

DEVELOPMENT AND ASSESSMENT OF A TACTILE MOBILITY MAP FOR THE
VISUALLY IMPAIRED

by

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DEVELOPMENT AND ASSESSMENT OF A

TACTILE MOBILITY MAP FOR THE

VISUALLY IMPAIRED

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ABSTRACT

Independence of mobility remains a pressing problem for the visually impaired. Even with the technological and engineering advances of the last two decades, blind individuals still rely heavily on assistance from orientation and mobility instructors to expand their activity space and learn new routes. Whereas many blind people have sufficient orientation and navigation skills for safe and effective locomotion in familiar areas, they often lack sufficient knowledge of the structure of unfamiliar space to allow them to feel secure in their movements. Research on tactile mobility maps represents an attempt to enhance independence of mobility by providing the map reader a more comprehensive image of the structure of space and its component parts.

This thesis attempts to evaluate the effectiveness of a tactile mobility map as a navigation aid to assist travel along unfamiliar routes. The travel performance of two groups of functionally blind subjects over a test route was compared, one group using a tactile map to navigate and the other navigating based on memorization of the route after a single walk through. Subjects were assigned to the groups to assure a balance of fast and slow travelers in each group. Each subject's performance was assessed in terms of the speed of movement and the number of navigation errors. In addition, the map reading behaviours and comments of the map users were recorded and analyzed.

The results showed that the map could be used to plan and travel an unfamiliar route, but that navigation with the map was more cumbersome than navigation based on first-hand experience. Subjects using the map took substantially longer to complete the route and made significantly more navigation errors in the process. From the comments and observed reading behaviours of the map users it was apparent that map reading skills declined significantly from the pre-test planning stage to the active travel stage. The cognitive demands of travel along an unfamiliar route were such that the introduction of a secondary task overloaded the capacity of the subjects to respond effectively, diminishing their performance in the primary task (orientation and mobility) and the secondary task (map interpretation).

The study concluded that training in the use of tactile maps is essential if such devices are to become effective aids to orientation and mobility. In the rush to improve design and reproduction techniques little attention has been paid to the needs of the map user. Future research must concentrate on the development of systematic map training programmes for the visually impaired.

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DEDICATION

To my mother and father

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CHAPTER I

INTRODUCTION

There has been an increasing interest over the past two decades in various applications of tactile maps for the blind as more tactile graphics have become available to the visually impaired population. One area of particular interest to peripatologists and geographers has been the use of tactile maps as mobility and orientation guides to increase the activity space of the visually impaired.

This study evaluates the efficacy of tactile maps as aids to independent travel for the visually impaired, by attempting to determine how successfully blind students at Vancouver Community College could employ a tactile map of the campus to plan and walk an unfamiliar route within the campus building.

This chapter examines the need for this type of research and reviews the literature that deals with tactile maps. Chapter 2 outlines the method used. Chapter 3 describes the design and production of the campus map. The results of the mobility tests and a discussion of the findings appear in chapter 4, and chapter 5 provides a summary, conclusion and suggestions for future work.

PROBLEM STATEMENT

One of the most significant problems facing a blind person is the attainment of independent mobility in unfamiliar environments. While many blind people have sufficient orientation and navigation skills for safe and effective locomotion in familiar environments, they invariably lack sufficient knowledge of the structure of unfamiliar space to allow them to feel secure in their movements (Simpkins, 1979). Independent navigation, that is, purposeful, self-directed movement from one place to another, depends largely on the ability to maintain spatial orientation that provides the traveler with a moment-to-moment knowledge of his immediate environment and enables him to control his movements with respect to the features of that environment. Visual impairment substantially reduces the amount of information that an individual receives from the environment since up to 80% of our knowledge of space is derived from vision¹. A sighted person can use vision instantaneously to receive detailed information about the route he is following, the obstacles and features he may encounter along that route, and the landmarks he can use to fix his position in space. The blind person is less capable of making such a detailed inventory of the route since his remaining vision, if any exists, and his auditory, kinesthetic and haptic senses provide only a narrow and fragmented image of the route. Therefore, when faced with an unfamiliar setting, the

^①see Simpkins (1979)

blind traveler may be unable to gather the information about his surroundings needed to effectively orient himself. Even if enough environmental information were available, he might still find orientation extremely difficult. Shingledecker (1983) suggests that the cognitive demands of blind travel are so great that the individual's travel performance rapidly declines when he encounters a new set of environmental stimuli. The auditory and haptic senses (and remaining vision) may be incapable of receiving and processing the type of information that is essential for safe and stress-free navigation. The mental effort of travel in unfamiliar areas may therefore deter many individuals from exploring new routes.

Efforts to assist visually impaired individuals in achieving greater independence of mobility have been of two types (Shingledecker, 1983). The first involves instruction from Orientation and Mobility (O & M) specialists in travel skills that are tailored to suit the physical capabilities and social needs of the individual. The second type of approach involves the development of sensory aids designed to "enhance the ability of the functioning sensory systems to acquire the spatial information upon which successful mobility depends".

(Shingledecker, 1978, p.274) These aids have been many and varied, ranging from the relatively simple innovation of the Long Cane to advanced electronic devices like the Pathfinder which converts ultrasonic pulse-echos from the environment into an auditory image that can be understood by the observer. The

tactile map is another type of sensory aid that conveys information about the environment to the reader in a tactile format.

Tactile maps can assist orientation and mobility in a number of ways

1. They can help individuals overcome their ambiguous and inaccurate concepts of the world (Gibson et al., 1965). People blinded at an early age often have confused and distorted impressions of environmental features as they not only lack visual imagery, but also invariably have limited direct experience of the features in the environment. These incomplete and distorted images of space have meant that blind children often lack confidence in their ability to travel and are discouraged from exploring new space. Bentzen (1980) documents a number of examples in which maps have been useful in helping congenitally blind subjects understand the form of different types of intersections to avoid veering when crossing these features.
2. Maps can provide a framework for understanding the component parts of space and their geographical relationship (Gibson et al., 1965; Bentzen, 1980). Visually impaired people often learn about the make-up of space through verbal descriptions; a disadvantage of this method of learning about that space is that it provides an incomplete cognitive map of space. A cognitive map is a learned mental image of the environment (James, 1982), in which the individual can

store information received from the environment and from which he can recall and manipulate information about the environment that may be required for successful travel (Downs and Stea, 1977). If a person's understanding of space is based on a sequence of verbal images, or on sensory information from the remaining non-visual senses, his internal representation of that space is likely to be loose and piecemeal, lacking any substantial integration and organization into a realistic framework of the relationship of objects in space (Revez, 1950). Without vision, an understanding of the relationship of objects in space is difficult to achieve. Maps can provide a means by which a Gestalt of environmental relationships can be appreciated and a comprehensive spatial frame of reference devised. Through the map the individual can envision not only the objects and features that make up space but also how they are related to one another.

3. It has also been suggested that maps can help reduce the memory load which characterizes the blind mobility problem (Bentzen, 1980). In order to progress along a route one must be aware of his position in relation to the start and finish. The sighted traveler can normally gain his bearings during travel by referring to a variety of visual cues along the route. He does not need to refer to a memorial representation of that route for every step he takes because the visual cues can often be used to fix his position in space from some distance. On the other hand, the blind

traveler is often deprived of visual cues and cannot benefit from the rich supply of information that characterizes sighted travel. The blind pedestrian is not always able to use landmarks to 'fix' his position in space and must therefore maintain an ongoing record of travel, remembering such things as the number of street crossings or turns that have been made. This method of keeping track "imposes additional demands on the blind person's short term memory and is yet another processing activity that must be carried out during the mobility task" (Shingledecker, 1983, p.335). A map may offer some of the information that is needed to 'fix' one's position in space and therefore to reduce the heavy memory load of blind mobility.

4. Maps can provide a preview of the environment. Environmental preview enables the traveler to anticipate upcoming objects and features in the environment so that appropriate decisions and actions can be formulated into an effective response strategy. Perceptual anticipation is a necessary condition for the formulation of an effective response strategy (Barth & Foulke, 1979). A blind pedestrian receives minimal preview and important events can therefore catch the traveler unaware with a flood of information for which no actions have been devised. Incapable of processing and transmitting the information rapidly enough, the traveler becomes confused and disorientated.

DEFINITIONS

The following terms are used extensively and are defined to avoid confusion:

MOBILITY

The physical process of locomotion, encompassing self-propelled movement of the individual in relation to spatial features (Foulke & Berla, 1979). Mobility comprises a group of skills which must be mastered if a person is to move safely from place to place.

ORIENTATION

A skill which provides the traveler with a moment-by-moment awareness of the immediate environment through a knowledge of the make-up of that space. It involves knowing where objects and features are in the environment, their relationship to one another, and their relationship to the traveler and his/her body.

NAVIGATION

Entails purposeful self-directed movement between predetermined starting and destination points. For an individual to navigate effectively, he/she must be proficient in orientation and mobility skills.

LITERATURE REVIEW

Tactile maps are not an invention of the modern technological age; in fact the production of single copy maps goes back to the 18th century. The earliest known tactile images were produced by

embossing paper and by sewing beads and threads into linen (Bentzen, 1972). Although the custom designed single copy maps were of use to those blind individuals who came in contact with them, they were not readily available to the blind population at large. It was not until the 1960's and 1970's that printing technology was extensively used for the reproduction of multi-copy maps, making tactile maps available to a large population. With improved production and reproduction techniques and the increasing availability of tactile maps, academic interest in tactile maps blossomed amongst mobility specialists, educators of the blind, psychologists, geographers and cartographers.

Tactile maps fall into two broad categories: 'functional maps' which can be used as orientation and mobility guides to provide information about the layout of the environment at a large scale; and 'geographic' maps which are essentially thematic maps, portraying information about the distribution of features in space. The majority of the research that has been undertaken has concentrated on geographic maps as aids that can be used in classroom teaching. Functional maps have not received as much interest because they have been very slowly adopted, if at all, into the orientation and mobility training of blind individuals (Wiedel & Groves, 1969a). Although individual O & M specialists have used maps in their training programmes, only the United Kingdom has a systematic programme for the use of tactile maps in mobility training. Research specifically dealing

with the utility of mobility maps has therefore been limited as there is little familiarity with, or experience of, mobility maps among the blind population. Although little research has been done on the application of mobility maps, there is a fairly extensive body of literature that deals with design principles for tactile maps of both functional and thematic kinds. The first part of this literature review outlines some of the important cartographic principles which must be considered when designing a tactile map, and the second examines the research that has been undertaken on the application of tactile mobility maps.

