SCALE VARIATION IN TACTUAL MAPS: IMPLICATIONS FOR IMPROVED MOBILITY

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Scale Variation in Tactual Maps: Implications for

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ABSTRACT

Tactual mobility maps often fall short of the visually impaired person's needs, due to a tendency by mapmakers to perform a direct translation from the visual printed map into the tactual map form. At best, a slight (and arbitrary) simplification is performed, and even this is frequently done from a sighted perspective. Little consideration is given to the different processing abilities of touch compared to vision.

This thesis attempts to determine whether or not tactual mobility maps, as aids to conventional mobility training, assist in easing the movement of visually impaired persons through a large-scale environment. It evaluates the efficacy of two tactual maps: one with a fixed-scale, which is orthographically equivalent to the conventional visual map, and a variable or flexible-scale map, which presents a topological representation of space. It was suggested that in the tactual mobility map, scale variation might be more appropriate due to the visually impaired persons' haptic perception, spatial cognition, and their means of organizing information. These maps were compared in two different environments, one with relatively uniform element distribution and one with relatively clustered elements.

Visually impaired and blindfolded sighted subjects participated in the examination of three map conditions (verbal guidance instructions, flexible-scale map, and fixed-scale map)

in both environments. Each person's speed of movement, number of errors, and subjective comments on map preferences were recorded and analyzed.

Results of the research indicate that, although the flexible-scale maps do not significantly improve travel performance, performance and map type preference differences favour the flexible-scale map. Thus, such maps may provide a useful introduction to the general relationships among objects in large-scale environments. Therefore, tactual mobility maps, in conjunction with verbal guidance instructions are considered to be useful aids in visually impaired orientation and mobility within large-scale environments.

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CHAPTER I

INTRODUCTION AND PROBLEM IDENTIFICATION

Introduction

This study aims to ascertain whether or not the use of tactual mobility maps, as aids to conventional mobility training, assist in easing the movement of visually impaired persons through a large-scale environment. It evaluates the efficacy of the tactual mobility map using two scales - a fixed-scale, which is orthographically displayed on the conventional visual map and a variable or flexible-scale, which presents a topological representation of space, and in relation to two different environments - one with relatively uniform element distribution and one with relatively clustered elements. The thesis will discuss the theoretical foundations of the use of the different scales within the tactual map and will examine the comparison of the two scales in relation to successful orientation and mobility by visually impaired persons. The emphasis of the study is on a young adult visually impaired population, who are unusual in terms of their level of education and physical abilities and activities. As was the case with Brown's (1978) work, the results and conclusions of this study are not solely restricted to those visually impaired persons who are skilled in map use, as so few have had exposure to tactual maps for any purpose. Suggested future directions for tactile map design and use and suggestions for further research with respect to the results conclude the thesis.

Purpose of the Study : Problem Identification

Any physical disability leads to a reduction in the range of options and choices open to those with the impairment. In the particular case of blindness, mobility is significantly curtailed. The visually impaired person is unable to move freely from origin to a destination and is forced to rely on other means of orientation in order to move from place to place. This effect of blindness can never be completely circumvented; but the person's usually restricted knowledge and understanding of spatial and geographical concepts can be overcome by enabling the visually impaired pedestrian to experience at a symbolic level the environment around him. Tactual maps are one type of aid that allows the visually impaired to broaden their options and cognizance.

Tactual maps "make use of raised symbols on the page to outline and identify the various features that one sees orthographically displayed in the conventional map" (Dayton, 1979, p.13). As a supplemental aid for travel and navigation, the tactual map user can rely on the mobility map to help make independent travel decisions, to organize internal spatial images and to form spatial constructs (Andrews, 1983). Independent travel can be classified as successful only if certain obstacles within the environment are known, if one has a knowledge of one's current location, if terrain changes are understood and if mental maps of the desired route (origin to the destination) are formulated (Kidwell and Greer, 1973, p. 10). Therefore, the tactual map should present to the user spatial information that is not easily communicated through other means (James, 1982, p.336).

Tactual mobility maps, however, often fall short of the visually impaired user's needs due to a tendency by mapmakers to perform a direct transliteration from the visual printed map into the tactual map form. At best, a slight (and arbitrary) simplification is performed and then it is frequently done from a sighted perspective. Little consideration is given to different processing abilities of touch as compared to vision.

One cannot assume that touch operates like vision. Lederman and Campbell (1982) noted:

> "that designers have commonly assumed that touch works as vision does, and that what works for vision will also work for touch. The usual design procedure has been simply to translate visual designs into their raised tactual equivalents. With some simple formats (e.g., line and bar graphs, simple geometric shapes and pictures), visual-to-tactual translation may be quite appropriate. However, direct translation of certain other formats, such as complex pictures and geographical maps, probably cannot be interpreted easily by the haptic system" (pp.85-86).

The visually impaired person is required to integrate information from several senses to compensate for a lack of vision. Therefore, elements noted in the environment may differ in content and quality from those noticed by the sighted individual. Haptic perception, which is essentially the sensation of touch as mediated by the skin, does not automatically yield an holistic impression and appreciation of an object or a space in one step. The visually impaired person is required to code in a sequential operation. Objects are haptically organized and observed in successive and therefore linear operations. Ultimately, the resulting reactions may be merged into a whole. Foulke (1982) observed that the visually impaired person is not directly informed about space until he or she has moved into it. Lederman and Campbell (1982) indicated that because of the sequential and slow nature of the haptic input, which may prevent or hinder an holistic impression of graphic information, it is necessary to design various graphics according to the haptic system's processing characteristics.

As a scaled-down form of representation, maps are an aid to the organization of information, movement and location. They are two-dimensional abstractions of an environment that make locational statements about some group of potentially useful phenomena. It is important to select data that are relevant to the purpose of the map, so as to map efficiently and effectively from the informational environment. This is always important and may be especially vital in the case of designing tactual mobility maps.

Difficulties arise in the recognition of life-sized patterns in real space when translated into small tactual forms, especially for the congenitally blind who lack that partial recollection of sight-based spatial concepts. [1] Only information that is essential to the task of mobility and orientation should be included on a tactual map. This involves the careful selection of mapable information, which precludes the straight transliteration of sighted maps, which encode information selected for the sighted person's utility. It is more important for the visually impaired traveller to have information about the relation between himself and aspects of the environment, than to have descriptions of the environment without such relations (Brambring, 1982).

Additionally, tactual legibility is often hindered by a poor choice of symbols, by the use of ineffective methods of production and reproduction and by the limited knowledge of appropriate reading methods (Lederman and Campbell, 1982, p.85). Adequate legibility is essential to facilitate the reading of tangible graphic displays. It rests on overcoming problems encountered with size and clutter, figure-ground relationships, and discernible symbols (Berla,1982, p.365). Only through thoughtful design and production methods can legibility be maximized.

A design paradox exists, as noted by Nolan and Morris (1971) and Bentzen (1980). Ideally, tactual mobility maps should be small in size, because for successful haptic

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[1] Distinctions commonly are made between two categories of visual impairment: the congenitally blind and the adventitiously blind. The congenitally blind are born without sight, whereas the adventitiously blind have lost their eyesight at some time after birth.

perception two-handspans is the maximum map width. The perceptual span for touch is limited , making map search slow and laborious. If maps are made using smaller dimensions, it is more likely that an holistic impression will be obtained by the reader, with less of stressful reliance on memory to integrate essential information. The finger, however, is much less acute than the eyes. Thus, for symbols to be discriminable, the symbol size should be larger than the visual equivalent. Therefore, tactual maps should be larger than visual maps. In order to resolve this paradox, it is proposed that the mapmaker might utilize a variable scale within the tactual map. The limitations of the haptic system and tactile abilities make some displays and parts of a fixed-scale display illegible, especially those parts with a high information content.

It is evident from the existing literature that there is support for the use of both the fixed consistent scale (Berla and Butterfield, 1977; Schiff, 1982; Wiedel and Groves, 1969), and the variable or flexible scale (Bentzen, 1980, 1982; Castner, 1983; Jansson, 1983; Lederman et al, 1985); but the use of fixed and flexible scales has never been rigorously compared within the context of the tactual map. This study is directed toward this comparison.

> "Perhaps the most challenging tactual communication problem is the representation of distance on a map" (Brown, 1978, p.16).

Scale, in the visual map context, is the most important factor in the relationship between the map and reality and between the map and its use (Keates, 1982, p.105). Within the visual printed map, there is a predominant and near universal use of a fixed consistent scale; but, in the tactual mobility map, scale variation might be more appropriate because of the nature of haptic perception, the means of organizing information by the visually impaired, and their cognition of space. James (1972) and Jansson (1983) have suggested that:

> "Uneventful sections of a mobility map may be made smaller than sections with many landmarks in order to match the blind person's perception of the relative length of the different sections. This means that, for a blind person, correct spatial information about the length of a walk is less important than more detailed information about critical portions of the map. The same may be true also about a sighted pedestrian but to a lower degree" (Jansson, 1983, p.70).

In the current study, the element of scale within the tactual mobility map was analyzed in terms of its effect on both the user's speed of movement and the ability to interpret the map and apply it to a specific mobility situation . Two general questions were addressed:

1. As an aid to conventional mobility training, can tactual maps improve a visually impaired person's speed of movement and understanding of a large-scale environment?
2. Does the tactual mobility map have a differential utility
   a. in an environment with relatively clustered elements and in an environment with relatively uniformly distributed elements? and
   b. with a fixed-scale or with a flexible-scale?

Definition of Terms

It is necessary to provide operational definitions of terms frequently referred to throughout this study, since theoretical definitions are not always appropriate when applied in a particular operational context.

Tactual Perception

Tactual refers to active exploration and manipulative touch (Schiff and Foulke, 1982,p.xi). Thus, by its very nature, tactual perception is a fragmentary and serial process of obtaining useful information about the surrounding environment. Simpkins (1979) wrote that:

> "Tactual perception requires successive operations (actions) within the restraints of spatial relations for recognition. To form a conclusion on the basis of these operations, the individual must tactually observe, systematize the actions, and finally merge the resulting reactions" (p.94).

Tactual Perception

- is the communication of information through the skin. It includes the active exploration and observation of tactual displays through the medium of touch.

Mobility

Several defintions have been applied to the term mobility. Since mobility is central to the research conducted in this study, it was deemed necessary to include a suitable definition. Foulke's (1971) definition has been quoted many times in the tactual map literature. He stated that:

> "The ability to travel safely, comfortably, gracefully, and independently, referred to hereafter by the single term "mobility" is a factor of primary importance in the life of a blind individual" (p.1).

Later, he added: "that mobility must be purposeful and goal-oriented" (1983, p.127), and , "that spatial ability is one of the prerequisites of mobility. By spatial mobility, I mean the ability to discover, by observation and inference, the spatial extension of objects, the arrangement of objects in space, and their states of motion" (1983, p.127). Other researchers have suggested similar definitions, emphasizing only particular attributes of mobility alluded to by Foulke. In the context of this research, mobility is suitably defined in the aforementioned comments by Foulke.

Mobility

- The spatial ability of a visually impaired person to travel safely, comfortably, gracefully, quickly and independently from a fixed start to a predetermined destination.

Orientation

In his discussion of spatial orientation, Maglione (1969) referred to the notable work of Howard and Templeton (1966) as the basis for his theoretical writings. He indicated that:

> "the authors maintained that human spatial orientation is the result of two factors, i.e., conditioned responses to internal bodily constraints and conditioned responses to the external environment and its constraints. The term 'constraint' indicates the limiting (and hence, shaping) action of these bodily and environmental features" (1969, p.11).

Other researchers focusing on the same topic mention similar prerequisites for defining orientation. Within the context of the research reported, the following definiton is considered as most appropriate.

Orientation

- The process of ascertaining distances and directions from the self to significant objects in the surrounding environment by any means available to the individual.

Visually Impaired

- Although visual impairment can vary in level and extent, for purposes of this study, it is defined as a total lack of vision. This definition is in accordance with the fact that all subjects were deprived of any light perception, by wearing a black eye mask, while testing was in progress.

Map Use

- This term is defined as, "the combined process of map reading and interpretation, which is the interaction of referent identities received from the map image in a real world situation" (Brown, 1978, p.8).

Map Reading

Bluestein and Acredolo (1979) offer a most succinct definition of map reading, and it will be used here as the operational definition for this term.

Map Reading

> "is defined as the ability to make judgments about position in a three-dimensional, large-scale space from information presented in a two- or three- dimensional small-scale representation of the space. Such map-reading inferences appear to be based on at least two distinct cognitive processes.... The first is the differentiation of cartographic or pictographic symbols and the understanding that they refer to real three-dimensional counterparts.... The second process is the projection or superimpositon of the map upon the space, or the space upon the map, so that judgments about position can be made from one to the other" (p.691).

Landmark

Locating landmarks is a central task in the mobility exercises used to assess the tactual maps in this research. It was deemed useful to provide a clear definition of the term at the outset. Rieser's definition of landmark is used in this study.

Landmark

> "is anything which is distinctive within its particular locale, visible (or otherwise perceptible) from numerous points of observation, and used to guide search for a target which is out of view" (1979, p.1079).

Flexible or Variable Scale

The information contained within a flexible-scale map is presented according to the haptic and spatial perception of the visually impaired individual.

> "Displays should be designed according to the principles of haptic perception and not merely be raised visual displays. This will, at times, mean altering both the content and the organization of a display as well as making intelligent choices of symbols" (Bentzen, 1982, p.402).

While the topological properties of an environment are retained, an absolute fixed scale is not. Thus, the tactual flexible-scale map expands the complex sections resulting in less clutter and more useful information being provided. At the same time, relatively uneventful sections of a route are contracted. The effect aims to make more efficient use of the coding space available within the tactual map (James, 1972 ; Bentzen, 1980).

Flexible Scale

- The flexible-scaled tactual map varies map scale, in accordance with the visually impaired person's perception of space and distance. The result is a non-Euclidean representation and an undefined relationship to a linear scale.

Fixed Scale

One set of maps used in this study made use of what is termed a fixed scale. In fact, this is the scale commonly seen orthographically displayed in the conventional sighted map. As Robinson and Petchenik (1976) explained:

> "In its most basic sense the term "scale" refers to the simple, numerically stated relations between a given magnitude of a map, and the real magnitude of the milieu which it represents, usually involving real distance or area in Euclidean terms" (p.122).

Several cartographers have noted the complexity of this concept while emphasizing its importance to the representation of the contents of the map. Henning (1983) alluded to this fact when he stated that:

> "Scale is in fact a very complex concept, transcending its elementary mathematical component to incorporate the very transformation of physical and spatial elements of the real world to sensory elements of a map" (p.119).

In the context of this research, fixed scale is suitably defined by the following quotation.

Fixed Scale

> "Scale is the ratio of distance on the map to the corresponding distance on the ground" (Monmonier, 1977, p.4).

Environment with Relatively Uniformily Distributed Elements

- An environment containing relatively uniform distribution of elements is, for the visually impaired subject, simple and evenly patterned in its layout . Within the context of this research, such an environment is best found in a building hallway. Most elements, such as doorways, are evenly spaced and can be used as reliable landmarks. The environment is without alterations in elevation and there are few adjunct paths off the main pathway. Very few, if any, of the permanent features could be classified as obstacles obstructing the path of travel.

Environment with Relatively Clustered Elements

- An environment containing relatively clustered elements is more complex for the visually impaired subject. Features that are considered as reliable landmarks tend not to be spaced evenly within the environment itself, and so navigation through the area can be difficult. Indentations and alcoves, along with adjunct pathways add to this complexity. Obstructions in one's path of travel are more prevalent than in an environment with relatively uniformily distributed elements. Furthermore, elevation changes may exist. This study focuses on a building hallway as an example of an environment containing relatively clustered elements.

Spatial Cognition

- Spatial cognition denotes, "the knowledge and internal or cognitive representation of the structure, entities, and relations of space" (Hart and Moore, 1973, p.248).

Spatial Perception

- Spatial perception is a subsystem of spatial cognition. "Spatial perception has a more direct sensory referent than spatial cognition, which occurs in a spatial context of such extent that all of the space cannot be acquired immediately, but would require memory of portions of it" (Hollyfield, 1981, p.5). Previous experience, attention, and expectations also influence how the environment is perceived, thereby influencing one's spatial perception.

CHAPTER II

REVIEW OF THE LITERATURE

Cartographic Communication

Cartography presents an analysis of spatial relationships of phenomena and the processes between these phenomena occuring in geographical space (Ratajski, 1973). Thus cartography is an integral part of the practice of geography. The map is the central element of cartography and serves as a medium for transmitting information about spatial relationships. In this sense, the map becomes an abstraction and a scaled-down representation of the real world. Writing in 1908, Eckert concluded that: "Undoubtedly the most important objective of maps is to portray on a plane the surface of the earth or some larger or smaller portion of it" (Guelke, 1977, p.1).

Recently, concern has developed for the map image and the purpose of spatial communication. Blakemore (1981) emphasized that:

> "As with traditional approaches, the map is the focus of cartography, but the processes of creating the image no longer involve a direct transfer of surveyed reality to spatial summary. Cartographers now see cartography as a communication system (i.e. it transmits spatial messages), and subsequent discussions have utilized the theme and terminology of communication" (1981, p.30).

Subsequently, much attention has been directed to the relationship between the map makers (and their activities) and the map users (and their needs). Many theories and ideas regarding cartographic communication have been proposed. Those of Kolacny (1977), Ratajsky (1973), and Robinson and Petchenik (1975), along with developments by Morrison (1974; 1977) have been the most influential. Kolacny first suggested that cartographers should be concerned with both the map construction and map use. He placed predominant emphasis and importance on cartographic information. Thus, he was concerned with the maps user's total gain in knowledge, as opposed to 'map content'.

Ratajsky who argued that cartography should be approached as "... part of the informatics or the new large science of communication" (1973, p.217). Based on this conception, he devised a model in which the map is the 'channel' of transmission, the cartographer is the 'transmitter', and finally the map user is the 'receiver'.

In opposition to these theories, Robinson and Petchenik (1975) stressed that communication theory should not be integrated directly into cartographic practice; rather it should be adapted carefully to suit the particular map. Within their proposed cartographic communication system, they distinguished clearly between the map reader, the map user and the map percipient, thereby placing emphasis on different levels of map-using operations. The map percipient can be distinguished from the map user by the manner in which the map is used. As a result of examining a map, the map percipient augments his or her knowledge of the area. On the other hand, the map user employs the map for a specific purpose, but does not necessarily add to any personal existing spatial knowledge.

Morrison (1974; 1977) developed the work of Ratajsky by both accepting and further expanding his structural model. He suggested three stages that provided the cartographer with a means of communicating to the map reader. These were labelled: 1. selection, 2. classification, and 3. simplification (1977, p.63). Morrison felt that cartography possessed the ability to enlarge the cognitive realm of both the initiator (the cartographer) and the receiver of the communication. He surmised that this was possible because induction and, specifically, generalisation existed as elements of cartography, and it was essential that both the cartographer and the map reader shared the same cartographic language (1977). [1]

Several attempts have been made to model cartography as a 'communication system'. The validity of the usual assumptions has been questioned by Guelke (1977), Petchenik (1977) and Salichtchev (1978). Salichtchev's argument is representative:

> "Especially questionable, and in my view unacceptable, is the striving to base mapping processes as a whole on a mathematical theory of information. This stems from ideas on the linear transmission of information along a channel with obstacles that cause distortion and loss of information. Such an approach reduces the tasks of cartography to merely the lessening of the loss of cartographic communication and excludes concern for the expansion of information" (1978, p.93).

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[1] A succinct outline and critical review of cartographic communication theories is presented in Keates (1982).

Thus, it seems that Salichtchev is arguing for a map that maintains a generative role, and not just an informative one. In other words, the map should not only exhibit the data essential to its theme , but should also imply to the reader much more information through certain graphic qualities.

It is apparent that agreement on the theoretical model of cartographic communication still remains less than complete. The above ideas concerning the importance of the map reader's involvement in the mapping process, however, present some pertinent concepts that can be applied to this research study. In the same way in which importance has been attached to the relationship between the map maker and the map reader in these theories, so too has this association been recognized as a vital component of tactual mobility map design, particularly in relation to scale.

<u>The Value of Scale Within the Map</u>

The importance of scale within the map has received much attention.

> "In the cartographic literature scale is treated, often implicitly, as one of the most fundamental concepts in cartography, and heretofore it has been hard to account for its overwhelming significance" (Robinson and Petchenik, 1976, p.121).

Keates (1982) stated:

> "Yet in the relationship between map and 'reality', and in most cases between map and map user, scale is the most important factor. It is scale - the ratio between what the map describes and reality - which makes maps

> useful (as miniaturised representations), and at the same time introduces many important cartographic problems" (1982, p.105).

Later he concluded that:

> "Generally speaking, the decision about scale is the most fundamental decision about any map" (p. 105).

The cartographic problems in relation to scale are largely relevant to the tactual map situation. Such aspects as generalisation, the metrical problems of projection transformation, the map use limitations imposed by a particular scale, and the difficulties of the user in interpretation and application of scale in relation to surroundings (Keates, 1982, p.105) are all clearly evident in the tactual map research literature.

The visually impaired person lacks the ability to perceive large gestalts, due to the limitations of the haptic system, a system which is relied upon heavily.

> "The haptic system can acquire information about the spatial extension and surface of objects, but its capacity for pattern resolution is limited. A more serious limitation still is the necessity of establishing physical contact with objects in order to perceive them. The haptic system's field of view is so small that large objects and spatial arrangements of objects must be perceived serially" (Shingledecker and Foulke, 1978, p.283).

The representation of distance and spatial arrangement on the tactual map then becomes a fundamental challenge, and a tactual communication problem (Brown, 1978, p.16). The selection of the most appropriate scale has been recognized as imperative in the design of the map with respect to the amount of information that can be portrayed, as well as in relation to the percipient's conception (Robinson, 1965; Hway-Hwa Kuo, 1978; Henning, 1983; Sharan, 1984).

Scale has been defined several times over in the literature. In its simplest form, "Scale is the ratio of distance on the map to the corresponding distance on the ground" (Monmonier, 1977, p.4), but Robinson, Sale and Morrison (1978) explain that as the essential transformation of data from the sphere to the plane occurs, "the scale on a map must vary from place to place and will commonly also vary even in different directions at a point" (1978, p.45). Naturally, this applies to small scale maps, in which projections and the resultant patterns of deformation exist. So too, the focus is centered on the fixed consistent scale commonly portrayed in the visual map. Yet, the fact that scale can be so elusive, allows for the challenge of its use and credibility, with respect to specific user requirements and applications. Muehrcke (1972; 1976) has indicated that one best scale does not exist, but only a most convenient one. Muehrcke argued that the purpose of the map dictates the scale relationship between the map and reality. Finally, he concluded that:

> "Given that geographical problems are scale-dependent, we should suspect that the data input for a good map at one scale is not simply transformed into equally good data for maps at other scales" (1972, p. 13).

Canter (1966, p.79) stated that both maps and cognitive systems use a metric by which the experienced physical world is transformed, in other words a 'scale'. In his illuminating paper entitled, "Introducing the Cartography of Reality", Wood commented that:

> "While the map maker's metric itself may be arbitrary, its fixed scales often fail to coincide with the variability, contingency and fluidity of cognitive assessments" (1978, p.207).

The present study further develops these arguments,examining the question of scale variation in the tactual map, and its relation to the spatial perception of the visually impaired.

Spatial Perception of the Visually Impaired

Spatial Imagery

In her examination of the visually impaired persons' spatial cognition attained through tactual maps, Andrews (1983) denotes two potential processes through which internal imagery is formed. Based on the work of Downs and Stea (1973, p.14), she attributes the formulation of this internal imagery to either a perceptual process, the immediate apprehension of an object by one or more senses, or a cognitive process, which is a more general term encompassing perception, spatial organization of ideas and problem solving. Large-scale spaces are cited as being organized cognitively rather than perceptually (1983, p.32).

Andrews' analyses led her to conclude that the visually impaired person's internal spatial imagery is different from that of the sighted person. It is known that a holistic impression of spatial information may be hindered by the sequential nature of haptic input (Lederman and Campbell, 1982;

Millar, 1982). Reliance on the tactual sense essentially means that any environment is sequentially perceived (also Millar, 1982). Thus, the internal spatial imagery of the visually impaired person must be conceptual rather than perceptual. This is in agreement with Simpkin's results (1979, p.82). In the case of the sighted, an area can be perceived simultaneously, allowing for a perceptual internal image. Both Andrews and Casey (1978) claim this formation and image type to be superior. Therefore, Andrews assumes that there are two main factors that contribute to the differences in these internal spatial imageries: the perceptual (sighted) versus conceptual (visually impaired) difference, and differential access to abstract environmental models (e.g., maps) from which they can facilitate their spatial understanding.

Another approach to perception and cognition by the visually impaired is to examine them from the perspective of orientation, as Brambring (1976) has done. Brambring's ideas are central to the concept of geographic orientation, which he defines as:

> "a person's ability to establish his actual position in relation to a not directly visible topographical space, for example, the ability to maintain a sense of direction when moving about in familiar and unfamiliar surroundings. Thus, a geographical orientation requires first the establishment of one's actual position relative to the immediate environment (estimate of distance and direction), and secondly the establishment of one's actual position in relation to a topographical reference system (cognitive and perceptual spatial orientation)" (p.284).

Brambring refers to perceptual orientation as the pedestrian's ability to recognise a previously walked route, as well as the ability to find a route independently from additional verbal or tactual information sources. It is essential in order to reproduce a spatial relationship. On the other hand, cognitive orientation refers to the ability to return on the shortest route after a detour. Cognitive orientation is orientation in a topographical space without previous experience of that particular route. Although Andrews and Brambring differ in their outlook on perception and cognition, it is evident that the views are complementary and, indeed, related to a degree.

According to Howard and Templeton (1966) the role and the extent of visual experience in geographic orientation can be best assessed by analyzing the performances of the sighted, and the early and late blinded. Worchel (1951) and Juurmaa (1965) focused solely on the accuracy of the fixation of goal points within certain routes, disregarding the manner in which the performance was achieved. Instead, Brambring studied the cognitive information processing of orientation in the congenitally blind, the adventitiously blind, the blindfolded sighted and the sighted with visual pre-orientation.

Extensive individual differences exist amongst visually impaired subjects, with some even matching the performance of the sighted. Authors have generally attributed the variation to one of two main reasons: either to the amount of visual experience enjoyed by the individual subjects, or to the degree of spatial imagery involved. Von Senden (1932; 1960) announced his firm belief that "the congenitally blind patient lacks everything that would entitle one to speak of a tactile awareness of space" (1960, p.279), and "imaginative retention of a completed whole is not possible with tactile impressions" (1960, p.288).

Early attempts to understand the spatial organization of the visually impaired revealed similar assumptions. Both Worchel (1951) and Revesz (1950) indicated that without vision, spatial organization suffered because of difficulties encountered in integrating information from different sense modalities. Thus, the spatial organization of the visually impaired was impoverished and different from that of those with sight.

Worchel's study was one of the first specifically to focus on the spatial knowledge of the visually impaired. He compared the ability of the congenitally and adventitiously blinded, and the sighted blindfolded to orient themselves spatially on a triangle completion task. He concluded that blindness, regardless of age of onset, deprived the victim of general spatial abilities. The sighted blindfolded exhibited significant proficiency advantage over the blind in their ability to manipulate spatial cues. Likewise, the adventitiously blind were found to be more skilled than the congenitally blind. Worchel noted that the blind tended to use time in estimating distance, and attributed their poorer overall performance to a lack of visual imagery. Ability to estimate direction accurately, rather than distance estimation, was also measured. Brambring (1976) criticized Worchel for using only the accuracy of the fixation of a certain point as the dependent variable, and for failing to record how the actual performance was achieved.

Although the work of these early researchers has been of great value, it has also been criticized vigorously. Brambring's concern with the previous results and explanations led him to analyze the metric of haptic space from the perspective of the geographical orientation of the blind. He postulated that differences in the cognitive approach to spatial arrays existed between the sighted and the visually impaired, regardless of the group's level of accuracy in reading the specified goal points of right angle triangles. His analyses indicated that the congenitally blind can produce new spatial relationships in haptic space, although these might be somewhat less stable than those of persons who have had some visual experience. Thus, he placed emphasis on accuracy, rather than on the manner by which the groups achieved spatial orientation.

Fletcher (1980) categorized the literature into three main theoretical groups: deficiency theory, inefficiency theory, and difference theory (pp. 381-382). Deficiency theory states that the visually impaired do not have the ability to develop a spatial reference system (e.g. Von Senden, 1932). According to inefficiency theory, the visually impaired have the ability to develop a spatial frame of reference, although it is not nearly as sophisticated as that of the sighted person (e.g. Revesz, 1950; Worchel, 1951). Finally, difference theory indicates that a lack of vision slows down ontogenetic spatial concepts, but does not eliminate them (e.g. Juurmaa, 1973).

In Fletcher's work blind and blindfolded sighted children explored a real or a model room, either freely or guided along a predetermined route. The subjects were asked 'route' questions, incorporating information obtained directly from the traversed route, or 'map' questions, which required the formation of a cognitive map in order to be answered. The results revealed that the blind, as a group, performed better with route-type questions than with map-type questions. However, some blind were as proficient as the sighted on map questions. Thus, the deficiency theory was rejected as untenable. The data did not provide conclusive support for either the inefficiency or the difference theory (p.385).

The debate has continued, as the work of Herman, Herman and Chatman (1983) is at variance with that of Fletcher. Herman et al. had congenitally blind subjects explore haptically a subset of spatial relations among objects in a table model. Then, in the large-scale space which had been modelled, subjects traversed those paths making object location judgments. Of specific interest to the authors was how well subjects were able to deduce spatial relations among objects in the large-scale environment after encountering only a subset of the relations on the small-scale model (p.197). Bentzen (1972) and Leonard and Newman (1970) have indicated that the visually impaired person's ability to navigate in large-scale environments has benefitted from training on small-scale models. Herman et al. observed that training on a model provided adequate information about overall spatial arrangements which could be successfully translated into large-scale spatial operations.

With respect to Fletcher's results, Herman et al. determined that map questions were more difficult than route questions for the visually impaired. They attributed the discrepancy to the number of objects used in the two studies (p.198). They argued that tactual maps could provide a useful introduction for the visually impaired to the general rather than specific relationships among objects in a large-scale environment.

Herman, Chatman and Roth (1983) compared sighted blindfolded, congenitally blind and sighted in their spatial representations of unfamiliar large-scale environments. While walking a Z-shaped route, the subjects deduced spatial relationships amongst four objects. Herman et al. surmised that if visual imagery facilitated the acquisition of spatial information, then the sighted should perform more accurately. Support for this belief is evident in the work of Worchel (1951) and Marmor and Zaback (1976). Herman et al.'s analyses suggested that past visual experiences facilitated spatial information acquisition, especially in unfamiliar large-scale environments. Neither their results nor those of Fletcher have lent complete support to Juurmaa's (1973) conclusions, since the sighted performed more accurately than the congenitally blind in both cases on spatial tasks in large-scale environments. Juurmaa had indicated that the superiority of the sighted over the visually impaired on spatial perception tasks was the result of using visually familiar spatial patterns. At the same time, he contended that in unfamiliar forms, the blind performed as well as the blindfolded sighted. Interestingly, as will be reviewed later, the research of Landau, Gleitman and Spelke (1981) substantiated Juurmaa's results and ideas to some extent.

Juurmaa's studies have, however, been criticized. Juurmaa (1965; 1967) outlined a number of studies utilizing visually unfamiliar forms in which blind subjects performed as well as, or more accurately than, blindfolded subjects (Herman, Chatman and Roth, 1983, p.162). Juurmaa argued that in studies where the sighted subjects performed more accurately than the blind subjects (e.g. Worchel, 1951), they were "visualizing". When they were without "visualization" the sighted tended to rely on a spatial sense in the same way that the congenitally blind do. This argument that the congenitally blind have a spatial frame of reference that is not different from that of the sighted can be questioned in light of other work focusing on frames of reference. Ewart and Carp (1963) found that the congenitally blind exhibited an improved performance if they possessed better verbal-conceptual abilities with which to conceive spatial relationships. Fisher (1964) introduced an artificial frame of reference (in the form of a contextual cue), which resulted in improved auditory localization by the congenitally blind, although the sighted did not exhibit any improvements. Thus, the sighted obviously possessed an internal frame of reference.

Warren, Anooshian and Bollinger (1973) examined the influence of early vision on spatial performance of the visually impaired. They concluded that the late blind performed significantly better than the congenitally blind, because of the perceptual advantage of early vision. Thus, the congenitally blind tend to depend more on verbal skills. The researchers labelled this perceptual advantage as a "frame of reference", an integration of haptic and auditory cues into the organization of spatial information. Warren et al. assumed that for spatial tasks, visual imagery is not imperative. They suggested, however, that operating with a frame of reference derived from previous visual experience, improves spatial performance.

Rosencranz and Suslick (1976) stated that:

> "A frame of reference in one's internal representation of space seems to require a simultaneously global and spatial symbol structure. If a person is born blind, such simultaneity can only be achieved through combinations of perceptual symbol structures from different modalities. The congenitally blind may never develop the combinations to the point of possessing a

frame of reference" (p.188).

