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**Mapping for a visually impaired audience:
A case study on the legibility and cognition of tactile maps
for education**

By:

Anik Fortin, B.A. Honours

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of
Master of Arts

Department of Geography and Environmental Studies
Carleton University, Ottawa, Ontario
January 2003

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Submitted by Anik Fortin, B.A. Honours
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Master of Arts

Thesis Supervisor

Chair, Department of Geography and Environmental Studies

Carleton University
January 2003

ABSTRACT

The present study focuses on the importance of access to information and educational resources in geosciences for a visually impaired audience. The goal of this study is to facilitate the transfer of geoscientific information between tactile maps and the visually impaired reader. Three map variables were chosen for the purpose of this study, those of which are believed to affect the cognition and legibility of tactile maps. Visually impaired participants were surveyed on their abilities to recognize map projections, area symbology and auditory maps. The hypotheses stated that 1) the choice of map projection, 2) the type of area symbol used in maps and 3) auditory maps can influence the legibility and cognition of tactile information. It was found that the results of the survey supported all three hypotheses of this research. It was also found that the major constraint presented by the visually impaired participants, in accurately reading and understanding the tactile maps, was the degree of visual impairment. These results indicate that maps need to be specialized for a heterogeneous visually impaired audience.

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CHAPTER 1

INTRODUCTION

"For information to be truly accessible, and to make effective communication a reality, information must be made available to people with disabilities in their preferred reading media if at all possible."
(American Foundation for the Blind, Summary,
http://www.afb.org/info_document_view.asp?documentid=169, July 2002)

1.1 RIGHTS TO EDUCATION AND ACCESS TO INFORMATION

Education is directly related to the accessibility of information. As stated in Article 26 of the *Universal Declaration of Human Rights*, every person has a right to education and to accessible information. "Everyone has the right to education. Technical and professional education shall be made generally available and higher education shall be equally accessible to all on the basis of merit." (Office of the High Commission for Human Rights,
<http://www.unhchr.ch/udhr/lang/eng.htm>, April 2002). Despite some progress in making education accessible to all, this right has not yet been fully exercised for individuals with disabilities. Some children have been deprived of a good education and access to information simply because they were blind, deaf or suffered from learning disabilities. Deprivations may be the result of misinterpretations of Article 26 mentioned above where it says: "...education shall be accessible to all on the basis of merit". Don't people with disabilities deserve this right to education and accessible information? Whatever the interpretation, the statement does not explicitly recognize disabled people as there is no mention of "disability" in Article 26. Disabled people have been overlooked in written law and in society often because they

have special needs and require individual attention. As a first step to remedy this problem, new laws need to be developed and implemented in order to recognize the educational needs of people living with disabilities.

In 1975, the American government introduced *The Education for All Handicapped Children Act*. This law states that every child with a disability has the right to receive free public education through an individualized education program (IEP):

This law mandated free appropriate public education for all children with disabilities. It ensured due process rights, mandated education in the least restrictive environment, and required that students receiving special education services have an individualized education program (IEP). (National Center for Learning Disabilities, EHA-Public Law 94-142, <http://www.ld.org/advocacy/fedlaws.cfm>, April 2002).

In 1990, the title of this Act changed to *Individuals with Disabilities Education Act* or *IDEA*. In Canada, the educational rights of the disabled were finally recognized in 1982 through the *Canadian Charter of Rights and Freedoms*. The Charter states the importance of equal rights to all individuals:

Every individual is equal before and under the law and has the right to the equal protection and equal benefit of the law without discrimination and, in particular, without discrimination based on race, national or ethnic origin, colour, religion, sex, age or mental or physical disability (Constitution Act 1982, <http://lois.justice.gc.ca/en/charter/>, April 2002).

With these new laws in place, people with disabilities are slowly getting access to good education and information, although

implementation has been slower than many disabled persons would have liked. New equipment and services are being tailored for specific needs, depending on the impairment.

1.2 ACCESSIBILITY OF INFORMATION FOR PEOPLE WITH A VISUAL IMPAIRMENT

A visual impairment is related to the loss of sight. Vision is usually measured on a ratio scale, where 20/20 signifies "perfect" vision. The level of impairment becomes greater as the denominator increases. For example, a person having 20/30 vision signifies that that person can clearly see objects at 30 feet where another person, with normal vision, can clearly see the same objects at 20 feet. According to the Canadian Ophthalmological Society, a person having 20/60 to 20/190 vision is considered to have low vision, and a person having 20/200 is classified as being blind (The Canadian Ophthalmological Society, <http://www.eyesite.ca/english/public%2Dinformation/eye%2Dconditions/low%2Dvision.htm>, July 2002). There are approximately 3 million people who are blind, visually impaired and print disabled in Canada (CNIB, *Library*, <http://www.cnib.ca/library/>, July 2002). The total number of people with some degree of visual impairment worldwide is nearly 180 million people, where 45 million are completely blind and 135 million have low vision (International Agency for the Prevention of Blindness 1996).

Blind and visually impaired people need special equipment and additional resources to facilitate learning. Among these, Braille is the most widely used and is considered to be the fundamental tool for learning and communication. Braille is a tactile system of raised dots that represent the letters of the alphabet (CNIB, *Publications and Resources*, <http://www.cnib.ca/eng/publications/pamphlets/sixdots/6dots.htm>, July 2002). The Braille system is based on a cell, called the Braille cell, comprised of six dots (Figure 1.1).

FIGURE 1.1: Braille cell

Source: CNIB, *Publications and Resources*,
<http://www.cnib.ca/eng/publications/pamphlets/sixdots/6dots.htm>,
July 2002.

Each dot is numbered in a specific order and the combination of dots represents a letter. For example, dot 1 represents the letter "A" and dots 1, 2 and 4 represent the letter "F". Braille was invented in 1824 by Louis Braille but was not fully implemented until the late nineteenth century in Britain, and later during the twentieth century in North America (Enabling Technologies, <http://www.brailleur.com/braillehx.htm>, April 2002). Since the introduction of Braille in North America, the visually impaired have slowly been gaining access to information over the years. During the 20th century,

the blind community has had increased access to Braille books and magazines. There are an estimated 15,000 titles (in English) in Braille books and 50 Braille magazines available in the Canadian National Institute for the Blind (CNIB) library (CNIB, *Library*, http://www.cnib.ca/library/reader_services/about.htm, July 2002). More recent introductions include books recorded on cassettes, computer software programs with audio and Braille translating components. Tactile maps and diagrams are also recent, but very limited (Matthews 1978, 205; Golledge 1993, 69; Golledge *et al.* 1994, 1). In the CNIB library for example, tactile maps are only produced on demand. Because most visually impaired people have not been exposed to maps, the demands have remained slim (Groves 1972, 2; Goodrick 1984, 629). This thesis aims to make a contribution in the education of the visually impaired through tactile maps. It is hoped that this study will encourage others in the creation of tactile maps for education to help increase their number and availability among the visually impaired community.

1.3 CENTRAL PURPOSE

The main goal of this study is to facilitate the transfer of information between maps and the visually impaired reader; to determine the most promising method of delivering geoscientific information that visually impaired people can read and understand with minimal effort. Because a multitude of factors can affect the transfer of tactual information (for example map printing methods, design techniques, feature generalization, etc.), three variables

were chosen for the purpose of this study. The selected variables which are believed to affect the cognition and legibility of maps are map projection, area symbology and auditory maps. The hypotheses within this research are the following:

- Map projections can be distinguished through touch.
- The type of area symbol used in tactile maps can increase the legibility of surface areas.
- Auditory maps can enhance the cognition and legibility of tactile information.

The following is a brief discussion of each variable and the reasons for their selection.

- A map projection is the transformation of information from a spherical surface to a flat surface. Because all projections display some level of distortion of the truth (as a result of the transformation process) it is important to select one which will display the target information most appropriately (Robinson *et al.* 1995, 70 National Atlas of Canada Website, *Carto Corner: Map Projections*, http://atlas.gc.ca/site/english/learning_resources/carto/cart003.html, July 2002). Map projection was chosen as a case study because of their high relevance to conventional cartography and their questionable absence in tactile mapping.

- Symbology is a key element in map communication (Franks 1983, 42; Barth 1983, 11). Tactile symbols must be easily discriminated and recognizable through touch for the coherent intake of information (Berla 1982, 375). Area symbologies, in particular, were chosen because of the varying viewpoints of some researchers with regards to this symbology's tactual stimuli and haptic discrimination (Jansson 1983, 71; Tatham 1991, 163).
- Adding sound to a map can enhance map communication. It is a complementary component used for transmitting spatial, geographic information (Parkes 1988, 25; Dahlberg 1997, 1420). Auditory maps were chosen because they are an innovation which will gain more importance in the future of tactile mapping.

The findings conducted by this research will hopefully contribute to the creation of more suitable tactile maps for educational purposes; maps that blind people can use and understand. Such maps should educate the visually impaired on geoscientific information and help them develop an accurate perception of space at larger scales.

1.4 ORGANIZATION AND LIMITATIONS OF THE PRESENT STUDY

This research study is divided into six chapters. This chapter (Chapter one) introduces the thesis. It discusses the *Rights to Education and Access to Information*, the *Accessibility of Information for People with a Visual Impairment*, the *Central Purpose*, and lists the *Definitions* of terms which will

be used throughout the paper. Chapter two covers the *Cognitive Perception of the Visually Impaired*, focusing on the *Cognition of Space*, the *Theoretical Debates on Space and the Blind*, the *Cognition of Maps* and *The Influence of Sound*. Chapter three is a *Literature Review* of previous research on tactile maps. The topics covered are the *Perspectives on Maps for the Blind: Past and Present*, *Maps for the Visually Impaired* and *Variables in Tactile Map Design*. Chapter four describes the *Methodology* used in the present study, with a description of the *Participants*, the *Survey Instruments*, the *Survey Procedure* and the *Map Making Procedure*. Chapter five focuses on the *Statistical Results and Analysis* with sections on the *Statistical Results*, the *Analysis*, the *Relationship Between the Results and the Hypotheses* and the *Strengths and Weaknesses* of the present study. Chapter six presents the *Conclusions* of the thesis.

The major limitation associated with the present study is the number of blind participants involved. Due to the limited number of visually impaired people living in the Ottawa valley and surrounding regions, the test group was restricted to 16 visually impaired and 5 sighted participants. This has been a major constraint for other studies in the field (Coulson 1991, 358; Ungar, <http://www.lgu.ac.uk/psychology/ungar/lecturenotes/spatial/spatial04.html>, July 2002). In most cases the number of blind participants varies from 5 to 30 visually impaired people (Andrews 1983; Offenbergh 2000, 16; Luxton *et al.* 1994, 78). In one study, conducted at the University of Washington, the number of visually impaired participants was nil. Instead, the participants

were blindfolded sighted people (Culbert and Stellwagen 1963, 547). This greatly weakened the validity of the findings. The study failed to consider the possible differences in tactual discrimination between the sighted and the visually impaired.

1.5 DEFINITIONS

The following is a brief description of the terminology used in this research:

Audio-tactile maps or auditory maps: tactile maps that have an added audio component.

Cognition: the process of learning and psychological reasoning (RhymeZone, <http://www.rhymezone.com/>, July 2002).

Cognitive maps: internal spatial representations or stored memories of experienced environments (Golledge 1999, <http://psycprints.ecs.soton.ac.uk/archive/00000671/#html>, October 2002).

Geographic Information Systems (GIS): Geographical computer applications used to capture, store, manipulate, analyse and display spatial and attribute data. The output of geographical data is presented through tables, graphics or maps (National Atlas of Canada Website, *Carto Corner: Glossary of Cartographic Terms*, http://atlas.gc.ca/site/english/learning_resources/carto/index.html, July 2002).

Geoscience: "Any of various sciences, as geography, geology, or meteorology, that deal with the earth, its composition, or any of its changing aspects." (Infoplease.com 2002,

<http://www.infoplease.com/ipd/A0419859.html>, May 2002)

Haptic: relating to, or proceeding from the sense of touch (RhymeZone, <http://www.rhymezone.com/>, July 2002).

Tactile or tactual: relating to, or pertaining to the sense of touch (Offenberg 2000, 5).

Tactile maps: maps showing raised points, lines and polygon surfaces. These maps are meant to be read and examined through touch.

Thematic maps: "maps that portray qualitative and quantitative geographical information. They show location, pattern, and structure of geospatial data on a wide variety of themes such as population, climate or industry." (Vasconcellos 2001, 2).

Definitions related to visual limitations:

Blind: individuals who have completely lost the sense of vision. The loss of sight may or may not include light perception (Barraga 1983, 22). For the purpose of this study, this category may also include people who have a visual impairment.

Congenitally blind: individuals who have been blind since birth (Kitchin *et al.* <http://garnet.acns.fsu.edu/~djacobso/haptic/nsf-und/Pihg96.PDF>, October 2002).

Low vision: individuals who have less than normal vision. The visual impairment may be significant, but there is still a small level of usable vision (Barraga 1983, 22).

Tunnel vision: "where a person has a very clear central vision at a specific point of focus but could not see to either side" (Barraga 1993, 24).

Visual disability: "disability refers to the lack, loss or reduction of the ability to perform certain tasks such as reading, writing and driving" (*Disability Awareness Kit: Print Disability*, <http://www.openroad.net.au/access/dakit/printdis/pdhandout1.htm>, July 2002).

Visual handicap: "handicap refers to social and environmental factors and results in disadvantage in areas such as education, employment, leisure and recreation" (*Disability Awareness Kit: Print Disability*, see web address for *Visual disability*, July 2002).

Visual impairment: "impairment denotes limitation of one or basic components of the visual system, - the eye, optic nerve and visual centre in the brain" (*Disability Awareness Kit: Print Disability*, see web address for *Visual disability*, July 2002). For the purpose of this study, this term will be used as a generic term for all levels and severity of visual problems.

CHAPTER 2

COGNITIVE PERCEPTION OF THE VISUALLY IMPAIRED

A key to developing more useful and informative maps for a visually impaired audience is to learn about their cognitive abilities (Golledge 1991, 298).

People who are blind must rely on other senses, such as touch, sound and smell to explore and understand the world that surrounds them (Millar 1988, 71; Golledge 1991, 297). Is it possible for a blind person to perceive space and develop a spatial awareness of their environment? If so, how difficult is it to construct a mental image of an object or a room without any previous use of sight? How accurate would the mental image be? Do the blind have a more acute sense of touch than the sighted? If so, does it help them in understanding spatial structures? These are examples of questions that should be asked and reviewed before creating any device or tool targeted for a visually impaired audience. Learning about their strengths, weaknesses and capabilities could potentially increase the usability of a device. As a minimum this will at least help to lead a research in the right direction. This chapter will explore the psychological and visual world of the sight impaired, focusing on the *Cognition of Space*, the *Theoretical Debates on Space and the Blind*, the *Cognition of Maps* and the *Influence of Sound*.

2.1 COGNITION OF SPACE

The cognition of space for the visually capable is rendered predominantly by sight (Hermelin and O'Connor 1982, 52; Sedgwick 1982, 3; Vasconcellos

1996, 92; Golledge 1991, 297). Vision is considered to be the most important of all senses for perceiving space (Juurmaa 1973, 87; Golledge *et al.* 1994, 1). As described by one researcher in the area of psychology: "the visual system is the spatial system par excellence" (Foulke 1982, 61). The advantages of having sight are numerous and can sometimes be taken for granted. Vision allows us to collect colossal amounts of spatial information in a minimal period of time (Krueger 1982, 6; Berla 1982, 375; Millar 1988, 74). The size of objects and the space between them is apparent (Berla 1982, 376). Perceiving distances and dimension are other advantages that are naturally overlooked in the daily life of a sighted person. Several studies have been conducted on the perception of space for those who have sight (Sedgwick 1982; Downs & Stea 1973; Hart & Moore 1973). The issue of space has been an important research topic because it is fundamental to being mobile and it is at the base of the spatial behavioural sciences (Ungar, <http://www.lgu.ac.uk/psychology/ungar/lecturenotes/>, October 2002). Spatial behaviour or behavioural geography is the study of how organisms move in the environment (Robinson *et al.* 1998, 374; Ungar, <http://www.lgu.ac.uk/psychology/ungar/lecturenotes/>, October 2002). Research in this area is particularly important for environmental design and planning of urban and rural structures (Hart & Moore 1973, 285).

Most sighted people will categorise space in terms of the objects that surround them and the degree of clustering between these objects (Golledge 1993, 68; Berla 1982, 376). For the blind, the cognition of space is

obviously different and is based on the construction of elements and the building of spatial structure through touch, sound and smell (Krzywicka-Blum and Kuchmister 1998, 141; Krueger 1982, 6). Of these three senses, touch is considered to be the best sense for acquiring information on the composition of space (Foulke 1982, 63, Révész 1950 referenced in Millar 1988, 75) Compared to vision, the exploration of space through haptic means is a particularly long process because it is done in a piecemeal fashion (Berla, 1982 375; Foulke 1982, 63; Millar 1988, 74; Von Senden 1960, 285). Each object is examined by touch, memorized to some extent, then mentally constructed together to form one whole entity (Foulke 1982, 63 & 65; Hermlin & O'Connor 1982, 36; Von Senden 1960, 285). This procedure is much the same when exploring two-dimensional representations such as tactile maps. As Coulson (1991) describes it: "tactual interpretation is based on scanning the map, from one part to another: it cannot be experienced as a complete entity as the sighted person views a map, picture or scenic view" (Coulson 1991, 355). This type of insight is very important when attempting to create tactile maps for usability purposes.

2.2 THEORETICAL DEBATE ON SPACE AND THE BLIND

The issue of space and blindness has created controversial perspectives in both past and more recent literature (Golledge 1993, 71). The questions that have stirred up debates are the following: *Are blind people capable of understanding space* and *Do blind people have the ability to develop mental images of objects and spatial structures of their environment?* The answers

to these questions are particularly important for the present study. If the visually impaired are capable of creating spatial concepts and mental imagery, then tactile maps are the tools needed for developing these skills further. Maps may help to increase understanding of relationships between spatial entities and help develop a spatial perception of environments at different scales (Luxton 1994, 76).

