without entries were searched by scrolling through the entire table. Inevitably, there were blank rows which are missed elements on the sketch map, usually they are small marks or dots and were visually difficult to identify. In the interest of thoroughness, these gaps were completed.

3.6 Chapter Summary

This chapter presented a comprehensive view of the MMAPIT tool, from its components, to the intermediate steps to set up the tool, to the data it collects. Although MMAPIT comprised a tablet PC and used only two software packages, it was sufficient to collect the verbal record for each sketch map, the sketch maps themselves and a video that captured the sequence of the drawing process.

The first task of this research was to develop and assemble MMAPIT. The second step was to create a template for subjects to draw on. Since subjects were from three different study sites, each template was customized with appropriate reference points. The reference points were selected from a pre-test of residents who live in each study site.

The most difficult step in this research was recruiting subjects who fit the list of criteria. For this reason, the interviews with subjects took place separately over a five-month period. Once all forty-five subjects were interviewed, the data were prepared differently. The GPS data were prepared and given field headings before importing them into a GIS environment. The verbal data were transcribed in order to elicit map element sequences. The sketch maps were projected into geographic space for incorporation into a GIS environment.

At the end of the data collection and data preparation, four datasets were collected from each subject, including the verbal record, the video of sketch map drawing, the sketch map and the GPS traces. The verbal record includes the identification, explanation and frequency of element use. The video shows from beginning to end the whole sketch map drawing process. The sketch map was drawn on the tablet PC, which can be analyzed in its native Corel Draw format or exported to a GIS. After the interview, the subjects were asked to carry a GPS GeoLogger from the time they left their home to the time they returned home from Thursday to Sunday. This activity took place during the subject's own time after the interview. Of the four datasets, only the verbal record dataset was analyzed thoroughly. The results and description of the analyses are discussed in the next chapter.

Chapter 4

RESULTS

The analysis is divided into two parts. The first evaluates the MMAPIT tool and compares to previous cognitive mapping studies the quality of sketch maps collected in this study. The second part of the analysis focuses on the sequence of map creation. Four areas of analyses are performed from this, namely examining map types with sequence, frequency of element use plotted against standardized sequence, fish tail patterns resulting from plotting the percentage of elements to the standardized sequence, and running strings of sequence through the ClustalW software package. A minor research focus examines the landmark element as well as differences between gender and city of residence in terms of sketch map creation.

4.1 EFFECTIVENESS OF MMAPIT

The effectiveness of MMAPIT was evaluated by three criteria, namely data collected, sketch map quality, and subject's commentary of MMAPIT.

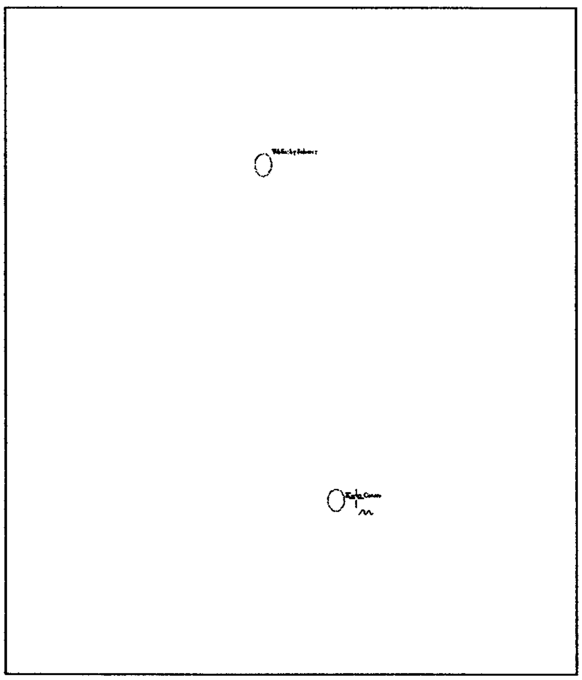
4.1.1 Types of MMAPIT Data

MMAPIT generated three new datasets compared to past studies. The new datasets include verbal records that complement each sketch map, a video that captured the sketch map creation, and a database linked to each sketch map in a GIS environment. The assessment of MMAPIT was based on two factors, namely the volume of data produced and the integration of sketch maps into a GIS environment.

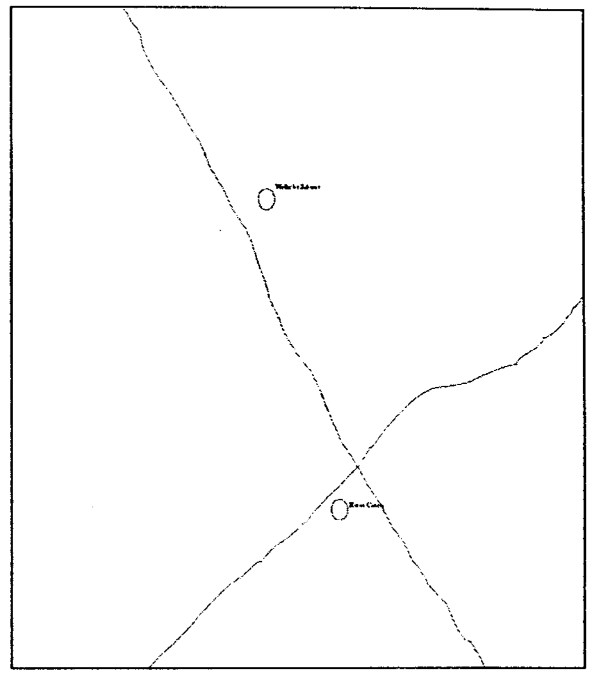
MMAPIT generated a large volume of data. Forty-five sketch maps were collected using an easily replicating task compared with the traditional pen/pencil and paper method. However, three sets of new data distinguish MMAPIT from past methodologies. The first is a total of 22.5 hours of verbal data produced by the forty-five subjects during the interview, averaging 30 minutes per subject. The second dataset are the video recordings of the sketched map drawing process, as shown in Figure 4.1, snapshots 1 through 5. Snapshot 5 shows the final product of the sketch map, common to other studies. These unique images are captured from Snapshot 1 showing the two reference points given to the subject, to Snapshot 2, depicting the first two elements drawn. In this case, they are paths. Snapshots 3 and 4 show the subject filling in the space with landmarks after setting the boundary with paths. This pattern continues, drawing paths, nodes and filling space with landmarks, until the sketched map is complete in Snapshot 5. It is apparent from the snapshots that the video shows the whole process from beginning to intermediate to final steps of a sketch map development, distinguishing it from past studies.

Figure 4. 1 Example Sequence of Snapshots taken from Video of Sketch Map Creation

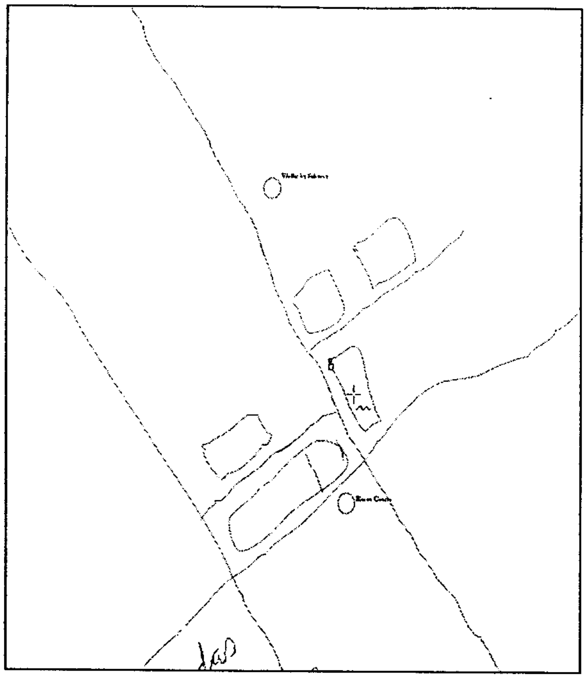
Snapshot 1: two reference points presented to subject



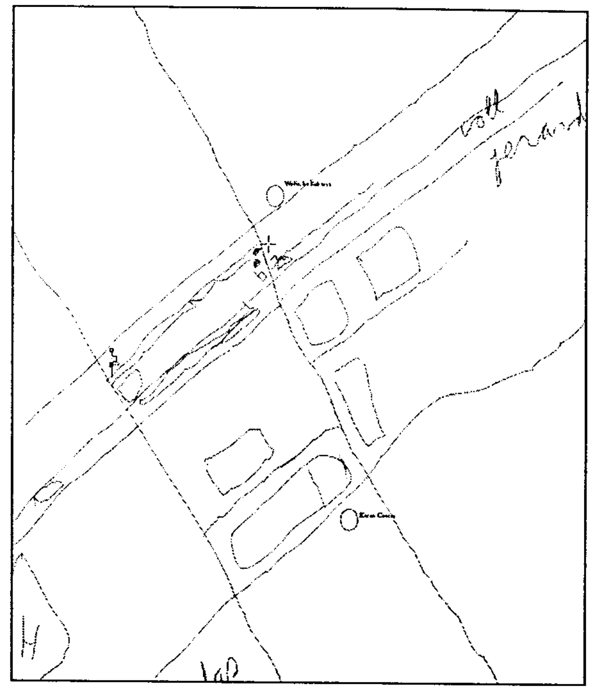
Snapshot 2: subject draws two paths, both major roads going through the reference points



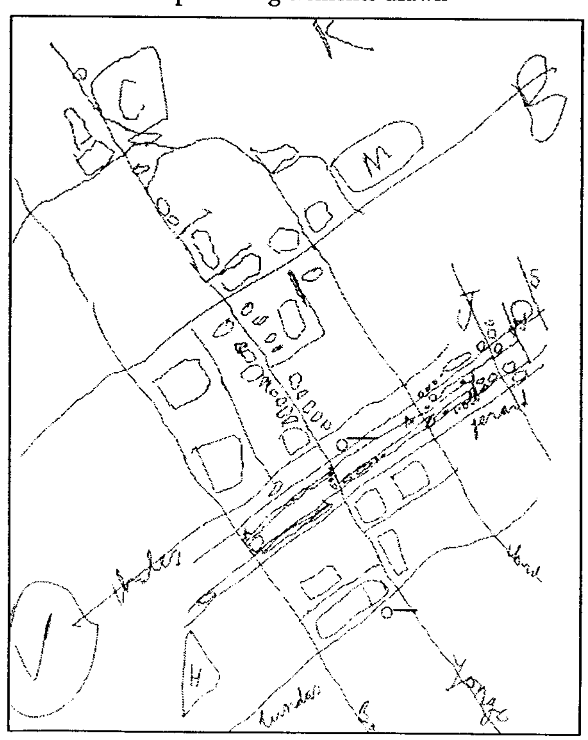
Snapshot 3: Subject fills in sketch map with more paths and landmarks



Snapshot 4: subject continues to fill sketch map with more paths, landmarks, and nodes.



Snapshot 5: final sketch map showing elements drawn

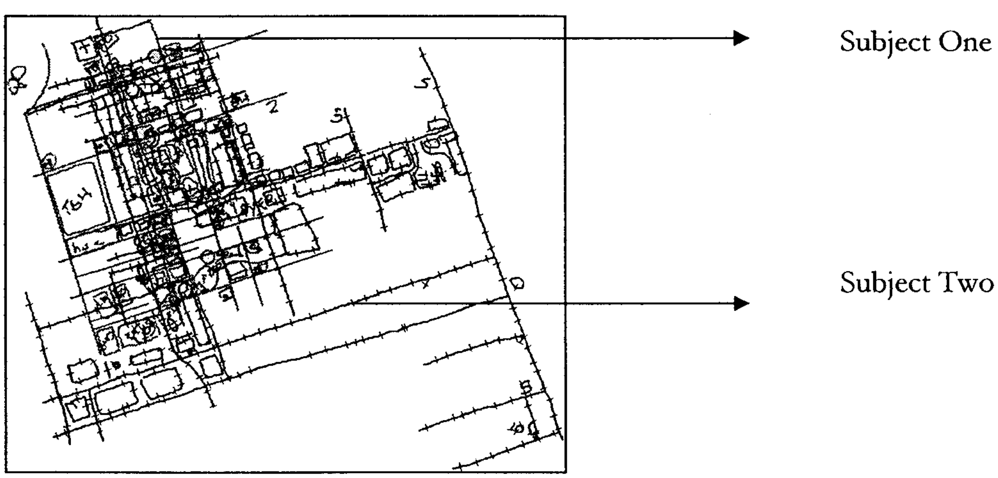


Although video data are valuable, they require large disk space, ranging in this case from 60 megabytes to 115 megabytes per video. The disk space requirement is dependent on the interview length. In this study, the total space needed to store all videos was 3.5 gigabytes. The third dataset produced in this study was the production of 3,703 records in the database (average of 82 records per subject) when the sketch maps were exported into a GIS environment.

Only a handful of researchers who, up to this time, have published work on the integration of sketch maps into a GIS (Weiner 1995, Cinderby 1999 and Tagg et al. 1996). Their approach required digitizing each map by hand. Although digitizing was an option, there are many drawbacks to this method. One drawback is the inevitable introduction of errors, for example, subjective errors both systematic and random. A second limitation is the large time expenditure for digitization.

Additional analyses could have been performed on the sketch maps upon export into the GIS environment. For example, metric distortions could be studied by overlaying multiple sketch maps forming a composite map as shown in Figure 4.2.

Figure 4. 2 Two Different Sketch Maps Overlaid in a GIS Environment

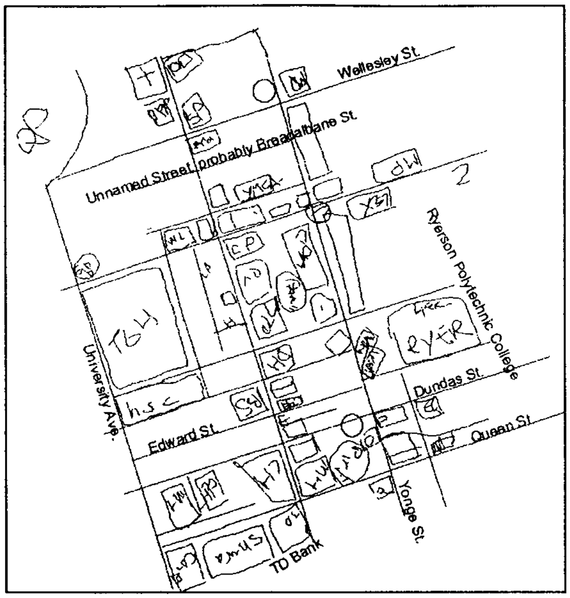


The addition of sketch maps into a GIS environment allowed a database table to be coded for each map. Each database table could be modified to include both qualitative information, such as verbal data, and quantitative data with each row linked to an element from the sketch map. The benefit of a database table is that information is organized into rows, reflecting individual map elements, including but not exclusive to element sequence, element name, element type, and verbal comments (Table 4.1). In turn, the information can be used as labels for map features as shown in Figure 4.3.