They expanded Juurmaa's conclusions through a room memorization task. The central question was whether or not a congenitally blind person was able to, "form a two-dimensional symbol structure of a two-dimensional furniture arrangement, presented to them in a one-dimensional manner" (p.190). In other words, they tested the assumption that for the internal representation of space, vision is necessary. They examined a small number of subjects, who were not matched for variables such as mobility training, travel experience and age. Thus, their results should be considered as suggestive, and not conclusive. They concluded that for development of a spatial frame of reference, experience with the visual modality was beneficial. Thus, possession of a frame of reference was deemed essential for the ability to form two-dimensional structures, which in turn related to previous visual experience (p.193). Rosencranz and Suslick suggested that:

> "Only those congenitally blind with sufficient general intelligence will eventually combine nonvisual symbol structures in such a way so as to develop a frame" (p.194).

On the other hand, Landau and Spelke (in press) argue that an essentially Euclidean spatial system may be in place quite early in life for both the blind and the sighted, although children cannot always demonstrate that knowledge (p.36). The researchers have recognised that spatial knowledge of distances and directions among places in a layout is necessary so as to detour effectively, as well as to navigate along a previously learned route. The authors have been examining the spatial abilities of one totally blind child in comparison to blindfolded sighted children. This child has exhibited a set of capacities that constitutes a system of spatial knowledge. At the age of fifty-four months, she began to make use of maps to guide her locomotion. The experimenters demonstrated that:

> "Kelli understood the relationships displayed on the map to be independent of her own position relative to the map. Kelli's ability to systematically locate the target objects using only the information provided on these maps is testimony to an underlying system of knowledge that was sufficiently rich to make contact with a highly abstract form of experience - a real map" (p. 35).

On a specified navigation task both the blind child and the blindfolded sighted performed satisfactorily. However, on a rotation task, the blind child systematically failed prior to the age of five. Landau and Spelke claimed that the difficulties encountered in the rotation task did not result from spatial knowledge deficiencies. Instead, they reasoned that often a visually impaired subject is not able to demonstrate spatial knowledge, since certain features involved in the testing tasks lead the individual to bias toward an "egocentric location" of objects. The outcome is a masked expression of spatial knowledge (pp.49-50). It is important to recognize that Landau and Spelke attributed both the discovery of objects as reliable and utilitarian landmarks and the ability to align oneself as fundamental parts of the development of spatial abilities and not as part of the development of spatial knowledge itself (p.50). In other words, this is pragmatic rather than theoretical understanding.

Spatial Coding Strategies

Casey (1978) examined the manner in which congenitally blind persons conceptualize and order features in large-scale environments, using tactual maps. Ten congenitally blind and ten partially sighted subjects constructed small-scale models of a familiar area. The models were evaluated in terms of the number of elements included and the overall organizational accuracy. The models indicated that the congenitally blind lacked a knowledge of spatial relationships among buildings. Organizing in a piecemeal fashion, they portrayed pathway configurations with significant distortions. A few of the subjects displayed a capability to produce accurate and well-organized maps. Casey attributed the accuracy of map construction to the level of independent travel abilities. It was evident that proficiency in the perceptual and conceptual realms improved the individual's methods for categorizing elements and for cognitive mapping in a large environment.

Casey's conclusions are supported by more recent research. Rieser, Lockman and Pick (1980) supported the conclusion that poorer spatial orientation is exhibited by the visually impaired. The authors addressed two issues: (1) whether comparative distance judgments among pairs of locations conformed to three distance conditions or types and (2) the degree of flexibility by the visually impaired person in efficiently using spatial knowledge (p.186). The method involved congenitally blind, adventitiously blinded and sighted subjects making distance judgments under three sets of conditions or instructions:

1. Neutral - the ability to perform efficiently and with ease on specified triadic comparisons.
2. Euclidean - the ability to base triadic comparisons on straight line distances between landmark locations, as if one could actually walk through walls.
3. Functional - the ability to base triadic comparisons on the shortest functional distances between locations. Functional distance refers to actual walking distance, incorporating memorized sequences of turns and distances (p.186).

The study site was a familiar indoor environment. Using the method of triadic comparisons, distance judgments were collected from fifteen selected landmark locations. "Three were named and the subjects were asked to identify the two that were closest together and the two farthest apart" (p.186). All subjects performed the comparisons under the three instructions.

The analyses indicated that although differences between the sighted, congenitally blind and adventitiously blinded groups existed, "the accuracy of the blind subjects' knowledge of this large-scale spatial layout" was impressive (pp.189-190). Multidimensional scaling analysis indicated that the blind subjects exhibited remarkably good Euclidean knowledge. It was evident that visual experience, whether specific or general influences the accuracy of Euclidean judgments, as the congenitally blind performed worse than the other two groups. The authors suggested that, "prior visual experience may make one more flexible in the use of spatial metrics" (p.188).

In terms of configurations, the blind subjects, especially the congenitally blind, tended to "exaggerate euclidean distances between locations that are *functionally separated* by corners and turns more than did sighted subjects" (p.188). Casey (1978) also reported spatial distortions, as the visually impaired consistently perceived curved walkways as straight paths. In the case of Rieser et al.'s work, the main weakness of the visually impaired was attributed to the difficulty in shifting from a Functional to an Euclidean basis in distance judgments. The authors inferred that both specific and general visual experience was important in representing space, as indicated by the accuracy of the groups' judgments (p.190). The outcome of this work was congruent with other literature on the extent of visual experience required to perform spatial tasks (Pick, 1974; Warren, Anooshian and Bollinger, 1973).

Rieser et al. examined the visually impaired person's knowledge of spatial relations in a multi-level indoor environment. Lockman, Rieser and Pick (1981) evaluated spatial knowledge in an outdoor environment. They outlined two major procedures for organizing the knowledge of locations of places.

Spatial knowledge can be organized in a functional manner, as memorized sequences of distances and turns. However, difficulties frequently arise in the ability to plan detours and turns. In contrast, spatial organization can be performed in an Euclidean,or maplike manner, which permits greater travel flexibility when detours and shortcuts are required (p.321).

Comparative distance judgments among three locations were performed by ten adventitiously visually impaired subjects. The data were analyzed with multidimensional scaling procedures. "It was assumed that maps derived from subjects who have relatively accurate Euclidean knowledge of the actual space would more closely resemble the actual city map than those derived from subjects whose Euclidean knowledge is less accurate" (p.324).

Although the focus of the report was an evaluation of the multidimensional scaling technique as an objective method for measuring spatial knowledge, accounts of individual performances were identified as important information sources for deriving knowledge of the visually impaired person's spatial cognizance. Among the group tested, capabilities differed with respect to experiences and vision status. In fact, one subject had had no previous experience with the test area and had learned the layout while blind. The map derived from his judgments closely matched the ideal Euclidean map derivative (p.324). In two cases, the functional properties of the space influenced the subject's conceptions of it, even to the extent that locations positioned relatively close to one another were interpreted as being far apart (p.325).

It was apparent that of the ten visually impaired subjects, at least two were able to organize spatial knowledge in a maplike manner that could be used to plan new routes. At the same time, it was evident that at least two of the participants did not exhibit Euclidean spatial knowledge. It was suggested that strategies for acquiring spatial layout knowledge differed with experience and with the level of vision.

Dodds, Howarth and Carter (1983) examined the structure of spatial representations in both congenitally and adventitiously blind children. The tasks of pointing , map drawing and spatial reasoning disclosed distinct differences between the two groups. The majority of the congenitally blind subjects showed a complete lack of spatial understanding. Their spatial coding strategies indicated an 'egocentric' perspective. In contrast, the adventitiously blind were able to utilize externally referent spatial strategies that were compatible with two-dimensional maps. The authors concluded that some visual experience aids the development of external spatial coding strategy, although it may not be a necessary precondition in order to represent a spatial layout.

Millar (1975) arrived at similar conclusions. Millar's work has dealt primarily with small-scale patterns felt by the finger. Her research has been directed toward ascertaining optimal coded imagery for the representation of geographical space. Millar outlined three abilities required for successful representations:

1. the ability to discriminate spatial objects or shapes;
2. the ability to locate objects in relation to the self; and
3. the ability to locate objects in relation to each other (p.131).

Three main coding strategies for blind movements were found to be: "(1) spatial self-reference (when locations can be coded reliably relative to the body midaxis), which is relatively easy with repeated inputs but demands processing capacity; (2) movement coding (by blind and sighted with unfamiliar lengths, and by the blind when self-reference was disrupted), which seemed to be independent of limited capacity; and (3) spatial coding derived from visual experience which required processing capacity (for the sighted, only when self-reference was disrupted)" (1981, p.301). It was apparent that 'modality-specific' information was involved in all of the strategies (p.304). In the context of Millar's research, processing capacity refers to the manner in which visually impaired subjects code movements and subsequently the demands that are placed on the memory load. Summarizing her research findings, Millar (1982) concluded that, "the matter of whether or not memory for movements demands processing capacity does not depend on the presence of location cues as such, or on visuospatial experience" (p.299).

Differences between the manners in which the blind and the sighted code information about shape, distance, location and direction as mediated through touch and movement have been reported in the literature. Worchel (1951) revealed that his visually impaired subjects had difficulties with spatial inference tasks. As Millar noted, however: "there was no suggestion that his blind adults were incapable of deductive inference on any other type of material" (p.154). Leonard and Newman (1967) concluded that visual experience was not required for spatial thinking, and that intelligent blind adults can infer shortcuts in a familiarized area. Kosslyn et al. (1977) reported that the visually impaired were perfectly capable of demonstrating a kind of external representation demanded by a drawing task. but the drawings frequently symbolized rather than pictured a three-dimensional object.

With respect to gaining spatial information while moving through an environment, Barth and Foulke (1979) examined the role of anticipation as a means of attaining a certain level of performance in perceptual motor skills. Barth and Foulke recognized that:

> "...much of the skill negotiating an environment successfully depends upon preview of upcoming events. Preview is a requirement for mobility in general, regardless of visual status" (p.41).

The authors acknowledged two forms of anticipation which operate in conjunction as components of preview. Sensory anticipation and perceptual anticipation are essential components of successful orientation and mobility. The work of

Shingledecker (1978) has demonstrated the value of perceptual anticipation for visually impaired and sighted-blindfolded pedestrians. Shingledecker observed that fewer safety errors occurred and an increase in walking efficiency resulted from reducing the cognitive processing load through the provision of anticipatory information. Perceptual anticipation also benefitted those encountering turns in a route.

The research of these investigators is primarily directed towards the formulation of mobility training programmes and mobility devices. Their work is concerned with the ability of the blind traveller to use information that is presented immediately ahead of him while using a particular aid. Specifically, their research centred on the Laser Cane, the Sonic Pathfinder and the Sonicguide (TM). Thus, they focused on the immediate and upcoming events and relevant stimuli that could be perceived through the use of these apparatuses.

Intermodality Organization

Millar (1982) argues that central to the explanation of different abilities or spatial skills of the visually impaired is the distinction between 'capacity' and 'competence' (p.153). Thus, to indicate that the visually impaired have the capacity to detect spatial relations does not necessarily signify that they have acquired adequate spatial concepts or that they are spatially competent. She believes that no one modality is crucial; rather the sense modalities should be regarded as providing complementary information (1981). Thus, Millar (1982) contends that visual experience is neither necessary nor is it sufficient for spatial organization. Unlike the blindfolded sighted, who operate with map-like coding strategies when other strategies prove inappropriate, the visually impaired utilize an event-to-event (sequential) strategy derived from moving through a space. Although the visually impaired are capable of using external relations, they prefer to rely on self-reference and movement cues. External sources frequently provide unreliable or insufficient feedback. Thus, optimal forms of coding for the visually impaired result from the combination of various types of imagery. Millar insists that blindness does not impair the ability or the capability to solve spatial problems.

Millar's conclusions are in agreement with those of Kerr (1983) who stated that congenitally blind adults are capable of preserving and processing spatial images in a manner very similar to that used by sighted subjects. They invariably take more time than their sighted counterparts, but they are not limited to a modality-specific image process. In fact, Kerr suggested that imagery processing need not depend on visual experience but, instead, might rely on a form of spatial imagery that is not sense specific (p.275) (e.g. Jones, 1975; Neisser, 1976; 1978). Today the assumption that the visually impaired are capable of maintaining spatial imagery would be disputed by few.

The Controversy Over the Use of the Euclidean or the Topological Scale

Traditionally, maps have been formulated within the constraints of Euclidean geometry. Within Euclidean space, straight lines, angles, curves, and distances are conserved (Swallow and Poulsen, 1972). This, then, means that the shortest distance between any pair of points in a space can be described by a straight line (Brambring, 1976, p.287). It has been a convenient metric for abstracting information from reality and summarizing it in map form. Golledge and Hubert (1982) note that within the Euclidean framework, space is conceived as being isotropic and that parallels do not converge (p.107). However, the question arises:

> "Can spatial patterns generated by behavioral processes which are markedly non-Euclidean be analysed effectively with maps which are by convention based on an irrelevant Euclidean space?" (Muehrcke, 1972, p.43).

Golledge and Hubert (1982) further explain that:

> "At the very least, one can argue that the internal geometry of the world of perception and cognition may have very few of the attributes of Euclidean geometry and may more likely be represented in non-Euclidean formats.
> If this is the case, then the adoption of the Euclidean perspective for one's maps, models, and theories, involves not only a complex abstraction from the real world, but a conscious distortion of perceptual data...'Distance' then becomes an *experience* which should not necessarily lead to a response that is best represented in Euclidean terms" (p.108).

Luneburg (1947, 1950) demonstrated that the Euclidean metric is not valid for visual space (Brambring, 1976, p.287). With regards to haptic space, a mathematical formulation has not yet been developed (Brambring, 1976, p.287).

The literature suggests that a basic topological concept be employed in spatial perception and cognition. Topology is defined as:

> "the study of the properties of figures that remain constant in such a manner that the points of the resultant figures are in a one-to-one correspondence with the originals, as when a figure is stretched" (Webster New Encyclopedia Dictionary, 1975, p.1038).

Central to topology is the notion of "closeness-at-a-scale", which is also a functional element in cartography and geography. It is also involved in the logical processes of differentiation and scaling (Robinson and Petchenik, 1976, p.122).

Byrne and Salter (1983) investigated the representation of distance and direction in congenitally blind and sighted subjects. The subjects were examined on their knowledge of locations in their neighbourhood from their home, and from an imagined but existing location. The visually impaired were significantly worse than the sighted when direction was estimated from an imagined distant location. Estimated bearings were more accurate if made from a known home location. This indicated that the visually impaired operated from a predominantly egocentric perspective rather than from a geographic reference system (also Dodds et al., 1983; Millar, 1982; Pick, 1980). However, no differences were found between the visually impaired and the sighted in terms of magnitude of errors made on distance judgments.

These results are akin to Piaget's findings (Piaget and Inhelder, 1965). Young sighted children's early spatial representations in cognitive maps were influenced by topological relations. They were, "unable to describe a neighbourhood as a whole because landmarks were placed in subgroups based on independent vantage points used by each child" (Simpkins, 1979, p.94). Byrne suggested that the blind were operating with a 'network map', which preserves topological connectedness, as opposed to a 'vector map, which is based on two-dimensional vector distance information. Thus, the order of locations and turns within the 'network map' allows for successful navigation. An ideal example is the current London Underground Map, which retains pertinent topological properties (Canter, 1966, p.73).

A tendency for the visually impaired to exaggerate the Euclidean distances between locations separated by pathways incorporating turns and corners has been reported by Rieser et al. (1980). Casey (1978) observed that the blind commonly perceived curved walkways as straight, thereby making systematic distortions. Without the visual information to which a path can be related, a pathway commonly is interpreted as "from here to there" by the visually impaired pedestrian. This interpretation is similar to what Piaget, Inhelder and Szeminska (1966) claim young children rely on for spatial perception. Unlike the sighted, the visually impaired are less likely to retrace any distorted routes or to explore surrounding areas, so as to refine their spatial knowledge (Acredolo, 1983, p.155). Although the tactual map can readily provide information to overcome these distortions, unfortunately the visually impaired tend not to use such aids, because of a lack of readily available and coherent tactual maps.

Simpkins (1979) hypothesized that: "topological relations would play an important role in the tactual recognition of shapes in young blind children" (p.94). Based on the cognitive theory of Jean Piaget, the development of visually impaired children's spatial concepts was compared with that of sighted children. Piaget and Inhelder (1965) presented information revealing that children understood topological relations prior to projective (concepts of perspective and projection) or Euclidean (concepts of distance and measurement) ideas. Embodied within topological spatial relations are the chronological concepts of (1) 'nearbyness', (2) 'separation', and (3) 'enclosure' (Simpkins, 1979, p.93). Simpkins' results parallel Piaget's spatial development findings with sighted children. The understanding of topological and curvilinear-rectilinear relationships preceded Euclidean concepts.

Gill (1974) appealed for research to be conducted on the incorporation of a topological scale in tactual mapping. James (1972) remarked that:

> "Undoubtedly topological representation of geographical space has many advantages in view of the limited coding space available for the tactile map" (1972, p.88).

It is evident that interpretation by the mapmaker is required, so as to design a legible and useful tactual map within the limitations of the haptic sense. Craig and Sherrick (1982) clearly defined the issue as being one of a pictorial versus a coded approach to pattern recognition.

> "Designers of such displays attempt to incorporate symbols that suggest the object they are meant to represent. If pictorial approaches are not necessarily superior to coded approaches, then the search for the haptic equivalents of visual objects needs to be broadened. It should not be assumed that some direct, albeit reduced, representation of a visual object makes the representation for the skin" (1982, p.217).

A simple and direct transliteration of a visual display into a tactual one has often resulted in confusion and difficulties on the part of the reader (Barth, 1984; Bentzen, 1979). Jansson (1984) recognized the importance of this problem, especially with regards to the visually impaired pedestrian. Awareness of directions and distances by the visually impaired traveller has been identified as essential to successful navigation. Jansson, however, observed that:

> A visually impaired person is handicapped both in the immediate grasp of information a map gives before and during travel. This is an important reason why tactual maps should differ from visual maps in kind and not

only amount of information" (1984, p.3). Amendola (1976) contended that schematization is more important than either the consistency of scale or the accuracy of direction. By incorporating purposeful variations in the scale, she believed that the initial cognitive mapping of an area is facilitated, although the map is somewhat limited in its accuracy.

James (1972) theorized that by designing route maps with varying scales, a blind traveller's perception of distance may be more clearly represented. He acknowledged the fact that distance is frequently judged by the time taken to complete a journey, along with the number of reliable landmarks contacted. This led him to suggest that sections perceived as uneventful or shorter should receive less emphasis, unlike sections with several important landmarks.

Preiser (1983) simplified and distorted a tactual route map, yielding a result similar to a circuit diagram. Route configurations were presented at different scales, thereby including only information that was absolutely necessary for orientation by the visually impaired. Preiser claimed that the topological map assisted in creating images of an unfamiliar environment. Unfortunately, the topological map did not necessarily improve travel performance (1983, p.87). It can be concluded, however, that the formation of a mental image benefitted from the sequential presentation of landmarks. The partial success of Preiser's topological map was the result of the visually impaired person's capabilities in utilizing cross-modality transfers of environmental information (as suggested by Millar, 1981), such as smells, sound and changes in path gradient and texture (Castner, 1983, p.8). Although design constraints exist in the formulation of tactual maps, Castner indicated that:

> "There is evidence that they are able to accept a greater variation in map scale within a given map. It is unclear whether blind users are less distracted by the very global attributes of a display which we sighted users regard as so valuable, or they do not attend to the areal relationships as much as to the sequence with which information is being accessed. Certainly, they are not as able as you to uncritically accept an image for what it appears to be" (1983, p.7).

In order to use a tactual mobility map successfully, and to relate the abstract representation on the map's surface to reality, the reader must understand the concepts of scale, distance and relative position (James, 1982, p.336). Invariably, the choice of scale will determine the overall size of the map, which in turn will limit the amount of information to be presented clearly, given the minimum size of tactile symbols and the principles of haptic perception. This has led certain researchers (Bentzen, 1980; Brown, 1978; Kidwell and Greer, 1973) to apply a fixed scale in the representation of particular sections of the map. Yet, by distorting certain other areas, they were able assure symbol separation and tactual legibility. The visually impaired users were able to apply and accept these distortions, although, in Bentzen's study, some subjects found the variation in scale annoying when first applied to travel.

Other researchers (Berla and Butterfield, 1977; Schiff, 1982; Wiedel and Groves, 1969) have insisted on designing the tactual map with a fixed scale. Wiedel and Groves believed that subjects exposed to large-scale maps incorporating an inconsistent scale were more confused than by small-scale maps with an inconsistent scale. Schiff (1982) indicated that wherever possible, tactual maps should be designed to scale. Deviations should arise only when the true scale has interfered with the discriminability of the map. At the "First European Symposium on Tactual Town Maps for the Blind", Brussels, 1983, various map attributes, including scale, were discussed. The tactual maps for Brussels itself were designed on the basis of a variety of fixed scales, rather than on a purely topological basis. The design of these town maps was based on:

1. "scales of roughly 1/1,800 for complicated sections, and
2. 1/1,800 to 1/2,500 for uncomplicated sections of the town, it being understood that street names would be written in Braille" (p.18).

The application of numerous scales allowed for tactual legibility and clarity of information portrayal at several densities.

Summary

Bentzen (1982) observed that, "there is no agreement on whether tangible graphic displays should reproduce exactly what is present in visual form" (p.388). The literature , however, tends support the contention that tangible counterparts of visual displays are not considered to be appropriate for the visually impaired map reader. Both Armstrong (1973) and Maglione (1969) indicated that in terms of a map's usefulness, absolute consistency in scale is not essential. Maglione stressed that:

> "the relative unimportance of scale as a factor to complicate map production and design would be given even more emphasis by this writer to the extent of stating that even a building or a courtyard plan requires only the crudest relationship to linear scale" (1969, p.43).

It is apparent from this literature review that consideration for the principles of haptic perception, along with the visually impaired person's understanding of space and distance is imperative in tactual map design. A holistic impression of the graphic information is hindered by the sequential nature of haptic input (Andrews, 1983; Lederman and Campbell, 1982; Millar, 1982). Yet the visually impaired are able to develop spatial frames of reference although these are commonly less sophisticated than those of the sighted (Ewart and Carp, 1963; Fisher, 1964; Rosencranz and Suslick, 1976; Worchel, 1951).

By combining several reliable sense modalities, the visually impaired person is able to solve spatial problems (Kerr, 1983; Millar, 1982). Strategies for acquiring spatial layout knowledge appear to differ with experience and degree of blindness. Most visually impaired individuals tend to exaggerate Euclidean distances and yet manage to operate spatially with some form of metric, most frequently a functional metric (Rieser, Lockman and Pick, 1980). The congenitally blind in particular have demonstrated that 'egocentric' responses are quite reliable for deriving spatial arrangements (Dodds et al.,1983; Millar, 1975).

It is possible for visually impaired observers to learn and to apply information from tactual graphic displays to deduce spatial relations in large-scale spaces. The tactual map can be a valuable aid for gaining spatial knowledge, thereby allowing the user to develop beyond the 'egocentric' approach. Rather than performing a visual-to-tactual translation, tactual map design should be performed from a map user's perspective. The representation of distance and spatial arrangement and the choice of legible tactual symbols would then probably suit the needs of the visually impaired pedestrian. Limitations in coding space and the need to emphasize critical portions of the map could be overcome through a topological representation of geographical space. Thus, less emphasis might be placed on the consistent fixed-scale, and more on characteristics important to the visually impaired.

CHAPTER III

HYPOTHESES AND DESIGN

Statement of Specific Questions and Hypotheses

Specific Questions

Tactual mobility maps have the potential to be useful tools in assisting the mobility of the visually impaired. Although many persons are engaged in tactual map research, the maps produced have failed to meet fully the requirements of the visually impaired pedestrian. Conveying information about a particular environment on a tactual map is frequently hampered by design and production methods. The fact that the majority of mapmakers are working from a sighted-base approach causes numerous difficulties. For a sighted person the map usually can provide a means of checking perception of distance against reality. However, for the visually impaired individual this comparison is more difficult.

James (1972) stated that:

> "There has been no research giving evidence on the usefulness of a map constructed to scale for blind travellers. Scale must feature as an important consideration if we are to define more clearly map design parameters" (p.88).

He suggested that the possibility of altering a perfect scaled map-route relationship to meet the needs of the visually impaired person's perception might be incorporated into the design of tactual maps.

A close examination of the available literature reveals that little has been conducted regarding the use of a flexible scale within the tactual mobility map. Thus the following questions were posed and examined with respect to the visually impaired person's movement in a space:

1. Will a tactual map better aid mobility for a visually impaired person moving through a large-scale environment than will relying solely on verbal instructions?

2. Will a flexible-scale tactual map better aid mobility for a visually impaired person moving through a large-scale space than will a fixed-scale tactual map?

3. In environments with uniformly distributed elements, will both the flexible-scale tactual map and the fixed-scale tactual map equally aid mobility of a visually impaired pedestrian?

4. Will use for a flexible-scale tactual map result in a relatively better performance than that with a fixed-scale tactual map in environments with clustered elements compared to environments with uniformly distributed elements?

Hypotheses

The following hypotheses were posited with respect to the above questions.

I.A. Tactual map assisted visually impaired persons will complete a given route more rapidly than they will if relying solely on verbal instruction guidance methods in a large-scale environment.

I.B. Tactual map assisted visually impaired persons will complete a given route with fewer errors than they will if relying solely on verbal instruction guidance methods in a large-scale environment.

In the past, mobility training instruction was based heavily on detailed verbal descriptions or a 'verbal' map. Brambring (1982) indicated that the verbal description was the most common means of conveying geographic information. 'Verbal maps' were explicitly related to one particular route. Insufficient information was provided to allow the user to detour or to plan different routes. This then dictated the preparation of a second description for a return journey along the same path. At the same time, information concerning the surrounding locality was not available. The form of the information, however, could be varied to suit the requirements of an individual. This manner of conveying route-information was most useful to the non-braille reader (James and Armstrong, 1976).

Recent methods in mobility training do not emphasize verbal direction. In fact, new approaches with the congenitally blind instruct the individual only on the general terrain. The person is encouraged to find the landmarks for himself. Thus in this author's opinion, the tactual mobility map designed from the visually impaired person perspective, would be a useful aid for providing relevant information for travel in conjunction with verbal instructions.

Maglione (1969) presented the participants in his research with instructions and a tactual map of a particular route. He indicated that: "It is thought that the map simply gave the subjects additional information since the verbal description alone did not suffice for the subject to organize effectively" (p.10). He confirmed this statement later, as the subjects provided with a tactual map and a verbal description made fewer errors and took less time than those with only the verbal descriptions (p.49). Maglione's results suggest that the learning process is augmented by the provision of greater amounts of information accessible to the user. Gibson and Gibson (1955) suggested that, in order to learn a series of acts, the person must partake in a process of selective attention whereby fine discriminations are synthesized. The tactual map should enable that user to determine a strategy which would allow for improved mobility through an unfamiliar area, either complex or simple.

II.A. For any given large-scale environment, a visually impaired person with a flexible-scale tactual map will complete a given route more rapidly than the same person with a fixed-scale map.

II.B. For any given large-scale environment, a visually impaired person with a flexible-scale tactual map will complete a given route with fewer errors than will the same person with a fixed-scale map.

III.A. In a large-scale environment with relatively uniformly distributed elements, the rates of travel of a visually impaired person using either a fixed-scale tactual map or a flexible-scale tactual map will be the same.

III.B. In a large-scale environment with relatively uniformily distributed elements, the number of errors committed by the visually impaired persons using the fixed-scale tactual map or the flexible-scale tactual map will be the same.

IV.A. In a large-scale environment with relatively clustered elements, a visually impaired person using a flexible-scale tactual map will complete a given route with fewer errors than will the same person with a fixed-scale map.

IV.B. In a large-scale environment with relatively clustered elements, a visually impaired person using a flexible-scale tactual map will complete a given route more rapidly than will the same person using a fixed-scale map.

The subjects involved in the map testing exercises of this study were tested for their speed of movement and for the number of errors that they made while using the maps. Error in this situation refers to the failure of an individual to locate a specified landmark successfully on the map and/or in the environment. This results first in the recognition that the landmark has been missed, and then an examination of the map to locate the self and the object and finally the location of the landmark, which usually requires backtracking along one's route. Simultaneously, time to completion was being recorded by the experimenter as one measure of their performance.

Experimental Design

Two groups of subjects (visually impaired and sighted blindfolded) were tested individually under relatively controlled experimental conditions. Within each group, subjects were randomly assigned to one of four experimental sub-groups or orders (Table 3.1). The eighteen visually impaired subjects were divided into the four orders in the following manner: four persons to orders I and II and five persons to order III and IV. The twelve sighted subjects were evenly distributed amongst the four orders. The orders varied in sequence of the maps presented to the subject and of the environment that was first encountered. For both the simple and the complex environments, the subject was required to pursue a route following three different conditions (a verbal description or map, a fixed-scale map and a flexible-scale map) at different times. All participants were involved in the testing of each condition, since the number of potentially available subjects was quite limited.

Due to the fact that all the participants partook in the testing of all map conditions and that each subject brought to the experiment certain well-established mobility characteristics, each person participated in a 'preview' exercise in areas similar in design and layout to the actual test sites. Time was recorded as subjects moved along a specified route without the aid of a map, once from the point

Table 3.1: Orders and Map Conditions.

Order I	Order II	Order III	Order IV
No-Map Scarfe[1]	No-Map Law	Fix-Map Scarfe	Fix-Map Law
Fix-Map Scarfe	Fix-Map Law	Flex-Map Scarfe	Flex-Map Law
Flex-Map Scarfe	Flex-Map Law	No-Map Scarfe	No-Map Law
No-Map Law	No-Map Scarfe	Flex-Map Law	Flex-Map Scarfe
Flex-Map Law	Flex-Map Scarfe	Fix-Map Law	Fix-Map Scarfe
Fix-Map Law	Fix-Map Scarfe	No-Map Law	No-Map Scarfe

[1]No-Map implies verbal guidance instructions or a "verbal map"

of departure to the destination, and again along the identical path, but in reverse. A brief announcement about turns and relevant and identifiable features began each passage. The experimenter, recording the total time elapsed per preview 'walk-through', accompanied the subject. Since all participants were involved in testing each of the conditions (although in different sequences), it was necessary to obtain some basis against which their movement with the maps, verbal or tactual, could be compared. The 'preview' times provided a baseline measurement for each individual.

The 'preview' provided the subjects with an opportunity to familiarize themselves with an exercise and with environments similar to those which they would encounter in the testing stages. [1] 'Preview' has a more general application in this research study than in the "anticipatory skills" usage of Barth and Foulke (1979). Barth and Foulke remarked that as the blind pedestrian learns from experience, sensory and perceptual forms of anticipation begin to function. By encountering this 'preview' exercise prior to actually testing the maps, all the subjects had exposure to traversing a hallway and to operating completely without sight. Thus each participant was provided a standard experience similar to the other members of his or her group.

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[1] As several of the visually impaired persons and the sighted experienced light perception, they were required to wear a mask for standardization purposes. The preview gave them an opportunity to gain some confidence with their new situation.

Immediately following the 'preview' exercise, the subjects were led to all of the study sites to commence the testing procedure. The subjects were tested individually in sessions that lasted for approximately an hour in each area. Participants who had any light perception were required to wear a black satin eye mask as they had done in the preview session, standardizing sensory exposure. This was needed, as visual impairment refers to several levels of vision from totally and congenitally blind to those with enough sight to travel successfully without an aid in daylight.

Those persons who commonly used a mobility aid, whether a dog or a cane, were encouraged to do so in this instance. The reasoning being that in a normal, daily travel situation, a tactual mobility map would probably be used in conjunction with another aid. Simultaneously, this study aimed to ascertain whether or not the use of the tactual mobility map, portrayed at different scales and as an additional aid, assisted in easing the movement of the visually impaired pedestrian.

No one was permitted to see or scan either site prior to encountering it. The subject was provided with a flexible-scale tactual map, or a fixed-scale tactual map, or a verbal description of the area. The map sequence varied from individual to individual. The orders of presentation are summarized in Table 3.1. All possible combinations of testing formats were not used, because of the limited number of available subjects.

Everyone received approximately the same instructions, which were given in a fairly flexible and informal manner. An outline of the directions for map use, and the verbal map description may be found in Appendix A. The particular map being presented was not identified to the individual. The subjects, however, were aware that they would be given two maps portraying different scales. A legend accompanied the tactual map of the complex environment, since clutter problems would have arisen if all information had been portrayed on the display. [2] Those who read braille could take advantage of the labels exhibited on the maps, otherwise the experimenter carefully explained all of the symbols within their context. Each subject was directed in a passive exploration of the raised-line drawing; index finger guided by the experimenter around the plan (Magee and Kennedy, 1980). Subjects were encouraged to examine, and familiarize themselves completely with the map and its contents prior to travel.

Before testing the maps, each subject listened to a set of instructions. These were not as detailed as the 'verbal map'. Instead, the instructions included an outline of the map layout, map reading training and directions for the testing of the maps. They were repeated for clarification. The experimenter told the participants to work at their own pace; they were reminded that they were testing the maps as aids to

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[2] Clutter refers to the situation in which too many symbols occur on a tactual map or the symbols are placed too close together to allow for clear identification (Brown, 1978).

mobility, not their personal travel abilities. They oriented the map in a manner that was meaningful to them. Although not told to do so, most people oriented the map with the direction of their movement at the top. This was an interesting observation, as the majority of the visually impaired volunteers had had little exposure to any form of a tactual map and very few had used them while travelling.