Some researchers argue that people who have very little peripheral vision or tunnel vision have a different understanding of space than those who are completely blind (Dacen 1987 referenced in Siekierska 2002, 4). Even with extremely limited vision, there is an advantage of receiving instantaneous feedback from the environment. This feedback can promote the development of spatial awareness and mental imagery in some individuals (Millar 1988, 73). Where researchers have a difference of opinion is in the cognition of space of people who are completely blind at birth. At one end of the spectrum, it is argued that those completely blind have absolutely no understanding of space, while at the other end they are considered to have the same spatial abilities as the sighted. One researcher, Fletcher (1980), categorized the differences in perspectives into three theoretical classes: the deficiency theory, the inefficiency theory and the difference theory.

2.2.1 The deficiency theory

The deficiency theory states that people who are blind at birth are incapable of understanding any spatial references and are unable to "develop a spatial

relational schema” (quote from Golledge 1993, 71; Fletcher 1980, 381; Andrews 1983, 31) According to the researchers whose beliefs fall in this category, the only means of obtaining spatial awareness is through vision (Von Senden 1960, 309; Jacobson *et al.* <http://garnet.acns.fsu.edu/~djacobso/haptic/nsf-und/3theory.PDF>, October 2002). Having not been exposed to two and three dimensional arrangements, the blind are unable to evoke visual or mental images of their environment (Von Senden 1960, 289; Foulke 1982, 39). The first researcher to express this viewpoint was Von Senden in the early 1930’s. According to Von Senden’s research, only those blind from cataracts have the potential to perceive space. His hypothesis suggests that the restoration of sight through cataract operation is the only way to attain spatial awareness (Von Senden 1960, 309). Today, few researchers support this theory due to numerous related studies that have demonstrated quite different results (Andrews 1983, 31; Juurmaa 1973; Jacobson 1998, 291).

2.2.2 The inefficiency theory

The inefficiency theory recognizes the spatial abilities of the congenitally blind. The gathering of spatial information is done primarily through auditory and haptic means (Jacobson *et al.*

<http://garnet.acns.fsu.edu/~djacobso/haptic/nsf-und/3theory.PDF>, 4, October 2002). According to this theory, blind people can mentally manipulate spatial concepts but their comprehension and visual imaging are inferior to those who have sight (Golledge 1993, 71; Kennedy 1983, 84;

Révész 1950 referenced in Krueger 1982, 6; Kitchin

<http://garnet.acns.fsu.edu/~djacobso/haptic/nsf-und/Pihg96.PDF>, 5, October

2002). Discrepancies exist in linking the likeness of mental images to real objects. Mental images are not as accurate as those created by sighted people (Kruegel 1982, 6; Cornoldi & Vecchi 2000, 149) because there is a higher likelihood that some information may be overlooked when using alternative senses (Foulke 1982, 63; Millar 1988, 74).

2.2.3 The difference theory

The difference theory suggests that the spatial abilities of the blind are comparable to those of the sighted (Juurmaa 1973, 115; Fletcher 1980, 382; Kitchin <http://garnet.acns.fsu.edu/~djacobso/haptic/nsf-und/Pihg96.PDF>, 5, October 2002). This hypothesis implies that vision is not necessary for appreciating perspective, understanding relations between objects or for spatial encoding (Kennedy 1983, 84; Millar 1988, 83). This theory is not without its drawbacks. The differences between the sighted and the blind in perceiving space are the procedures used during the cognitive processes and the time allocated in building spatial concepts (Ungar, <http://www.lgu.ac.uk/psychology/ungar/lecturenotes/spatial/spatial04.html>, October 2002; Juurmaa 1973, 115). As explained in section 2.1 (*Cognition of Space*), the procedures used in gathering spatial data and combining it to form one entity are done sequentially. Learning spatial concepts in this manner is a very slow process. Other delaying variables include access to information (e.g. maps), experience and stress (Millar 1988, 72; Jacobson et

a/. <http://garnet.acns.fsu.edu/~djacobso/haptic/nsf-und/3theory.PDF>, 4, October 2002). The two former variables may be interconnected where the inaccessibility to maps delays educational development and experience. Finally, stress can become a factor due to the inexperience of a visually impaired user in reading maps.

While the majority of research tends to favor the view that the congenitally blind are able to recognize space (Jacobson 1998, 300; Juurmaa 1973; Millar 1988), little is known about their processing of imagery (Fletcher 1980, 381; Cornoldi & Vecchi 2000, 149). The likeness of a mental image to the truth and the cognitive mapping processes of the blind are still largely unknown and may depend on individual experiences and cognitive abilities (Cornoldi & Vecchi 2000, 168; Golledge 1991, 296). Teaching the blind how to read and use tactile maps is a step in the right direction toward exercising and developing their visual abilities. Having access to maps and graphics may prove the difference theory to be correct. Whatever the outcome, it is hoped that the frequent use of maps by the blind will eventually increase their abilities, mentally and tactually, to synthesize the information they receive by touch into a well defined mental representation.

2.3 COGNITION OF MAPS

Sighted people have the advantage of using their visual experience for reading and understanding maps. Vision facilitates the cognitive process of transforming real world entities into map features, and vice versa (Millar

1988, 85). Can the visually impaired recognize map elements and relate them to three-dimensional surfaces? According to some researchers in the area of tactile mapping, the visualization of map features is possible for the blind, but remains a challenging task (Luxton 1994, 75; Millar 1988, 78). How then do the blind perceive maps? The cognitive processes used in identifying two-dimensional features on a map are similar to those used in the recognition of three-dimensional spaces (see Chapter 2, section 2.1: *Cognition of space*). Each feature is examined individually, memorized to a certain extent and then built together to form one spatial unit (Coulson 1991, 355; Wiedel 1969 referenced in Nolan and Morris 1971, 2).

The cognition of maps remains an ongoing learning process for all visually impaired people but some individuals may encounter more difficulties than others. Some of the many reasons are the degree of sensory impairment, the lack of knowledge of fundamental geographic and cartographic concepts, and the inexperience in reading and using tactile maps (Perkins & Gardiner 1997, 1160; Thompson 1983, 104; Vasconcellos 2001, 3).

2.3.1 Degree of sensory impairment

Map interpretation abilities of those completely blind and partially blind may differ considerably (Groves & Wiedel 1972, 1; Wolfgang 1983, 88).

Vasconcellos (1996) identified potential problems in the use of maps by people with low vision; problems that would not arise with people who are totally blind. The main problem was their failure to rely entirely on either

vision or touch (Vasconcellos 1996, 93). The consequences of this mental conflict are a lack of consistency in visual acuity and cognitive restraints (Vasconcellos 1996, 94). Krueger (1982) also discussed the debates between vision versus touch. He stated that under these circumstances, vision normally dominates touch unless the conflict has been prolonged, in which case touch eventually becomes the leading sense (Krueger 1982, 5). Unfortunately, there is a lack of information on the subject of creating tactile maps for a heterogeneous blind audience. Apart from the two references mentioned above (Vasconcellos 1996 and Krueger 1982), little mention of this subject was found during the literature review.

2.3.2 Lack of knowledge in geography

Another reason why some blind people may encounter difficulties in understanding maps is the lack of knowledge of geographic and cartographic concepts. Geography in the grade school curriculum is heavily map oriented where many of the textbooks illustrate various maps and figures (Matthews, 1978, 205). The lack of access to tactile maps for education has placed visually impaired students at a disadvantage to their sighted peers when learning geographical concepts (Gardner 1996, <http://dots.physics.orst.edu/tactile/tactile.html>, October 2002; Kadmon 1991, 178). Many blind people have not received adequate education related to geography and consequently, have varying degrees of knowledge in this subject matter (Thompson 1983, 104; Hampson and Daley 1989 referenced in Siekierska 2002, 4).

2.3.3 Inexperience in reading tactile maps

Blind peoples' inexperience in map reading contributes to the difficulties associated in their cognition of maps. In general, the haptic skills of blind people in examining and reading maps are poor (Berla 1982, 379; Turk 1983, 6). Those who do have some experience are likely to have a better perception of maps than those who have no experience (Berla 1982, 380). External qualitative and quantitative factors, such as the poor quality and availability of maps, are at fault for the blind's lack of experience in reading tactile maps (Millar 1988, 72). First of all, the quality of maps for the blind has been inferior to those created for the sighted (Lederman 1982, 156; Berla 1982, 365). Generally, tactile maps are too complex for visually impaired users to understand (Matthews 1978, 207; Bentzen 1982, 387). In such cases, interest may be lost, as will be the potential to gain experience. Secondly, the availability of tactile maps has been quite limited (Golledge 1993, 69; Pearce 1983, 62). The lack of access to this type of information decreases the opportunities for education and experience.

Some of these factors, such as the degree of sensory impairment and the experience in reading tactile maps, have been assessed in the present study. The maps created for this study were greatly simplified to facilitate a blind person's perception of map features. Another element known to aid the perception process is auditory output. The next section, section 2.4 *The Influence of Sound*, discusses this topic further.

2.4 THE INFLUENCE OF SOUND

Sound is an important element used for communicating, transmitting spatial information and in understanding the world around us (Webb, <http://www.humsci.stir.ac.uk/>, December 2002; Parkes 1988, 25; Dahlberg 1997, 1420). For the visually impaired, sound is considered an important constituent in the cognition of space, and to some extent the understanding of maps (Krzywicka-Blum and Kuchmister 1998, 141; Krueger 1982, 6).

Only recently has sound been researched for the benefit of the visually impaired. What influence does sound have in helping the user understand spatial relationships? Is sound considered a spatial language? Most studies related to this subject have focused on two-dimensional and three-dimensional auditory information for education and mobility (Krygier 1994; Golledge *et al.* 2002; Kawai & Tomita, <http://staff.aist.go.jp/y.kawai/Paper/mva2000.pdf>, December 2002). Other studies discussed the use and benefits of sound systems for computer users who are blind (Darvishi *et al.* 1994; Shepherd, http://www.chelt.ac.uk/gdn/disabil/blind/ch6_3.htm, December 2002).

According to some researchers in psychology and modern cartography, sound is a perception tool which contributes to the creation of mental images or maps (Holliday, http://www.gisca.adelaide.edu.au/~dhollida/new_tech/125sound.html, December 2002; Krygier 1994, 162). It is an alternative method used for

representing visual data. Krygier (1994, 153) established a list of abstract sound variables (cues to alert or direct) to be used for geographic visualization. Amongst these are the location, loudness, pitch and duration of sound. These variables can be used to represent map data on nominal and ordinal scales of measurement. For example, loudness would be appropriate for displaying ordinal data because it represents an orderly measure or magnitude of a sound (Krygier 1994, 154). Location could be used to show nominal and ordinal data. The ability to locate sound on a map could be particularly useful for learning spatial relationships (Krygier 1994, 152). Another form of two-dimensional auditory information for educational uses was found in the article written by Lunney & Morrison (1981). The article discussed the development of electronic voice aids for scientific instruments at East Carolina University. Visually impaired students attending the University now have the ability to make accurate laboratory measurements, using talking thermometers, calipers and multimeters (Lunney & Morrison 1981, 228). The use of sound for educational advancement was highlighted throughout this article.

Sound has also been considered a spatial and educational language in three-dimensional systems. Golledge *et al.* (2002) conducted a study on the ability to reach a target location, in an environmental setting, using non-repetitious sound and speech from a loud speaker. Blind-folded and visually impaired participants were tested on their ability to convert sound and verbal description into a spatial image and then update the spatial image while

walking and turning to reach the target location. The goal was to determine the participants' perception and visualization capabilities. The results showed that sound, speech or non-speech, is a contributing factor in developing mental images of an environment, and that the participants were able to spatially update the target locations in their minds. Another study by Kawai and Tomita (<http://staff.aist.go.jp/y.kawai/Paper/mva2000.pdf>, December 2002) used sound for three-dimensional spatial referencing. This study discussed the development of a recognition support system using three-dimensional virtual sound for mobility purposes. The system converts visual information into auditory information. Information on specific targets, obstacles and direction are expressed using abstract sounds into a virtual space environment (a head set worn by the traveler). A user must learn the correspondence between the sounds and objects before using the device. After testing on blind-folded and visually impaired participants, the main problem discovered with the system was the difficulties associated with the recognition of sounds. Perhaps spoken sound would prove to be more useful? This system was still in the development stage when it was tested. The problems encountered were recognized and modifications are in effect.

The main problems associated with the use of sound for spatial recognition and educational development, are perceptually and cognitively related (Krygier 1994, 159). In terms of the perceptual issues, a better understanding of "the sound perception capabilities of the human physiological system" is needed (Krygier 1994, 159). In other words, how

many different sounds can humans successfully distinguish? Are spoken sounds more easily recognized than abstract sounds? The cognitive issues deal with recognition, problem solving and memory retention (Krygier 1994, 159). As demonstrated in the study by Kawai and Tomita (<http://staff.aist.go.jp/y.kawai/Paper/mva2000.pdf>, December 2002), the recognition of sound proved to be problematic. If cognition is based on individual capabilities, how then can sound be used to answer the needs of all visually impaired individuals? Research on the influence of sound, such as the present study, is a step in the right direction.

In general, according to the studies referenced in this section, sound has been considered an influential aid for the visually impaired. It has been referenced as a perception tool used to aid in the creation of mental images of the surrounding environment, at both two-dimensional and three-dimensional scales (Holliday, http://www.gisca.adelaide.edu.au/~dhollida/new_tech/125sound.html, December 2002; Krygier 1994, 162).

CHAPTER 3

MAPS FOR THE VISUALLY IMPAIRED: A LITERATURE REVIEW

A review of cartographic literature has revealed that maps for the visually impaired began to receive serious international attention around the beginning of the 1980's. Most papers written before this time originated from Great Britain and Australia. Researchers from these countries were among the first to recognize the importance of tactile maps. Some researchers have commented on the slow development of this topic in literature, and have pointed out dates at which the subject became a relevant research area. Goodrick observed that: "The first mention of tactile maps in cartographic literature was in 1954..." (Goodrick 1984, 631). Wiedel, another researcher, said: "The first record in this country of a professional cartographer involved in graphics for the blind dates back only to 1958." (Wiedel 1969, quoted in Nolan and Morris 1971, 1).

Literature on tactile mapping is slowly gaining recognition throughout the cartographic community, especially through cartographic associations and at cartographic conferences and symposiums (Greatorrex 1986, 1). A few examples are the *Australian Cartographic Conference*, the *International Cartographic Conference* (or *International Conference on Cartography*) and the *Commission on Maps and Graphics for the Visually Impaired People* established by the International Cartographic Association. The International

Conference on Cartography is an excellent example where the subject of tactile maps has gained recognition.

There have been 20 International Cartographic Conferences in total. The only papers found were those between the 6th and the 20th International Cartographic Conferences. The first five were therefore not considered for the literature review. The earliest mention of tactile maps was in 1972, at the 6th International Cartographic Conference. The only paper on maps for the blind presented at this conference was entitled '*The development of spatial concepts through tactual graphics: A mobility and orientation program for blind children*', by Groves & Weidel (1972). Since the 6th conference, the number of papers related to tactile maps has increased. Some conferences had no mention of tactile maps but did address the subject of maps for handicapped people. One example is a paper written for the 12th International Cartographic Conference. Under the subject heading *Cartographic Education*, Exler & Brouwer (1984) wrote a paper entitled '*Mapping for the handicapped: A procedure from data collection to final product*'. As papers increased in number at each conference, categories were formed for each subject theme. A distinct category was formed for tactile and specialized mapping in 1987 at the 13th International Conference on Cartography. The category was called *Tactual Mapping and Atlases* and two studies discussed the issue of mapping for the blind. The first one was called '*The standardization of the tactile mobility map symbols in Japan*', written by Katoh (1987). The second was called '*Problems in cartographic*

education: the design and reproduction of tactile maps and graphics', written by Wiedel (1987). The latest International Cartographic Conference took place in 2001 and there were 8 papers related to mapping for the visually impaired under the subject theme *Maps for the Handicapped People*. Among some of the papers were '*Atlas Tactil de Latino America (Tactile Atlas of Latin America)*' by Taylor (2001), '*How to make tactile maps discriminable for touch?*' by Eriksson and '*Tactile mapping project at Canadian federal mapping agency: mapping services branch*' by Siekierska et al. (2001).

3.1 PERSPECTIVES ON MAPS FOR THE BLIND: PAST AND PRESENT

3.1.1 Past perspectives

There are some significant reasons why tactile maps have been produced on a very limited scale. One reason is that the visually impaired constitute a small market (Dahlberg 1997, 1417). Another is related to the narrow viewpoint of different groups and organizations who believe that "the blind don't actually need maps".

Maps for the blind have not received the attention they deserve due to the small number of visually impaired people. This group is insignificant in comparison to the population at large. In 1991 the visually impaired accounted for 2.8% of the Canadian population (Statistics Canada, <http://www.statcan.ca/english/Pgdb/health12a.htm>, October 2002). The visually impaired represent one of the smallest groups when compared with other disabled groups. The three largest disability groups of the Canadian

population in 1991 were people with a disability in mobility (10.8%), agility (9.9%) and hearing (5.5%) (Statistics Canada, <http://www.statcan.ca/english/Pgdb/health12a.htm>, October 2002).

Another reason for the slow advancement in the research on maps for the blind is the viewpoints of the communities, governments and the blind themselves. Governments have not perceived the visually impaired as needing maps because they were believed to lack spatial cognitive abilities (Goodrick 1984, 630; Coulson 1991, 354). Even some blind people have not seen the usefulness of maps (Goodrick 1984, 628). The reasons differ depending on the individual. Some found that tactile maps were too complex to understand because "they too closely resembled the maps prepared for the sighted" (Golledge 1993, 69). Others were discouraged by the poor quality of maps and found the symbols difficult to discriminate through touch (Lederman 1982, 156; Matthews 1978, 207; Nolan and Morris 1971, 2). Some people lacked interest because they found maps to be uninformative (Jansson 1983, 690; Bentzen 1982, 387). Perhaps the reason was because tactile maps usually contain less information than maps for the sighted (Coulson, 1991, 355). Finally, certain blind people didn't see the usefulness of maps because they lacked haptic abilities or map reading skills (Berla 1982, 365; Millar 2000, 124). Although research in this area has increased, some of these issues still remain today.