Table 4. 1 Qualitative Data in a GIS Database Linked to each Element of a Sketch Map

ID	Text	Element	Code	Name	Sequence	Frequency use
1	Yonge St.	Path	1	Yonge St.	5	0
2	Yonge St.	Path	1	Yonge St.	5	0
3	Yonge St.	Path	1	Yonge St.	5	0
4	Yonge St.	Path	1	Yonge St.	5	0
5	Bay St.	Path	1	Bay St.	6	10
6	Dundas St.	Path	1	Dundas St.	7	8
7	Queen St.	Path	1	Queen St.	8	0
8	College & Carleton St.	Node	3	College & Carleton St.	9	20
9	Unintentional mark			Unintentional mark		
10	Grosvenor St.	Path	1	Grosvenor St.	10	0
11	"I can picture it, but I can't name it"	Path	1	Unnamed Street, probably Breadalbane St.	11	0
12	Edward St.	Path	1	Edward St.	12	2
13	Elm St.	Path	1	Elm St.	13	2
14	Elizabeth St.	Path	1	Elizabeth St.	14	20
15	Elizabeth St.	Path	1	Elizabeth St.	14	20
16	Laplante Ave.	Path	1	Laplante Ave.	15	30
17	Gerrard St. –runs from the University Ave. to the Beach	Path	1	Gerrard St.	16	0
18	College Subway station	Node	3	Home	17	13
19	Dundas Subway station	Node	3	Home	17	13
20	Atrium on Bay	Landmark	2	Shopping centre	18	0

Figure 4. 3 Sketch Map in GIS Labelled with database table Information



4.1.2 Comparing Sketch Maps Produced with MMAPIT and those from Past Studies

MMAPIT simultaneously allows collection of a wide range of qualitative and quantitative data. Figures 4.4 through 4.6 illustrate sketch maps created with MMAPIT. Figures 4.7 through 4.12 display sketch maps from past studies (Devlin 1976; Wong 1979). The time it took subjects to draw and the number of elements in sketch maps are summarized in Table 4.2

Figure 4. 4 Subject 1, Toronto resident

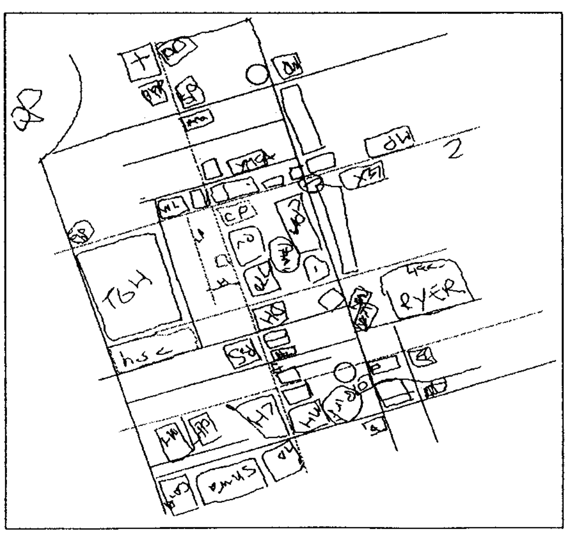


Figure 4. 5 Subject 2, Scarborough resident

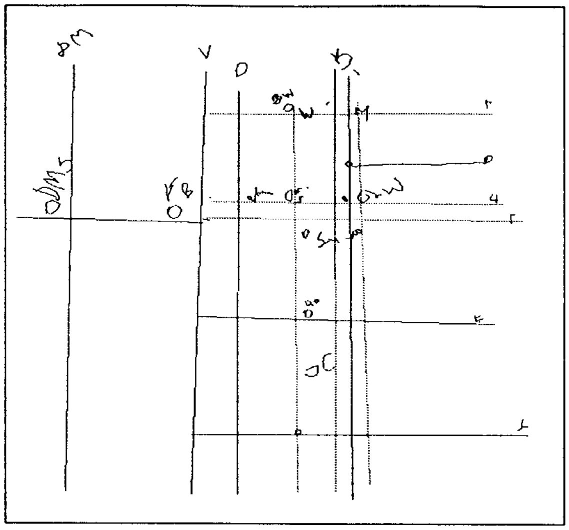
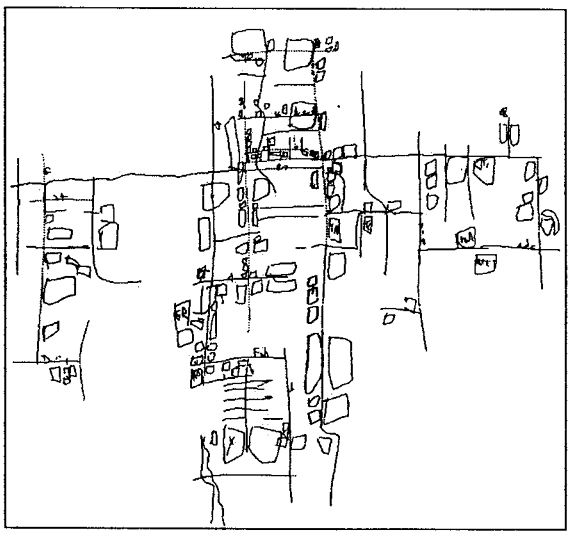
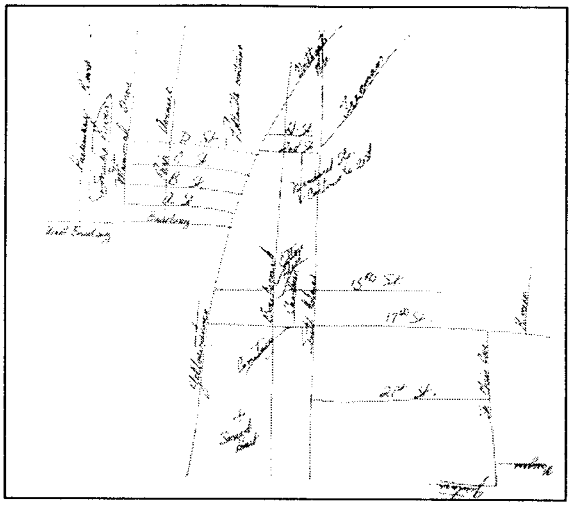


Figure 4. 6 Subject 3, MRV resident



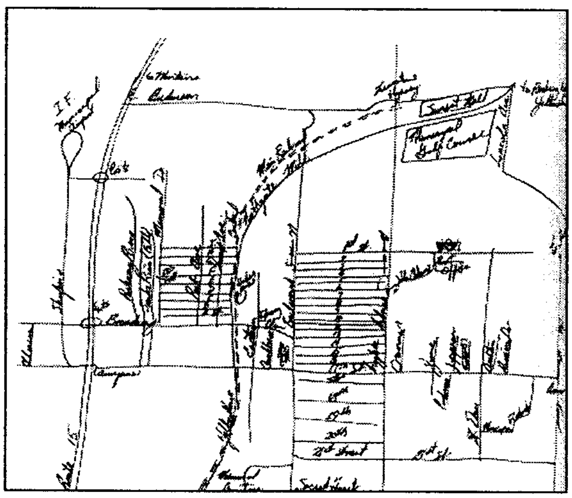
The next three sketch map samples come from Devlin's (1976) study on the effects of landmarks on peoples' knowledge of places and the speed at which places are learned. Devlin (1976) interviewed thirteen housewives of navy soldiers who were stationed in Idaho Falls, Idaho. The wives were asked to draw a sketch map upon their arrival then a second sketch map three months later.

Figure 4. 7 Subject 4



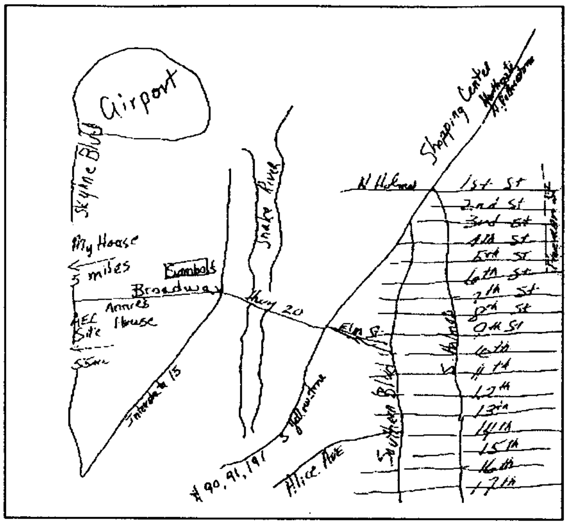
Source: Devlin (1976)

Figure 4. 8 Subject 5



Source: Devlin (1976)

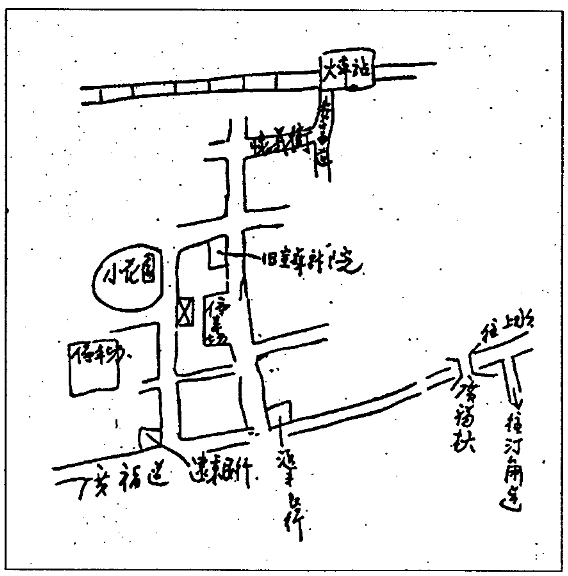
Figure 4. 9 Subject 6



Source: Devlin (1976)

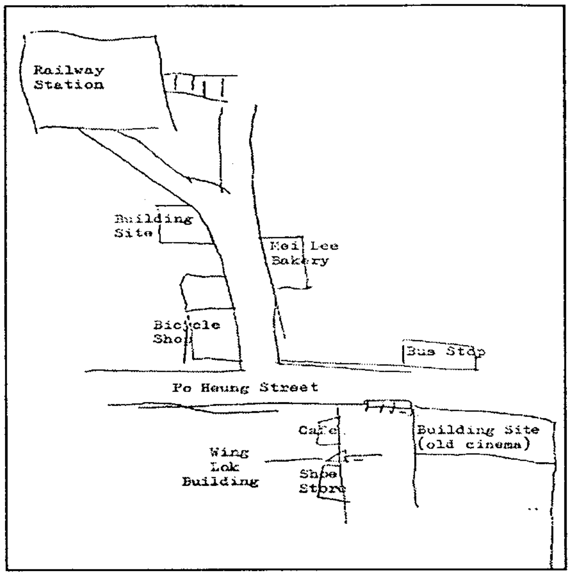
Three sketch maps from Wong's (1979) study comprise the next comparison set. Wong's (1979) interest was to study people's perception of their living space in Tai Po, Hong Kong. The findings were used to plan for future human settlements.

Figure 4. 10 Subject 7



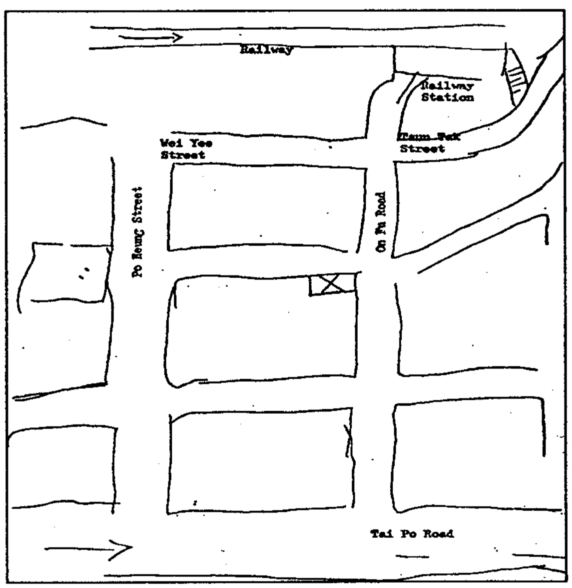
Source: Wong (1979)

Figure 4. 11 Subject 8



Source: Wong (1979)

Figure 4. 12 Subject 9



Source: Wong (1979)

The sketch maps are not uniform for a few reasons. First, the sketch maps from Wong's (1979) and Devlin's (1976) studies lack information on the length of drawing time. Second, the element count may not be accounted for due to ambiguous elements which were not clearly identifiable from the sketch map. Third, the different study sites may influence the elements people draw. Fourth, the instructions given to subjects may differ, affecting what people draw.

The sketch maps produced by Wong (1979), Devlin (1976) and MMAPIT appear similar. Paths and landmarks are easily identifiable in all three results, despite the different graphical representations of paths (single versus double line). One noticeable difference is the minimal amount of labelling in MMAPIT maps compared to Wong's (1979) and Devlin's (1976) maps. However, the verbal data accompanying the MMAPIT sketch maps clarified and helped identify ambiguous elements such as boundaries and districts, whereas this information is lost in the other two studies. Second, MMAPIT maps appear neater due to less writing on the map and single lines that represent paths. By observation, the use of MMAPIT does not compromise the appearance of the sketch maps in any way.

Table 4. 2 Summary of Element Count between Three Sets of Sketch Maps

Map 1 Element count	**MMAPIT** (Figure 4.4)	**Devlin (1976)** (Figure 4.7)	**Wong (1979)** (Figure 4.10)
Time taken to draw	24 minutes	Unspecified	Unspecified
Path	14	7 (2)	19
Landmark	10	8 (1.25)	1 (10)
Node	0	1	Unknown
District	0	Unknown	Unknown
Boundary	0	Unknown	Unknown
Total	24	16 (1.5)	20 (1.2)
Map 2 Element count	**MMAPIT** (Figure 4.5)	**Devlin (1976)** (Figure 4.8)	**Wong (1979)** (Figure 4.11)
Time taken to draw	39	unspecified	unspecified
Path	27	4 (6.7)	35
Landmark	75	10 (7.5)	4 (19)
Node	3	Unknown	2 (1.5)
District	1	Unknown	Unknown
Boundary	0	Unknown	Unknown
Total	106	14 (7.5)	41 (2.6)
Map 3 Element count	**MMAPIT** (Figure 4.6)	**Devlin (1976)** (Figure 4.9)	**Wong (1979)** (Figure 4.12)
Time taken to draw	33 minutes	unspecified	unspecified
Path	44	7 (6.3)	25 (1.76)
Landmark	189	4 (47.25)	3 (63)
Node	10	Unknown	1 (10)
District	0	Unknown	Unknown
Boundary	0	Unknown	1
Total	243	11 (22)	30 (8.1)

The second criterion used to assess MMAPIT was to compare the sketch maps quantitatively with the sample maps. Although the sketch maps appear similar by visual inspection, the element count differs greatly. Table 4.2 summarizes the element count of each map in Figures 4.4 through 4.12. The number of times a MMAPIT map element is greater than an element from a comparison map is displayed in a bracket beside the element count.

The sketch maps collected with MMAPIT, in comparison to the pen/pencil and paper method employed by Devlin (1976) and Wong (1979) maps, are quantitatively superior. First, all MMAPIT produced sketch maps have more elements than either of the two comparison map samples. Second, maps collected with MMAPIT have more features in the five element groups, likely because ambiguous elements such as districts and boundaries are not identifiable in the comparison samples.

Strong conclusions cannot be made of MMAPIT's advantage over the pen/pencil and paper method because the difference in element counts can be attributed to the amount of time each study allowed for subjects to draw. For example, MMAPIT maps may have more elements because subjects were allowed a maximum of 30 minutes, whereas Wong may have allowed 10 minutes, but time allowance was not mentioned in either paper. Alternatively, the variations in the depth and detail of the maps produced are due to the subjects' awareness of the contextual environment. Nevertheless, it is apparent that MMAPIT refines the quality of sketch maps by making district and boundary elements more visible through the additional verbal record and a neater appearance such as less cluttering from labels. Overall, it appears that MMAPIT at least reproduces the same level of sketch map quality as previous methods.

4.1.3 Subject Feedback on MMAPIT

The following was asked of the subjects, "Please comment on the tool you used to draw the sketch map, noting any advantages or difficulties you experienced." The answers given were divided into negative comments, neutral comments, positive and negative (hybrid) comments, as well as positive comments on the tool. A slight majority only, specifically twenty-seven of forty-five subjects, preferred pen/pencil and paper as the drawing medium. A minority, six subjects, preferred the computer over pen/pencil and paper method. The remaining twelve subjects had no preference and were indifferent. Although this last group was comfortable with pen/pencil and paper, they would be equally comfortable with the computer if they had more time to practice with the tool.

The criticisms as well as advantages cited were consistent across the forty-five subjects. There were two key criticisms and two key advantages noted by subjects. Six subjects had difficulty with map scale, and many more noted this during the drawing exercise. Subjects noted that scale affected their judgment of distance and relative position of elements. One subject said, "Scale was frustrating hence diagram is not to scale". Many subjects cautioned while they were sketching the map "This is not to scale". From the interviewer's observations and anecdotal notes, this difficulty arose in subjects who zoomed in and out of their map, but in the process subjects did not consider proportional changes in element size. This can be resolved if subjects used the scroll bar to navigate left/right or top/down for more drawing space instead of zooming in/out.

The most problematic issue encountered by subjects was not having full control of MMAPIT. These hurdles included drawing a polygon, slow reaction of tool, switching between tools, and labelling. The first difficulty encountered was a lack of control over drawing, whether it was creating a square or a box. One subject said, "It was not easy to draw, especially little boxes because it was hard to control and hard to get straight lines." The second comment was the slow appearance of a shape after it had been drawn, a lengthy lag time between drawing and appearance of object was noted by seven subjects. Subjects found it difficult to continue drawing if they did not see what they last drew. One subject clarified "I cannot dictate the speed of writing or appearance of drawn object on the computer, thus slowing the process." This difficulty is not an issue with pen and paper because elements can be easily controlled and they appear immediately on the paper as they are drawn. The third problem encountered by six subjects was selecting and switching drawing tools, making the process cumbersome. For example, if the subject wanted to erase, they had to select the object, pick the 'cut' button to erase then pick the 'draw' tool to resume drawing. This sequence was not as intuitive as using an eraser on paper. A subject commented on this tediousness, "Drawing can be confusing because one needs to switch between options." The last setback, noted by three subjects concerned labelling because letters or words were not consistently legible and sometimes, parts of a word did not show up. A subject said, "Difficulty was in writing especially taking the wireless pen off the page or pressing the wrong button on the pen."