MAP DESIGN

The essential problem for the cartographer in making maps an effective communication form is to determine principles, materials and techniques that can best provide the blind with the stimulation required to effect perception of the map (Hway-Hwa Kuo, 1978). Unfortunately, many tactile maps have been produced by people who know little about haptic perception; consequently the maps have been designed without proper consideration of the capabilities and limitations of the haptic sense (Nolan & Morris, 1971; Bentzen, 1980; James, 1982; Berla, 1982; Lederman, 1982). The tactual acuity of the fingertips is far inferior to the visual acuity of the eyes; the millions of nerve fibres in the eye are capable of receiving and transmitting minute detail from a map, whereas the sense of

touch is only capable of two point discrimination at distances of greater than 2.3mm, or 0.090in (Nolan & Morris, 1971). As the acuity of the fingertips is much poorer, far less information can be presented on a tactile map than on a printed map. In many cases in the 1960's and 1970's tactile maps failed because they were direct transliterations of visual maps and invariably contained too much detail for the blind.

INFORMATION CONTENT

When designing a tactile graphic one needs first to determine the type of information to be included on the map and second, to assess how much of this information can be portrayed on the map without making the display illegible to the intended reader. Although these considerations depend on the objective of the map and the capabilities of the reader, there are some general rules:

1. Information should be kept to a minimum. Only the information that is absolutely necessary to the task should be included (Armstrong, 1973; Gill, 1974; Bentzen, 1980; Prieser & Bercht, 1981; Horsfall & Cox, 1984). Tactual exploration is extremely slow and laborious when compared to vision (Castner, 1983) and an excess of information (over and above the task for which the map is intended) may obscure the most important features and relationships on the map.
2. The information that is chosen, in the case of a mobility

map should be selected on the basis of a personal exploration of the area to be mapped by a trained O & M specialist. Wiedel and Groves (1969b) maintain that this is necessary as the map must include only that information that is of significance to the orientation and mobility of the blind traveler. Some tactile mobility maps may include information that is nonvisual, like prominent smells and sounds in the environment (sensory cues which can often be helpful to the blind travelers).

3. In general, information density can increase as the reader develops a more extensive understanding of maps (Wiedel & Groves, 1969b). Kidwell & Greer (1973) found in tests with their complex map of the Massachusetts Institute of Technology, that some blind students actually preferred too much information to too little.
4. One way of including a high density of information on a map without confusing the reader is to display the information in progressive steps using underlays and overlays. Angwin(1968), Wiedel & Groves (1969b), Kidwell & Greer (1973) and Armstrong (1973) have all designed maps which use underlays and overlays. The best example of this technique is to be found in Bentzen's map of the Perkins School for the Blind. The campus map included 4 levels or overlays, a top sheet with braille labels and a grid, a sheet under that with the dominant features of the campus, below that a sheet showing the buildings and walkways, and a base map which contains information essential for independent route

planning.

MAP SIZE

As Nolan and Morris (1971) point out, the size of a tactile map is a compromise that is made necessary by the paradox and limitations of touch. The perceptual span of touch is limited by the span of the hands and the area that can be covered in one instant by the fingertip. Because the reader gathers information in a very slow and laborious manner it is best to make maps as small as possible to accommodate the very limited perceptual window of the fingertips. In comparison with vision however, tactual acuity is coarse, and therefore, to be discriminated tactile figures must be larger than visual figures on a map (Nolan & Morris, 1971). Researchers generally agree that the optimal size for maps is roughly equivalent to the span of both hands (James & Armstrong, 1976; Bentzen, 1980; Berla, 1982). The map reader can then use his hands as a reference network to locate features on the map.

SCALE

Uniformity of scale is normally implicit in the design of large scale visual maps. Such is not the case in the design of graphics for the blind; indeed parts of tactile maps would be rendered illegible if they were designed with a constant scale. Bentzen (1980) and Nolan & Morris (1971)

point out that the map designer must often exaggerate the distance between features on the map in order that the reader may distinguish two symbols as separate.

Many workers have shown that a consistent scale is less useful than schematization (Wiedel & Groves, 1969b; James, 1972; Kidwell & Greer, 1972; Armstrong, 1973; Amendola, 1976; Bentzen, 1980; Castner, 1983). In recent studies, Jansson (1983) and Preiser & Bercht (1981) have shown that a distorted scale can actually help students create a more complete mental image of a route than can a fixed scale. As blind travelers judge distance primarily by time taken to complete a journey and by the number of landmarks encountered along the route, it is often preferable to design route maps with a varying scale, so that relatively uneventful sections are shown to be shorter and relatively eventful sections are longer (James, 1972).

SYMBOL CHOICE

The three types of symbols used in tactile map design are: point, areal and linear. The choice of symbols is based on

- a. discriminability - how easily they can be recognized as distinct from other symbols by the tactual sense.
- b. discernability - how symbol design can help readers to remember their meaning.

There has been much research over the past decade by psychologists, geographers and educators of the blind to

identify discriminable sets of symbols (Heath, 1958; Morris, 1961; Schiff, 1966; Wiedel & Groves, 1969a; Nolan & Morris, 1971; Gill & James, 1973; James & Gill, 1975; Berla & Butterfield, 1977; Bentzen & Beck, 1979; Easton & Bentzen, 1980; Horsfall & Vanston, 1981). The largest set of discriminable point and linear symbols was determined in experiments by Gill & James (1973) to be thirteen and ten respectively. Nolan & Morris (1971) confirmed the largest set of areal symbols to be eight. Since there is no common method for producing maps, standardization of discriminable symbol sets is neither appropriate nor possible.

A large body of literature deals with design factors which contribute to the traceability of line symbols, but no consensus exists as to the best design for lines. The research to date has produced conflicting conclusions: in some tests a broken line was easier to trace than a smooth line (Wiedel & Groves, 1966; Leonard, 1966a; Angwin, 1968), in other tests single smooth lines were found to be better (Gill, 1973; Bentzen & Peck, 1979; Easton & Bentzen, 1980) and in others, double lines with a tracing furrow were traced most efficiently (Amendola, 1976; Berla & Butterfield, 1977; Brambring & Laufenberg, 1979). As Barth (1983) pointed out, there may simply be no optimal line design, as the appropriateness of any particular design may ultimately depend on the haptic acuity of the reader and the medium in which the map is being produced.

Researchers have also looked at the ways in which symbol discernability can be enhanced to permit the retention of symbol meaning. Schiff (1966) successfully designed a directional tactile arrow that was used to represent linear flow information. Wiedel & Groves (1969a) further developed Schiff's arrow to design a stair symbol that indicated both the orientation of the staircase and the direction of movement (i.e., up or down). The most extensive research in this area has been undertaken by James & Gill (1974) who conducted a series of experiments with blind students to assess the degree to which subjects could retain learned symbol meanings. The results of the tests formed the basis for the design of the symbols that were subsequently used in the Nottingham Map Kit², a map-making process that has now been adopted internationally³.

FIGURE-GROUND RELATIONSHIPS AND BACKGROUND NOISE

Figure and ground relationships have to be considered in the design of any type of map if the cartographer is to communicate effectively the important data to the reader. The success of a map as a communication device will largely depend on how well the reader perceives the elements in the figure and ground relationship. The figure elements of a map comprise the thematic data of current interest, while the ground elements include the frame of reference (base map) in which the thematic information

²see James & Armstrong 1976.

³ the kit was adopted by the 1st International Symposium on Tactile Maps for Urban Areas in Europe 1983.

is placed. Hway-Hwa Kuo's doctoral thesis (1978) is a most comprehensive study of figure-ground relationships in tactile mapping. In tests conducted with adventitiously and congenitally blind students, Hway-Hwa Kuo showed the importance of ground elements in the comprehension of figure information on tactile maps. Maps in which only half of the haptic field was covered by areal pattern were difficult to comprehend because the ground (areal pattern) was perceived as part of the thematic information of the map. Furthermore, subjects could not distinguish between surfaces on the map if they were separated by lines alone. The author concluded that heterogeneous surfaces were necessary on maps if the figure information was to stand out from the tactual field.

Berla & Murr (1975) have undertaken extensive research in the same area but their results conflict with Kuo's. Their research looked at the effect of background information ('noise') on the location and recognition of figure information (point and line symbols). In tracing tests with seventy-two braille reading students, Berla & Murr (1975) found that areal texture (ground information) actually decreased the accuracy and efficiency of line tracing and symbol identification on political pseudo-maps. Berla and Murr's (1975) findings seem to be more applicable to maps that require the recognition of shape alone (i.e., outline maps of states and countries); maps which include a wider variety of thematic information should include areal texture to enhance figure-ground relationships.

LABELLING AND INDEXING

- a. LABELLING - Bentzen (1980) points to the fact that labelling on tactile maps often increases the problems of information density, scale and the choice of symbol size. Unlike print, braille cells cannot be reduced in size and so the inclusion of braille labels will often clutter the map (Wiedel & Groves, 1969). Wiedel & Groves devised a way to reduce the clutter by the addition of braille labels and by the elevation of the symbols above the braille so that the labels could be distinguished clearly from the symbols. Clutter can also be reduced by using braille abbreviations (Bentzen, 1980). Alternatively, all of the braille can be included on an overlay (Angwin, 1968; Wiedel & Groves, 1969a; Kidwell & Greer, 1973).

Braille should normally run in the same (east-west) direction. However, Bentzen (1980) maintains that it can also be placed in a north-south direction.

- b. GRID - On large maps it is often helpful for the reader to have the use of a tactile grid to assist the location of specific points. Haptic scanning is much more time-consuming than is visual scanning and it is therefore important that the map designer ease the burden of haptic search with the provision of a reference grid. Grids have been used on a number of maps (Kidwell & Greer, 1972; Bentzen, 1982; Squirrel & Horsfall, 1982).