It is hoped that this study will play a small role in changing the perspectives on the usefulness of maps for the blind. The production of legible and informative maps will hopefully increase the enthusiasm of many visually impaired people. Despite the past perceptions of governments and communities, most have now recognized the importance of maps for the visually impaired. Evidence of this is the increase in the number of papers related to tactile maps in recent years.

3.1.2 Recent perspectives

About 85% of the books and articles found during this literature review dated from the 1980's to the present. Why this sudden interest in mapping for the blind? It could be due to the increase in the number of visually impaired people in Canada. As stated in a news release by the Canadian National Institute for the Blind (CNIB): "There are currently 105,000 Canadians registered with the Canadian National Institute for the Blind as blind or severely visually impaired. That number is currently increasing by 1000 per month - a rate that will lead to a doubling of the number of blind and severely visually impaired Canadians in the next 10 years." (CNIB, *National Coalition for Vision Health News Release*, http://www.cnib.ca/eng/about/news/natcol_report.htm, October 2002). The news release noted that the increase is related to the aging of the "baby boom" generation. Once the baby boomers reach the age of 65, one in nine Canadians is estimated to experience vision loss (CNIB, *National Coalition for*

Vision Health News Release,

http://www.cnib.ca/eng/about/news/natcol_report.htm, October 2002).

Another reason for the increased interest in maps for the visually impaired is linked to the rights of people with disabilities. The rights of people having a disability were recognized in Canada in 1982 through the *Canadian Charter of Rights and Freedoms* (see Chapter 1, section 1.1 *Rights to Education and Access to Information*). The United Nations identified the rights of the disabled in 1975 with The United Nations Declaration on the Rights of Disabled Persons (Siegal, http://www.aclu.org/library/iclr/2001/iclr2001_4.pdf, October 2002). Many countries today have some form of disability rights law, although they may not all follow the same ideology as the United Nations (Siegal, http://www.aclu.org/library/iclr/2001/iclr2001_4.pdf, October 2002). These countries include the United States with the Americans with Disabilities Act in 1990, Australia's Disability Discrimination Act in 1992, Nigeria's Disability Decree in 1993 and Israel's Equal Rights for People with Disabilities Law in 1999 (Disability Rights Education & Defense Fund, <http://www.dredf.org/symposium/lawindex.html>, October 2002).

The papers referenced in this review focused on maps for the blind. Some of these papers also discussed the rights of the disabled population and their needs for learning geographic space (Golledge 1993; O'Brien & McFetridge 1991). The following sub-sections will focus on topics recurrently found

during the literature review. The topics of discussion include *Maps for mobility*, *Maps for education*, and *Map variables in tactile map design*.

3.2 MAPS FOR THE VISUALLY IMPAIRED

Research on maps for the blind has focused primarily on the choice of legible tactile symbols (Lederman 1982, 156; Nolan & Morris 1971, 3; Jansson 1983, 69; Luxton, Banai & Kuperman 1994, 76). Three classes of symbology are typically used in tactile maps: point, line and area symbols (Barth 1983, 11; Greateorex 1986, 17; Tatham 1991, 161). Point symbols are used to identify a single landmark or location, lines represent boundaries and area symbols are used to differentiate spatial regions (Nolan & Morris 1971, 3; Robinson *et al.* 1995, 322; Wolfgang 1983, 89). The choice of symbol is dependant on the type of information to be displayed.

Because maps show such a variety of geographic information, they can be grouped into different categories. Tactile maps are generally categorized into two distinct groups: maps for mobility and maps for education (Greateorex 1986, 17). One discovery made from the literature review is that most research on tactile maps has been carried out for mobility purposes (Thompson 1983, 104; Offenbergs 2000, 7). The primary reason being that mobility is considered to be the "most common need" and is important for ordinary everyday functioning (Goodrick 1980, 2; Jacobson 1998, 291). The literature found on maps for education is much smaller. Because they don't

present as great a need as maps for mobility, maps for education have been somewhat neglected in the past (Thompson 1983, 104).

3.2.1 Maps for mobility

Mobility maps are guiding supplements intended for navigation (Offenberg 2000, 7; Wolfgang 1983, 87). They usually focus on areas that are often visited by blind people, for instance university campuses, shopping centers and public transport interchanges (Greatorex 1986, 17; Golledge 1991, 298; Perkins & Gardiner 1997, 1160). These maps show the location of buildings, streets and walkways and may also include the location of hazards and obstacles (Andrews 1983, 34; Clark 1994, <http://www.sgi.ursus.maine.edu/gisweb/spatdb/acsm/ac94120.html>, October 2002). Figure 3.1 is an example of a mobility map, the Pasadena (California) City College campus, with added text to explain the map features.

Occasionally, research on the creation of mobility maps has involved visually impaired people (Groves & Wiedel 1972; Wolfgang 1983; Golledge 1991). In these cases blind participants were asked to travel to a specific destination. The goal of such exercises was to see if the tactile information could easily be understood and used effectively for traveling. An example of such studies appears in a paper written by Sona Darentz Andrews (1983). In this study, blind students attending Arizona State University were given maps of their campus. The maps showed the locations of buildings, streets,

FIGURE 3.1: Mobility map

Source: Clark, Jerry (1994). *Creating Tactile Maps for the Blind using a GIS, ASPRS/ACSM*.

(<http://www.sgi.ursus.maine.edu/gisweb/spatdb/acsm/ac94120.html>, October 2002)

walkways and obstacles zones. The goal was to discover how much information was gained and retained from using the maps. The results showed that students developed a broader mental image of the campus grounds, and the frequent use of maps increased their confidence level. Their travel patterns also became more diversified because they could better locate themselves. Other studies, such as those by Groves & Wiedel (1972) and Luxton *et al.* (1994) have had similar positive results. It has been concluded from these studies that mobility maps have assisted the visually impaired to become more independent, and to some degree, more integrated into society (Nobilta 1998, 147; Lederman 1982, 156).

3.2.2 Maps for education

Maps for education have been specially designed for education in geography, history and all other subjects having a spatial component (Siekierska *et al.* 2001, 2939). For the purpose of this study, maps for education will consist of geographic maps.

Geographic maps can be classified into two groups: general reference maps and thematic maps (Vasconcellos 2001, 2; Thompson 1983, 104). General reference maps are basemaps that show the location of geographical features such as water bodies, coastlines and political boundaries (Robinson *et al.* 1995, 13; Andrews 1983, 35). Examples of such maps are found in the Tactile Atlas of Canada (Figure 3.2). The maps produced for this study fall under the category of thematic maps. These maps concentrate on specific

FIGURE 3.2: Reference map of Canada

Source: Mapping Services Branch (2001). *Tactile Atlas of Canada, Edition 2*. Ottawa, ON: Natural Resources Canada.

topics or “themes” such as precipitation distribution or vegetation cover of a region (Robinson *et al.* 1995, 13). While both types of maps show qualitative data such as lakes and boundaries, thematic maps may also show quantitative measures, for example the population density of a particular area (Andrews 1983, 35; Thompson 1983, 104; National Atlas of Canada Website, *Carto Corner: Maps, what are they?* http://atlas.gc.ca/site/english/learning_resources/carto/cart001.htm, May 2002).

Three thematic tactile atlases were found during the literature review. The Braille Atlases of Canada developed by the Canadian National Institute for the Blind (CNIB 1977) in Toronto Canada, the Tactual Atlas of Australia created at the Department of Resources and Energy in Australia (Goodrick 1978) and the Atlas of Latin America developed by Taylor at Carleton University in Ottawa, Canada (Taylor 2000). All three atlases are composed of a series of national scale maps showing the spatial distribution of geoscientific information. The Braille Atlases of Canada focuses on six main themes for education in geography. Some of the themes are climatic regions, vegetation (Figure 3.3) and land surfaces. The Tactual Atlas of Australia is the largest of the three atlases and covers a variety of subjects such as the geology and precipitation distribution (Figure 3.4) of Australia. Finally, the Atlas of Latin America covers themes related to population density, physical relief and other geoscientific topics (Figure 3.5).

**FIGURE 3.3: Thematic tactile map of Canada:
Vegetation distribution**

Source: Canadian National Institute for the Blind (1977).
Braille Atlases of Canada, volume 3. Toronto, Canada.

**FIGURE 3.4: Thematic tactile map of Australia:
Precipitation distribution**

Source: Goodrick (1978). *Tactual Atlas of Australia*.
Canberra, Australia: Department of Resources and Energy.

The category of thematic maps was chosen for this study because the need to learn geosciences is great among the visually impaired community (Nolan & Morris 1971, 1; Coulson 1991, 356; Siekierska *et al.* 2001, 2939). Few attempts have been made by researchers to design thematic tactile maps (Perkins & Gardiner 1997, 1160). The conclusions drawn from this research will hopefully act as a guide for the future development of geoscientific maps for the visually impaired.

3.3 VARIABLES IN TACTILE MAP DESIGN

Mapping for the visually impaired is not a simple conversion of conventional maps into tactile format (Goodrick 1980, 1; Vasconcellos 1996, 94; Perkins & Gardiner 1997, 1160). Maps must be designed for tactile reading, and the users must be able to understand through touch, the information being displayed. As mentioned in Chapter 2 (*Cognitive Perceptions of the Visually Impaired*) "a key to developing informative maps for the blind is to learn about their cognitive abilities". Learning about their haptic abilities is equally important (Berla 1982, 375). Depending on several factors (i.e.: experience and level of visual impairment) visually impaired people have varying degrees of haptic skills (see Chapter 2, section 2.3: *Cognition of maps*). Regardless of skill levels, the fingers remain far less discriminating than the eyes (Tatham 1991, 158; Krueger 1982, 6; Kadmon 1991, 176; Perkins & Gardiner 1997, 1160). For this reason, it is essential to keep tactile maps as simple as possible to increase legibility of the information (Tatham 1991, 165; Luxton, Banai & Kuperman 1994, 76).

Three variables, symbology, map projections and auditory maps are the test elements for this research. These variables were chosen because they are believed to affect the cognition and readability of tactile maps.

3.3.1 Symbology

Area symbology was chosen as a research topic because of the varying viewpoints of some researchers with regards to this symbology's legibility and haptic discrimination. Among the researchers found during the literature review are Culbert & Stelwagon 1963, Nolan and Morris 1971, Matthews 1978 and The N.S.W. Tactual Mapping Committee 1987.

Culbert & Stelwagon (1963) tested a sample of forty patterns for haptic discrimination with blind-folded sighted students. Each two-inch square pattern was printed using an embossage technique, producing a plastic-like solid raised image. Individual patterns were tested with other patterns, and with themselves. The measure of legibility was determined by the number of discrimination errors performed during the testing of each pattern. Of the forty patterns, fourteen were found to be most easily discriminated (see Figure 3.6).

Nolan and Morris (1971) tested a series of patterns for legibility and ease of discrimination among blind students. Each pattern-filled polygon was evenly spaced out on a vacuumed formed plastic sheet. Students were asked to "pair-compare" the patterns, individually. A legible pattern was defined as

one that was "not confused with any other pattern or itself more than 10% of the time" (Nolan and Morris 1971, 4). The results are shown in Figure 3.7.

Matthews (1978) conducted a survey of tactually discriminating area symbols on low vision and visually handicapped students. Seventeen patterns were selected and dispersed arbitrarily among polygons; some of which appeared more than once (Figure 3.8). The students were asked to assess the legibility of each pattern by simply indicating "those which they liked, and those they considered were difficult to differentiate" (Matthews 1978, 207). The results showed that no particular pattern gained acceptance over any other.

In contrast with the three researchers mentioned above, the paper written by The N.S.W. Tactual Mapping Committee (1987) does not describe the methodology of a survey, but only the results (Figure 3.9). Ten patterns were chosen as the most discriminating symbols used on swell paper (heat activated rising paper).

FIGURE 3.6: Most legible patterns as defined by Culbert & Stelwagon.

Source: Culbert, Sidney S. & William T. Stellwagen (1963).
Tactual Discrimination of Textures. *Perceptual and Motor Skills*,
vol. 16, pp. 546. Missoula, MO: Southern Universities Press.

FIGURE 3.7: Most legible patterns as defined by Nolan & Morris.

Source: Nolan, C.Y. and J. E. Morris (1971).

Improvement of tactual symbols for blind children, pp. 6, 7, 17.

Louisville, Kentucky: American Printing House for the Blind.

FIGURE 3.8: Most legible patterns as defined by Matthews.

Source: Matthews, G.J. (1978). *An Atlas of Canada for the Visually Handicapped*.
Third Australian Cartographic Conference, pp. 208.

Brisbane: The Australian Institute of Cartographers.

**FIGURE 3.9: Most legible patterns as defined by
N.S.W. Tactual Mapping Committee.**

Source: The N.S.W. Tactual Mapping Committee (1987).
A Guide for the Production of Tactual and Bold Print Maps.
The N.S.W. Tactual Mapping Committee, 15.

The symbol of choice, for displaying area surfaces, was patterns for all four studies. Unfortunately, when comparing the results of these studies, the research on the discrimination of patterns revealed inconsistent results. One study revealed no preference of pattern at all. Of the studies which revealed preferences, some of the choices were consistent, for example the dots and the diagonal lines, but many were not. Some of the reasons why the results of these studies differ may be related to the testing methodologies, the type of paper/plastic used for printing, the definition or measure of "legibility" and the choice of participants. The goal of researching symbology in this study is to determine the most legible types of area symbols. One method of attaining this goal is to test alternative ways of displaying patterns and to seek alternative area symbols.

3.3.2 Map Projection

Another variable that is believed to affect the cognition and legibility of maps is map projection. This subject was chosen as a research topic because of the important role it plays in conventional cartography. Most cartography books discuss the issue of map projections and when to use them (Campbell 1993, 42; Robinson *et al.* 1995, 59). The proper selection of projection can ultimately contribute to an enhanced display of information (Robinson *et al.* 1995, 70). If this is such a relevant topic in conventional cartography, why is it not a key element in tactile map design?

Map projections have been greatly overlooked in tactile mapping literature. A paper written by Kadmon (1991) was the only one found during the literature review which discussed this topic thoroughly. Kadmon talked about the blind and their difficulties in mentally transforming three-dimensional surfaces into two-dimensional images. The suggested use of projection for tactile maps was also discussed (Figure 3.10). According to Kadmon's hypothesis, presenting the world as two hemispheres instead of one ellipsoid provided a "more comprehensible picture of the earth" (Kadmon 1991, 179). No studies were conducted on projection types and no conclusions were reached. However, the paper stressed the importance of follow-up studies in this area.

3.3.3 Auditory maps

Auditory maps are maps that have an added audio component. The added sound is a complementary component used for transmitting spatial, geographic information (Parkes 1988, 25; Dahlberg 1997, 1420). This variable has been tested in the present study because it is believed to improve the cognition of maps among a visually impaired audience. It has been chosen also for its growing recognition in recent cartographic literature (Parkes 1998; Golledge *et al.* 1994; Taylor 2001; Dahlberg 1997).

The potential benefits of auditory maps have been recognized in recent years. Adding sound to maps allows for the creation of simple maps and allows for a broader range of blind users. Firstly, when sound is added to a

FIGURE 3.10: Suggested use of projection for tactile maps by Kadmon.

Presenting the world as two hemispheres (A) is preferred over the ellipsoid projection (B).

Source: Kadmon, Naftali (1991).

Tactile Map Projections and Computerized Thematic Maps and Atlases.
Proceedings of the 15th Conference and 9th General Assembly.
International Cartographic Association, vol. 1, 177.

map Braille can be omitted (Parkes 1994, <http://cleo.murdoch.edu.au/gen/aset/confs/edtech94/mp/parkes.html>, November 2002; Taylor 2001, 2895), thus freeing the map from excessive information (Landau & Gourgey 2001, <http://www.rit.edu/~easi/itd/itdv07n2/tablet.htm>, November 2002). Tactile maps have often been categorized as being too complicated for users to understand (see Chapter 2, section 2.3: *Cognition of maps*). Excluding text can decrease the complexity of maps (Parkes 1996, 5). Other benefits of excluding Braille from maps (or adding sound) is the potential to reach a larger user group; those who are non-Braille readers (Parkes 1996, 3). Eighty to eighty-five percent of visually impaired people are unable to read Braille (Loetzsch, <http://www.rit.edu/~easi/easisem/loetzsch.html>, November 2002; Lunney 1981, 228). This means that the majority of visually impaired people are unable to gain access to a large amount of information (Parkes 1996, 3). Perhaps auditory maps will help remedy this problem.

Three audio systems were found during the literature review. Among them are the Tactile Audio Graphics (TAG) system developed by Don Parkes at the University of Newcastle in Australia, the Talking Tactile Tablet (TTT) created by Touch Graphics, a for-profit company in the United States, and Audio-Touch developed by the Blind and Visually Disabled Union in Germany. Don Parkes is considered the pioneer of auditory graphics for the visually impaired (Oka 2001, 2927; Gardner 1996,

<http://dots.physics.orst.edu/tactile/node13.html>, November 2002). His system has been most frequently referenced in the literature (Taylor 2001, Oka 2001; Siekierska 2001; Parkes 1996; Landau & Gourgey 2001; Loetzsch). The TAG system was used for this study because it was readily available.