These difficulties can be resolved with the following recommendations. First, more practice time should be given to acquaint subjects with the tool and software. Second, a computer with more speed would help. The response of the drawing software was slowed by running two programs simultaneously, namely the drawing software and the video software, with the latter taking up much memory to run.

When asked to comment on the methodology, subjects noted two types of advantages the tool brought to their experience and to the research. Specifically, they enjoyed the different drawing options compared to pen/pencil and paper. Two subjects enjoyed the neatness, particularly the different options to erase errors. Two subjects liked the ease of drawing straight lines, which would not have been possible without a ruler if drawing on paper. A subject's summary of this was "I preferred the computer for purposes such as drawing lines and erasing mistakes." Four other subjects appreciated the options to move, shrink, or enlarge elements easily without having to erase and redraw. Two subjects noted, "It was easier to shrink an object and shift lines."

The second advantage of MMAPIT concerns its contribution to research. Three subjects were aware and mindful of the research benefits that MMAPIT can contribute. Each subject had separate views that complement the tool on saving paper, easy to organize data, and a good way to store voluminous data.

A few subjects recognized other benefits. For example, two subjects, upon seeing the tool, exclaimed "What a 'cool' toy." After using the tool, the reaction of three subjects was that it was fun to use.

4.2 THE FIVE LYNCH ELEMENTS

Lynch (1960) developed five elements that together can describe all physical elements in an urban environment. These five elements are paths, landmarks, nodes, boundaries and districts. Although Lynch (1960) produced successful results from his sketch map analyses using these elements, other researchers found that they did not apply to all cities. In particular boundaries and districts were problematic. In this section of the analysis, the five elements is examined in three ways. The first analysis shows the proportion of elements reported, and whether the elements are represented in three Southern Ontario cities. The second analysis is dividing the highly reported landmarks into groups to represent the types of landmarks reported better. The last section examines whether elements reported differ between gender and city of residence.

4.2.1 Element Hierarchy

Lynch (1960) proposed that urban imageability comprises paths, landmarks, nodes, districts and boundaries. The forty-five subjects in this research collectively displayed Lynch's five elements in varying degrees. Table 4.3 shows the overall number of sketch map elements and their range.

Table 4. 3 Distribution of Sketch Map Elements (45 subjects)

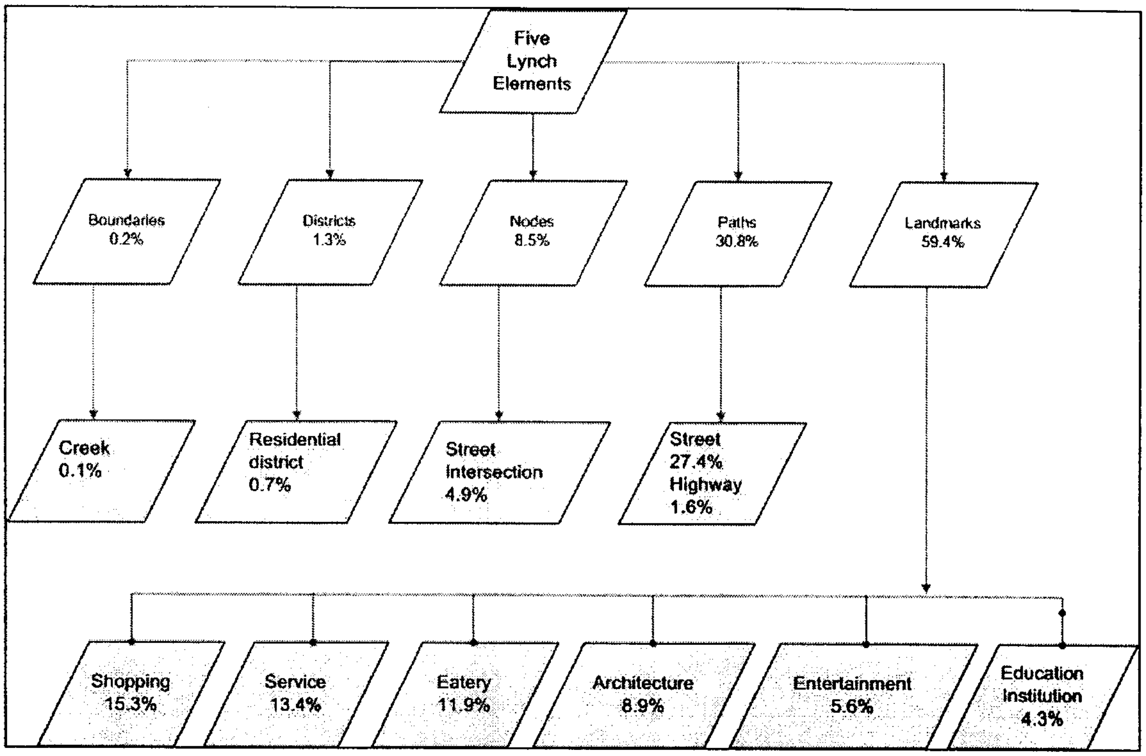
Element	*Sum*	*Percentage of total*	*Mean*	*Std. Deviation*	*Minimum*	*Maximum*
Landmark	2187	**59.0**	49	36.5	5	187
Path	1147	**31.0**	25	12.4	8	73
Node	316	**8.5**	7	4.8	1	24
Boundary	47	**1.3**	1	1.3	0	5
District	6	**0.2**	0.13	0.6	0	2
Total	3703	**100.0**	82.1			

The highest reported element in Table 4.3 is landmarks. The large standard deviation suggests that not every subject drew as many in their sketch map, some subjects drew very few while others drew many. The least drawn elements appear to be then nodes (8.5%), boundaries (1.3%) followed by districts (0.20%). Paths and landmarks were the best known, representing 31.0%

and 59.0% respectively of all sketch map elements. Similar findings to this study are presented by a number of researchers (Lynch 1960; Lee 1968; Appleyard 1970; Devlin 1976; Pocock 1976a; Banai 1999). Devlin (1976) and Appleyard (1970) found paths and landmarks to be dominant elements, but at different learning stages, such that paths were dominant on short-term residents' sketch maps while increased landmarks and greater integration of paths and landmarks were found on longer-term resident's maps. Lynch (1960) and Pocock (1976a) also found a dominance of paths and landmarks, similar to this study, the number of paths fell below the number of landmarks. Pocock (1976a) did not include 'boundary' in the study and found the term 'district' to be inappropriate as subjects more often referred to this as neighbourhood. The dominance of landmarks on a sketch map was also found by Lee (1968) whose study found that landmarks comprised 50-60% of a sketch map. The boundary visibility was described by Lee (1968) as an ambiguous element because boundaries could be distinct to some subjects but blurred to others. Banai's (1999) results were similar to those from this study, with the exception of nodes, which was highest (37.2%), followed in descending order by landmarks (26.6%), paths (21.9%) and a tie between edges and districts (7.1%).

Figure 4.13 is a hierarchy showing the breakdown of element types and the percentage they comprise of all elements produced from the forty-five sketch maps collected in the research. Similar elements were grouped and regrouped into the five Lynch elements. The number of identified elements from each group was divided by the total number of elements (3703) to provide percentages. In addition to showing a classification of Lynch's five elements, the hierarchy in Figure 4.13 displays a cross sectional representation of the elements in all sketch maps. The landmark element had so many points of presence that it could be further divided into six subgroups to keep it in line with previous sketch map classification (Lynch 1960; Appleyard 1970; Pocock 1976b). The six landmark subgroups in descending order of proportion are shopping, service, eatery, architecture, entertainment and educational institutions.

Figure 4. 13 Landmarks Divided into Subgroups, showing Percentage Occurrence in Sketch Maps



Hierarchy modified from Gatrell (1983)

4.2.2 Map Elements Analyzed by Gender and City of Residence

The second analysis is to explore element frequency by gender and city of residence. Table 4.4 and Table 4.5 provide the distribution in count and percentage of map elements by gender and city of residence respectively. A Chi-squared test was calculated to test for any statistical differences in each table. Districts were not included in the statistical tests because there were too few to make any meaningful comparison.

The Chi-square test showed that both gender (X^2 = 18.76, df = 3, ρ < 0.001) and city of residence (X^2 = 39.04, df = 6, ρ < 0.001) had a significant impact on the distribution of map elements. Overall, the general trend is that females reported marginally more elements than males. However, there were two major differences between gender, namely landmarks and paths. Females drew more landmarks (7.3%) than males, a finding that has been found by other researchers (McGuinness et al. 1983; Denis 1997). Males drew more paths (6.3%) than females.

Table 4. 4 Distribution of Sketch Map Elements by Gender

Element	Female n = 23	Male n = 22	Total
Path			
Count	**583**	**577**	**1160**
% total	28.6%	34.9%	
Landmark			
Count	**1260**	**901**	**2161**
% total	61.8%	54.5	
Node			
Count	**166**	**157**	**323**
% total	8.2%	9.6%	
Boundary			
Count	**30**	**15**	**45**
% total	1.5%	0.9%	
District			
Count	**0**	**5**	**5**
% total	0%	100%	
Total Count	**2039**	**1655**	

Differences between city of residence included three elements, namely paths, landmarks and nodes. Toronto subjects reported 6% fewer paths than Scarborough residents. Second, Scarborough subjects reported approximately 6.7% fewer landmarks than Toronto and 8.6% fewer than MRV residents did. A third difference is produced by MRV subjects who drew 2.9% and 3.6% fewer nodes respectively than either Toronto or Scarborough. Note, however, that the sample size in each study site was small, thus the Chi-square results should be interpreted with caution.

Table 4. 5 Distribution of Sketch Map Elements by City of Residence

Element	Toronto n = 15	Scarborough n = 15	MRV n = 15	Total
Path				
Count	380	395	385	1160
% total	28.9%	34.9%	30.9%	
Landmark				
Count	788	603	770	2161
% total	59.9%	53.2%	61.8%	
Node				
Count	125	116	82	323
% total	9.5%	10.2%	6.6%	
Boundary				
Count	20	18	7	45
% total	1.5%	1.6%	0.6%	
District				
Count	2	1	2	5
% total	0.2%	0.09%	0.2%	
Total Count	**1315**	**1133**	**1246**	

4.3 THE MEANING OF SEQUENCE IN SKETCH MAP CREATION

The majority of sketch map studies and analyses in the past have focused on topological measurements and element counts. However, by looking at a sketch map, it is difficult to recognize patterns and interactions between elements. In this study, the sequence in which elements were drawn was investigated in an attempt to understand the dynamic(s) of sketch map creation.

4.3.1 Sketch Map Classification using Sequence

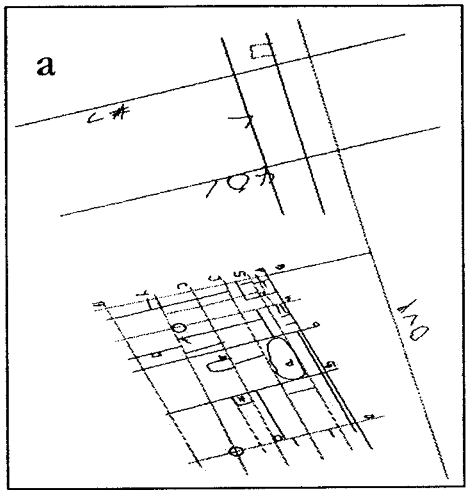
As noted in the literature review, much of the research on sketch maps have been focused on extracting metric distortions and comparing them to ground elements, modelling environmental learning and applications to planning. The organization or grouping of sketch maps was developed much later in the field by two independent researchers, namely Ladd (1970) and Appleyard (1970). Ladd's (1970) classification schemes were too simplistic for the purpose of this study so Appleyard's (1970) classification scheme was explored for the forty-five sketch maps.

It is often difficult to classify sketch maps because they are unique to their creator, so an objective method is needed. Appleyard (1970) identified two map types, namely sequential and spatial sketch maps. Paths dominate sequential sketch maps while spatial maps primarily contain spatial elements such as buildings, landmarks, or districts. Each map type is further divided into four subgroups. A sequential map ranges from those that are fragmented with increasing complexity to those that feature chains, branches, loops and ultimately networks. A spatial map starts with a scattered map, progresses to a mosaic, linked and finally a patterned map. Although Appleyard (1970) mentioned that the best maps are a combination of the two map types and contain two dominant elements, namely paths and landmarks, there has been no further discussion of this intermediate 'hybrid' group of maps in the literature. The goal of this section is to show that sequence can complement Appleyard's classification scheme to differentiate between sketch map types.

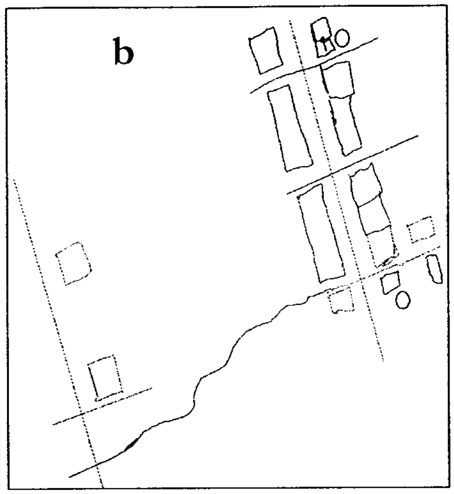
Using the same method defined by Appleyard (1970), sketch maps from this study were grouped into either spatial, sequential or hybrid types. Examples of these are provided in Figures 4.14a through 4.14c. Although Appleyard (1970) described clearly the sequential and spatial categories, the task of separating and grouping maps in this research was less obvious and more confusing than expected. It was particularly difficult using only paths or landmarks to separate map types because some maps which fell in the spatial group could have also been placed in the sequential group. It was clear from this process that using solely the topology of elements in the static sketch map to understand city structure is not sufficient. This is also noted by Appleyard (1970) who stated that, "It must be emphasized that we do not gain a complete understanding of city structuring purely through examination of subject maps" (pg. 109).

Figure 4. 14 Examples of Sketch Maps Classified by Appleyard's Classification Scheme and Sequences of Drawing Process

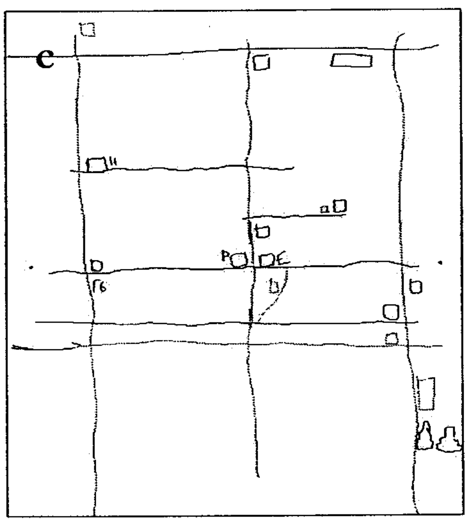
4.14a Sequential map



4.14b Spatial map



4.14c Hybrid map



Despite difficulties, classification of the forty-five sketch maps was completed. The most dominant map type was found to be spatial maps, compared to a dominance of sequential maps found by Appleyard (1970) and Wong (1979). The spatial map type was dominant with twenty-four maps (53.3% of total) followed by hybrid maps which consisted of eighteen maps (40.0% of total) and three sequential maps (6.7% of total). Although the map type results do not correspond to the results of past studies, this process revealed that an examination solely on sketch maps do not portray the complete understanding of sketch map formation nor element interrelatedness. As stated in the hypothesis, sequence may be a variable that can better clarify the two map categories. If there is a true sequential map, then it should reveal many paths, clustered throughout the process of sketch map creation and the same should be true for spatial maps, marked with clusters of landmarks and nodes. For this reason, sequence will be applied on these maps as an experiment to test whether they can better classify map types and make the classification process more transparent.

The sequence is condensed by using codes and numbers. The elements are represented by letters P = path, L = landmark, N = node, D = district, B= boundary. The numbers preceding letters represent the frequency of that element. Figure 4.14a can be depicted with the sequence 15P 1L 4P 1L 4P 1L 4P 1L 1P 1N 1L 4L 1L 5P 1L (43 elements), Figure 4.14b with 3L 1P 4L 1P 3L 2P 12L 1P 10 1N 2L 3L (43 elements) and Figure 4.14c with 2P 2L 1P 3L 2P 1N 1L 1P 1L 1N 1P 2L 2P 1N 4L 1P 1L 1N 1P 1L 1N 6L 1P 2L 1N 1L 1N 1L (45 elements). The first sequence supports a sequential map because of the large number of paths at the start, followed by a consistent display of multiple paths and landmarks interspersed throughout. The second sequence supports a spatial map because of clusters, large and small, of landmarks throughout the map, and the likely use of paths as links or connectors between these clusters. The third sequence is a hybrid map for several reasons. First, the number of landmarks and paths are similar to each other (±10). Second, the number of paths and landmarks are quite equally distributed throughout the sequence of map development.