Using the given map or following the verbal instructions, the subjects were asked to locate six landmarks on four passages through the hallway, which the author labelled as 'forward' and 'reverse', the former being a passage from the entrance to the exit (1) and from the exit to the entrance (2), and the latter being a passage in the opposite direction (3) and (4), as indicated in Figures 3.1 and 3.2. They were to stop and identify (touch) each landmark in the environment and on the map, if they possessed one at that time. A time was recorded from the previous landmark to the location of the object. Errors, such as bypassing the object, were noted. Errors in navigation or in locating landmarks, that the subject was able to correct without assistance were not corrected by the experimenter. If errors resulted which in the experimenter's opinion, completely disrupted the person's ability to successfully complete a segment of the route, he or she was returned to the last point of departure to begin again. Once times and errors had been noted, the subject was told to proceed to the next landmark. The experimenter accompanied the

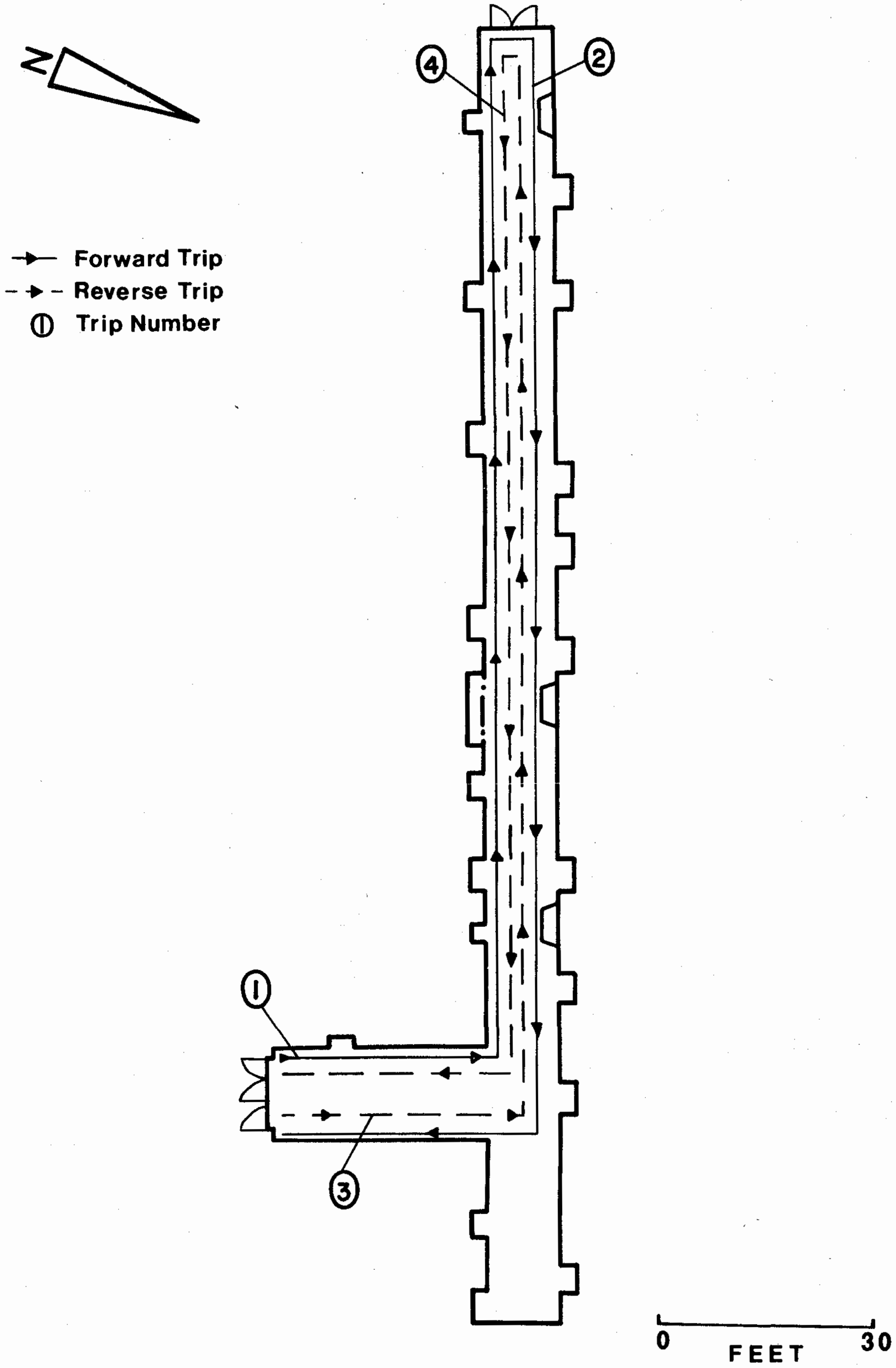

Figure 3.1: The four test passages through the Scarfe Building.

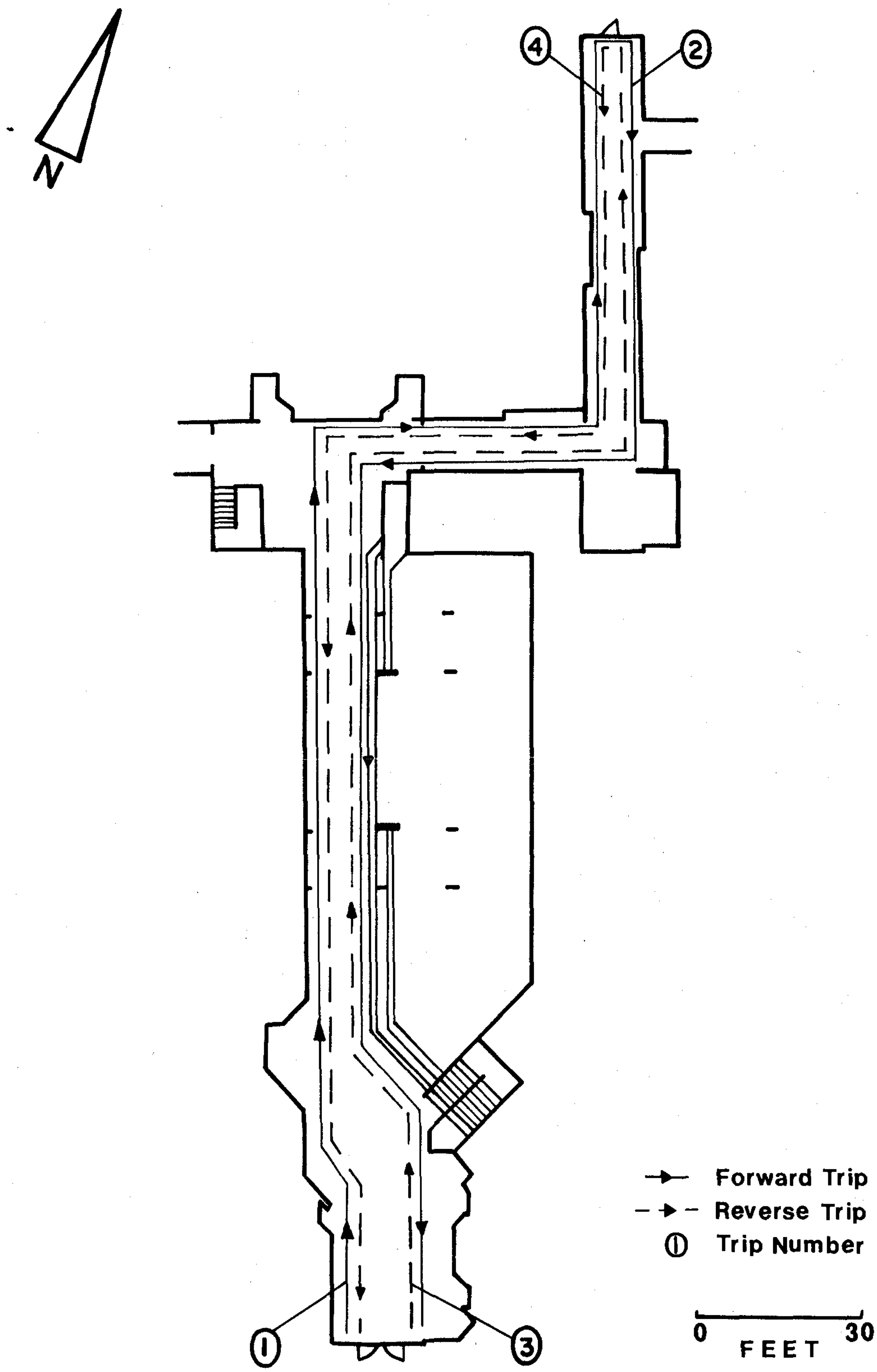

Figure 3.2: The four test passages through the Law Building.

subject closely enough to make observations on the person's abilities and reactions to the maps. At the same time, any objects that were temporarily positioned in the area and would not be indicated on the maps were identified for the subject. The procedure was repeated twice with the remaining two conditions. Thus, each subject passed through each of the two halls twice (forward and reverse) under three conditions.

Originally, the question of "reversibility" was to be examined; in other words, whether or not the subjects were capable of going not only from point A to point B, but also from B to A. Evidence from the research of Pick (1972), Herman, Chatman and Roth (1983) and Hollyfield (1981) has suggested that visually impaired individuals were capable of performing these tasks, and reversibility is not examined in this study.

It is important to know that some of the subjects had to contend with large gatherings of people in the Law School hallway. Usually, the subjects were encouraged to continue with the task, since mobility maps are meant to aid the traveller regardless of the environmental conditions. Testing was resumed at a later time if the crowd made mobility impossible.

The Sample

Research projects that involve the visually impaired frequently encounter the problem of insufficient numbers of readily available and accessible subjects. This project was no exception, and so the decision was made to include a group of sighted blindfolded.

With the assistance of The Crane Library at The University of British Columbia, a list of visually impaired potential subjects was obtained, and so a small population was relatively accessible for testing the maps. Sighted students, from The University of British Columbia and Simon Fraser University, already familiar with and interested in the project design were personally contacted and invited to participate.

The visually impaired subjects were mailed a letter of introduction, describing the purpose and the scope of the study, and the procedure for further contact. Later, they were telephoned, and if they were willing to participate in the project, arrangements for testing were made for a specific time and day. As the majority of them attend or had attended The University of British Columbia, participant transportation was no problem.

Each person was individually tested in each of the two locations. Sessions lasted for approximately one hour in each environment.

The Visually Impaired

Of a population of thirty-four visually impaired members registered with The Crane Library, twenty-five were potentially available to assist in the project. Ultimately, eighteen participated in the examination of the maps. The visually impaired sample contained approximately equal numbers of males (N = 10) and females (N = 8).

All participants were capable of independent travel. Eleven of them used a mobility aid - four travelled with a dog and seven used a cane. Eleven of the subjects had no experience with tactual maps in any form. The rest had had minimal exposure, except for one person who had worked extensively with many types of tactual maps, for both mobility and educational purposes. Of the seven people who had been exposed to tactual maps, five were congenitally blind (four of them were totally blind). Even if a visually impaired person has had exposure to tactual maps, it is often not sufficient to assume skill in the interpretation and the use of the graphics.

This is a relatively unique population. It is important to recognise that the subjects are competent, verbal adults. Cane use is being successfully taught to mentally handicapped blind persons, who might or might not benefit from tactual mobility maps. All the subjects in this study knew what a map was and did not require map explanation or definition. These people were either currently attending university or had been registered in an academic programme. This generally young group was actively involved in a variety of disciplines (law, education, psychology, English, literature, geography and therapeutic recreation) and at different levels. Many were physically active. Although two subjects were multihandicapped, they were not hampered or deterred in their mobility efforts. It is apparent then that this group is not representative of the typical blind population.

As one would expect, the levels of visual impairment varied, although all participants were considered to be legally blind. The Canadian National Institute for the Blind states that: "a person is considered 'blind' if the visual acuity in both eyes with proper refractive lenses is 20/200 (6/60) or less with Snellen Chart or equivalent, or if the greatest diameter of the field of vision in both eyes is less than twenty degrees" (Dayton, 1979, p.12). Eleven of the subjects were blinded early in life (the latest at approximately three and one half years of age), the remaining seven were blinded totally or experienced a degeneration of vision at a later stage in life. Six of the participants were totally impaired and twelve experienced various degrees of light perception. Some had enough sight to be classified as having independent guiding vision, and therefore were required to wear an eye mask during the course of the study. Five of the twelve who had light perception used a mobility aid (two worked with a dog and three with a cane). Ten of the subjects had a working knowledge of Grade Two Braille and the remaining eight were not familiar with braille in any form. [3] These eight participants were all partially impaired and several of them used powerful and

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[3] Grade Two Braille uses a number of contractions and is frequently incorporated into the design of graphics for the visually impaired, due to a limited availability of space within the display.

sensitive visual aids to read print. Only three of them had been impaired late in life. It was not imperative that the subjects be fluent in any level of Braille for the purposes of this study. Table 3.2 summarizes the characteristics of the visually impaired subjects, obtained through a brief personal history questionnaire (Appendix B).

The Sighted Blindfolded

Twelve sighted university students also served as subjects in the study. The blindfolded sighted sample contained eight male and four female participants. Nine of these volunteers had never had any exposure to tactual maps. Three were familiar with tactual maps, but had never used them in any manner.

Many studies have compared the visually impaired and the blindfolded sighted at different ages. They have examined issues such as the estimation of distance and direction (e.g. Byrne and Salter, 1983; Juurmaa, 1965; Rieser, Lockman and Pick, 1980; Worchel, 1951), the ability to conceptualize and order elements of a large environment (e.g., Casey, 1978; Landau et al., 1984); the ability to localize tactile and auditory stimuli (e.g. Fisher, 1964; Juurmaa and Suonio, 1975; Millar, 1981, 1982; Warren and Pick, 1970); and the spatial ability of the two groups (e.g., Cratty et al., 1968; Landau and Spelke, 1985; Rieser, Lockman and Pick, 1980; Worchel, 1951). A central focus of these studies is whether or not visual experience is a prerequisite for certain spatial and

Table 3.2: Characteristics of the Visually Impaired Subjects.

Visual Impairment Level

	Total	Totally Blind	Partially Blind
Number of Subjects	18	6	12
Congenitally Blind	11	4	7
Adventitiously Blind	7	2	5

Use of an Aid

	Dog	Cane	No Aid
Number of Subjects Using An Aid	4	7	7

Familiarity With Tactual Maps

	None	Some
Tactual Map Exposure	11	7

Braille Proficiency

No Working Knowledge of Braille	8
Grade 2 Braille	10

Grade 2 Braille

Congenitally Blind		Adventitiously Blind	
Total	Partial	Total	Partial
4	2	2	2

mobility strategies.

In all of these examinations, the sighted subjects have been required to perform with blindfolds, on the supposition that the sighted blindfolded will then provide a valid comparison to the blind of non-visual abilities. Schmitt (1978) suggests that this reasoning is specious. His concerns evolved from two observations about the sighted blindfolded. The blindfolded sighted individual has had the advantage of relying on vision and therefore has established a frame of reference for spatial layouts, although not always accurate. Thus, blindfolding does not necessarily allow for the evaluation of other modalities devoid of the influence of vision. On the other hand, the blindfolded sighted subject is essentially a newly blinded person and therefore has had little experience in perceiving without vision. Schmitt has found that all too often most projects provide few opportunities to adjust to this new experience:

> "therefore the performance level obtained from blindfolded sighted Ss may represent not a stable level but rather an arbitrary point taken from a growth curve" (1978, p.27).

Warren, Anooshian and Bollinger acknowledged a similar difficulty when they remarked that:

> "The blindfolded sighted person is in effect a person who has just become blind. It takes a great deal of adjustment to get along without a modality on which one has depended for years, and thus the blindfolded sighted is not an appropriate control for comparison with the blind" (1973, p.151).

Problems become evident with the interrelations in blind and sighted of visual and tactual spatial performances and of kinesthetic-proprioceptive locomotion performances (Juurmaa, 1965). Thus, ascertaining quantitative differences between the performance variables of the two groups creates difficulties.

It was decided to include a group of sighted people for several reasons. In terms of the experimental framework, it was recognized that eighteen subjects was not adequate for most statistical analyses. It is often difficult to contact and locate visually impaired persons who are available to assist. By assuming that the sighted blindfolded are similar to the newly blind, the sample size could be increased substantially. It has been recognized that a certain degree of map reading training is essential in order successfully to understand and operate with a tactual map (Bentzen, 1982). This was taken into consideration when the subject was presented with a map for testing, and all the subjects were provided with some training.

The sighted blindfolded were involved in the same testing procedures as were the visually impaired. The preview session provided an opportunity for all subjects to become familiar with this unique situation. In fact, those visually impaired who regularly operated with some degree of guiding vision also had to adjust to being blindfolded. The preview session probably could not be classified as an adequate warm-up exercise by Schmitt's standards, on account of its brevity.

CHAPTER IV

THE SITES, APPARATUS, AND ASSUMPTIONS

The Sites

Certain questions of method have arisen in research conducted on tactual maps for orientation and mobility. One concern has been the environment in which the testing is to occur. Two possible options exist: the laboratory setting and the real world. Schingledecker and Foulke (1978) have analyzed carefully the benefits and the disadvantages of each of the possibilities. In the case of the laboratory environment:

> "the investigator is better able to meet the requirements of a well designed experiment by controlling for the effects of extraneous variables. However, this control is often achieved at the expense of fidelity to the real world in which the performance of interest ordinarily occurs, and as fidelity declines, there is an increasing probability that laboratory results cannot be generalized to the real world" (1978, p.277).

On the other hand, experiments may be conducted in actual environmental conditions in the real-world situation. As the authors state:

> "However, fidelity is often achieved at the expense of the control over extraneous variables that is needed to make an experiment conclusive" (1978, p.277).

Their solution to this dilemma was to create a laboratory environment that simulated closely the attributes of a real-world situation, thereby allowing for both experimental control and reasonable fidelity. In doing so, they presumed that the newly created area would simulate, "the real-world environment in which the performance of interest ordinarily occurs" (1978, p.277). They noted, however, that expense invariably overrode the possibility of constructing an ideal simulation.

The examination of possible study sites included exterior and interior locations, as well as simple and complex environments. Since mobility maps were the focus of the research, it was necessary to choose a small area for the test site. Mobility maps are large in scale and attempt to provide the visually impaired with some concept of space, distance and direction, as feature information is portrayed. A limitation for the visually impaired subjects, was an accessibility factor. Since they all were affiliated with The University of British Columbia, sites on the campus were regarded as preferable. Yet, the final choices needed to be relatively unfamiliar to most subjects. This was another limiting factor.

This dictated environments that allowed for real-world characteristics and provided a situation readily encountered by the visually impaired traveller. Two different hallways were deemed appropriate, as some control of their contents could be assured. A variation in complexity between the two hallways was necessary in order that scale flexibility of the graphics could be analyzed over disparate levels of route difficulty.

The University of British Columbia had several hallways which met the initial criteria set by the author for the different study sites. At the same time, these were accessible to the participants, who were relatively familiar with the campus, but not necessarily with the sites themselves. Indoor environments permitted the research study to be conducted without concern about weather. The hallways were considered to be an appropriate size for the examination of this particular map type. Building hallways are common locations encountered by the visually impaired, and so floor plans in the form of tactual maps were viewed as appropriate subjects for study.

A comprehensive survey of potential on-campus sites was conducted on foot. Taking into consideration the comments of those familiar with the visually impaired's use and accessibility to the university buildings, the author identfied the environmental features that would characterize a complex area with relatively clustered elements, and one with relatively uniformily distributed elements.

The choice of locations was evaluated by a visually impaired assistant, thereby incorporating his spatial perceptions. The assistant is a totally congenitally blind and yet highly mobile and independent male. The final decision was to use the second floor of the Scarfe Building Classroom Block (Education) as the simple area and the main floor of the Faculty of Law Building as the complex site. As Wiedel and Groves (1972) stated,

"An accurate map can only be produced by the map designer or other competent person walking the area and attempting to identify landmarks that are meaningful to

> the blind. There is nothing to be said in favor of copying a sighted map as these all too often contain minor inaccuracies which, if transplanted onto a tactual map, destroy the confidence of the blind map user. For mobility maps, therefore, walking the area prior to map design is an absolute must" (1972, p.55).

The second floor of the Scarfe Building could be described as a lopsided "T" (Figure 4.1). The hallway is uncomplicated, with no elevation variations. Unobstructed movement through it is possible. Two entrances/exits led into the hall, one located at the south end of the site and the main one at the end of the east-facing adjunct passage. The main portion of the hall is 54.86 metres (180') long and 3.048 metres (10') wide. The shorter section is 11.58 metres (38') long and 4.75 metres (15') wide. Throughout the passageway, doors opening into classrooms, offices and resource rooms are positioned at relatively regular and predictable intervals. Lockers flush with the walls border the hall. Due to the fact that this has been designated as the Science floor, several unique features are incorporated into the area (which were later to be used as landmarks). Three animal cages, of a bay window design, were built into the wall. Located on the same side of the hall, they housed birds, an iguana and a chinchilla respectively. Across from the iguana cage was an aquarium that was flush with the wall and bordered with wood paneling. Features common to any hall, such as a drinking fountain and fire extinguishers also were found within this environment.

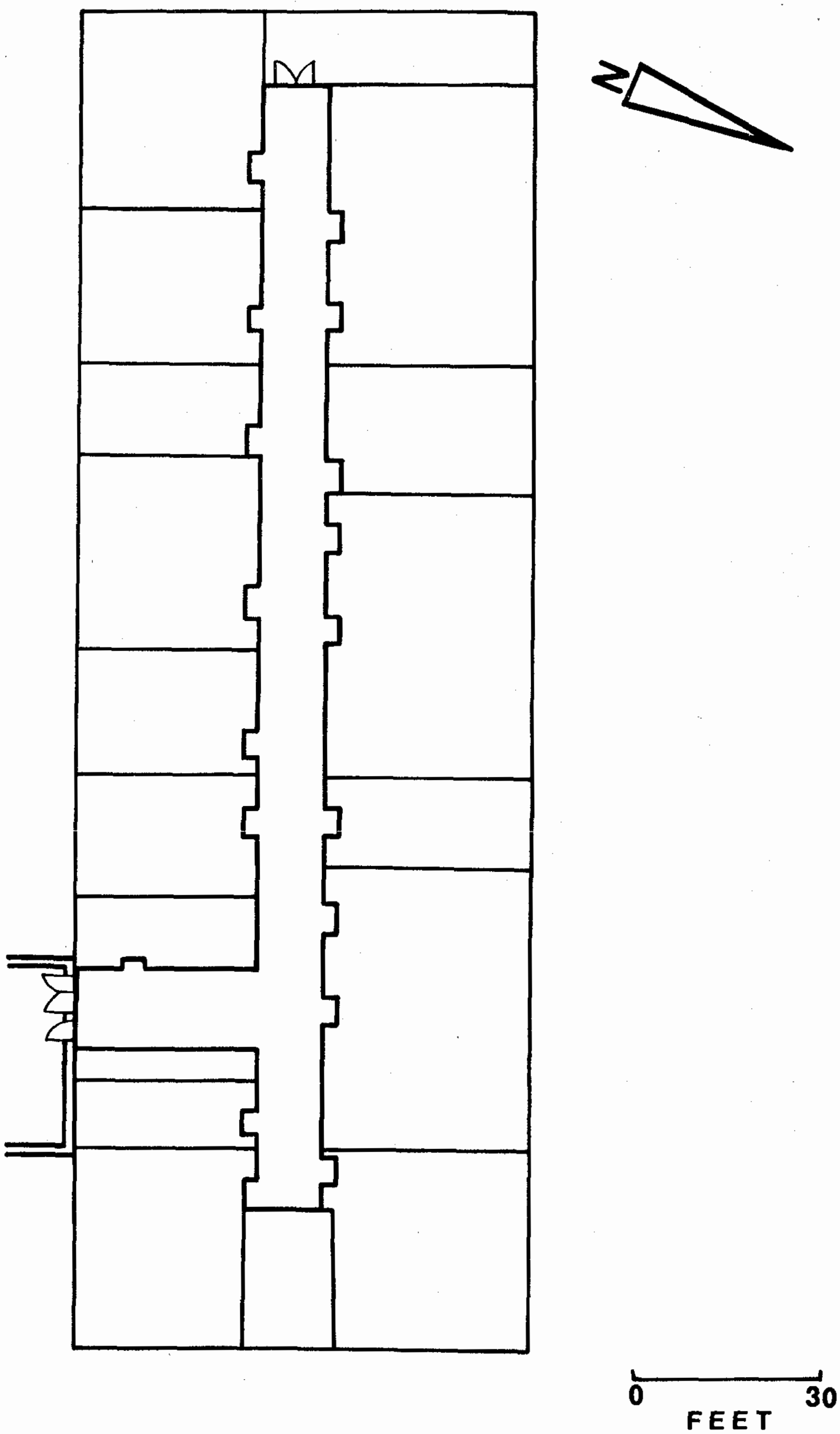

Figure 4.1: Scarfe Building, Classroom Block, Second Floor.

In comparison to the complex environment, this hallway was relatively symmetrical and uniform. Schingledecker's (1983, p. 336) three criteria for determining and selecting route and environmental complexity were utilized: (1) orientation complexity, incorporating landmark usage and ease of straight line travel, (2) clutter, referring to the number of obstacles and their predictability, and (3) level of functional difficulty, involving a general descriptive judgement of route complexity. The Scarfe Building second floor was classified as a route of low complexity. The hall incorporating one adjunct corridor was a straight pathway of constant width. No permanent obstacles were situated on the footpath. Landmarks were reliable and distinct.

The Law Building, because of its high degree of complexity, is more difficult to describe (Figure 4.2). It has a modern design and the basic structure is essentially "Y" shaped. The testing was conducted in the main hallway and the corridor branching to the right. Thus the subjects encountered several turns along the test-route. Although several staircases leading to other levels existed, the subjects did not make any elevation changes.

The main hall was 50.29 metres (165') in length. The width varied continuously along the length of the corridor from 3.429 metres (11.25') at the narrowest point to 11.43 metres (37.5') at the widest. At the main entrance, the hall was open and wide, incorporating alcoves, doorways and staircases. The

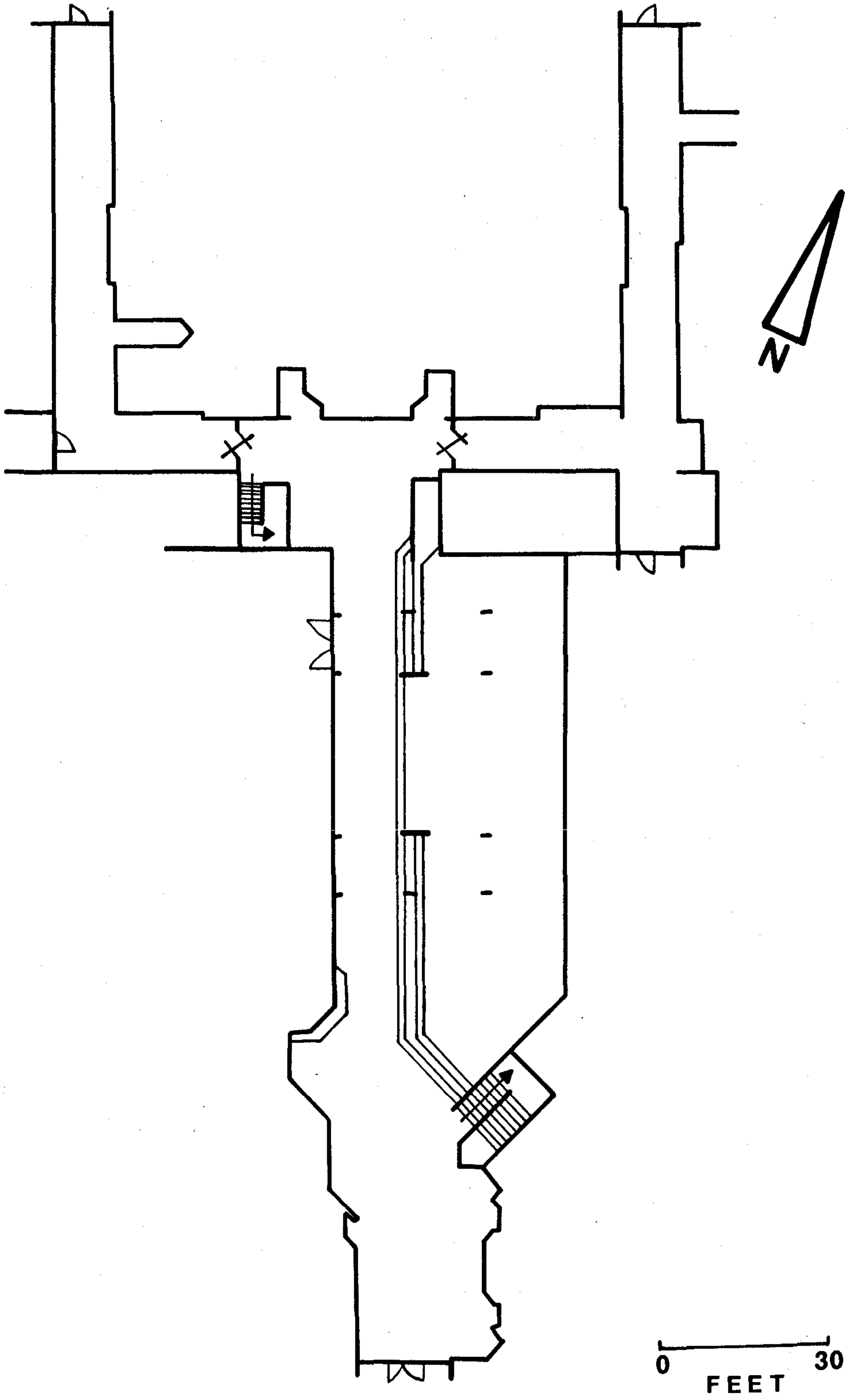

Figure 4.2: Law Building Floor Plan.

visually impaired assistant agreed with the author's belief that it was a complex environment. In fact, he described it as having a "railway station" atmosphere, especially when it was occupied by many people. Conforming to the definition of a relatively clustered environment, objects and features were not symmetrically positioned and therefore were not predictable. Obstructions existed within the passageway, such as doors, tables and a photocopy machine. Other obstacles, such as easels, chairs, and floating blackboards, were frequently and temporarily placed within the area and therefore could not be identified on the map.

The main hallway was delineated by a variety of textures and features. Walls were glass, stucco, or plaster and one even involved a corrugated folding door. In one section, part of the hall was bordered by a shallow staircase leading up to a lounge. Within these stairs were pillars and a planter. At another point, the hall was lined by a ramp and railing rising above the ground level.

The adjunct corridor had a standard width of 3.048 metres (10'). Like the main hall, it was lined with a variety of objects, including a set of telephones, shelving, and pillars. At the ends of the corridor were entrance/exit doors. The subjects were required to negotiate from the main entrance to the exit at the far end of the adjunct corridor, a route which was approximately 84.58 metres (277.5') long.

Preparation and Design of the Test Maps

Mapping from the visually impaired person,s perspective required several developmental stages. In the first stage, the experimenter accompanied the visually impaired assistant through the environments, recording features commented upon while en route. The visually impaired assistant identified those elements which served him as useful cues for orientation and mobility on a second observational walk. These features were located on sketch maps by the experimenter. Only information that was relevant to the task of mobility and orientation was included in the tactual maps. This involved the careful selection of mapable information, and precluded the straight transliteration of sighted maps. It was more important for the visually impaired traveller to have information about the relation between himself and aspects of the environment, than to have descriptions of the environment without such relationships (Brambring, 1982).

Thus the basis for the design of these tactual maps was the visually impaired person's perspective. It was important to take this approach in order to understand what appears relevant to the visually impaired pedestrian and then to create a meaningful and useful map. The intent was to build from the visually impaired person's understanding of reality. Turk (1983) emphasized the approach of utilizing a blind-user feedback in all stages of design. Jansson (1984) commented:

> "This need of addition as well as subtraction of information in a tactual mobility map makes it impossible, in most cases, to translate a visual map into a tactual one in a simple way. The editing of a tactual map is to-day mainly based on practical experience" (p.6).

The assistant and the experimenter worked closely together to determine meaningful and identifiable features and obstacles that could be classified as landmarks. The inclusion of relevant landmarks stems from Brambring's (1982) research. Brambring analysed the verbal information supplied by blind people for a familiar route. He examined the extent of agreement between various blind subjects in providing geographic information as data. He categorized the data into four classifications: distances, direction, landmarks, and obstacles. Brambring determined that landmarks were the most frequently named items. He surmised that:

> "it can be inferred that the blind need more orientation information about such 'neuralgic' points if they are to continue in safety. This fact should be given due consideration in describing routes to blind persons and in the construction of maps for the blind" (1982, p.209).

In comparison with sighted counterparts, the blind require considerably more geographic information for orientation, and information that is person-oriented, i.e. that can be personally checked (1982, p.217).