TAG is composed of several computer programs with a built-in voice synthesizer and a touch sensitive pad or tablet (Gardner 1996, <http://dots.physics.orst.edu/tactile/node13.html>, November 2002). Both sighted and non-sighted people can use this system (Parkes 1994, <http://cleo.murdoch.edu.au/gen/aset/confs/edtech94/mp/parkes.html>, November 2002; Oka 2001, 2928). The main programs included in TAG are *QikTac*, *TraceME*, *AudioCAD*, *AudioPIX* and *AudioTRIP* (Parkes & Dear 1999, 2; Taylor 2001, 2895). Each program completes different tasks and is used for different purposes. For example *AudioTRIP* was designed for use in orientation and mobility (Parkes & Dear 1999, 2; Parkes 1996, 3; Taylor 2001, 2895). *AudioCAD* is for the creation of graphics by blind users, and *AudioPIX* is used for reading tactile graphics with speech (Parkes & Dear 1999, 2; Parkes 1996, 2; Taylor 2001, 2895). *AudioPIX* was the only program used in the present study. It was used to describe the tactile maps created for this research.

The Tactile Audio Graphics system has both its advantages and disadvantages. Of course the benefits mentioned earlier for auditory maps

are those shared by TAG. Other advantages, specific to TAG, include a spoken or digital sound output in one of four languages: English, Spanish, Portuguese or Swedish (Taylor 2001, 2895). It is also possible to have many "levels" of information organized in a tree-like structure (Parkes & Dear, *TGD AudioPix* , 11). For example, three sentences can be divided into three levels of speech. The user has the choice to listen to all three levels, or may choose to only listen to the first. Having more than one level of information allows the user to go deeper in the information mass. The TAG system also supports a large variety of graphic images such as maps, pictures, graphs and diagrams (Parkes 1994, <http://cleo.murdoch.edu.au/gen/aset/confs/edtech94/mp/parkes.html>, November 2002; Landau & Gourney, <http://www.rit.edu/~easi/itd/itdv07n2/tablet.htm>, November 2002). Any sound can be attached to the images, making them useful for any subject matter (Taylor 2001, 2895). Finally, this system has a Braille tutor program called *BrTutor* which has been designed to teach Braille reading (Parkes & Dear 1999, 2). Some of the disadvantages associated with the TAG system appear within both the speech and graphic media. The digital speech is not very clear and at times difficult to understand (Laudau & Gourney, <http://www.rit.edu/~easi/itd/itdv07n2/tablet.htm>, November 2002). Also, resolution of the tablet is low, making it difficult to achieve a precise correspondence with the graphic images (Laudau & Gourney, <http://www.rit.edu/~easi/itd/itdv07n2/tablet.htm>, November 2002).

CHAPTER 4

METHODOLOGY

The methodology developed for testing the hypotheses of this research consists of several steps. These steps are described within the four sections of this chapter, entitled *Participants*, *Survey Instruments*, *Survey Procedure* and *Map Procedure*. The first section, *Participants*, explains the different categories of participants. The section on *Survey Instruments* describes the Case Study Booklet and the Tactile Audio Graphics system used for the survey. A description of the questionnaire and the interview procedure is discussed in the *Survey Procedure*. The last section, *Map Procedure*, explains the creation of the tactile maps and auditory maps using ArcView, a Geographic Information System (GIS), Corel Draw, a graphic software, and *AudioPix* an audio graphics system.

It is important to mention that the current researcher was involved in the production of a Thematic Tactile Atlas for the Mapping for the Visually Impaired (MVI) project with the Mapping Services Branch, Natural Resources Canada (NRCan) during this study. This atlas is still in the development stage and completion is planned by the spring of 2003. There is a direct relationship between the MVI project and the present study. Some of the choices made for the Case Study Booklet (i.e.: symbology, target audience) were influenced by the choices made for the Thematic Tactile Atlas. For example, the Thematic Tactile Atlas was designed primarily for young adults but also older people. It was decided, by the researcher, that the Case

Study Booklet would target the same audience. Many of the facilities at the Mapping Services Branch were used for the creation of the maps produced for the Case Study Booklet. The MVI team financed the printing of the Case Study Booklet, supplied usage of the Tactile Audio Graphics system and provided contacts with people who work with the visually impaired. This support was important to the completion of this thesis and was carried out under a memorandum of understanding (MOU) between Carleton University and NRCan.

4.1 PARTICIPANTS

The present study surveyed 21 people. Of the 21 participants, 16 were visually impaired and 5 were sighted individuals. In both the sighted and non-sighted groups, females represented a slight majority of the population. The visually impaired group was made up of 9 females and 7 males. The sighted group consisted of 3 females and 2 males.

4.1.1 Visually impaired participants

The visually impaired were made up of two age categories; youths and adults. Eight youths were aged between 14 to 18 years old and eight adults were between 21 and 65 years old (Table 4.1). Of the 8 youths, 3 were enrolled in regular secondary schools in Ottawa, Ontario. They attended regular classes and were integrated among sighted students, but received additional help from a special education teacher. The remaining youths were enrolled at the W. Ross Macdonald School for the Blind in Brantford, Ontario.

This school is a primary and secondary school for deaf and blind children and young adults. Of the 8 adults, 2 were students enrolled in college and university in Ottawa and 1 was active in the workforce. The remaining 5 adults, over age 50, were retired or semi-retired.

The history and category of visual impairment varied among individuals. Each variant is represented in Table 4.2. The history of impairment represents individuals who were *Blind at Birth* and those *Blind after Birth*. The category *Blind after Birth* implies an age group between 6 months to 19 years old, and is representative of the study group. Of the 7 participants blind after birth, only 2 became blind in their teens, the remaining 5 lost their sight before age 6. The cause of visual impairment was not recorded since it was not relevant to this study. The types of blindness were divided into the following categories: *Completely Blind*, *Light and Shadow Perception*, *Tunnel Vision* and *Some Residual Vision*. All participants fell into one of these categories with the exception of two participants who fell into two categories. These individuals both had tunnel vision in one eye and were completely blind in the other. Since they weren't completely blind in both eyes, they were classified under the *Tunnel Vision* category.

The level of geographic education of all participants was recorded. The youths enrolled in the regular school system follow the same curriculum as their sighted classmates. One geography course is mandatory in the regular

TABLE 4.1:
Age Category of the visually impaired participants

Age category	Count
10-15	3
16-20	5
21-25	2
26-30	0
31-35	0
36-40	1
41-45	0
46-50	0
51-55	3
56-60	0
61-65	2
Total	16

TABLE 4.2:
Classification of impairment of the visually impaired participants

Category/History of blindness	Blind at birth	Blind after birth	Total
Completely blind	4	3	7
Light and shadow perception	3	2	5
Tunnel vision	2	1	3
Some residual vision	0	1	1
Total	9	7	16

high school system, and it is usually taken in grade 9 (Ottawa-Carleton District School Board, http://www.ocdsb.edu.on.ca/General Info/Fact Sheets/2002_03_SS_Courses.pdf, November 2002). At the W. Ross Macdonald School, geography is offered until grade 9. There are no geography courses offered in grade ten. Beyond this grade, geography is taken on the basis of interest. However, the classes are offered only if the number of students make up the minimum requirement for a class. According to a teacher at the W. Ross Macdonald School, geography has not been offered past grade 9 for the past couple of years, due to the small population and low demand. It can be concluded then that all youths have, at least, a grade 9 level of geographic education. It is not known if the secondary school curriculum of 10 to 30 plus years ago followed the same content and approaches as today. The level of geographic education had to be asked of the adults. Their answers indicated that they all received some level of education in geography. Table 4.3 shows the educational background for both visually impaired youths and adults.

4.1.2 Sighted participants

All 5 sighted participants had some daily connection with the visually impaired. Three were teachers of special education, one was a mobility instructor and one was a retired teacher with specialization in geography and vision. These people were asked to be participants for two reasons: to receive feedback from those who know the needs of the blind and to increase the number of participants. Because these people have received

TABLE 4.3:
**Educational background of
the visually impaired participants**

Educational background	Youths	Adults
Primary	0	0
Secondary	8	3
Post-secondary	0	5
Last grade to receive education in geography		
Primary	0	1
Secondary	8	6
Post-secondary	0	1

special training in working with the visually impaired on a daily basis, they have good insight into their needs. Another reason why the sighted were asked to participate in the survey was to increase the number of people in the test group. The number of visually impaired participants is relatively small and is one of the limitations of this study.

4.2 SURVEY INSTRUMENTS

The survey instruments used during the research consisted of a Case Study Booklet, a questionnaire and a Tactile Audio Graphics system.

4.2.1 Case Study Booklet

The full title of the booklet is the Thematic Tactile Maps of Canada Case Study Booklet (Appendix A). This is a 14 page booklet composed of a table of contents, 10 thematic tactile maps of Canada including their legends and 1 page of test patterns. The design of the Case Study Booklet was inspired by the Tactile Atlas of Canada, a series of general reference maps of Canada, developed by the MVI team. The choice of theme and scale (national scale maps) was inspired by the grade 9 textbook, *Making Connection's: Canada's Geography* (Clark & Wallace, 1999), used in the regular school system and at the W. Ross Macdonald School. This textbook was chosen as a guide because the level of education coincides with that of the primary target audience; young adults. It seemed most logical to create maps that resembled those reviewed in class.

The Booklet was printed in both official languages, French and English as text and Braille. The Braille maps appear on the right side of each page in the booklet. The Braille was transcribed from regular text using the Braille true type font in Microsoft Word, found at the Summer Institute of Linguistics International website (SIL International, <http://www.sil.org/computing/fonts/LANG/Braille.HTML>, November 2002). A printed text version of every map is displayed on the left side of each page. Designing the atlas to have text on the left and Braille on the right was inspired by the Tactile Atlas of Canada. The purpose of including text is to have the information accessible for people who can see the maps but cannot read Braille. This group may include visually impaired people having some residual vision, sighted teachers or parents.

The Case Study Booklet was printed by Tactile Vision. This is a raised printing company whose primary audience is the visually impaired. Their printing method involves the deposition of a polymer on a wide range of papers (Tactile Vision, <http://www.tactilevisioninc.com/who.html>, November 2002). According to a contact at Tactile Vision, cover stock (a type of cardboard) is the preferred medium because it resembles Braille paper used in embossing. It also works well with the polymer printing technique and is more durable than regular paper. An 8.5" by 11" cover stock size was used for the Case Study Booklet. The choice in paper size could not be larger because the maps had to remain within the limits of the Tactile Audio

Graphics (TAG) touch sensitive tablet, which was to be used for testing the audio maps.

The Case Study Booklet is divided into two major sections: map projection and symbology. The following is a detailed description of both sections.

Case Study #1: Projections

The hypothesis in this research with regards to map projections is that different projections can be distinguished through touch. It was therefore important to compare projections that presented landforms differently.

Only two projections were selected, Lambert Conformal Conic and Hammer-Aitoff, to keep the survey from being too complex (pages 2 and 3 in the Booklet). The Lambert Conformal Conic projection is a conformal projection, which preserves shapes at the mid-latitude zones (Robinson *et al.* 1995, 77). It was selected because of its inherent characteristics and because it was the projection used in the Tactile Atlas of Canada (Mapping Services Branch, 2001). The Hammer-Aitoff projection is an ellipsoid equal - area projection, which aims to maintain areas (Savard, <http://members.shaw.ca/quadibloc/maps/meq0801.htm>, November 2002). It was chosen primarily because of the horizontal display of landforms at the central meridian. Latitude and longitude lines were included in both maps for global reference and to emphasize the differences in projection types. The legend is presented on a separate page to reduce clutter (page 1 in the

Booklet). All line types and sizes, with the exception of the latitude and longitude segments and the neat line, were inspired by the Tactile Atlas of Canada. The dotted latitude and longitude lines were selected because they were believed to be most discriminating alongside the solid lines used for the landforms. A double thin line was used for the neat line to delineate the map limits.

Case Study #2: Symbology

The second section of the Booklet deals with symbology. This section is composed of 8 maps of Canada: 4 maps are projected using the Lambert Conformal Conic projection and the other 4 maps, displaying the same information, are projected in the Hammer-Aitoff projection. Because the first section of the Booklet deals with projection types, it was only logical to test the second hypothesis using the preferred projection of each participant. This way, the participants would be familiar with the projection, allowing them to focus on the subject at hand; symbology.

The hypothesis on symbology, in this research, states that the type of area symbol used in tactile maps can increase the legibility of surface areas.

Many researchers have used patterns as their symbol of choice for mapping areas (Culbert & Stelwagon 1963; Nolan and Morris 1971; Matthews 1978; The N.S.W. Tactual Mapping Committee 1987), though their findings in tactual discrimination have often been inconsistent (see Chapter 3, section 3.3.1 *Symbology*). Since the testing of patterns had already been explored

in many studies, it was decided to focus on alternative ways for displaying patterns, and to find symbols other than patterns for presenting areas.

Two symbol types were selected for this study: lines with Braille numbers and area filled patterns. The lines are used for delineating areas, with the numbers as classifiers of each area. The patterns are used as fillers for each area. These symbol types were chosen because they represent space differently, where one completely fills areas and the other delineates them. Two display methods were used for each symbol type. For purposes of clarity, the two maps with lines and Braille will be referred to as MAP1 and MAP2, and the two maps showing patterns as MAP3 and MAP4. The display methods used for the lines and Braille are based on complexity of information. MAP1 displays two levels of information, the map theme and the provincial boundaries of Canada (page 5 or 10 in the Booklet). Having two levels of information adds more information to the map, but it also increases the complexity and clutter. MAP2 displays one level of information, the map theme (page 6 or 11 in the Booklet). The choice to use lines with Braille as a symbol type was inspired by the thematic tactile maps used in the geography class at the W. Ross Macdonald School (Figures 4.1 & 4.2). Figure 4.1 is a map showing the map theme; forest distribution. Figure 4.2 shows the map theme, soil distribution, and the provincial boundaries. The goal of testing these two display methods was to learn if the participants would prefer simpler maps with less information or more complex maps with more data. The display methods used for the patterns are based on pattern

layout. MAP3 displays patterns that fill the entire surface area (page 7 or 12 in the Booklet). This method was primarily inspired by the maps created for the Tactual Atlas of Australia (see Figure 3.4). MAP4 displays patterns 3 millimeters away from the boundary line of each region (page 8 or 13 in the Booklet). This method was taken from one of the design guidelines of The N.S.W. Tactual Mapping Committee (The N.S.W. Tactual Mapping Committee 1987, 7).

The choice of pattern was restricted by the software package used for the map design and particularly by the printing techniques used by Tactile Vision. Although it was important to select patterns that had been tested and labeled 'discriminable' by previous researchers, it was essential to use patterns which presented good printing results. Tactile Vision was asked to provide a series of area patterns which they believed to be most appropriate for tactile mapping (Figure 4.3). The majority of their recommended patterns resembled those approved by previous researchers (see Figures 3.6 to 3.9). Thus, the final selection of patterns was based on the series provided by Tactile Vision.

The patterns used for the thematic maps were selected based on their 'texture perception'. The term texture perception is defined by Lederman (1982) as "any number of surface qualities, for example, roughness, smoothness, hardness, coarseness and graininess" (Lederman 1982, 131). Depending on the spatial frequency of points or lines within a pattern, the

**FIGURE 4.1: Line symbols showing one level of information:
Map theme**

Source: Clark, Bruce W. & John Wallace (1999). *Making Connections: Canada's Geography*. Prentice Hall Ginn Canada.

Transcribed into Braille by Jymico (2000). Charlesbourg, Québec.

**FIGURE 4.2: Line symbols showing two levels of information:
Map theme and provincial boundaries**

Source: Clark, Bruce W. & John Wallace (1999). *Making Connections: Canada's Geography*. Prentice Hall Ginn Canada.

Transcribed into Braille by Jymico (2000). Charlesbourg, Québec.

FIGURE 4.3: Recommended Patterns by Tactile Vision.

Source: Tactile Vision (2002). Raised printing for the blind.

Tactile Vision Inc. Retrieved November 2002, from

<http://www.tactilevisioninc.com/who.html>.

surface can feel smooth or rough to the fingers (Lederman 1982, 142; Krueger 1982, 42). Based on the researchers' personal tactual sensitivity, the patterns were selected to represent differences in elevation, which is the map's theme. The goal was to create a link between the tactual geometry of the polymer and the data itself (or a tactual metaphor). A smooth pattern was selected for those areas of low relief, and a rough pattern was chosen for regions of high elevations. Of course not all themes can be displayed metaphorically. Physiographic regions and relief are two good candidates. Relief was selected because it is self descriptive and simple to understand. A series of patterns were included at the end of the booklet for testing. Many of the patterns resemble those labeled 'discriminable' by previous researchers. Others were selected arbitrarily from the list of patterns provided by Tactile Vision. Though it was not the main goal of this study to test the discrimination of patterns, it was added to the study for additional input on future pattern selections.

The general layout of each map resembles that of the projection maps, with a few modifications. The latitude and longitude lines were taken out due to their predicted poor legibility over patterns. The Great Lakes and the neatline were both excluded to make room for a legend of area symbols at the bottom of the map. The legend at the bottom of the map describes the area symbols used in the thematic map, thus can be referenced as the thematic legend. The number of categories for the thematic legend was modified from the original map legend to decrease the complexity of the

map. According to some researchers (The N.S.W. Tactual Mapping Committee 1987, 14; Massey 1983, 22; Nolan & Morris 1971, 49), the number of categories should be kept to a maximum of five. Too many categories can overload the memory, especially if the information is to be memorized tactually (Tatham 1991, 164). For this reason, the number of categories was changed from its original number of 12 to 4 classes. A contact from the Geological Survey of Canada reviewed the modifications made to the thematic legend for approval. Some minor changes were suggested, and the legend and map were corrected to increase the accuracy of information. A second legend was included to explain the line symbols. This legend appears only once, on a separate page, at the beginning of the section on symbology. The reason for its location apart from the map is due to space restraints and to avoid repetition of information. Because the same line symbols were used for every map, it seemed unnecessary to repeat the information on different pages. Two north arrows were included in the legend with the line symbols. The participants were asked to select the arrow of preference. This map element was chosen to be tested because of its significance in global referencing and direction (Robinson *et al.* 1985, 337). It is a key element in conventional cartography, and thus should be prudently selected for tactile maps.