The classification of Figures 4.14a through 4.14c suggests that the classification of maps into map subtypes can be more accurate with the use of sequence in which the maps were drawn. The same technique was used to classify the remaining forty-two sketch maps. Overall, this classification grouped fourteen sketch maps as sequential maps (31%), thirteen as spatial maps (29%) and eighteen as hybrid map types (40%). This trial classification is followed by a more rigorous method using a statistical method, namely ClustalW (introduced in Section 4.3.4) to classify forty-five sketch maps.

4.3.2 Sequence of Drawing Sketch Map

Different studies, including this one, have consistently shown a dominance of the path and landmark elements (Lynch 1960; Appleyard 1970; Devlin 1976; Pocock 1976) in sketch maps. However, this may be a function of the research question asked and methods of data collection. Nevertheless, the prominence of path and landmark familiarity to subjects is an indication that there may be an underlying interaction between these elements in urban perception. In this section, Figures 4.15 through 4.18 illustrate the resulting patterns when sequence was used as a variable plotted against the percentage of elements drawn.

Figure 4.15 shows the percentage of element type drawn at each step in the drawing sequence from the 1st through 243rd sequence. This produced two patterns. The first pattern is the decline in the number of subjects relative to the number of elements drawn on the sketch maps. After the 25th element, the number of subjects drawing begins to decline. After 160th element, only one person is left drawing for a maximum number of 243 elements. This suggests that the majority of the sketch maps were drawn within the first seventy elements, after which most subjects have already finished drawing.

The second pattern is the interrelatedness of elements. The most distinct pattern is between paths and landmarks. Paths tend to be more frequently drawn at the beginning of the sketching exercise, but begin to decline by the 10th step, at which time the frequency of landmarks drawn begins to exceed that of paths. Nodes were more uniformly reported throughout the drawing sequence, while boundaries increased in number from start to end of exercise. Districts were rarely reported, with a few at the beginning of the drawing exercise.

Figure 4. 15 Number of People Left Drawing their Sketch Map with the Progression of Time

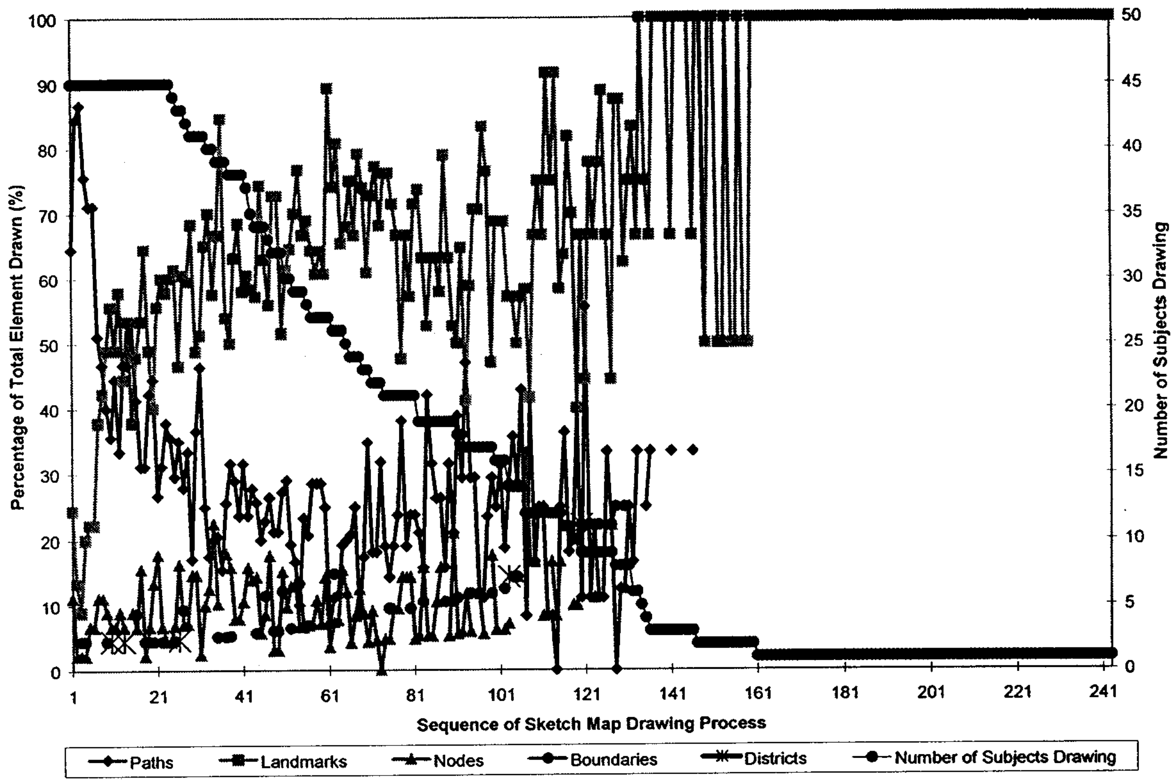
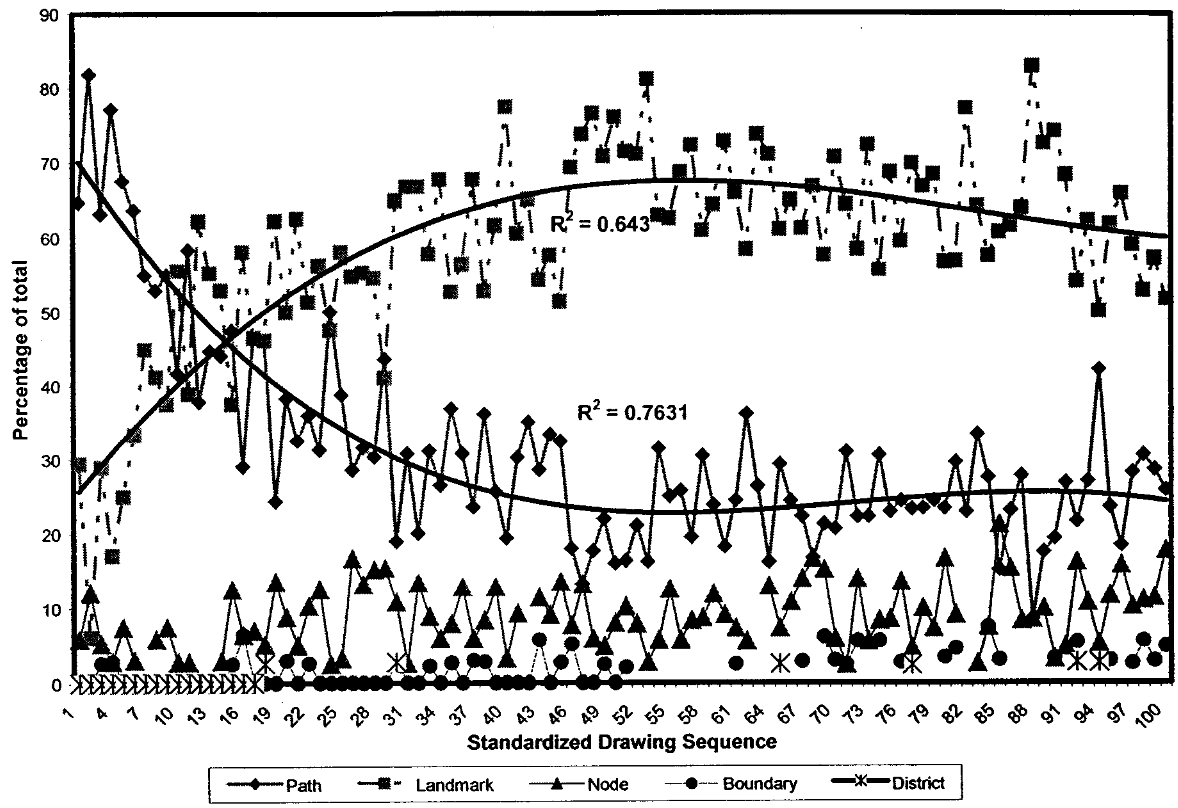


Figure 4.15 is perhaps not an optimal way to compare sequence in sketch maps because everyone reported a different total number of elements, ranging from 24 to 243 elements. Another way to represent Figure 4.15 is to "standardize" the drawing sequence, as shown in Figure 4.16. This graph is easier to compare element interrelatedness because the sequence order has been standardized to range from the beginning (0%) to the end (100%) of the drawing exercise, eliminating different sequence numbers between subjects thus allowing for overall comparison of the forty-five subjects. An extensive description of the calculation of standardized sequence and the proportion of elements at each sequence was described in Section 3.4.3.

Figure 4. 16 Proportion of Each Element Drawn in a Sketch Map as the Drawing Exercise Proceeded from Start to End



In Figure 4.16, square symbols represent the total percentage of landmarks drawn at each standardized sequence. Diamond symbols represent the distribution of paths along the same standardized sequence. These are the two most visible elements because they make up the largest proportion of a sketch map. Nevertheless, nodes also comprise a fair proportion of a sketch map, although not to the same extent. There is fluctuation in all elements which means that the total percentage of each element changes at each sequence. The resulting pattern shows a dominance of paths at the beginning of the sketch map process. However, this ceases at about 12% through the drawing exercise and declines from thereafter. Paths initially make up 78% of the overall sketch map but drop to 45%. Landmarks show the opposite trend, starting at low numbers and increasing after 12% through the drawing exercise to become the dominant element throughout the sketch map creation. Landmarks begin at 25% and increase to 45%. Conversely, nodes have a uniform representation throughout the map creation process, meaning they were likely drawn at any stage in the sketch map exercise. Boundaries and districts were the least mentioned and represent only 1.45% and 0.1% respectively of total elements drawn. Boundaries were drawn closer to the middle and end of the sketch map creation, whereas districts were concentrated at the beginning and end of the drawing.

The trends in Figure 4.16 were emphasized by fitting a trendline through the points for each element. The trendline is a mathematical function that measures the least squares fit through points to display trends. It can be represented as a line or as a curve, depending on the equation chosen to fit through points. For example, a linear equation will produce the best-fit trendline through data as a linear function (i.e. straight line). In this study, the polynomial equation, to the power of three, was used to calculate the trendlines for Figures 4.16 through 4.18. Notice that the polynomial trendlines are curved rather than straight. A trendline's degree of fit is represented by an R^2 value that measures the variation of data points accounted for by fitting a curve line through the data. The closer the R^2 value is to 1.0, the stronger the trend or less variation in data points along the x-axis, and the opposite is true of R^2 values closer to 0.0. In all trendline calculations, the standardized drawing sequence is the independent variable and element is the dependent variable.

The two trendlines in Figure 4.16 emphasize the fluctuating pattern of paths and landmarks, showing the rapid rise and plateau of landmarks as well as the rapid drop and plateau of paths. The R^2 value for paths is 0.7631 and that for landmarks is 0.643. This suggests that paths exhibit a pattern of tighter fit than landmarks. The resulting pattern is termed the "fish tail" from its resemblance to a fish's tail.

The same patterns found in Figure 4.16 reoccur to a varying degree for both gender. Figure 4.17 and 4.18 shows the pattern for female and males separately. The R^2 value for paths drawn by males (Figure 4.18) is lower than those drawn by females (figure 4.17) suggesting that females show a tighter fit to the fish tail pattern.

Figure 4. 17 Proportion of Each Element Drawn in a Sketch Map as the Drawing Exercise Proceeded from Start to End (23 Female Subjects)

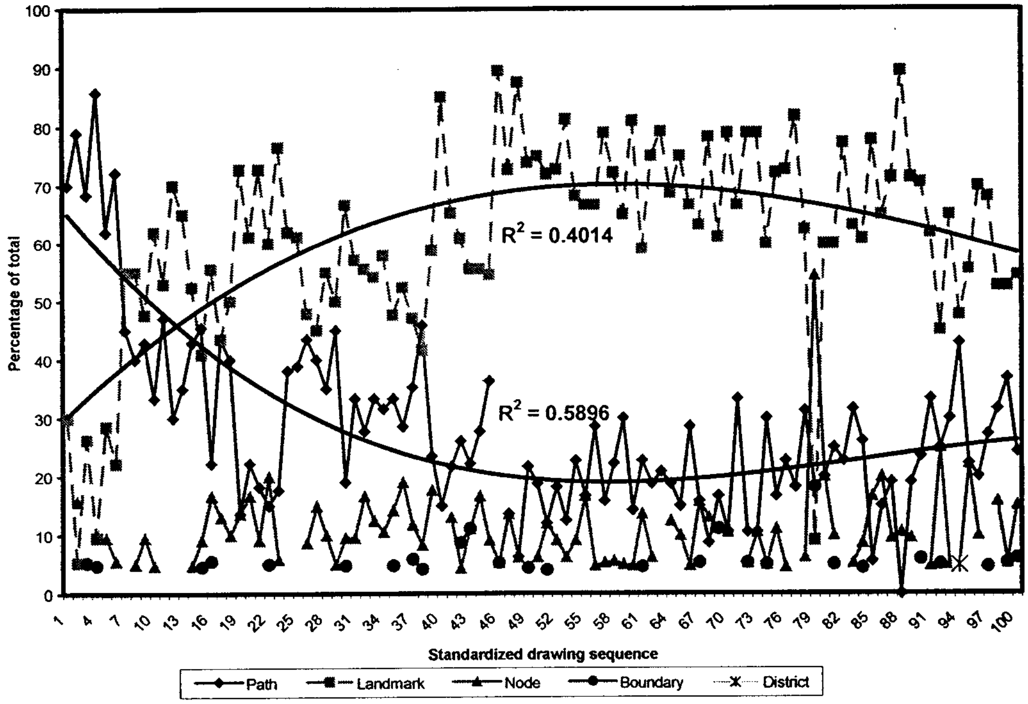
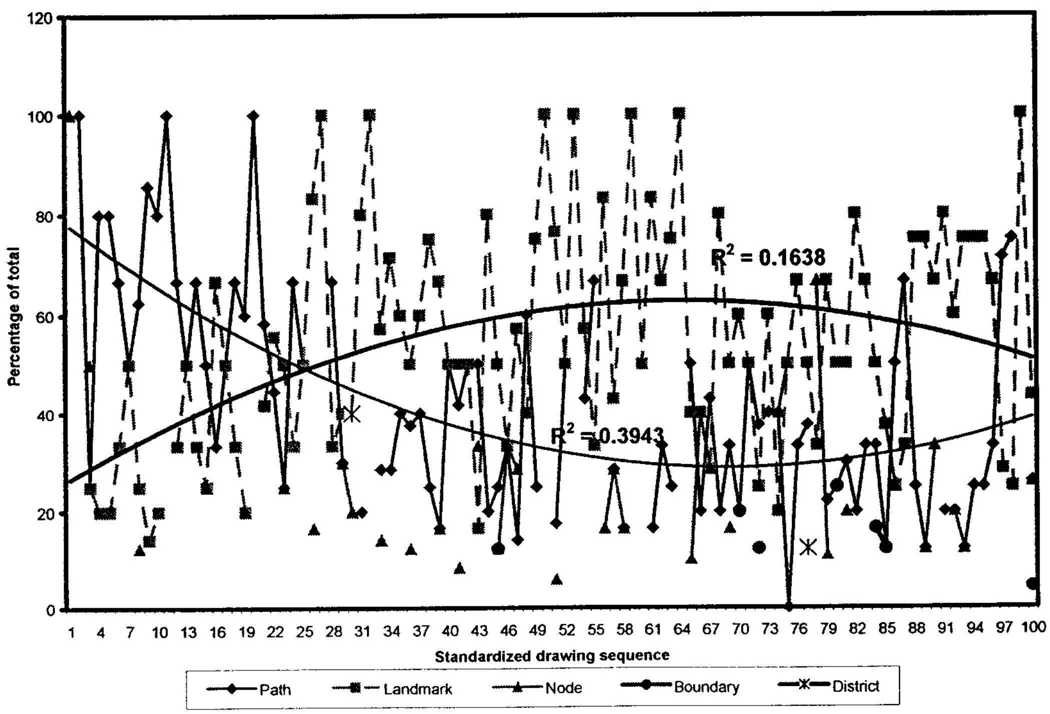


Figure 4. 18 Proportion of Each Element Drawn in a Sketch Map as the Drawing Exercise Proceeded from Start to End (22 Male Subjects)

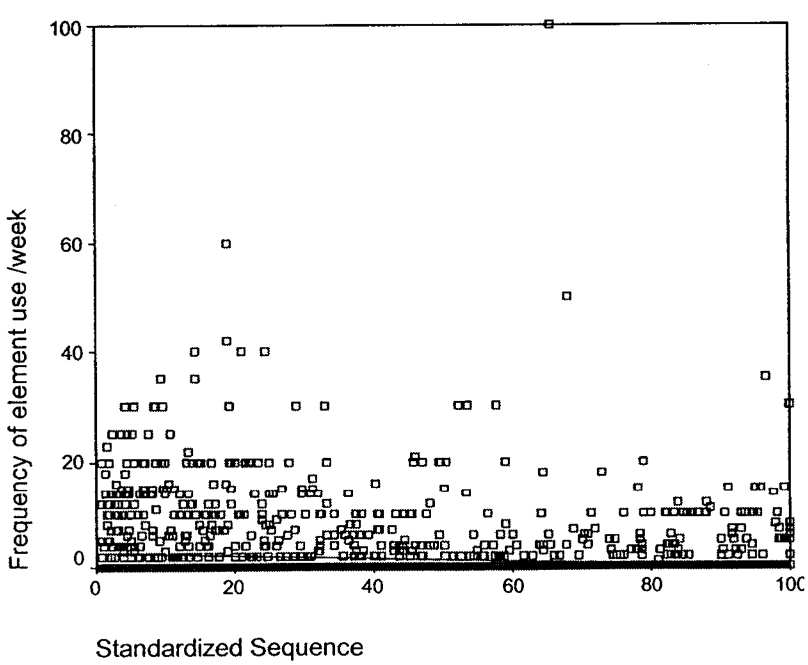


4.3.3 Frequency of Element Use

In the latter part of each interview, subjects were asked to identify paths and landmarks by the frequency of element use per week. The total number of elements reported was 13.7% of all drawn elements (3703) which consisted 27% of all paths, 3.7% of all landmarks, 3.7% of all nodes and 2.1% of all boundaries. This classification suggests that subjects drew many elements, but travelled on or visited only a small proportion of those elements.