MAP ORIENTATION

Most designers of mobility and educational maps for the blind consider that compass directions are essential for effective map orientation, since a lot of blind people use polarcentric reference systems for mobility and orientation. Wiedel & Groves (1969b) suggested that the north edge of the map should be marked with a distinctive line and that the traditional compass rose was of no value because it was not tactually distinctive. James (1975) designed a special line texture for the north edge of maps, that is now included in the Nottingham Mobility Kit.

KEY AND PRINTED INTRODUCTION

A key is often confusing for the blind reader and, as James (1975) points out, it may significantly detract from map comprehension. Other researchers suggest that whenever possible there should be a verbal introduction to the map to complement the brailled introduction (Kidwell & Greer, 1973, Bentzen, 1972). Keys should not appear on the same sheet as the map, as they may be confused with the map itself.

MOBILITY EXPERIMENTS

That there is a paucity of research into the application of tactile maps as orientation and mobility aids for the visually impaired is partly due to the limited attention given to such devices by O & M experts. Of the eight studies dealing with

tactile mobility maps that the present writer found in the literature, only two were conducted by O & M specialists, the remainder were by geographers, psychologists and architects. Indeed, there seems to be a good deal more interest in tactile mobility maps from academics than from practitioners working with the blind.

Leonard and Newman (1967) were the first to demonstrate that congenitally blind school children could use tactile route maps to navigate in unfamiliar urban areas. In a series of mobility experiments in the streets of Leamington Spa, blind students were provided with tactile maps of a route and asked to complete it unassisted. Although the results of this and later experiments (Leonard & Newman, 1970) were encouraging, they dealt only with the route map which is extremely limiting in terms of the flexibility it offers the blind traveler. Such a map provides only the information that is essential for the completion of the designated route and therefore any deviation from that path, intentional or unintentional, could place the traveler in a novel situation which is not covered by the map. Errors in navigation might therefore be very difficult to rectify with the use of a route map. A map that is more helpful in such circumstances is a mobility map, which provides the reader with a comprehensive representation of the elements in space and their relationship to one another. Such a map can provide the blind traveler with a variety of travel options and a means by which navigational errors can be rectified. If

independence of mobility is the prime concern when designing maps for travel, then clearly the mobility map is of more use.

Maglione (1969) continued the research effort in this area by undertaking experiments with blind and blindfolded subjects using tactile route maps to travel a maze pattern. The results from these experiments showed that the congenitally blind, adventitiously blind, and sighted subjects could complete the maze more quickly and with fewer errors with the assistance of a map accompanied by verbal instructions than with the assistance of verbal instructions alone. The map appeared to help subjects select the most important information in the verbal instructions and eliminate information that was less important.

Unfortunately, Maglione's impressive results must be tempered by the fact that his subjects were all volunteers and therefore likely to have been highly motivated and proficient travelers, unrepresentative of the blind population at large. In addition, the superior performance of the map-assisted group might have had a lot to do with the inadequacies of the taped instructions. The tape contained twenty-seven separate pieces of information that had to be committed to memory after only two playings of the tape. The non-map group may therefore have been overloaded with information which they could not adequately process and commit to memory.

At a more practical level, Wiedel and Groves (1969b) designed a campus map of the University of Maryland for blind students and completed a series of mobility tests using the

tactile map as an orientation aid. In the tests, subjects who had received instruction in the use of the campus map, and who had been familiarized with the map for a week, out-performed subjects who had not received instruction in the use of the map, and who received the map at the onset of the mobility test. A comprehensive description of this experiment and its results is not available in the literature, and apart from emphasizing the need for instruction in the use of tactile maps the study added little to the body of knowledge on the application of mobility maps for independent travel.

Leonard and Newman (1970) continued their earlier work in experiments which compared the viability of portable tactile route maps with three other types of maps: the verbal map (a tape recording describing the test route and mobility instructions for its completion), a memory disc (a disc with braille instructions for the completion of the test route) and a three-dimensional spatial model of the test route. Adventitiously and congenitally blind subjects (ages 14-58) were split into four groups, each group using a different type of map to complete the 2km (1.25 miles) test route. Half of the subjects using the tactile route map completed the route with no errors and the remainder completed the route with fewer than three errors. Although the performance of the map group was encouraging, it was not significantly better than the performances of those groups using the taped and disc maps. The tactile map, in particular, was more favoured by the younger

subjects; the older subjects in that group complained that the tactile map was difficult to read, substantially increasing the stress of the journey.

The first experiment demonstrating that blind subjects could successfully use tactile maps to plan and navigate their own routes in unfamiliar spaces was conducted by Bentzen (1972) at the Perkins School for the Blind in Massachusetts. Six congenitally and adventitiously blind subjects were provided with instruction in map reading and given maps of the campus from which they were to plan routes to three different destination points. Using the maps the subjects were able successfully to locate and walk to the three destinations without any assistance. Two of the subjects completed the route with no disorientations, while the remainder completed the route with fewer than two disorientations each. The subjects found the map to be very helpful, and in general a far better method of learning a new route than receiving a verbal description of that route.

Kidwell and Greer (1972-73) designed a tactile map of the Massachusetts Institute of Technology with the help of blind students at the campus and used the map in tests with blind subjects, but the map experiments involved passive map reading sessions rather than active use of the map in a mobility test. Therefore, the worth of the map as a mobility aid was not addressed. Although the subjects in the reading tests were particularly enthusiastic about the potential of the map, it

would be difficult to gauge to what extent such optimism was justified. Understanding a map and the relationships portrayed therein does not automatically mean that it can be successfully employed as a navigational tool during travel.

James and Swain (1975) working at the Blind Mobility Research Unit at the University of Nottingham, England, conducted an interesting mobility experiment with four blind subjects in which tactile maps were used to help subjects plot the route taken on four different bus journeys. Having received an intensive course in the interpretation and use of tactile maps, the subjects were put on a bus and required to track their course on a tactile map of the bus route, describing the features of the route as they passed them. Three out of four subjects followed the bus route using the map with no errors, keeping a moment-by-moment assessment of their position on the map. All of the subjects commented that the map was helpful, providing them with a framework for gathering information about space and a schema for comprehending it as a Gestalt.

More recently Preiser & Bercht (1981) undertook mobility tests with blind students at the University Student Building, University of New Mexico, to determine the extent to which tactile maps could be used as navigational guides to complete unfamiliar routes in the building. The performance of the map-assisted group over the test route was far inferior to that of a control group, who had memorized the route after the benefit of one walk through with a sighted mobility instructor.

Although the map-assisted group found route planning with the map relatively straightforward, navigating with the map was extremely difficult and took significantly longer than was the case in the control group. In later experiments the authors found that the combination of a map for route planning and an electromagnetic guidance system for navigation was a more effective method of learning and traveling routes than the memorization of routes after a walk through.

That there is a need for more research on the application of tactile maps as orientation and mobility aids is apparent from the limited amount of documentary evidence on this subject. Furthermore, the research that has been completed has generally failed to assess the extent to which tactile orientation maps are an alternative to traditional methods of learning and traveling new routes. Although it may be helpful to know that a tactile map can help blind individuals travel unfamiliar routes, one needs to know how this method of navigation compares to existing methods of navigation employed by blind travelers. After all, it is unreasonable to suppose that blind travelers will switch to using maps if, by so doing, they substantially increase the mental effort of travel. Most visually impaired individuals without functional mobility vision navigate new routes on the basis of memory, having walked over the route with a Orientation and Mobility instructor. The current study was therefore designed to assess the effectiveness of a tactile map as a navigation aid in travelling a test route, compared to

navigation over the same route based on memorization of the route after a single walk through. If it can be shown that map-assisted travel is as effective as travel based on memorization, then tactile mobility maps will be a beneficial tool for planning and traveling new routes; such a means of navigation would provide the individual with a far greater degree of independence and would release him/her from reliance on an O & M instructor.

This report therefore aims to add to the limited body of knowledge about the application of tactile orientation maps by reporting the results of a study which evaluates the effectiveness of map-assisted travel. The writer also hopes that the method used in this study will be of benefit to future work and that it can be reproduced to evaluate the potential of tactile maps in other situations. Last but not least, this research was undertaken to provide blind students at Vancouver Community College with a tactile map of their campus, a device which it is hoped will enhance their knowledge and enjoyment of the campus.

CHAPTER II

DESIGN

The primary purpose of this study was to determine the extent to which uncharted routes in a familiar building environment could be planned and navigated with the use of a tactile map. To this end, a mobility test was devised which would compare travel performance of a group using a tactile mobility map to that of a control group, over a test route at Vancouver Community College campus¹.

The test route was contained within a section of corridor on the second level of the King Edward campus (see Figure 1) and was unfamiliar to the subjects in the test. Subjects were required to begin at the point indicated by the black square on Figure 1 and find their way, unassisted, to the objective (the fire doors next to the number one) and back. The route was 120 metres long.