4.2.2 Tactile Audio Graphics (TAG) system

Another survey instrument used in this research was the Tactile Audio Graphics (TAG) system. This audio system was used in conjunction with the

thematic tactile maps and the questionnaire. The hypothesis on auditory maps, in this research, states that map cognition and legibility are enhanced with added sound. Because sound is considered a complementary component for transmitting information (Parkes 1988, 25; Dahlberg 1997, 1420), it was important to introduce the audio system only after the participants had fully examined the tactile maps. Through the touchpad, spatial information (map features) was input into the TAG system and saved as an electronic file. Up to two levels of speech were attached to some of the map features. The first level described the theme category and the second level named the provinces in which fell that particular category. It was decided to include two levels of speech to provide as much information possible about the maps.

4.2.3 Questionnaire

Two questionnaires were produced for this study; a Braille version for the visually impaired and a text version for the sighted participants (Appendix B; Appendix C). Both versions were designed to be used with the Case Study Booklet and the TAG system. Both questionnaires are composed of the following: an introductory page, a letter of consent, three sections for each case study and closing questions. The questionnaire used for the visually impaired has an additional section, *Background Questions*, which asks questions on educational background and previous experience with tactile materials such as tactile images, charts and maps. The introductory portion of the survey defines thematic maps, and explains the testing procedure and

items to be tested. The three main sections of the survey focus on the map projection of Canada, symbology and auditory maps. The closing questions enquire about the interviewees' comments on the survey and suggestions for future map development.

The questionnaires consist mainly of closed questions with a few open questions. A rating scale, specifically the "rank order", was the type of closed format questioning selected for this survey. Rank order is a form of multiple choice questioning, usually with no more than five options (Robinson 1998, 386). This type of question format allows the respondent to rank each answer according to the ranking system developed by the researcher. The ranking scale in the survey is inconsistent and is dependent on the question. The majority of questions have four ranks: *Very much*, *A bit*, *Very little* and *Not at all*. Other questions have three or two ranks; where the respondent is limited to one choice or the other. Closed format questions are advantageous for both the interviewee and interviewer. For the interviewee, it simplifies the interview. For the interviewer, it allows for a predefined analysis. Once answered, the questions are already categorized and ready for comparison. Open questions entail more effort for both interviewee and researcher. They require interviewees to elaborate on their thoughts, which may be difficult for some individuals. They may also present difficulties for the interviewer during analysis, due to the uniqueness of answers. Open questions do, however, provide more elaborate information that cannot be obtained from closed questions.

4.3 SURVEY PROCEDURE

The Case Study Booklet and questionnaire were sent to participants prior to the interview. The material was personally delivered by the researcher if the participants resided in Ottawa. Otherwise they were delivered through the mailing system. Each participant was given enough time to review the booklet and questions. In most cases the time lapse averaged out to about one week. It was important to have the participants feel comfortable with the material in order to receive adequate, well developed feedback in a timely manner during the survey. There are certain advantages of having participants review the material before questioning. It allows them to ponder the questions in a familiar environment, in their residence or school, and to properly develop their answers. It also helps to keep the interview session from being too long. The longer an interview session, the more likely participants will become tired and unenthusiastic, which may affect the reliability of responses. Unfortunately, due to unforeseen circumstances, one participant did not receive the survey material prior to the interview. This participant did, however, answer all questions in the time allocated for the interview session.

The interview was a one on one, informal session with an allocated time of 45 minutes to one hour. The Case Study Booklet and Braille questionnaire were placed in front of the interviewee. The list of items to be tested and the purpose of the survey was explained to each participant before questioning. When the participants felt ready, the task questions for the first two sections

(map projection and symbology) of the survey began. Each question was read aloud and repeated if necessary. The participants had the option to read along silently while the interviewer read the questions. All answers were recorded on an answer sheet. Some of the first interview sessions were recorded on a tape recorder for fear of missing important information. The tape recorder was excluded after realizing that the majority of participants provided short and straight forward answers, facilitating the note taking. Upon completion of the first two sections of the survey, the interviewees were briefed for the final section, auditory maps. Unfortunately due to unforeseen circumstances one participant, a mobility instructor, was not able to meet for an interview session, and therefore was not exposed to the TAG system. All questions were answered by the mobility instructor on the answer sheet, except for the section on auditory maps.

The TAG system was introduced and explained to each participant. A brief demonstration on the system's functionality was given prior to questioning. In order to test the hypothesis on auditory maps, it was important for the participants to feel comfortable and familiar with the maps. The participants were asked to select their map of choice from the booklet; a map which displayed their preferred projection and symbols. If no preference was indicated, a map was selected by the interviewer. The hardcopy map was then inserted onto the tablet, and the electronic file was loaded onto the computer with the *AudioPix* software. The participants were given some time to explore the audio system, and to familiarize themselves with its

functionality. Each participant was asked to press, with their fingers, on tactile features presented on the map. When pressed, the information on the tactile feature was presented in the form of synthesized speech. If a map feature had more than one level of information, the system notified the user by saying "More details" through synthesized speech. The user was then instructed to press the space bar to hear the second level of information. The participants had the freedom to retrieve information on any element found on the map. Some interviewees had difficulty achieving a precise correspondence with the map features due to the low resolution of the tablet. For example, they would press on a map feature and no sound would be transmitted. When this happened, the participants were guided by the interviewer to press harder on the tablet or to move their fingers to a neighboring location. Once they had completed their exploration, they were asked to answer questions on the audio system. As was the procedure for the first two sections of the survey, the questions were read aloud and answers were noted on an answer sheet. Upon completion of all tasks, the participants were thanked and excused.

4.4 MAP MAKING PROCEDURE

This section deals with the step by step procedure involved in creating the thematic tactile maps and audio maps for this study. The thematic tactile maps were created using ArcView and Corel Draw software. The audio maps were created using the TAG software system.

4.4.1 Methodology for creating thematic tactile maps

Two different software systems were used for the creation of thematic tactile maps in this study: ArcView and Corel Draw. ArcView was used because it is a good software for digitizing and working with polygons. The digitization process is possible in Corel Draw, but is limited to segments. Corel Draw has no tool for creating closed composite polygons, which is necessary for displaying patterns. Categorized as a Geographic Information System, ArcView has projection transformation capabilities, whereas Corel Draw does not. Corel Draw is a graphic software and was used for its design capabilities. Patterns can be created, and existing patterns within the software can be edited. ArcView has patterns and some design capabilities, however these components are quite limited. It was decided to use the strengths of two distinct systems for optimal results.

The creation of thematic tactile maps found in this study is achieved through a series of steps:

- a) Retrieve an existing thematic map*
- b) Digitize the thematic map using ArcView*
- c) Export the map from ArcView and Import it into Corel Draw*
- d) Graphic design of thematic map using Corel Draw*
- e) Tactile output*

a) Retrieve an existing thematic map

- The first step in creating a thematic tactile map is to find an existing thematic map, where the information can easily be replicated through

digitization. A softcopy map stored as an ArcView “shapefile” is preferable, or an image file that can be viewed in ArcView (example: .tiff file). The basemaps used for the Case Study Booklet were taken, with permission, from the National Atlas of Canada: Fifth Edition, NRCan.

b) Digitize a thematic map using ArcView

- Digitize a new map from an existing thematic map, using the on-screen digitizing tool in ArcView.
- Create a *new polygon theme*, and digitize the information in a generalized fashion. In other words, simplify the map as much as possible, making sure to maintain the general shape of landforms. Simplification is necessary, especially if the map is to be read by touch.
- Complete all edits and save the map layer. The final product is a theme layer made up of several polygons or categories.

c) Export the map from ArcView and import it into Corel Draw

- Export the final digitized map as a *Postscript (EPS)* file from ArcView. When a theme is exported, it must be the only visible *Theme* in the *View*.
- If more than one theme was digitized in ArcView, each theme must be exported separately.
- Import the map as a *Postscript Interpreted (PS, PRN, EPS)* file into

Corel Draw.

d) Graphic design of thematic map

- Ungroup the image. The map is imported as a grouped object in Corel Draw, and therefore must be ungrouped to make any graphical changes. A grouped object is a set of objects which behave as one unit (Corel Draw Help Index, *CorelDraw Version 9.0*). Any operations performed on a group apply equally to each of its components (Corel Draw Help Index, *CorelDraw Version 9.0*). In order to perform operations on individual components (i.e.: polygons or line segments), a grouped object must be ungrouped.
- Each polygon will have the same colour. The colour must be replaced by different patterns or other symbol, such as numbers, to make the categories distinctive. This is done by editing the properties of each individual polygon. If a pattern is to be used, each polygon must be a closed unit before it can be filled with the pattern. The *Auto-Close Curve* tool is used to close a polygon.
- Add text and other map elements such as a legend and north arrow.
- Transcribe the text to Braille. As mentioned in section 4.2.1, *Case Study Booklet*, the Braille true type font can be downloaded at the Summer Institute of Linguistics International website:
<http://www.sil.org/computing/fonts/LANG/Braille.HTML>. Once downloaded it is usually placed in the local drive under Windows/Fonts (this location may vary depending on the Windows version used for a PC).

e) Tactile output

- A tactile map can be printed several different ways, depending on the choice of media. The maps produced for this study were printed externally by a respected raised printing company, Tactile Vision. The Corel Draw files were sent to this company electronically. Tactile Vision printed the maps and sent the hardcopies by courier to the researcher.
- Tactile maps can be printed internally if special equipment is available. For example, the MVI team often prints tactile maps using capsule paper with a Stereo Copying Machine. The capsule paper is a heat activated rising paper. The Stereo Copying Machine generates heat to raise the printed surfaces.

4.4.2 Methodology for creating auditory maps

The TAG system was used for this study primarily because it was readily available. The procedure for creating auditory maps, using *AudioPix*, is described in the Tactile Audio Graphics Manual, written by Don Parkes and Richard Dear (Parkes & Dear 1999). The manual can be found at the Tactile Graphics Designer website at <http://www.tactileaudio.com.au/>.

Auditory maps created for this study were achieved through the following steps:

- a) Select the AudioPix program and create a drawing file*
- b) Input digitized speech onto map features*

a) Select the AudioPix program and create a drawing file

- Start the TAG system and select the *AudioPix* program to enter the *AudioPix* Main Menu.
- Select *F6-New Drawing* from the Main Menu. At this point, a graphic title must be entered as well as a file name. Once the information has been registered and saved, the speech can be input into the system.

b) Input digitized speech onto map features

- Insert a hard copy tactile map onto the touch tablet.
- Input speech into the system through the keyboard. The text is input only once a specific shape has been selected. Shapes are used to create map features. Some shapes include the boundary of a rectangle and the fill of a rectangle. For this study, three shapes were selected to create the map features: *boundary of irregular shape*, *fill an irregular shape* and *single point of information* (Parkes & Dear 1999, *AudioPix*, 9). These shapes were created by following the instructions in the Manual.
- It is possible to add up to three levels of information for each map feature. One and two levels of speech were linked to the map features in this study.
- Save the map and close the program.

CHAPTER 5

STATISTICAL RESULTS AND ANALYSIS

"Observation of visually impaired users during trials of pilot maps, coupled with structured and unstructured interviews, can lead to a realistic appreciation of what is needed" (Perkins & Gardiner 1997, 1159).

The visually impaired participants, who were surveyed in this study, were very insightful about the improvements needed for the test maps. Answers to the survey and analysis of results have been described within four sections of this chapter. The four sections are: the *Statistical Results*, the *Analysis*, the *Relationship Between the Results and the Hypothesis* and the *Strengths and Weaknesses*. The first segment, *Statistical Results*, displays the results of the questionnaire. The *Analysis* section is divided into three categories: the *Analysis of Experience*, the *Analysis by Category of Blindness* and *Analysis by History of Blindness*. The hypotheses were compared with the statistical results in the section called *Relationship Between the Results and the Hypotheses*. Finally, the section on *Strengths and Weaknesses* discusses the strong points of the case study and the problems discovered within the methodology.

5.1 STATISTICAL RESULTS

The answers provided by the participants were consolidated using *Microsoft Excel 2002*, a spreadsheet software package. The frequency of response was tallied and converted to a percentage. The statistical results were divided

into two tables: *Response from Visually Impaired Participants* and *Response from Teachers*. The responses were separated for two reasons. Although the sighted participants have very good insight on the needs of the blind, they still function in a visual world, which could influence their responses. Secondly, the questionnaires produced for the visually impaired and sighted participants were not identical. Calculating the frequency of answers for all questions was therefore problematic. The responses provided by the visually impaired participants are of primary importance and will determine the outcome of the hypotheses. The questions and answers for the visually impaired participants are presented in Appendix D. The questions and responses provided by the teachers are displayed in Appendix E.

5.1.1 Background Questions

All participants, with the exception of one, had Braille reading skills. More than half of the participants (63%) had some level of experience in reading tactile images and maps. The other 38% had never been exposed to these learning methods. Secondary school is the lowest level of education received by the test group, and 88% of them took geography classes at this level.

5.1.2 Section 1: Projection of Canada

Visually Impaired Participants

According to the responses provided by the participants, 81% already knew the shape of Canada, and 63% knew the definition of a map projection.

Although 75% of them claimed to feel, to some extent, a difference in the two projections of Canada, a mere 38% could develop a general idea of the tactual outline of Canada. The greater majority answered correctly to the question on the boundary line between Canada and the United States. Sixty-three percent agreed that both the Lambert Conformal Conic boundary and the actual boundary (actual earth) was curved. Eighty-eight percent agreed that the Hammer-Aitoff boundary was straight. The preferred projection was the Hammer-Aitoff projection with 44%. There were however 31% of the participants who had no preference at all. The primary reason for choosing the Hammer-Aitoff projection was due to the horizontal display of Canada. According to the participants, horizontal lines are easier to follow when reading tactually.

Teachers

The teachers responded differently with respect to the cartographic knowledge of the visually impaired. There were uncertainties, among the teachers, whether the visually impaired knew the definition of a map projection. The similarity in views, between the blind and the teachers was the discrimination between projections. Sixty percent of teachers agreed that the blind could distinguish between the two map projections, but they remained unsure about the landform legibility capabilities. In the opinion of 60% of the teachers, the Lambert Conformal Conic projection was most suitable for tactual discrimination. According to the teachers, this projection displays a more realistic view of Canada.

5.1.3 Section 2: Symbology

MAP1 – Visually Impaired Participants

MAP1 displays lines with Braille numbers showing two levels of information, the map theme and the provincial boundaries of Canada (page 5 or 10 in the Booklet). The display of symbology in this map was one of the least preferred by all visually impaired participants. Only one participant favored this map over the three others. Most of them had difficulty identifying the two levels of information. When asked to identify the theme categories, 50% had much difficulty with the task. When asked to identify the political boundaries, 44% reported some difficulty. Only 13% said that they could distinguish both categories without difficulty and about 22% were incapable of distinguishing them at all. Although the display of information was not favored, the type of symbol was well liked. Fifty percent rated the symbol to be “*Very much*” appropriate for displaying the information and the other 50% rated it to be “*A bit*” suitable. The most common criticism of this map was the similarity in line types. The most frequent positive comment was based on the two levels of information. Most participants want to receive as much information as possible but in a simplified manner, or as one participant commented: “additional information is very important, but not useful if it can’t be interpreted”.

MAP 1 - Teachers

As was the case for the visually impaired, MAP1 was classified as one of the least preferred by all teachers. The majority of teachers expected the blind

to do better at identifying the different theme categories. Twenty percent of them believed that the blind could identify the theme categories “*Very much*” and 60% said that they could probably identify them “*A bit*”. There were mixed opinions about the clarity of two levels of information on one map. Some thought that it would be very confusing while others saw no problems with the readability of information. Similar to the blind participants, the majority of teachers (80%) were satisfied with the symbol type for map communication, but found the line types to be too similar.

MAP2 – Visually Impaired Participants

MAP2 displays lines with Braille numbers showing one level of information, the map theme (page 6 or 11 in the Booklet). Fifty percent of the participants chose this map as the most favored, which classified it as the number one choice of all four maps. The main reason for its wide acceptance was its simplicity. Of the 16 participants, 69% could “*Very much*” identify the theme categories and 81% found the map easier to read without the political boundaries. With regards to the north arrow 75% were able to find it quite easily, and the majority (44%) preferred the conventional type of arrow. Those who preferred the conventional type arrow, and even those who didn’t select this arrow as their favorite, expressed that the triangle-shaped arrow could potentially be mistaken for an island. This reason and familiarity were the primary reasons for favoring the conventional arrow.

MAP2 - Teachers

Unlike the visually impaired, this map was classified as the second most preferred map by the teachers. Other than the final rating of this map, teachers' answers mirrored those provided by the blind. All 5 teachers estimated the blind to have little difficulty identifying the theme categories, and 80% of them favored the exclusion of political boundaries. Simplicity was MAP2's strong point. The majority of teachers (60%), as did the visually impaired, preferred the conventional arrow over the triangle-shaped arrow.

MAP3 – Visually Impaired Participants

MAP3 displays patterns that fill the entire surface area (page 7 or 12 in the Booklet). The display of symbology in this map was one of the least preferred by the test group. Only one participant favored this map over the three others. The main problem with this map was the continuous layout of patterns. According to some participants, it was difficult to feel where one pattern ended and another began. Although 44% of participants claimed to "*Very much*" easily identify the theme categories, 25% had considerable difficulty with the task and 13% found it impossible to distinguish between classes. The patterns themselves received positive feedback. Fifty-six percent "*Very much*" liked them and 38% liked them to some extent or "*A bit*". Most of the participants (75%) classified this symbol type as being somewhat ("*Very much*" or "*A bit*") effective at displaying the information.

MAP3 - Teachers

In accordance with the views of the visually impaired participants, the display of symbology in this map was one of the least preferred by teachers. The teachers didn't express as great a concern about the continuous layout of patterns as did the blind participants. However, there were mixed opinions about the tactual readability of theme categories. Just as the blind favored this symbol type, all teachers rated it as being "*Very much*" effective for displaying the information and 80% "*Very much*" liked the patterns.

MAP4 – Visually Impaired Participants

MAP4 displays patterns 3 millimeters away from the boundary line of each region (page 8 or 13 in the Booklet). This map was classified as the second most preferred map by the visually impaired (31%). Of the 16 participants, 56% could "*Very much*" identify the theme categories and 25% could identify them "*A bit*". Eighty-one percent preferred to have the pattern symbol 3 millimeters away from the boundary lines over having the patterns fill the entire surface area. According to the participants, the boundary lines on this map were more easily recognized as was the discrimination of patterns. The most common positive remark was the "filler" characteristic of patterns. There is an advantage of feeling the full extent of an area when patterns are used, unlike lines where the fingers must delineate an area to ascertain its full coverage.

MAP4 - Teachers

This map was classified as the most preferred by the teachers. Once again, other than the final rating of this map, the teacher's answers mirrored those provided by the blind. All teachers estimated the blind to have little (40%) or no difficulty (60%) identifying the theme categories. Eighty percent preferred to have the pattern symbol 3 millimeters away from the boundary lines. One reason for preferring this map over MAP2 was the "filler" characteristic of patterns and the advantage of feeling the full extent of an area. Another reason was the various tactual sensations offered by patterns. Several teachers believed that textures would be more enjoyable to read tactually.

Test Patterns – Visually Impaired Participants

Many blind participants enjoyed rating the test patterns. The most liked patterns were numbers 3, 6 and 8. These include a somewhat dense dot pattern with a 45° layout (1 millimeter in diameter and spaced out at 4 millimeters), diagonal lines (0.5 millimeters in width and spaced at 5 millimeters) and a very dense vertical line pattern (0.5 millimeters in width and spaced at 1 millimeter). The least liked patterns were pattern numbers 9, 10, 11 and 12. These include the tree pattern and the two plaid patterns.

Test Patterns - Teachers

Some similarities and differences exist in pattern preferences between the blind participants and teachers. Just as selected by the visually impaired, the

teachers liked pattern number 3 (dot pattern with a 45° layout) and disliked pattern number 12 (plaid pattern). The teachers disliked pattern number 8 (vertical line pattern), which was one of the preferred patterns among the blind. Teachers found this pattern to be non-discriminating. Both groups agreed that the patterns increase or decrease in discrimination based on neighboring patterns.

5.1.4 Section 3: Auditory maps

Visually Impaired Participants

The larger majority (75%) preferred to examine the map with sound. Seventy-five percent declared that they understood the map better and thought they could learn the map much faster with sound. Two levels of sonic information were preferred over one level of information by 88% of the respondents. All participants, with the exception of one, were regularly exposed to some sort of audio device such as text reading software (i.e.: jaws) or books on cassettes.

Teachers

The answers given by the teachers reflected those provided by the visually impaired participants. Sixty percent of teachers agreed that sound could speed the learning process, and 80% claimed that sound could increase the cognition of maps. They too preferred, by 80%, two levels of information for maximum information output.

5.2 ANALYSIS

The results provided by the survey were analysed by organizing the visually impaired participants into four different categories: education, experience, category of blindness and history of blindness. The goal was to recognize the main factors influencing the legibility and cognition of maps and to rate the reading abilities of each user group. The first three categories were discussed in Chapter 2 section 2.3, *Cognition of maps*, and were classified as key elements for the cognition of maps (Perkins & Gardiner 1997, 1160; Thompson 1983, 104; Vasconcellos 2001, 3). The history of blindness was chosen to be part of the analysis. The population represented a good balance between those blind at birth and those blind after birth.

The analysis focused primarily on reading capabilities and cognition of maps. Only the questions where participants were asked to read and identify information on the maps were analysed. The questions which focused on the personal opinions of participants were excluded from the analysis. The results within each section (map projection, symbology and auditory maps) were grouped according to a scale gradient and averages were computed based on the total frequency of answers. The scale gradient is based on averages: *Above Average* and *Below Average*. Answers which were calculated in the *Above Average* category include "Yes" answers, "Very much" and "A bit" answers. Answers which were calculated in the *Below Average* category includes "No" and "Unsure" answers, "Very little" and "Not at all" answers. The three questions on the boundary line between Canada

and the United States were categorized based on the correct answers. The correct answer for question 10, the Lambert Conformal Conic projection, was “*curved*”. The correct answer for question 11, the Hammer-Aitoff projection, was “*straight*” and for question 11 the actual boundary is “*curved*”. These answers, “*curved – straight – curved*” were classified as *Above Average*. Those who chose the wrong answers, or who were “*Unsure*” were classified as *Below Average* for readability and cognition of information.

5.2.1 Analysis by Education

Due to the similarities in educational background in geography this issue was not a key determinant for analysis.

5.2.2 Analysis by Experience

Appendix F displays the results of the survey into two classes of experience: those who had *Previous Experience* in reading tactile charts, images or maps and those with *No Previous Exposure*. According to the statistical results, those who had previous experience with tactile maps all had *Above Average* Braille reading skills. The group having no previous experience with tactile maps had various Braille reading skill levels (60% of individuals classified as *Above Average* and 40% as *Below Average*). It can be conjectured that above average Braille readers may have a more developed sense of touch, which may allow them to better recognize other forms of tactual information.

Both groups (previous experience and no previous experience) scored comparably in *Section 1: Projection of Canada* of the survey. They both scored *Above Average* for the legibility and cognition of map projections. However the group with no previous experience scored 6% higher. There is no plausible explanation as to why the score would be higher. Having no previous experience, this group was expected to have more difficulty reading and understanding the maps. They did, however, experience difficulties identifying the symbology. The group with no previous experience barely attained *Above Average* (56%) for legibility of the symbols. Those with previous experience had much less difficulty with the tasks and scored 71% *Above Average*. Both groups scored *Above Average* in *Section3: Auditory Maps*. The individuals having no previous experience were estimated to need more assistance in reading tactile maps, thus scoring higher for auditory maps. The results were as predicted. More people in this group understood the maps much better with sound, and scored higher than the group with previous experience by 7%.

5.2.3 Analysis by Category of Blindness

Appendix G displays the results of the survey according to the category of blindness: those who were *Completely Blind* and those who presented *Various Levels of Visual Impairment*. The individuals with various levels of visual impairment were expected to have less difficulty identifying map features than those who were completely blind. Having some level of vision was presumed to be advantageous over no vision at all. The results of the

survey support this premise. Individuals with various levels of visual impairment scored higher for the legibility and recognition of map projections and symbology, with *Above Average* scores of 74% and 78% consecutively. Those who were completely blind scored relatively poorly, with scores of 52% *Below Average* for the readability of map projections and 51% *Above Average* for the section on symbology. Both groups scored *Above Average* in *Section3: Auditory Maps*. Those completely blind had a score of 86% and the group with various levels of visual impairment finished with 67%. It makes sense that the completely blind group would score higher for auditory maps. Their need for auditory assistance in tactile reading should be greater, not having the advantage of some limited vision.

5.2.4 Analysis by History of Blindness

Appendix H displays the results of the survey with a focus on the history of blindness: individuals who were *Blind at Birth* and those who became *Blind after Birth*. Several individuals who previously had sight declared to have remembered seeing maps. Having this memory of visual images is conjectured to be most advantageous in recognizing landforms and interpreting map features. This group was therefore expected to have less difficulty than those blind at birth in identifying information on the maps. Again, as in the *Analysis by Experience*, the results for *Section 1: Projection of Canada* were unexpected. Both groups scored *Above Average* for the legibility of map projections. However, those blind after birth scored 10% lower, indicating that they had more difficulty with the task. Identification of

symbolology was more challenging for those blind at birth. This group scored lower for the readability and cognition of map symbols, with an *Above Average* score of 58% whereas those blind after birth scored 77% *Above Average*. Finally, the individuals estimated to need additional assistance in reading tactile maps were those blind at birth. As predicted, this group scored higher in *Section 3: Auditory maps*. Eighty-nine percent of the people blind at birth, as opposed to 57% of those blind after birth, understood the maps much better with sound.

5.2.5 Concluding Analysis

In almost every case study (map projection, symbolology and auditory maps), by category of analysis, answers were rated *Above Average* for the legibility and cognition of information. Statistically 85% of the answers were *Above Average* and 15% *Below Average*. This indicates that the elements tested in this study were identifiable and ratable by a visually impaired audience.

It should be noted that other factors, not examined in this thesis, may effect the readability and understanding of tactile information. Among them are the intelligence level, memory retention, spatial abilities and tactile sensitivities. A study conducted by Nolan & Morris (1971) recognized one such factor. One conclusion drawn from their study showed that the ability to discriminate patterns was slightly related to mental ability (Nolan & Morris 1971, 4). This factor, and others mentioned above, may have influenced the results of this research.

5.3 RELATIONSHIP BETWEEN THE RESULTS AND THE HYPOTHESES

The results provided by the survey support all three hypotheses in this research.

The first hypothesis stated the following:

- Map projections can be distinguished through touch.

The large majority of visually impaired participants were able to recognize the differences in the projection of Canada. Although most of them had difficulty reading the outline of Canada, they did answer correctly to the questions on the boundary line between Canada and the United States. The strong point in favour of this hypothesis is the fact that 69% of the population selected one of the two projections for readability and cognition. The teachers' responses also support this hypothesis. The majority of them agreed that the blind could distinguish between the two map projections, and 80% of them agreed that one projection was more suitable than the other for tactual discrimination. The fact that the teachers chose the Lambert Conformal Conic projection and the visually impaired preferred the Hammer-Aitoff projection does not disprove the hypothesis. It simply demonstrates that the teacher's viewpoint can not, at times, be aligned with the self identified needs of the visually impaired.

The second hypothesis declared:

- The type of area symbol used in tactile maps can increase the legibility of surface areas.

Depending on the type of area symbol used, the visually impaired participants had much difficulty or ease when reading tactually. All visually impaired participants, with one exception, selected one of the four symbol types for improved legibility. The symbol type that proved to be most legible was the lines with Braille numbers, displaying one level of information (MAP2). The display of patterns 3 millimeters away from the boundary line (MAP4) also proved favorable for readability. These symbol types were the preferred methods of delivering information that could be read and understood with little effort. These symbol types were also preferred by the teachers, though MAP4 was preferred over MAP2. Again, the fact that the teachers chose the second most preferred map by the visually impaired as their number one choice does not disprove the hypothesis. Their choices are comparable, having not selected one of the least preferred by the visually impaired group. The teachers responses support the hypothesis by indicating that the type of area symbol used can effect the legibility of surface areas.

The third hypothesis stated the following:

- Auditory maps can enhance the cognition and legibility of tactile information.

The majority of visually impaired participants agreed that textual sound could improve the cognition and legibility of maps. Seventy-five percent understood the test maps much better once the sound was added. The auditory maps were especially favored for the multiple levels of information included. Not only are auditory maps advantageous for the cognition of maps but they provide access to large amounts of information, which would otherwise be excluded from maps for reasons of complexity and clutter. The teacher's responses also support this hypothesis. The majority of them agreed that sound could speed the learning process and increase the cognition of maps.

5.4 STRENGTHS AND WEAKNESSES

As with all research, this study has both strengths and weaknesses. Overall, the study was successful and the feedback gathered from the participants was most insightful. There are, however, a few specifics that require mentioning.

5.4.1 Participants

The major limitation of this study is the size of the test group; only 16 visually impaired participants. However, when compared to other studies related to tactile maps, such as Offenbergl (2000), Andrews (1983) and Culbert and Stellwagen (1963), this number is large enough to generate valid results. The research conducted by Offenbergl (2000) surveyed 12 visually impaired adults. Andrews (1983) described a series of studies on tactual

mapping in her paper, 6 in total. The number of visually impaired participants involved in each study varied from 5 to 10. The study by Culbert and Stellwagen (1963) was composed of 0 visually impaired participants. Blindfolded sighted participants were used as an alternative.

The individual differences of the participants were not measured in the analysis, and are considered a weak point in this study. The intelligence level, memory retention, spatial abilities and tactile sensitivities may have influenced the participants' answers to the survey, and thus the results of this research.

5.4.2 Case Study Booklet

The design, test items and media chosen for the Case Study Booklet were very successful. Every participant had positive remarks about these elements. They particularly liked the size of the Booklet and the material used for the raised printing. The weaknesses were discovered by the researcher after interviewing the participants. The case study on symbology should not have been divided into two separate sections: symbology with the Lambert Conformal Conic projection and symbology with the Hammer-Aitoff projection. Though it was important for the participants to feel comfortable with the maps on symbology, using the preferred projection may not have been necessary. A few participants were confused with the two sections, thinking they were identical. Their titles certainly didn't help the situation since they were both categorized as Case Study #2, yet another weak point

of the Booklet. The participants were positive about the thematic legend used to describe the area symbols. They were very happy to find it on the same page as the map for ease of legibility. Some of the map features should have remained consistent. For example, the Great Lakes and the neatline should have been included for every map since they are good referencing elements. Maintaining consistency would also have alleviated the need for two legends showing the line symbols. This also confused some participants. Finally, MAP1 (line symbol showing two levels of information: the theme with provincial boundaries) should have appeared after MAP2 (line symbol showing one level of information: the theme). No participants commented on this; however the researcher believes that the complexity of maps should have been progressive. As for the test patterns at the end of the Booklet, they should have been identified with numbers or letters for identification purposes.

5.4.3 Tactile Audio Graphics (TAG) system

As demonstrated in the statistical results, all participants responded positively to the auditory system. Some of the disadvantages of the system have been mentioned earlier in Chapter 3 section 3.3.3, *Auditory maps*. Other weaknesses of the system were discovered by the researcher during the course of this study. The TAG system offers the option of adding up to three levels of information for every feature. The researcher found the input procedure, beyond the first level, to be very complicated. Instructions in the Tactile Audio Graphics Manual were carefully followed, without success. The

researcher eventually found out, through a colleague, that the instructions in the Manual were incomplete. The vocal output, beyond the first level of information, also proved to be problematic. According to the instructions in the booklet, the system will say "*More details*" when a map feature with more than one level of information has been touched. This attribute is useful for knowing which map features contain more detailed descriptions. What the instructions fail to mention is that the map feature must be touched twice before the second level of information is activated. This means that the first level of information is repeated twice. Repeating the first level of information can become time consuming, especially if the information is lengthy.

5.4.4 Survey procedure

It was definitely advantageous to have the participants review the Case Study Booklet and questionnaire before the interview session. Those who had spent a lot of time reviewing the maps provided more feedback than those who had read quickly through it. Some participants had filled out the questionnaire on their own, which meant they took the time to thoroughly read each question and review each map. The only weak point was not following the proper survey procedure with two participants. As mentioned in Chapter 4 section 4.3, *Survey Procedure*, unforeseen circumstances prevented one participant from reviewing the survey material prior to the interview. The feedback provided by this participant may or may not be as valid as the information given by the other participants. The second

participant could not attend the interview session, and therefore was categorised as “*Unsure*” in *Section 3: Auditory maps*.

CHAPTER 6

CONCLUSION

The results of this research suggest that the choice of map projection, the type of area symbol used in maps and auditory maps can influence the legibility and cognition of tactile information. It can be concluded then that the data collected has proven the hypotheses of this study to be valid.

Visually impaired people are able to read and interpret map features to a relatively high degree. According to the analysis in this study, most answers provided by the participants were rated above average for legibility of information. The majority of participants were able to make a distinction between the tested elements to the point where they could establish preferences. The results displayed strong, valid preferences in at least two of the three sections. Fifty percent of the participants selected MAP2 (lines with numbers showing one level of information) as the preferred symbol for legibility. Seventy-five percent of them declared that they understood the map better with sound. The results for the section on map projection present the hypothesis to be valid, in view of the fact that sixty-nine percent of the population selected one of the two projections for discrimination. However the preferences are not as convincing as those presented for symbology and auditory maps. Although one projection was preferred over the other, the range in statistical value between choices was not great. This small variation in preference suggests that much research is needed in projection types for tactile display. While map projections can influence the

legibility of tactile information, the ideal projection to use in tactile map design remains somewhat questionable.

The constraints presented by the visually impaired participants in accurately reading and understanding the tactile information were the inexperience in reading and using tactile maps, and the degree and history of visual impairment. The factor of greatest influence among the three categories of analyses was the category of blindness. Those completely blind scored poorly compared to the group with various levels of impairment. The statistical variability in other categories, for legibility abilities, was also evident but to a lesser extent. The results on symbology and sound for these two categories of analysis (level of experience and history of blindness) were well predicted. Those having no previous experience in reading tactile charts, images or maps had more difficulty reading and understanding the symbols, as did those blind at birth. These same groups of visually impaired people needed sound, as a complementary aid, to a greater degree for reading the maps. The legibility of map projection however did not prove to be problematic for these two groups. The unpredicted results for the section on map projection suggest, once again, that more research is needed in this area. Overall, the variability in results by experience, category of blindness and history of blindness strongly suggest that maps need to be specialized for different user groups.

6.1 SUGGESTIONS FOR THE FUTURE DEVELOPMENT OF GEOSCIENTIFIC MAPS FOR THE VISUALLY IMPAIRED

The main suggestion is to integrate the visually impaired into the design and production of tactile maps. The visually impaired provided insightful and pertinent information for the current study, as they expressed their preferences and dislikes about the tactile maps. Teachers of special education and mobility instructors have good insight on some of the needs of the visually impaired. However, living and functioning in a visual world has influenced their perspectives to some degree. The teachers' responses to the survey support this premise. Their answers did not always correspond with those provided by the visually impaired participants. For example, their preferred map projection and symbology did not coincide with those selected by the visually impaired. It should be noted though, that sighted people who work closely with the visually impaired can provide insightful information, to a certain level of accuracy. Their suggestions are still more legitimate than those of sighted individuals who have no daily contact with visually impaired people.

Another suggestion would be to keep tactile maps as simple as possible, without excluding too much information. Simplified maps are likelier to reach a larger audience. Though it may be difficult to design maps that all blind individuals can understand, learning about the cognitive perceptions of the visually impaired will provide useful insight. Knowledge on their cognition of

space, maps and tactile sensitivities are key elements for developing useful and informative maps.

Finally, the results provided by this research can be considered a guide to the future development of tactile maps for education:

- Map projections, showing a horizontal display of landforms such as the Hammer-Aitoff projection, are easier to read tactually. The reason could potentially be related to the fact that Braille is read horizontally. Being accustomed to read, with the fingers, in a horizontal motion may have an influence on the way maps are read. It is therefore recommended to use this type of projection over conical projections or any other projection where the parallels of latitude are not horizontal.
- Using lines with Braille numbers, showing one level of information, to display surface areas is highly recommended. The pattern symbol 3 millimeters away from the boundary lines would also present tactile information effectively. It is advisable to use lines with Braille for individuals who can read Braille and patterns for those who are non-Braille readers. The preferred patterns to use are dots, perpendicular lines, vertical and horizontal lines. It should be noted that patterns increase or decrease in discrimination based on neighboring patterns.

- Sound should be used whenever possible. Most visually impaired people use some sort of audio device on a regular basis (i.e.: text reading software, books on cassettes). Auditory maps can provide the reader with information that may be overlooked when reading tactually. Not only will sound provide the visually impaired with additional information, but it may increase their interest to read maps.

6.2 CLOSING STATEMENT

The goal of this thesis was to determine the most promising methods of delivering geoscientific information that visually impaired people could read and understand with minimal effort. The conclusions drawn from the results of the survey are an important stepping stone for the future creation of informative, educational maps. Educational maps can assist the visually impaired to become more knowledgeable about their surrounding environment and the geophysical world at large. It is hoped that this study will encourage other researchers in the creation of tactile maps for education, so as to increase their number and availability. Having access to information can help visually impaired persons to become more independent and integrated into society. These are goals we all strive to achieve as individuals, disabled or not.

APPENDIX A
CASE STUDY BOOKLET
(booklet attached to back cover)

APPENDIX B
QUESTIONNAIRE
FOR VISUALLY IMPAIRED PARICIPANTS

**SURVEY FOR THE
THEMATIC TACTILE MAPS OF CANADA - CASE STUDY BOOKLET
Copy for Visually Impaired Participants**

THEMATIC TACTILE MAPS

Thematic maps are maps that display spatial information on one particular theme such as vegetation cover, or population distribution. Tactile maps are maps composed of raised contours or surfaces, which are "read" through touch. These maps have been designed for visually impaired and blind people, and are essential in learning the basics of geography.

TESTING PROCESS

Testing of the map samples will be conducted through an informal interview process. The interview may be tape recorded to substitute for note-taking, which can sometimes be insufficient and time consuming.

This survey along with the Thematic Tactile Maps of Canada Case Study Booklet will be sent to participants before the interview session. Participants will have the opportunity to examine the booklet and questionnaire on their own time. During the testing process, participants will be asked to express their thoughts openly and to give helpful suggestions.

LIST OF ITEMS TO BE TESTED

The questionnaire is divided into three main sections.

Section 1: Projection of Canada

This section deals with questions on the projection of Canada. There are two projection types displayed in the booklet: Lambert conformal conic and Hammer-Aitoff. The main purpose of this section is to learn if participants understand the concept of map projections, and if they have a preference between the two projections displayed in the booklet.

Section 2: Symbolology

This section deals with questions on the use of symbols for the identification of different theme categories. The different symbols used in the booklet are lines with numbers and pattern-filled areas. Participants may examine the symbols in the projection of their choice. The purpose of this section is to find out which of the symbols are most effective at displaying the information.

Section 3: Auditory maps

This section deals with questions on the use of sound as an additional component for the transmission of information. During the interview session, an audio component will be added to the sample maps. The purpose of this section is to learn if the audio component increases legibility of the maps.

BACKGROUND QUESTIONS

1. Do you have experience in reading Braille?

Yes _____

No _____

If yes, what level of Braille can you read, grade 1 or grade 2?

Grade 1 _____

Grade 2 _____

Not applicable _____

How would you rate your Braille reading skills?

Very good _____

Average _____

Started learning _____

Not applicable _____

2. Until what level did you attend school?

Primary _____

Secondary _____

Post-secondary _____

3. Until what level did you receive education in geography?

Primary _____

Secondary _____

Post-secondary _____

4. Do you have experience in reading tactile charts or images?

Yes _____

No _____

If yes, what level of experience?

Very good _____

Average _____

Started learning _____

Not applicable _____

5. Do you have experience in reading tactile maps?

Yes _____

No _____

If yes, what level of experience?

Very good _____

Average _____

Started learning _____

Not applicable _____

SECTION 1: PROJECTION OF CANADA

Two map projections have been sent to be reviewed: Lambert Conformal conic and the Hammer-Aitoff projection. These maps are found on pages 2 and 3. Both maps project a slightly different outline of Canada.

6. After examining the maps, do you have a general idea of the shape or outline of Canada?

Yes _____

No _____

Unsure _____

7. Do you already know what the outline of Canada is?

Yes _____

No _____

Unsure _____

8. Would you say that the projections of Canada for the two maps (page 2 and 3) are very different?

Very much _____

A bit _____

Very little _____

Not at all _____

9. Do you know what a map projection is?

Yes _____

No _____

Unsure _____

10. After examining the Lambert Conformal Conic projection (page 2), do you get the impression that the boundary between Canada and the United States is curved or straight?

curved _____

straight _____

Unsure _____

11. After examining the Hammer-Aitoff projection (page 3), do you get the impression that the boundary between Canada and the United States is curved or straight?

curved _____

straight _____

Unsure _____

12. When you imagine the earth as a sphere, do you think that the actual boundary between Canada and the United States is curved or straight?

curved _____

straight _____

Unsure _____

13. Which of the two projections do you prefer?

Lambert Conformal Conic _____

Hammer-Aitoff _____

No preference _____

14. Please explain the reasons for your preference.

SECTION 2: USE OF SYMBOLS

Different symbols have been used to identify categories of elevation in Canada. The symbols used are lines with numbers and patterns. The symbols have been displayed in both projections; Lambert Conformal Conic and Hammer-Aitoff. Participants may examine the symbols in the projection of their choice. To examine the symbols with the Lambert Conformal Conic projection, please go to pages 5, 6, 7 and 8. To examine the symbols with the Hammer-Aitoff projection, please go to pages 10, 11, 12 and 13.

MAP 1

Please examine the first map on page 5 or on page 10. This map uses lines and numbers to show two levels of information: the categories of elevation and the provincial boundaries.

15. Can you easily identify the different categories of elevation?

Very much _____

A bit _____

Very little _____

Not at all _____

16. Can you easily identify the provinces and territories?

Very much _____

A bit _____

Very little _____

Not at all _____

17. Do you think the use of this type of symbol (lines with numbers showing two levels of information) is effective at displaying the information?

Very much _____

A bit _____

Very little _____

Not at all _____

MAP 2

Please examine the second map on page 6 or on page 11. This map uses lines and numbers to show only one level of information: the categories of elevation. It does not show any provinces or territories.

18. Can you easily identify the different categories of elevation?

Very much _____

A bit _____

Very little _____

Not at all _____

19. Is this map easier to read with or without the provinces and territories?

With political boundaries _____

Without political boundaries _____

Unsure _____

20. Do you prefer the map with or without the provinces and territories?

With political boundaries _____

Without political boundaries _____

Unsure _____

21. Were you able to find the north arrow easily?

Yes _____

No _____

MAP 3

Please examine the third map on page 7 or on page 12. This map uses patterns to show the categories of elevation. The patterns completely fill each category.

22. Can you easily identify the different categories of elevation?

Very much _____

A bit _____

Very little _____

Not at all _____

23. Do you like the patterns used for each category?

Very much _____

A bit _____

Very little _____

Not at all _____

24. Do you think the use of this type of symbol (pattern-filled areas) is effective at displaying the information?

Very much _____

A bit _____

Very little _____

Not at all _____

25. When referring to the north arrow, do you prefer the conventional arrow (on this map), or the triangle-shaped arrow (on the previous map)?

Conventional arrow _____

Triangle-shaped arrow _____

No preference _____

MAP 4

Please examine the fourth map on page 8 or on page 13. This map uses patterns to show the categories of elevation. Unlike the previous map, the patterns are 3 millimeters away from the boundary lines. They do not completely fill each category.

26. Can you easily identify the different categories of elevation?

Very much _____

A bit _____

Very little _____

Not at all _____

27. Do you prefer to have a pattern symbol fill the entire area or have it 3 millimeters away from the boundaries?

Pattern fills an entire area _____

Pattern 3 millimeters away from the boundaries _____

No preference _____

28. Which of the four symbol types do you prefer?

MAP 1: Lines with numbers showing two levels of information _____

MAP 2: Lines with numbers showing one level of information _____

MAP 3: Patterns that fill an entire surface area _____

MAP 4: Patterns 3 millimeters away from the boundary line _____

29. Please explain the reasons for your preference.

Test patterns

Please examine the test patterns on page 14.

30. Please select the patterns you like based on clarity and feel.

31. Please select the patterns you dislike based on clarity and feel.

SECTION 3: AUDITORY MAPS

During the interview session, an audio component will be added to the elevation map. Participants will have time to re-examine the map with added sound.

32. Do you prefer to examine the map with or without sound?

With sound _____

Without sound _____

33. Does the sound help you to understand the map much better?

Yes _____

No _____

Unsure _____

34. Do you think you could learn the map faster with sound?

Yes _____

No _____

Unsure _____

35. There are two levels of speech for the two levels of information (map theme and provincial boundaries). Do you prefer to have two levels of speech or would you be content with just one level?

One level _____

Two levels _____

Unsure _____

36. Do you use vocal output devices for reading or writing (ie: jaws)?

Always _____

Sometimes _____

Rarely _____

Never _____

CLOSING QUESTIONS

37. Did you think the questionnaire was too long?

Yes _____

No _____

38. What did you think about the items that were tested? Do you think they are important or unimportant for tactile map design?

important _____

unimportant _____

39. Do you have any suggestions for tactile map design?

**Written consent of participants who were involved with the
thematic tactile mapping project**

I was a voluntary participant for the thematic tactile mapping project, where I was informally interviewed by the researcher. I was fully aware that the interview may be tape recorded, and consented to it.

I was told that the information gathered during the interview was going to be used for a Master's Thesis at Carleton University, and for the creation of thematic tactile maps at Natural Resources Canada. I consent that all of the information I gave during the informal interview session be used for these purposes.

Name of participant

APPENDIX C
QUESTIONNAIRE
FOR TEACHERS

**SURVEY FOR THE
THEMATIC TACTILE MAPS OF CANADA - CASE STUDY BOOKLET
Copy for Teachers**

THEMATIC TACTILE MAPS

Thematic maps are maps that display spatial information on one particular theme such as vegetation cover, or population distribution. Tactile maps are maps composed of raised contours or surfaces, which are "read" through touch. These maps have been designed for visually impaired and blind people, and are essential in learning the basics of geography.

TESTING PROCESS

Testing of the map samples will be conducted through an informal interview process. The interview may be tape recorded to substitute for note-taking, which can sometimes be insufficient and time consuming.

This survey along with the Thematic Tactile Maps of Canada Case Study Booklet will be sent to participants before the interview session. Participants will have the opportunity to examine the booklet and questionnaire on their own time. During the testing process, participants will be asked to express their thoughts openly and to give helpful suggestions.

LIST OF ITEMS TO BE TESTED

The questionnaire is divided into three main sections.

Section 1: Projection of Canada

This section deals with questions on the projection of Canada. There are two projection types displayed in the booklet: Lambert conformal conic and Hammer-Aitoff. The main purpose of this section is to learn if participants understand the concept of map projections, and if they have a preference between the two projections displayed in the booklet.

Section 2: Symbology

This section deals with questions on the use of symbols for the identification of different theme categories. The different symbols used in the booklet are lines with numbers and pattern-filled areas. Participants may examine the symbols in the projection of their choice. The purpose of this section is to find out which of the symbols are most effective at displaying the information.

Section 3: Auditory maps

This section deals with questions on the use of sound as an additional component for the transmission of information. During the interview session, an audio component will be added to the sample maps. The purpose of this section is to learn if the audio component increases legibility of the maps.

SECTION 1: PROJECTION OF CANADA

Two map projections have been sent to be reviewed: Lambert Conformal conic and the Hammer-Aitoff projection. These maps are found on pages 2 and 3. Both maps project a slightly different outline of Canada.

1. Do you know what a map projection is?

Yes _____

No _____

Unsure _____

2. In your opinion, would a visually impaired person know what a map projection is?

Yes _____

No _____

Unsure _____

3. After examining the maps tactually, would it be possible to have a general idea of the shape or outline of Canada?

Yes _____

No _____

Unsure _____

4. Would it be possible to tactually distinguish the differences in the two map projections (page 2 and 3)?

Yes _____

No _____

Unsure _____

5. In your opinion, which of the two projections would most suitable for tactual discrimination?

Lambert Conformal Conic _____

Hammer-Aitoff _____

No preference _____

6. Please explain the reasons for your preference.

SECTION 2: USE OF SYMBOLS

Different symbols have been used to identify categories of elevation in Canada. The symbols used are lines with numbers and patterns. The symbols have been displayed in both projections; Lambert Conformal Conic and Hammer-Aitoff. Participants may examine the symbols in the projection of their choice. To examine the symbols with the Lambert Conformal Conic projection, please go to pages 5, 6, 7 and 8. To examine the symbols with the Hammer-Aitoff projection, please go to pages 10, 11, 12 and 13.

MAP 1

Please examine the first map on page 5 or on page 10. This map uses lines and numbers to show two levels of information: the categories of elevation and the provincial boundaries.

7. Would it be possible to identify the different categories of elevation through touch?

Very much _____

A bit _____

Very little _____

Not at all _____

8. In your opinion, would it be confusing for a blind person to have two levels of information on the same map (ie: the categories of elevation with the political boundaries)?

Very much _____

A bit _____

Very little _____

Not at all _____

9. Do you think the use of this type of symbol (lines with numbers showing two levels of information) is effective at displaying the information?

Very much _____

A bit _____

Very little _____

Not at all _____

MAP 2

Please examine the second map on page 6 or on page 11. This map uses lines and numbers to show only one level of information: the categories of elevation. It does not show any provinces or territories.

10. Would it be possible to identify the different categories of elevation through touch?

Very much _____

A bit _____

Very little _____

Not at all _____

11. In your opinion, which map would be easier read tactually: the map with or without the political boundaries?

With political boundaries _____

Without political boundaries _____

Unsure _____

MAP 3

Please examine the third map on page 7 or on page 12. This map uses patterns to show the categories of elevation. The patterns completely fill each category.

12. Would it be possible to identify the different categories of elevation through touch?

Very much _____

A bit _____

Very little _____

Not at all _____

13. Do you like the patterns used for each category?

Very much _____

A bit _____

Very little _____

Not at all _____

14. Do you think the use of this type of symbol (pattern-filled areas) is effective at displaying the information?

Very much _____

A bit _____

Very little _____

Not at all _____

15. When referring to the north arrow, do you prefer the conventional arrow (on this map), or the triangle-shaped arrow (on the previous map)?

Conventional arrow _____

Triangle-shaped arrow _____

No preference _____

MAP 4

Please examine the fourth map on page 8 or on page 13. This map uses patterns to show the categories of elevation. Unlike the previous map, the patterns are 3 millimeters away from the boundary lines. They do not completely fill each category.

16. Would it be possible to identify the different categories of elevation through touch?

Very much _____

A bit _____

Very little _____

Not at all _____

17. In your opinion, which type of pattern would be easier to read tactually?

Pattern fills an entire area _____

Pattern 3 millimeters away from the boundaries _____

Unsure _____

18. Which of the four symbol types would be easier read tactually?

MAP 1: Lines with numbers showing two levels of information _____

MAP 2: Lines with numbers showing one level of information _____

MAP 3: Patterns that fill an entire surface area _____

MAP 4: Patterns 3 millimeters away from the boundary line _____

19. Please explain the reasons for your preference.

Test patterns

Please examine the test patterns on page 14.

20. Please select the patterns you like based on clarity and feel.

21. Please select the patterns you dislike based on clarity and feel.

1_____ 2_____ 3_____ 4_____

5_____ 6_____ 7_____ 8_____

9_____ 10_____ 11_____ 12_____

SECTION 3: AUDITORY MAPS

During the interview session, an audio component will be added to the elevation map. Participants will have time to re-examine the map with added sound.

22. In your opinion, would sound help a blind person to better understand the maps?

Yes _____

No _____

Unsure _____

23. Would the learning process be much faster with the use of sound?

Yes _____

No _____

Unsure _____

24. There are two levels of speech for the two levels of information (map theme and provincial boundaries). Do you prefer to have two levels of speech or would you be content with just one level?

One level _____

Two levels _____

Unsure _____

CLOSING QUESTIONS

25. What did you think about the items that were tested? Do you think they are important or unimportant for tactile map design?

important _____

unimportant _____

26. Do you have any suggestions that would improve this sort of tactile mapping?

**Written consent of participants who were involved with the
thematic tactile mapping project**

I was a voluntary participant for the thematic tactile mapping project, where I was informally interviewed by the researcher. I was fully aware that the interview may be tape recorded, and consented to it.

I was told that the information gathered during the interview was going to be used for a Master's Thesis at Carleton University, and for the creation of thematic tactile maps at Natural Resources Canada. I consent that all of the information I gave during the informal interview session be used for these purposes.