One might expect that frequently used elements would be drawn earlier in the sketching sequence. To explore this, the frequency of element use (measured as the number of times a path was travelled on or a landmark was noticed in a week) was graphed against the standardized sequence to determine whether frequently used elements is associated with the order in which elements are drawn in the sketch map. Overall results are shown in Figure 4.19 with an R^2 value of 0.027. This suggests a loose fit of association between element frequency of use per week and the order in which they were drawn on a sketch map. GPS traces can be used to confirm the lack of relationship between frequency of element use and order drawn on sketch map. This is discussed further in Chapter Five.

Figure 4. 19 Frequency Use of All Reported Elements Plotted against Standardized Sequence



The same lack of association between frequency of use and sequence was found when examined by element type, gender and city of residence. (i.e. the R^2 values were very low, ranging from 0.001 to 0.06). This strongly suggests that the frequency of element use has no relationship with the sequence it was drawn on the map. This is a surprising finding as more frequently used elements were expected to be drawn early in the process, as predicted by the anchor point theory.

4.3.4 Sequence of Two Important Nodes: Work and Home

Two important nodes were chosen for further analysis - home and work - given their prominence as anchor points for most people. Figure 4.20 and 4.21 shows the distribution when each subject recalled home and work during the sketch map creation process. The trend exhibited in Figure 4.20 suggests that 'work' is either identified at the beginning or at the end of the map creation process, with few people identifying 'work' in the middle of the sketch map exercise. The trend exhibited by Figure 4.21 has a slight positive skewness for the identification of 'home', with a small peak at the end. This suggests that more subjects drew 'home' early on in their sketch map with a few people drawing it towards the end.

Figure 4. 20 Distribution of Subjects by when Work was Recalled

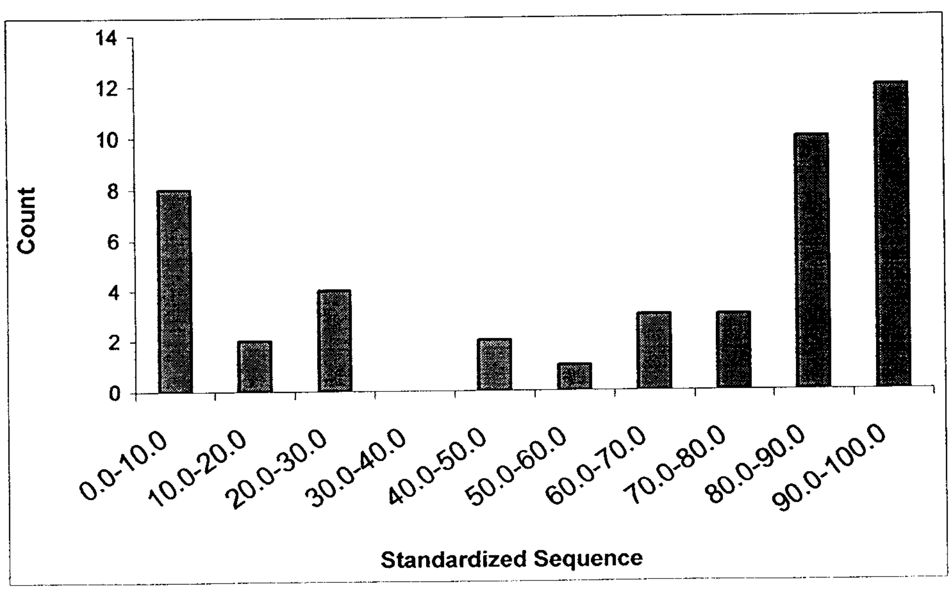
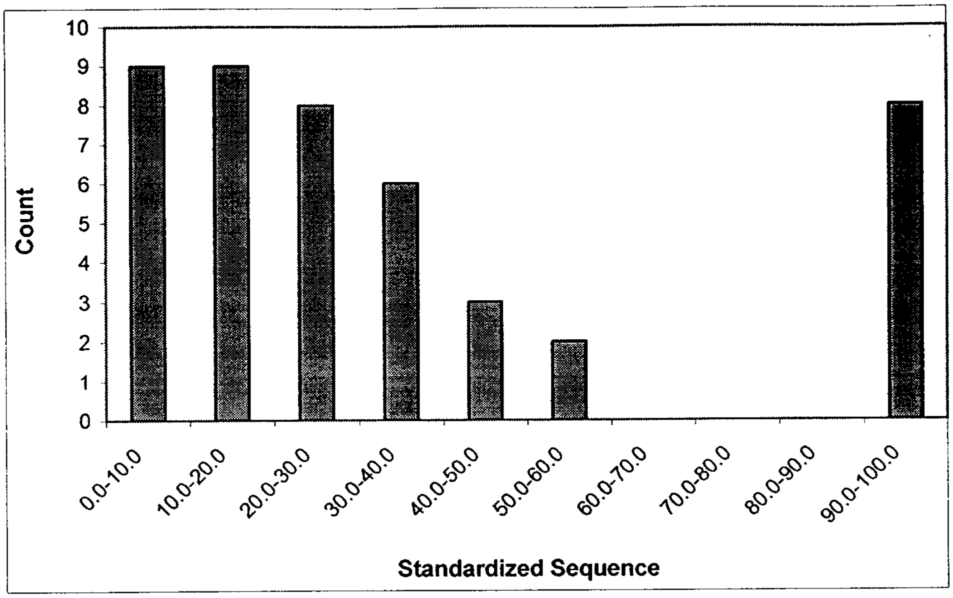


Figure 4. 21 Distribution of Subjects by when Home was recalled

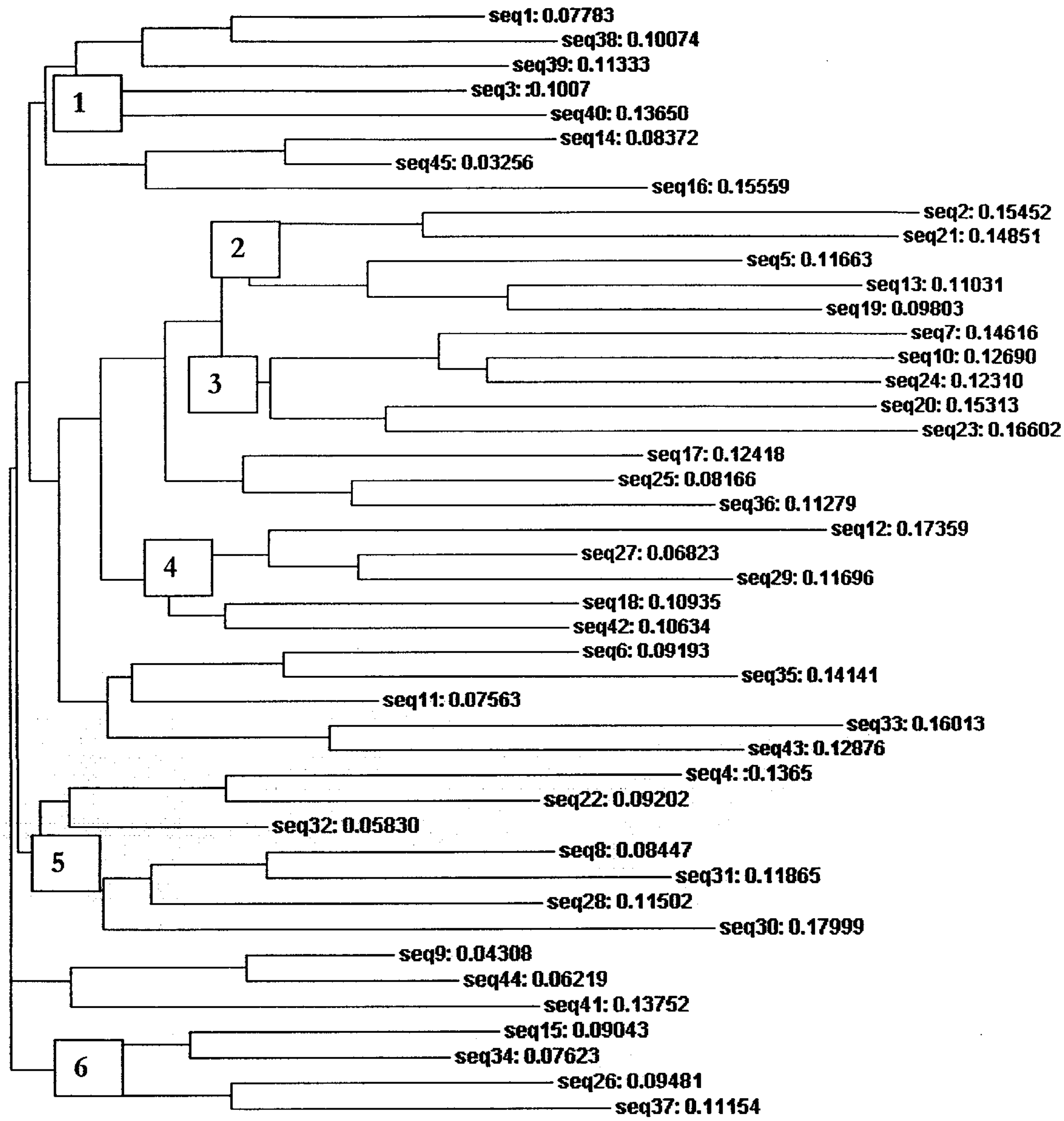


4.3.5 Sequence Analyzed with ClustalW

The above analysis serves to explore the basic relationships between the sequences of image elements. In this section, a more stringent statistical method was used to analyze the forty-five sequences.

The sequence strings of the forty-five sketch maps (as described in section 4.3.1) were analyzed in ClustalW, which produced the phylogram diagram in Figure 4.22. The phylogram is a hierarchical tree showing the relationships and groupings within the sequences. There are six distinct groups evident, suggesting that there were six distinct ways that subjects constructed their sketch maps. The 'Seq#' value represents individual subjects. Beside each subject identification 'Seq #' is a numerical value denoting the distance the branch is from the root of the tree. The larger the number, the less related the subject is to all other subjects and to subjects in the same group.

Figure 4. 22 Phylogram Results from ClustalW: Clusters of Forty-Five Sequence Strings



To validate each group and ensure there is a high percentage of matching between all sequence strings within a group, the average of all paired relationships was calculated by adding all matching percentages calculated by ClustalW and dividing by the total number of pairs. For the example shown in Table 4.6, the percentage of matching between each pair of sequence string is shown, from which the average matching for the seven sequence sets of strings was calculated to be 72.8%. This average matching value is significant because it serves as the confidence level of matching between sequence strings. In this example, the value means that on average, 78% of all elements were matched between the seven sets of sequence strings. The remaining elements were in such different sequence that they did not match. The higher the average matching value is, the higher the confidence that the sequence strings are properly matched. Despite the high matching percentage, there are gaps in the cluster method. For example, sequences 11, 33, 35 and 43 are clustered in group four, but the phylogram shows that these sequences are one node away, or distance from group 4. This technique must be thoroughly investigated before applying it to future studies.

Table 4. 6 Percentage of Sequence Matching Between Pairs of Sequence Strings

Group 1							
	Seq3	Seq31	Seq32	Seq38	Seq39	Seq41	Seq44
Seq3	100	79	79	78	74	68	72
Seq31		100	73	64	60	62	70
Seq32			100	87	77	78	78
Seq38				100	76	58	73
Seq39					100	70	75
Seq41						100	78
Seq44							100

The percentage of matching for Figure 4.22, based on the average scores is quite good, considering the long sequence length and the number of variables, five in this context, to be considered in any sequence string. Group 6 has the highest matching (76.2%), followed closely behind by Group 1 (72.5%). Group 5 (69.2%), Group 4 (65.8%), Group 3 (65.0%), Group 2 (65.5%) have similar matching scores. Since integration of unidimensional sequence alignment with human geography is new, there is currently no recommended or stated percentage of acceptance. However, in similar work in biology, the matching is usually exceptionally high, reaching over 99% in most cases, especially when used to match DNA for such things as paternity tests or crime. For the purposes of exploratory research such as in this study, 60% is deemed an acceptable matching level, especially given the behavioural rather than physical nature of the data.

Each group of sequence strings matches at eight different “alignment” parts. Alignment, in this context is defined as a segment of a sequence string that matches with segments of other sequence strings as demonstrated in Figure 4.23. Figure 4.23 shows three such matching alignments along the sequence strings. For example, these fifteen sequences match at the first alignment because at that particular segment of the sequence string, they all have a cluster of paths. In alignments two and three, the sequence string segments all have a clustered mix of landmarks and path.

The degree of similarity in the groups was then crosschecked with the average scores calculated between each sequence string, similar to Table 4.6.

Figure 4. 23 Example of Alignments along a Stretch of Sequences that Match

Matching of sequences at different alignment points

```
                     ↓1                  ↓2                    ↓3
seq1    ----------PPLLPPL----LPL------LLPPPP----------LLLLPLLLPLPLPL 30
seq38   ---------------------------------PPP--------------PLLLP----- 8
seq39   -------------------------------LPPPP----------PNPPPPLLPPP--- 16
seq3    LPPPNPPPLLLPLLLLLPPLLLLL------LLLLLP----------LPLPLLLLPLLLL- 43
seq40   ----------LPLLLLL----LLL------LLLLLP----------PLLLLLLPPPPPP- 29
seq14   ------------------------------LLLP----------------LLLLP----- 9
seq45   ---------PPPPPPLPPLLLPPL------LLLPPL----------LLLLLLLLPPLLLP 35
seq16   ---------------------PPP------LLLP----------------LLLLB----- 12
seq15   --------------PPPPPPPPNN------PPLLPP----------PPPPNLPLLPLLL- 29
seq34   ---------------PPPPPPPN-------PLLLPL----------PPLPN--LLP---- 22
seq26   ----------NPNLLLPPPPLPLP------PPLPLP----------PPLLNLPLLPLLL- 33
seq37   ----------------PPP--PPP------PPPPPP----------PPLLN--------- 17
seq9    ----------------PPPPPPN-------LLL--------------------------- 10
seq44   --------------PPPPPPPPP-------LLLPPL----------PLLLLLLLLLNPP- 28
seq41   ---------------LPPPPLPP-------NLLPPL----------PLLLPLDLLP---- 24
```

4.3.6 Sequence Alignment Group Interpretation

There are concrete differences between each group, mainly in the order and dominance of elements in the sequences. Table 4.7 summarizes the six sequence groups in detail. The first group is dominated by paths with landmarks interspersed throughout. The second group is also dominated by paths but only at the beginning of the drawing process. Thereafter, landmarks and nodes are more prominent. The third group is very similar to the second group except that paths are dominant throughout, with a visible number of nodes situated between landmarks or path clusters. The fourth group is composed of clusters of paths followed by clusters of landmarks throughout the drawing. The fifth group is dominated by paths at the beginning, followed solely by landmarks. The sixth group is dominated by paths at the beginning, followed by landmarks that dominate the rest of the sketch map, except for a few paths and nodes.

The new classification proposed in Table 4.7 borrows the spatial and sequential map type categories from Appleyard (1970). However, a third group labelled 'hybrid' is added. The hybrid group, although suggested by Appleyard (1970), was not formally defined or discussed. In the context of this study, the hybrid group describes sketch maps that have both qualities of sequential (path oriented) and spatial (landmark oriented) maps but do not fall neatly into either group.