The pertinent landmarks of the two respective environments have been indicated in Figures 4.3; 4.4, and 4.5; 4.6. The six objects in each environment were assigned representative

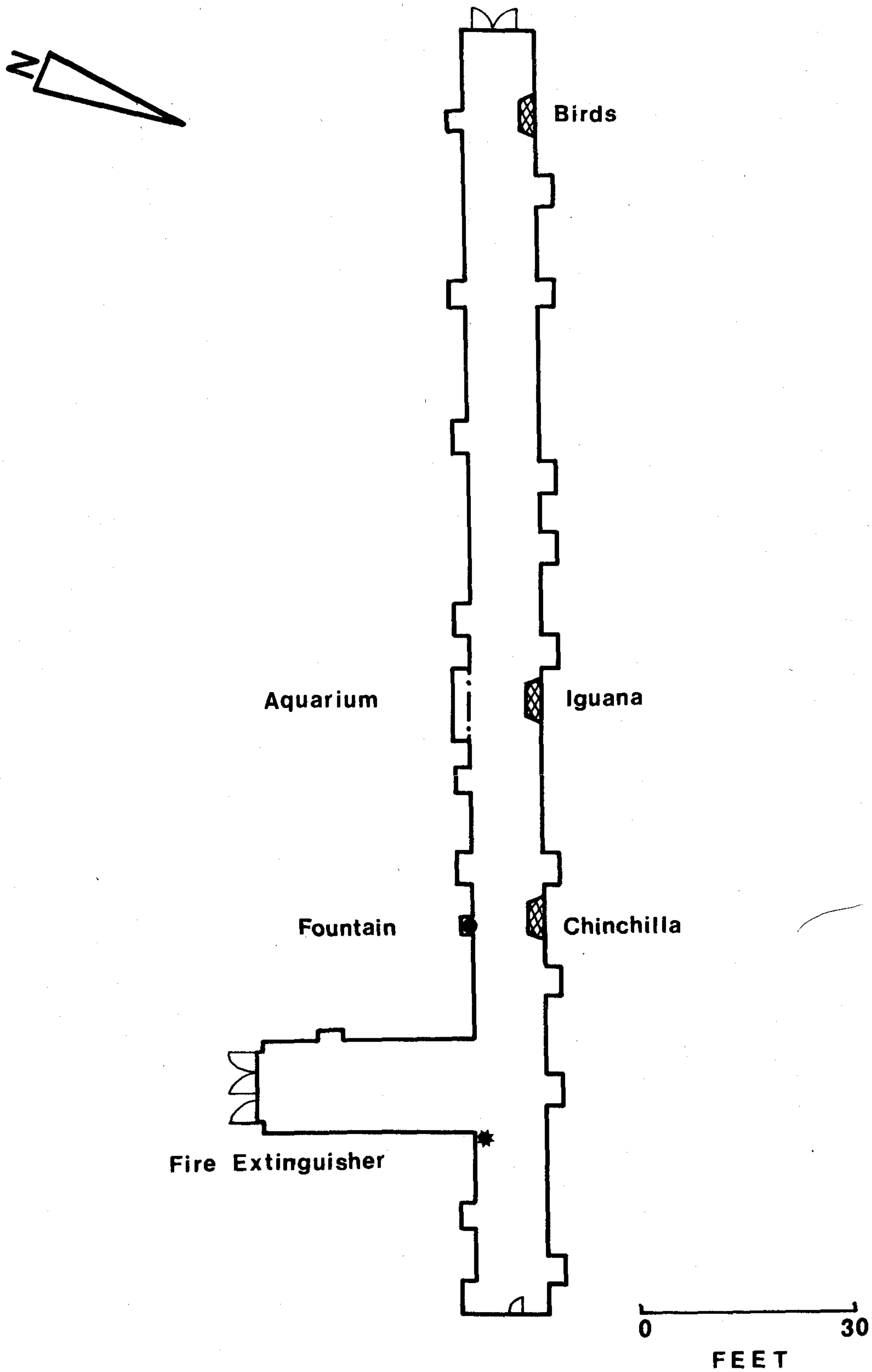

Figure 4.3: Landmarks identified in the Scarfe Building.

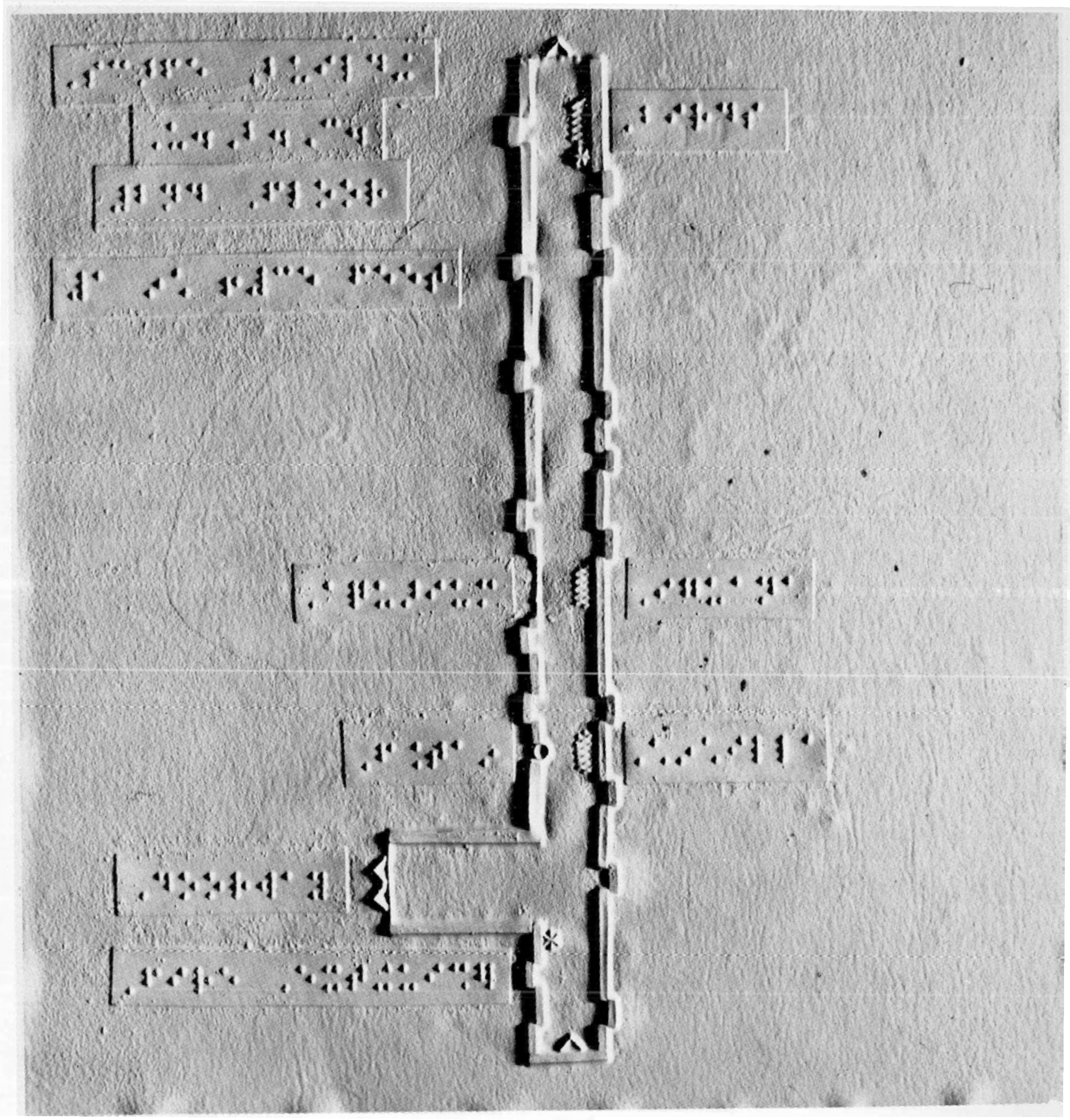

Figure 4.4: Scarfe Building – Fixe(

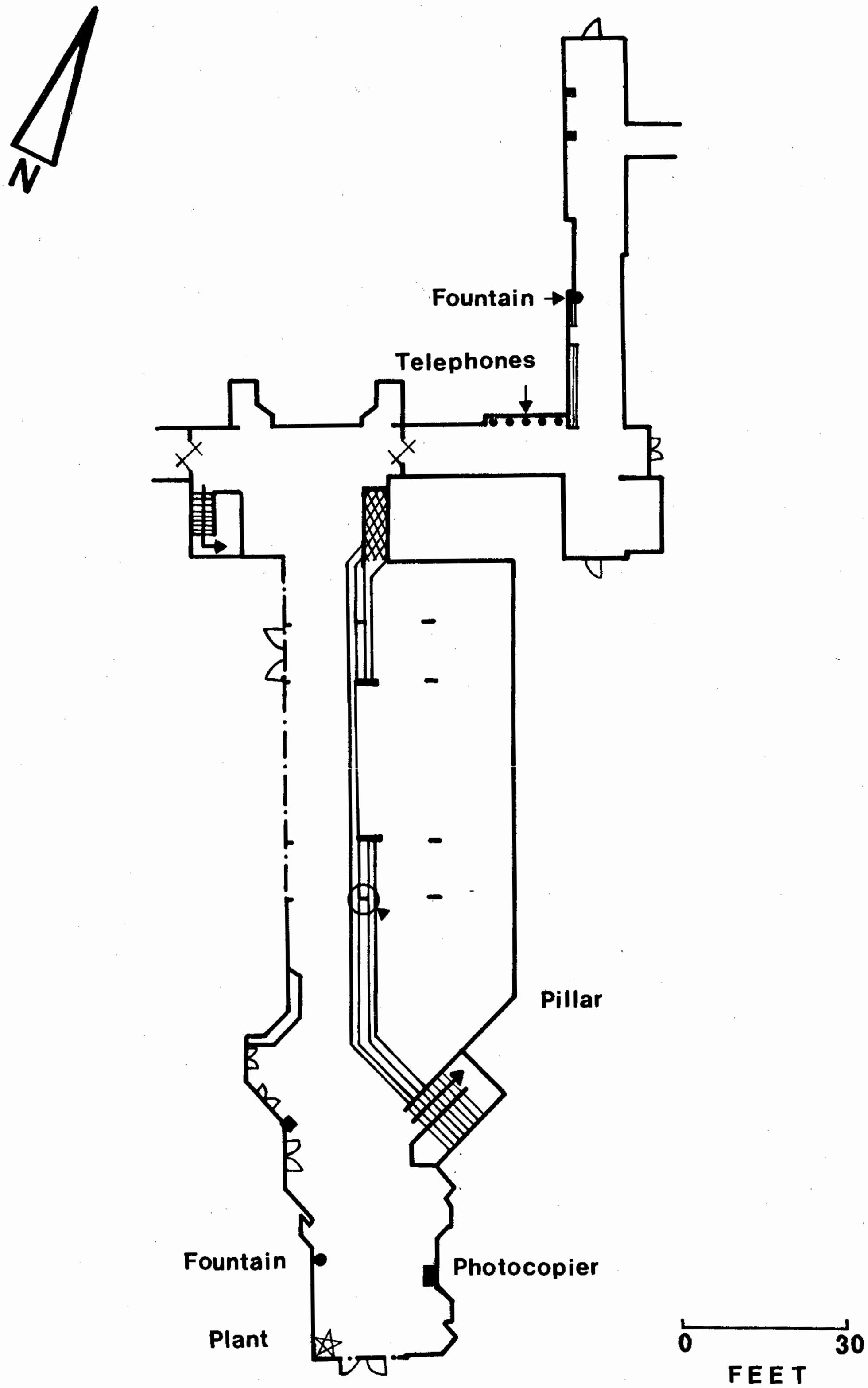

Figure 4.5: Landmarks identified in the Law Building.

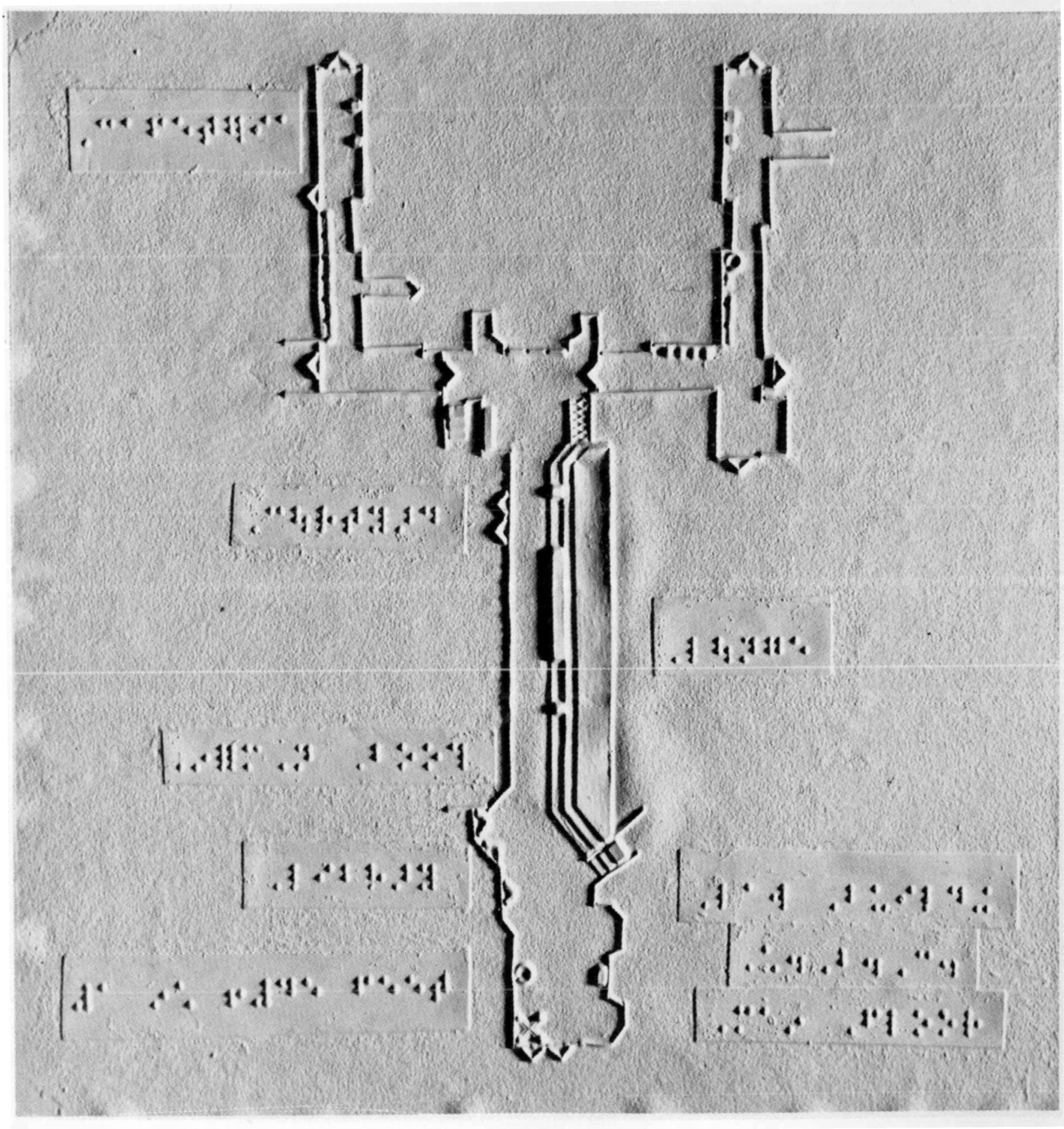

Figure 4.6: Law Building – Fixed-Scale Map.

symbols in consultation with the assistant.[1] Standard symbols established by the working party attending The First European Symposium on Tactual Town Maps For The Blind, Brussels, 1983, were selected for use. [2] The majority of these symbols originated from the Nottingham Kit for the Blind (James and Armstrong, 1976) and have been determined to be both discriminable and legible by the visually impaired. The symbols which were selected as being the most representative of the chosen landmarks appear in Figure 4.7 and 4.8.

Another trip through the environments produced distance judgments and estimates by the visually impaired assistant. This helped to establish and design a map that was representative of the visually impaired person's conception of an environment with relatively uniformly distributed elements and one with relatively clustered elements. The assistant indicated his perceptions of distance between designated points, as well as his overall conceptions of the lengths and layouts of the hallways. Finally, travel times were recorded

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[1] The symbols selected to represent certain elements in the hallways could be used in other contexts, meaning and symbolizing other things.

[2] A large body of literature has dealt with the design of legible tactual symbols. However, to date, no standardization of discriminable symbol sets has been established. This lack of consensus inevitably has stemmed from the individual variations in haptic acuity, along with the several media of tactual map reproduction (Barth, 1983). The objective of this symposium was to adopt a set of symbols to be standardized and used on tactual town maps. The members unanimously agreed to adopt thirty of the suggested thirty-three symbols, many of which were included in the Nottingham Kit for the Blind.

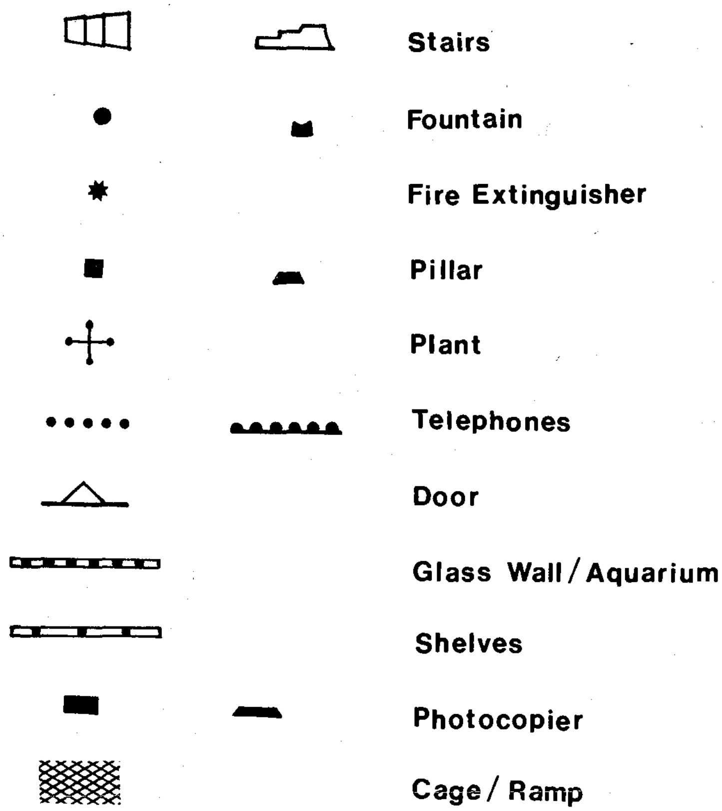

Figure 4.7: Representative symbols of the chosen landmarks.

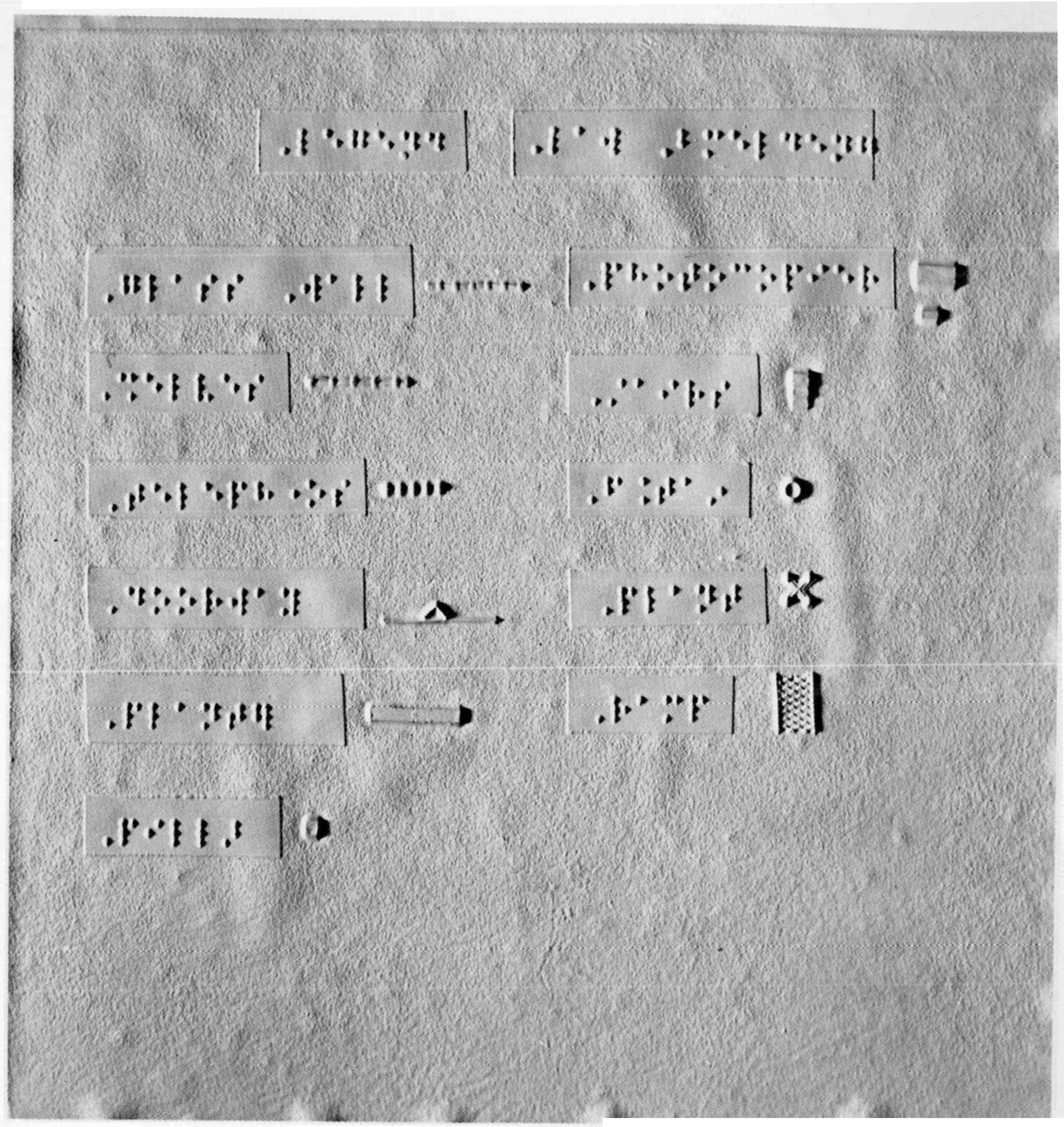

Figure 4.8: Representative Symbols c

between locations en route and for the route as a whole, serving as an additional source of information for map design.

The map image size was restricted to a maximum of 10 by 10 1/2 inches by the use of the Thermoform method of map reproduction. [3] This size is relatively easy to read, since everything in the map is kept within a handspan's distance. One section of the map can be associated quickly with another, without having to rely heavily on memory.

Floor plans drawn to a scale of one inch to thirty feet (1" = 30') provided the bases for the fixed-scale tactual maps. To fully use the available image area, the Scarfe Building map was enlarged to the scale of one inch to forty-five feet (1" = 45') and the Law Building was enlarged to one inch to thirty-five feet (1" = 35').

The final flexible-scale tactual maps were formulated after several attempts to match the visually impaired person's perceptions of the hallways with "mock-up" maps. Taking into consideration the assistant's impressions and preferences, and the results of others' research, the experimenter designed maps that represented the assistant's verbal understanding of the areas. Thus sections that had seemed particularily long or wide were portrayed as such. Emphasis was placed on the portions

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[3] The standard thermoform machine dictates that the sheet to be vacuum formed has the dimensions of 11 by 11 1/2 inches. The maximum image size of any copy is restricted to 10 by 10 1/2 inches, because beyond these boundaries, processing diminishes the resolution.

that were deemed especially difficult or complicated for navigation, such as the entrance to the Law Building. Sections that had been perceived as uncomplicated or uneventful received less attention (James, 1972; Jansson,1983). Figures 4.9 and 4.10 indicate the versions that ultimately became a basis for the final flexible-scale tactual maps. After the maps were produced, the assistant made a last examination for clarity, readability and credibility, while traversing the hallways.

The Thermoform method of production was selected for the production of the maps, because it was compatible with the symbol format chosen by the assistant. At the same time, the author had access to reliable equipment and advice on the thermoforming process. The maps were formed in Brailon plastic, allowing for the portrayal of several symbol heights and textures with adequate resolution and durability. The maps' features were readable and distinct with regards to haptic perception. The maps were attached to a light foam board backing, thereby making them durable, portable and weather-proof.

The 'preview' locations were identified by the author after the test sites had been chosen and mapped. According to the application of the term 'preview' in this study, the sites needed to be similar, yet different in layout and character from the main test sites. The 'preview' sites provided the subjects with an opportunity to familiarize themselves with an exercise and environments in an area similar to the testing

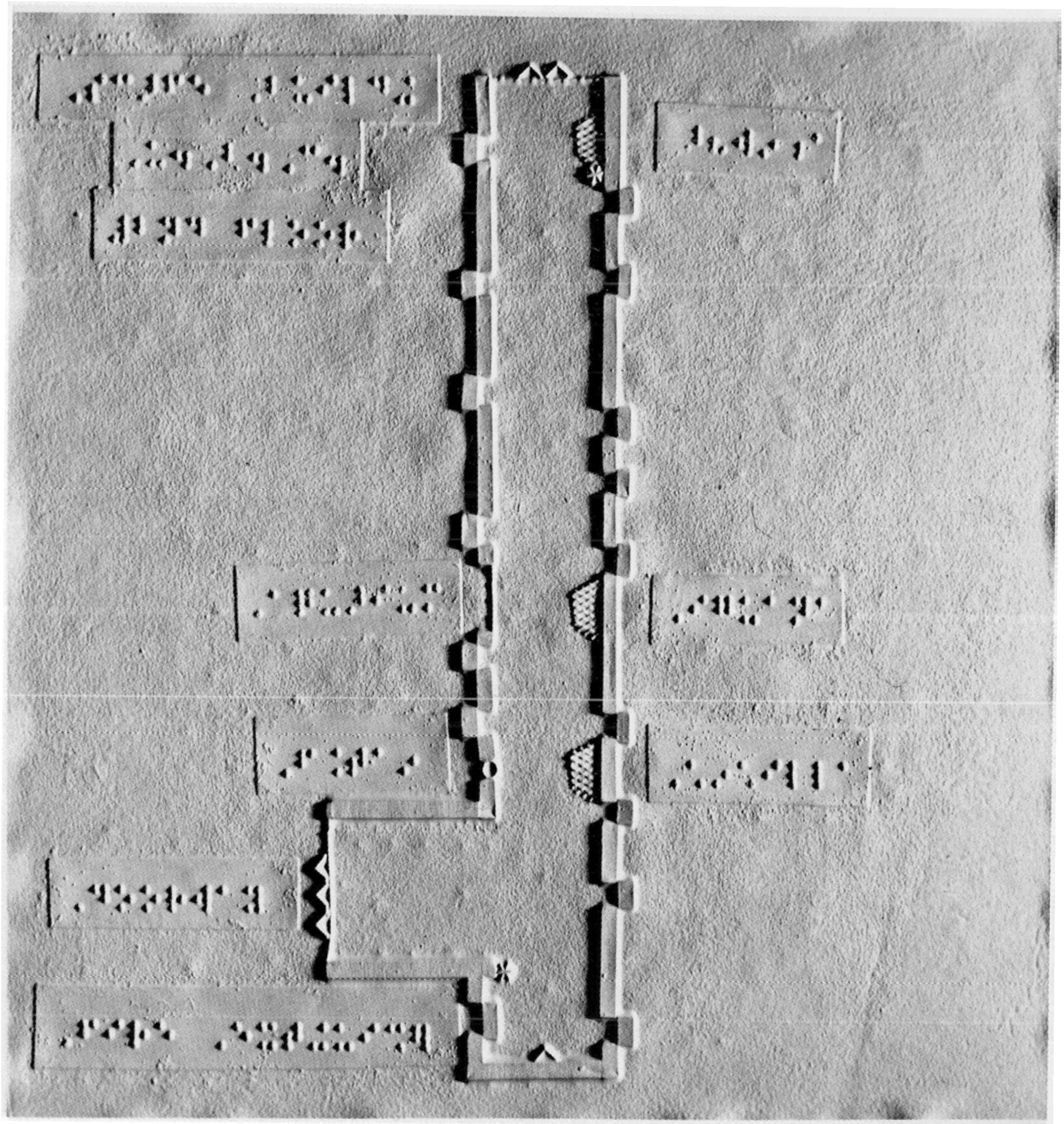


Figure 4.9: Scarfe Building – Flexible–Scale Map.

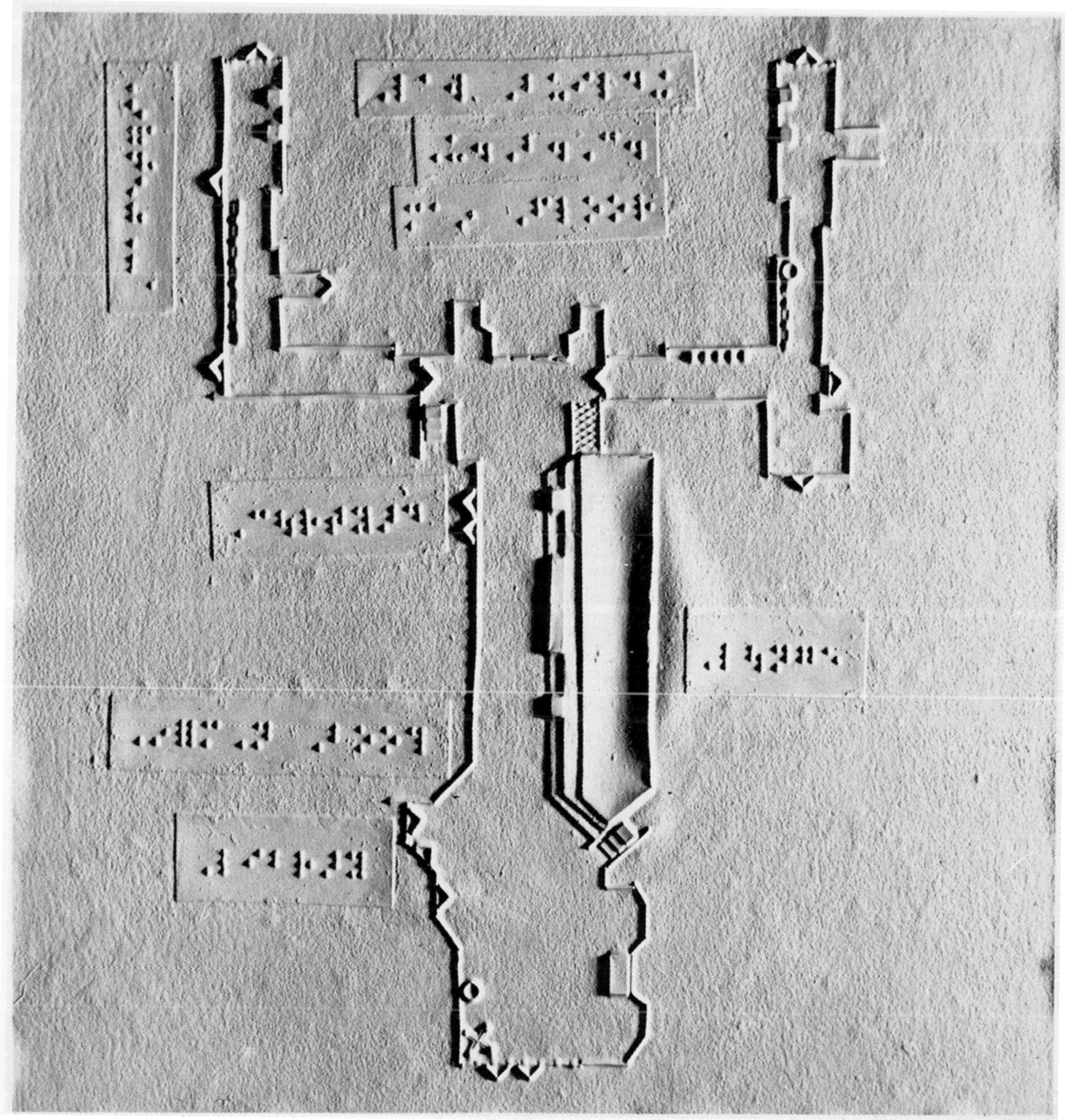


Figure 4.10: Law Building – Flexible-Scale Map.

stages. The 'preview' site for the Scarfe Building Classroom Block test site was the third floor of the same building. It was as uncomplicated and uniform as the test site (Figure 4.11). The Law Building's 'preview' site included the main floor hallway (as did the test site), but incorporated the corridor branching to the left (as opposed to the right-branching corridor of the test site). The 'preview' site layout then was essentially a mirror image of the test site (Figure 4.12). Only verbal explanations were available for these sites.

Research Assumptions

Certain assumptions with respect to the tactual maps, subjects' performances, and data analyses were made for this study. It was assumed that the tactual mobility maps derived from the blind assistant's perspective would be useful and effective for the visually impaired subjects partaking in this study. This was based on the fact that the assistant was congenitally blind and his spatial interpretations had not been influenced by previous visual images. Although the degree of blindness varied from individual to individual, the commonalities found within the group and with the assistant, such as education level and mobility capabilities, indicated that they would be able to work with the maps, irrespective of the fact that the maps might not match each person's spatial perceptions.