THE MAP ASSISTED GROUP

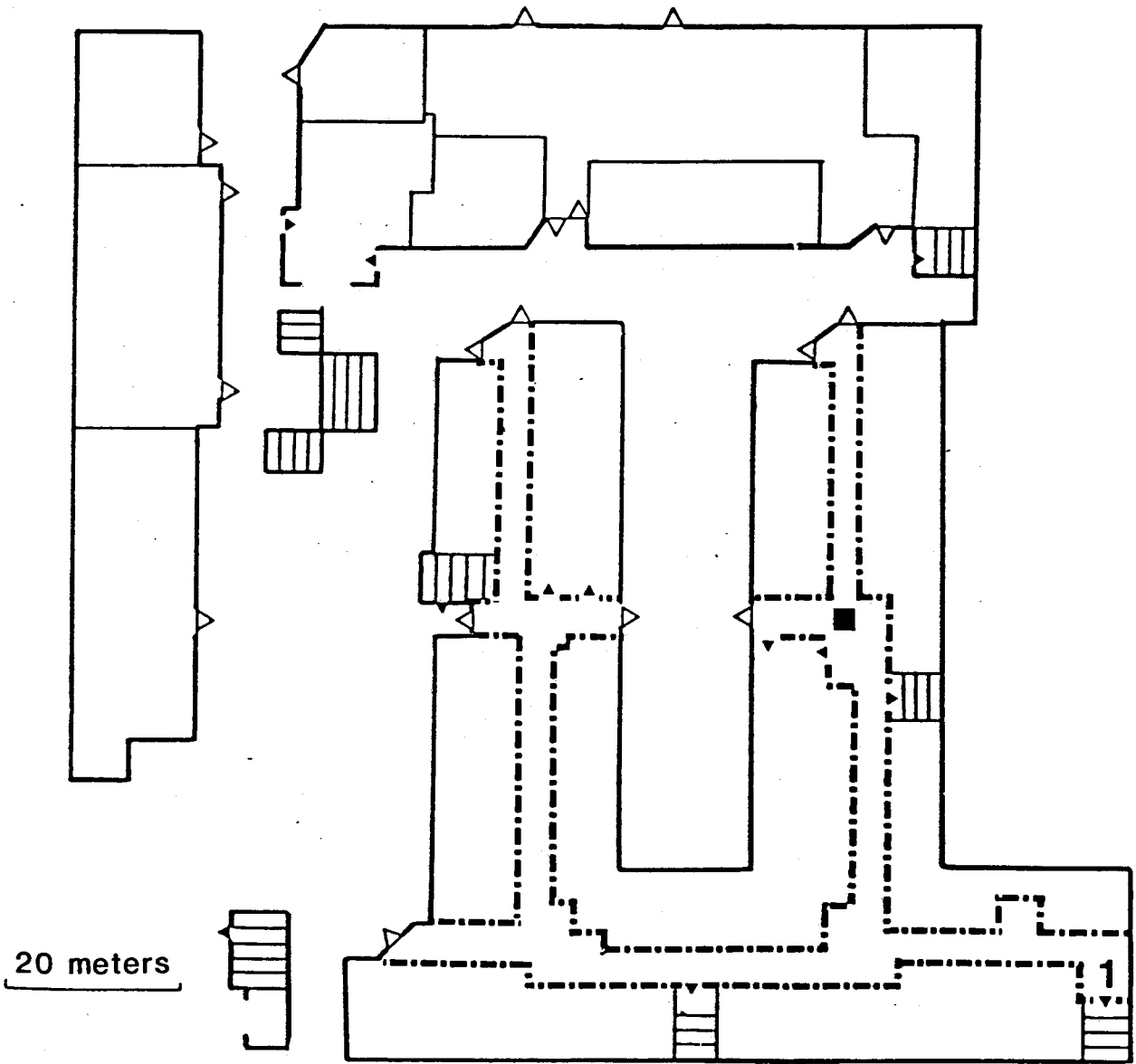
Because of a lack of experience with tactile maps² and with mobility maps in particular, the subjects in the map-assisted group were given instruction in map reading and interpretation

¹The Vancouver Community College (King Edward Campus) was used as a test site as it had a fairly large enrolment of blind students, most of whom were prepared to participate in the test. The campus facility was also made available to the author.

² Only one of the subjects in the map-assisted group, subject F, had any experience with tactile mobility maps.

FIGURE 1

VANCOUVER COMMUNITY COLLEGE
LEVEL 2



over a two week period before the mobility test ³. In addition, each subject in the map-assisted group was made familiar with the tactile map of the campus at least two days before the mobility test ⁴ , so that the map and its use were not too foreign to the subjects at the outset of the test.

An hour before the beginning of the test the subjects were given a campus map on which was included the starting point and objective for the test. The subjects were asked to study the map and use it to plan the shortest possible route between the start and objective. Having plotted a route between the two points, the subjects were required to trace their chosen path on the map. After this the author accompanied the subjects to the start where they received the final instructions for the test⁵. Oriented towards the objective and furnished with a map mounted on a firm base, the subjects were requested to begin the test.

THE CONTROL GROUP

The control group was familiarized with the route in the conventional manner, as if an Orientation and Mobility specialist were teaching them a new route. On an individual basis the author walked each subject along the test route, locating the start and objective as well as the most salient features along the route which could help orient the traveler.

³ See Appendix 1.

⁴See Appendix 1.

⁵See Appendix 2

During the walk, the author responded to any questions that the subjects had concerning the route. Having completed the familiarization process and committed the route to memory, the subjects were given a two hour break, after which they were taken to the start, oriented towards the objective and asked to begin the test.

The test conditions for all subjects were kept as constant as was reasonably possible. During the test the author followed two paces behind the subject, following the path set by the individual. Upon reaching the objective the subjects were to notify the examiner and, if correct, were given a 2 minute rest after which they were required to return to the starting point. The test was completed when the subject successfully returned to and located the starting point. While the test was in progress the author remained silent; no assistance was offered the subject, unless he/she became disoriented (see below) or was in danger of colliding with an object or pedestrian. The starting point and objective were quite prominent features which could not be confused with other features along or near the route. The starting point was a concrete column in the middle of the corridor and the objective a fire door leading to a stairwell.

While the test was in progress the experimenter recorded the following:

1. The number of DEVIATIONS; a deviation was, in essence, an error in navigation that was rectified by the subject. A deviation was recorded if a subject deviated from the

designated path by more than ninety degrees, taking more than five paces in that direction. If the subject did not regain the designated path within three minutes of the onset of the deviation it became a disorientation.

2. The number of DISORIENTATIONS; a disorientation occurred if the subject deviated from the route and was unable to regain the route after three minutes, or if the subject specifically requested help from the author (a practice that was discouraged unless the subject felt incapable of reorienting him/herself to the designated route). In the event of a disorientation, the subject was notified that he/she had made an error in judgement and was returned to the starting point (if the objective had not yet been reached), or to the objective (if the return journey had been started) and asked to resume the test.
3. TIME TAKEN to complete the route; the author recorded the time it took each subject to complete the route. Timing started at the outset (the starting point) and continued until the subject returned to and successfully located the starting point. The watch was stopped for the two minute break at the objective and whenever a disorientation was committed. In the event of a disorientation the timing was resumed when the individual restarted the test (the timing did not start afresh after each disorientation). There was a time limit of forty minutes for the test. If the subjects had not completed the test within that time period (which was more than ample to permit numerous restarts and for the

very slowest of travelers) the author assumed that the subject was either incapable of completing the task or that the task was taking longer than the period for which one would reasonably expect a subject to concentrate.

4. The MAP READING BEHAVIOURS AND COMMENTARY OF THE MAP GROUP; after the test was completed, the map-assisted group was asked to comment on the map and the problems they encountered in its use.

Travel performance in this study was therefore measured in a number of ways:

- a. Completion of a task - in this case successfully reaching an objective in space and returning to the starting point. Purposeful travel can be said to be effective only if it permits movement from a predetermined point in space to a predetermined goal.
- b. Time taken to complete the route - effectiveness of travel was assumed to relate to the speed with which the route could be completed. Prior to the test, subjects had been told that they would be timed, and were asked not to treat the test as a race, but to walk the route at their normal walking speed.
- c. The number of disorientations and deviations - The author assumed that there was a negative relationship between the number of navigational errors (disorientations and deviations) and the efficiency of travel. A error in navigation that leads the traveler astray invariably

unsettles the individual, increasing the mental and physical demands of travel. As the number of navigational errors increases it is reasonable to assume that the traveler will become more confused and anxious, making additional travel more cumbersome and stressful. In this regard a deviation is not as serious as a disorientation, as the former results in only a temporary loss of orientation, while the latter results in a more permanent loss of orientation and necessitates a restart.

THE SAMPLE

Any research project involving blind subjects faces problems of insufficient numbers at any one place. This study was no exception; only ten subjects that met the criteria for the study were available and willing to take part in the project. To be suitable for the study an individual had to:

1. Be registered as legally blind (i.e., less than 20/200 vision with correction).

2. Read grade 2 braille. This ensured that:

the subject could read the tactile map of the campus on which grade 2 braille was used and that in all probability the individual did not have any functional mobility vision. The study was concerned with an aid that would be of use to those without any functional vision. Individuals with functional travel vision have little need of a tactile map as they can, in general, read large print maps.

3. All subjects had to be enrolled at the V.C.C. campus as students at least three weeks prior to the test. This was to ensure that subjects had some degree of familiarity with the campus. It was decided to use subjects who had experience of the campus in the belief that subjects new to the campus would be at a marked disadvantage. The mere fact that a subject was on 'home turf', even if he/she was navigating an uncharted route, would instill a fair measure of confidence in that individual.

Of the ten subjects in the study (aged 20-53) six were congenitally blind, and four adventitiously blind, while six were female and four male. All subjects used the long cane for travel. Subjects were assigned to the groups in the following manner:

1. Individuals were paired and placed in separate groups based on their O&M ability, to ensure that there was a balance of fast and slow travelers in both groups. The assessment of individual O&M abilities and the pairing of subjects based on this criterion was completed by the Director of the Adult Special Education Programme who had a comprehensive knowledge of the travel competence of the individuals.
2. There was a balance between groups in terms of the number of late and early blind subjects. Each group had three congenitally and two adventitiously blind subjects. Although there was little to indicate that the congenitally blind subjects in the study were more proficient travelers than

the adventitiously blind subjects or vice versa, a pre-test survey revealed that the adventitiously blind subjects had far greater exposure to the concept and use of maps. It was felt, therefore, that the map-assisted and control groups should have the same ratio of late and early blinded subjects.

HYPOTHESES

The following hypotheses were tested in the study:

1. **Subjects who are provided with the tactile map will travel the test route as quickly as the trained control group.**
Travel along unfamiliar routes requires a good deal of mental effort and is cognitively very demanding⁶; therefore the faster the route can be completed the less stressful it becomes for the traveler. Faster travel also frees time which can be productively spent in other pursuits.
2. **Subjects provided with the tactile map will complete the route with no more navigation errors than the trained control group.**

By providing the user with a more comprehensive understanding of the structure of the route and how it relates to other features and objects in that environment, it is hoped that the map will enhance spatial orientation and thereby decrease the likelihood of navigational errors. The navigational errors for each individual will be the sum of the deviations and disorientations incurred.