Name of participant

APPENDIX D

STATISTICAL RESULTS

RESPONSE FROM VISUALLY IMPAIRED PARTICIPANTS

Appendix D
Statistical Results of the Survey
Response from Visually Impaired Participants

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BACKGROUND QUESTIONS	visually impaired N=16	
	count	%
1. Do you have experience in reading Braille?		
yes	15	94
no	1	6
If yes, what level, grade 1 or grade 2?		0
grade 1	2	13
grade2	13	81
not applicable	1	6
How would you rate your Braille reading skills?		0
very good	8	50
average	6	38
started learning	1	6
not applicable	1	6
2. Until what level did you attend school?		
primary	0	0
secondary	11	69
post-secondary	5	31
3. Until what level did you receive education in geography?		
primary	1	6
secondary	14	88
post-secondary	1	6
4. Do you have experience in reading tactile charts or images?		
yes	10	63
no	6	38
If yes, what level of experience?		0
very good	2	13
average	7	44
started learning	1	6
not applicable	6	38
5. Do you have experience in reading tactile maps?		
yes	10	63
no	6	38
If yes, what level of experience?		0
very good	2	13
average	7	44
started learning	1	6
not applicable	6	38

Appendix D
Statistical Results of the Survey
Response from Visually Impaired Participants

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SECTION 1: PROJECTION OF CANADA	visually impaired N=16	
	count	%
6. After examining the maps, do you have a general idea of the shape or outline of Canada?		
yes	6	38
no	5	31
unsure	5	31
7. Do you already know what the outline of Canada is?		
yes	13	81
no	3	19
unsure	0	0
8. Would you say that the two projections of Canada (p.2&3) are very different?		
very much	4	25
a bit	8	50
very little	1	6
not at all	2	13
unsure	1	6
9. Do you know what a map projection is?		
yes	10	63
no	6	38
unsure	0	0
10. After examining the Lambert Conformal Conic projection, do you get the impression that the boundary between Canada and the United States is curved or straight?		
curved	10	63
straight	2	13
unsure	4	25
11. After examining the Hammer-Aitoff projection, do you get the impression that the boundary between Canada and the United States is curved or straight?		
curved	2	13
straight	14	88
unsure	0	0
12. When you imagine the earth as a sphere, do you think that the actual boundary between Canada and the U.S. is curved or straight?		
curved	10	63
straight	3	19
unsure	3	19
13. Which of the two projections you prefer?		
Lambert Conformal Conic	4	25
Hammer-Aitoff	7	44
no preference	5	31

Appendix D
Statistical Results of the Survey
Response from Visually Impaired Participants

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OPEN QUESTION		
14. Please explain the reasons for your preference.		
SECTION 2: SYMBOLOGY	visually impaired	N=16
MAP 1	count	%
15. Can you easily identify the different categories of elevation?		
very much	2	13
a bit	6	37
very little	4	25
not at all	4	25
16. Can you easily identify the provinces and territories?		
very much	2	13
a bit	7	44
very little	4	25
not at all	3	19
17. Do you think the use of this symbol (lines with numbers showing two levels of information) is effective at displaying the information?		
very much	8	50
a bit	8	50
very little	0	0
not at all	0	0
MAP 2	count	%
18. Can you easily identify the different categories of elevation?		
very much	11	69
a bit	4	25
very little	0	0
not at all	1	6
19. Is the map easier to read with or without the provinces and territories?		
with provincial boundaries	0	0
without provincial boundaries	13	81
unsure	3	19
20. Do you prefer the map with or without the provinces and territories?		
with provincial boundaries	1	6
without provincial boundaries	12	75
unsure	3	19
21. Were you able to find the north arrow easily?		
yes	12	75
no	4	25

Appendix D
Statistical Results of the Survey
Response from Visually Impaired Participants

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MAP 3	count	%
22. Can you easily identify the different categories of elevation?		
very much	7	44
a bit	3	19
very little	4	25
not at all	2	13
23. Do you like the patterns used for each category?		
very much	9	56
a bit	6	38
very little	1	6
not at all	0	0
24. Do you think the use of this symbol (pattern-filled areas) is effective at displaying the information?		
very much	4	25
a bit	8	50
very little	1	6
not at all	3	19
25. When referring to the north arrow, do you prefer the conventional arrow, or the triangle-shaped arrow?		
conventional	7	44
triangle-shaped	6	38
no preference	3	19
SECTION 2: SYMBOLOGY (continued..)	visually impaired	N=16
MAP 4	count	%
26. Can you easily identify the different categories of elevation?		
very much	9	56
a bit	4	25
very little	2	13
not at all	1	6
27. Do you prefer to have a pattern symbol fill the entire area or have it 3 millimeters away from the boundaries?		
pattern fills an entire area	1	6
pattern 3 millimeters away from the boundaries	13	81
unsure	2	13

Appendix D
Statistical Results of the Survey
Response from Visually Impaired Participants

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28. Which of the four symbol types do you prefer?		
MAP 1: Lines with numbers showing two levels of information	1	6
MAP 2: Lines with numbers showing one level of information	8	50
MAP 3: Patterns that fill an entire surface area	1	6
MAP 4: Patterns 3 millimeters away from the boundary line	5	31
no preference	1	6
OPEN QUESTION		
29. Please explain the reasons for you preference.		
SECTION 2: SYMBOLOGY (continued..)		
TEST PATTERNS		visually impaired N=16
	count	%
30. Please select the patterns you like based on clarity and feel.		
1	4	25
2	5	31
3	10	63
4	1	6
5	2	13
6	10	63
7	3	19
8	11	69
9	3	19
10	2	13
11	4	25
12	0	0
none	2	13
31. Please select the patterns you dislike based on clarity and feel.		
1	1	6
2	2	13
3	1	6
4	1	6
5	1	6
6	1	6
7	1	6
8	1	6
9	4	25
10	4	25
11	4	25
12	4	25
none	5	31

Appendix D
Statistical Results of the Survey
Response from Visually Impaired Participants

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SECTION 3: AUDITORY MAPS	visually impaired N=16	
	count	%
32. Do you prefer to examine the map with or without sound?		
with sound	12	75
without sound	3	19
unsure	1	6
33. Does the sound help you to understand the map much better?		
yes	12	75
no	4	25
34. Do you think you could learn the map faster with sound?		
yes	12	75
no	3	19
unsure	1	6
35. There are two levels of speech for the two levels of information (map theme and provincial boundaries). Do you prefer to have two levels of speech or would you be content with just one level?		
one level	0	0
two levels	14	88
unsure	2	13
36. Do you use vocal output devices for reading or writing?		
always	11	69
sometimes	4	25
rarely	1	6
never	0	0
CLOSING QUESTIONS	visually impaired N=16	
	count	%
37. Did you think the questionnaire was too long?		
yes	0	0
no	16	100
38. What did you think of the items that were tested. Do you think they are important or unimportant for tactile map design?		
important	15	94
unimportant	0	0
unsure	1	6
OPEN QUESTION		
39. Do you have any suggestions for tactile map design?		

Appendix E
Statistical Results of the Survey
Response from Teachers

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SECTION 1: PROJECTION OF CANADA	TEACHERS N=5	
	count	%
1. Do you know what a map projection is?		
yes	4	80
no	1	20
2. In your opinion, would a blind person know what a map projection is?		
yes	2	40
no	2	40
unsure	1	20
3. After examining the maps tactually, would it be possible to have a general idea of the shape or outline of Canada?		
yes	2	40
no	2	40
unsure	1	20
4. Would it be possible to tactually distinguish the differences in the two map projections (page 2 and 3)?		
yes	3	60
no	0	0
unsure	2	40
5. In your opinion, which of the two projections would most suitable for tactual discrimination?		
Lambert Conformal Conic	3	60
Hammer-Aitoff	1	20
no preference	1	20
6. Please explain the reasons for your preference.		
SECTION 2: SYMBOLOGY	TEACHERS N=5	
MAP 1	count	%
7. Would it be possible to identify the different theme categories through touch?		
very much	1	20
a bit	3	60
very little	1	20
not at all	0	0
8. In your opinion, would it be confusing for a blind person to have two levels of information on the same map (ie: map theme with the political boundaries)?		
very much	2	40
a bit	1	20
very little	2	40
not at all	0	0

Appendix E
Statistical Results of the Survey
Response from Teachers

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9. Do you think the use of this type of symbol (lines with numbers showing two levels of information) is effective at displaying the information?		
very much	3	60
a bit	1	20
very little	1	20
not at all	0	0
SECTION 2: SYMBOLOGY (continued.)	TEACHERS	N=5
MAP 2	count	%
10. Would it be possible to identify the different theme categories through touch?		
very much	1	20
a bit	4	80
very little	0	0
not at all	0	0
11. In your opinion, which map would be easier read tactually: the map with or without the political boundaries?		
with provincial boundaries	0	0
without provincial boundaries	4	80
unsure	1	20
MAP 3	count	%
12. Would it be possible to identify the different theme categories through touch?		
very much	2	40
a bit	1	20
very little	1	20
not at all	1	20
13. Do you like the patterns used for each category?		
very much	4	80
a bit	0	0
very little	1	20
not at all	0	0
14. Do you think the use of this type of symbol (pattern-filled areas) is effective at displaying the information?		
very much	5	100
a bit	0	0
very little	0	0
not at all	0	0

Appendix E
Statistical Results of the Survey
Response from Teachers

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15. When referring to the north arrow, do you prefer the conventional arrow (on this map), or the triangle-shaped arrow (on the previous map)?		
conventional	3	60
triangle-shaped	2	40
no preference	0	0
SECTION 2: SYMBOLOGY (continued..)	TEACHERS	N=5
MAP 4	count	%
16. Would it be possible to identify the different theme categories through touch?		
very much	3	60
a bit	2	40
very little	0	0
not at all	0	0
17. In your opinion, which type of pattern would be easier to read tactually?		
pattern fills an entire area	0	0
pattern 3 millimeters away from the boundaries	4	80
unsure	1	20
18. Which of the four symbol types would be easier read tactually?		
MAP 1:Lines with numbers showing two levels of information	0	0
MAP 2:Lines with numbers showing one level of information	1	20
MAP 3:Patterns that fill an entire surface area	0	0
MAP 4:Patterns 3 millimeters away from the boundary line	3	60
unsure	1	20
19. Please explain the reasons for your preference.		
TEST PATTERNS	TEACHERS	N=5
	count	%
20. Please select the patterns you like based on clarity and feel.		
1	2	40
2	2	40
3	4	80
4	1	20
5	0	0
6	2	40
7	3	60
8	2	40
9	1	20
10	1	20
11	0	0
12	0	0
none	0	0

Appendix E
Statistical Results of the Survey
Response from Teachers

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21. Please select the patterns you dislike based on clarity and feel.		
1	1	20
2	2	40
3	1	20
4	2	40
5	3	60
6	0	0
7	0	0
8	3	60
9	2	40
10	2	40
11	2	40
12	3	60
none	0	0
SECTION 3: AUDITORY MAPS		
	TEACHERS	N=5
	count	%
22. In your opinion, would sound help a blind person to better understand the maps?		
yes	4	80
no	0	0
unsure	1	20
23. Would the learning process be much faster with the use of sound?		
yes	3	60
no	0	0
unsure	2	40
24. There are two levels of speech for the two levels of information (map theme and provincial boundaries). Do you prefer to have two levels of speech or would you be content with just one level?		
one level	0	0
two levels	4	80
unsure	1	20
CLOSING QUESTIONS		
	count	%
25. What did you think about the items that were tested? Do you think they are important or unimportant for tactile map design?		
important	5	100
unimportant	0	0
unsure	0	0
26. Do you have any suggestions that would improve this sort of tactile mapping?		

APPENDIX F

ANALYSIS OF RESULTS

EXPERIENCE IN READING TACTILE IMAGES, CHARTS OR MAPS

Appendix F

Analysis of Results: Experience in reading tactile images, charts or maps

BACKGROUND QUESTIONS		PREVIOUS EXPERIENCE	N=11	NO PREVIOUS EXPERIENCE	N=5
		count	%	count	%
Braille reading skills (Q1)					
above average		11	100	3	60
below average		0	0	2	40
Total frequency of answers		11	100	5	100
SECTION 1: PROJECTION OF CANADA		PREVIOUS EXPERIENCE	N=11	NO PREVIOUS EXPERIENCE	N=5
		count	%	count	%
Legibility and cognition of map projections(Q6, Q10, Q11)					
above average		20	61	10	67
below average		13	39	5	33
Total frequency of answers		33	100	15	100
SECTION 2: SYMBOLOGY		PREVIOUS EXPERIENCE	N=11	NO PREVIOUS EXPERIENCE	N=5
		count	%	count	%
MAP 1					
Legibility and cognition of map symbols (Q15, Q16)					
above average		14	64	3	30
below average		8	36	7	70
Total frequency of answers		22	100	10	100
MAP 2					
Legibility and cognition of map symbols (Q18)					
above average		11	100	4	80
below average		0	0	1	20
Total frequency of answers		11	100	5	100

APPENDIX G

ANALYSIS OF RESULTS
CATEGORY OF IMPAIRMENT

Appendix G
Analysis of Results: Category of Impairment

BACKGROUND QUESTIONS		COMPLETELY BLIND	N=7	VARIOUS LEVELS OF VISUAL IMPAIRMENT	N=9
		count	%	count	%
Braille reading skills (Q1)					
	above average	6	86	8	89
	below average	1	14	1	11
	Total frequency of answers	7	100	9	100
SECTION 1: PROJECTION OF CANADA					
		COMPLETELY BLIND	N=7	VARIOUS LEVELS OF VISUAL IMPAIRMENT	N=9
		count	%	count	%
Legibility and cognition of map projections (Q6, Q10, Q11)					
	above average	10	48	20	74
	below average	11	52	7	26
	Total frequency of answers	21	100	27	100
SECTION 2: SYMBOLOGY					
		COMPLETELY BLIND	N=7	VARIOUS LEVELS OF VISUAL IMPAIRMENT	N=9
		count	%	count	%
MAP 1					
Legibility and cognition of map symbols (Q15, Q16)					
	above average	5	36	12	67
	below average	9	64	6	33
	Total frequency of answers	14	100	18	100

MAP 2							
Legibility and cognition of map symbols (Q18)							
above average				6	86	9	100
below average				1	14	0	0
Total frequency of answers				7	100	9	100
MAP 3							
Legibility and cognition of map symbols (Q22)							
above average				3	43	5	56
below average				4	57	4	44
Total frequency of answers				7	100	9	100
MAP 4							
Legibility and cognition of map symbols (Q26)							
above average				4	57	9	100
below average				3	43	0	0
Total frequency of answers				7	100	9	100
Total of 4 maps							
above average				18	51	35	78
below average				17	49	10	22
Total frequency of answers				35	100	45	100
SECTION 3: AUDITORY MAPS							
				COMPLETELY BLIND	N=7	VARIOUS LEVELS OF VISUAL IMPAIRMENT	N=9
				count	%	count	%
Cognition of map with sound (Q33)							
above average				6	86	6	67
below average				1	14	3	33
Total frequency of answers				7	100	9	100

APPENDIX H

ANALYSIS OF RESULTS
HISTORY OF BLINDNESS

Appendix H

Analysis of Results: History of Blindness

BACKGROUND QUESTIONS		BLIND AT BIRTH count	N=9 %	BLIND AFTER BIRTH count	N=7 %
Braille reading skills (Q1)					
above average		8	89	6	86
below average		1	11	1	14
Total frequency of answers		9	100	7	100
SECTION 1: PROJECTION OF CANADA		BLIND AT BIRTH count	N=9 %	BLIND AFTER BIRTH count	N=7 %
Legibility and cognition of map projections (Q6, Q10, Q11)					
above average		18	67	12	57
below average		9	33	9	43
Total frequency of answers		27	100	21	100
SECTION 2: SYMBOLOGY		BLIND AT BIRTH count	N=9 %	BLIND AFTER BIRTH count	N=7 %
MAP 1					
Legibility and cognition of map symbols (Q15, Q16)					
above average		7	39	10	71
below average		11	61	4	29
Total frequency of answers		18	100	14	100
MAP 2					
Legibility and cognition of map symbols (Q18)					
above average		8	89	7	100
below average		1	11	0	0
Total frequency of answers		9	100	7	100

MAP 3							
Legibility and cognition of map symbols (Q22)							
above average				4	44	4	57
below average				5	56	3	43
Total frequency of answers				9	100	7	100
MAP 4							
Legibility and cognition of map symbols (Q26)							
above average				7	78	6	86
below average				2	22	1	14
Total frequency of answers				9	100	7	100
Total of 4 maps							
above average				26	58	27	77
below average				19	42	8	23
Total frequency of answers				45	100	35	100
SECTION 3: AUDITORY MAPS							
				BLIND AT BIRTH	N=9	BLIND AFTER BIRTH	N=7
				count	%	count	%
Cognition of map with sound (Q33)							
above average				8	89	4	57
below average				1	11	3	43
Total frequency of answers				9	100	7	100

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Cartes tactiles thématiques du Canada
Livret d'une étude de cas

Étude de cas #1: Projections
Étude de cas #2: Symbologie

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Étude de cas #1: Projections

Projection:

Conique conforme de Lambert

500 km

Projection:

Hammer-Aitoff

500 km

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Étude de cas #2: Symbologie

Projection: Conique conforme de Lambert
Thème: Relief

Relief

- ☐ 1 0 - 200 mètres
- ☐ 2 201 - 500 mètres
- ☐ 3 501 - 1000 mètres
- ☐ 4 1001 - 5000 mètres

Relief

☐ 1 0 - 200 mètres

☐ 2 201 - 500 mètres

☐ 3 501 - 1000 mètres

☐ 4 1001 - 5000 mètres

Relief

Relief

Étude de cas #2: Symbologie

Projection: Hammer - Aitoff

Thème: Relief

Relief

500 km

1	0 - 200 mètres
2	201 - 500 mètres
3	501 - 1000 mètres
4	1001 - 5000 mètres

Relief

Relief

500 km

- 0 - 200 mètres
- 201 - 500 mètres
- 501 - 1000 mètres
- 1001 - 5000 mètres

Relief

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Motif de test