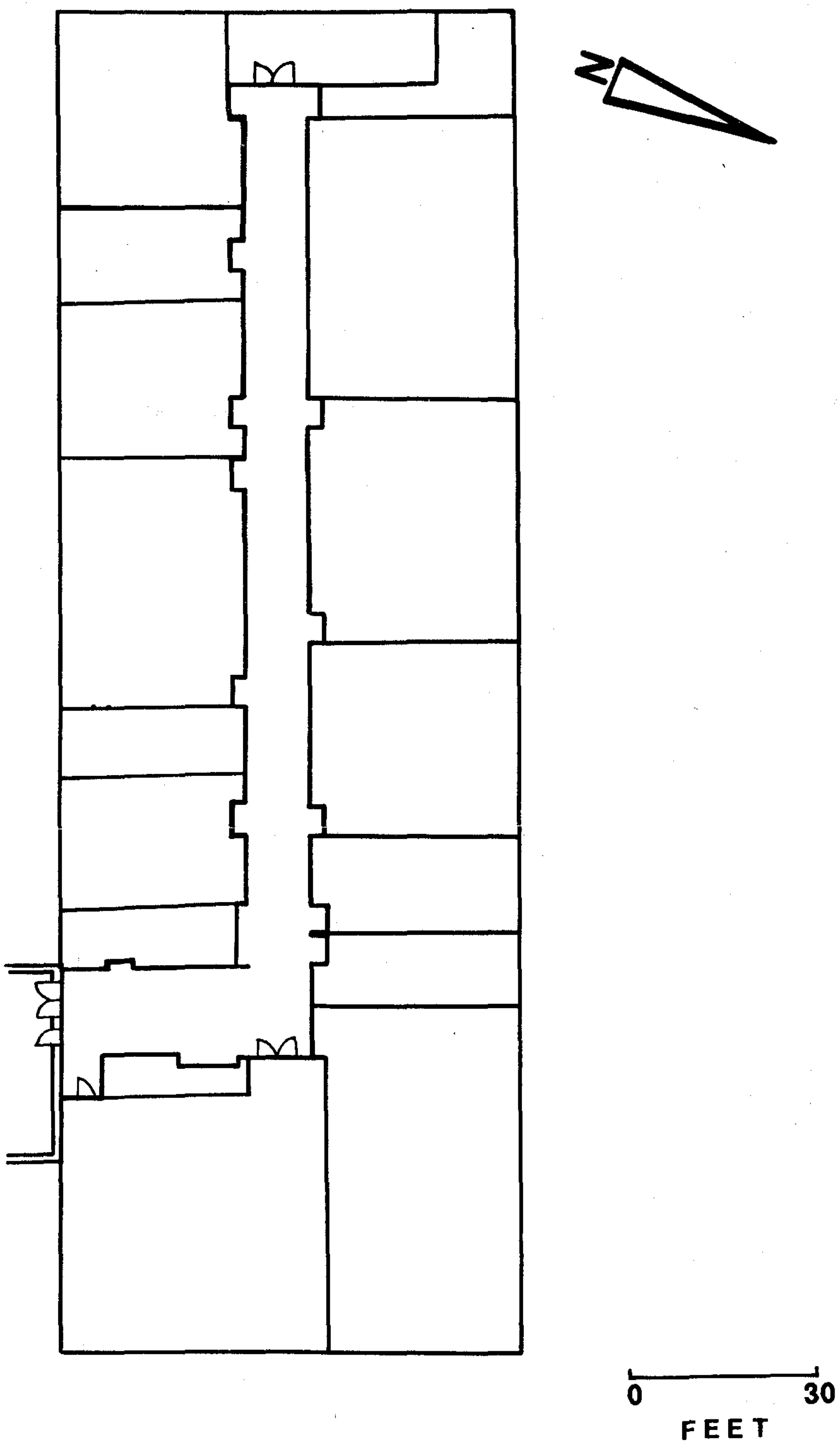


Figure 4.11: Preview Site - Scarfe Building, Third Floor, Classroom Block.

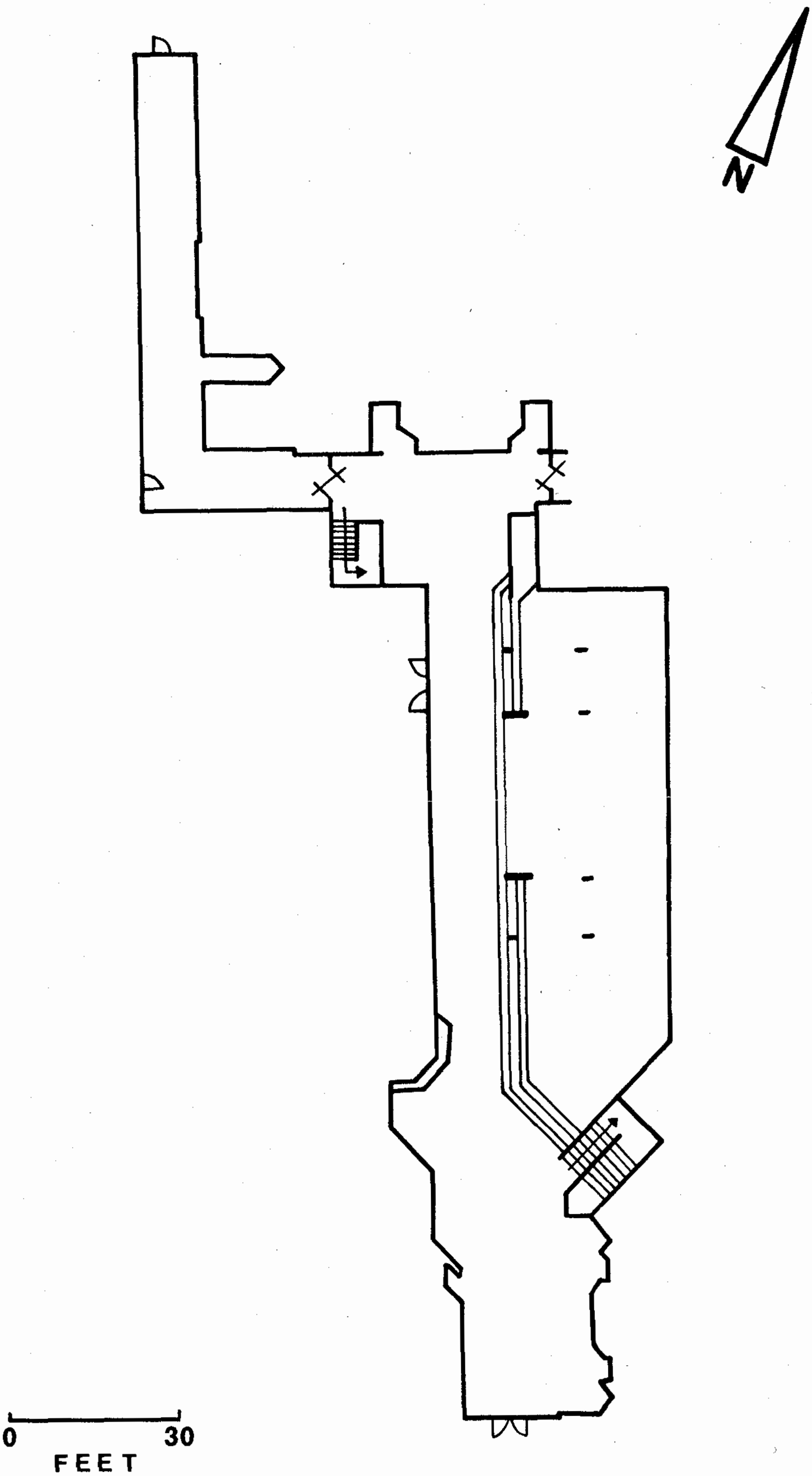


Figure 4.12: Preview Site - Law Building .

With regard to the subjects' performances, it was assumed that there was a negative relationship between the number of navigational errors and the efficiency of travel. Navigational errors would invariably result in more mental and physical demands, resulting in stress and stress-related actions. This in turn would influence the individual's performance and travel efficiency throughout the remainder of the study. Although bypassing a landmark is not nearly as serious or upsetting as permanently losing one's location, both are assumed to affect mobility confidence and proficiency.

Another data analysis was based on the descriptive data presented by the subjects. Their map preferences and opinions are just as important to the conclusions as are the travel time scores. It was imperative to recognize that travel times do not totally reflect individual mobility level, ability to work with a tactual map, or the superiority of a particular map type. Coordinating tactual map reading, ambulatory skills and sometimes a mobility aid requires considerable attention and proficiency. Although a person might be an independent and competent traveller and understand map concepts, difficulties may arise in attempting to combine these tasks. Thus, the subjects' comments offer some insight into their map type preference in relation to gaining knowledge and comprehension of spatial relations.

The statistical model created for this research design incorporated certain assumptions. It is evident that a learning effect resulted from the subjects passing over the same route several times, even though they were working with different map conditions. This increasing familiarity could not be overcome, resulting in certain assumptions being held when interpreting the model. It was assumed that there was no relation between the map condition (flexible-scale map, fixed-scale map, or verbal instructions) and the amount learned. It was also assumed that there was no interaction between the building that the subject learned in and the amount learned. Finally, the amount learned in either building or with any map was assumed not to be affected by the vision status of the subject.

CHAPTER V

RESULTS

Analysis of Speed of Movement

Since, there is an unequal number of male and female subjects in each group, an initial series of t-tests assesses possible sex differences in travel speed. For the visually impaired sample, the values of the t statistic comparing males and females were 0.324 (Scarfe) and 0.0062 (Law). The blindfolded sighted group yielded similar results, with $t = -0.442$ (Scarfe) and $t = 1.265$ (Law). Thus, speed of travel did not vary significantly with sex in either building, for either sample.

A modified repeated measures analysis of variance was used to test the data collected on the times each subject took to complete the map tasks. The design of the analysis encompassed the learning effect problem encountered by the subjects, as they passed through the study sites several times, while using the different map conditions. The dependent variable, time was analyzed. Times for each subject, as he or she progressed from landmark to landmark were collapsed into a "forward" and a "reverse" trip time. These two times were further combined into one total time, on which the analysis was performed. Thus, time was treated as a performance variable of the subjects, as they engaged in the experimental tasks.

Three models were used to examine as many main effects and interactions as possible within the design. Models I and II aggregated the values for the visually impaired and the blindfolded sighted to examine the other variables. Thus individual factors and interactions were examined and evaluated.

Each model varied with respect to the different main effects and interactions that were included. Model I incorporated one main effect for sight, two map type main effects, a building main effect, five main effects for trip number, which examined the effect of learning, and a building by map interaction. Subjects nested in a sight by order condition were also analyzed. Model I utilized 34 parameters and 180 data points. Model II was similar to Model I, except for the incorporation of a trip by building into the data analysis. Thirty-nine parameters and 180 data points were used in this analysis.

Model III was designed to include several more terms. Main effects for sight, trip number, map type and building were examined. The two factor interactions of sight by map, sight by building, and building by map, along with a three-way interaction of sight by map by building were integrated into the data analysis. Subject effects nested in a sight by order interaction were also treated. This model was similar to Model II in that 39 parameters and 180 data points were analyzed.

Caution must be applied in the interpretation of the results of the data analysis, for three reasons. The first is the extensive variability in the trip times taken by the thirty subjects. Secondly, the small sample size did not allow for definitive statements to be made. Thirdly, as more parameters were fitted into the model, difficulties arose in the ability of the F statistic to detect sensitive significance values. Such was the case when the analysis of the principal null hypothesis was interpreted. The model was designed to investigate the null hypothesis that there was no significant difference between using the flexible-scale tactual map and the fixed-scale tactual map in environments with relatively uniform element distribution (the Scarfe Building) and in environments with relatively clustered elements (the Law Building). The results of the analysis for the map effect were $F = 1.9706$ ($p = 0.1020$) at 4 and 146 degrees of freedom and $F = 2.0017$ ($p = 0.0975$) at 4 and 144 degrees of freedom for Models I and II, respectively. Although the difference between the two outcomes is not great, in both cases, the results are judged to be non-significant.

Further examination of the estimated map effects lent support for the flexible-scale map in comparison with the fixed-scale. Parametrized for map effects, the model tested the use of the different maps in the two buildings. The subjects were treated as one group. The cost of using a map in the study sites was assessed. Estimates of the fixed-scale/no map (verbal) contrast were examined. In other words, the difference between the mean time taken with the fixed-scale map and the mean time taken with the verbal instructions was assessed. A similar analysis was conducted to examine estimates of the flexible-scale/fixed-scale map contrast. Thus, the extent to which the flexible-scale map resulted in improved performance was examined. Table 5.1 presents the results of the analyses for Models I and II.

The estimates in Table 5.1 show that the use of the fixed-scale map slowed subjects down, by comparison with the no-map condition in both buildings. Only in the Law Building was the result statistically significant ($p = 0.0081$ for Model I Analysis, $p = .0101$ for Model II Analysis). The differences in the Scarfe Building were not detected as statistically significant, due to the large subject to subject variability.

An examination of the best estimates of using a flexible-scale map in the two buildings revealed an 8.1 second and 14.7 second difference between the average time taken for the flexible-scale map and the average time taken with the fixed-scale map. Although the p values were not statistically significant, the negative estimates suggested that the flexible-scale map benefitted the subject more in terms of speed of movement than did the fixed-scale map.

A difference between using the flexible-scale map and the no-map condition in the Scarfe Building was evident from the

Table 5.1: Summary of the main effects, Models I and II.

	Mean Differences (seconds)	S.E. of Differences (seconds)	t	Probability $p < 0.05$
MODEL I				
Cost of Using A Map				
Fix-Map vs. No-Map Scarfe	34.833	40.048	.87102	.3852
Fix-Map vs. No-Map Law	107.44	40.048	2.6827	.0081
Flexible-Scale Map Improvement				
Flexible-Map vs. Fix-Map Scarfe	-8.1061	40.048	-.20241	.8399
Flexible-Map vs. Fix-Map Law	-31.326	40.048	-.78821	.4354
MODEL II				
Cost of Using A Map				
Fix-Map vs. No-Map Scarfe	30.425	42.910	.70904	.4795
Fix-Map vs. No-Map Law	111.89	42.910	2.6076	.0101
Flexible-Scale Map Improvement				
Flexible-Map vs. Fix-Map Scarfe	-14.672	42.910	-.34193	.7329
Flexible-Map vs. Fix Map Law	-24.760	42.910	-.57701	.5649

calculated times of 26.7 seconds and 15.7 seconds in Models I and II Analyses, respectively. In the Law Building, the times of 76.1 seconds (Model I Analysis) and 87.1 seconds (Model II Analysis) were detected as the difference between the flexible-scale map and the no-map condition. Thus, the flexible-scale map tended to slow travel rate, when compared to relying on the verbal directions.

A significant building effect was determined in both Models I and II Analyses. The average times for all the subjects were significantly less through the Scarfe than through the Law, as indicated by Table 5.2. The coefficients represent the mean trip times through the buildings, using the sum of "forward" and "reverse" for each subject. These means provide the baseline to which other coefficients in the model form corrections. The mean times are thus, an estimate of average time on the first trip through either of the building sites without a map.

Each subject completed six test trips, three through each of the study sites. As indicated by Table 3.1, subjects were allocated to one of four orders. The sequence in which the orders tested the maps in the different buildings varied. The trip by building interaction was examined in Model II to determine the effect of performing a particular trip in a specific sequence. Trip effects indicated how much faster a trip was after adjusting for the different maps used on different trips made in different buildings. Thus the estimates

Table 5.2: Summary of Building Effects, Models I and II.

	Mean Trip Time (seconds)	Std. Error (seconds)	t	Significance $p < 0.05$
MODEL I				
Scarfe	415.41	35.977	11.546	.0000
Law	709.80	35.977	19.729	.0000
MODEL II				
Scarfe	406.07	43.627	9.3077	.0000
Law	719.13	43.627	16.484	.0000

were essentially estimates of improvements due to learning by repeated exposure to the sites. Trip numbers 2, 3, 5, and 6 were significantly faster than the first trip. However, Trip 4 was not judged to be significantly faster than Trip 1 with p values of 0.5335 and 0.8991 for Scarfe and Law, respectively (Table 5.3). This different relationship was the result of the testing sequence, as subjects in Trip 4 always encountered a new building site, along with a new map condition. As indicated by Table 3.1, subjects allotted to Orders 1 and 3 were encountering the Law Building for the first time, and those in Order 2 and 4 were new to the Scarfe Building. Overall, the trip number effects themselves were marginally significant after having allowed for the different map types. However, the trip by building interaction was not statistically significant. Therefore, Model II Analysis did not provide a significant improvement over Model I Analysis. The conclusion that Model II Analysis was essentially no different from Model I Analysis can be drawn.

The effect of sightedness was examined with respect to the time it took each individual to complete the map tests. A significant difference between the visually impaired and the blindfolded sighted was found ($t = -7.3277$; $p = 0.0000$). The coefficient of -80.051 was a correction term for the visually impaired subjects; thus the visually impaired persons were 80 seconds faster than the average of all the subjects through both buildings. The blindfolded sighted were 80 seconds slower

Table 5.3: Summary of Trip by Building Interaction, Model II

	Improvement Over Trip 1 (seconds)	Std. Error (seconds)	t	Significance
SCARFE				
Trip 2	-33.780[1]	56.711	-.59565	.5524
Trip 3	-52.051	56.711	-.91784	.3603
Trip 4	-35.715	57.214	-.62423	.5335
Trip 5	-82.538	56.131	-1.4705	.1437
Trip 6	-117.00	52.515	-2.2279	.0275
LAW				
Trip 2	-133.82	56.711	-2.3597	.0197
Trip 3	-137.27	56.711	-2.4208	.0168
Trip 4	-7.2681	57.214	-.12703	.8891
Trip 5	-89.989	56.131	-1.6032	.1111
Trip 6	-126.67	52.515	-2.4120	.0172

[1]A negative sign denotes reduced travel time, or improved performance.

than the average time, yielding a significant difference of 160 seconds between the visually impaired and the sighted blindfolded subjects.

Individual subjects' performances were coded and examined within their respective orders. Each subect's time to complete all the map condition tests was compared to the average of the order. It was evident from the analysis of the times that variability among the subjects was extensive, although not always significant within the specific orders themselves.

Model III Analysis tested three hypotheses regarding the different map effects. The first test was designed to investigate the hypothesis of no significant difference in the interaction effect of sightedness and map versus no-map condition in the two environments. The null hypothesis could not be rejected ($F = 1.1635$; $p = .3254$), and no interaction effect was detected.

A further examination of the first eight variables revealed some interesting results on the use of maps in buildings (Table 5.4). The blindfolded sighted using a fixed-scale map in the Scarfe Building were on average 19.1 seconds slower than when relying on verbal directions. However, this was not a statistically significant difference. On the other hand, in the Law Building their speed of travel was slowed by a significant 113 seconds ($p = 0.0509$). When used in the Scarfe Building, the flexible-scale map also slowed the sighted blindfolded

Table 5.4: Summary of Interaction Effects, Model III.

	Difference (seconds)	Std. Error (seconds)	t	Significance
BLINDFOLDED SIGHTED				
Effect of Using A Fixed-Scale Map				
Fix-Map vs. No-Map Scarfe	19.104	57.558	.33191	.7404
Fix-Map vs No-Map Law	113.35	57.558	1.9694	.0509
Corrections to Fixed-Scale Map Times				
Flexible-Map vs. Fix-Map Scarfe	2.8862	57.558	.50143 -1	.9601
Flexible-Map vs. Fix-Map Law	-9.2805	57.558	-.16124	.8721
VISUALLY IMPAIRED				
Effect of Using A Fix-Scale Map				
Fix-Map vs. No-Map Scarfe	45.426	47.810	.95013	.3437
Fix-Map vs. No-Map Law	103.52	47.810	2.1651	.0321
Corrections to Fixed-Scale Map Times				
Flexible-Map vs. Fix-Map Scarfe	-15.516	47.810	-.32454	.7460
Flexible-Map vs. Fix-Map Law	-15.516	47.810	-.96433	.3365

subjects. The saving of 22 seconds in comparison to the fixed-scale map was not significant. In the Law Building, the use of the flexible-scale map resulted in a 9 second improvement over the use of the fixed-scale map, although this difference was not significant.

The visually impaired were also slowed by the use of the fixed-scale map in both buildings, as compared to working with verbal instructions. In Scarfe, they were slower by a non-significant 45 seconds and in the Law Building they were on average 103 seconds slower ($p = 0.0321$). Both of the results related to the use of the flexible-scale map indicated an improvement over the fixed-scale map, although not a significant one. In the Scarfe Building, there was a 15 second improvement and in the Law Building, a 4.6 second improvement.

To examine whether or not the visually impaired differed from the blindfolded sighted in the amount of time it took them to pass through a study site, the building by sight interaction was examined in Model III. The resulting coefficients estimate the average time of the first trip through a building assuming a no-map condition. In both cases, the visually impaired were significantly faster than the blindfolded sighted ($p = .0000$). In Scarfe, the average time was 367.40 seconds for the visually impaired subjects, as opposed to 447.09 seconds for the blindfolded sighted. In the Law Building, the average times were 600.43 and 833.53 seconds for the visually impaired and blindfolded sighted respectively.

In addition to examining individual coefficients, the models were used to generate F tests of the overall hypothesis that flexible-scale maps were no different than fixed-scale maps in any building by sight condition. The resulting F statistic (0.25276; p = 0.9076) at 4 and 141 degrees of freedom did not allow the hypothesis to be rejected; the flexible-scale map did not significantly improve the subjects' mobility in comparison to the fixed-scale map.

A final analysis evaluated whether any map (flexible-scale or fixed-scale) in either building was no different than working without a map for both subject groups. Again, the appropriate overall F statistic proved to be not quite significant (F = 2.1180; p = 0.0815). Nevertheless, in the Law Building, the effect was pronounced (p = .0291). In both building and sight conditions, the map estimates indicated that subjects were slowed down by map use. Thus, Model III Analysis confirmed the conclusions of Models I and II Analyses regarding the sight effect.

To assess the assumed normality of errors within the regression, a Scatter Plot, a Probability Plot, and an Histogram were drawn of the residuals. The Probability Plot (Figure 5.1) suggested that the model applied to the data was adequate. A correlation coefficient of .9940, resulting from the Probability Plot led to a test of error normality using a formal hypothesis testing procedure. A p value of 0.111 was obtained (Stephens and D'Agostino, 1986). As, the residuals are

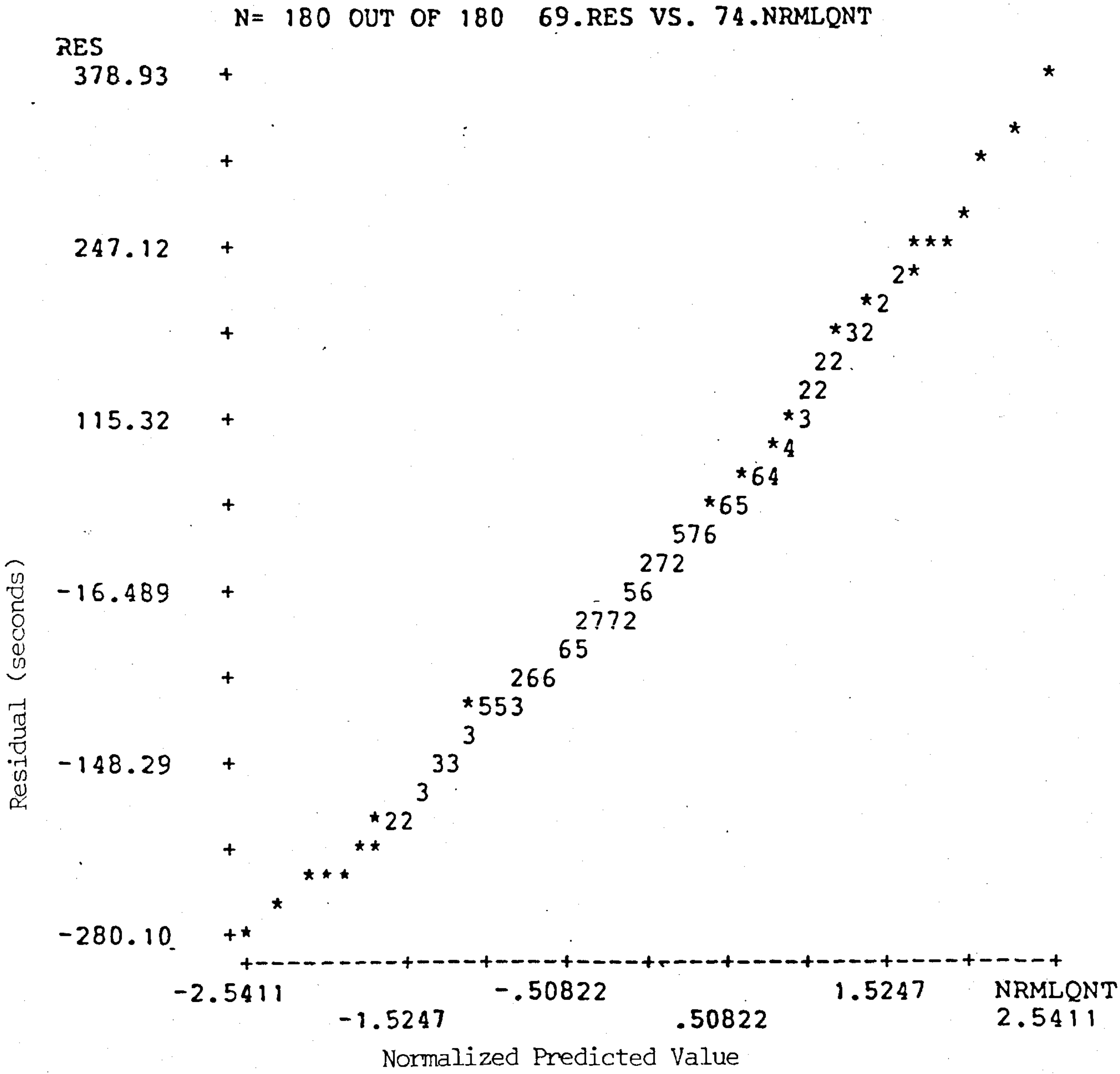


Figure 5.1: Normal Probability Plot of residuals (in seconds) about normalized predicated values in Model III.

acceptably normal in appearance, the decision was made not to consider transformation (such as log transformation) of the times.

In summary, the three models yield the following conclusions. First, the visually impaired are significantly faster than the blindfolded sighted. Second, the use of a map slows both blindfolded sighted and visually impaired subjects, although the difference is only marginally significant. Third, the flexible-scale map gives somewhat faster travel times than the fixed-scale map, though the difference is far from statistical significance. Fourth, there is a highly significant learning effect. The learning appears to be primarily due to exposure to the buildings, rather than to practice with the maps. Support for this conclusion comes from the fact that the average Trip 4 times were not very different from the average Trip 1 in the same building. Thus, whether or not the subject had already experienced working with maps, the first trip in each building was consistently slower.

Analysis of the Errors

Error, defined as the failure of an individual to locate a specified landmark in the environment provided another means of examining the performance of a subject while testing a particular map condition. Each subject identified six landmarks in each site, in each of the map conditions. Table 5.5

indicates the frequency with which the landmarks were missed by the participants in each of the hallways.

The primary null hypothesis is that there would be no difference in the number of errors made by a visually impaired person using a tactual map and those relying only on verbal guidance instructions. The observed and theoretical distributions were compared using the Chi-Square test. At a 0.05 level of significance and with one degree of freedom, the calculated Chi-Square value of 12.082 allowed rejection of the null hypothesis, suggesting a difference between the map and the no-map conditions. The tactual map did seem to affect the performance of the visually impaired subjects with respect to missed landmarks. Unfortunately, the effect was to increase the number of errors. A further test was performed to examine the possible difference between the flexible-scale map and the fixed-scale map. The observed frequencies were identical, yielding a non-significant Chi-Square of 0.

A third hypothesis, relating specifically to the environment with relatively uniform element distribution was examined. It was hypothesized that in such an environment, the number of errors made by a visually impaired person would be the same, whether using a fixed-scale map or a flexible-scale map. The Chi-Square value of 0.888 suggests no difference between the map conditions.

Table 5.5: The Number of Errors Made or Landmarks Missed by the Thirty Visually Impaired Subjects.

SCARFE BUILDING

Landmarks	Flexible-Scale Map	Fixed-Scale Map	No-Map Condition
Fountain	5	0	3
Iguana	1	2	2
Extinguisher	2	2	0
Chinchilla	1	2	0
Aquarium	1	0	0
Birds	1	1	0
Total	11	7	5

LAW BUILDING

Landmarks	Flexible-Scale Map	Fixed-Scale Map	No-Map Condition
Photocopier	2	1	0
Telephones	0	3	0
2nd Pillar	6	6	2
Plant	0	2	0
Fountain (1)	4	7	5
Fountain (2)	10	7	2
Total	22	26	9

The final test analyzed the null hypothesis that in an environment with relatively clustered elements, a visually impaired person using a flexible-scale map would make fewer errors than operating with a fixed-scale map. Again the Chi-Square of 0.332 led to a conclusion of no difference.

<u>Map Type Preferences</u>

In an attempt to gain further knowledge of the subjects' understanding of the tactual maps, map preference data were examined. Although considered valuable data sources, the travel times did not completely reflect the participants' abilities to work with the maps or their preference for a map type. Thus, the preference data were analyzed using Chi-Square and the Fisher Exact Probability Tests. Table 5.6 summarizes the subjects' map type preference for both study sites.

Separate Chi-Square tests were used to examine the hypotheses that for the Scarfe Building, or the Law Building the three preference outcomes were equally likely. For the Scarfe Building, a Chi-Square value of 10.4 was obtained. With two degrees of freedom, this is significant at the 0.01 level of significance. Similar results were obtained for the Law Building, (Chi-Square = 11.4, p = 0.01). Thus, for each building, a preferred map type(s) existed.

The Fisher Exact Probability Test was used to compare the visually impaired and the blindfolded sighted in the preference

Table 5.6: Preference Expressed for a Tactual Map Condition. Responses to the question: "Of the maps that you have used, which map do you prefer?

	Prefer Fixed-Scale Map	Prefer Flexible-Scale Map	No Preference Expressed
SCARFE			
Visually Impaired	0	9	9
Blindfolded Sighted	2	7	3
LAW			
Visually Impaired	3	10	5
Blindfolded Sighted	0	8	4

for either of two map types, combining both environments. No difference was found (p = 0.3637). A similar test compared preference for the fixed-scale map and the lack of preference for any map. Again, no difference was found (p = 0.3721).

Comparing the two groups' preferences for a fixed- or flexible-scale maps in the Scarfe Building failed to demonstrate a difference (p = 0.2353). A second comparison (preference for a fixed-scale map versus no preference) also displayed no difference (p = 0.1098). Thus, the Fisher Tests revealed that the visually impaired and the blindfolded sighted did not differ in their map type preference in Scarfe.

The Fisher Test was applied to the same comparisons for maps used in the Law Building. Once again, no significant results arose from the tests. The visually impaired and the blindfolded sighted did not differ in their preference for the flexible-scale map or the fixed-scale map (p = .2150), or when comparing preferences for fixed-scale to no preference for either (p = 0.2545). Thus, the visually impaired and the blindfolded sighted operating with different maps in the Law Building did not differ in their map type preference.

Since they did not differ, a final analysis involved combining the two subject groups. The Fisher Test was applied to investigate the null hypothesis that there was no significant difference between the two buildings in subject preference for the flexible-scale map or the fixed-scale map. A significant p of 0.0176 was obtained, demonstrating differences in the subjects' preference for a particular map type between the two environments.

A similar test involved a comparison of preference for a fixed-scale map and the lack of preference for any map between the two sites. No difference was found ($p = 0.3043$).

While the analyses yielded non-significant results, the differences are consistent with a subject preference for the flexible-scale map in comparison to the fixed-scale map.

The Effect of Preview

The "forward" and "reverse" map condition times had been combined, yielding three total times for each individual. First, comparisons were performed on these total times. Mean travel times for the four orders appear in Figures 5.2, 5.3, 5.4, and 5.5. Due to the fact that all participants were involved in testing each of the conditions (although in different sequences), a baseline against which their movement in the map condition could be compared was provided by a preliminary walk through a similar environment. Two 'preview' times (taken from the point of departure to the destination and in reverse) were combined into a total time for each subject in each building.