STATISTICAL ANALYSIS

A Mann Whitney U test was used to test the hypotheses of no difference between the two groups in terms of time and error scores. The U test was particularly appropriate given the small

⁶See Shingledecker (1983)

number of subjects in the test.

CHAPTER III

THE DESIGN OF THE CAMPUS TACTILE MAP

To be an effective communication device the tactile map must provide information about the environment sufficient for self-directed navigation and in a form that is comprehensible to the reader. Design strategies must therefore consider what is relevant and necessary for orientation and mobility, and what are the most effective ways of representing that information in a tactual format, given the limited processing capabilities of the haptic sense. With these concerns in mind this chapter outlines the way in which the campus map was designed and the cartographic principles which provided a rationale for that design.

One of the first things to be considered when designing a map is its purpose, in this case, a mobility map of the V.C.C. campus to help visually impaired individuals to plan and walk unfamiliar routes. The map was not intended as a route map (i.e., a map which displays only that information pertaining to the route) as such a map would:

1. Preclude the need to plan a path between two points - an important skill in itself.
2. Provide a means by which subjects could correct a departure from the prescribed path. Significant deviation from the route would leave subjects in a novel situation, uncharted on the map. The route map could not therefore be used to

reorient the subject to the route if he/she had wandered off the prescribed path. In contrast the orientation map, which provides information about the designated route and its relationship to surrounding features, does provide a means by which subjects can correct significant errors in navigation and reorient themselves to the route.

3. Although the mobility map was designed with the test route in mind, it was also intended to be of practical use to the blind students at V.C.C. as a general mobility guide and reference map of the campus. Responses to a questionnaire given to the Adult Special Education Department students showed that those with negligible functional travel vision had very restricted activity fields in the campus and were, in some cases ignorant of the full range of facilities and services on campus. It was hoped that the mobility map could enhance students' use and enjoyment of the campus by extending their understanding of its physical structure.

The design of any tactile graphic depends largely on the production process employed to make map masters and the manufacturing process used to reproduce individual map copies. A variety of different techniques exists for the production of map masters, while the reproduction of maps is largely done by the process of thermoforming¹, thermoengraving² and embossing. Given the resources available, the Nottingham Map Making Kit was chosen as offering the most viable map production process. The kit consists of adhesive-faced cellulose master sheets upon which point, line, and areal symbols can be stuck. Completed, the cellulose master sheet is placed in a vacuum forming machine and map copies reproduced on 'Brailon' sheets 11"x11.5". The Nottingham Kit was chosen for the following reasons:

1. The map kit is widely used in Britain (where mobility maps produced with the kit are now an integral part of mobility training), Europe³ and North America. Furthermore, the symbols used in the kit have been evaluated experimentally in the United Kingdom (James & Armstrong, 1972; James, 1972; James & Gill, 1974) as discriminable in the context of the

¹Using a vacuum forming machine light plastic (brailon) is placed over the map master and a vacuum created so that the thin sheet of brailon is sucked down over the relief of the master. At the same time heat is applied and a permanent impression left on the brailon.

² thermo sensitive powder is sprinkled on a recently printed map so that the powder adheres to the wet solution. The excess powder is shaken off the map and the remainder passed through a heat tunnel. The powder melts at a critical temperature, producing a smooth, waxy raised line.

³The 1st International Symposium on Tactile Maps for Urban Areas adopted the Nottingham Kit as the production process to be used to produce maps of European cities.

map.

2. The map copies that are reproduced from the Kit master are of a good quality, giving high, crisp relief.
3. The brailion copies are relatively inexpensive when compared with other map reproduction methods. The Kit itself is also relatively inexpensive.
4. A thermoform machine was made available to the author.
5. Some of the test subjects had experience of maps reproduced with the Nottingham Map Kit.

After choosing the map production method the next step was to determine what information should be included on the map and the manner in which the symbols provided in the Kit could best be used to represent that information in a comprehensible form to the reader. The design strategy was devised, in so far as was possible, in consultation with the blind students in the A.S.E.D. programme and the director of the A.S.E.D. programme. As the author had very limited knowledge of blind orientation and mobility and the type of information that would be required to assist blind navigation, it was essential that the map be devised with this type of co-operation. Furthermore, it was felt to be important that the blind map reader have some input into the choice and design of symbols used, if the map was to be meaningful to him/her.

INFORMATION CONTENT

As mentioned in the literature review, it is essential that a tactile map be simple and the information content kept to a minimum due to the very slow, laborious and complex task of map reading (Castner, 1983). While preserving simplicity, however, a compromise must be struck because sufficient information must be available on the map to accommodate successful navigation. Given that the map was to be a mobility map of the campus and not just a route map for the purposes of this mobility test, the following information was highlighted as being important for orientation and navigation:-

Exterior walls, corridors, doorways, pillars in the corridor, washrooms, elevators, telephones, stairs, courtyards, walkways, water fountains, the roads adjacent to the campus, the cafeteria, student lounges, library, auditorium, bookstore and the location of the departments throughout the campus.

Unfortunately, in the interest of keeping information density to a level that could be accommodated by the reader, a substantial portion of this information had to be excluded from the map. Had all this information been included, the display would have been either too cluttered and confusing for the visually impaired students, or much too large to be of use. The information that was eventually represented was therefore selected as most important for orientation and mobility:

1. The exterior walls - used as boundaries during travel and therefore essential.
2. The corridors - the walls of the corridors were also used as boundaries. The corridors were the major mobility channels

in the campus for the visually impaired students.

3. The doorways - there was no way to represent all the doorways, for there were far too many of them and only limited space on the map. It was therefore decided to show only those doors which were exits/entrances to the buildings, fire doors, doors leading to the washrooms.
4. Elevators - were used by the blind students and therefore an important feature. The auditory clues provided by the elevators could be used by the students as spatial referents.
5. Stairs - the majority of the students used the stairs, especially the cluster of staircases in the southwest corner of the campus. As with the elevators, the stairs provided auditory clues that could be used as spatial referents.
6. Courtyards/Walkways - the exterior areas of the campus were split into two zones based on their utility to the students. The courtyards were landscaped plazas with large concrete planters, and the walkways served as thoroughfares.
7. Campus facilities - if the map was to be of use as a guide to the campus it had to include the location of general amenities and departments. All of the department areas were indicated on the map as well as a number of the more important communal services (the cafeteria, library, bookstore, student lounges, washrooms, car parks and auditorium).
8. Roads - the students used the roadways ringing the campus as spatial referents around which they would organize their

mental images of the campus. The inclusion of the roadways was therefore of crucial importance on the map.

Figure 2 shows the information finally selected for the tactile map of the campus.

SYMBOL CHOICE

Careful consideration had to be given to the manner in which the information selected could best be illustrated on the map. As the Nottingham Map Kit was primarily designed for small scale maps of urban areas (rather than building interiors) the symbols in the kit had to be adapted to represent different categories of information. It was felt that an alteration in the symbol meanings was practical for the following reasons:

1. Subjects did not have extensive familiarity with the Nottingham Kit and therefore would not be confused that the symbols on the map were representing different categories of information than was originally intended.
2. Map reading should be a flexible skill and there is no reason to suppose that a competent map reader cannot comprehend and assimilate alterations in symbol meaning.
3. The symbols in the map kit were not strikingly linked to any particular environmental feature or object, and it was therefore unlikely that any of the readers would be confused by the 'new' meaning of any of the symbols on the campus map; the one exception, the stair symbol based on Schiff's directional arrow (Schiff, 1965) was clearly identifiable as