Table 4. 7 Summary of Phylogram Classification Produced from Forty-Five Sketch Maps

Group number	Map type	Number of subjects in group	Distinct description
Group 1	Sequential	8	-dominated by paths -landmarks are interspersed amongst paths
Group 2	Sequential	5	-paths dominate the start of the sequence -the middle to end of the sequences are dominated by a fairly consistent pattern of paths, landmarks and nodes
Group 3	Spatial	8	-dominated by paths - nodes are evident either between landmarks and paths
Group 4	Hybrid	10	-pattern of groups of paths followed by landmarks throughout the drawing
Group 5	Hybrid	10	-the start of the sequence is dominated by paths followed by landmarks thereafter until the end of the map creation
Group 6	Spatial	4	-the start of the sequence is dominated by paths -the rest of the sequences include landmarks interspersed with a few paths and nodes throughout

4.3.7 Sequence Alignment Interpretation by City of Residence

A phylogram was produced to study the different ways of sketch map drawing by city of residence. In this procedure, the sequences for subjects belonging to their respective city of residence were grouped and run through ClustalW.

Figures 4.24 through 4.26 show the results for Toronto, Scarborough and MRV respectively. Since the number of subjects dropped from the total forty-five subjects to fifteen for each area, the phylogram looks much simpler than Figure 4.22.

Figure 4. 24 A Phylogram Produced from Toronto Subjects' Sketch Maps

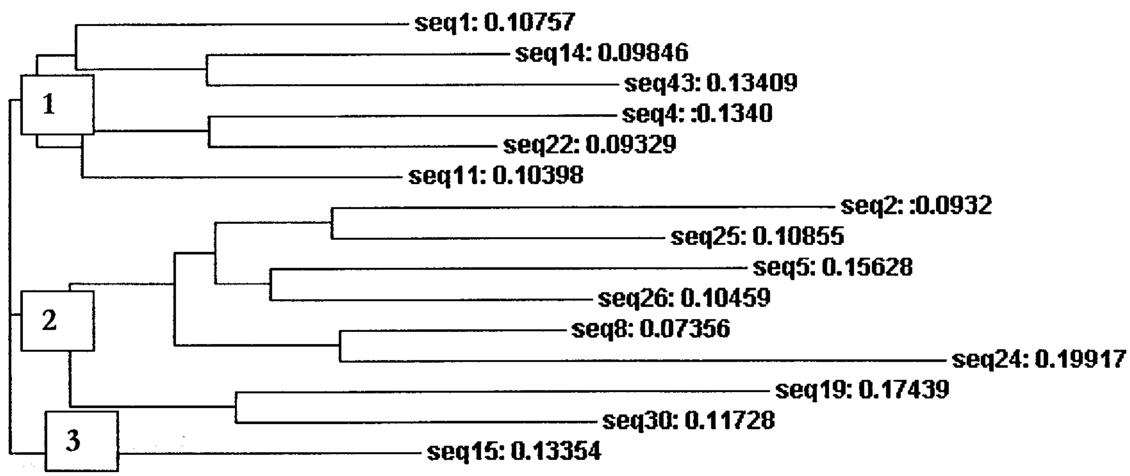


Table 4. 8 Summary of Phylogram Classification Produced from Toronto Subjects

Group number	Map Type	Number of subjects in group	Distinct description
Group 6	Spatial	6	-dominated by landmarks throughout -sparsely populated with paths and rarely nodes
Group 2	Sequential	8	-paths dominate the start of the sequence -the middle to end of the sequence are dominated by a fairly consistent pattern of paths, landmarks and nodes
Group 4	Hybrid	1	-paths dominate the start of the sequence -good mix of paths and landmarks throughout

Figure 4.24 shows the phylogram for Toronto subjects. There are three distinct drawing styles for this group, with an overall matching percentage of 77.5%. Group 3 (100%) received the highest matching because the average score was calculated with only one subject in the group, followed by Group 1 (69.9%) and Group 2 (62.6%). Group 1 is dominated by landmarks, and

interspersed with paths, making it a spatial map type. Groups 2 and 3, however, are hybrid map types. The only difference between these two groups is that Group 2 has nodes mixed with paths and landmarks whereas Group 3 has no nodes in the path and landmark combination of elements (Table 4.8).

Figure 4. 25 A Phylogram Produced from Scarborough Subjects' Sketch Maps

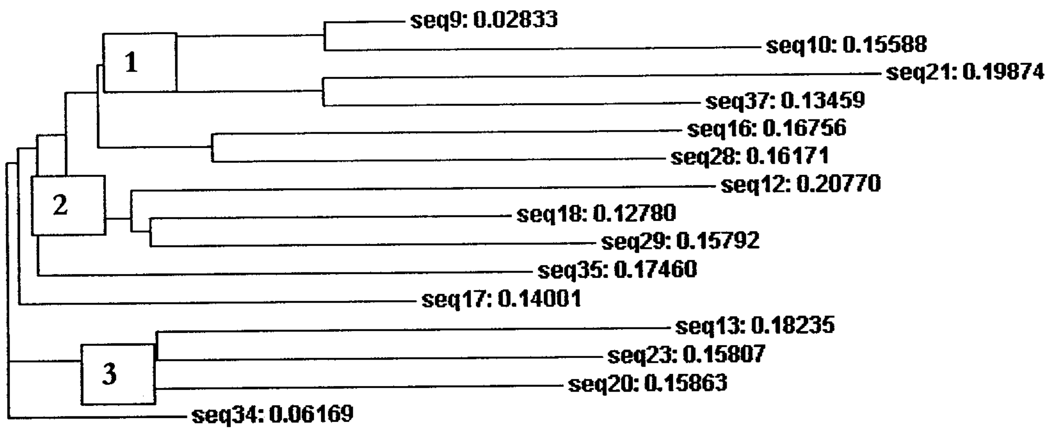


Table 4. 9 Summary of Phylogram Classification Produced from Scarborough Subjects

Group number	Map Type	Number of subjects in group	Distinct description
Group 1	Sequential	4	-dominated by paths at the beginning -followed by landmarks, nodes and paths
Group 2	Sequential	7	-paths dominate the start of the sequence - middle to end of sequence dominated by a paths, landmarks and nodes
Group 5	Hybrid	4	-paths dominate the start of the sequence -landmarks, paths and nodes make up the end of the sequence

Figure 4.25 shows the phylogram for Scarborough subjects. There are three distinct drawing styles for this group, with an overall matching percentage of 63.3%, lower than matching between Toronto subjects. All groups received an average in the 60% range, led by Group 3(67.8%), followed by Group 2 (62.0%), and trailed by Group 1 (60.0%). It appears that all three

groups are hybrid map types. All three groups have paths, landmarks and nodes but in different orders and proportions. Group 1 is dominated by paths at the beginning, followed by landmarks, with a few nodes and paths throughout. Group 2 is dominated by paths at the beginning of the drawing, but the middle and end are equally distributed with paths, landmarks and nodes. Group 3 is similar to Group 2 except that paths dominate throughout with only a mix of landmarks and nodes at the end (Table 4.9).

Figure 4.26 shows the phylogram for MRV subjects. There are three distinct drawing styles for this group, with an overall matching percentage of 71.2%. Group 3 (77.0%) had the highest match, followed by Group 1 (72.8%) and Group 2 (63.9%). It appears that all three groups are hybrid map types. Group 1 is dominated by paths at the beginning followed solely by landmarks, with paths throughout. Group 2 is dominated by paths at the beginning of the drawing, but the middle is equally distributed with paths and landmarks until the end, which is dominated with landmarks. Group 3 is similar to Group 2 except that paths dominate the start of the map, until the middle. The end has a combination of landmarks and paths (Table 4.10). These results are discussed further in Chapter 5.

Figure 4. 26 A Phylogram Produced from MRV Subjects' Sketch Maps

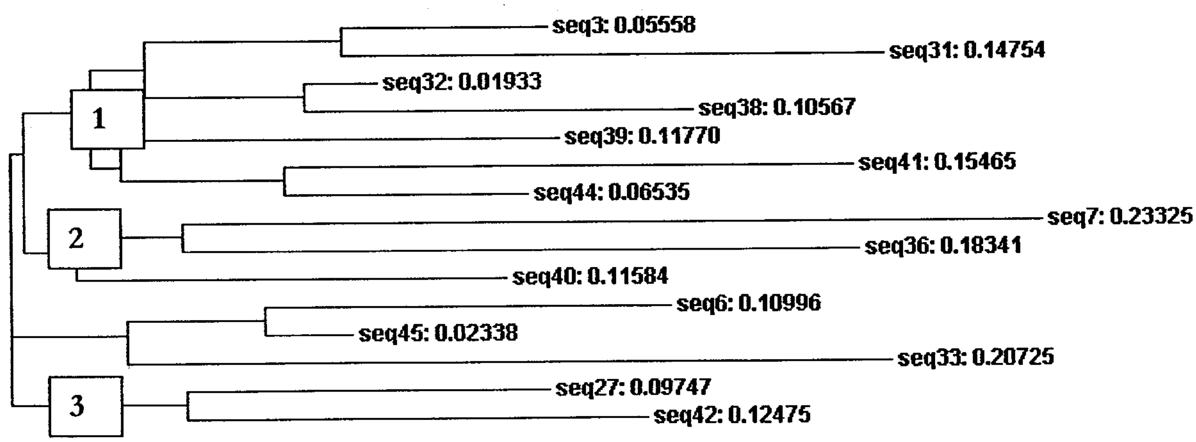


Table 4. 10 Summary of Phylogram Classification Produced from MRV Subjects

Group number	Map Types	Number of subjects in group	Distinct description
Group 5	Hybrid	4	-dominated by paths at the beginning -followed by a domination of landmarks from thereafter
Group 1	Sequential	7	-paths dominate the start of the sequence -the middle of sequence dominated by a fairly consistent pattern of paths, landmarks -landmarks are markedly dominate towards the end
Group 4	Hybrid	4	-paths dominate the start of the sequence -landmarks and paths make up the rest of sequence

4.4 CHAPTER SUMMARY

This chapter presented and described the results of the analyses undertaken on data collected. There were two major and one minor analysis foci. The first major focus considered the performance of MMAPIT and whether it could collect sketch maps with at least the same level of quality as pen/pencil and paper method. Using qualitative and quantities measures, it was concluded that MMAPIT was able to collect sketch maps that are very similar to those collected with a pen/pencil and paper method. Second, it has the potential to collect more data such as visual and voice recording during the sketch mapping exercise and sequence of drawing process.

The second major focus was on the sequence of sketch map creation, which produced four sets of results, using sequence as the main variable. The first result concerns the classification of map types using sequence strings. In this context, the sequence string can be used in combination with Appleyard's (1970) sketch map classification to separate quantitatively sketch maps into three groups, namely sequential, spatial and hybrid groups.

The second analysis was to graph the percentage of total elements drawn at each standardized sequence. This generated a very distinct fish tail pattern. The fish tail pattern demonstrates a relationship between paths and landmarks where paths make up a large proportion of the early development of a sketch map. However, this quickly declines and thereafter landmarks become the dominant element.

The third analysis goal was to explore relationships between the frequency of element use with standardized sequences. The R^2 values turned out to be very low. A detailed discussion including possible reasons for these results is in Chapter Five.

The fourth analysis was using a software, namely ClustalW, to analyze sequence strings. This analysis generated phylograms and groups of subjects who drew elements in a similar manner.

The minor focus examined the number of elements drawn by gender and city of residence. The Chi-square test confirmed that there is statistical difference between the number of elements drawn by females and males. The Chi-square was also applied to the city of residence. The result verifies that there is statistical difference in the number of elements identified in each of the three cities of residence. These tests suggest, in the confines and limitations of this exploratory study, that the number of elements drawn is dependent on gender and city of residence. Possible reasons for these observations are discussed further in Chapter Five.

Chapter 5

DISCUSSION

Chapter Five discusses the interpretations of results and attempts to explain observed patterns. The results are discussed in context to past literature, studies and theories. This chapter builds upon the objectives and hypotheses presented in Chapter One and Two. First, the MMAPIT tool is discussed in relation to its performance in this study and its implications for future cognitive work. The second section discusses the findings from sketch map drawing sequence, namely sequence as a criterion to group sketch maps, the fish tail graphical pattern, relationship between frequency of element use and drawing sequence as predicted by the anchor point theory, as well as phylograms created from sequence strings. Next, discussion of unexpected results, namely the division of landmarks into subgroups, followed by differences of element count by gender and city of residence. This chapter concludes with a summary of the overall findings and recommendations for future research.

5.1 MMAPIT: Current and Future Implications to Data Collection

This section summarizes the MMAPIT tool, the data that were collected with the tool as well as projections of MMAPIT's contributions for future research.

5.1.1 Sketch Maps Collected with the MMAPIT Tool

One of the goals of this study was to develop a new computerized method to collect sketch maps and the sequence of their creation. Past methods of sketch map collection included pen/pencil and paper methods and using building blocks to recreate a mental map. However, it was felt that these methods were too simplistic and generated only the sketch map while losing other accessory data in the process. A comparison between sketch maps generated by MMAPIT and those from past studies was conducted in Chapter Four. The results in Table 4.2 support the notion that there is no significant difference between past and current sketch map samples.

There are two reasons for this. The first reason is that drawing a sketch map on MMAPIT is not different from drawing with pen/pencil and paper. Both methods require a writing utensil on a hard surface. The second reason is that all subjects were exposed to computers at some point in their lives so they were comfortable with a computerized method.

The results show that the typology of sketch maps is similar regardless of collection method. Nevertheless, delving underneath the surface to examine elemental dynamics reveals more differences than expected. Table 4.2 showed the results of element comparison. In all three samples, sketch maps drawn with MMAPIT have higher element counts than comparative samples. In addition, boundaries and districts were clearly apparent on the MMAPIT sketch maps whereas they were ambiguous on the sample maps. One obvious reason is that MMAPIT captured verbal *as well as* visual data, so in reviewing the video, it was clear what each element was. The second explanatory factor is that subjects from this research had a maximum of 30 minutes, whereas subjects participating in the sample maps may have received less time, which would account for fewer elements drawn. The third explanation is that MMAPIT'S drawing area was potentially larger because subjects could stroll up/down and left/right to increase the drawing space. The subjects can then draw more elements in a larger drawing space compared to the fixed size of a piece of paper. In this context, the MMAPIT tool has the potential to generate data that allow researchers to revisit and clarify past methods and theories. In particular, the sequence of sketch map creation provides another way to classify sketch maps, building on the work of Appleyard (1970).

Sequence can be used as a variable to show the percentage of element composition of sketch map creation through time, from 1% to 100% of drawing process. This technique produced the fish tail graphical patterns. More important is the exploration of associations between the frequency of element use and testing it against the predictions from the anchor point theory and the different sketch map drawing styles.

5.1.2 Data Volume

Sketch map drawing usually limits a subject by its drawing space. Often, the subject draws too many elements, which cannot be deciphered later or the subject labels too many objects making the map illegible. A goal in this study was to give as much free drawing space as possible. This was achieved by two techniques. The first technique was to record all verbal comments so that subjects could name an element without labelling it. The second technique was to provide the option to scroll up/down or left/right on the computer to increase the drawing surface. These two methods generated 3.5 gigabytes of video data and a total of 3,703 drawn elements from the forty-five subjects.

If researchers in developing countries wanted to collect sketch maps through PPGIS, MMAPIT would be a suitable choice for three reasons. First, MMAPIT can provide the familiar pen/pencil and paper design and feel to subjects. Second, researchers no longer need to digitize the maps. Third, MMAPIT is a portable tool.

5.2 Patterns Observed from Sketch Map Drawing Sequence

Sketch map drawing sequence is the primary focus of this study. Analysis methods produced four results including classification of sketch maps, graphical representations, frequency of element use along sequence, and different sketch map drawing styles. These are discussed in the following sections.

5.2.1 Sequence as a Criterion to Classify Map Types

Research on sketch maps rarely focused on classifying them into subgroups. One obvious reason is that sketch maps are subjective and personal to the person drawing them. It is difficult to develop a set of objective criteria to compare subjective data. However, in 1970, sketch map classification was initiated by the work of Appleyard (1970), who devised a classification system to filter sketch maps into sequential and spatial maps. Although researchers such as Pocock (1976b) later revised the classification scheme, there were two problems with this classification method. The first problem is that the classification criteria were based solely on topological features drawn, ignoring the sketch map drawing process. The second issue was not apparent until Murray et al. (1979) classified maps drawn at different scales. It became obvious that small-scale maps would likely be grouped as spatial maps, whereas large-scale maps were likely to be sequential maps. It became clear that the classification was a function of map scale, having little to do with how people saw the environment but rather how people reacted to drawing different sized environments.

It was hypothesized in Chapter Two that sequence could be used as a criterion to categorize sketch maps. This is particularly important because the final sketch map product between two people may look similar, yet the retrieval strategies or sequence of spatial memory is different. The results in Figure 4.14a through 4.14c show a set of sketch maps that could be classified into the same group using Appleyard's (1970) classification scheme. However, when sequence was used to differentiate them, they were actually shown to be quite different types of maps. Hence, sequencing could be a more objective method to classify sketch maps and possibly a more accurate one. However, it is time consuming to create the sequence and the comparison may be difficult if there are too many sequences. One solution is to use ClustalW or a statistical clustering method to cluster sequence strings into groups.

5.2.2 The Proportion of Elements Drawn at each Sequence

The primary goal of this study was to examine the sequence of sketch map drawing. Sequence can be examined in many ways, whether as a potential criterion to classify maps, in simple graph form, or analyzed by DNA software.

A comparison between the proportion and type of elements drawn in sequence, from the beginning to the end of the drawing process was shown in Figure 4.16 and explained in Chapter Four. The fish tail pattern can be seen and partially explained by the work of other researchers, bringing together fragmented findings of many research projects. The role of landmarks in spatial organization was summarized by Montello (1998) in the dominant framework approach which states that landmarks are discrete objects that have important roles for the organization of spatial knowledge. Second, paths serve as a framework. The relationship between landmarks and paths is that landmarks are linked by frequently used paths which serve as connectors

(Montello 1998). Figure 4.16 seems to illustrate the same pattern where paths were drawn first to create boundaries and connectors to link landmarks. The landmarks were like anchor points, each landmark addition contributing to the overall pattern of spatial knowledge organization.

Figure 4.16 offers two perspectives on sketch map creation because the importance of the path and landmark elements can be debated either way. For example, it is possible to argue that paths are important because they frame the whole drawing by acting as boundaries. The opposite view is that paths are only accessories that help locate landmarks, which are the important element because of their large number. Nevertheless, regardless of which element is more important, neither of them can appear alone in a sketch map, suggesting that they are dependent upon each other. This is observed by Montello (1998) in the revised new framework which states spatial knowledge cannot only contain landmarks *or* paths.

Figure 4.16 shows that the landmark element is the most dominant in number, as noted by many other researchers (Hart et al. 1973; Siegel et al. 1975; Pocock 1976a). Landmarks have also been identified as having importance in route decision making (Siegel et al. 1975; Presson et al. 1988). Siegal et al. (1975) even noted that "a person's account of his spatial representations generally begins with landmarks". However, as shown by the fish tail pattern discussed in Chapter Four, this is not always true in the present context. Presence of the two anchor points may have affected the initial elements subjects drew. Perhaps subjects may have drawn landmarks first if they were not presented with the two anchor points and were allowed to draw freely. This can be investigated in future studies, with a control group (without anchor points) and a test group (with anchor points). In addition, Denis (1997) observed that landmarks were given more importance in route description than other elements, which is supported by the steep increase of landmarks in Figure 4.16 and Table 4.3.

According to Lynch (1960), subjects who knew the city best rely more on landmarks than on paths or regions (Lynch 1960) . Does the high number of landmarks in this study suggest that overall subjects were very familiar with their neighbourhood and city? A little less than two thirds of subjects lived in the same residence for five or more years and the rest between two to four years. Hence, Lynch's (1960) theory may be true but will require more rigorous testing in future research.

The fish tail pattern in Figure 4.16 was replicated by female (Figure 4.17) and male (Figure 4.18) subjects with differences. The fish tail pattern was less distinct for males than females. There are two reasons for this difference. The first reason is rooted in the small sample size. A larger sample size may derive a more comparable pattern between the two genders. The second reason is that males switched frequently between paths and landmarks because they needed paths to set the orientation or coordinate reference system.

Figure 4.17 displays the female fish tail pattern and that it is more distinct than the male fish tail pattern. This suggests that there was more fluctuation in the male data than female data. In addition, males rely on paths to create their sketch maps, found by other researchers (McGuinness et al. 1983). An explanation of this observation can be found in McGuinness et al. (1983) whose study found that females drew few connectors (i.e. paths) between landmarks compared to males. Accordingly, the fluctuation in Figure 4.18 could be a result of male subjects switching often between drawing paths and landmarks. The role of paths serve as connectors to landmarks creating a geometric framework and fulfilling the male tendency to create a coordinate reference system as a map foundation, as suggested by McGuinness et al. 1983. For females, there is less fluctuation because they are consistent in drawing more landmarks and switch between these two elements in a consistent fashion rather than intermittently.

Nodes were the next frequently named elements after paths and landmarks, appearing uniformly throughout the pattern such that at three to five sequence intervals, the number of nodes peaked to comprise approximately 15 percent of the sketch map elements (Figure 4.16). This pattern confirms that nodes were evident throughout the entire sketch mapping exercise. This suggests that they may play an important role in the map creation process. Since nodes were mainly comprised of home, work and TTC subway stations, they may well have been anchor points for the sketch map, although not at the beginning. A reason for this is that the two given anchor points may have influenced the start of the drawing whereas anchor points that were important to individuals became apparent shortly into the drawing process. As the anchor point theory predicted, home and work were expected to be drawn early in the drawing process. In this study, they were, but not always (Figure 4.20 and 4.21). The anchor point theory also states that the hierarchical ordering of anchor points was individual, depending on their significance to the subject. Given this, it was expected that a majority of subjects would draw home and work as anchors since these were the two places that subjects went to and from every day, for a minimum of five days a week. This was observed in Figures 4.20 and 4.21 but not always. A reason for this is that home and work may not be everyone's absolute anchor points among other choices.

The node category in the fish tail pattern included different types of nodes such as subway stations, home and work. For this reason, Figures 4.20 and 4.21 was created to show specifically the distribution of subjects who named 'work' and 'home'. The results show that subjects who drew 'home', were more likely to draw it closer to the start of the sketch map, but not always. 'Work' tended to be drawn at the beginning and spiking toward the end of the drawing exercise. It was expected that subjects draw home and work early in the exercise because they are the two most likely places people visit frequently. Hence, it was surprising that work (and sometimes home) were not always drawn early in the sketching process.

Of the five elements, districts and boundaries were the least recalled. Figure 4.16 shows the small role that districts and boundaries have in the construction of a neighbourhood sketch map. This is a surprising finding since other researchers praised the importance of boundaries and districts. For example, Canter et al. (1975) stated that boundaries such as roads, railways and rivers, gave a city structural coherency. Lynch's (1960) work also showed that districts and boundaries had prominent roles in the composite sketch maps. However, in this study districts and boundaries, at best could be described as minor elements, appearing sparsely at the beginning and end of the mapping sequence. Nevertheless, the finding of low boundary and district counts support other researchers' arguments (Norberg-Schulz 1971; Pocock 1976) that only three of the five Lynch elements are useful in urban perception and description, namely paths, landmarks and nodes.

The low boundary and district result can perhaps be explained by five reasons. The most obvious reason is different study sites. In Lynch's (1960) study, the three study sites were Boston, Los Angeles and Jersey City, all American cities. Boston and Jersey City are special in that they fit into the Burgess concentric zone model (Burgess 1968) which segregates and divides the downtown core and suburbs into concentric circles, according to land use. This type of city usually has definitive boundaries dividing contrasting districts such a road dividing the rich and poor districts. Another division is race, as confirmed in a sketch map study by Ladd (1967; 1970). When residents live in these cities, it is hard for them to miss the obvious districts and boundaries. In addition, Boston has natural boundaries including the Charles River. Jersey City was noted for its strong boundaries including overhead lines of railroads, highways and two waterfronts (Lynch 1960).

These conditions differ in the three Canadian cities/towns studied, namely Toronto, Scarborough and MRV. First, although Toronto has a waterfront, it was seen more as a landmark, a place to visit, rather than as a barrier that separates the city from Lake Ontario. However, it was surprising that so few districts were mentioned, particularly in Toronto where there are many ethnic areas, such as Chinatown, Little Italy and India Town to list a few. The low recall of natural boundaries such as rivers is slightly surprising. In particular from Toronto and MRV subjects because approximately 2 Km from the Toronto study site is the Don River and located in the MRV study site is the Rouge River. One explanation is that Toronto subjects see the Don River as part of the natural ecological setting, located in a ravine, instead of a division in the city.

Scarborough and MRV are quite uniform because they are dominated by residential land uses but also have 'ghetto' areas versus 'wealthy' areas. In addition, there are many Chinese-dominated shopping plazas, often dubbed as the 'second and third Chinatowns' in both Scarborough and MRV but these were not mentioned as districts. A few reasons can explain this lack of district and boundary knowledge. One possibility is that Canadians do not see racial districts isolated by boundaries but rather as part of an integrated city. Building on the Burgess model, the Canadian cities do not fit so well, particularly Toronto which is of mixed use planning.

The second explanation for the low boundary number is that possibly people do not detect boundaries well. Lee (1968) also found low numbers of boundaries in neighbourhood sketch maps and attributed it to the fact that concepts of geographical area have no definable boundary. Lee (1968) found no collective agreement on boundaries; some subjects knew of distinct boundaries, others thought the boundaries were blurred, and others saw smooth gradients "Boundaries are subjective experiences but in other cases they were blurred or consciously recognized as smooth gradients" (Lee 1968, pg. 249).

The third reason is that concepts such as boundaries and districts are terms used by geographers to classify and organize areal features on the ground as well as on maps. However, a layperson may perceive districts and boundaries only as landmarks or as a collection of landmarks. The fourth reason may be attributed to people's increasingly hectic lifestyle. People rush to and from a destination without noticing the surrounding features, particularly ambiguous elements such as districts and boundaries.

Finally, the high path and landmark count maybe be a function of the instruction given to the subject. The suggestion of paths and landmarks in both graphic and verbal form in the instruction could have super-sensitized subjects to those elements. The element results must be interpreted in light of this bias.

Past research and the findings of this study strongly suggest that our image of the city, as we are able to recall it from memory, unfolds in a sequence. It can be imagined as a series of frames in a film or animation. In terms of cognitive psychology this cognitive function is known as sequential spatial memory. Thus, the image of the city that we acquire, store, and recall is not well represented by a sketch map, a two-dimensional planar surface. Rather it must be seen as a four-dimensional representation which reflects our own movements through space and time in sequence. Although the sketch map does not reveal this, the analysis of sequence does. The sketch map reflects other cognitive functions including topological rather than metric properties, hierarchical organizational memory. A third function of a sketch map is the sequential spatial memory of element images. Whether this is a recall method of hierarchically structured elements or a recall method on its own need to be further explored. The understanding of how people recall spatial features from memory can form a set of rules or algorithms for modelling. This can lead to the prediction of peoples' travel behaviour, habits, or choices in different environmental settings.

The discussion above appears to support past studies that show paths and landmarks as playing central roles in the map creation process. These two elements complement each other, one forming boundaries, the other filling in the space within the boundary. In addition, the results show that nodes were evident throughout the drawing exercise and may be important as a framework for the development of a sketch map. The node element has been ignored in the research literature but its importance suggested by this study calls for focused studies to learn more about their role in sketch map creation.

5.2.3 Frequency of Element use and its Implications for Anchor Point Theory.

Frequency of element use and sequence has never been examined together. If an element was frequently used, it was expected that it would be drawn earlier in the drawing process. This hypothesis was based on the anchor point theory, which suggests that the most important anchor points, in hierarchical order, primary, secondary and tertiary paths, landmarks and nodes, would be used to form the skeletal structure of a sketch map (Golledge et al. 1997). Based on this theory, it was hypothesized in Chapter Two that frequently used objects would be drawn early on in the sketch map since their frequent exposure would increase the accuracy and knowledge of the map elements (Montello 1998).

Surprisingly, there was no statistical significance between frequency of element use and their drawing order. There are a few reasons for this observation. The first explanation for this result is the presence of the two predetermined anchor points. Since the first few anchor points restrict the sketch map development (Day 1976), it is possible that the given anchor points influenced the elements drawn. The second reason is the general difference in methods and questions from past studies, which may affect the order of frequently used elements. The third reason is that there is no relationship between frequency of element use and sequence. If this is the case, then the anchor point theory does not appear to hold very strongly in this study. In fact, MacEachren (1992) also found that the anchor point theory for environmental learning did not account for learning from maps, in particular when landmarks were given and represented by abstract symbols. Perhaps the anchor point theory explains observations when subjects are given a blank drawing surface, without the interference of reference points.

Although a rigorous analysis was not performed between GPS traces (action space) and sketch maps (mental space), GPS traces can support the hypothesis. For example, if the GPS traces show a distinct travel pattern, this suggests that subjects travel frequently along certain paths and visit certain landmarks. The next step is to determine whether those highly frequented city elements were drawn first on the sketch map.

5.2.4 Six Drawing Patterns Resulting from Clustering Sequence Strings

In this study, ClustalW was used to cluster similar parts of sequence strings, creating results in Figures 4.22 and Figures 4.24 through 4.26. These figures illustrate different sketch map drawing methods and perhaps revealing the recall process of environmental elements. This section explores sketch map classification, sketch map drawing methods and mental organization of urban environments versus suburban environments.

The trial classification of sketch maps using Figures 4.14a through 4.14c was very similar to the results using ClustalW, in Table 4.7. In both methods, sketch maps were classified as either sequential, spatial or hybrid map types. These results suggest that ClustalW can be used to classify statistically sketch maps into groups. This allows researchers to compare cognitive development based on map type and other variables such as age, gender or length of residence.

Although there are potentially an infinite number of ways to draw a sketch map, three similar methods were found in each study site. This is normal since individuals exposed to the same area may have different spatial knowledge which can be attributed to their degree of knowledge integration (Montello 1998). An examination only of the typical 'static' final product can be limiting. In Chapter Two, it was hypothesized that the sequence of sketch map drawing differed between subjects living in urban and suburban residence. Across the three study sites, the way subjects drew their sketch maps had some similarities. The first similarity is that all sketch maps started with a dominance of paths. This was followed with either a dominance of landmarks or a mix of paths and landmarks. Only in the rare instances did nodes become apparent. Districts and boundaries were not important in the classification of any group, due mainly to their small numbers recalled during the drawing process. These results suggest two points. The first is that paths were drawn first in all sketch maps because they were used to form boundaries or a framework to locate subsequent elements. The second point is that the drawing sequence is city independent due to the three similar sequence groups in each city (Table 4.8-4.10).

The dominance of paths in the initial sketch mapping process is an indication that urban perception is reliant on this element. This could have applications in planning. If paths are what people draw first and perhaps, what they associate with in navigation, then an imageable city or living space might be best based on paths. A second point to ponder is how the dominance of paths might affect the way road maps are created, locating optimal advertising spots and development sites, or even on how directions are given by and internalized by people or in-car GPS systems.

The most obvious finding from this analysis is that people draw sketch maps differently, usually falling into one of the three methods described in Tables 4.8-4.10. This suggests that although the topology of sketch maps appears similar, subjects had different recall strategies or sequential spatial memory.

The sequence string of each sketch map is similar to a string of DNA, in particular, neither sequence strings nor DNA strands from two people are identical. This suggests the potential for sequence strings to help identify people's environmental awareness and perception. It may also predict people's sketch maps, when given the first part of the sequence. To begin these experimentations, a set of base sequence strings must be isolated to compare with test sequences. The base sequence can be extracted from subjects who fit the same criteria, such as city of residence, gender or income. First, a group of test subjects fulfilling the variable must produce a sketch map to create a sequence string. The sequence strings can then be run through ClustalW to generate the base sequence string. An example of this application is if a test subject from Toronto drew primarily paths at the beginning, this sequence string is compared with the Toronto base sequence string. If a typical Torontonian's base sequence string has a mix of landmarks, then it can be predicted that this test subject will draw a mix of landmarks. From there, the types of landmarks, location of landmarks can also be deduced. This can lead to predicting people's action space, their shopping locations and travel patterns. A second potential research is creating a complementary strand to the base sequence string. The complementary sequence string may suggest alternative environmental perceptions under different situations. However, concrete understanding of the base sequence string must first be accomplished before meaning can be construed from the complementary strand.

5.3 PATTERNS OBSERVED FROM LANDMARK HIERARCHY

A discussion of landmarks' importance in sketch map drawing as well as its classification scheme developed from this study follows.

5.3.1 Reclassifying the Landmark Element

In Lynch's (1960) work, the imageability concept was founded on the development of five elements. These five elements were generic terms used to create a general image of a city. These five elements were studied by numerous subsequent researchers, nevertheless there has been little work done to classify each of the five elements further. Perhaps perception of city space can be better understood when the elements are divided into finer categories. Although Lee (1968) was a pioneer who divided landmarks into categories, namely areas, houses, shops and amenities, these classifications are too coarse to encompass the different types of amenities and shops verbalized and depicted on sketch maps. In this study, a similar procedure, although not new, is repeated to divide the landmark element into finer categories.

In this study, the focus was on landmarks because of their dominance in sketch maps, making up 59.1% of all sketch map elements. This is not surprising as landmarks have been known to help people organize features in a spatial setting (Allen et al. 1978; Siegel 1981).

Results from this study are not unique, as Lee (1968) found similar results where shops and amenity buildings comprised 50-60% of the sketch maps. A few reasons can explain landmark dominance in sketch maps. A reason hypothesised by Lee (1968) is that the relationship between action space and social participation/behaviour develops knowledge of surrounding landmarks. Lee (1968) found that the more heterogeneous the physical content of a neighbourhood, the more socially involved the people will be. If people are more socially active, then they will be more likely to be exposed to the external environment, creating more awareness and a positive feedback to spatial learning. Another reason could be the degree of urbanization of living areas. When a neighbourhood goes from farmland, with few landmarks, to a city, the number and types of landmarks increase rapidly.

The result in Figure 4.13 shows six landmark categories namely shopping (15.3%), service (13.3%), eatery (11.9%), architecture (8.9%), entertainment (5.6%) and education institution (4.3%). Lynch (1960) used imageability as a way to measure and illustrate how our complex urban environment shifts. Since there was no study on the different types of landmarks recalled by subjects, this study cannot compare changes in landmark pattern. However, due to the prominence of landmarks in this study and in other studies, it is fair to conclude that landmarks play a crucial role in a city's imageability. In this study, the breakdown of landmarks shows, in descending order of landmark imageability the following implied hierarchy of importance to people: shopping, service, eatery, architecture, entertainment and education institution.

When people recall their neighbourhood, the primary landmarks seem to be shopping areas. Due to restrictions of the study, it is not clear whether these shopping areas were recalled because of their size, corporate advertisement or because they were important to the livelihood of the subjects. The next popular group of landmarks falls into 'service', a mixed group of landmarks which include consumer-based services, to public social services. This group, in addition to shopping and eateries, may be an indication of our consumption-based lifestyle. Although eateries include grocery stores, the highest percentage goes to restaurants.

Entertainment was listed fourth. Although people spend their money in shopping malls and plazas, they do not seem to notice entertainment, whether it is green space or built infrastructures. In last place are educational institutions of all levels.

It can be argued that the recollection of landmarks on a sketch map is merely a reflection of what people see in the external environment. If this is the case, it is reasonable to ask why some landmarks were added and others ignored in the sketch maps. Are there personal reasons for these choices? For example, the interviewer observed that people who drive were more likely to add gas stations to their sketch map than people who do not drive. Another example is a subject who used shopping malls as one of her landmarks because she enjoys shopping and is therefore aware of her spatial location by shopping malls. She used shopping malls and shopping districts as her primary reference points and navigated with them. These observations beg the question of whether the personality of a person can be derived by looking at their sketch map and landmark composition.

5.4 Differences between Gender and City of Residence

This section discusses quantitative differences and similarities of sketch maps between females and males as well as subjects' city of residence.

Many researchers in the past have persisted with the view that gender-related differences occur in recalling and recreating sketch maps (McGuinness et al. 1983; Miller et al. 1986; Galea et al. 1993). Females tended to draw more landmarks and recalled more street names than males (McGuinness et al. 1983).

It was hypothesized in Chapter Two that there is no difference in the number of elements drawn by females and males. The Chi-square results displayed in Chapter Four did not support the hypothesis. The largest difference between gender was in landmarks and paths. Females reported more landmarks while males report more paths (Table 4.4). As have been found by other studies, females tend to use landmarks for navigation, which can explain their familiarity hence higher reporting on their sketch maps (Appleyard 1970). McGuinness et al. (1983) speculates that female predilection for landmarks is because they create their sketch maps by grouping proximal elements, such as organizing landmarks that are before, behind and next to each other creating a map from part to whole, whereas males tend to focus on establishing a set of coordinates before drawing landmarks. Since subjects may have considered nodes as landmarks, such as subway stops, home and work, they were also highly reported by females for the same reason as landmarks. In addition, a number of studies have shown that females have better visual-item memory so they are able to recall solitary entities or objects like landmarks (Galea et al. 1993).

The second finding from the Chi-square test shows differences in the number of elements drawn, by city. Table 4.5 shows three elements that were significantly different between cities, including paths, landmarks and nodes.

Toronto subjects recalled fewer paths than either Scarborough or MRV subjects. Table 3.2 shows that Toronto has the greatest number of short-term residents (60%) of the three cities. Perhaps the length of residency affects the types of elements one draws. This was suggested by Appleyard (1970) who explained that short-term residents used more paths to represent their sketch map than longer term residents.

The second difference between cities is the landmark element. Scarborough subjects reported 6.7% and 8.6% fewer landmarks than Toronto and MRV subjects respectively. MRV was expected to show less reporting of landmarks due to the homogenous city structure, more so than in Scarborough. This observation can be accounted for by a few reasons. First, Scarborough subjects may not have considered what other subjects considered as landmarks, such as buildings. Second, Scarborough subjects may not have focused on landmarks, but on other elements instead in the drawing.

MRV subjects reported fewer nodes 13.4% and 10.2% than Toronto and Scarborough subjects respectively. Nodes included home, work and TTC subway stations. Since TTC subway stations are absent in MRV, but serve as an important mode of transportation to Toronto and Scarborough subjects, the difference in node could be due to this reason.

5.5 Chapter Summary

This chapter discussed the results of the analyses undertaken on a portion of the collected data. This chapter was discussed in three main parts, namely the MMAPIT tool, sequence results and two unexpected findings.

The first discussion was focused on the prospects of MMAPIT. The MMAPIT methodology produced sketch maps no different in appearance from past pen/pencil and paper methods. The benefits of MMAPIT include an efficient tool capable of collecting many datasets, ability to capture sequence of sketch map drawing and a new way to sketch maps. The future of MMAPIT is dependent on the software added combined with innovative ways to test and explore old cognitive mapping practices.

Sequence has dominated the analysis and discussion of this thesis. Three hypotheses were based on sequence, two of which have been rejected by the findings. The accepted hypothesis found that sketch map types could be generated by examining the sequence of the sketch mapping process. The first rejected hypothesis found no relationship between frequently used elements and the order they were drawn. The second rejected hypothesis found no difference in the sketch map drawing sequence between urban and suburban subjects. Although the results were unexpected, the sequence has provided another way to explore the data collection and analysis techniques.

The first unexpected finding is the subgroups of the landmark element. The landmark element was divided into six subgroups that allow a closer examination of the different landmark types reported by subjects. The results suggest that our society is food-consumer oriented based on the high proportion of eateries recalled. The six subgroups also give an overall picture of our city's structure, giving a sense of what people are surrounded by in their environment.

The second unexpected finding is rooted in gender and city of residence. Gender and city of residence were tested for association with the number of elements recalled. The rejected hypothesis found differences between females and males. Females tended to recall more landmarks than males. However, males recalled more paths than females. Comparing cities, the results showed differences in the number of paths, landmarks and nodes drawn.

Chapter 6

CONCLUSION

6.1 RESEARCH SUMMARY

This chapter concludes the whole thesis and provides suggestions for future work. The first part of the chapter summarizes the findings and the development of the MMAPIT tool. The second part is a discussion of the challenges and limitations this study has encountered and resolved. The final component of this chapter presents a table and explanation of potential research goals using the MMAPIT tool.

In terms of the methodology used in this study, the innovative use of computer hardware and software technologies had many benefits to this exploratory project. Clearly, MMAPIT fulfilled the role of providing a new and innovative tool by collecting sketch maps, it allowed easy incorporation into a GIS environment, and it facilitated tracing new attributes such as the sequence of sketch map creation. The tablet PC can have multiple functions or programs running at the same time. In this study, it allowed subjects to draw on-screen as well as record both sound and action. The benefit is that it captures much more raw data than methods of past studies. However, a few ergonomic factors must be taken into account. Subject feedback suggested that the pen was too sensitive or not sensitive enough for different tasks. This small problem can be corrected with more practice time for subjects. Second, while the screen size of the tablet PC (7.5" x 10") is close to that of a standard 8½" by 11" piece of paper, subjects commented that they would be much more efficient drawing on an 8½" by 11" piece of paper. Although collecting data with a computer was not the preference for all subjects, there was no extreme negative feedback, which is an encouragement to work towards incorporating technology in participatory research.

The findings from the forty-five subjects suggest that people recall information concerning the cognitive image of their urban environments in different ways, but with some strong similarities. Paths are dominant on sketch maps and are especially significant at the beginning of the drawing. Their importance changes and takes second place to landmarks about a quarter of the way into the drawing process. Nodes are drawn constantly throughout the sketch map, however edges and districts are not well represented. Whether this is a result of the methods used in this research, the question posed to subjects, the way people perceive and organize information about the environment, or the way our cities are structured all beg more future research. In this context, these future explorations and cognitive representations of urban space is part of a large area of research. Urban cognition is a concept that includes the urban environment and interaction of subject with the environment. This process elicits feedback from experience with the environment, which creates meaning and relations for the subject (Downs et al. 1973b).

There is potential bias in the data on element count. The instruction and Figure 3.3 given to subjects made specific reference to landmarks and paths. This may have predisposed subjects to the idea that they should draw paths and landmarks, neglecting other elements. Hence, interpretations made on the data maybe a function of the question more so than the recollection process of the subjects.

With regard to past theories, the sequential analysis presented in this study helps to extend the sketch map classification produced by researchers such as Appleyard (1970). Appleyard classified sketch maps into two groups based on the number of paths and landmarks on the sketch map. However, once the sketch maps in this research were divided into the two groups, the process of finer classification became subjective because there were no clear criteria except for a few of Appleyard's sketch map examples. This study has demonstrated a potential new way to categorize sketch maps using a sequence alignment technique, resulting in the identification of three distinct groups, namely sequential, spatial and hybrid map types. The addition of sequence to Appleyard's classification is potentially of great benefit to the group of map types because the quantitative clustering through statistical means makes it less subjective and easier to distinguish different groups. A second major finding is based on frequency of element use and the order in which they are drawn. The lack of statistical support between frequency of element use and standardized order is surprising and does not follow the predictions of the anchor point theory.

The findings from this research can be a starting point for potential research projects in the future. In particular, it is hoped that renewed focus on the sequencing of sketch map creation and information recall will provide a new means to model the extent and content of people's mental maps. For instance, the results of this study strongly suggest that replicating a person's mental map should not be a random process of adding elements. Variations and refinements on this process were found to be possible using the more sophisticated unidimensional sequence alignment technique. The six distinct groups of sequences detected further suggest that there are differences in mental map creation, and that perhaps correlating factors exists (such as gender, length of residence). Incorporation of these into practice models would go a long way towards replicating the objectives and choice set from which people choose travel routes and activity destinations.

6.2 Challenges and Limitations

This study confronted numerous challenges and limitations since its inception. The two most challenging areas were finding subjects appropriate for the study and technological glitches.

To keep variables constant a list of subject criteria was developed. However, this attempt to keep a more controlled experiment also created problems in recruiting subjects. To gain an unbiased sample that was statistically sound is actually a very difficult task. For this reason, it took five months to recruit and interview forty-five subjects.

The balance for meaningful data is time and cost. Although forty-five subjects were moderately sufficient to produce statistically sound results and conclusions, this was only an exploratory study. In the future, a larger sample size that would include an equal split by gender and diversity would be necessary to draw conclusions that apply to a larger population. However, this could take significantly more time and resources to complete.

The second challenge was technology. Although the technology was very advanced, it was difficult to make technology and software work together. One such example was trying to import sketch maps drawn using Corel Draw 9 into a GIS package. In general, progress was limited by the lack of compatibility between technology and software, the number of technology failures and working with many new software packages at once.

The third challenge is the large volume of data. This was beneficial because the researchers could analyze the data from different angles, however, it was a burden for several reasons. First, there was so much data it was difficult to decide what analyses to perform. Second, the large volume of data was overwhelming and took a lot of space to store.

6.3 Recommendations for Future Work

Preceding chapters have described and explained in detail the development of MMAPIT as well as data preparation. Each component had its strengths and limitations. However, the limitations deserve attention in order to improve future work in this area.

MMAPIT met many goals of this study. However, the accomplishments were shadowed by sensitivity of the wireless pen. The sensitivity caused one line segment to be broken up into many, represented in the GIS attribute table as many rows, instead of one. This can be improved and even removed altogether with further testing and calibration of the wireless pen. Once this issue is resolved, the integration of data into a GIS database should be straightforward and less time consuming.

The data collected for this study were impressive in volume. However, there must be an efficient way to collect only required data, cutting down on the data preparation time. This area needs more exploration to make MMAPIT an efficient and user-friendly tool for researchers and subjects alike. The most cumbersome task of transcription can be omitted with the use of voice-to-text software such as "Dragon Naturally Speaking Via Voice". While the subject speaks, the verbal information is automatically transcribed into a word processor. This requires time investment at the beginning of the interview when the subject is guided through a voice recognition process to train the software. However, in the long term such an approach is expected to decrease the amount of time the researcher spends transcribing the data. The second recommendation is to have a laptop with enough memory and speed to run multiple programs simultaneously, without compromising any program performance or creating lag times in the drawing, which frustrated a minority of subjects in this research.

Although technology has been coordinated to capture a variety of data from subjects, the most important source is the interviewer. The interviewer is able to process the sentiments of subjects, the actual reactions of subjects, and take anecdotal notes on subject performance. Otherwise, these emotional cues would be lost since technology does not recognize emotions.

In a social studies context, ClustalW is a new application to group elements. Although its results were satisfactory for this exploratory study, it must be further developed to explain the distance between sequence strings and some gaps in the phylogram.

6.4 Future Research of MMAPIT and Sketch Mapping

Although not perfect, MMAPIT, as a methodology, has strengths that differ from past sketch map collecting methods. These differences boost MMAPIT's potential contribution to cognitive mapping research.

The first potential contribution is providing a new concept 'tool' and methodology due to the flexibility in software exchanges. The collection of existing software programs used can drastically change the dataset collected. This emphasizes the relationship between methodology and data collection, as discussed in Chapter Two. The second contribution, which is central to this study, is collecting sequence data from sketch maps. Closely related is the addition of qualitative data from the verbal recordings and their addition into a GIS environment that traditionally houses quantitative data.

There are more distant contributions, such as examining sketch map distortion, or exploring potential relationship(s) between action space and cognitive space. Table 6.1 attempts to organize, outline and describe the potential contributions and future research direction MMAPIT can offer to the field of cognitive mapping, in particular sketch map collection. This is important as future researchers can focus on an aspect of the data collection, depending on their interest and focus, thus preventing over data collection.

Table 6. 1 Summary of Potential Cognitive Mapping Analyses

Data from MMAPIT	Potential Future analysis
GPS points	Activity space versus cognitive space
Sketch Maps (forty-five subjects)	1. Distortion between subjects of the same city, sex, age, or other demographic factors 2. Predict sketch maps based on given sketch maps and GPS traces
Sequence	Element interrelation analysis
Verbal record of sketch map creation	A complementary database to quantitative data, which can be analyzed using specialized software for qualitative data (e.g. NVivo)
Interviewer anecdotal notes concerning subject comfort level with tool	Future development of a sketch map collecting tool
Interviewer anecdotal notes: Effects of reference points on sketch map	Improve design of future sketch map study so subjects are less influenced by given anchor points
Audio and visual recording of sketch map creation	Study the sketch map creation process
Time of sketch map completion	Use as a variable to compare the differences in subject sketch map quality
Frequency of element use (path, landmark, node, district, boundary)	Model and predict the elements that people will likely use, based on current use pattern
Database table	Variables can be derived and studied

Like the cognitive mapping field, this study bridges several fields including geography, planning and psychology. For example, the MMAPIT tool can be used for psychology or cognitive scientists to examine the implications of the fish tail patterns and to push the understanding of what subjects are thinking when thy produce a sketch map or perform a similar task. Another application is to build an archive of sketch maps and reminisces in an augmented oral history project. The archive may serve as historical, research oriented (e.g. as a cultural geographer might try to reconstruct a landscape as understood by subjects) or applied purposes (e.g. land use planning, preservation, environmental equity work) (Walls 2004). In addition, the

MMAPIT tool can also be considered a PPGIS effort because the public was asked to participate in drawing their sketch maps which were then exported to GIS for further analyses.

The sequence puzzle has only started. There needs to be more collaboration of research between geography, psychology, planning and other appropriate disciplines to understand more of the role that elements and sequence plays in our understanding of the environment and how we recall it. Before recall secrets and modelling of these similar retrieval strategies are revealed we must have a better understanding of the mechanisms involved in sequential spatial memory.

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