Figure 5.3: Mean Travel Times for the Four Orders in Scarfe – Blindfolded Sighted

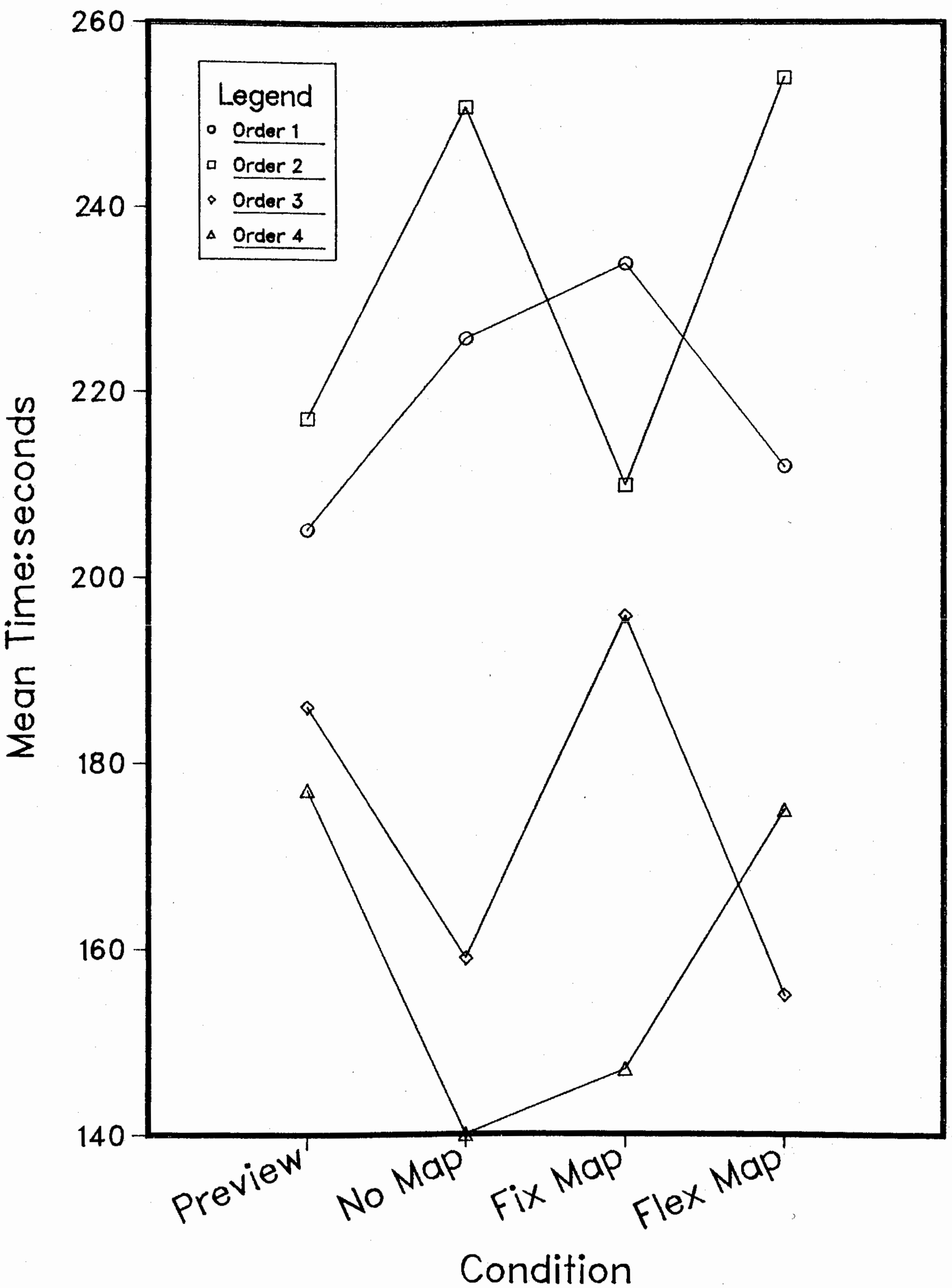


Figure 5.2: Mean Travel Times for the Four Orders in Scarfe – Visually Impaired

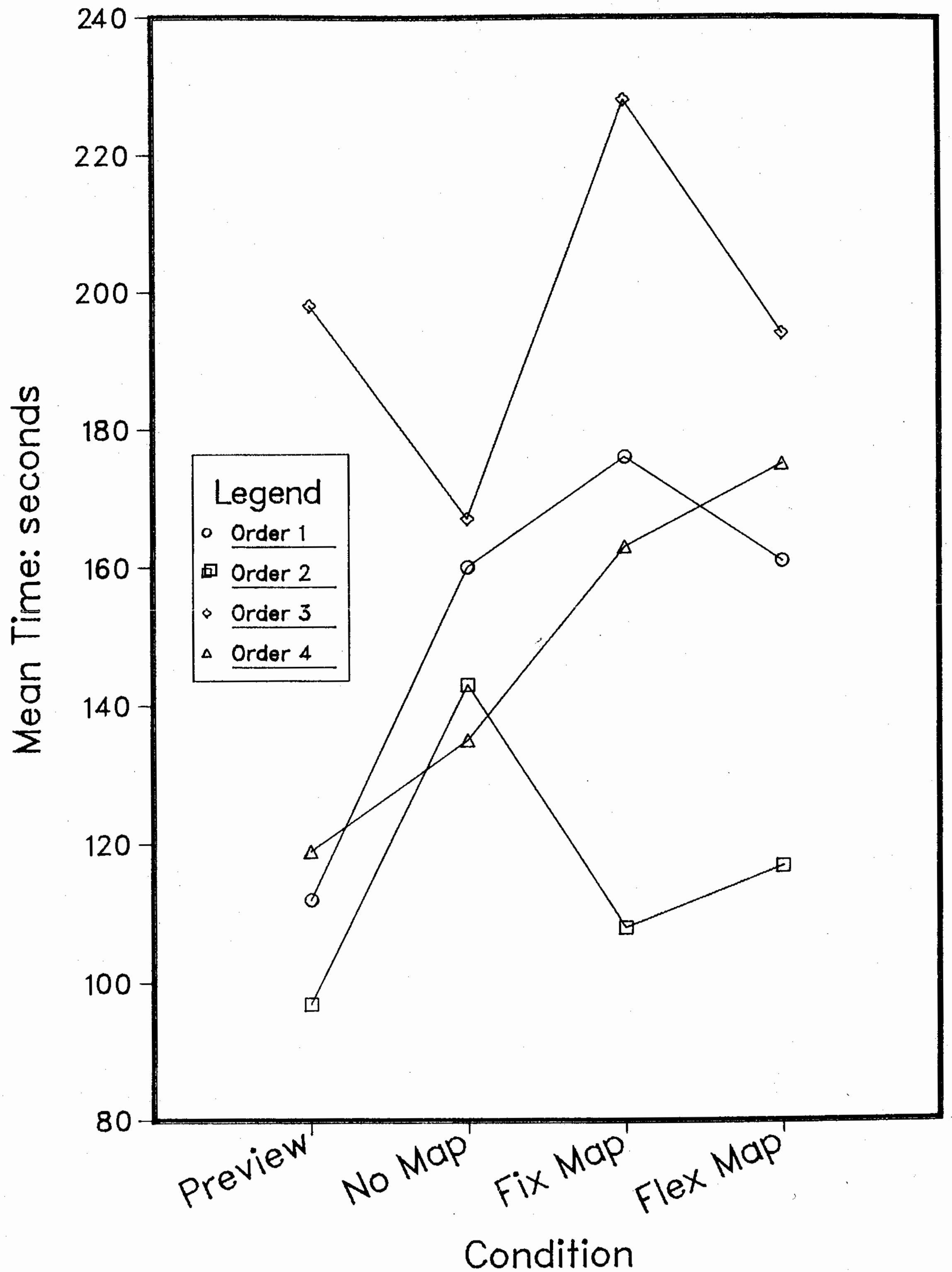


Figure 5.4: Mean Travel Times for the Four Orders in Law – Visually Impaired

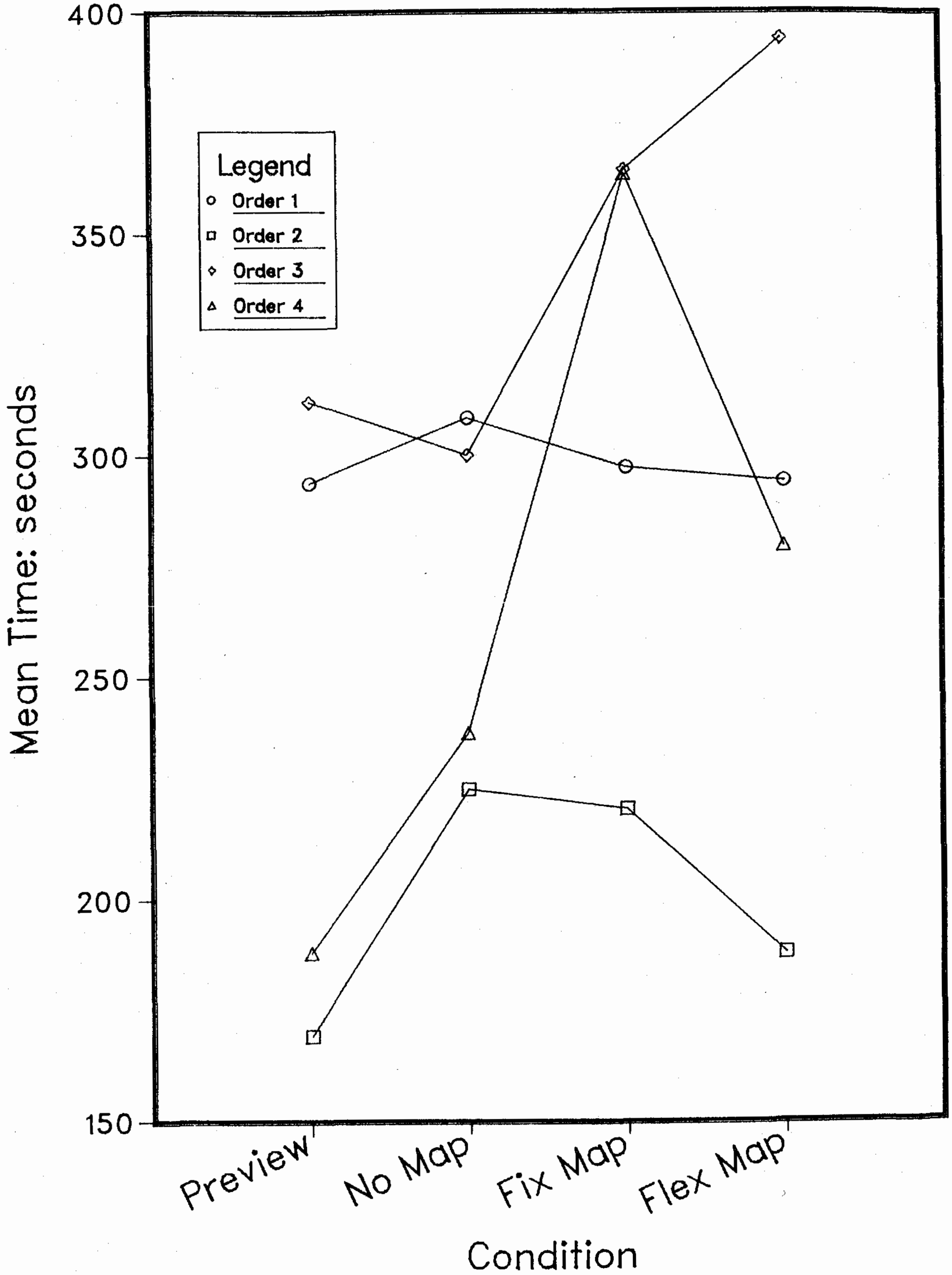
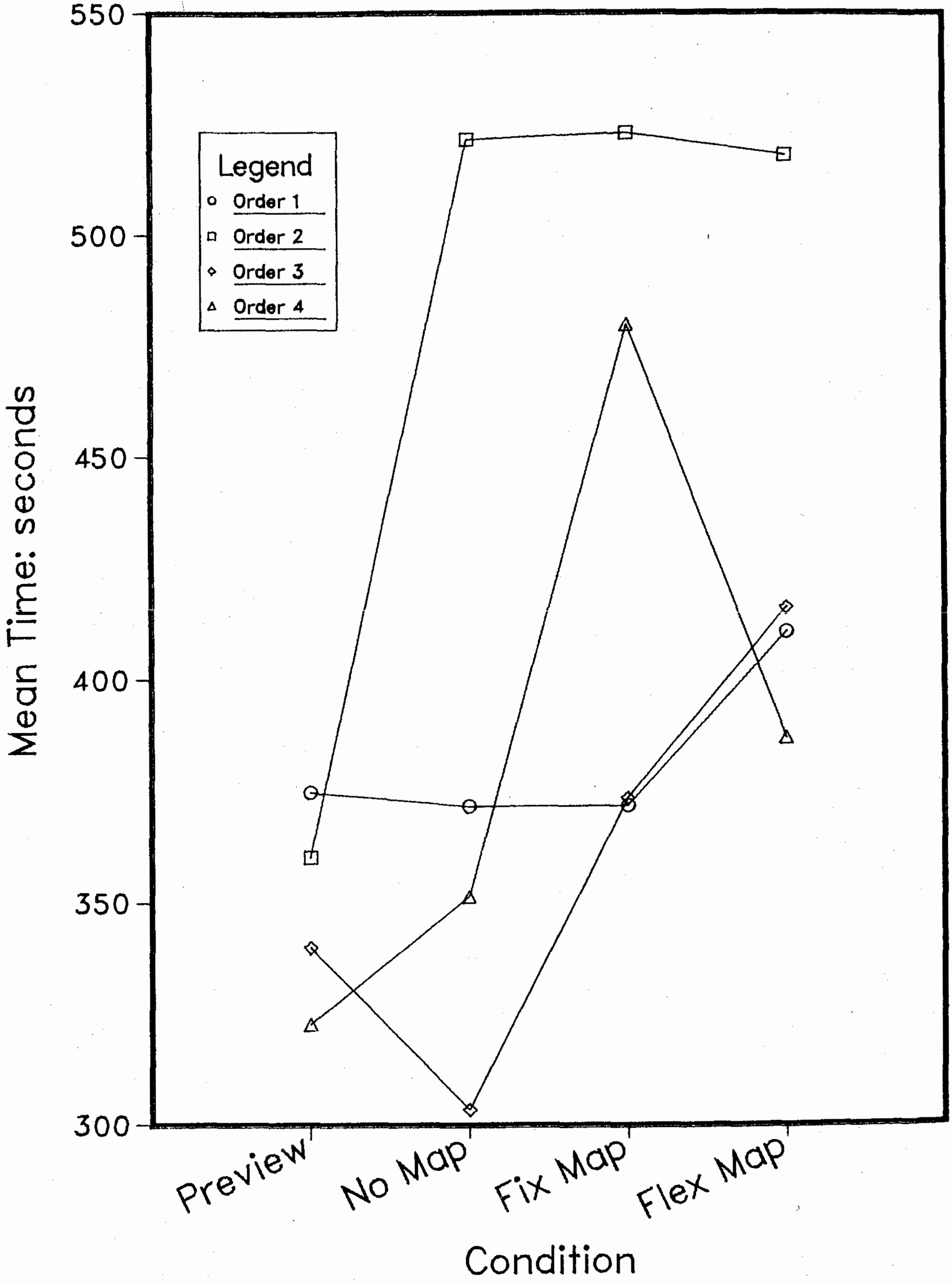


Figure 5.5: Mean Travel Times for the Four Orders in Law – Blindfolded Sighted



To minimize inappropriate error variances of the individual travel times, each individual's total time for each map condition was subtracted from his or her 'preview' time. By making these adjustments, the author was able to partly compensate for extensive variation in subjects' baseline speeds.

Following this baseline adjustment, four total mean times and standard deviations were again calculated for all the subjects, and for orders (refer to Table 3.1 for the map test sequence of each order). The two subject groups and the two buildings were separated, and graphs of all the compilations were drawn, allowing for a clear visual comparison of performance values and rates.

A comparison of the unadjusted (Figures 5.2, 5.3, and 5.4, 5.5) and adjusted (Figures 5.6, 5.7, and 5.8, 5.9) mean times reveals few changes in the ordering of the various groups. The patterns remain very similar in all cases, in both the Scarfe and the Law Buildings, while variability about most means shrank with the adjustment. Therefore, the following analyses focus primarily on the adjusted mean time values.

Figure 5.10 depicts the differences between the visually impaired and the blindfolded sighted in the Scarfe Building, combining all orders. It is evident that order effects and the individual learning effects are not easily separable. While, the graph does indicate that the visually impaired were slower

Figure 5.6: Adjusted Mean Travel Times for the Four Orders in Scarfe – Visually Impaired

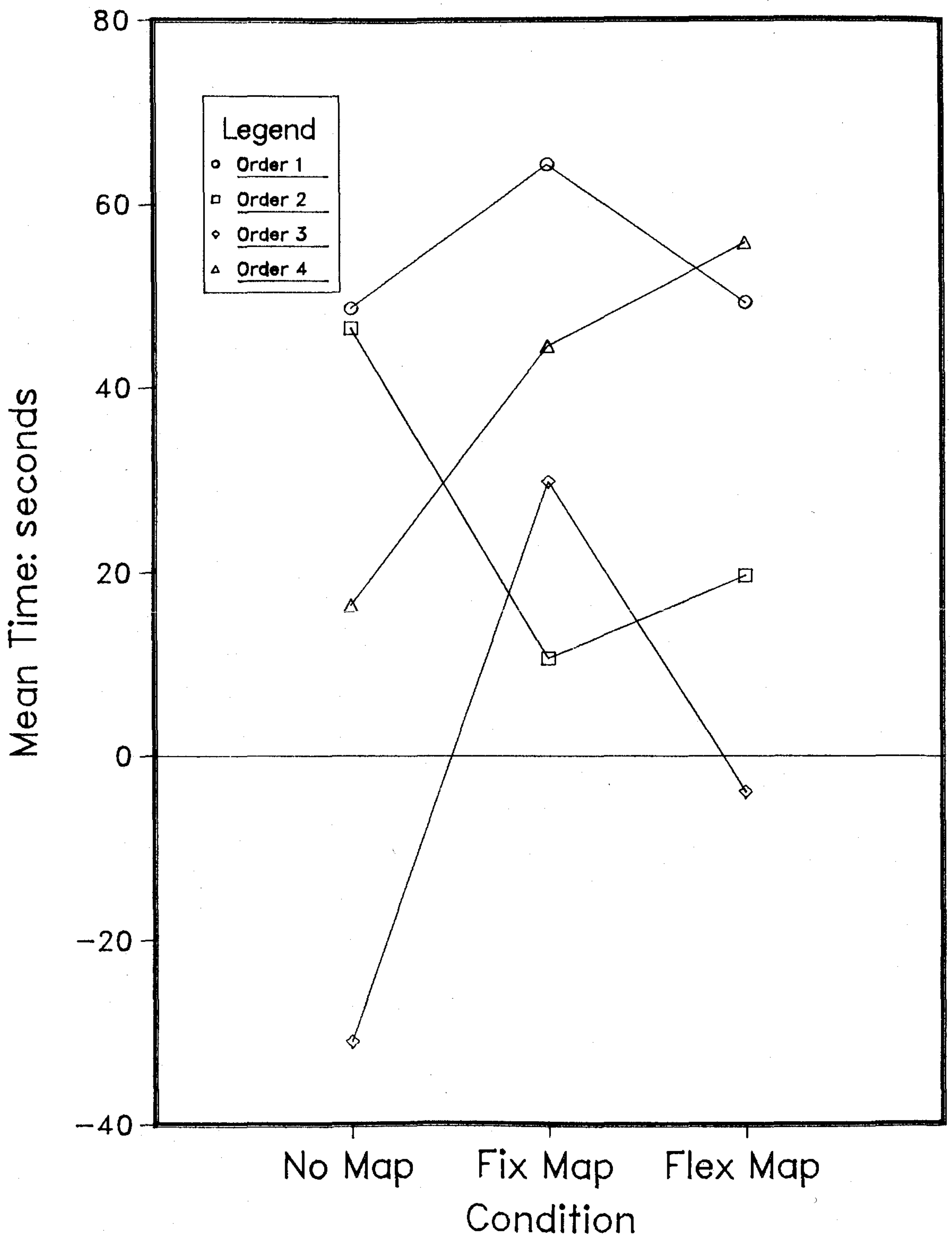


Figure 5.7: Adjusted Mean Travel Times for the Four Orders in Scarfe – Blindfolded Sighted

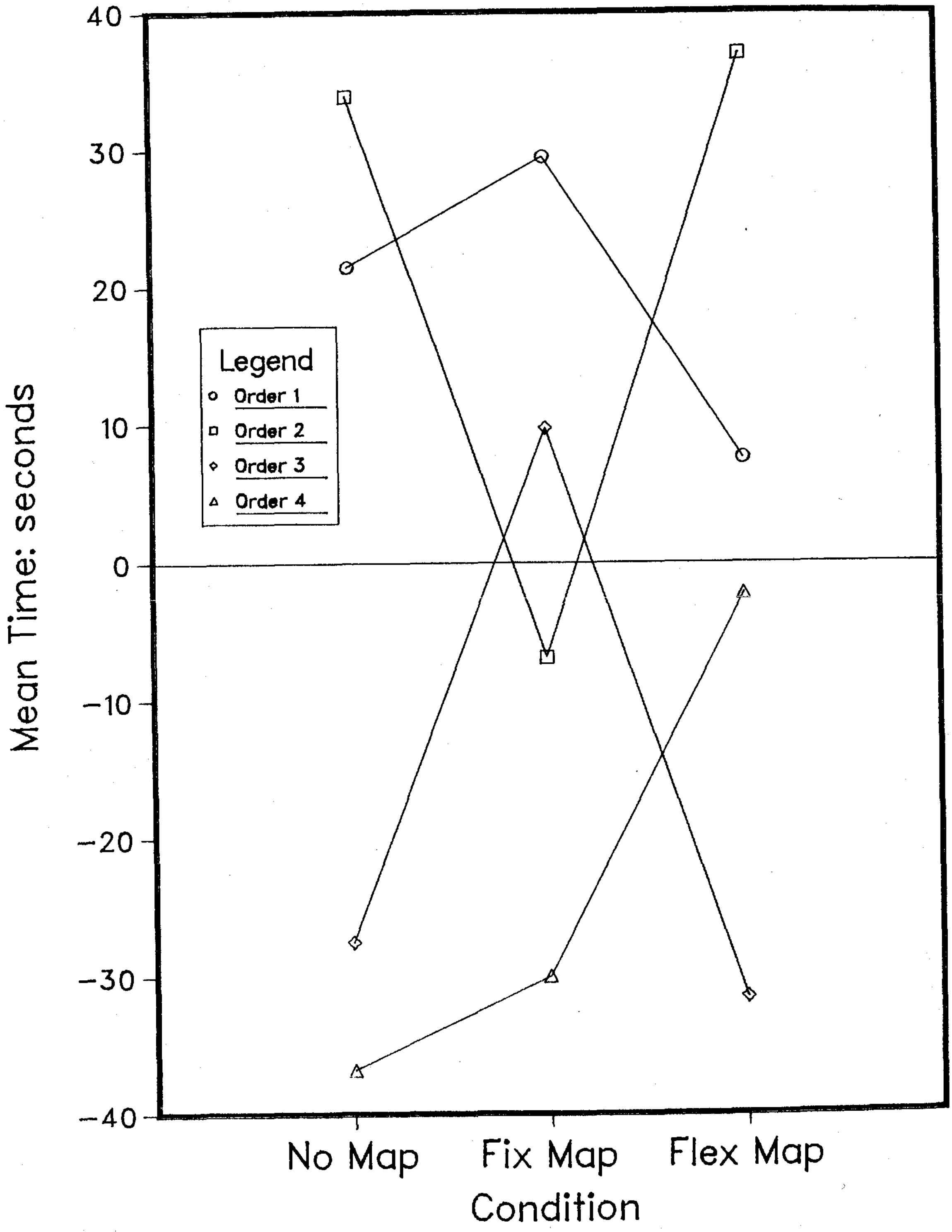


Figure 5.8: Adjusted Mean Travel Times for the Four Orders in Law – Visually Impaired

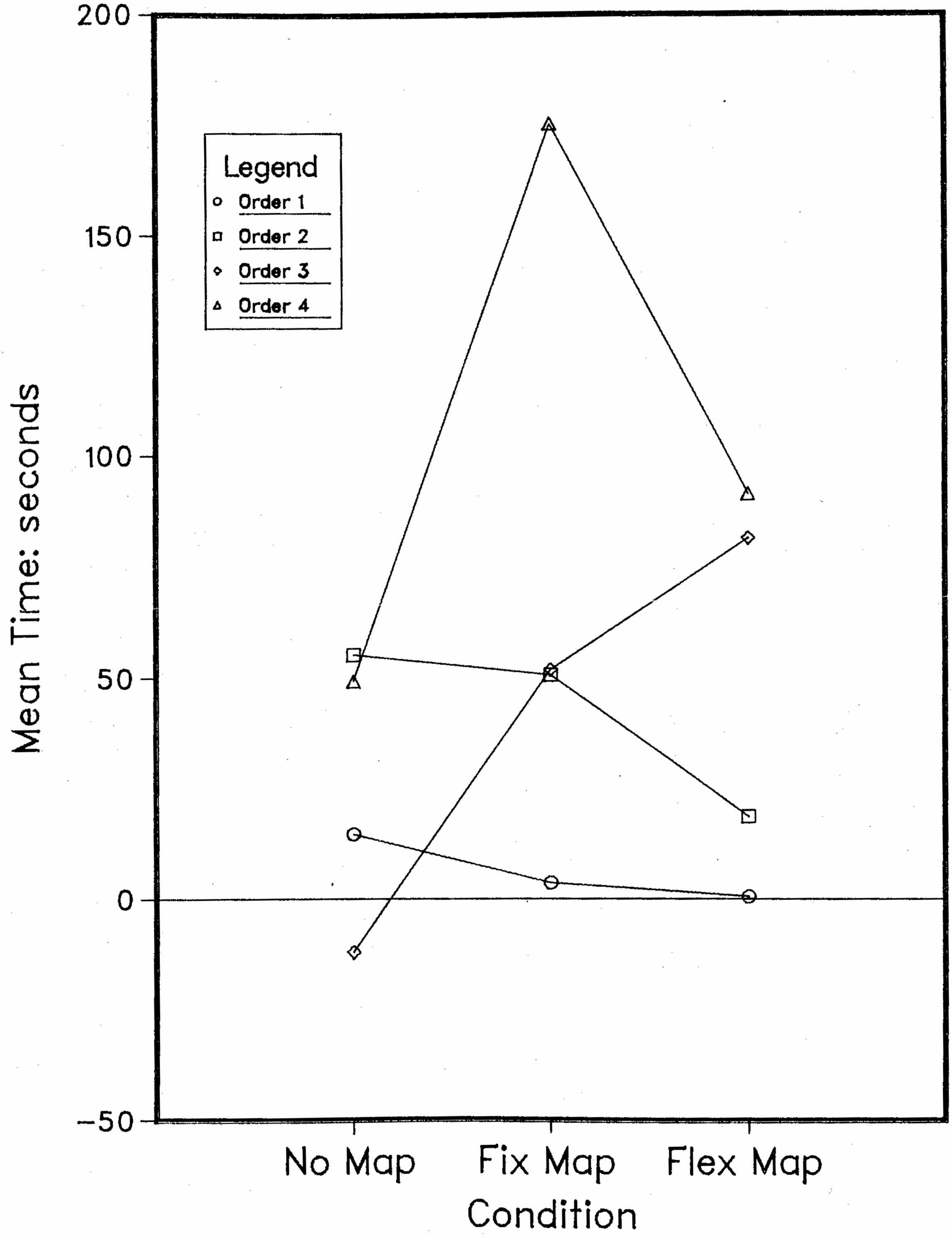


Figure 5.9: Adjusted Mean Travel Times for the Four Orders in Law – Blindfolded Sighted

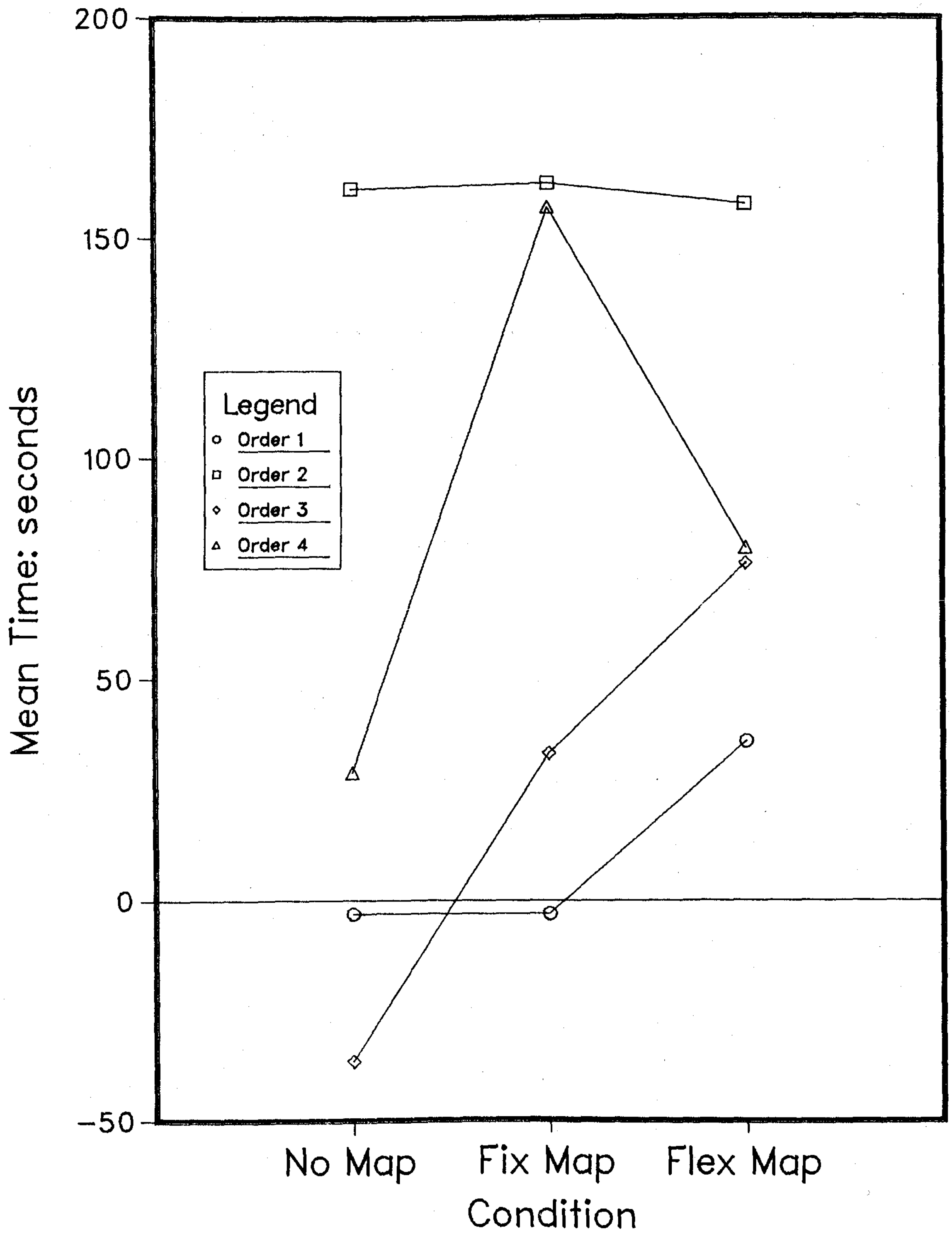
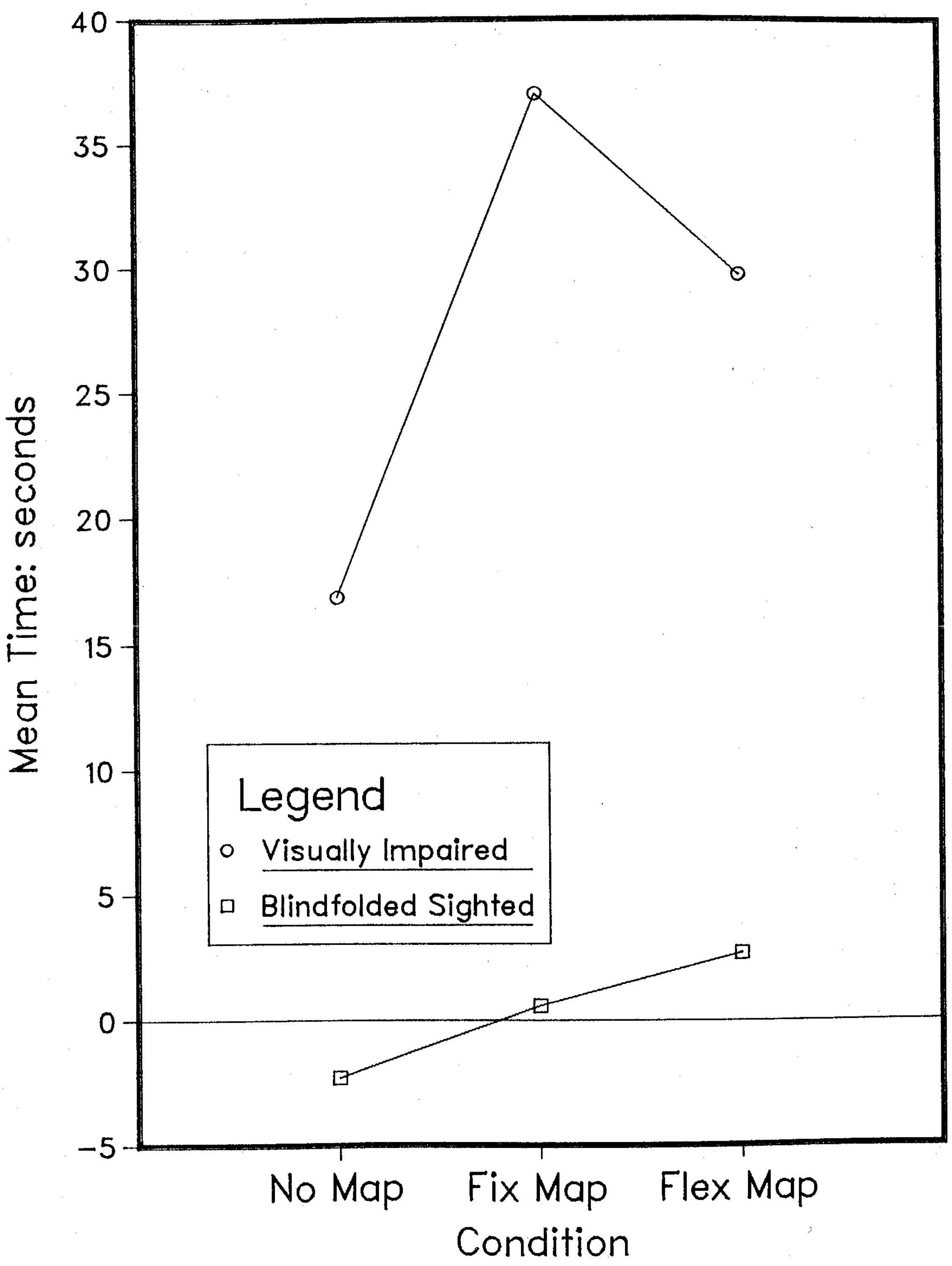


Figure 5.10: Adjusted Mean Travel Times: Visually Impaired & Blindfolded Sighted – Scarfe



than the blindfolded sighted, this is an artifact of the adjustment procedure. Reference to Figures 5.2 and 5.3 show that the visually impaired are consistently faster than the blindfolded sighted. The visually impaired were slowed the most by the fixed-scale map condition, although this was not the case for the blindfolded sighted. In the Law Building, the visually impaired were again slowed by the fixed-map condition. However, the difference between the fixed-scale map and the flexible-scale map was negligible for the blindfolded sighted, with the flexible-map being the slower of the two, as depicted in Figure 5.11. Figures 5.6 and 5.7 indicate the adjusted mean times for the visually impaired and the blindfolded sighted in the Scarfe Building. Observing each of the curves for the individual orders reveals that, as each order progresses through the map testing sequence, mean times improve. The graphs suggest a learning effect, as the subjects undertake the map test sequence. Figure 5.12 further clarifies the proposition that the subjects were showing a learning effect in their repeated passages through the halls. Trials are aggregates of the four order mean adjusted times and the sequence in which a particualr map was used. Thus, for example, all the map conditions utilized on the first map test were summed into the Trial 1 value. It is evident that as the subjects progressed through the test format, their times decreased, as their familiarity increased.