FIGURE 2a

INFORMATION INCLUDED ON THE TACTILE MAP

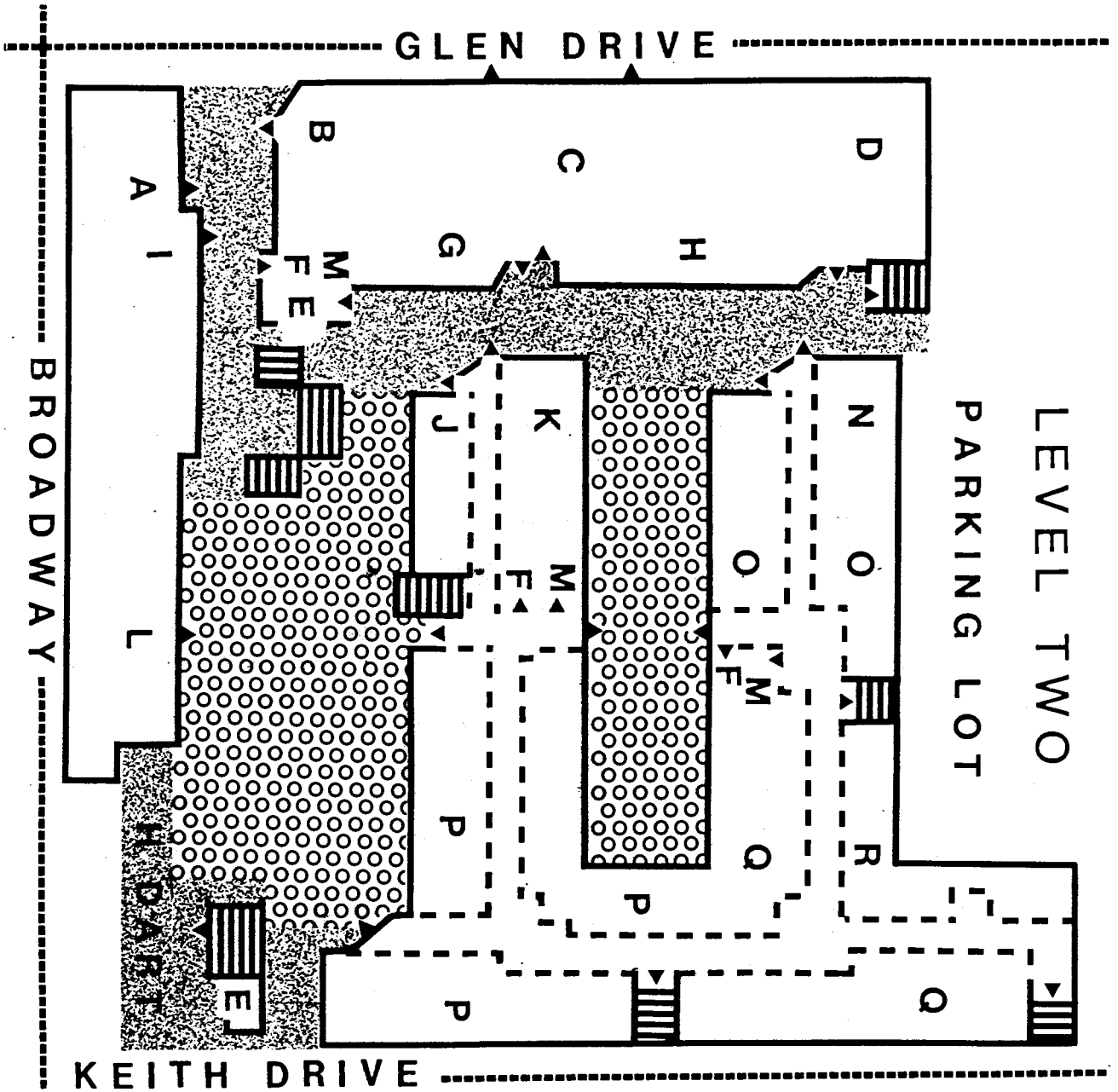










FIGURE 2b

KEY TO FIGURE 2a

- | | | | |
|---|------------------------|---|--------------|
| A | AUDIO VISUAL |  | STAIRS |
| B | BOOKSTORE | | |
| C | CAFETERIA |  | DOOR |
| D | STAFF LOUNGE | | |
| E | ELEVATOR |  | CORRIDOR |
| F | FEMALE (F) | | |
| G | GAMES ROOM |  | WALKWAY |
| H | KITCHEN | | |
| I | AUDITORIUM |  | OUTSIDE WALL |
| J | A.S.E.D. OFFICE |  | OPEN AIR |
| K | A.S.E.D. | | |
| L | LIBRARY |  | COURTYARD |
| M | WASHROOM (M) | | |
| N | BUSINESS |  | START |
| O | BASIC EDUCATION | | |
| P | TRAINING & DEVELOPMENT | | |
| Q | B.T.S.D. | | |
| R | STUDENT LOUNGE | | |
| S | HEALTH SERVICES | | |
| T | COLLEGE FOUNDATION | | |
| U | LEARNING CENTRE | | |
| V | E.L.T. | | |
| 1 | OBJECTIVE | | |

H DART Handi-Dart drop off.

such. Fortunately, that symbol was used on the campus map to represent stairs.

POINT SYMBOLS

There were only 9 different point symbols in the kit, far too few to represent uniquely the 27 pieces of information that had to be included on the map in this format. It was therefore decided to use braille lettering in addition to the point symbols from the kit to represent point information. Four point symbols from the kit were used: the stair symbol, the cross symbol (which represented the female washrooms), the star symbol (which represented the male washroom) and the triangle (representing doorways). The remaining information (i.e. the departments and general facilities) was represented solely by braille lettering.

LINEAR SYMBOLS

Three categories of information were to be represented in a linear form: the roads, the exterior walls and the corridors. As there were 6 linear symbols in the map kit the author decided to pick those symbols that were the most discriminable to avoid any possible confusion between the 3 different line types. The choice of the symbols assigned to each of the features was based on the importance of the feature and the prominence of the line symbol - the most prominent line symbol representing the most

important linear feature⁴ In the context of the test the corridor walls were the most important linear feature and were therefore represented by the rough dotted line (Barth, 1983). The outside walls were represented by the smooth line and the roadways by the dashed line symbol.

SINGLE OR DOUBLE LINES

There is no agreement as to whether single lines or double lines are more effective in representing linear information on tactile maps. As far as ease of tracing is concerned the evidence is conflicting, some results suggesting that single lines are easier to trace (Bentzen & Peck, 1979; Easton & Bentzen, 1980), while others suggest that double lines are better (Amendola, 1976; Berla & Butterfeild, 1977; Brambring & Laufenburg, 1979). Single lines take up less space than do double lines and are therefore more beneficial if there is a lack of room and/or a high density of information on the map. In most cases, double lines provide a more literal representation of the features they represent. Consequently, they make it easier for the reader to conceptualize the structure of the particular feature. As the roadways were peripheral to the map and only relevant to the reader as distal elements they were represented by single lines to save space on the map. The walls of the building were also represented by single lines, because they

⁴see Amick (1982) .

were experienced as unilinear structures; representating them in a double line form might have caused confusion. In contrast, the corridors were represented by double lines for the following reasons:

1. The corridor presents the subject a choice of two walls and it is important that the map reader consciously make a decision as to which wall to follow and plan a strategy based on that choice.
2. Some of the congenitally blind subjects were uncertain of the structure of the corridor. One congenitally blind subject in the map-assisted group was actually unaware of the fact that the corridors had two adjacent sides; she had envisaged the corridor as she had experienced it - a unilinear structure with only one side. Representing the corridor with double lines was therefore benefical for the subjects who did not have a comprehensive or accurate image of the structure of the corridors.

AREA SYMBOLS

Hway-Hwa Kuo's work (1978) attested to the need for map designers to use varied surfaces on tactile maps through the use of area symbols, by showing how difficult it was to locate figures if maps have homogeneous surfaces. The initial map of the V.C.C. campus did not have area symbols to differentiate the interior and exterior areas of the campus and in many cases the readers were incapable of distinguishing the inside of the

buildings from the outside courtyards and walkways. The addition of two textures provided a frame of reference through which interior areas could be discriminated from exterior areas.

THE DISTORTION OF BACKGROUND NOISE

Berla and Murr's (1975) work on line tracing and shape recognition on maps with and without area texture (which they termed "background noise") points to the fact that too much area texture can significantly impair line tracing and point location. It was therefore felt that the interior of buildings (where a majority of the point and linear symbols was located) should be kept free of area symbols to enhance line tracing and symbol identification.

SCALE

Although visual maps are invariably designed with a fixed scale, tactile maps benefit from the use of a flexible scale. Indeed, it is often essential that the tactile map be designed with a distorted scale if the map is to remain legible. Schematization is more important than accuracy of scale because travelers often judge distance in terms of time taken to complete the journey rather than the actual distance (Amendola, 1976). There is evidence to suggest that blind people can not only accept substantial distortions in scale on a map, but may even form more realistic mental images of the mapped space from such distortions (Preiser & Bercht, 1981). A flexible scale was

therefore adopted on the campus map to include all information that was relevant in a form that would be legible to the map readers.

LABELLING

Labelling is kept to a minimum on tactile maps because it invariably increases the clutter of information on the map and makes it harder to read. Apart from the braille letters representing the departments there were only 6 labels on the map: the title, labels for the 3 roads and a label for the disabled and student parking.

Ideally, the labels would have been elevated above the other information on the map so that they could be clearly distinguished from the point, line and area symbols; given the resources of the Nottingham Kit this was not possible. The majority of the braille on the map ran in a W - E direction (the normal direction for braille to be read), exceptions being the labels for Glen Drive and Keith Road which were placed on a S - N axis to conserve space.

KEY

A braille key sheet was designed to explain the meaning of the point, line and area symbols on the map. As few of the students in the map-assisted group had experience in using maps, the author also provided the subjects with a verbal explanation of

the key sheet and map.

MAP ORIENTATION

Bentzen (1982) suggests that during navigation map readers should keep the map in its proper orientation, such that the northern edge of the map corresponds to the north in space. To help map readers keep the device oriented to the environment, the edges of the map must be distinguishable and/or the north edge of the map clearly marked. Although the map kit provided a linear symbol to mark the northern edge of the map the author used the title as the north indicator. As the title was already placed at the top (north edge) of the map, it was more convenient to use as an orientation device than to add another symbol to the map and thereby increase the clutter.

CHAPTER IV

RESULTS

The purpose of this study was to test the effectiveness of a tactile mobility map as a navigation aid to help students plan and travel unfamiliar routes on their campus. The effectiveness of travel over the route was compared with the performance of a control group which was familiarized with the route in the conventional manner. The subjects taking part in the test were both congenitally and adventitiously blind students at Vancouver Community College. None of the subjects retained any functional mobility vision. The subjects were assigned to the groups so that there was a balance of fast and slow travelers in each group. Two of the subjects in each group were considered to be 'fast' travelers, while the remaining three in each group were considered to be relatively slow. Each subject's performance was measured over the route in terms of time taken to complete the test route (the time score) and the number of navigational errors (the error score). The resulting data were analysed using a Mann Whitney U test.

Table 1 presents the time score for the two groups and Table 2, the error scores. The numbers in parentheses denote the rank values of the scores - the fastest time and smallest number of errors having the lowest rank value and the slowest time and greatest number of errors having the highest rank value. Even without the benefit of any statistical analysis it is evident from a quick glance at the tables that the map group were much

slower in completing the route and made more errors in the process than did the control group. Applying the Mann Whitney U test in both cases yielded a U statistic of 0, low enough to reject the null hypothesis of no difference ($\alpha=0.004$) and accept the alternative hypothesis. There was therefore a difference between the two groups in terms of the time taken to complete the route (the map group took significantly longer) and in terms of error score (the map group made significantly more navigational errors during the test).

An analysis of the sample means reveals the extent to which the control group outperformed the map-assisted group. The average time taken by the map group was 17 minutes 30 seconds, compared to 7 min. 11 sec. for the control group. The range of times for the map group was 10 min. 43sec., while the range for the control group was only 4min. 29sec. In every case the subjects in the control group outperformed their counterparts in the map group, and even the slowest performer in the control group (9min. 31sec.) was substantially faster than the fastest in the map-assisted group (11min. 58sec.). The number of error scores (sum of deviations and disorientations) was also far greater for the map group which accumulated 39 errors, an average of nearly 8 per subject. The control group incurred 10 errors, an average of only 2 per person. When categorized into disorientations and deviations, the difference in error scores between the two groups was even more marked. As previously mentioned, disorientations were far more serious navigation

TABLE 1

TIME SCORES (Minutes:Seconds)

SUBJECT	CONTROL GROUP	SUBJECT	MAP GROUP
A	5:02 (1)	F	11:08 (6)
B	7:17 (3)	G	22:41 (10)
C	7:59 (4)	H	18:17 (8)
D	6:49 (2)	I	19:28 (9)
E	9:31 (5)	J	15:55 (7)
	MEAN 7:11		MEAN 17:30

* Numbers in parenthesis denote the ranked value of the scores, the lowest rankings represent the fastest time.

TABLE 2
ERROR SCORES

CONTROL GROUP

SUBJECT	DISORIENTATIONS	DEVIATIONS	TOTAL ERRORS
A	0	2	2 (3)
B	0	1	1 (1)
C	1	1	2 (3)
D	0	2	2 (3)
E	1	2	3 (5)
TOTAL	2	8	10
		MEAN	2

MAP-ASSISTED GROUP

SUBJECT	DISORIENTATIONS	DEVIATIONS	TOTAL ERRORS
F	1	3	4 (6)
G	5	8	13 (10)
H	4	4	8 (8)
I	4	5	9 (9)
J	2	3	5 (7)
TOTAL	16	23	39
		MEAN	7.8

*Numbers in parenthesis denote the ranked values of the scores, the lowest value representing the lowest error score.

errors than were deviations, as they resulted in a loss of orientation which could not be rectified by the traveler. Deviations only resulted in a temporary loss of orientation. The number of disorientations occurring in the map group was substantially higher than for the control group, the former having 16 (an average of 3 per person) while the latter group had only 2 (an average of only 0.4 per person). Therefore, the main reason for the observed difference in error scores between the 2 groups is the excessively high number of disorientations committed by the map users. Having committed a deviation the map group became disoriented 75% of the time, whereas the control group only became disoriented 25% of the time when they previously committed a deviation.

The results suggest that the map users, having deviated from the route, were less capable of reorienting themselves to the route than were the control group.

MAP READING BEHAVIOURS

The author noted the map reading behaviours of those using the tactile map in the pre-test planning stage and during the test in an active mobility setting.

1. All of the subjects were able to locate the start and objective on the map and successfully plan the shortest possible path between the two. Indeed, during the planning stage the subjects exhibited far better map reading behaviours than was evident later during the mobility test.

The subjects had little difficulty in locating and discriminating the point, line and area symbols. As they had been taught earlier, each subject scanned the map in a vertical fashion before conducting a more detailed search for the objective and start.

2. When the test was under way the map reading behaviours declined noticeably. Most of the subjects had difficulty finding the route on the map because they neglected to scan the map systematically. Upon referring to the map, three of the subjects began a detailed search of the map at whatever point their finger landed on the map, instead of first scanning the map to find prominent features from which a more detailed search could be conducted. Only one of the subjects appeared to search the map in the proper fashion, scanning the display to locate the northeast corner (from which point it was easy to find the route). The haphazard search pattern of the other four subjects was, in comparison, time consuming and confusing.
3. It was also notable during the test that subjects were having difficulty in discriminating symbols and tracing lines. Two of the subjects, in particular, had difficulty distinguishing the smooth line representing the exterior wall from the rough line which represented the corridor. Indeed, at times these subjects were tracing the line of the wall and following that on the map, rather than tracing the linear symbols representing the corridor.
4. The three slowest travelers in the map group were reluctant

to use the map, seldom referring to it during travel. This was particularly evident at the major decision points (places at which a change in direction was demanded) where the individuals failed to consult the map to confirm that their choice of direction was consistent with the information provided on the map. In contrast, the subject who performed the test in the shortest time and with the least errors frequently referred to the map during travel. At the decision points this subject would always stop and consult the map before making a decision as to which way to turn. The remaining subject did surprisingly well in the test given that she was initially thought to be the least confident traveller in the group. She kept her finger on the map most of the time, following the route as she progressed along it.

5. All of the subjects had difficulty in knowing what to do with the map when they made a change in direction. They all made the mistake of letting the map turn with their bodies, instead of keeping the map oriented in the correct manner. Obviously, they had not grasped the fact that it was they who were turning and not the map or the environment it represented. Keeping the map oriented so that the north side was facing the north had been recommended to the subjects during the training period, but this was evidently a skill that they had not yet mastered.

THE COMMENTS

After the test was finished, the subjects were asked to comment on the problems they had met in using the map and the advantages that they felt the map provided them as a travel aid. From the responses it was clear that the subjects had, in general, not found the map very easy to use. Four of the five subjects had particular difficulty in using the map, a feeling that was summed up in the following comments:

"I do not know how to use the map"

"It was a big mental strain for me.... I didn't use it much because I didn't understand it".

"Until you walk the route it (the map) doesn't make sense"

"It was difficult using the map, I will certainly need more practice."

The responses also indicated that the subjects had difficulty in locating the route and the start.

"I had problems finding where I was on the map."

"I couldn't find the start."

"It was difficult finding the route on the map."

Several of the subjects also commented on their difficulty with understanding the manner in which changes in direction could be interpreted on the map:

"It was hard to relate a change in direction to the map".

"I didn't know what to do with the map when I turned."

Problems also arose because the subjects found it difficult to use their canes and at the same time refer to the map:

"I didn't have enough hands"

"I couldn't keep my hands on the map while I was traveling."

Not all comments were negative. Most of the subjects were of the opinion that, although the map was difficult to use as a mobility aid during active travel, it was useful in the planning stage and had given them a far better impression of the structure of the space in which they were moving than was normally the case:

"It gave me an impression of the corridor and the junction, which was good".

The map is helpful...it helps me figure out where things are in relation to each other."

Indeed, for one of the congenitally blind subjects the map had been of remarkable value. Using the map in the test, this subject had realized, for the first time, that the corridor consisted of two adjacent walls/barriers. Previously, she had envisaged the corridor as a unilinear structure with one wall, reflecting her own experience of that environment.

DISCUSSION

As shown by table 1 and 2, and confirmed by the Mann Whitney U test, the performance of the map-assisted group in the mobility test was inferior to that of the control group. The map group made significantly more errors in the course of the test and took significantly longer to complete the route than did the controls. Therefore, Hypothesis 1: **Subjects who are provided**

with the tactile map will travel the test route as quickly as the control group. was rejected, as was Hypothesis 2: Subjects provided with the tactile map will complete the route with as few navigation errors as the control group.

That the map group found it more difficult to complete the route than the control group was only too evident from the mean time and error scores. The map group's mean score was more than twice the mean time score for the control group. The map group not only took longer to complete the route they also made more errors in the process. The mean error score for the map group was 7.8 and that for the control group 2.00. Furthermore, even the poorest performer in the control group, who was considered a poor traveler in the pre-test assessment, outperformed the fastest performer in the map group, a subject who was one of the most proficient travelers in the A.S.E.D. programme. The results therefore proved conclusively, that the mobility map was considerably less effective as a means of navigating an unfamiliar route than was memorization of the route from first-hand experience.

The comments of the map users and the map reading behaviours of the subjects in the map group provide some explanation for the relative ineffectiveness of the mobility map as a navigation aid in this study.

1. It was apparent from the comments of the map users that they did not fully understand how to use the map as an orientation aid during travel. Even with the benefit of a

few weeks of training it was hard for some of the subjects to comprehend fully how the map could be of use to them.

2. During the test the map reading skills of the subjects declined markedly from those observed in the pre-test planning stage. Upon referring to the map they did not use a preliminary scan, as they had been trained to do. Their line tracing skills deteriorated. They found it more difficult to distinguish symbols on the map.

It was probably the case that the cognitive demands of travel along an unfamiliar route were such that the introduction of a secondary task (in this case, interpretation of a tactile map) overloaded the individual's capacity to respond effectively, diminishing performance in both the primary task (orientation and mobility) and the secondary task (map interpretation).

3. Carrying and referring to the map while using the cane was not always easy or practical. Most subjects could not keep their hand on the map for a continuous update of their position, and at the same time use their cane. Therefore, they only consulted the map when they stopped. As subjects had difficulty in locating the route on the map, this sporadic map use often proved to be both time consuming and frustrating.
4. A majority of the disorientations occurred at the T junction and the start, where subjects had to make decisions about which way to turn. In these situations it appeared that the

subjects had trouble understanding how a change in direction could be conveyed on the map. At the start many of the subjects turned the wrong way upon reaching the wall, while at the T junction some made a right, instead of a left turn. In some cases the subjects actually made the correct turn but became disoriented because they neglected to keep the map in the proper orientation when turning (letting the map turn with their bodies) and became confused that the corridor did not appear to be "heading in the same direction as they were".

5. The map did not help subjects re-orient themselves to the route in the eventuality that they deviated from the prescribed path. The results showed that on average the map assisted group became lost (disoriented) 75% of the time when they deviated from the route, whereas the control group only became disoriented 25% of the time after deviating from the route. That the subjects could not use the map to retrace their steps or re-establish the correct path was hardly surprising considering the infrequency with which the map was consulted during the test. The map seemed to be of little practical value to them during travel and they navigated as if they were relying on their mental image of the route as formulated from the map, instead of using the map to update their position in space and to orient themselves to the surroundings. This was more than evident at the start and T junction where subjects would sometimes turn without consulting the map and head off in the wrong

direction, oblivious to the fact that they had made a mistake. In these situations subjects were therefore unaware that they had deviated from the route and consequently their deviations quickly became disorientations. Only subject F seemed to systematically refer to the map at decision points; not suprisingly, he was the best performer in the map group.

LIMITATIONS

This study presents evidence that tactile maps used as travel aids can, under certain conditions, assist blind subjects to plan and navigate unfamiliar routes. However, the results indicate that navigation with a tactile map was far more cumbersome and difficult than navigation based on route memorization (on the basis of one walk through). Because the subjects in the experiment were mostly young adults it would be improper to suggest that the results of this experiment could be extended to the blind population at large. The subjects in this test were a motivated group; it is doubtful that a similar study with elderly blind people, who are the majority of the blind population¹ would produce the same result. Indeed, it would be reasonable to assume that the elderly blind would have even more trouble than did the current groups in using the map as a travel aid, as they are generally less motivated and less mobile as a group.

¹ 65% of the legally blind are over 50 (Dayton, 1979).

A lack of subjects meant that the this study was not able to compare adventitiously and congenitally blind subjects. As a large body of literature points to a significant difference in the spatial abilities of these two groups (Worchel, 1951; Foulke & Pick, 1964; Juurmaa, 1970; Kephart et al., 1974; Casey, 1978; Reiser et al., 1980; Hollyfield & Foulke, 1983) future studies of this nature might appropriately highlight the different problems that the early and late blind may have reading and using tactile mobility maps.

CHAPTER V

CONCLUSION

Independence of mobility remains a critical problem for a vast majority of the blind population. Even with the technological and engineering advances of the last two decades, blind people still rely heavily on assistance from O&M instructors to expand their activity space and learn new routes. Unfortunately, as the demand for O&M instructors and their expertise far outstrips their supply, many blind individuals add few, if any, new routes to their repertoire. Research on tactile mobility maps represents an attempt to enhance independence of mobility by providing blind individuals with a means by which a more comprehensive and accurate image of space and its components can be formulated. Although mobility maps are, at best, only supplemental tools to assist travel and can in no way replace competent orientation and mobility skills (Maglione, 1969), they can supply information about space to well trained map readers which they would otherwise have no way of comprehending (Kidwell & Greer, 1972).

Although the present study deals only with tactile maps as travel aids for the blind, an area only slightly documented in the research literature, there are other applications for tactile maps. In the classroom setting, tactile maps and graphics are being increasingly used as learning tools to explain concepts in subjects as diverse as history , geography, math and biology. Despite a few inroads into the lives of blind

people , maps still remain a novelty to a vast majority of the blind population. That this is the case is not entirely due to a lack of academic research; there has been extensive research, notably in the area of map design. The limited use of tactile maps has probably been a result of expensive and inadequate map making processes (Maglione, 1969) and the inability of educators of the blind to adopt tactile maps as a useful tool and to train blind people in their use.

THEORETICAL ASSUMPTIONS

Tactile mobility maps can help blind travelers attain spatial information that is not otherwise easily communicated (James, 1982). Graphic representations offer significant advantages over traditional methods of representing space to the visually impaired:

1. They can help to dispel the ambiguous and inaccurate concepts about features in the environment which have been formed from the blind person's limited direct experience with those features (Gibson et al., 1965).
2. They can help the reader to develop a framework for understanding and organizing the components of space (Bentzen, 1980).
3. They can supply the reader with a rich supply of spatial information which can enhance orientation and thereby make independent travel safer and less stressful.
4. They can help to reduce the heavy memory load which typifies

much of blind travel. Travelling unfamiliar routes can place heavy demands on blind individuals, who often have to memorize routes step by step. Maps can relieve travelers of such restraints by providing them with a framework from which they can periodically 'fix' their position in space.

5. They can provide a preview of the environment and thereby offer blind travelers an opportunity to formulate effective travel strategies in advance of decision points.

RESULTS

HYPOTHESIS 1: was rejected; subjects using the map were significantly slower than those subjects navigating on the basis of route memorization.

HYPOTHESIS 2: was rejected; subjects in the map assisted group made significantly more navigation errors while traversing the route than did the control group.

DISCUSSION

Navigation with a tactile map along an unfamiliar route was more time consuming and stressful than was the conventional method of navigating new routes (on the basis of a single walk through and verbal description). Although the subjects in the map group used the map successfully in a passive situation (to construct a route in space between the start and objective) in the planning stage, they seemed unable to use the map as an effective orientation device during active travel.

The reading behaviours of the map group declined noticeably during the mobility test, and as a result their comprehension of the map deteriorated. Subjects were reluctant to consult the map during the test, partly because they found it hard to travel with a cane while holding and reading a map, and also because they were having difficulty interpreting their movements on the map. This was particularly evident at the decision points where subjects were unable to keep the map properly oriented as they made changes in direction. A majority of the map users seemed to be navigating solely on the basis of their mental image of the route as formulated from the map, rather than using the map to update their position and progress in space.

IMPLICATIONS

The study set out to assess the effectiveness of tactile mobility maps as travel aids by comparing map-assisted navigation with traditional methods of navigation along an unfamiliar route. The results indicated that map assisted travel was more cumbersome than travel based on first-hand experience. It has been suggested that the relative ineffectiveness of the map in the context of this experiment was due to poor map reading and map interpretation skills during travel. Subjects' map reading skills deteriorated noticeably between the passive, pretest route planning stage and the active mobility setting of the test. Subjects who had previously displayed the ability to efficiently scan, trace and discriminate features on the map in

the planning stage were unable to reproduce such skills in the active travel situation. Not only did subjects have considerable difficulty in reading the map during the test, they also had difficulty in comprehending how the map could be used to interpret their changes of direction in space. Therefore, in spite of the fact that the map was useful in the pre-test stage to provide subjects with an accurate image of the travel environment from which a route was successfully planned, under the pressure of active travel the subjects were unable to use the full potential of the map as an orientation device.

Although the results appear disappointing, the study was hardly a failure. That all of the subjects in the map group actually managed to navigate an unknown route by themselves was a success in itself, and an achievement of no small import to the individuals in the group, some of whom were sceptical about their chances of success before the mobility test. Considering that even sighted students can be notoriously poor map users it is little wonder, therefore, that the blind subjects, navigating with much less information than would be available to the sighted, had difficulty in using the tactile map. It was to be expected that subjects with negligible experience of maps and/or tactile maps would have difficulty in using such devices in an active mobility setting given the limited amount of training that the present writer could supply. The study does not, therefore, suggest that, because this experiment illustrates that maps are difficult to use, their potential is limited;

rather, it indicates that the full potential of tactile maps cannot be realised unless the map users are well trained.

The efficacy of any travel aid must be assessed on the basis of costs and benefits. The costs are the mental and physical effort demanded by the use of the aid, and the benefits are the improvements in performance attainable with the aid. For an aid to be successful the benefits must outweigh the costs. If the current study is to be applied to the blind population in general, then future research must concentrate on reducing the cost (mental effort) of using tactile maps. An area of vital importance in this context is the development and implementation of map reading and interpretation programmes among the potential map using population. Unfortunately, in the rush to improve map design, production and reproduction techniques, "little attention has been paid to the user's needs, and specifically to the need for training in map use and map concepts" (Horsfall & Cox, 1984). It is really no wonder that the blind population finds tactile mobility maps of such little practical value if they have not received adequate training in their use. After all, a map, no matter how perfect, is valueless to an untrained recipient. In the final analysis it is better to have poorly designed maps and well trained map users, than to have poorly trained map readers using well designed maps; the former will at least derive some benefit from the device, the latter may gain none.

Despite the fact there exists a wide disparity of map reading and comprehension abilities among the blind (James, 1982), a systematic training programme which introduces both congenitally blind and adventitously blind to the concept of tactile maps can be of immense value. Map training programmes should work from the small and personal, starting with the immediate living environment of the classroom and working towards the larger and more abstract levels of unfamiliar space (Horsfall & Cox, 1984; Berla, 1982). Instruction should be provided as early as kindergarten in order to assist blind children to develop knowledge and skills in spatial relationships at an earlier developmental stage (Berla & Butterfield, 1975). If systematic map training programmes of this nature are not adopted by institutions and educators of the blind, the substantial improvements that have occurred in the design and manufacture of tactile maps over the last decade will be of little worth and maps will continue to remain an enigma to a majority of the blind population.

APPENDIX 1

INSTRUCTION IN MAP READING AND INTERPRETATION

For a two week period before the test each individual in the map-assisted group was given ten hours of map training on a one-to-one basis with with author. The training involved six sessions, the components of which are explained below.

MAP SENSING

To introduce subjects to the idea that the environment could be represented graphically each was given a simple outline map of his/her classroom, illustrating the four walls of room. Subjects were asked to explore the map and locate the following features on it: the window, the two doors and the blackboard.

MAP SYMBOLISM

The subjects were shown how objects and features in space could be represented on a map. Using the same outline map of the classroom, symbols were added to represent the window, the two doors and the blackboard. The subjects were asked to comment on the manner in which the features had been symbolised and, whenever possible, to suggest alternative symbol designs. During this stage the concept of a key was also introduced.

LOCATIONAL AND DIRECTIONAL REFERENTS

This stage of the programme was designed to show subjects how the location of known and identifiable features on the map can be used to ascertain the position of other objects and features in space. A map of the classroom was used again, but this time the positions of a number of imaginary pupils were included. Subjects were given an opportunity to explore the map and accompanying key sheet after which they were questioned about the position of the pupils in relation to each other and to the objects in the room. After this exercise the map was clipped to indicate the northeast corner, and the subjects were shown how such a clue could be used to evaluate the cardinal positions of objects and features on the map.

SYSTEMATIC SCANNING

Subjects were taught how to scan a tactile map systematically. An effective scanning technique is essential if the blind reader is to absorb information from the map quickly and efficiently. Covering an illustration from left to right, subjects were shown how to search the map, using their fingertips in a vertical scanning motion from the top to the bottom of the map.

ROUTE PLANNING

Subjects were familiarized with a map of the campus and required to indicate on the the map some of the routes they commonly use in the campus. Having successfully completed this task the subjects were then asked to use the map to plan and trace a variety of routes with which they were not familiar.

USING THE MAP AS A NAVIGATION AID DURING TRAVEL

To give the subjects practice using the map in an active travel situation, a pre-test trip was arranged with each of the subjects. Each of the subjects was given the opportunity to use the map, with the assistance of the author, to travel his/her daily route into and out of the campus.

APPENDIX 2

INSTRUCTIONS GIVEN TO SUBJECTS AT START OF TEST

"Follow the prescribed test route as best you can. Let me (the author) know when you think you have reached the objective. If you are correct, you will be given a two minute rest before resuming the test which will involve returning to the starting point. During the test I follow you at a distance of two paces and will not intervene or assist you in any way unless:

1. you are in danger of colliding with an object.
2. you leave the prescribed route and are unable to regain the path within three minutes.
3. you are confused and specifically request help.

In the event of the last two cases you will be returned to the start, or objective (should you be on the return journey to the start), and asked to resume the test from there. The test will be finished when you have successfully returned to, and located, the starting point.

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