Figure 5.11: Adjusted Mean Travel Times: Visually Impaired & Blindfolded Sighted – Law.

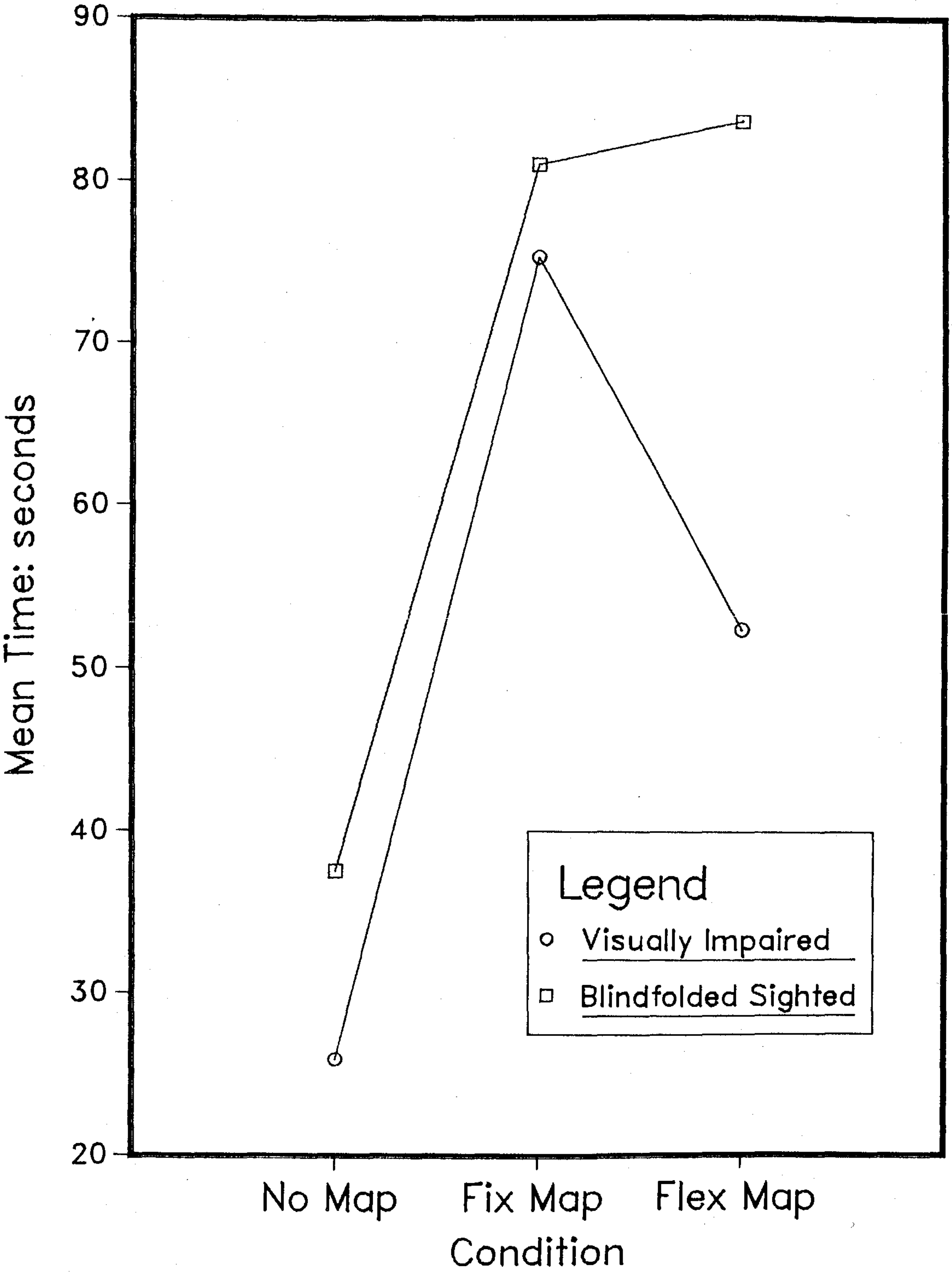


Figure 5.12: Learning Effect Of The Visually Impaired & Blindfolded Sighted – Scarfe

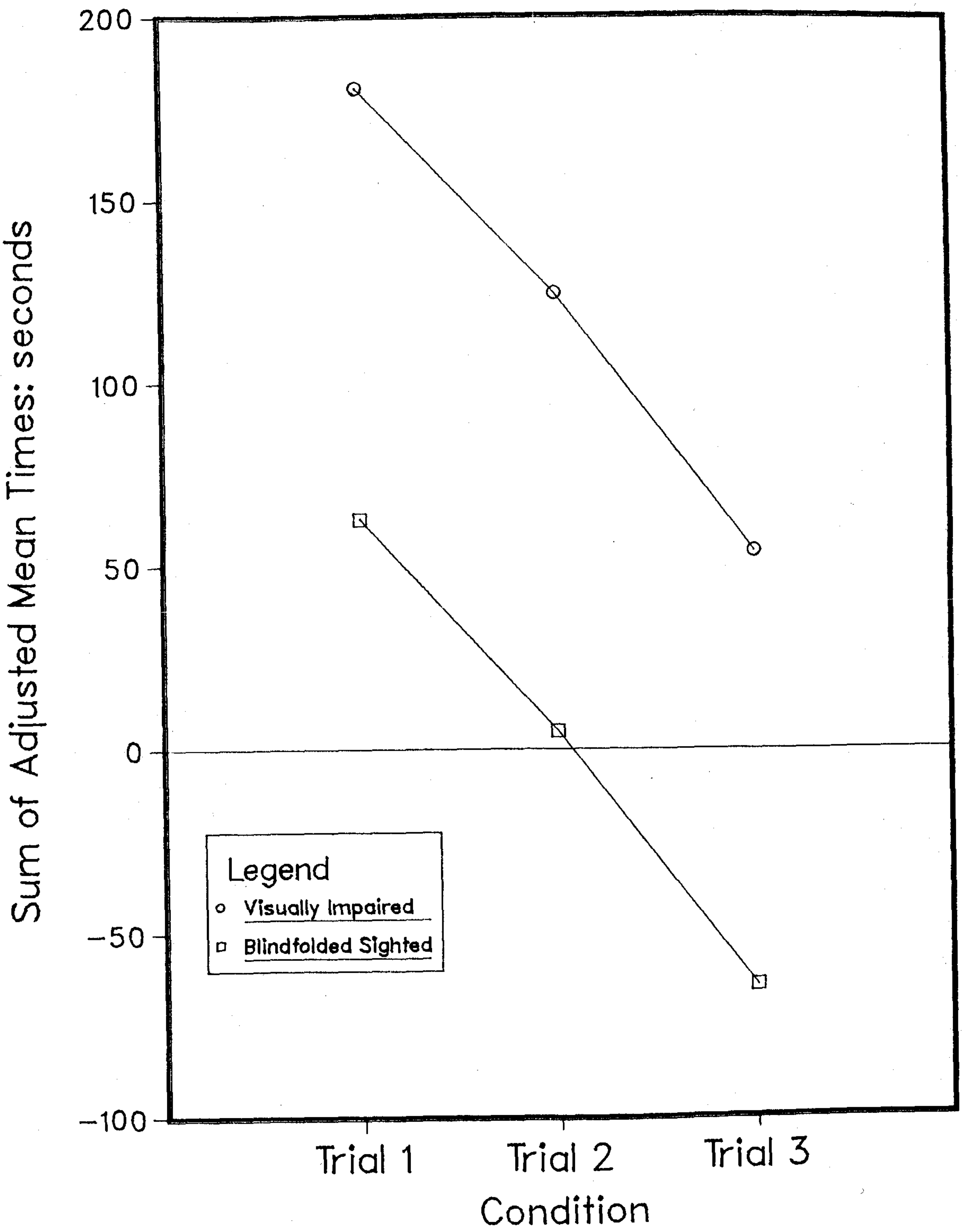
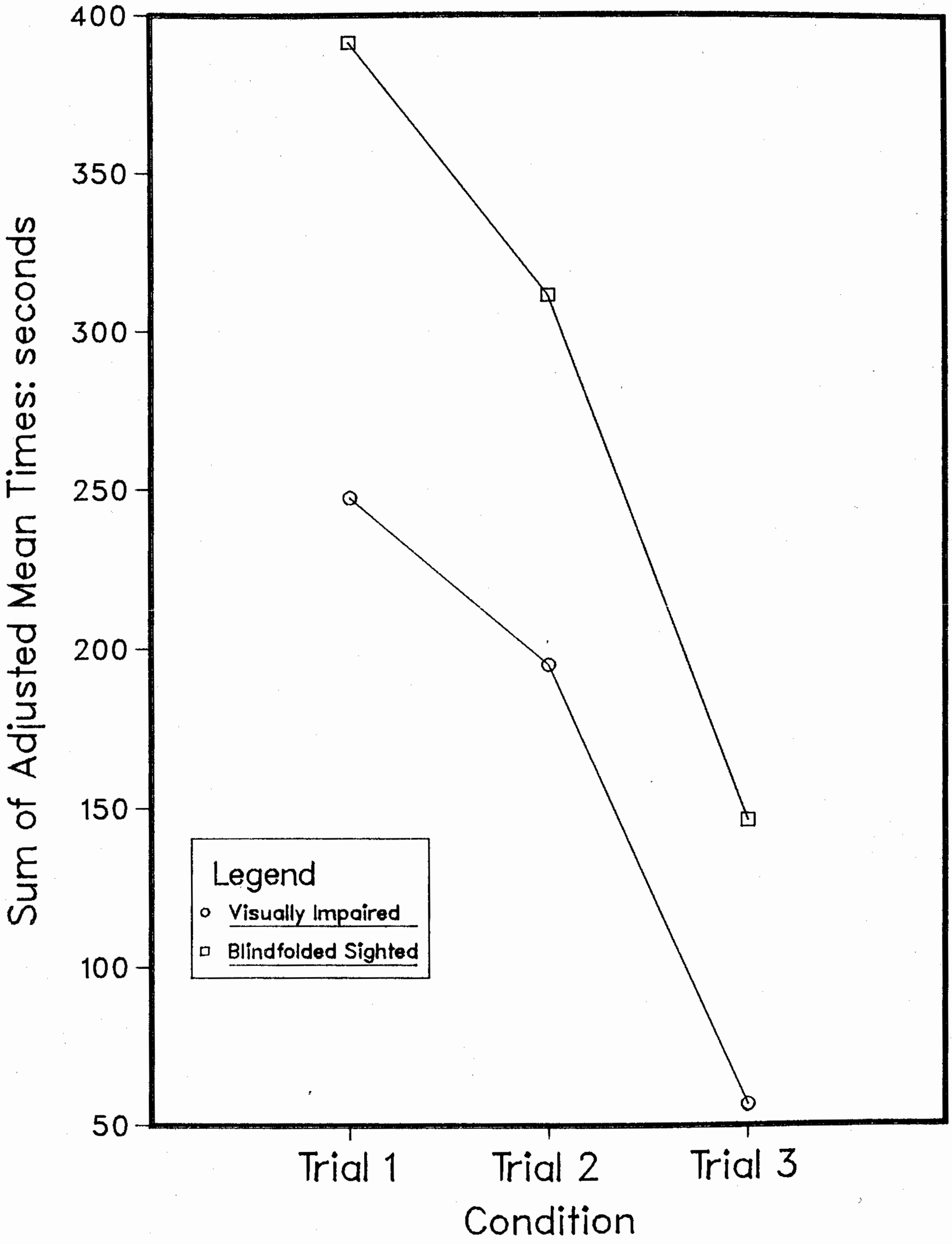


Figure 5.13: Learning Effect Experienced By The Visually Impaired & Blindfolded Sighted – Law



Similar conclusions can be drawn from observing the time values of the three trials in the Law Building. Figure 5.13, which lends further support to the fact that a learning experience evolved from repeated map use and hallway exposure.

An examination of the graphs emphasizing the orders' differences reveals that in the Scarfe Building, Orders 2 and 3 appear to exhibit the most extreme fluctuations, especially in the fixed-map condition. They have both the fastest and the slowest adjusted mean times. This can be attributed to the sequence in which the maps were presented and used. In the case of Order 3, the subjects, both visually impaired and blindfolded sighted, were performing a map test for the first time. This involved the coordination of several factors such as map reading, mobility, and use of one's haptic sense, which may or may not be developed to the required level. Order 2 indicates the adjustment that occurred as the subjects progressed through using the map conditions. By the final map (fixed-scale) their skills had sharpened enough to exhibit times that were superior to the verbal directions and the flexible-scale map times. The author suggests too, that they may have learned the route sufficiently, to allow for a faster movement.

In the Law Building, the values in Order 4 exhibited extreme fluctuations for both the visually impaired and the blindfolded sighted. The author suggests that the great difference between the fixed-scale map mean value and the flexible-scale map mean value was attributable to the fact that this was the first opportunity the subjects in Order 4 had to complete one test and they were both working with the more difficult map, and beginning the whole testing procedure in the more complicated of the two sites. In Orders 1 and 2, those subjects began with a verbal map, allowing them to develop some spatial knowledge of the site without having to coordinate their mobility abilities with map use skills. In Order 3, although the subjects were commencing with a map, they were using the less difficult of the two maps. They also had experienced map use and the required tasks, as they had already been through the Scarfe Building with three conditions.

CHAPTER VI

DISCUSSION

Several questions and hypotheses were posed to examine the extent to which a tactual mobility map with a flexible-scale would assist a visually impaired pedestrian in comparison with a fixed-scale tactual map. Each of these questions and hypotheses will be discussed in turn, with respect to the reported results of the research.

Thirty subjects were involved in the study, including eighteen visually impaired and twelve blindfolded sighted participants. The blindfolded sighted were not considered to be a control group. Leonard (1972) and Hollyfield (1981) have recognized that all too frequently the mobility standards of the sighted are the criterion against which the visually impaired person's abilities are judged. Hollyfield cautions that invariably the sighted pedestrian's abilities in spatial tasks are probably overrated. Likewise, Warren (1977) and Schmitt (1978) question the validity of having the blindfolded sighted as a control group. Schmitt advocates that until appropriate training and practice studies have been conducted with the blindfolded sighted subjects, sensory compensation cannot be assumed to accompany blindness (p. 103). This author agrees that the two groups cannot be compared on their non-visual abilities. Thus in the interpretation of the data, the blindfolded sighted were treated as being newly blinded, with minimal exposure to their new situation. It is imperative to recognize that for several of the visually impaired subjects, being totally impaired was equally uncomfortable. Many likened the experience to negotiating at night and in the dark. Although, for these subjects the adjustment was not as dramatic. All of the subjects were brought to a standard level, as they partook in a 'preview' exercise and those with some light perception wore an eye mask.

Speed of movement, measured by the variable time, and error, which was measured by the number of landmarks that a subject failed to identify during the map tests, were the two central indicators of a subject's improvement or lack of improvement with a particular map condition. In locating landmarks, relatively linear paths were taken by the participants. The maps allowed them to plan their own strategies for travelling from landmark to landmark. Depending on the sequence in which the no-map condition was encountered, the subjects either relied on the verbal instructions, which led them along a straight-line route or they utilized an individual plan that had been developed while testing the maps. Thus path from landmark to landmark was individual and could not be evaluated. The author used the number of landmarks missed or passed as one of the measures for map and spatial knowledge.

The results of this study should be applicable to visually impaired persons of varying degrees of tactual map experience and capabilities, given the variability evident within the subject population of this study. Caution should be applied in extending any of the results to other populations of visually impaired persons, because of the relatively uniform age and high degrees of intelligence and mobility of these subjects.

Two general questions were posed at the beginning of the thesis. This section of the thesis examines each of the specific questions and related hypotheses.

The first question and hypotheses examined the map effect. It was predicted that the visually impaired person moving through a large-scale environment would complete a given route more rapidly and with fewer errors than if relying on verbal guidance instructions. No map effect was found. The results of Models I and II indicated that using a flexible-scale or a fixed-scale tactual map in either of the halls slowed a person, in comparison to the no-map condition. In the Law Building, using a map slowed a pedestrian significantly. The results of Model III also revealed no map effects.

The author suggests several reasons for the slower times found with both maps in comparison to the verbal directions. Both the sighted participants and some of the visually impaired had to adjust to operating without any light perception. At the same time, all participants had to coordinate their visual impairment with map reading and use, mobility capabilities, as well as with another aid (for eleven of the subjects). If maintenance of orientation while walking requires focal attention, Book and Garling (1978) assumed that a demanding subsidiary task carried out concurrently should interfere with orientation performance. Similarily, Shingledecker (1978) has demonstrated that a secondary task will increase the amount of stress experienced by the individual, which in turn will invariably have the effects of cognitive overloading, things being overlooked in mobility settings, and resultant slower times. Such was probably the case in this research, especially in the Law Building.

The data analysis indicated significantly longer times taken by the subjects in the Law Building. This was attributable to both the length and the complexity of the hallway. Some of the landmarks to be identified, such as the drinking fountains were obscure both in form and location in the environment. At the same time, temporary objects were occasionally placed in the hallway; these could not be mapped. The subjects were always informed of the placement of these obstacles prior to commencing the map tests. However, this would result in an increased memory load, which along with the obscurity of certain landmarks contributed to the travel times and the missed landmarks.

Variability in subject travel times was apparent. Time values reflected both walking speed and errors made. Thus the 'preview' was performed to provide a baseline measurement for each individual. Yet the outcome in the map tests favoured the no-map condition, as it yielded superior values in comparison to moving with a map.

No difference was found between the number of errors made by the subjects using a tactual map and the errors of those relying on verbal directions. Thus, in terms of the number of landmarks missed, the tactual map did not improve mobility performance; its effect was to increase the number of errors. Again, it is suggested that this is a consequence of having to coordinate several skills simultaneously. Despite the fact that the maps were designed in conjunction with a totally and congenitally blind assistant and from his perceptions, it became evident that in the future, maps should be tested by the user population under realistic conditions.

The verbal directions consistently produced shorter times than the map conditions. The "verbal" map was somewhat detailed, as its format was based on the past mobility training instruction methods. The author suggests that the verbal guidance instruction times reflected the subjects' reliance on and familiarity with the verbal directions, as opposed to depending on their relatively unskilled map reading and map use techniques.

Preiser and Brecht (1981) also encountered inferior performance in the map-user group. Similar to Preiser and Brecht, the results of this research may be partially a consequence of an experimental constraint. Normally, tactual map-users would utilize information gained from the map, supplemented by assistance from other information sources and from people. During the map tests, the subjects had only the maps and/or verbal directions to locate spatial positions without sight.

Although the blindfolded sighted were not regarded as a control group, differences in performance levels in comparison with the visually impaired subjects were observed. Several researchers, including Rieser, Lockman and Pick (1980), Warren, Anooshian and Bollinger (1973), and Worchel (1951) have proposed that the satisfactory and occasionally superior performance of the blindfolded sighted is due to a retention in memory of a visual context. Thus for the blindfolded sighted, having visual experience should facilitate the acquisition of spatial information. The blindfolded sighted , however, performed significantly more poorly than the visually impaired, regardless of their maintenance of visual spatial imagery. Hollyfield (1981) reported that:

> "Also, the blindfolded subjects took much longer on all trials to walk the route, because their fears made them very cautious in moving forward over the route" (p. 152).

Herman, Chatman and Roth (1983) and Schmitt (1978) suggested that the blind may perform more accurately in an unfamiliar environment, since they have always operated with lack of vision and therefore have had more practice. Maglione (1969) observed that the late-blind subjects in his research exhibited a performance both in a life-size maze task and on a finger-maze task significantly better than the early-blind and sighted groups. He attributed their performance results to past visual experience (p.119). It is evident that a reduction of the cues that guide performance results from the absence of visual stimulation. Thus, as Shingledecker and Foulke (1978) recognized, because of "an attenuation of redundancy which imposes on the blind pedestrian the necessity of maintaining a more selective attentive adjustment", the individual becomes more vulnerable to the effects of interference and of missed cues (p. 284).

Evidence from the literature offers support for the flexible-scale as the preferable means of portraying information to the visually impaired in the tactual map form (Armstrong, 1973; Bentzen, 1980; Castner, 1983: James, 1972; 1982; Jansson, 1984; and Lederman and Campbell, 1982). Despite this, the results of the present study were non-significant in all three models. Thus, the flexible-scale map did not significantly improve speed of travel in comparison to the fixed-scale map. The flexible-scale map did, however, yield somewhat faster travel times than the fixed-scale map.

Neither the flexible-scale map nor the fixed-scale map was demonstrably superior with regard to landmark location. The number of errors made did not differ significantly between the two map types.

It is also necessary to note the difference in the map preferences of the subjects. The overall analysis detected no significant performance effects. The subject population, however, exhibited a difference in their preference for either fixed-scale map or flexible-scale map between the two environments. Generally, the differences indicated a preference for the flexible-scale map.

Preiser's (1983) topological tactual map, which resembled a circuit diagram, depicted route configurations at different scales. The map was designed to supply only information that was imperative for orientation and mobility. Results of his analysis indicated that the map assisted in the formation of mental images of the environment, although, it did not necessarily improve travel performance. The results of this thesis suggest similar conclusions.

An examination of the specific comments made by the subjects about the flexible-scale map for both study sites allowed a clearer understanding of their appreciation of certain map characteristics. Positive comments were directed towards the presentation and representation of symbols, landmark and positional information, haptic presentation (including the allottment of space for the exploration of the tactile perimeter without confusion with other information), encouragement of spatial perception, the distortion of certain areas, and the clarification of the spatial layout. Negative comments included symbol presentation and representation, especially for the Law Building, and scale distortion which created difficulties in deriving reliable distance judgments or planning route strategies. Thus, subjects did not clearly agree on a number of the map characteristics evaluated in this study.

It was proposed that in an environment with relatively uniform element distribution, no differences would result from the use of the fixed-scale and the flexible-scale maps. In this study, the representative site was the second floor hallway of the Scarfe Building Classroom Block. In comparison to the no-map condition , the flexible-scale map slowed the subject's travel in the Scarfe Building. Again, this could be attributed to the coordination of and concentration on several skills simultaneously.

A comparison of visually impaired and blindfolded sighted provides additional information. The blindfolded sighted were impeded by the flexible-scale map by a non-significant 22 seconds, in comparison to the fixed-scale map. The visually impaired improved their times with the use of the flexible-scale map, although not by a statistically significant amount. Considering the three models together, the flexible-scale map times yielded a non-significant travel improvement over the fixed-scale map.

In the Scarfe Building hallway, no difference was obtained in the number of errors made (or the landmarks missed) between the flexible-scale map and the fixed-scale map. In this case, neither of the maps was demonstrably superior. In addition, the two groups did not differ in their map type preference in the Scarfe Building.

In summary, for the Scarfe Building, it was apparent that the use of flexible-scale and fixed-scale maps yielded no dramatic differences in travel times, the number of errors made, or of the preferences indicated by the subjects. The author suggests that the uniformity and the simplicity of the environment was such that either of the maps assisted the subjects' orientation and mobility. The two maps did not differ in their content. In the flexible-scale map, only the widths and distances in portions of the hallway were changed. The author assumed that the flexible-scale would enhance users' spatial impressions, but that travel competence would be efficient regardless of the scale. Comments about the flexible-scale map emphasized clarity and readability, yet the subjects did not differ in their map type preferences. Thus, the two map types assisted equally in the orientation and mobility of visually impaired subjects in the Scarfe Building.

The Law Building, with relatively clustered elements presented a totally different situation. It was anticipated that in an environment with relatively clustered elements, a flexible-scale tactual map would result in the visually impaired subject completing a given route more rapidly and with fewer errors than if using a fixed-scale tactual map.

For all subjects operating with the two map conditions, travel times were slower in the Law Building than in the Scarfe Building. However, the fixed-scale map/no-map comparison demonstrated that using a fixed-scale map had the effect of significantly slowing a visually impaired person's progress. The fixed-scale map also impeded an individual's travel time more than the flexible-scale map, although not to a significant degree.

Model III Analysis further supported the previously obtained map effect results. Using a fixed-scale tactual map in the Law Building significantly slowed the blindfolded sighted subjects, and the visually impaired subjects. The flexible-scale map values reduced the time needed by the blindfolded sighted, but not to a significant degree. The visually impaired subjects' times also indicated a non-significant flexible-map improvement. Thus, the flexible-scale tactual map yields faster travel in an environment with relatively clustered elements, although the differences were non-significant.

The visually impaired and the blindfolded sighted did not differ in the number of errors made with either of the maps in the Law Building. An analysis of the subjects' map type preferences resulted in similar conclusions. Although a map type preference was evident among the subjects for the Law Building (Chi Square = 11.4, $p = 0.01$), a global comparison of the two subject groups on preference for the fixed-scale map or the flexible-scale map, yielded no significant difference.

It is apparent that the flexible-scale map did not significantly improve the performance of the visually impaired subjects in an environment with relatively clustered elements. However, the fixed-scale map slowed travel to a significant degree. Both the number of errors made and the map type preference results revealed no significant difference between the two map types.

These results may be attributed to several factors. The hallway characteristics were complex enough to make passage through the Law Building difficult. The occasional large amount of pedestrian traffic and temporary placement of objects hindered orientation and mobility even further. The nature of the hallway created difficulties in designing a clear and operable flexible-scale map within the map size limitations, regardless of the fact that the map's design included the visually impaired assistant's perspectives. Both the flexible-scale map and the fixed-scale map attracted negative comments regarding symbol legibility within the context of the surrounding information (such as fountain 2 and the corridor doors), despite the fact that the assistant had reviewed the maps prior to the testing sessions. Several subjects indicated that the flexible-scale map provided them with an overview that clarified any confusions regarding hall layout. For locating specific landmarks, however, the value of the map diminished. Once again, the conclusions were similar to those of Herman,

Herman and Chatman (1983) and Preiser (1983) in that the maps assisted the individual in the attainment of general information, rather than of specific details.

Although it was assumed that the perceptions of the congenitally blind assistant would be useful and effective in designing maps for all visually impaired map users (whether newly impaired or totally blind from birth), it became evident that variation in spatial abilities and perceptions, and in haptic skills existed within the subject population. All were able to work with the flexible-scale maps, as had been assumed, but this ability also varied from individual to individual. Thus individual travel times reflected those varied abilities. Nevertheless, by incorporating the perceptions of the visually impaired assistant, the flexible-scale map was better understood and preferred (although not by a significant amount). Although specific details were not always discernable (especially in the Law Building), the flexible-scale map did assist in general orientation and understanding.

The study disclosed an apparent learning effect. During successive trips through the hallways, the subjects' familiarity and travel speed was enhanced. Lindberg and Garling (1978) observed that with repeated exposure to the same path/environment, maintenance of orientation improves. Shingledecker and Foulke (1978) recognized that sufficient repeated experience with a route would lead to an acquisition of a memorial representation of the route. As learning progresses, the researchers noted that certain distinctive features become cues for orientation (pp. 284-285). For some of the subjects in the current study (particularily the visually impaired), that acquired knowledge was sufficient to allow the individual to move without continuously relying on the maps for orientation and mobility. It was evident from observing the subjects' travelling that the maps aided in determining landmark to landmark strategies. It seems that this learning and resultant confidence may have resulted in less attention being paid to detail, thereby causing subjects to bypass certain landmarks. This may explain why eleven errors were made with the flexible-scale map in the Scarfe Building, while only seven were made with the fixed-scale map.

The failure to locate a landmark usually involved the subject simply passing the object, and having to return along the same path until it was found. In addition to the above explanation, several other reasons can be given for the errors. Some of the landmarks were obscure both in form and positioning in the environments. Occasionally, the temporary placement of another object in the Law Building resulted in a detour. The subject would usually overestimate the distance in an attempt to return to the path of travel, and would miss the landmark. This may be attributed to the functional manner of acquiring spatial knowledge, noted by Lockman, Rieser and Pick (1980). Certain landmarks, especially the drinking fountains, posed difficulties in symbol identification on the map. Due to their placement within the environments themselves, attempts were made to replicate the landmarks positioning on the maps within the limits of haptic perception. The symbols, however, became somewhat "hidden" within the surrounding features. In addition, the stress factor acknowledged by Shingledecker (1978) invariably contributed to the objects being passed.

Considering the different ways in which the subjects operated with the maps and the number of trips that they initially performed with each of the maps in the environments, it is suggested that the significant learning effect arose primarily from exposure to the buildings, rather than from practice with the maps. The maps certainly aided the individual in gaining an informative knowledge of the sites. Yet the times improved progressively with each passage, suggesting a familiarity with the sites. Considering all of the orders and subjects together, a comparison of travel speeds on Trip 1 with those on Trip 4 revealed no significant differences. Thus, within the context of this reseach, whether an individual has had experience with the map conditions (as in Trip 4) or is new to the site and the map conditions (as in Trip 1), the travel times will reflect a learning effect, as a result of building exposure.

The questions that had been initially posed were:

1. As an aid to conventional mobility training, can tactual maps improve a visually impaired person's speed of movement and understanding of a large-scale environment?

2. Does the tactual mobility map have a differential utility
   a. in an environment with relatively clustered elements and in an environment with relatively uniformily distributed elements? and
   b. with a fixed-scale map or with a flexible-scale map?

The literature review supports the contention that tangible counterparts of visual displays are often not appropriate for the visually impaired user. It is imperative that the design of the tactual map incorporate the principles of haptic perception, and the visually impaired person's understanding of space and distance. The results of this research show that it is possible for the visually impaired individual to learn and apply information obtained from the tactual graphic displays to deduce spatial relations in large-scale spaces.

Performance with the tactual maps did not significantly improve when compared to the verbal directions (conventional mobility training) with respect to either time taken or errors made. This accords with the conclusions of Preiser (1983, p.87) who found that travel performance did not necessarily improve when a subject traversed an area with a tactual map. However, the map did assist Preiser's subjects in creating spatial images. Maglione (1969) has determined that visually impaired persons make fewer errors, take less time, and learn what not to consider when they are provided with both verbal directions and a tactual map, as opposed to those subjects using only verbal directions. Observations from the current research have led the author to conclude that using a tactual map without any additional information sources (excepting perhaps a cane or a dog) enables the user to gain an overall and general understanding of spatial relationships. This conclusion is similar to that of Herman, Herman and Chatman (1983).

The flexible-scale tactual map in both environments enhanced that spatial understanding to a greater extent than did the fixed-scale tactual map. Although differences were non-significant, the fixed-scale map values yielded slower times in both environments, with the Law Building values being significantly slower. The tactual maps, however, did not improve speed when compared to the verbal guidance instructions in either of the sites. Likewise, an analysis of the errors suggested a difference between the map and no-map conditions in both environments. Unfortunately, the effect was to increase the number of errors made when using a tactual map. Finally, although not statistically significant, the subjects' comments reflected a preference for the flexible-scale maps in both environments.

In both environments, the maps had a tendency to slow the subjects in comparison with the verbal directions. In an environment with relatively uniform element distribution (the Scarfe Building), no significant differences in the subjects' performances were observed between the fixed-scale tactual map and the flexible-scale tactual map. In the environment with relatively clustered elements, differences arose between the two map types with the fixed-scale map resulting in significantly longer times taken. Thus it can be concluded that flexible-scale tactual map and the fixed-scale tactual map are of different utility, although, use of the tactual map did not result in a significant improvement over the verbal directions.

CHAPTER VII

CONCLUSIONS

As a scaled-down form of representation, maps are an aid to the organization of information, movement and location. To map effectively and efficiently from the informational environment, it is imperative that only data relevant to the purpose of the map are selected and used. Both the sighted individual and the visually impaired person are required to perform spatial tasks. The blind, however, need to integrate information from several senses to compensate for a lack of vision, and must sequentially code and interpret the given information. Thus an understanding of the role of spatial and haptic perceptions of the visually impaired is essential to the development and design of tactual maps. Tactual maps represent a means of facilitating the visually impaired person's understanding of an environment, and assist in the deduction of spatial relations.

The present research examined the effectiveness of using a varying scale within the tactual map. It has been recognized in the cartographic literature that the association between the map maker and the map reader is a vital component of map design. This association is also important in the design of tactual maps. The incorporation of a flexible-scale, which reflects the haptic and spatial perceptions of the visually impaired, is a result of this approach. It was suggested that a flexible-scale map in conjunction with verbal directions (labelled as conventional mobility training) would assist the mobility performance of the visually impaired traveller.

Within the tactual mobility map, scale was analyzed in terms of its effect on both speed of movement and number of errors committed. Specifically, the research evaluated the efficacy of two tactual maps, one with a fixed-scale, and one with a variable or flexible-scale map. The maps were also compared to verbal directions or "verbal" map. These map conditions were compared in two different environments, one with relatively uniform element distribution and one with relatively clustered elements. Eighteen visually impaired and twelve blindfolded sighted subjects participated in the examination of the three map conditions.

This research has helped to clarify the role of the tactual map for orientation and mobility. Performance with tactual maps did not significantly improve with respect to time taken or errors made when compared to the verbal directions. It was evident though, from the subjects' comments that it was possible for the visually impaired individual to learn and apply information obtained from the tactual graphic display to deduce spatial relations in large-scale spaces. Thus, this research leads to the conclusion that use of a tactual mobility map can enable the visually impaired person to gain an overall and general understanding of spatial relationships. Details may be grasped, but the subject population varied in its ability to ascertain such specifics.

The results of this study are applicable only to situations using similar map types for indoor environments. It is evident that additional research and refinement of tactual maps are required, so as to map the environmental information in a meaningful manner for the visually impaired traveler. This would invariably require the assistance of visually impaired assistants.

As a consequence of the research design, a significant learning effect appears in the results, attributable to exposure to the buildings, rather than to practice with the maps. Regardless of the learning effects, however, it is apparent that the flexible-scale map in both environments is more effective than the fixed-scale map in enhancing the visually impaired person's spatial understanding. This became especially evident in the subjects' comments on the maps themselves. To a lesser extent, support for the flexible-scale map was demonstrated in comparison to the fixed-scale map. The fixed-scale maps yielded slower times in both environments, with the Law Building values being significantly slower. On the other hand, although not statistically significant, times taken, errors made, and subjects' comments reflected a preference for the flexible-scale map in both environments.

The effort to provide the visually impaired with information for safe and efficient travel in the form of a tactual map has been moderately successful to date. Research findings on the role of the tactual map and the flexible-scale suggest several avenues for research.

It is evident that the perceptual system of the visually impaired has been insufficiently studied, and deserves closer attention, as it is crucial to the development of successful graphics. Symbol discriminability and standardization should correspond to the natural capacity of touch. If tactual maps are to be designed from the visually impaired person's perspective as advocated here knowledge about information needs specific to the visually impaired traveler are essential. Research into the ability of different types of displays to communicate required information is necessary. At the same time, the skills and concepts required to read and understand the resulting maps demand attention. Reseach into user abilities would inevitably contribute to more appropriate choices of information and symbols for inclusion into tactual mobility maps.

This study offers some possible directions for future research. Obviously future work should involve participants who are reasonably skilled in map use. It is evident that the flexible-scale map benefitted the visually impaired traveler, but problems with imagery are evident. If the visually impaired person is to understand and utilize a flexible-scale map, then even more extensive dimensional alterations to ensure symbol clarity and legibility are necessary. Given these two suggestions and based on the results of the current study, the question of independent mobility with a flexible-scale tactual map in an unfamiliar environment arises. Owing to the manner in which the visually impaired person is required to negotiate an area, appropriate use of a tactual mobility map will probably be to provide an overview for the user rather than an immediate aid to full and independent mobility. Thus, regardless of a high proficiency level, the visually impaired person would still be required to use additional information sources for efficient and safe orientation and mobility.

REFERENCES

Acredolo, L.P. Spatial Orientation in Special Populations: The Mentally Retarded, the Blind, and the Elderly. In H.L. Pick and L.P. Acredolo (Eds.), Spatial Orientation: Theory, Research, and Application. New York: Plenum Press, 1983, 143-160.

Amendola, R. Practical Considerations in Tactile Map Design. Long Cane Newsletter, 1976, 9 (2), 22-24.

Andrews, S.K. Spatial Cognition Through Tactual Maps. J.W. Wiedel (Ed.), Proceedings of the First International Symposium on Maps and Graphics for the Visually Impaired. Washington, D.C.: Association of American Geographers, 1983, 30-40.

Armstrong, J.D. The Design and Production of Maps for the Visually Handicapped. Nottingham: University of Nottingham, 1973, Mobility Monograph No. 1.

Barth, J.L. Factors Affecting Line Tracing In Tactile Graphs. Journal of Special Education, 1983, 17 (2), 215-226.

Barth, J.L. Incised Grids: Enhancing the Readability of Tangible Graphs for the Blind. Human Factors, 1984, 26 (1), 61-70.

Barth, J.L. & Foulke, E. Preview: A Neglected Variable In Orientation and Mobility. Journal of Visual Impairment and Blindness, 1979, 73 (2), 41-48.

Bentzen, B.L. Production and Testing of an Orientation and Travel Map for Visually Handicapped Persons. New Outlook for the Blind, 1972, 66, 249-255.

Bentzen, B.L. Orientation Aids. In R.L. Welsh and B.B. Blasch (Eds.), Foundations of Orientation and Mobility. New York: American Foundation for the Blind, 1980, 291-356.

Bentzen, B.L. Tangible Graphic Displays in the Education of Blind Persons. In W. Schiff and E. Foulke (Eds.), Tactual Perception a sourcebook. Cambridge: Cambridge University Press, 1982, 387-404.

Berla, E.P. Haptic Perception of Tangible Grpahic Displays. In W. Schiff and E. Foulke (Eds.), Tactual Perception a sourcebook . Cambridge: Cambridge University Press, 1982, 364-386.

Berla, E. & Butterfield, L.H., Jr. Tactile Political Maps: Two Experimental Designs. Journal of Visual Impairment and Blindness , June 1977, 262-264.

Blakemore, M.J. Cartography. In R.J. Johnston (Ed.), The Dictionary of Human Geography. Oxford: Basil Blackwell Publisher Ltd., 1981, 29-33.

Bluestein, N. & Acredolo, L. Developmental Changes in Map-Reading Skills. Child Development, 1979, 50, 691-697.

Book, A. & Garling, T. Processing of Information About Location During Locomotion: Effects of a Concurrent Task and Locomotion Patterns. Umea, Sweden: University of Umea, Department of Psychology, 1978, Umea Psychological Reports, No. 135.

Brambring, M. The Structure of Haptic Space in the Blind and Sighted. Psychological Research, 1976, 38 (3), 283-302.

Brambring, M. Language and Geographic Orientation for the Blind. In R.J. Jarvella and W. Klein (Eds.), Speech, Place, and Action . New York: John Wiley & Sons Ltd., 1982, 203-218.

Brown, D.L. The Application of Denotative Mappping Techniques to Problems in Tactual Map Use. Madison, Wisconsin: University of Madison, Unpublished Master's of Science Thesis, 1978.

Byrne, R.W. and Salter, E. Distances and Directions in the Cognitive Maps of the Blind. Canadian Journal of Psychology, 1983, 32 (2), 293-299.

Canter, D. The Psychology of Place. London: The Architectural Press, 1977.

Casey, S.M. Cognitive Mapping by the Blind. Journal of Visual Impairment and Blindness, 1978, 72 (8), 297-301.

Castner, H.W. Tactual Maps and Graphics - Some Implications for our study of Visual Cartographic Communication. Cartographica, 1983, 20 (3), 1-16.

Cleaves, W.T. and Royal, R.M. Spatial Memory for Configuration By Congenitally Blind, Late Blind and Sighted Adults. Journal of Visual Impairment and Blindness, 1979, 73, 13-19.

Craig, J.C. and Sherrick, . Dynamic Tactile Displays. In W.Schiff and E. Foulke (Eds.), Tactual Perception a sourcebook. Cambridge: Cambridge University Press, 1982, 209-233.

Cratty, B. Movement and Spatial Awareness in Blind Children and Youth. Springfield, Illinois: Charles C. Thomas, 1971.

Cratty, B.J., Peterson, C., Harris, J., and Schoner, R. The Develpoment of Perceptual-Motor Abilities in Blind Children and Adolescents. New Outlook for the Blind, 1968, 62, 111-117.

Dayton, M.F. Maps for the Blind. Bulletin, Association of Canadian Libraries, No. 32, 1979, October, 12-15.

Dodds, A.G., Howarth, C.I., and Carter, D.C. The Mental Maps of the Blind. Journal of Visual Impairment and Blindness, 1982, 76 (1), 5-12.

Downs, R.M. and Stea, D. Image and Environment. Chicago: Aldine Publishing Co., 1973.

Eckert, M. On the Nature of Maps and Map Logic. Cartographica , Monograph 19, 1977, 1-7.

Ewart, A. and Carp, M. Recognition of Tactual Form By Sighted and Blind Subjects. American Journal of Psychology, 1963, 76, 488-491.

First European Symposium on Tactual Town Maps for the Blind, General Report. Bruxelles, Belgique: 1983.

Fisher, G.H. Spatial Localization By The Blind. American Journal of Psychology, 1964, 77, 2-13.

Fletcher, J.F. Spatial Representation in Blind Children. Journal of Visual Impairment and Blindness, 1980, 74, 381-385.

Fletcher, J.F. Spatial Representation in Blind Children. Journal of Visual Impairment and Blindness, 1981, 75, 1-3.

Fletcher, J.F. Spatial Representation in Blind Children. Journal of Visual Impairment and Blindness, 1981, 75 (2) 46-49.

Foulke, E. The Perceptual Basis for Mobility. Research Bulletin, American Foundation for the Blind, 1971, No.23, 1-8.

Foulke, E. Perception, Cognition and the Mobility of Blind Pedestrians . In M. Potegal (Ed.), Spatial Abilities: Development and Physiological Foundations. New York: Academic Press, 1982, 55-76.

Foulke, E. Spatial Ability and the Limitations of Percpetual Systems. In H.L. Pick and L.P. Acredolo (Eds.), Spatial Orientation Theory, Research, and Application. New York: Plenum Press, 1983, 125-141.

Gibson, J.J. and Gibson E.J. Perceptual Learning: Differentiation Or Enrichment. Psychological Review, 1955, 62 (1), 32-41.

Gill, J.M. Orientation Maps for the Physically Handicapped. Cartographic Journal, 1974, 11 (2), 94-98.

Golledge, R.G. and Hubert, L.J. Some Comments on Non-Euclidean Mental Maps. Environment and Planning, 1982, A14, 107-118.

Guelke, L. Cartographic Communication and Geographic Understanding. Cartographica, 1977, No. 19, 129-145.

Hart, R.A. and Moore, G.T. The Development of Spatial Cognition: A Review. In R.M. Downs and D. Stea (Eds.), Image and Environment Chicago: Aldine Publishing Co., 1973, 246-288.

Henning, M.D. Toward an Understanding of Scale and Its Relevance to Cartographic Communication. The Cartographic Journal, 1983, 20 (2), 119-120.

Herman, J.F., Chatman, T.G., and Chatman, S.P. Constructing Cognitive Maps From Partial Information. Journal of Visual Impairment and Blindness, 1983, 77 (5), 195-198.

Herman, J.F., Chatman, T.G., and Roth, S.F. Cognitive Mapping in Blind People: Acquisition of Spatial Relationships in a Large-Scale Environment. Journal of Visual Impairment and Blindness, 1983, 77 (4), 161-166.

Hermelin, B. and O'Connor, N. Location and Distance Estimates By Blind and Sighted Children. Quarterly Journal of Experimental Psychology , 1975, 27, 295-301.

Hermelin, B. and O'Connor, N. Spatial Modality Coding in Children With and Without Impairments. In Potegal, M. (Ed.), Spatial Abilities: Development and Physiological Foundations, New York: Academic Press, 1982, 35-54.

Hill, E.W. and Ponder, P. Orientation and Mobility Techniques. New York: American Foundation for the Blind, 1976.

Hollyfield, R. The Spatial Cognition of Blind Pedestrians. Louisville, Kentucky: University of Louisville, Unpublished Doctoral Dissertation, 1981.

Hollyfield, R. and Foulke, E. The Spatial Cognition of Blind Pedestrians. Journal of Visual Impairment and Blindness, 1983, 77 (5) 204-210.

Howard, I.P. and Templeton, W.B. Human Spatial Orientation New York: John Wiley and Sons, 1966.

Hway-Hwa Kuo, E. Tactual Thematic Map Design. North Carolina: University of North Carolina, Unpublished Doctoral Dissertation, 1978.

James. G.A. Problems in the Standardization of Design and Symbolization in Tactile Route Maps for the Blind. The New Beacon, 1972, 56, 87-91.

James, G.A. Mobility Maps. In W. Schiff and E. Foulke (Eds.), Tactual Perception a sourcebook. Cambridge: Cambridge University Press, 1982, 334-363.

James, G.A. and Armstrong, J.D. Handbook on Mobility Maps. Mobility Monograph No.2. Nottingham: University of Nottingham, Department of Psychology, 1976.

James, G.A., Armstrong, J.D. and Campbell, U. Verbal Instructions Used by Mobility Teachers to Give Navigational Directions to Their Clients. The New Beacon, 1973, 57, 86-91.

Jansson, G. Tactile Maps as a Challenge for Perception Reserch. Proceedings on the First International Symposium for the Visually Impaired. Washington, D.C.: Association of American Geographers, 1983, 68-75.

Jansson, G. Research Needed to Obtain More Useful Tactual Maps. Aids and Appliances Review, 1984, No.14, 3-6

Jansson, G. Perceptual Information for Orientation and Mobility. XXIII International Symposium, Congress of Psychology - "Possibilities and Limitations in Sensory Substitution". Mexico: 1984.

Jones, B. Spatial Perception in the Blind. British Journal of Psychology, 1975, 66(4), 461-472.

Juurmaa, J. An Analysis of the Components of Orientation Ability and Mental Manipulation of Spatial Relationships. Helsinki: Institute of Occupational Health, Report No. 28, 1965.

Juurmaa, J. Ability Structure and Loss of Vision. New York: American Foundation for the Blind, Research Series No. 18, 1967.

Juurmaa, J. Transposition in Mental Manipulation, A Theoretical Analysis. American Foundation for the Blind, Research Bulletin , 1973, 26, 87-134.

Juurmaa, J. and Suonio, K. The Role of Audition and Motion in the Spatial Orientation of the Blind and the Sighted. Scandinavian Journal of Psychology, 1975, 16 (3), 209-216.

Keates, J.S. Understanding Maps London: Longman Group Ltd., 1982.

Kerr, N.H. The Role of Vision in "Visual Imagery" Experiments: Evidence from the Congenitally Blind. Journal of Experimental Psychology: General, 112 (2), 1983, 265-277.

Kidwell,A. and Greer, P. Sites Perception and the Nonvisual Experience. Designing and Manufacturing Mobility Maps. New York: American Foundation for the Blind, 1973.

Kosslyn, S.M., Ball, T.M. Reiser, B.J. Visual Images Preserve Metric Spatial Information: Evidence from Studies of Image Scanning. Journal of Experimental Psychology: Human Perception and Performance , 1978, 4, 47-60.

Landau, B., Spelke, E., and Gleitman, H. Spatial Knowledge in a Young Blind Child. Cognition, 1984, 16, 225-260.

Landau, B. and Spelke, E. Spatial Knowledge and Its Manifestations. In H.M. Wellman (Ed.), Children's Searching: The Development of Search Skills and Spatial Representation. Hillsdale, N.J.: Erlbaum, (in press).

Lederman, S.J. The Perception of Texture By Touch. In W. Schiff and E. Foulke (Eds.), Tactual Perception a sourcebook. Cambridge: Cambridge University Press, 1982, 130-167.

Lederman, S.J. and Campbell, J.I. Tangible Graphics for the Blind. Human Factors, 1982, 24 (1), 85-100.

Lederman. S.J., Klatzky, R.L. and Barber, P.O. Spatial and Movement-Based Heuristics for Encoding Pattern Information Through Touch. Journal of Experimental Psychology: General, 1985, 114 (1) 33-49.

Leonard, J.A. and Newman, R.C. Spatial Orientation in the Blind. Nature, 1967, 215 (5108), 1413-1414.

Leonard, J.A. and Newman, R.C. Three Types of Maps for Blind Travel. Ergonomics, 1970, 13, 165-179.

Lindeberg, E. and Garling, T. Acquisition of Locational Information About reference points During Blindfolded and Sighted Locomotion: Effects of a Concurrent Task and Locomotion Paths. Umea, Sweden: University of Umea, Umea Psychological Reports, No. 144, 1978.

Lockman, J.J., Reiser, J., and Pick, H.L. Assesing Blind Travelers' Knowledge of Spatial Layout. Journal of Visual Impairment and Blindness, 1981, 7, 321-326.

McReynolds, J. and Worchel, P. Geographic Orientation in the Blind. Journal of General Psychology, 1954, 51, 221-236.

Magee, L.E. and Kennedy, J.M. Exploring Pictures Tactually. Nature, 1980, 283, 287-288.

Maglione, F.D. An Experimental Study of the Use of Tactual Maps As Orientation and Mobility Aids for Adult Blind Subjects. University of Illinois: Unpublished Doctoral Dissertation, 1969.

Marmor, G.S. and Zaback, L.A. Mental Rotation By the Blind. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 515-521.

Millar, S. Spatial Memory By Blind and Sighted Children. British Journal of Psychology, 1975, 66 (41), 449-460.

Millar, S. Spatial Representation By Blind and Sighted Children. In G. Butterworth (Ed.), The Child's Representation of the World. New York: Plenum Press, 1977, 129-138.

Millar, S. The Utilization of External and Movement Cues In Simple Spatial Tasks By Blind and Sighted Children. Perception, 1979, 8, 11-20.

Millar, S. Crossmodal and Intersensory Perception and the Blind. In Walk, R.D. and Pick, H.L. (Eds.) Intersensory Perception and Sensory Integration. New York: Plenum Press, 1981.

Millar, S. Self-Referent and Movement Cues in Coding Spatial Location By Blind and Sighted Children. Perception, 1981, 10, 255-264.

Millar, S. Studies of the Deaf and Blind. In A. Burton (Ed.) The Pathology and Psychology of Cognition. London: Methuen & Co., Ltd., 1982, 135-168.

Millar, S. The Problem of Imagery and Spatial Development in the Blind. In B. de Gelder (Ed.), Knowledge and Representation. London: Routledge & Kegan Paul Ltd. 1982, 111-120.

Monmonier, M.S. Maps, Distortion, and Meaning. Washington, D.C.: Association of American Geographers, Resource Paper No. 75-4, 1977.

Morrison, J.L. A Theoretical Framework for Cartographic Generalization with Emphasis on the Process of Symbolization. International Yearbook of Cartography, 1974, XIV, 115-127.

Morrison, J.L. The Science of Cartography and Its Essential Processes. Cartographica, 1977, No. 19, 58-71.

Muehrcke, P. Thematic Cartography. Washington, D.C.: Association of American Geographers, Resource Paper, No. 19, 1972.

Muehrcke, P. Concepts of Scaling from the Map Reader's Point of View. American Cartographer, 1976, 3 (2) 123-141.

Neisser, U. Cognition and Reality. San Francisco: W.H. Freeman and Co., 1976.

Neisser, U. Anticipations, Images, and Introspection. Cogntion 1978, 6, 169-174.

Nolan, C.Y. and Morris, J.E. Improvement of Tactual Symbols for Blind Children. Louisville, Kentucky: American Printing House for the Blind, 1971.

Petchenik, B. Cognition in Cartography. Cartographica, Monograph No. 19, 1977, 117-128.

Piaget, J. and Inhelder, B. The Child's Conception of Space. New York: Norton, 1967.

Pick, H.L., Jr. Perception, Locomotion, and Orientation. In R.L. Welsh and B.B. Blasch (Eds.) Foundations of Orientation and Mobility. New York: American Foundation for the Blind, 1980, 73-88.

Pick, H.L., Jr. Tactual and Haptic Perception. In R.L. Welsh and B.B. Blasch (Eds.) Foundations of Orientation and Mobility. New York: American Foundation for the Blind, 1980, 89- 113.

Preiser, W.F. A Combined Tactile/Electronic Guidance System for the Visually Handicapped. J.W. Wiedel (Ed.), Proceedings of the First International Symposium on Maps and Graphics for the Visually Handicapped Washington, D.C.: Association of American Geographers, 1983, 86-98.

Preiser, W.F. and Brecht, M. Design and Evaluation of a Tactile Building Directory for the Visually Impaired. In A.E. Osterberg, C.P. Tiernan, and R.A. Finlay (Eds.), Design Research Interactions, 12th International Conference. Ames, Iowa: Environmental Design Research Association, 1981.

Psathas, G. Mobility, Orientation, and Navigation: Coceptual and Theoretical Considerations. The New Outlook, 1976, November, 385-391.

Ratajski, L. The Research Structure of Theoretical Cartography. International Yearbook of Cartography, 1973, XIII, 217-228.

Revesz, G. The Psychology and Art of the Blind. London: Longmans, Green, 1950.

Rieser,J., Guth, D.A., and Hill, E.W. Mental Processes Mediating Independent Travel: Implications for Orientation and Mobility, Journal of Visual Impairment and Blindness, 1982, June, 213-218.

Rieser, J., Lockman, J.J., and Pick, H.L., Jr. The Role of Visual Experience in Knowledge of Spatial Layout. Perception and Psychophysics, 1980, 28 (3), 185-190.

Robinson, A.H. and Petchenik, B. The Nature of Maps. Chicago: University of Chicago Press, 1976.

Robinson, A., Sale, R., and Morrison, J. Elements of Cartography. New York: John Wiley and Sons, 1978.

Rosencranz, D. and Suslick, R. Cognitive Models for Spatial Representations In Congenitally Blind, Adventitiously Blind, and Sighted Subjects. New Outlook for the Blind, 1976, 70, 188-194.

Salichtchev, K.A. Cartographic Communication/Its Place in the Theory of Science. Canadian Cartographer, 1978, 15 (2), 93-99

Schiff, W. Tangible Graphics: A User's View. In W. Schiff and E. Foulke (Eds.), Tactual Perception a sourcebook. Cambridge: Cambridge University Press, 1982, 430-453.

Schiff, W. and Foulke, E. Tactual Perception a sourcebook. Cambridge: Cambridge University Press, 1982.

Schmitt, T.L. Early Experience and Spatial Functioning in the Blind. Riverside, California: University of California, Unpublished Doctoral Dissertation, 1978.

Sharan, P. Possibilities and Limits of the Use of Tactile Representations in Training of Blind Pupils. International Conference on Tactile Representations for the Blind. Berlin, G.D.R.: 1984.

Shingledecker, C.A. The Effects of Anticipation on Performance and Processing Load in Blind Mobility. Ergonomics. 1978, 21 (5), 355-371.

Shingledecker, C.A. Measuring the Mental Effort of Blind Mobility. Journal of Visual Impairment and Blindness, 1983, 77 (7), 334-339.

Shingledecker, C.A. and Foulke, E. A Human Factors Approach to Assessment of the Mobility of Blind Persons. Human Factors, 1978, 20, 273-286.

Simpkins, K.E. Development of the Concept of Space. Journal of Visual Impairment and Blindness, 1979, 73 (3), 81-85.

Simpkins, K.E. Tactual Discrimination of Household Objects. Journal of Visual Impairment and Blindness, 1979, 73 (3), 86-92.

Simpkins, K.E. Tactual Discrimination of Shapes. Journal of Visual Impairment and Blindness, 1979, 73 (3), 93-101.

Stephens, M.A. and D'Agostino, R.B. Goodness-Of-Fit Techniques . New York: Marcel Dekker, 1986.

Swallow, R.M. and Poulsen, M.K. Application of Piagetian Theory to the Concept of Space in Visually Limited Children. Proceedings, Second Annual U.A.P. Conference - Piagetian Theory and the Helping Professions. Los Angeles, California: 1972, 39-43.

Turk, A. Blind Leading the Blind. J.W. Wiedel (Ed.), Proceedings of the First International Symposium on Maps and Graphics for the Visually Impaired. Washington, D.C.: Association of American Geographers, 1983, 1-9.

Von Senden, M. Space and Sight (P. Heath, trans.). London: Methuen & Co., Ltd., 1960. (Originally published, 1932).

Warren, D.H. and Pick, H.L., Jr. Intermodality Relations in Localization in Blind and Sighted People. Perception and Psychophysics, 1970, 8 (6), 430-432.

Warren, D.H., Anooshian, L.J. and Bollinger, J.G. Early versus Late Blindness: Role of Early Vision in Spatial Behavior. American Foundation for the Blind Research Bulletin, 1973, 26, 151-170.

Warren, D.H. and Kocon, J.A. Factors in the Successful Mobility of the BLind. American Foundation for the Blind Research Bulletin , 1974, 28, 191-218.

Webster's New Encyclopedia Dictionary. Springfield, Mass.: G. and C. Merriam Co., 1975.

Welsh, R.L. and Blasch, B.B. Foundations of Orientation and Mobility. New York: American Foundation for the Blind, 1980.

Wiedel, J.W. (Ed.). Proceedings of the First International Symposium on Maps and Graphics for the Visually Impaired. Washington, D.C.: Association of American Geographers, 1983.

Wiedel, J.W. and Groves, P.A. Tactual Mapping: Design, Reproduction, Reading and Interpretation. College Park, Maryland: University of Maryland, Occasional Papers in Geography, No. 2, 1972.

Wood, D. Introducing the Cartography of Reality. In D. Ley and M.S. Samuels (Eds.), Humanistic Geography. Chicago: Maaroufa Press, Inc., 1978, 207-219.

Worchel, P. Space Perception and Orientation in the Blind. Psychological Monographs, 1951, 65 (15, Whole No. 332).

APPENDIX A

Directions for Map Use

Map Instructions - Scarfe Building

For this portion of the study you will be blindfolded and provided with a map. This map is to be used as an aid to mobility while walking through the second floor of the Scarfe Building, Classroom Block. En route, you will be encouraged to identify several landmarks in the environment and on the map. I will record what you locate. You will be timed as you move from one landmark to the next one. When you arrive at a landmark, please stop in order that notes can be made. I will be with you as you pass through the hall to prevent from any mishaps occurring. You will be provided with a map with either a fixed-scale or a flexible-scale, which has been derived from a visually impaired person's perspective. Please keep in mind that this is a collaborative effort. We are evaluating the maps and not your personal performance specifically. You are welcome to ask questions at any time. You may use any other mobility aid that you are accustomed to traveling with.

Now, take the time to scan the map. We will be working through the whole hallway. Once you are comfortable with the map, we will begin the evaluation. We will be going through the hallway twice. On both passages, please locate the following six landmarks.

Begin at the entrance doors and move through the hall, ending at the exit doors. Locate:

1. the drinking fountain;
2. the aquarium.

Begin at the exit doors and move through the hall, ending at the entrance doors. Locate:

1. the bird cage;
2. the iguana cage;
3. the chinchilla cage;
4. the fire extinguisher.

We will then follow the routes in reverse. I will repeat the list of landmarks before each trip through the hallway.

Map Instructions - Law Building

For this portion of the study you will be blindfolded and provided with a map. This map is to be used as an aid to mobility, while walking through the main floor hallway of the Law Building. En route, you will be encouraged to locate several landmarks both on the map and in the environment. I will record what you locate. You will be timed as you move from one landmark to the next one. When you arrive at a landmark, please stop in order that notes can be made. I will be with you as you walk to prevent from any mishaps occurring. You will be provided with a map with either a fixed-scale or a flexible-scale, which has been derived from a visually impaired person's perspective. Please keep in mind that this is a collaborative effort. We are evaluating the maps and not your personal performance specifically. You are welcome to ask questions at any time. You may use any other mobility aid that you are accustomed to traveling with.

Now, take the time to scan the map. We will be working through the main hallway and the corridor branching to the right. Once you are comfortable with the map, we will begin the evaluation. You will be passing through the hallway twice, and locating six landmarks.

Begin at the entrance doors and continue through the hall, ending at the exit doors located at the end of the right-branching hallway. Locate:

1. the plant;
2. the drinking fountain;
3. the telephones;
4. the drinking fountain.

Begin at the exit doors and return to the entrance doors. Locate:

1. the second pillar, located after the planter;
2. the photocopier.

We will then follow the route in reverse. I will repeat the list of landmarks before each trip.

Verbal Map Directions

Verbal Map Directions - Scarfe Building

For this portion of the study you will be blindfolded and given specific verbal directions, which will enable you to walk through the second floor hallway of the Scarfe Building, Classroom Block, without a map. I will be with you as you walk to prevent from any mishaps occurring. En route, you will be encouraged to locate six landmarks and I will record what you identify. You will be timed as you proceed from one landmark to the next one. Please stop when you locate a landmark, so that notes can be made. You will be passing through the hall twice, following different routes. To enable you to fulfil the task with the least amount of trouble, please listen to the instructions carefully. I will repeat them twice, before each passage. You are welcome to use any other mobility aid that you are accustomed to traveling with.

ROUTE I

- You are now at the main entrance to the Scarfe Building, Classroom Block, second floor. The hall is essentially "L" shaped. On this route you will be locating two landmarks.
- Using the wall on your left as a guide, follow it until it turns 90 degrees to the left. At the corner, turn left and continue to follow the wall a short distance. Locate the first landmark - a drinking fountain. Stop.
- Continue forward a short distance, bypassing two alcoves, and locate the aquarium. Stop.

- Continue to use the wall on your left side and walk to the end of the hall, bypassing four alcoves. Stop at the glass exit doors facing you.

ROUTE II

- Beginning at the glass exit doors, track the wall on your left (the opposite side to which you were just moving along). You will be locating four landmarks.
- Proceed forward a few feet, until you locate the first landmark - a bird cage, which protrudes into the hall. Stop.
- Continue down the hall, bypassing five alcoves and locate a second animal cage. This distance will be longer. When you locate it, stop.
- Continue forward past one alcove, which will be a short distance. Locate a third animal cage. Stop.
- The final landmark to find is a fire extinguisher, located on the other side of the hall. Walk to the end of the hall, past three alcoves. Turn right and walk a few feet and then turn right again. Pass by two alcoves and walk to the end of the wall. You are now standing at a corner in the hall. Locate the fire extinguisher, which is positioned on the corner. Stop. Turn left 90 degrees and walk to the end of the corridor to the main entrance, where you began.

Verbal Map Directions - Scarfe Building

For this portion of the study you will be blindfolded and given specific verbal directions, which will enable you to walk through the first floor hall of the Law Building without a map. En route, you will be encouraged to locate six landmarks and I will record what you notice. You will be timed, as you proceed from one landmark to the next one. Please stop when you locate the landmark, in order that notes may be taken. You will be passing through the hallway twice, following different routes. To enable you to fulfil the task with the least amount of trouble, please listen to the instructions carefully. I will repeat them twice prior to each passage. You are welcome to use any other mobilty aid that you are accustomed to traveling with.

ROUTE I

- You are now at the main entrance of the first floor hall of the Law Building. Use the wall on your left side as your guide. Proceed ahead.
- Locate the first landmark just after you have started walking - a plant. Stop.
- Follow the wall a short distance until you locate a drinking fountain. Stop.
- The wall will become angled, encompassing entrances into a library and another hall, as well as an information booth. The doors open out into the hall, so be careful. Just after the information booth, the wall becomes a glass

window/wall. Follow it to the end.

- At the end of the glass wall, you will encounter an open space. Walk straight ahead, crossing that open area, until you reach a corrugated wall in front of you. Turn 90 degrees to your right and follow the wall (now on your left side). Bypass a small alcove, until you arrive at a set of doors, opening toward you. Go through the doors and continue along the left side of the hall.
- Locate the telephones and stop. This is the third landmark.
- Continue to follow the wall on your left. You will be making a 90 degree turn to your left immediately after the phones. Pass by a set of shelves, within which there is a door. Locate a drinking fountain just past the shelves. Stop.
- Proceed to the end of the hall, past two pillars, to the exit doors at the end of the hall. Stop.

ROUTE II

- This passage will take you back to the original starting point, which are the entrance doors. Follow the right side of the corridor (the same side that you just traveled). Go through the set of doors and now keep to the left-side of the main hallway.
- Go around the ramp. If need be, use the ramp's hand-rail to guide you. At the end of the ramp, on your left, there will be no wall, instead a small set of stairs will be in front of you. Do not go up them, but use them as a guide to follow on your left. They are long and encompass an

elevated lounge.

- Positioned within the stairs are a concrete planter and two pillars, located before and after the planter. Locate the second pillar, just past the planter. Stop. You are now approximately half way through the hall.
- The next landmark to be identified is near the entrance doors - a photocopier. To find the photocopier continue to follow the stairs in the same manner. They will turn to the left. After the turn, you will approach a wall ahead of you. This is the end of the stairs. Go around it and walk past a set of stairs, which lead to the second floor. Past the stairs, the wall becomes angled incorporating two small alcoves. Walk past these and locate the photocopier. Stop.
- From this point, walk straight ahead about ten feet and you will be at the entrance again. Stop.

APPENDIX B

<u>Personal History Questionnaire</u>

Name:

Address:

Telephone Number:

Education Level:

Vision Level:

Onset of Visual Impairment:

Mobility Aid Use:

Extent of Mobility Aid Use:

Exposure and Use of Tactual Maps:

Braille Proficiency:

Familiarity with Scarfe Building 2nd Floor:

Familiarity with Scarfe Building 3rd Floor:

Familiarity with Law Building: