Understanding Data Selection in Tactile Mapping: An Inclusive Design Approach

by

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A thesis
submitted to the Victoria University of Wellington
in partial fulfilment of the requirements for the
degree of Master of Science
in Geographic Information Science.

Te Herenga Waka - Victoria University of Wellington
2023

Acknowledgements

This research would not have been possible without all the participants who generously volunteered their time to contribute. Words cannot express my deepest appreciation to these individuals.

I am extremely grateful to my supervisors Dr Mairéad de Róiste and Dr Wokje Abrahamse. I could not have completed this work without their knowledge, expertise, insights, reviews, and ongoing support.

I'd also like to thank my family, their belief and encouragement has kept me motivated. A special note of thanks is due to Chris Bennett for his proof reading and reviews.

This work was funded by the Post Graduate Geographic Information Science Scholarship, awarded by Toitū te Whenua - Land Information New Zealand.

Abstract

According to the World Health Organisation, approximately 285 million people are visually impaired, globally. In New Zealand, it is estimated that 150,000 people have low vision and approximately 30,000 individuals are blind. Tactile maps are graphical representations of geographic information read through touch. Research has found that tactile maps effectively contribute to the development of a blind or low vision navigator's cognitive map. Tactile maps are useful tools, they are used to develop spatial awareness of remote locations and they improve retained knowledge of surrounding environments.

Data selection is the process of determining the necessary information to include on a map, it is key in tactile mapping. Tactile maps require substantial generalisation as the discrimination of the finger is less than the eye. When constructing a tactile map, if data is incorrectly selected, the map can become difficult for a navigator to use. Past tactile mapping research has found that current standards lack necessary data selection recommendations.

This research consisted of two interview sessions in which participants who were blind or low vision were asked about their opinions and experiences with tactile maps, and their data selection preferences. Thematic analysis of the initial interview sessions revealed the value participants placed on tactile maps and their preferences. Four sample tactile maps were presented during the second interview sessions. The association between data selection and tactile map usability was assessed via usability analysis. Based on the ISO 9241-11:2018 guide definition preferences (satisfaction), time taken (efficiency), and task success (effectiveness) were key metrics.

The research found that tactile maps remain a valuable product in the blind and low vision community. Participants value the choice, independence, and improved spatial ability that tactile maps provide. Data selection, however, was not associated with tactile map usability. However, in this research, participants preferred sample tactile maps that included intersection information, including street and road names, crossing type, and intersection type. Thematic analysis identified the importance of data currency, future research could explore this further. More generally, this research recommends investigating techniques to communicate changing spatial information to blind and low vision navigators.

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Chapter 1

Introduction

Tactile maps improve the spatial decision making of blind and low vision navigators (Blades et al., 1999; Lobben, 2005; Lobben & Lawrence, 2012; Perkins, 2002; Siekierska et al., 2003; Spencer et al., 1992; Ungar et al., 1993, 1997). In the past, tactile maps have been used as tools to promote an understanding of distant environments, as educational tools, and to support verbal or written directions (Baldwin & Higgins, 2022; Blades et al., 1999; Kulhavy et al., 1993; Ungar et al., 1995).

Data selection is the process of determining the necessary information to include on a map and it is becoming increasingly important as the availability of spatial data grows (Agrawala & Stolte, 2001). Data selection is particularly pertinent in tactile mapping, as tactile maps require substantial generalisation to be read by touch (Gardiner & Perkins, 2002; Mulíčková & Štampach, 2016). It is recommended that tactile maps only contain 10 to 15 different datasets (Wabiński & Mościcka, 2019).

In cartography, data selection depends on the map's purpose, design, scale, and level of detail required (Forrest, 1999; Robinson et al., 1995). If a cartographer does not correctly "distinguish between essential and extraneous" data, the map can be difficult for a navigator to use (Agrawala &

Stolte, 2001, p. 241).

Generalisation and data selection in tactile mapping is complicated (Gardiner & Perkins, 2002, Waller et al., 2015). Commonly cartographers are sighted and therefore lack the first-hand experience and knowledge to carry out data selection for tactile mapping (Breen, 2007). In addition, there is little guidance and detail within tactile mapping standards, putting tactile map makers in a unique position of uncertainty (Gardiner & Perkins, 2002). To address the uncertainty this research followed an inclusive design approach (Holmes, 2018; Keates & Clarkson, 2000).

Inclusive design enables informed decision making based on a well-grounded understanding of the end users. It is a method to obtain accurate results when personal knowledge or standardisation cannot be relied upon (Breen, 2007; Holmes, 2018). User involvement is an inclusive design principle, it values the involvement of users in product design early and often (Holmes, 2018).

Often map users are unaware of the data selection decisions a cartographer makes (Brown et al., 2013). User perspective insights can be obtained by thematic analysis and usability studies, conducted via one-on-one interview sessions.

Thematic analysis is a qualitative research method used to identify themes in data (Braun & Clarke, 2006). In this research thematic analysis was used to identify data selection preference themes within the blind and low vision community. Thematic analysis is a valuable tool for a sighted researcher, it can uncover previously unknown themes and opinions which may not be generated using other methods (Javadi & Zarea, 2016).

Usability studies are used to confirm and refine the results of thematic analysis. The primary goal of any usability study is to improve the product that is being tested (Dumas & Redish, 1999). The International Organisation for Standardisation (ISO) defines usability as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" in the ISO 9241-11:2018 standard (2018, p. 3.1).

1.1 Research Gap

Data selection is one of six common generalisation steps used in map production (Agrawala & Stolte, 2001; ICA and authors, 2014; Stern et al., 2014). Research has shown that generalisation is integral to successful map design (Harrie, 2001). Generalisation research has identified that tactile maps require considerably more generalisation than print maps, as the object discrimination of the skin and fingers is poorer when compared to the eye (Cholewiak & Sherrick, 1986; Jacobson, 1998; Lederman & Klatzky, 2009; Lobben, 2005). Despite these findings, data selection, for both tactile and print mapping, is not well researched in the literature.

In the past, researchers may have overlooked data selection as it is a common belief that map purpose drives data selection (Forrest, 1999; Robinson et al., 1995). In addition, past research into tactile mapping has been concentrated on tactile map design which occurs once the data has been selected. For example, symbology has been a significant focus of a number of research papers. This includes research into the legibility of tactile symbols in isolation (Lawrence & Lobben, 2011), the usability of different symbols on a tactile map (Bentzen, 1996; Gual-Ortí et al., 2015) and a comparison of symbols using different production methods (Auricchio et al., 2017; Brittell et al., 2018; Gual et al., 2015; Gupta et al., 2019; Perkins, 2001).

Today, the availability of spatial data is rapidly improving, and the position of the tactile map maker is being questioned. Once regarded as the expert, some now observe the tactile map maker as outsiders who may have the technical knowledge but lack the experience to make informed and appropriate data selection decisions. Using inclusive design, thematic analysis, and usability studies this study describes a framework through which tactile map makers can collaborate with users to create a solution.

1.2 Research Questions

This research investigated the data selection and tactile map preferences of blind and low vision participants across two interview sessions. During the initial interview participants were asked about their experiences and/or opinions about tactile maps and their usability. During the second interview usability analysis was conducted on four sample tactile maps. For each sample map participants were asked to complete three simple map reading tasks. The preferences (satisfaction), response times (efficiency), and success rates (effectiveness) measured tactile map usability.

This study aims to answer the following research questions:

What do blind and low and low vision tactile map users value about tactile map products?

What are the data selection preferences of blind and low vision tactile map users?

i. How does tactile map experience affect data selection preferences?

ii. How does tactile map purpose affect data selection preference?

How does data selection affect the usability of tactile maps for those whose are blind or low vision?

i. How does tactile map experience affect tactile map usability?

ii. How does map purpose affect tactile map usability?

1.3 Thesis Structure

Chapter Two provides a comprehensive literature review on tactile mapping, data selection, thematic analysis, usability tests, and inclusive design. In addition, Chapter Two explores standardisation, generalisation, map purpose, and map experience. Chapter Three describes the methodology used to conduct the two interview sessions and construct the sample tactile maps. Chapter Four presents the results, thematic analysis of participant responses during their initial interview and usability analysis of their interactions with the sample tactile maps. Chapter Five discusses the results. Chapter Six summarises the findings of this research, and presents practical recommendations for cartographers interested in designing tactile maps as well as proposes future research directions.

Chapter 2

Literature Review

Tactile maps are not mainstream cartography products. Despite advancements in technology, there remains limited research on the topic. Literature that exists on tactile mapping has largely been focused on symbology, standardisation, and printing methods (Auricchio et al., 2017; Bentzen, 1996; Brittell et al., 2018; Gardiner & Perkins, 2002; Holloway et al., 2018; Wabiński et al., 2022).

Data selection is the process of either removing unnecessary or including only necessary information on a map. As the amount of available geographic data grows, selecting the right datasets is increasingly important. Data selection in tactile mapping is complex and significant generalisation is required.

This research combines inclusive design principles, thematic analysis, and usability studies to draw conclusions. Usability studies focus on assessing map features to understand their effect on performance (Brittell et al., 2018). Thematic analysis is a common method used to analyse qualitative data and identify patterns (Nowell et al., 2017). Historically, usability studies have been known to support both cartographic and tactile mapping research. Inclusive design is a methodology which guides product design practices. Inclusive design has received little attention from within the Geographic Information Science (GIS) and cartography disciplines.

This chapter reviews past literature and research into tactile mapping, data selection, thematic analysis, usability studies and inclusive design. This literature review also examines generalisation, standardisation, map purpose and map experience.

2.1 Cartography

Humans have been producing and using maps for thousands of years. Early maps have been discovered in ancient rock carvings and the earliest known world map is a Babylonian etching on tile from the 5th or 6th century BC (Bagrow, 1964). As a scientific discipline, cartography emerged in the wake of the Second World War (Roth, 2013), during a time described by Robinson (1952, p. 4) as the "Golden era of Cartography." During the 20th century, cartography has seen rapid development including standardisation, aerial photography, electronics, and the automation of production (Robinson, 1952). Today, there is an abundance of data held digitally that describes the complexity of the Earth's geographic features (Harrie, 2001).

Cartography is commonly referred to as the art and science of map-making (ICA and the authors, 2014). Some research in cartography is concerned with depicting an accurate geographical representation of reality. However, interest has also grown into the design, aesthetics, and artistic components of maps (Cosgrove, 2005; Krygier, 1995). Some researchers (Harrie, 2001; MacEachren & Taylor, 1994; Medeiros, 2016) refer to cartographic products as a communication tool. Using this definition, maps can be described as a device through which the mapmaker can communicate knowledge or a message about reality to the map user (Roth, 2013).

2.2 Tactile Maps

Tactile maps are graphical representations of geography interpreted by touch (Eriksson, 1999). In comparison to visual cartography, tactile mapping has a short history. The first tactile map was recorded in the 18th century (Tatham, 2003; Wabiński & Mościcka, 2019). Tactile maps have often been cited as useful tools for individuals who are blind or have low vision (Kitchin et al., 1997; Lobben, 2005; Papadopoulos et al., 2018; Papadopoulos & Karanikolas, 2009). These researchers found that tactile maps are useful as a simple means for interpreting geography, as a tool to assist in developing spatial awareness, and as support for blind and low vision individuals to construct mental maps of their surrounding environments.

Keeping pace with advancements, tactile maps are having an:

"...increasing significance in the lives of blind and visually impaired individuals for education, work and leisure, as graphical information becomes ever more prevalent and central in our daily experience." - (Jehoel et al., 2006, p. 67).

2.2.1 Haptic Exploration

The process of using touch to interpret a tactile map is called haptic exploration. Haptic exploration is an interpretation technique that uses cutaneous (skin) and kinaesthetic (sensory) inputs, to derive information (Lederman & Klatzky, 2009).

Cutaneous receptors, on the human hand, include mechanoreceptors, responses to mechanical stimuli, and thermoreceptors, response to temperature stimuli, within the glaborous (hairless) skin of the hand and fingertips (Lederman & Klatzky, 2009; Yıldız, 2013). Table 2.1 explains the functions of the different receptors. Cutaneous inputs on a tactile map are the raised elevation symbols describing the geography. Kinaesthetic receptors are the position and movement of the mechanoreceptors in muscles, tendons and joints with respect to each other. Kinaesthetic inputs are used to determine relative location or distances of map symbols (Lederman & Klatzky, 2009).

Glabrous Receptor	Sensation
Meissner's Corpuscle	Fine Touch, Flutter and Movement
Merkel Complex	Touch and Pressure
Pacinian Corpuscle	Vibration
Ruffini's Corpuscle	Skin Stretch
Free Nerve Ending	Pain and Temperature

Table 2.1: The Function of Glaborous Receptors (Lederman & Klatzky, 2009; Yıldız, 2013)

To haptically explore a tactile map the user must employ serial exploration methods. Serial exploration is the act of using successive hand movements to sequentially piece together fine details of a map in order to construct an overall image (Ungar et al., 1993). In comparison, using visual exploration, the user first encounters a general view by observing the overall image, only then do they investigate the map to extract finer details (Jacobson, 1998).

2.2.2 Past Research into Tactile Mapping

Past research into tactile mapping has placed a significant focus on tactile map symbology including research into the legibility of tactile symbols in isolation (Lawrence & Lobben, 2011), the usability of different symbols on a tactile map (Bentzen, 1996; Gual-Ortí et al., 2015), and a comparison of symbols using different production methods (Auricchio et al., 2017; Brittell, et al., 2018; Gual et al., 2015; Gupta et al., 2019; Perkins, 2001).

There is also literature on wayfinding and navigating without the use of vision (Almeida et al., 2015; Jacobson, 1998), as well as abundant research into the cognitive maps and spatial abilities of blind and low vision individuals (Kitchin et al., 1997; Perdue & Lobben, 2016; Picard and Pry, 2009;

Siekierska et al., 2003; Spencer et al., 1992; Ungar et al., 1995, 1997).

2.2.3 Tactile Maps and Spatial Ability

Research indicates that the use of a tactile map contributes to a blind or low vision user's development of a cognitive map (Blades et al., 1999). Tactile maps offer an overall description of an area or place (Spencer et al., 1992). Cognitive mapping is defined as the process through which "... an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in [their] everyday spatial environment" (Downs & Stea, 2011, p. 312). As a result, making use of tactile maps, either before or during a navigation task, improves spatial decision making, enhances cognitive map generation and improves the likelihood of navigation success in large, complex, or changing environments (Blades et al., 1999; Lobben, 2005; Lobben & Lawrence, 2012; Perkins, 2002; Siekierska et al., 2003; Spencer et al., 1992; Ungar et al., 1993, 1997).

According to Parush et al. (2007), there is an observed need for the preservation of physical map products. Research has shown that despite advancements in technology and the automation of navigation, the tendency for a person to passively adhere to GPS instructions results in "reduced situation awareness" (Parush et al., 2007, p. 240) and "poorer topological accuracy" (Ishikawa et al., 2008, p. 74). Alternatively, active exploration encouraged through the use of tactile maps results in improved navigation skills and an increased likelihood of navigation success (Lobben & Lawrence, 2012; Ungar et al., 1995).

2.3 Map Experience

Map experience refers to the spatial abilities of an individual and is often grouped into three categories: novice, intermediate and experienced

(Ooms et al., 2012). An individual's spatial ability is considered both inherent and a set of skills that can be taught and learned (Huynh & Sharpe, 2013). Map experience can impact an individual's ability to interpret a map as well as their preferences of map design and data selection.

An individual's spatial ability is determined by their prior knowledge, learned skills and innate abilities related to their concepts of space, geography, and maps (Huynh & Sharpe, 2013). In geography, maps are a key tool used to understand and interpret space (Anderson & Leinhardt, 2002).

When interpreting a map, the user will first attempt to use the least demanding strategy. Therefore, the retrieval strategy is first used. This strategy is the process of recovering the solution from the user's long-term memory (Groen & Parkman, 1972; Siegler, 1987; Siegler & Lemaire, 1997). A simplified example of the retrieval strategy could be when a research participant is asked to locate a feature on a map. If the participant has previous experience with the map, they may remember the feature symbol and where it is located.

If the map user is unable to retrieve a solution from memory, they will have to use more demanding strategies to find a solution, such as deriving rules (Crowley & Siegler, 1993; VanLehn, 1988). Using the same example, if the participant has not used the map before, but recalls the symbol used to represent the feature, they can search the map for this symbol.

If the user does not have the required knowledge to construct these rules, they may be unable to reach a solution (impasse) (Brown & VanLehn, 1980; VanLehn, 1988). To resolve an impasse, problem solving methods must be used, which is commonly referred to as impasse-driven learning (Siegler & Crowley, 1991). An example of impasse-driven learning would be to consult the key to find the symbol that represents the feature in question.

Experienced users, people who use maps for their work or study, are more likely to have access to retrieval and rule-based strategies when interpreting a map. When experienced users are faced with an impasse, they are often able to explore the problem and generate new rules. In contrast, novice users are expected to follow more demanding impasse-driven learning strategies to generate a solution. Researchers have found, however, that due to reduced knowledge, novice users may construct their solution based on misconceptions and this may, in turn, lead to navigation failure (Anderson & Leinhardt, 2002; VanLehn, 1988).

Kulhavy and Stock found that spatial ability "...often develops at an early age as a result of exposure to maps in books, newspapers, etc." (1996, p. 103). At a young age children gain map reading experience and the basic skills required to interpret maps and retain spatial information (Kulhavy et al., 1993). When exposed to maps from a young age, Thorndyke and Stasz (1980) and Kinnear and Wood (1987) concluded that there is little difference between the abilities of novice and expert map users in their abilities to obtain information from a map. It is only when comparing technical tasks, such as understanding map projections or contours, where the difference is apparent (Anderson & Leinhardt, 2002).

Past research into map experience has investigated how experienced and novice map users interpret maps (Anderson & Leinhardt, 2002), Downs et al. (1988) studied how both children and adult map users "see through" the map to understand the world it represents, and Downs and Liben (1991) researched college students' ability to interpret map projections without any formal training.

In the tactile mapping community, it has been recommended that tactile map aids are introduced to blind and low vision individuals from a young age (Morsley et al., 1991; Ungar et al., 1993). In a survey conducted within the blind and low vision community in New Zealand, Higgins (1999) concluded that all participants indicated that spatial ability and map experience is essential for the growth and development of blind or low vision individuals. The respondents believed that if children who are blind or low vision did not receive training, they would face difficulties in the future.

Research has shown that blind or low vision individuals have the same spatial abilities when compared to sighted individuals, however their knowledge is different due to differing experiences and access to information (Perkins, 2002). As there is a lack of research and development into to tactile mapping, tactile resources are limited. Blind and low vision children therefore are disadvantaged in comparison to sighted children as they lack the exposure to maps and cartographic products from a young age. Research has determined that this lack of exposure impacts a blind or low vision child's spatial ability (Higgins, 1999; Perdue & Lobben, 2016).

Past tactile mapping research has primarily focused on production methods and materials. However, there is some information that can be extracted detailing how tactile map experience impacts tactile map data selection preference. In their survey, Rowell and Ungar found that participants who had recent experience with tactile map were "more likely to use a wider range of production methods" (2003a, p. 261), whereas participants who had not used tactile maps for some years preferred traditional tactile maps. Rowell and Ungar also discovered contradicting opinions among participants. They found that novice users "want maps they can read easily through touch", whereas experienced users argued that "tactile maps that do not provide enough relevant information are not particularly useful to them" (2005, p. 7).

2.4 Standardisation

The Oxford English Dictionary (1873) describes standardisation as the act of bringing "to a standard or uniform size, strength, form of construction, proportion of ingredients, or the like." Standardisation within the cartography discipline was introduced to enhance production, maintain consistency, and encourage collaboration (Forrest, 1999; Weber et al., 2002). Standardisation in cartography is becoming increasingly important as improvements in technology make it easier for the public to access map design software.

There is no global set of standards for map making as standardisation is only beneficial when based on user requirements (Weber et al., 2002). Most countries, for example New Zealand (Toitū Te Whenua Land Information New Zealand, 1999) and the United States (Davis et al., 2019), have developed standards or specifications for their own topographic map series. Orienteering is an early example of the adoption of standards in map production. To facilitate international orienteering competitions, the International Orienteering Federation was founded in 1961 and an international map legend was created (Zentai, 2001).

Although not official, cartographic conventions exist as a global set of guidelines. Cartographic conventions often result in globally consistent symbology, for example blue colours for water and black lines for roads (Lobben & Lawrence, 2012). While cartographic conventions are less conforming than standardisation, there is agreement that if correctly followed by map makers the resulting map will facilitate better map cognition of the users (Lobben and Lawrence, 2012; Medeiros, 2016).

Standardisation can improve the "quality, safety, and efficiency" of resulting products (Wears, 2015, p. 1). Standardisation is valuable as it contributes to effective communication and creates reproducible products and ultimately leads to transparency (Wears, 2015). Map users benefit from standardisation as it assists in removing the risk of misconceptions. For example, it is convention that water features are blue, if followed the risk of misinterpreting a red pond as a building is removed. Standardisation enables a mapmaker to communicate information to a user who may not have the advantage of the maker's prior knowledge (Forrest, 1999).

Most research surrounding cartographic standards focuses on specific details, like text placement, rather than on general overall decisions (Forrest, 1999). As Wears (2015) indicates, not all aspects of map making can be standardised and focusing solely on such specific details introduces a risk of incorporating unintended consequences or side effects into the final product.

2.4.1 Standards in Tactile Mapping

Currently, there are no global standards or cartographic conventions for tactile mapping (Lobben & Lawrence, 2012; Nogueira, 2009). However, some researchers advocate for the standardisation of tactile map elements (Lobben, 2005; Rowell & Ungar, 2003b). These researchers argue that maintaining consistency among tactile maps will reduce the amount of cognitive effort required to learn the product and allow more energy to be spent on interpreting the geography that the map represents (Lobben & Lawrence, 2012). Tables 2.2, 2.3 and 2.4 detail a literature search of tactile mapping standards, kits, and guidelines.

Numerous past studies have researched how standards may be applied to tactile maps. This research has produced the Nottingham Map Making Kit and the University of Oregon Euro Town Kit Adaptation (Brittell, et al., 2018). These kits, however, are not universal. For example, the Oregon Adaptation is for large scale reference maps on microcapsule paper (Brittell, et al., 2018).

The New South Wales Tactual and Bold Print Mapping Committee (2006) produced the Guide for the Production of Tactual Bold Print Maps, referred to in this research as the NSW Guide. The NSW Guide is used in both Australia and New Zealand and it provides recommendations on several key map elements such as size, braille labels, symbology, and legend.

Whist standards and guidelines support consistency within the creation of tactile maps, they also introduce some difficulties. These standards must be generalised so that they are applicable to a wide range of map products and this is often impractical (Lobben et al., 2015; Nicolle & Abascal, 2001). Researchers state that above all other considerations, readability is the most important cartographic principle of constructing a tactile map. Readability depends on the quality of the design, symbols and content of the tactile map (Gardiner & Perkins, 2002). Despite these suggestions however, standards often do not explicitly detail what data to include in the map products and for what purpose. Instead standards often only describe how to symbolise datasets.

Standards		
Title	Produced By	Date
Guidelines and Standards for Tactile Graphics	Braille Authority of North America	(2012)
Guide for the Production of Tactual and Bold Print Maps	Royal Blind Society of New South Wales & The New South Wales and Bold Print Mapping Committee	(2006)
A National Specification for Tactual and Low Vision Town Maps	National Mapping Council of Australia	(1985)
ISO 17049 – Accessible Design – Application of Braille Signage, Equipment and Appliances	International Organisation for Standardisation	(2013)
ISO 19028 – Accessible Design – Information Contents, Figuration and Display Methods of Tactile Guide Maps	International Organisation for Standardisation	(2016)
ISO 24508 – Ergonomics – Accessible Design Guidelines for Designing Tactile Symbols and Characters	International Organisation for Standardisation	(2019)

Table 2.2: Literature Search of Tactile Map Standards

Research		
Title	Produced By	Date
Guidelines for Standardizing the Design of Tactile Maps: A Review of Research and Best Practice	Jakub Wabiński, Albina Mościcka and Guillaume Touya	(2022)
A Systematic Literature Review on the Automatic Creation of Tactile Graphics for the Blind and Visually Impaired	Mukhriddin Mukhiddinov and Soon-Young Kim	(2021)

Table 2.3: Literature Search of Tactile Map Standards Research

Kits		
Title	Produced By	Date
Euro Town Kit	W. Laufenberg	(1988)
the Nottingham Map Making Kit	G. A. James	(1975)

Table 2.4: Literature Search of Tactile Map Kits

Note: In languages other than English standards also exist for Mexico (Esparza, 2014) and Poland (Olczyk, 2014).

2.5 Generalisation

A singular definition of generalisation does not exist in the cartographic discipline. However, generalisation has a longstanding history as a technique integral to successful map design (Harrie, 2001). Bard (2004), Harrie (2001), the International Cartography Association (ICA, 2014) and Weibel and Dutton (1999) describe map generalisation as a process that simplifies geographic data to fit the given scale. Alternatively, when considering a map as a communication tool, Robinson et al. (1995, p. 450) describes generalisation as a process "... to fit portrayal of selected features to the map scale and to the requirements of effective communication."

This thesis follows the generalisation guidelines of the International Cartographic Association (ICA). According to the ICA, the five different types of cartographic generalisation techniques are: selection, simplification, combination, smoothing and enhancement (ICA and the authors, 2014). Stern et al. (2014) and Agrawala and Stolte (2001) incorporate additional techniques: distortion, omission, and symbolisation. Figure 2.1 depicts some examples of generalisation techniques.

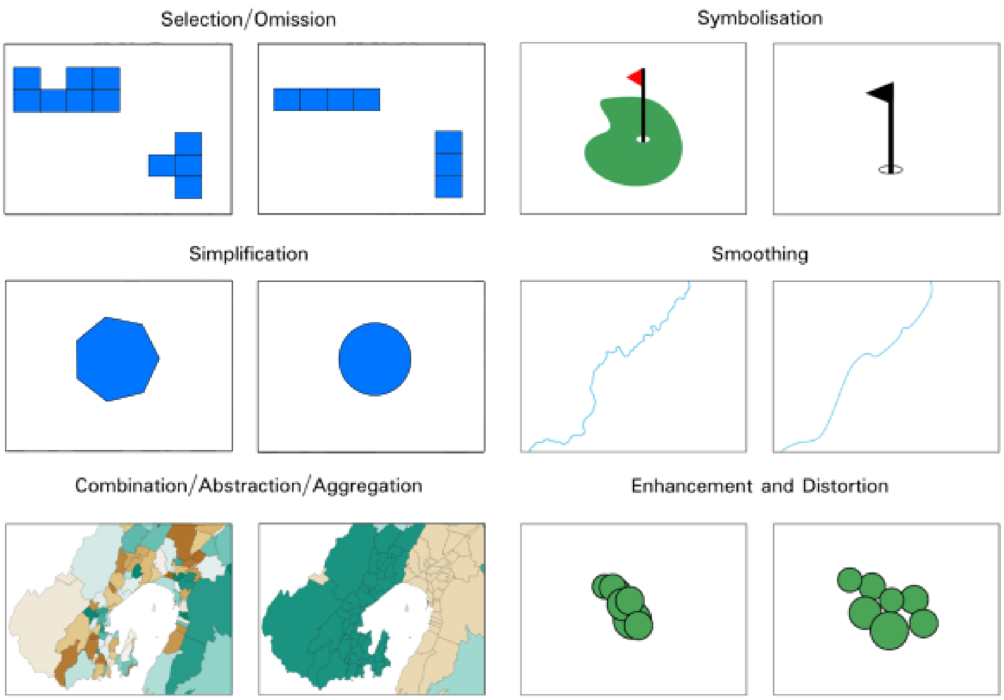

Figure 2.1: Map Generalisation Techniques, adapted from: Agrawala & Stolte (2001), the ICA & Authors (2014), and Stern et al. (2014)

The value of generalisation is realised when the techniques are used to effectively present complicated real-world geography in a simplified format. Generalisation enhances the relevant information and removes irrelevant data that detracts from the intended purpose of the map (Bard, 2004; Harrie, 2001). The spatial acuity of skin is poorer when compared to the eye, and it can be difficult for tactile map users to perceive detail (Cholewiak & Sherrick, 1986; Lederman & Klatzky, 2009). Therefore, tactile maps are often considerably more generalised than their visually interpreted counterparts (Jacobson, 1998; Lobben, 2005).

As data selection is the focus of this thesis it is the only generalisation method discussed in the following section. Other generalisation techniques were not analysed in this research but several studies have already researched their implications (example research includes: symbology (Bentzen, 1996; Brittell et al., 2018; Lawrence & Lobben, 2011; McCallum et al., 2006), aggregation (Pontius & Malizia, 2004), simplification and distortion (Gartner & Radoczky, 2005; Krisztián & Szigeti, 2018)).

2.6 Data Selection

Data selection is the process of either removing unnecessary or including only necessary information on a map (Agrawala & Stolte, 2001). Today, the risk of maps becoming cluttered with irrelevant information is high as there are large quantities of geographic data available to select from (Agrawala & Stolte, 2001). Data selection makes it possible for cartographers to emphasise important map elements such as navigational aids (major intersections) and remove less important information (Agrawala & Stolte, 2001; ICA and the authors, 2014).

In cartography, data selection depends on the map's purpose, design, scale, and level of detail required (Forrest, 1999; Robinson et al., 1995). Currently, no established rules determine the value of datasets. Sarma et al. (2012)

recommend that data is selected based on map objectivity, fairness, and importance. It is common practice that during data selection no modification is carried out, the task of the cartographer is simply to choose whether to include the element or not (Robinson et al., 1995).

Robinson et al. (1995) noted that within printed cartography, data selection has not received much consideration. This limitation persists today but in recent literature, researchers recognise the importance of data selection. However, they have shifted focus to data selection within digital maps with varying zoom levels (Guo et al., 2018; Sarma et al., 2012).

2.6.1 Data Selection in Tactile Mapping

Generalisation is a necessary step in tactile map production as most print maps contain too much detail to be converted to tactile maps. To produce haptically interpretable tactile maps significant data selection omission and inclusion decisions must be made. However, tactile map producers must be cautious when generalising products so as not to compromise the tactile map's purpose (Braille Authority of North America, 2012).

The generalisation of spatial data for tactile maps is considered complicated (Wabiński & Mościcka, 2019). Mulíčková and Štampach referred to the generalisation process in their research as "substantial and the most complex" component of tactile map creation (2016, p. 536). However, in essence, "the basic principle of tactile map design is to present an extremely simplified version of a visual image" (Gardiner & Perkins, 2002, p. 1).

Gardiner and Perkins (2002) noted in their research that unfortunately, minimal literature provides recommendations for data selection in tactile mapping. The NSW Guide contains no recommendations of required, useful or not required datasets, it only suggests that information irrelevant to the purpose of the map is omitted.

Rowell and Ungar (2005) conducted a survey of 30 blind and low vision people, in their results they made some data selection suggestions. Rowell and Ungar reported that participants place high importance on orientation cues and braille labels. However, they suggested that borders, gridlines, and printed text are less important. Survey participants ranked roads and paths as important linear features, street names and road crossings as important descriptive information, and transport features, such as train and bus stations as important point features. Rowell and Ungar (2005) concluded their research suggesting that tactile maps should always include orientation cues and roads, and that roads and streets should always be named.

Tactile Maps Automated Production (TMAP) is an online service that automatically generates tactile map products using data from Open Street Maps. TMAP is used in New Zealand by Blind and Low Vision Education Network NZ. TMAP displays streets, street and road names, paths, service roads and railways. These five features are all optional and can be selected or deselected by the individual creating the map (TMAP, 2018).

2.6.2 Data Currency

"Data in real-life databases becomes obsolete rapidly." - (Fan et al., 2012, p. 71)

"Maps are not meant to be long-lived." - (McGlamery, 1999, p. 1)

Currency is the measure of how up-to-date spatial data or map products are. Currency is often used to describe accuracy and temporal validity (Jeansoulin et al., 2006). Excluding fictional maps, McGlamery (1999, p. 1) states that maps and spatial datasets are created to "satisfy a particular hypothesis that relates to time and space". For example, Toitū Te Whenua, Land Information New Zealand (2022) produces topographic maps which provide a survey of the land. The topographic map and stored data describing the capital city, Wellington, has been updated and published six times since 2003.

Currency is an identified limitation of tactile maps. As a printed product, tactile maps often quickly become outdated (Ducasse et al., 2017; Yatani et al., 2012). Recent research into maintaining the currency of printed and tactile maps has been focused on automating the generalisation steps (Kazemi et al., 2004; Wabiński & Mościcka, 2019).

2.7 Map Purpose

"A hat worn for a business occasion in winter might require warmth and fashion while one worn for gardening in summer might emphasize coolness and functionality." - (Ratneshwar et al., 1999, p. 193)

During product design, purpose is a key consideration. Often purpose is used as a designer's starting point (Lutters et al., 2014). The extent to which various features of a product are considered beneficial depends on the user's and the product's purpose (Ratneshwar et al., 1999).

In cartography, numerous map types vary considerably in their purpose. For example, navigation maps depict routes between locations while general reference maps provide an overview of an area (Mosenthal & Kirsch, 1990). The variation in map purpose impacts decisions made on the data and level of detail required (Forrest, 1999).

Often tactile maps are used during orientation and mobility exercises or to support science, technology, engineering, and mathematics (STEM) study (Feucht & Holmgren, 2018; Higgins, 1999; Holloway et al., 2018; Kitchin, 1994; Papadopoulos & Karanikolas, 2009). Accessibility guidelines recommend that tactile maps are utilised in all instances where a spatial understanding is important (Braille Authority of North America, 2012).

Perkins (2002), and Rowell and Ungar (2005) suggest that most research has been conducted using large scale tactile maps as these are the preferred type of map. Participants in Rowell and Ungar's survey (2005, p. 10) indicated they "would rather use [tactile maps] for general orientation rather than follow them closely for very specific navigation purposes."

2.7.1 General Reference Maps

General reference maps are produced to display physical features of an area and support discovery and education (Intergovernmental Committee on Surveying and Mapping, n.d.). When using general reference maps, it is expected that the user will be able to obtain two types of information: "information about individual features on the map and information about the structural relationships between features that appear within the map space" (Kulhavy et al., 1993, p. 48).

General reference maps are often purposefully designed to simultaneously assist with several different purposes (Mosenthal & Kirsch, 1990). Therefore, general reference maps often contain a variety of features including buildings, land cover, roads, hydrographic features and elevation (Mosenthal & Kirsch, 1990). As it serves multiple uses the number of features on a general reference is high and these maps often contain more features than a navigation map (Mosenthal & Kirsch, 1990).

Substantial evidence suggests that geographic information presented in a general reference map supports an individual's ability to recall related text material (Amlund et al., 1985; Collins et al., 1976; Davis & Hunkins, 1968; Dean & Kulhavy, 1981)

2.7.2 Navigation Maps

Maps are often considered important resources when conveying or interpreting route information (Gartner & Radoczky, 2005). Navigation maps are often used to "depict a path from one location to another" (Agrawala & Stolte, 2001, p. 241). These maps are used either for planning before a trip or during the trip whilst actively navigating (Agrawala & Stolte, 2001).

To convey route information quickly, easily, and accurately navigation maps are often simplified and minimal. This simplification of information reduces the amount of cognitive processing required to interpret the map (Klippel, 2003). In navigation maps, it is common for roads to be displayed (Agrawala & Stolte, 2001). Other features included on the navigation map are dependent on the user's intended use of the map (Darken & Peterson, 2002). For example, if it is a navigation map for tourists it may include landmark information. If the map is for commuters, it may include transport information like bus stops and train stations.

Past research has demonstrated that navigation maps that contain highlighted routes and arrows depicting direction are the most efficient products when communicating directions (Radoczky & Gartner, 2005). In comparison with instructions provided in text format, Kray et al. (2003) concluded that despite the generalisation, simplification and distortion, navigation maps better support the user as they provide contextual information and encourage active navigation.

2.8 Thematic Analysis

Thematic Analysis is a qualitative research method that outlines a process to identify and organise themes within a given dataset. Thematic Analysis is a popular method used by researchers due to its accessibility and flexibility (Braun & Clarke, 2012). Thematic analysis is a foundational research method that lends itself to a variety of research questions (Braun & Clarke, 2012; Javadi & Zarea, 2016; Kiger & Varpio, 2020).

As the name suggests thematic analysis results in the identification of several themes. Numerous definitions of the word theme exist in literature:

> "A specific and distinctive quality, characteristic, or concern"

(Merriam-Webster Dictionary, 2022)

"... Patterns of meaning across a dataset"

(Braun & Clarke, 2012, p. 57)

Thematic analysis has widespread use in the blind and low vision research community. Research includes investigating the uses of technology (iPad) as a visual aid for individuals with low vision (Mednick et al., 2017), assessing the social integration of blind and low vision employees in the workplace (Naraine & Lindsay, 2011), to elicit common outdoor difficulties (Riazi et al., 2016), and to identify mobility and access to transport issues (Gallagher et al., 2011). Thematic analysis is not common in literature when researching tactile maps, only two articles were found which used thematic analysis in conjunction with tactile maps (Minhat & Universiti Sains Malaysia, 2020; Baldwin & Higgins, 2022).

2.9 Usability Studies

The ISO 9241-11:2018 guide defines usability as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (2018, p. 3.1). Expanding on this concept, Nielson and Levy (1994) explain that while usability is in essence an immeasurable concept, the attributes that make up the usability of a product can be measured.

The primary goal of every usability study is to improve the usability of the product being tested. There are, however, various methods that have been used to test usability (Dumas & Redish, 1999). These methods include surveys and focus group or interview sessions where the participants are encouraged to think aloud (Brown et al., 2013; Pickle, 2003). The parameters researchers use to test usability vary, but, they are "...generally either subjective, wherein users' preferences are evaluated, or objective, wherein users' capabilities for utilizing the system are studied" (Nielsen & Levy, 1994, p. 66). In the case of GIS and cartography, effectiveness relates to task completion, efficiency can be measured by the time it takes to make map related decision and satisfaction is found through interactions with the user, asking them about frustrations they found whilst using the product (Brown et al., 2013).

Often users are unaware of the ways in which a cartographer places geographic information on a map or the decisions they make surrounding data selection (Brown et al., 2013). These decisions, however, are fundamental to the usability of map products. As research has shown users, can become overwhelmed when too much information is displayed on a map (Fabrikant & Wachowicz, 2007).

There are some limitations to the definition of usability when applied to map products. The definition assumes that there is both a specified user of the product and specified goal, however these factors cannot always be considered known variables when creating map products (Brown et al., 2013). Hunter et al. (2003) recommend, however, that obtaining perfect and complete information is rare. Instead, designers should ask if there are fundamental elements of the product that are required for it to meet the usability requirements.

Numerous studies detail different aspects of usability within the tactile mapping community. Most tactile map usability research has investigated symbology, for example Lawrence and Lobben (2011) conducted research into the legibility of tactile symbols in isolation, Bentzen (1996) and Gual-Orti et al. (2015) researched the usability of different symbols on tactile maps. Often other tactile map usability research compares the usability of tactile map production methods (Auricchio et al., 2017; Brittell et al., 2018; Gual et al., 2015; Gupta et al., 2019; Perkins, 2001).

2.10 Inclusive Design

This thesis follows an inclusive design approach as it is an effective tool used to identify mismatches in design (Holmes, 2018). Inclusive design is a concept developed during the 1970s and 80s. The practice of inclusive design continues to grow today as it evolves alongside constant improvements made in digital technologies (Holmes, 2018; Microsoft, 2003). Inclusive design is the process in which the product is intentionally designed to be usable by as many people as possible (Holmes, 2018).

Inclusive design addresses the tendency of able-bodied designers to only consider their personal design requirements. Designers are often unaware of the needs of users beyond their own capabilities (Keates & Clarkson, 2000). By implementing inclusive design practices, designers can recognise the potential for exclusion that exists in decision making (Waller et al., 2015). The decisions made by designers often "determine who can participate and who's left out" (Holmes, 2018, p. 6). Inclusive design enables designers to make informed decisions that are based on a well-grounded understanding of the diversity of the people who will use their products (Waller et al., 2015).

Globally, approximately 285 million people are visually impaired (World Health Organisation, 2012). In New Zealand, it is estimated that 150,000 people have low vision and approximately 30,000 individuals are blind (Blind Low Vision NZ, 2022). As the inclusive design agenda aligns with the growing movement to integrate users with a wide variety of abilities into product designs, research into the applications of inclusive design to improve products for blind and low vision users has been a growing topic (Coleman & Lebbon, 1999; Newell et al., 2000). Inclusive design is only just emerging as a design tool within the blind and low vision community. Wu and Wang (2017) found that inclusive design encouraged a more detailed examination of their research into accessible signage.

User involvement is an inclusive design principle. User involvement advocates for the inclusion of users in product design early and often (Holmes, 2018). The value and importance of user involvement in the design and production of map products has only recently been recognised in the cartographic community (Lobben et al., 2015). Within the cartographic community, the perspective of researchers has been brought into question (Perkins, 2002). As Kitchin (1994) suggests, the greatest opinion and influence on the usability and design of a tactile map should be the blind user's view.

The recent change in perspective has led to more research into tactile maps and mapping, for example research into symbology (Brittell, et al., 2018; Jehoel et al., 2005; Lawrence & Lobben, 2011; Rowell & Ungar, 2003b). However, much of the research into tactile mapping has been reactive, focused on the translation of visually presented maps into their tactile counterparts (Lobben et al., 2015). Much of the tactile mapping research has placed a significant focus on creating standards and guidelines for tactile map production (Lobben, 2015; Rowell & Ungar, 2003b), and very few publications suggest that individuals who are blind or have low vision should participate in the design of tactile maps (Gardiner & Perkins, 2002).

The London 2012 Olympic Games is an example of effective inclusive design within the blind and low vision community. Inclusive design was integrated into the project from the outset, individuals with diverse abilities were employed as professional advisors and consultants, as well as representatives of local communities (Fleck, 2015). In sharing their experiences, these experts supported the designers to create accessible events centres. The inclusive design principles and user involvement which support the design of the Games is considered the largest contributing factor towards why the London 2012 Games is often referred to as the "most accessible Games" (Fleck, 2015).

Inclusive design presents an opportunity for tactile map researchers to work in partnership with users. Leading by example, research into tactile mapping clearly demonstrates to the cartographic community the benefits of incorporating user experience and opinions into the design process of map products (Rowell & Ungar, 2005).

2.11 Choice and Independence

Providing users with choice directly "challenges the authority of experts to make decisions on behalf of people with disabilities" (Wiesel & Fincher, 2009, p. 612). Choice is mentioned in the first general principle of the United Nations Convention on the Rights of Persons with Disabilities: "respect for inherent dignity, individual autonomy including the freedom to make one's own choices, and independence of persons" (United Nations Convention on the Rights of Persons with Disabilities, 2006, p. 5). Choice and control were also identified as key outcomes and actions of the New Zealand Disability Action Plan (Office for Disability Issues, 2019). Offering choice in the blind and low vision community is not unique, it is also common in other policies and documents for education, healthcare, and housing (Clarke, 2006; Jordan, 2006; Wiesel & Fincher, 2009).

The United Nations Convention on the Rights of People with Disability states that "State Parties shall take effective measures to ensure personal mobility with the greatest possible independence" (United Nations Convention on the Rights of Persons with Disabilities, 2006, p. 14). The convention expands on this statement suggesting the measures taken to provide independence includes choice: "facilitating the personal mobility of persons with disabilities in the manner and at the time of their choice" (2006, p. 14). However, Staw (1976) found that choice can be detrimental as, even when told their choice was incorrect or sub-optimal participants were hesitant to move away from their previous choices.

2.11.1 Awareness and Education

Blind, and low vision individuals have limited access to maps and spatial information. Siekierska et al. (2003) note that more research is required in the awareness of, evaluation of, and education about tactile maps. Perkins (2002, p. 522) also notes the lack of awareness and marketing of tactile products when he states: ”Tactile mapping is characterized by limited print runs, with design and production often strongly influenced by national blind charities, and almost no conventional market mechanism influencing practice.”

Chapter Summary

Tactile maps are a tool used by blind and low vision individuals to assist in their orientation and mobility. Research has found that tactile maps support and improve a blind or low vision navigator’s spatial ability. The United Nations Convention on the Rights of Persons with Disabilities instructs state parties to take measures that support independence by providing choice. Therefore, tactile maps are valuable tools, despite the introduction of audio assisted navigation (GPS).

Historically tactile mapping research has focused on production methods, symbology, and standardisation. As the amount of geographic data available to cartographers and tactile map makers grows so too does the importance of generalisation and data selection. Data selection has been identified as a crucial step in map development, research demonstrates that map purpose impacts data selection, however data selection suggestions are not often included in tactile mapping standards, despite their impacts on map usability.

Inclusive design principles, thematic analysis, and usability research can be used to determine user preference. Through tactile map and data selection research, tactile map makers can better understand how to create tactile map products.

Chapter 3

Methodology

This study investigates what blind and low vision participants value about tactile maps and how data selection is associated with tactile map usability. To align with inclusive design principles, interview sessions were conducted for data collection. This chapter presents the methodology of two interview sessions and the process of map production. This research was guided by combining several practices, methodologies and standards found in both tactile mapping and usability literature. The research was composed of three stages: 1) initial interview, 2) tactile map production and 3) usability study of the tactile maps from stage 2. Each stage is discussed in this chapter along with discussions of inclusive design, recruitment, demographics, tactile map experience, and map purpose. Ethics approval for this research was granted by the Victoria University of Wellington Human Ethics Committee (#0000029197).

Data selection is the focus of this research as it has received little attention within both the tactile mapping and wider cartographic disciplines. In 2001, Argrawala and Stolte noted that alongside advancements in technology, the number of geographic datasets had grown. Data selection is becoming an increasingly important step in map generalisation as the availability of data continues to grow today.

The initial interview: 'Part One: Experiences and Opinions' captured tactile map value through thematic analysis of participant responses and their preferences. Participants' preferences were used to inform the data selection decisions when creating four sample tactile maps. The four sample tactile maps were presented to participants in the second interview session.

During the second interview: 'Part Two: Usability Tests', participants completed a range of map reading tasks to determine each map's usability. The ISO 9241-11:2018 standard's measures of usability were employed to evaluate the tactile maps in this research. The standard defines usability as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (2018, p. 3.1). For the purpose of this research, to assess usability, participant response times, the rate of task success, and each participant's preferences were recorded.

3.1 Recruitment

Interview participants were recruited by email. Emails were distributed via local blind and low vision organisations. Blind Citizens New Zealand, Blind Low Vision New Zealand, The Albinism Trust, Retina New Zealand, and New Zealand Vision Impaired Empowering Women (VIEW) were contacted.

To promote participation, each interview session was designed to last up to one hour, and a twenty-five-dollar New World supermarket voucher was offered as koha [1]. Participants were encouraged to take part in both interview sessions, but this was not a requirement.

[1]New Zealand a koha a way of expressing gratitude in the form of a gift

3.2 Demographics

Demographic questions were asked at the beginning of each participant's first interview session (Table 3.1). Participants were asked their age, gender, and whether they were blind or had low vision. These questions assessed the representation of participants and provide contextual information. Some studies suggest that age (Salthouse, 1987), gender (Nash, 1975), type of vision impairment, and length of impairment (Passini & Proulx, 1988) impact spatial ability. Before each interview, participants could choose to remain anonymous in reported data or their information or opinions could be attributed to them.

1.	Would you mind telling me your age?
2.	What gender would you prefer to be used in this research?
3.	Would you mind telling me whether you are blind or have low vision?
4.	How long have you been blind or had low vision?

Table 3.1: Demographic Questions

3.3 Tactile Map Experience

At the beginning of their first interview, participants were asked questions about their experience with tactile maps. These responses were used to categorise participants into one of three tactile map experience groups: novice, intermediate, and experienced (Table 3.2). Establishing map experience groups allowed for a comparison of the opinions in the initial interviews and the results of the second interviews between the different experience groups.

Numerous studies (Anderson & Leinhardt, 2002; Kinnear & Wood, 1987; Rapp et al., 2007) categorise research participants by map reading experience. Most studies, however, categorise participants based on either education only or in reference to specific cartographic concepts. In contrast, this research measured spatial ability by following the guidelines of Huynh and Sharpe (2013).

Each participant was asked the same six closed questions regarding their tactile map experience (Table 3.2). Likert scale, yes or no, and listing questions were used. Participant responses were assigned values, an average of these values, rounded to the nearest whole number, was used to categorise participants into the three tactile map experience categories.

Question	Categories	value
Do you know what a tactile map is?	Yes	3
	No	1
How often have you used tactile maps?	Never / Once or Twice	1
	A few times a year	2
	A few times a month or more	3
Have you ever received training to use tactile maps?	No	1
	Yes, a while ago / limited	2
	Yes, comprehensive	3
Have you ever participated in designing a tactile map?	No	1
	Yes, a while ago	2
	Yes, recently	3
What purposes have you used a tactile map for?	1 tactile map listed	1
	2 tactile maps listed	2
	3+ tactile maps listed	3
On a scale of 1 - 3 how would you rate your tactile map experience?	1 - Novice	1
	2 - Intermediate	2
	3 - Experienced	3

Table 3.2: Map experience questions, categorisations and assigned values.

3.4 Interviews

Inclusive design advocates for the participation of many people, and for this to happen early and often during product design (Clarkson et al., 2007; Eisma et al., 2003; Fallman & Lindbergh, 2007; Waller et al., 2015). User involvement enables informed decision making, encourages designers to diversify their understanding of user requirements, and builds knowledge of the user population (Clarkson et al., 2007; Hanson, 2004; Waller et al., 2015; Wang et al., 2006).

A well developed understanding of user groups is beneficial to designers as it aligns product design with user requirements and ensures that a product meets a user group's expectations of its use (Holmes, 2018). In the context of this research following inclusive design principles can support the production of efficient and effective tactile maps (Coleman & Lebbon, 1999; Hanson, 2004).

The ISO Guide for addressing accessibility in standards advises that user involvement can consist of a variety of different strategies that translate the needs and considerations of users into specific accessibility requirements and recommendations (2014). In addition, user involvement should not be a one-off event in the lifecycle of a project (Kujala, 2003; Wilson et al., 1997).

In this research, users were involved with the project twice throughout its lifecycle, through the two interview sessions. The first interview occurred in the design phase of the tactile map product and enabled users to influence product design. The second interview occurred after product creation, where map reading tasks determined the usability of the product. After each interview session participants also had the opportunity to receive and provide feedback on the audio recordings, transcripts, or summaries of their interview session.

Each participant's initial interview concluded with a section on inclusive design. This section asked the participants four open ended questions about their opinions and/or experiences with tactile map design (Table 3.3).

How important is it to you to have blind and/or low vision individuals involved in designing tactile maps?
What could be done to improve tactile map design?
As a user of a map would you prefer to be involved in designing a tactile map, testing a product or both?
What tips or advice do you have for someone who designs maps for blind or low vision individuals?

Table 3.3: Inclusive Design Questions

Interview sessions allowed for a depth of information to be collected and clarification on conflicting information to be obtained (Harrell & Bradley, 2009). Interview sessions were preferred when compared to surveys as the researcher could analyse participant preferences using multiple methods, for example, using both qualitative and quantitative techniques (Harrell & Bradley, 2009). Interview sessions also have the capability of revealing unknown themes or assumptions about the targeted population (Hannabuss, 1996). Focus groups were not conducted due to the uncertainty of gathering restrictions in response to the COVID-19 Pandemic.

3.5 Initial Interview: 'Part One: Experiences and Opinions'

The initial interview session was designed to obtain insights into the experiences and opinions of blind or low vision tactile map users. The answers to these questions also provided guidance for the sample tactile maps used in the second interview.

The initial interview was completed in person or by telephone as determined by the preference of the participant or their geographic location. The audio of these interview sessions was recorded and transcribed. The transcriptions were then analysed using thematic analysis. If the interview was held in person, refreshments and light snacks were provided.

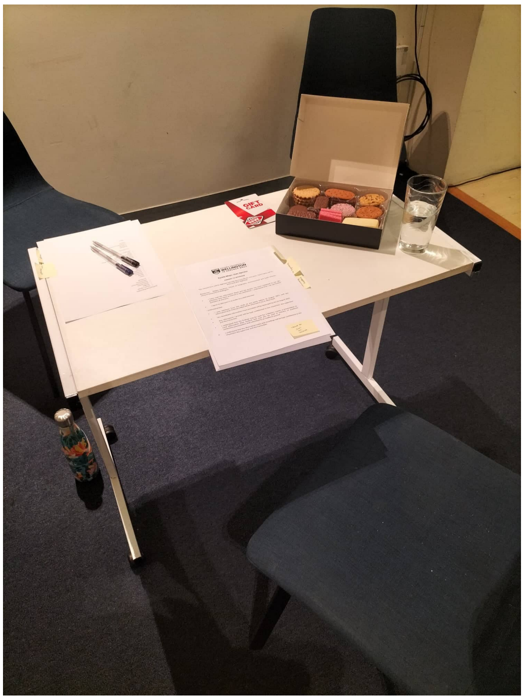

Figure 3.1: In-Person Initial Interview Setup

3.5.1 Initial Interview Experience and Opinion Questions

After asking the demographic and tactile map experience questions, the 'tactile map experiences and opinions' questions were presented (see Table 3.4 and 3.5). For each interview participants were separated into two streams. Streams were determined by participant responses to the experience questions: "Do you know what a tactile map is?" and "Do you or have you used tactile maps?" If the participant had some experience with tactile maps, they were asked a series of 19 questions based on their past experiences (Stream One). If the participant had no experience with tactile maps, a series of 15 questions was asked (Stream Two).

Both experienced and inexperienced question streams comprised three subsections. In each subsection, participants were asked a combination of open ended and dichotomous (yes or no) questions. Dichotomous questions were used to measure a participant's agreement or disagreement with statement or claim (Nielsen & Levy, 1994) about tactile map preferences. Open ended questions allowed the researcher to gather information about participant opinions and to motivate participants to explain their opinions, as these questions do not restrict participant responses to a fixed set of choices (Powell & Single, 1996; Züll, 2016).

For both streams, the first subsection asked participants about their general opinions of or experiences with tactile maps. For example, participants were asked: "Do you like tactile maps?" or "What has led to you not having used a tactile map?" This first subsection was designed to gather insights on what makes using a tactile map easy, difficult, enjoyable, or not enjoyable for participants. The second and third subsections included the analysis of participant data selection preferences. The same questions were asked to the participants twice, once in relation to the experiences or opinions of tactile maps used for navigation and the second in relation to tactile maps used for general reference. Navigation and general reference maps were selected as they are commonly used before and/or during a navigation activity (Agrawala & Stolte, 2001). Tables 3.4 and 3.5 list the experience and opinion questions asked during the initial interview.

General Questions
Do you like tactile maps?
How useful are tactile maps to you?
Can you describe to me a good experience you've had using a tactile map?
Have you ever had any bad experiences while using a tactile map?
What would you like to use a tactile map for?
In a location that you know well, how useful is a tactile map to you?
In a location that you don't know well, how useful is a tactile map to you?
Navigation Tactile Maps
Have you ever used a tactile map to assist you with navigation, for example getting from A to B?
If yes:
Can you describe your experience with that tactile map?
What features of that navigation map made that map difficult/unenjoyable?
What features of that navigation map made that map easy/enjoyable?
If no:
Would a tactile map that could help you get from A to B be useful?
What would you like it to display?
General Reference Tactile Maps
Have you ever used a tactile map for reference, eg- to learn about an area?
If yes:
can you describe your experience with that tactile map?
What features of that reference map made that map difficult/unenjoyable?
What features of that reference map made that map easy/enjoyable?
If no:
Would a tactile map that could helped you learn about a location be useful?
What would you like it to display?

Table 3.4: Stream One: Experience and opinion questions (experienced participants)

If the participant does not have experience with tactile maps:

General Questions
What has led to you not having used tactile maps?
Do you like tactile maps?
How useful would a tactile map be to you?
What, if anything, would you like to use a tactile map for?
In a location that you know well, would you find a tactile map useful?
In a location that you don't know well, would you find a tactile map useful?
Navigation Tactile Maps
If presented with the opportunity, would you use a tactile map to assist you with navigation, for example getting from A to B?
If yes:
What would you use it for?
What would you like the map to show?
Can you think of any features on a map that might make getting from A to B difficult?
If no:
What has led you to making this decision?
General Reference Tactile Maps
If presented with the opportunity, would you use a tactile map for reference, for example to learn about an area?
If yes:
What would you use it for?
What would you like the map to show?
Can you think of any features on a map that might make learning about an area difficult?
If no:
What has led you to making this decision?

Table 3.5: Stream Two: Experience and opinion questions (not experienced participants)

At the end of each interview participant was read a list of common accessibility datasets (Table 3.6). Each participant was asked if they would find the dataset useful or not useful. This was done to ensure all participants had equal opportunity regardless of map experience. The list was compiled by frequency analysis of TMAP, Open Street Map, and accessibility maps available on New Zealand council websites (11 Councils). These sources were selected as they are indicative and common examples of accessible and tactile map products in New Zealand.

Dataset	Appearances
Streets and Roads	13
Street/Road Names	12
Addresses	3
Bridges	6
Intersections	7
Crossings	2
Stairs	3
Ramps	3
Elevators	1
Footpaths	7
Curbs	1
Public Transport Stops	7
Car Parking Spaces	10
Taxi Stands	5
Building Outlines	6
Building Uses	11
Hills/Elevation	4
Land Cover (Open Land/Residential/Bush/Parks)	11
Water (Rivers/Lakes/Ocean)	13
Direction Indicators	3

Table 3.6: Common Datasets found on Accessibility Maps

3.5.2 Analysis of Initial Interview Responses

The main variables of the initial interview were the themes and data preference rankings obtained from analysis of participant responses. Thematic analysis was used to extract recurring themes relating to the value of tactile maps. Both thematic analysis and quantitative analysis were used to determine data preference rankings.

Thematic Analysis

Thematic analysis was selected to interpret key themes about map dataset preferences and the value of tactile maps. Thematic analysis is beneficial as it identifies, organises, and provides insight into patterns (themes) within a dataset (Braun & Clarke, 2012). In this research, thematic analysis was conducted following Braun and Clarke (2012). The analysis was separated into six key phases, described in Table 3.7.

Phase	Description
1. Familiarisation	Familiarised with data by listening to the audio, writing a transcript, and taking notes.
2. Generate Codes	Descriptive or interpretive labels for features of the dataset that were relevant to the research questions.
3. Find Themes	Identified areas of overlap or similarities between. The themes captured important aspects of the data in relation to the research questions.
4. Review Themes	Iterative analysis of the themes. This ensured the themes matched the datasets and there was enough meaningful data to support the theme.
5. Name and Define Themes	Constructed a table of themes, clearly defining the boundaries of the theme.
6. Report	Reported on the results of the analysis, relating the themes to the research questions and dataset.

Table 3.7: Braun and Clarke's (2012) six phases of thematic research

Quantitative Analysis

Dichotomous questions were also asked during the initial interview. Participant answers were coded into nominal variables. Quantitative analysis was used to provide a more complete description of the qualitative data collected (Lund, 2012). The quantitative data was only secondary information due to the low number of participants however, it supported the qualitative analysis of participant preferences.

Not all participant responses to dichotomous questions were direct answers (e.g. yes, no, maybe) this is common in interviews (Molenaar & Smit, 1996). When participants did not provide a direct answer, for example they discussed the dataset but did not specify an opinion, their response was recorded as 'not explicitly stated'.

3.6 Second Interview: 'Part Two: Usability Tests'

During the second interview session four 3D printed sample tactile maps were presented to the five participants. The tactile maps were created using a Tiertime Up300 printer and white PLA plastic filament. Data was selected based on participant responses to the initial interview questions. Two of the sample tactile maps were navigation tactile maps, the second two were general reference maps. The purpose of the second interview was to investigate the usability of the four sample tactile maps. For each navigation map, participants were asked to carry out three map reading tasks: search, list and estimate direction. For each general reference map participants were asked to search, list and count. The map reading tasks are explained in section 3.6.2.

As participants were required to use and assess tactile maps, the second interview could only occur in person. The interviews were held at meeting spaces or the participant's place of residence. Refreshments were provided at all interviews. To ensure interviewer safety a sign-in/sign-out system was established with a colleague. Video and audio recordings were taken during the second interview session. This was done to enable the researcher to identify which map or map feature the participants was discussing at different points of their interview. Care was taken when video recording to ensure only the participants' hand and map interactions were recorded. Figure 3.2 provides an example visualisation of the second interview setup.

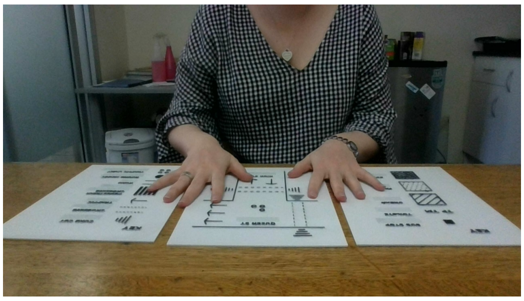

Figure 3.2: Example Screenshot of Interview Two Recording

One participant had not taken part in the initial interview so the demographic and tactile map experience questions were first asked. It was not necessary for the four returning participants to be asked the demographic or tactile map experience questions.

3.6.1 Sample Tactile Map Data Selection

Data selection was guided by the results of the initial interview sessions and the previously listed common accessible datasets (Table 3.6). Only 14 of the 21 common datasets were selected as Wabiński and Mościcka (2019) and Rowell and Ungar (2003b) state that tactile map producers should choose between 10 to 15 different symbols, most being point symbols. The 14 selected datasets were those that participants identified as high value during their initial interview sessions. High value datasets were those that had the highest number of participants indicate they would find them useful on a tactile map (more than three participants). The high value datasets were then separated into two types: common and uncommon. Common datasets were those that frequently appeared on the assessed accessibility maps (more than six maps (46%), uncommon datasets appeared less frequently.

To ensure the datasets were accurately compared, they were evenly distributed across the four tactile maps. Each navigation map (STM1 and

STM2) contained seven high-value datasets. STM1 contained common datasets and STM2 contained uncommon datasets. Each general reference map (STM3 and STM4) contained five high value datasets. Again, STM3 contained common datasets and STM4 contained uncommon datasets. Table 3.8 lists the datasets on the navigation maps and images of the navigation maps can be seen in Figure 3.3. Table 3.9 lists the datasets on the reference maps, images of the reference maps appear in Figure 3.4.

All participants discussed intersections or crossings during their initial interview sessions. Intersections and by extension, streets and roads were selected as the subject of all the sample tactile maps used in the second interview. This decision excluded other map purposes such as indoor venues. Indoor venues were mentioned in interview sessions by three participants. The tactile maps were generated using realistic intersection data and care was taken to ensure the sample tactile maps did not represent real locations. For example, it was checked that the road names in the sample tactile maps did not match major Wellington intersections. This was done to ensure no participant was placed at an advantage due to prior knowledge of a particular location.

All participants placed high value on road names, however not all accessibility maps contained road names. To assess participant reaction to this feature, STM3 did not contain road names. The navigation maps were designed to assist in discerning a route, therefore a 'you are here' symbol and label was added to both navigation maps. Whilst common, car parking (11 maps, 85%) was not selected due it's low participant value (1, 20%). Bridges and footpaths were also not selected due to their detrimental impacts on map complexity. Stairs, elevators and ramps were not included as they do not often exist at intersections. These features were mentioned as high value by participants, but they are more common on floor plans. To ensure consistent complexity across maps, addresses could not be included despite 60% of participants indicating they would be useful.

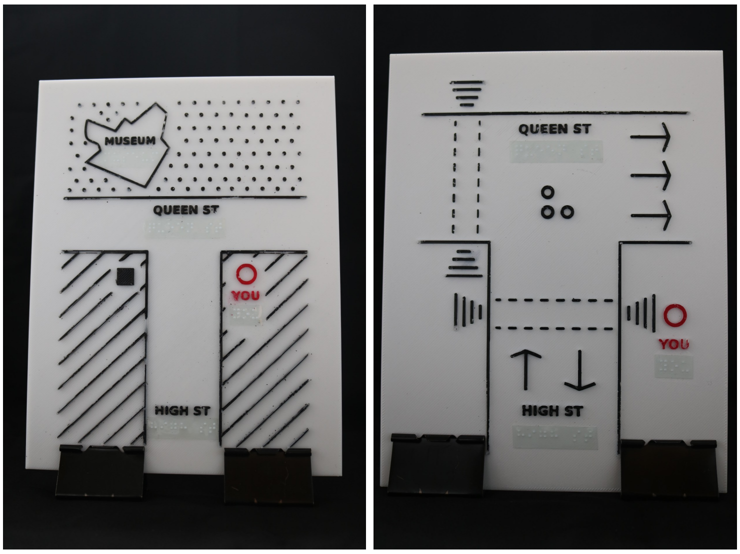

Figure 3.3: Navigation Sample Tactile Maps - L: Common (STM1); R: Uncommon (STM2)

Selected Dataset		Participant: Yes/Maybe	Appearances on Accessible Maps
STM1 (Common)	Streets and Roads	5	13 (100%)
	Street and Road Names	5	12 (92%)
	Land Use Classification	4	11 (85%)
	Public Transport	5	7 (54%)
	Building Use	5	11 (58%)
	Building Outline	3	6 (46%)
STM2 (Uncommon)	Streets and Roads	5	13 (100%)
	Street and Road Names	5	12 (92%)
	Crossing (Traffic Light)	5	2 (15%)
	Intersection Type	5	1 (8%)
	Curb Cut	5	1 (8%)
	Direction	5	3 (23%)

Table 3.8: Navigation Sample Tactile Map Datasets (STM1 and STM2)

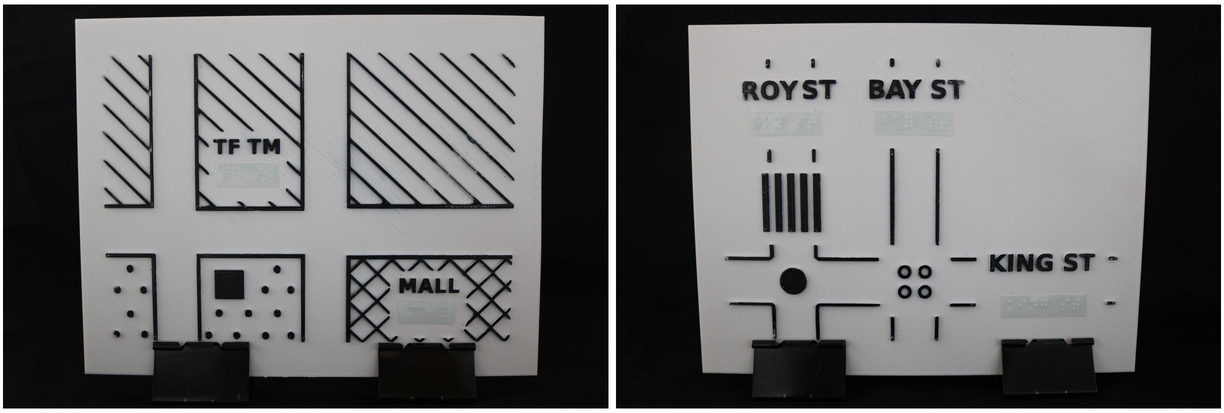

Figure 3.4: General Reference Sample Tactile Maps - L: Common (STM3); R: Uncommon (STM4)

	Selected Dataset	Participant: Yes/Maybe	Appearances on Accessible Maps
STM3 (Common)	Streets and Roads	5	13 (100%)
	Land Use Classification	4	11 (85%)
	Public Transport	5	7 (54%)
	Building Use	5	11 (58%)
	Toilets	2	10 (77%)
STM4 (Uncommon)	Streets and Roads	5	13 (100%)
	Street and Road Names	5	12 (92%)
	Crossing (Pedestrian)	5	2 (15%)
	Intersection Type (Traffic Light)	5	1 (8%)
	Intersection Type (Round About)	5	1 (8%)

Table 3.9: General Reference Sample Tactile Map Datasets (STM3 and STM4)

3.6.2 Tactile Map Reading Tasks

Interview two cycled through the four tactile maps. Each iteration began by setting the scene and describing to the participant a scenario in which they may use the presented tactile map. It was explained that STM1 and STM2 were designed to be situated in place at an intersection, whereas STM3 and STM4 were to be used prior to a navigation task, for example, at home. No tactile map was designed for the participant to navigate and move with. Participants were given an unlimited amount of time to familiarise themselves with the tactile map and to ask any questions.

Once familiar with the maps, the participants were asked to perform a series of map-reading tasks which enabled map usability assessment. On each map, participants were asked to perform three map reading tasks. In total, twelve objective-based user tasks suggested by Roth (2012) were used.

When using the navigation tactile maps (STM1 and STM2) participants were asked to list features, search for a feature, and estimate the direction between two features. When using the general reference tactile maps (STM3 and STM4), participants were asked to list features, search for a feature, and count how many times a feature appears on the map. Table 3.10 lists the map reading tasks asked.

On all maps:	
	What are your first impressions of this map?
STM1:	
	Can you point out to me where you are located on this map?
	Can you list all the information you can get from this map?
	On this map, how would you get to the museum?
STM2:	
	Can you point out to me where you are located on this map?
	Can you list all the information you can get from this map?
	On this map, how can you cross both the roads?
STM3:	
	Can you list all the information you can get from this map?
	Can you point out to me where the toilets are?
	How many bus stops are on this map?
STM4:	
12.	Can you list all the information you can get from this map?
13.	Can you point out to me where the pedestrian crossing is?
14.	How many intersections are on the map?

Table 3.10: Map Reading Tasks

These map reading tasks were selected as they could be carried out on a static handheld tactile map, they are some of the most simple map reading tasks, and they are also common in other tactile map usability research (Blades et al., 1999; Jehoel et al., 2005; Roth, 2012; Ungar et al., 1994). Consistency was maintained within the different map types (i.e. navigation and general reference), but some questions varied across map type as it was important that the tasks were appropriate to the map type (Board, 1978).

As participants completed map reading tasks for the four sample tactile maps, it was possible that they performed better due to their prior learning experiences with earlier maps. This is concept is referred to as priming and is common in usability tests (Budiu, 2016). To mitigate priming the maps were presented to participants in different order. The order participants were presented the tactile maps is outlined in Table 3.11.

Interview Number	1	2	3	4	5
Map Order	1,2,3,4	2,1,4,3	4,3,1,2	3,4,2,1	1,3,2,4

Table 3.11: Tactile Map Presentation Order

3.6.3 Map Design

The NSW Guide (2006) was used to guide the tactile map symbology decisions. The NSW Guide was the most applicable to a New Zealand environment when compared to other standards or kits. For example, the American standards: 'Guidelines and Standards for Tactile Graphics' standard symbol suggestions were only State and Country Abbreviations (Braille Authority of North America, 2012). However, the limitation of the NSW Guide is that it was originally produced in 1992, prior to the popularity of 3D printing. These guidelines therefore contain instructions specific to other tactile map creation techniques, such as microcapsule paper. The clarity of the map outweighs all other considerations (Gardiner & Perkins, 2002). The following subsections outline the guidelines followed for the different features on the tactile maps.

Lines

A line thickness between 1.5mm and 0.4mm was recommended for line features, a line thickness of 1.4mm was used for all line features in the four tactile maps (NSW Guide, 2006, p. 20). Contrasting lines were used to ensure different line features were distinguishable. In this research, solid lines representing roads were contrasted with dashed lines demonstrating pedestrian crossings. The gaps in the dashed lines were spaced 3mm to ensure discernability. To avoid confusion, the guidelines state that line features should not join, therefore, where two line features met a gap of 2mm was maintained (NSW Guide, 2006, p. 20). Figure 3.5 displays the two line symbols used in the sample tactile maps.

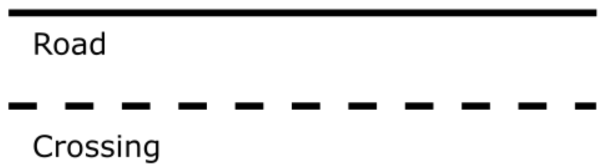

Figure 3.5: Lines

Patterns

Patterns "are comparable to colours for a sighted person" (NSW Guide, 2006, p. 20). Patterns are useful to display different regions or areas such as land-cover on tactile maps. In tactile mapping, patterns can be characterised using three features: style (dots, squares, or lines), pitch (the distance between elements), and thickness (the width of the elements). As the tactile maps prepared for this study required a key, the NSW Guide suggests all patterns used "should be tactually distinct so that they can be recognised. Ideally this means that each should have characteristics which are all quite different so that they can be recognised. In practice this is seldom possible for more than four patterns" (NSW Guide, 2006, p. 20).

In this research, three areas were selected to be represented by patterns: urban, building and park. Three patterns from a suggested set of eight unique patterns were chosen (2006, p. 21), these patterns can be seen in Figure 3.6. The selected pattern to represent a park contained dots, this pattern had additional requirements. The NSW Guide suggests ensuring dot patterns are distinguishable from braille by making them larger than 2mm or smaller than 0.7mm (2006, p. 20), in this research, a dot diameter of 2mm was used.

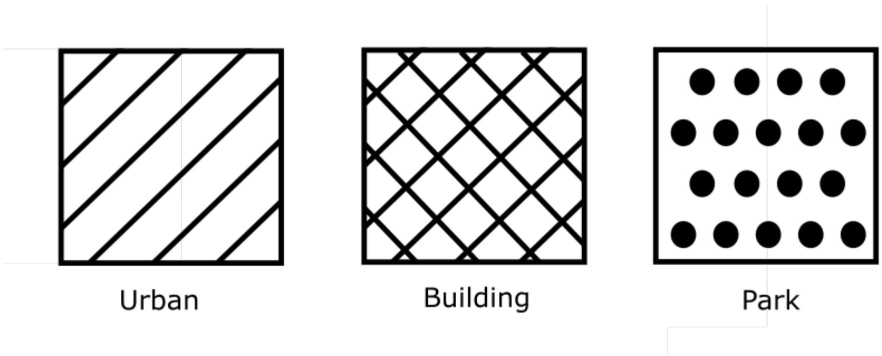

Figure 3.6: Patterns

Symbols

The NSW Guide standardised frequently used features. Figure 3.7 details the standardised symbols used in this research. Arrows were used in STM2 to demonstrate traffic direction. The NSW Guide instructed that an arrow shape has a "long shaft (20mm minimum), a wide-angle head (90 – 150 degrees) and arms which are at least 6mm long" (NSW Guide, 2006, p. 23).

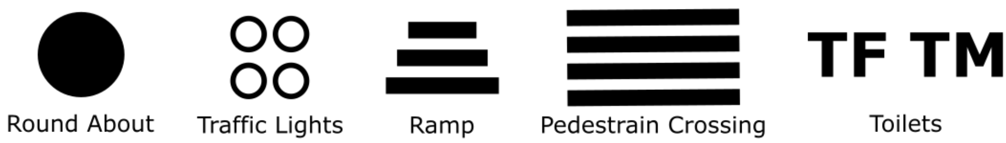

Figure 3.7: Recommended Standardised Symbols from the NSW Guide

For features not standardised in the NSW Guide the guide suggests representing them with abbreviations or labels as it requires fewer references to the key. Therefore, building uses were labelled on the tactile maps. Of the remaining symbols the guidelines states "the only symbols that can be recommended for general use are the circle, square and triangle" (NSW

Guide, 2006, p. 23). The remaining symbols used in this research are depicted in Figure 3.8. The guidelines stated if features are to be recognised, they should have one-dimension 6mm in length and be surrounded by 3mm of blank space.

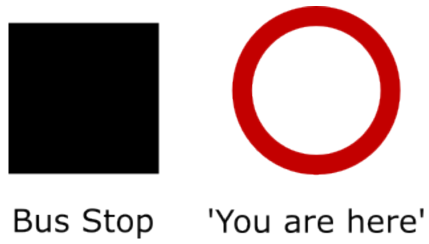

Figure 3.8: Additional Tactile Symbols

Labels

Labels were used to display road names and describe building uses. Both print and braille labels were applied to the map. Print labels were written in upper case letters using a sans serif, 20-point font, the print labels also had expanded letter and word spacing. To ensure they adhered to standard sizing and spacing regulations braille labels were created using a Reizen braille label-maker. 3mm of space surrounding the braille labels was included to ensure readability. Both print and braille labels were placed horizontally on the maps and where possible the full names of features were used. (NSW Guide, 2006)

3.6.4 Map Production

Digital Design

Lobben and Lawrence (2012) argue that for a product to be accessible it must be produced at a low cost. Perkins (2001) states that an accessible product must be reproducible. To align with these recommendations open-source software and tools were used to design the tactile maps.

First, the maps were designed in 2D, using Inkscape and then saved as SVG files. Inkscape is a vector illustration tool. Using an online tool (https://svg2stl.com/), the vector graphics were converted to STL files with a uniform height of 1.5mm. The STL files were then opened in Tinkercad (https://www.tinkercad.com), a free, easy-to-use 3D modelling webapp. In Tinkercad, a 2mm baseplate was added, making the overall elevation 3.5mm for all tactile maps.

Tactile Map Printing

At present, an individual may construct a tactile map using collage, etching or with other hand drawn methods (Lobben, 2005). Professionally, three tactile map production methods are common: microcapsule (swell) paper (Rowell & Ungar, 2005), thermoform printing (Gardiner & Perkins, 2002), or 3D printing (Gual-Ortí et al., 2015; Holloway et al., 2018; Jehoel et al., 2005; Perkins, 2001; Voigt & Martens, 2011). Historically, thermoform and microcapsule have been the most common printing methods (Rowell & Ungar, 2003b), but as technology develops the popularity of 3D printing methods has grown (Gual et al., 2015).

Due to the cost and availability of the technology, 3D printing was chosen. Obtaining the paper and heating device for microcapsule printing was more expensive than 3D printing. Thermoform printing was also not selected as products created using this method are not easily reproduced due to the requirement of a 'master' template (Perkins, 2001). In addition, locating thermoform printing services was difficult.

In a recent survey of the blind and low vision community 3D printed tactile maps were the preferred form of printing (Holloway et al., 2018). Survey participants preferred 3D printed tactile maps as they enabled better short-term recall and allowed for the use of easily understood icons (Holloway et al., 2018). 3D printing supports the creation of tactile products at low cost when compared to thermoform and microcapsule print.

Some researchers argue that low cost is an important consideration and contributes to the accessibility of a tactile product (Lobben & Lawrence, 2012; Wabiński & Mościcka, 2019).

The 3D printing services of The Hive at Johnsonville Library in Wellington were used to create the tactile maps. A Tiertime Up300 3D filament printer was used (https://www.tiertime.com/up300/). This printer has reliable print performance and dimensional accuracy for a reasonable cost ($2199.00 USD to purchase). The Hive charges $0.10 per gram for PLA filament, the total cost was $98.50 to print four sample tactile maps and two keys.

The Braille Authority of North America (2012) suggests a map size of 280mm by 430mm, however, Rowell and Ungar suggest tactile maps should be "two hand span maximum width that allows the hands to provide a frame of reference for coding the relative positions of map elements" (2003a, p. 261). Usability studies have been conducted to investigate how tactile map size impacted usability. Ohashi and Watanabe (2019) determined that map reading response times increased as the map became larger in size. Due to size constraints of the 3D printer used, all the tactile maps were created at 200mm by 250mm. This is approximately one handspan and therefore well within Rowel and Ungar's suggested constraints.

The Hive only has resources to print products using white PLA plastic filament. Colour contrast is useful for low vision map users when distinguishing features (Wurm et al., 1993). The 3D printed white maps were augmented using a White Rust-Oleum spray primer, black and red Rust-Oleum paints were used to provide colour contrast between the spatial datasets and the baseplate. The spatial datasets were all painted black, and the 'you are here' locations on the two navigation sample tactile maps (STM1 and STM2) were painted red.

3.6.5 Tactile Map Complexity

Complexity is defined by Oliva (2004 p. 1041) as "the degree of difficulty in providing a verbal description of an image." Complexity is known to affect usability and performance (Rosenholtz et al., 2005; Stigmar & Harrie, 2011). The impacts of complexity on tactile map usability were not a component of this research, therefore measures were taken to ensure complexity did not vary among the four tactile maps. Complexity was calculated using several map elements. In this research, the number of datasets used (Stigmar & Harrie, 2011), the total number of features separated into point, line, area, and label (van Smaalen, 2003; Wolfe, 1994) and the number of colours (contrast) (Oliva et al., 2004) were used to calculate complexity. To ensure complexity did not vary across the four sample tactile maps the total complexity figures should be the same or similar (± 1).

	Dataset Count	Colour	Feature Count				Total Complexity
			Label	Point	Line	Area	
STM1	7	2	4	2	13	3	31
STM2	7	2	3	11	7	0	30
STM3	5	1	2	1	14	6	29
STM4	5	1	3	3	18	0	30

Table 3.12: Tactile Map Complexity Calculations

3.6.6 Usability Analysis

In this research usability was defined by the ISO 9241-11:2018 standards, where usability is the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (2018, p. 3.1). Task success rates were used to establish tactile map effectiveness and time taken was used to measure efficiency. Participant preferences measured satisfaction.

3.6.7 Satisfaction

Satisfaction predominantly determined sample tactile map usability due to the low number of participants involved in the second interview (5). After completing the map reading tasks, for each tactile map, participants were asked four questions to determine their satisfaction with the map. This approach followed Nielsen and Levy (1994). The questions asked are presented in Table 3.13. Yes or No questions and Likert Scale questions were used to determine preferences. Participants were also asked to describe what they liked or disliked about each map. Quantitative (yes or no and Likert questions) and qualitative (describe) research methods were combined to provide an overall description of participant satisfaction and preference (Lund, 2012).

Additionally, at the conclusion of each interview session participants were asked to rank the four tactile maps. Participants were asked to rank the tactile maps overall (out of four) and by map dataset (STM1 vs STM2 and STM3 vs STM4). Participant rankings were also evaluated based on tactile map experience.

On a scale of 1 to 5 how easy was it to use this map?
What did you find easy?
What did you find difficult?
Would you use this map?

Table 3.13: Satisfaction/Preference Questions

3.6.8 Efficiency and Effectiveness

Speed and accuracy were used to measure tactile map efficiency and effectiveness (Brittell et al., 2018; Jehoel et al., 2005). Efficiency (speed) was measured by the time taken for participants to complete the map reading tasks. Time taken was recorded in seconds, continuously, from the time the map reading task had been read aloud to when the participant answered the question

Effectiveness (accuracy) was measured by task success rates. Task completion and success rates were classified by the numbers 0 or 1. Not completed or incorrect answers were classified as 0 whereas completed or correct answers were classified as 1. Most participants had limited prior experience with tactile maps and therefore it was not expected that the participants must complete the tasks. It was also not expected that the participants complete the tasks without asking for assistance as it had been established that most participants had limited experience with tactile maps. When asked for help the interviewer answered the questions of the participant. The number of questions asked was also recorded as a measure.

Statistical Analysis of Results

The low number of participants involved in the second interview meant that the statistical analysis conducted to assess effectiveness and efficiency could not be used to determine results. Instead the statistical analysis was used to identify variables that may yield significant results in future research with larger participant groups.

Independent variables were separated into two groups: common and uncommon (data selection), navigation and general reference (map purpose), and novice and intermediate (tactile map experience). These groups were assessed using statistical and crosstabulation analysis.

3.7 Limitations

3.7.1 Number of Participants

Five participants took part in both interview sets, with six participants in total. There are several reasons to explain the low number of participants.

First, this research involved a large time commitment from participants, up to two hours on two occasions. A large time commitment is a possible deterrent for participants when deciding whether to participate (Patel et al., 2003).

In addition, the second interview required an in-person interview, as the participants had to interact with sample tactile maps. This in person requirement immediately restricted an already small potential participant pool to a smaller group who reside within the Wellington region. The researcher ensured they arranged to meet each participant at a location determined by the participant, for example at their workplace or residence. If a potential participant was not aware these arrangements would be made this may have impacted their decision to take part. Previous research highlights that navigation, especially to a new location can be difficult for blind and low vision individuals (Chandler & Worsfold, 2013; Kitchin & Jacobson, 1997; Passini & Proulx, 1988). This research was conducted during the COVID-19 Pandemic (2020-2022) and involved a vulnerable population, it is likely the pandemic impacted people's decisions to take part in this research.

As a sighted Spatial Analyst, the researcher is an outsider in the blind and low vision community, although they are an insider of the cartography and GIS discipline. Recruitment was conducted using the assistance of blind and low vision organisations active in the Wellington Region, but being an outsider may have impacted participant buy-in (Breen, 2007).

Qualitative research often consists of smaller participant groups. DeMarrias suggested that a small number of participants is justifiable as "fewer participants interviewed in greater depth usually generates the kinds of understandings qualitative researchers seek" (2003, p. 61). Often researchers recommend a small number of participants, between 10 and 20 (Braun & Clarke, 2012; Yates & Leggett, 2016). This research followed the suggestions of academics who state the number of participants should not be defined prior to data collection (DeMarrais, 2003; Sargeant, 2012). Instead, these researchers indicate that interviews should conclude when they "do not result in identification of new concepts", a point also known as saturation (Sargeant, 2012, p. 1). The results of this research demonstrate clear consistency among responses, participants agreed on the value of tactile maps, they were consistent in their suggestions, and they were unanimous in their preferences for STM2.

3.7.2 Discussing a Technical Topic

During the interviews, it became evident that it was difficult to encourage participants to discuss data selection. As a domain specific topic, data selection is a map production consideration commonly entrusted to the cartographer (Robinson et al., 1995). This was a limitation when conducting qualitative user research. Participants were more likely to describe tactile map symbology when discussing their past experiences. Past research into tactile mapping has largely been focused on symbology (Brittell et al., 2018; Gual et al., 2015; Gual-Ortí et al., 2015; Lawrence & Lobben, 2011; McCallum et al., 2006). To mitigate the risk of not collecting enough information about data selection, participants were read a list of common accessibility datasets at the end of each initial interview. Participant were asked to state if they would find this dataset useful. In addition, to reduce participant confusion, when discussing a domain specific topic, the use of jargon was minimised (Fox et al., 2000). For example, participants were asked "if using a tactile map for navigation, what would you like the map to show?", if the participant's response was vague, for example, 'How to get from A to B', the participants were asked follow-up questions such as "what would you need on the map to help you get from A to B?". Using the word 'data' itself was avoided due to the risk of participants misinterpreting its meaning (Fox et al., 2000).

3.7.3 Participant Bias and the Hawthorne Effect

During each interview session, particularly during the second interviews when participants were interacting with the sample tactile maps, participant bias may have impacted results. Participant Bias is when participants change their answers in an attempt to please the interviewer (Greenberg et al., 1969). It was also possible that participants changed their behaviours in response to being observed in an interview environment, this is known as the Hawthorne effect (McCambridge et al., 2012). Both participant bias and the Hawthorne effect are a known limitations and past research has demonstrated they can introduce significant error (Gove & Geerken, 1977). For example, research results may not correlate to real-world observations.

To mitigate possible participant bias and Hawthorne effect participants were made aware at the beginning of each interview that they could choose to remain confidential and not have their comments or opinions attributed to them in this research (Farnsworth, 2019). One participant selected for their responses to remain anonymous, the remaining participants stated their comments and answers could be attributed to them by name in this research. In addition, the interview questions were phrased and as much as possible asked without judgement (Farnsworth, 2019). For example, if a participant indicated they did not believe tactile maps were beneficial the follow up question was "what has led you to making this decision?" as opposed to asking, "why not?" which can come across in an accusatory nature.

Chapter Summary

This study used two sets of interview sessions to investigate the value of tactile maps and determine how data selection is associated with tactile map usability. Value and dataset preferences were determined in the initial interview. Thematic analysis was used on participant responses about their past experiences or opinions. Usability was measured in the second interview where participants were asked to complete map reading tasks (search, list, count and estimate direction) on four different sample 3D printed tactile maps. Response time, tasks success rates and subjective user preferences were used to determine tactile map usability in accordance with the ISO 9241-11:2018 standard's measure of usability.

Chapter 4

Results

Between October 2021 and March 2022 ten interview sessions were held, six participants were involved. Participant experiences and opinions with tactile maps were discussed in the initial interview. Participants were asked a series of 19 or 15 questions, depending on their tactile map experience. Responses were analysed using thematic analysis. In the second interview, participants were given four tactile maps in varying order, and were asked to carry out some simple map reading tasks. In total, the research participants completed 60 map reading tasks. Usability of the sample tactile maps was measured by the time participants took to complete tasks, task success rates, and analysis of tactile map user satisfaction.

This chapter presents the results from both sets of interviews. Demographic and tactile map reading experience results are presented first. Next, the analysis of participant experiences and opinions is presented, then tactile map usability is covered. Throughout this chapter, results are compared across map purposes and between tactile map experience groups.

4.1 Demographic Results

Five participants took part in both interview sets, with six participants in total for both sets. One participant from the initial interview was unable to attend an in-person meeting for interview two, an additional participant took part for interview two. Most participants were blind, some had low vision. Participants ranged in age from 25 to 65, three were female and three male.

4.2 Tactile Map Experience

Six questions were asked to determine tactile map experience, Table 4.1 presents the results. Of the participants who had experience with tactile maps, three had used tactile maps for navigation, two had used tactile maps for reference. No participant indicated they had used tactile maps for any other purpose.

Four participants had not received any formal training in using tactile maps, two had received either minimal or no recent training. No participant indicated they had received comprehensive or recent training on how to use tactile maps.

Only one participant had previous experience with tactile map design. Judy Small led and supported the Hamilton City Council in the creation of both a tactile braille and large print map of the inner city.

	Calculated Experience Scores					
	Kaye	Jim	Tracy	Judy	Thomas	-
Do you know what a tactile map is?	3	3	1	3	3	3
How often do you use tactile maps?	1	1	1	2	2	1
Have you received tactile map training?	2	1	1	1	2	1
Have you assisted with designing a tactile map?	1	1	1	3	1	1
What purposes have you used a tactile map for?	2	1	0	1	2	1
Self Assigned Experience Group	Exp	Nov	Nov	Exp	Int	Nov
Average	2	1	1	2	2	1
Calculated Experience Group	**Int**	**Nov**	**Nov**	**Int**	**Int**	**Nov**

Table 4.1: Tactile Map Experience (Nov=Novice, Int=Intermediate, Exp=Experienced)

4.3 Interview One: Experiences and Opinions

Thematic analysis on initial interview participant responses established themes from the experiences and opinions of the blind and low vision participants. The major themes related to the research questions were extracted and are summarised in Table 4.2.

Research Topic	Theme	Interview Count that Mentioned Theme	Total Mentions of Theme
Value of Tactile Maps	Choice and Independence	4	14
	Spatial Ability	4	15
Data Preferences	Pedestrian Crossings & Intersections	5	10
	Data Currency	5	6
	Indoor Data	3	5

Table 4.2: Summary of Themes

4.3.1 The Value of Tactile Maps

All five initial interview participants stated that they liked tactile maps and found them useful. If the participant had no or limited experience with tactile maps, they indicated that they thought that tactile maps would be useful to them. The four participants with prior tactile map experience recalled more positive experiences with tactile maps than negative (Table 4.3).

	Positive Experience Count	Negative Experience Count
Kaye	2	1
Jim	1	0
Tracy	No experience	No experience
Judy	2	0
Thomas	4	1

Table 4.3: Positive and Negative Experiences with Tactile Maps

Choice and Independence

The most prominent recurring themes identified were the choice and independence that tactile maps provide to blind and low vision individuals as they navigate. The words 'choice' and 'independence' were directly mentioned six times during the initial interviews. The term choice was used to describe preference and to explain that blind and low vision navigators should be provided the same options as sighted navigators:

"I quite like them; I mean I'd rather have a tactile map if I had a choice." - Judy Small

"I think, it's important to have the choice, we should have the choice as well." - Kaye

During the initial interview participants provided examples of scenarios in which they would use tactile maps. Examples included Wellington City streets or within a shopping mall. Independence was mentioned when participants discussed navigating through these environments for example Kaye mentioned: "…if you can get from A to B and back again without having to ask anybody to help you it's a really good feeling... it's just a really nice, independent feeling."

Others referred to the theme of choice when discussing the lack of tactile maps available in New Zealand. For example, when asked if he used tactile maps today, Thomas stated "No, only because they're not really printed" he then continued on to say, "and that's a shame because, people take things in different ways." Similarly, Jim responded to the same question stating: "I would probably find them useful, but I would probably just appreciate the experience."

In addition, two participants mentioned that sharing of information regarding tactile maps and products is necessary for choice and independence. Kaye stated: "how would we be informed about where that sort of thing is?... if you didn't know then you're not going to run your hands all over walls to find these things, are you?", similarly, Thomas mentioned that he had "... used tactile maps before, but they're not easy to obtain."

Spatial Ability

The participants with past tactile map experience discussed how the tactile map they have used improved their spatial ability. Two participants with frequent previous tactile map experience stated that tactile maps better supported their understanding of a location.

> *"... I always found getting a tactile reference of something gave me a better dimension or understanding as to where things were... " – Thomas Bryan*

> *"... [tactile] map reading helped me to build that picture in my head." – Judy Small*

When prompted to explain how the tactile maps supported their understanding of space, these two participants explained that tactile maps provided them with more contextual or detailed information about the route or location.

> *"... I like to know which street runs in parallel, adjacent to or on an angle from another street and if it told me where north, south, east and west was so I knew which way the streets were running, that would be of interest to me." – Judy Small*

> *"It gives me a better concept of... you know, if someone says you go down Lambton Quay and you turn right and left well yeah, but are there actually other little streets that you have to cross along the way? It's never always that simple." – Thomas Bryan*

In addition, Judy and Jim explained the benefits of haptic exploration. They stated that tactile maps support this exploration method and complemented their learning styles.

> *"Even tactile images of animals are always interesting. Because you can get a*

whole idea about it, you can read about the animal, and you can know all about its height and its width and its size but a surface of it or a 3D model of it is quite a good way of learning about what it really does look like." – Judy Small

"If it was 3D, it would be a bit more full on and you could interact with it a bit more. It's how you interact, for the blind tactile is obviously a high point of interaction so that always going to benefit more." - Jim

Three participants, all with tactile map experience, compared their tactile map experiences to GPS. Comments ranged from indicating that the participant does not often use GPS, or that they prefer the ability to interact with a tactile map compared to the "flat screen" on their phone. One participant explained that sometimes GPS does not provide them with the detailed information they require such as a description of the pedestrian crossing or intersection. Kaye stated that she would use a tactile map for reference to learn about the area and combine it with GPS to provide navigation to "home in" on the address she was in search of.

All four participants with previous tactile map experience compared their experiences to audio assisted navigation. All four participants indicated that navigation assistance from tactile maps better assisted their spatial learning compared to following audio assisted navigation instructions.

"...and I've found [tactile maps] a lot better for me than trying to listen to someone else's instructions and memorise it..." – Thomas Bryan

"If you're planning a route to walk and you are going to use google to do it and it says, go down, cross so many roads and at the next intersection turn right, then cross the next street and then turn left and that sort of thing, that's a lot harder to put into my head visually than having the map in front of me." – Judy Small

"I think sometimes physically looking or feeling a map you get a better feel for it than just listening to something..." – Kaye

"Well, I would honestly prefer tactile, I understand the benefits of audio but

tactile to me would be of greater benefit." - Jim

Thomas had experience with a tactile map that included audio information accessed through a pen device, he spoke positively of this experience. When discussing how he might use a tactile map to navigate Thomas suggested:

"...when I get off [the bus] then I might find a place to stand where it's not in the way of everybody else check [the tactile map] out, check my bearings and then head off in the same direction. And I guess that's where you know a mixture of tactile and audible maps can really be an advantage." – Thomas Bryan

4.3.2 Data Selection Preferences

At the end of the initial interview, participants were read a list of common accessibility datasets (Table 3.6). Without the use of this list, it was sometimes difficult to get participants to discuss map data. All participants agreed that streets/roads, street/road names, public transport stops, pedestrian crossings, intersections, and building uses should be displayed on a tactile map (Figure 4.1). The definition of building uses varied, one participant referred to this as "big landmarks" like the Wellington Railway Station, another suggested just the buildings "you're looking for". The dataset of least importance to participants was car parking spaces. Only one participant indicated they would like car parking on a tactile map, this participant lives near a large car parking building, therefore this dataset was important to them personally.

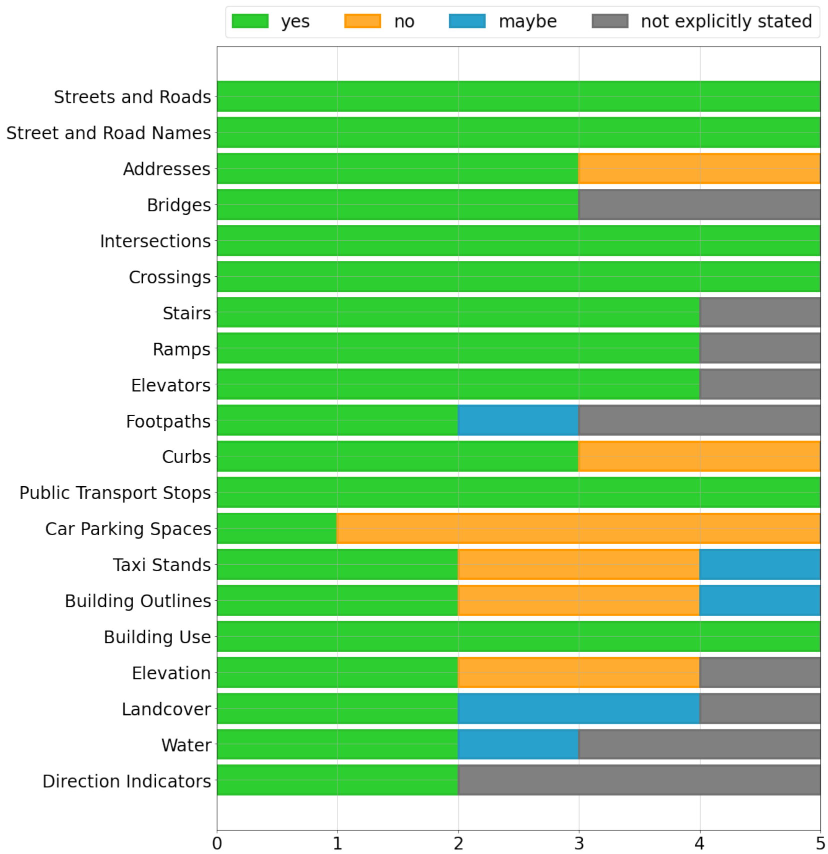

Figure 4.1: Data Selection Preferences

Participants were asked if there were any other datasets not mentioned that would also be useful (Table 4.4). The novice participants were just as likely to suggest additional datasets when compared to intermediate participants. Jim mentioned that he did not find additional map elements such as grid references, useful. Jim suggested they added clutter to the map, and he felt like they were designed more for visual interpretation.

COVID tracing/scanning/passport information
Tree lines and distinctive trees
Distances
Points of Interest
Traffic Data
Steps (when more than 2 or 3)
Mail/Post Boxes

Table 4.4: Additional Datasets Recommended by Participants

Crossing and Intersections

All participants indicated they would like pedestrian crossing and/or intersections on tactile maps. Tracy specifically asked if a tactile map could support her at pedestrian crossings and intersections, the other participants discussed the difficulties they have when using pedestrian crossings.

"If I get to a certain point in a dangerous place where I can't cross the road, I usually have somebody with me to go across those roads but yea... I was wondering if that sort of thing would help me with that situation?" - Tracy

"...some of the GPS don't always include some of the smaller side streets, or they don't tell you if it's an intersection that has a pedestrian crossing or not" – Thomas Bryan

"Most of the time now, you can tell with lights, because they've got sound. But I think pedestrian crossings, because sometimes there are pedestrian crossings that don't have sound, they don't have lights but it's still a pedestrian crossing, [tactile maps] could be quite helpful." – Kaye

All participants agreed that street and road names should be included on maps when possible. Three participants talked about the inaccessibility of street and road names at intersections.

"...the street signs aren't accessible. If the street signs were accessible or there was an easy way to get audible feedback as to what a street was when you were coming up to a crossing and in some places where to the left is one name and to the right is a different name it's really quite difficult so having street names on a map or some form is always really informative." – Thomas Bryan

"I can't see the roads signs... because all different places have their names on the top, very top and it's hard to, if I look up, I can't see what it is..." – Tracy

"...check in with somebody at the intersection that this is the corner of Angus Street and Ross Street..." – Judy Small

Similarly, participants also discussed curbs at pedestrian crossings and intersections. Three participants agreed that curbs would be useful to include on tactile maps at intersections.

"New road designs they're talking about where the pathway you cross is going to be at the same height as the footpath that could pose some other challenges in knowing where the intersection is or not" – Thomas Bryan

"Curbs, definitely in the sense that one would hope that if it was a crossing point it was going to have a curb cut anyway but not always but one would hope that it should do. But knowing possibly if there wasn't a curb would be helpful." – Thomas Bryan

"...if there's a curb, I don't know it's there until... gravity had done its thing... gravity doesn't care... so curbs would be absolutely critical." - Jim

Data Currency

All participants discussed data impermanence during their interview sessions. The intermediate participants were more likely to directly question the difficulty of mapping non-permanent data.

"...the other challenge is knowing that those places change quite often, you know what type of building or what sort of shop. But I guess if there was a way

of identifying that sort of information it would be helpful." – Thomas Bryan

"…[building uses] would be [useful] especially if its places you go every so often.. and then you find out it's no longer there or shifted somewhere else that certainly could be helpful." – Thomas Bryan

"…[the Hamilton tactile map] not been updated. And that's a bit of an issue for tactile maps, is how easy are they to keep current?" – Judy Small

"…it makes me aware of the fact I don't give [the Hamilton City Tactile Maps] to people to use so much now because there are some new changes, but not a huge change, it would be alright if I had a list of changes when I give the map to someone. I could be like here's a map, and these are the changes." – Judy Small

"...shops do change, but [building uses] would be quite good" – Kaye

In addition, Tracy mentioned that she tends to avoid navigation during busy times in the day on the footpaths and roads. Tracy asked if a tactile map could help her in this situation. Traffic information and store 'busy times' are visually presented on google maps however the data has not been adapted to be interpreted easily by blind or low vision navigators.

"…when I'm walking, I've got my cane, and I think because a lot of people don't really watch where they're going, they're just doing their thing, they don't worry about people coming towards them, so that can be frustrating because I wouldn't know which way to turn because there's people everywhere… I try to pick my times when I go out, in the not so busy times." - Tracy

Indoor Data

The three intermediate participants discussed the use of tactile maps indoors, indoor mapping was not mentioned by novice participants. Thomas explained that he had used an indoor map previously. Judy and Kaye suggested that a tactile map of indoor environments such as a "hotel", "shopping mall" or "local pool" would be of interest to them. Participants suggested that an indoor map may assist blind and low vision individuals in navigating through an "open plan" location such as a hotel lobby or to identify the location of shops within a shopping mall.

4.3.3 Map Purpose

Participants were asked what purposes they envisioned for tactile maps, specifically for reference and navigation maps. They were also asked to consider if being familiar with the location impacted their preferences.

Familiar vs Unfamiliar Locations

Participants were asked if they would find tactile maps useful in familiar or unfamiliar locations. All participants stated they would find a tactile map useful in unfamiliar locations.

"I find, the blind, if we know an area very well, that's second nature to us, we could walk around with our eyes closed is a bit of an understatement. But for areas we don't know as well it would be an advantage." – Jim

"We are always taught by our parents to plan ahead. I remember my father would always, whenever he was going out in a new area, he'd be on street view and things like that looking. Not really a tactile map but that worked for him every time. Results are results." – Jim

"I'd probably study it well before I left, and I might even check out a few things beforehand if I knew somebody else that knew that area quite well." – Thomas Bryan

"Say, for example, I have a great sense of satisfaction, ok I've got a guide dog, but if I'm going somewhere where I don't know, I find out. I get the instructions and if you can get from A to B and back again without having to ask anybody to help you it's a really good feeling." - Kaye

In familiar locations, four of the five participants indicated they would use tactile maps. Uses of a tactile map in familiar locations included to assist others who ask for directions, to refresh their memory if it has been some time, or to learn more detail about the location.

"...people do stop and ask for directions, and it would be a tool for assisting others." – Jim

"I might use it to explain to somebody else how to get there..." – Thomas Bryan

"...I might think well you know I haven't been there in three months I better refresh my memory as to what are the areas and streets I'm going to have to cross over beforehand..." – Thomas Bryan

"...if I wanted to go to a different destination on that route, I might just check out that it was between one or two streets or something like that." – Judy Small

"If it was an area that I was familiar with I would actually probably, like to know more detail..." – Kaye

Three participants discussed the lessening ongoing need for tactile maps as a location becomes familiar to them.

"...that's the difficulty with it, like most things once you know something you probably don't need to refer to it as often as you would have at the beginning." – Thomas Bryan

"If I was in an area that I know then you can just get it in your head and you know where you are as well. Your memory gets quite good after a while" – Kaye

"I don't know that I'd use it once I'd gotten used to the route that I'd be doing all the time." – Judy Small

General Reference Maps

Participants predominately indicated they have used or would find use for general reference tactile maps. All participants stated they would use a tactile map for reference or to learn about an area. For example, Thomas said he would use a tactile map "more to learn something than do something." When asked to describe their past experiences with tactile maps, seven of the eleven recounted experiences were about general reference maps. General reference tactile maps included those used at school depicting countries and topographic features as well as bespoke city or indoor maps.

Participants indicated they may use a general reference tactile map to plan before leaving their house or prior to going to a new location, for example on holiday.

"I might use it. . . as to what are the areas and the streets I'm going to have to cross over beforehand." – Thomas Bryan

"If I'm going somewhere having a tactile map might be quite useful to get a bit of a picture in my head the places of which I'm going to." – Judy Small

"If you were going on a trip or something it would be quite nice to be able to look at it before you left, that's quite difficult as well." - Kaye

"Planning ahead. Planning ahead is probably the most obvious use for a reference map." - Jim

Navigation Maps

Participants spoke less about using maps whilst navigating. Participants stated that often tactile maps are large, and this would impact their eagerness to use a tactile map while navigating:

"It's very difficult to read a tactile map while walking and so it's the sort of thing that I might read on the bus before I get there..." – Thomas Bryan

"If the map is more than one braille page it might be two or three pages taped together to get the whole size of the geographical area that you want to look at, and then you may have to key on another page as well. You need to spread it out on the kitchen table to have a good look at it and sort out where your north

southeast and west are and all that sort of stuff." – Judy Small

"It wouldn't be useful if I was walking around with a large piece of paper" - Tracy

"I definitely wouldn't use it while I was walking." – Judy Small

4.3.4 Inclusive Design

Four participants stated they perceived benefits of being involved in the design and testing phases of tactile map creation. One participant indicated they would only like to be involved with the testing phase of research. No participants stated they would not like to be involved. This result, however, is likely to have been somewhat impacted by voluntary response bias. As participants volunteered to be involved with this research, those who do not prefer an inclusive design approach may not have volunteered and therefore are are excluded from the results.

"If it was something specifically just for me ... then I might be able to sit with someone who can create it for me, and I can say the key things I want to know... and then have a look at it and provide some feedback if I didn't think it was doing what I needed it to do." – Thomas Bryan

"I think it's good to have our feedback because I would say that the people making the maps would be sighted, and they would be looking visually at what they're doing but it's probably important that someone gets to feel the map instead of looking at it visually." – Kaye

"Initial conversations I think are really useful and then look at the product before it is final." – Judy Small

Two participants recommended focus groups to assist with designing tactile maps, Judy had run focus groups for the design of a tactile map in the past. Judy described her focus group sessions:

"...we had two sessions about finding out about what they wanted and what

worked and didn't work, and I think the accessible formats people brought along some examples so they had choices and they could make decisions based on what they had been shown because some of them had never seen a map in their life and had no idea what a map should do." – Judy Small

Thomas and Kaye also discussed standards in tactile mapping. Thomas indicated that if the tactile map was not specifically for him and that tactile mapping standards were adhered to, he may not necessarily need to be involved in design.

"...probably wouldn't need to be really, as long as the map has been designed to a particular standard and I think there are particular guidelines and standards about producing tactile maps and if it adhered to those and I knew what they were then I wouldn't really need to be involved" – Thomas Bryan

"But I think, what you've got to do with maps you've got to be standard. Try and get a uniform key for different things so that you use the same thing all the time, for what you're trying to indicate." – Kaye

The involvement of professionals either tactile map designers, cartographers or GIS professionals was also discussed by Judy and Kaye. Both spoke of the benefit of a collaborative effort between members of the blind and low vision community and those with professional skills.

"I think it's important, but you also need professionals as well because they can tell you how professionally how to make a map or what they know works because they produce maps, and they can give you advice around production elements." – Judy Small

"...you get good information from users, but you get really good data from professionals. It's the difference between 'I use something, and I know how it works and it works fine for me' but actually I'm not an engineer and I don't design things and an engineer might go well that works fine for me, but it doesn't work well for someone using a wheelchair. That's where you need the expert advice to get your definition right" – Judy Small

4.4 Interview Two: Usability Studies

The remainder of this chapter presents the results of the second interview: 'Part Two: Usability Tests'. satisfaction, efficiency, and effectiveness were measured to analyse how data selection, map purpose, and experience may be linked to the usability of tactile maps. These results are not representative of the population of those who are blind or have low vision due to the low participation rate. They do, however, provide an indication of relationships and provide suggestions for future exploration. All statistical output presented in this section was calculated using SPSS. To generate large print graphs the data was visualised using the python module matplotlib.

Each participant answered three map reading tasks using four different sample tactile maps. In total 60 map reading tasks were completed. Participants took an average of 132.35 seconds to complete all three map reading tasks for each map. The quickest completion time was 28 seconds, the longest completion time was 298 seconds.

Minimum	Maximum	Mean	Median	Std. Deviation
28	298	130.6	112.5	69.841

Table 4.5: Descriptive Statistics of participant response times

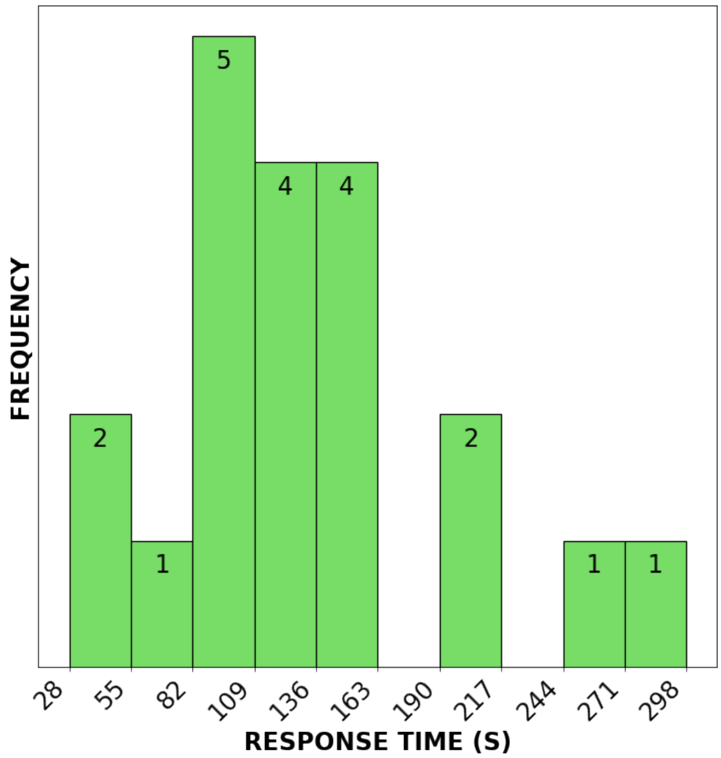

Figure 4.2: Participant Response Time Frequency Histogram (Total time to complete all three map reading tasks)

4.4.1 Satisfaction - User Preference

Once the map reading tasks were completed participants were asked what they liked or disliked about the four sample tactile maps. Participant responses were categorised and recorded as positive or negative, a frequency table (Table 4.6) displays these results. STM2 had both the highest number of positive (11) and negative comments (8). STM1 and STM4 shared the least number of positive comments (5).

Most negative comments (65%) discussed symbology. For example, participants stated they confused one symbol (you, crossing) for another (round about, park) or they found a particular symbol confusing (traffic light). Most positive comments (31%) were regarding spatial ability, for example participants stated they enjoyed finding symbols or identifying routes. One participant mentioned they enjoyed using the tactile map as it was "easy to picture in the mind's eye". Some participants discussed data selection (34% of both positive and negative comments), these comments were often the participant stating they liked having a dataset on the map (crossing information, traffic direction, and curb cuts). Participants also mentioned datasets that, if included, they would have found useful (pedestrian crossings and crossings).

	STM1		STM2		STM3		STM4	
	+	-	+	-	+	-	+	-
Participant One	1	3	4	2	0	4	1	3
Participant Two	1	2	1	3	0	2	1	1
Participant Three	2	1	1	1	0	1	0	2
Participant Four	0	1	2	1	0	0	2	0
Participant Five	1	2	3	1	1	0	1	1
Total	5	9	11	8	1	7	5	7

Table 4.6: Positive (+ve) and Negative (-ve) Comments Frequency Table

When asked if they would use a tactile map like the ones provided most participants responded yes (80%). One participant stated they would not use STM1, and another stated they would not use STM4. Some participants elaborated on their responses indicating they were more likely to use the tactile maps when going to new, unfamiliar locations. In reference to the navigation maps (STM1 and STM2), participants stated they would prefer to use the map at home before heading out.

Participants were also asked to rate how easy or difficult it was to use each tactile map using a scale from one to five. STM2 had the lowest rounded average (1) indicating that participants found this map the easiest to use, all other tactile maps had the same rounded average (2).

Tactile Map Rankings

To determine tactile map preference participants were asked to rank the tactile maps. All participants indicated their first preference map was STM2, the navigation map containing uncommon datasets (Figure 4.3). Participants were less unanimous with their remaining preferences. Three participants indicated STM4, the reference map containing uncommon datasets, was their second preference, ranking STM4 second overall. STM1, and STM3 were closely ranked by participants, STM1 marginally ranked higher and therefore is third.

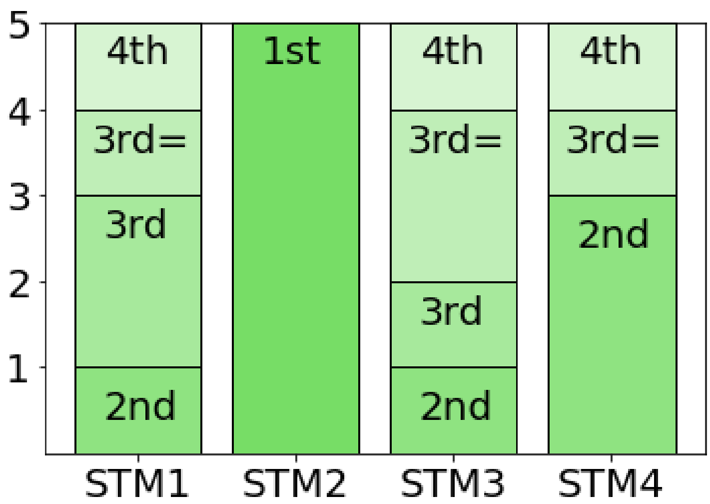

Figure 4.3: Sample Tactile Map Overall Preference

Participants were asked to rank the tactile maps within map purpose (Figure 4.4). When comparing STM1 and STM2 (navigation) all participants indicated they preferred STM2 (uncommon). When comparing STM3 and STM4 (general reference) these was less clarity among participants. More participants (4) ranked STM4 first or first equal, establishing STM4 (uncommon) as the preferred map. Therefore, across both navigation and reference map purpose participants indicated they preferred the maps with uncommon datasets.

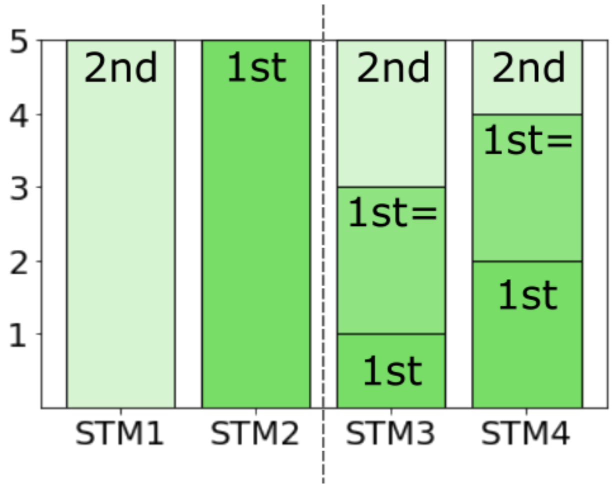

Figure 4.4: Preferences Grouped by Map Purpose (L: Navigation; R: General Reference)

Tactile Map Experience

All novice and intermediate participants ranked STM2 as the preferred of the four sample tactile maps presented during the usability tests (Figure 4.5). The intermediate participants were also unanimous in their ranking of second preference, both participants selected STM4. The intermediate participants marginally indicated they then preferred STM3 and opposed to STM1. The novice preferences were different, novice participants preferred STM1 as second and then STM3 and STM4 were third-equal.

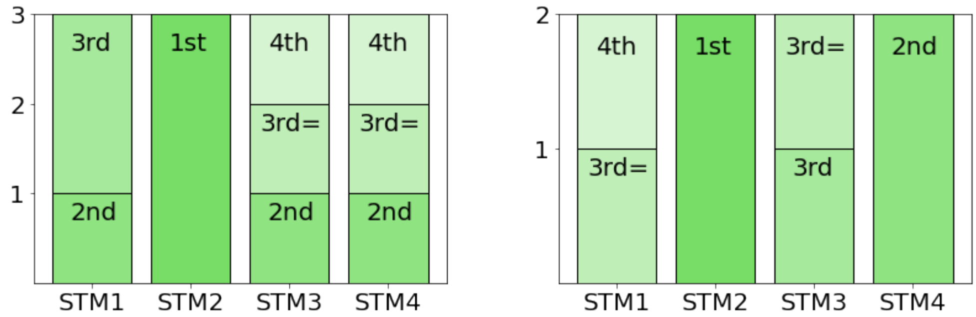

Figure 4.5: Novice (left) and Intermediate (right) Sample Tactile Map Preferences

4.4.2 Efficiency - Response Rates

Eta-squared statistics and t-tests were conducted to observe if there may be an association between participant response times and data selection, map experience, or map purpose. The measure of sample tactile map efficiency is not significant due to the number of participants however the results are presented below.

Data Selection

Data selection did not appear to be associated with participant response times. A detailed investigation of the data suggests there may be an association between data selection and participant response times when completing the estimate direction task. The estimate direction map reading task was the most complicated as it involved establishing a relationship between two points on the sample tactile maps. The indication of association here suggests that if this usability analysis was repeated with more participants completing more difficult map reading tasks statistically significant results may be observed.

	Eta-squared	F	t	Sig.
Map Datasets	0.0012	0.198	0.258	0.658
Search	0.049	2.604	0.967	0.124
List	0.0058	0.008	0.325	0.928
Count	0.096	0.001	-0.922	0.980
Estimate Direction	0.366	5.149	2.151	0.053

Table 4.7: Eta Squared statistic and t-test results for data selection

Map Experience

Statistical analysis of participant response times and map experience show no association. The calculations show there may be some association between tactile map experience and response times for the list map reading task. No association was observed between tactile map experience and participant response times for the search, count or estimate direction map reading tasks.

	Eta-squared	F	t	Sig.
Experience	0.019	6.781	1.052	0.297
Search	0.075	5.306	-1.21	0.242
List	0.217	8.423	2.236	0.038
Count	0.367	0.154	-2.153	0.063
Estimate Direction	0.382	5.992	2.223	0.057

Table 4.8: Eta Squared statistic and t-test results for tactile map experience

Map Purpose

Map purpose was not associated with participant response times in this research. As the count tasks were restricted to the reference maps and the estimate direction tasks were restricted to the navigation maps, these tasks were not evaluated regarding map purpose.

	Eta-squared	F	t	Sig.
Map Purpose	0.006	0.119	0.187	0.732
Search	0.1	3.781	-1.409	0.068
List	0.0017	0.262	-0.56	0.615

Table 4.9: Eta Squared statistic and t-test results for map purpose

4.4.3 Effectiveness - Success Rates

The measure of sample tactile map effectiveness is not significant due to number of participants however the results are presented below.

Data Selection

In general, data selection was not associated with map reading task success rates. Marginally (10%), participants were more successful when using the tactile maps with the uncommon datasets (STM2 and STM4). When completing the search, list, and estimate direction tasks, participants success rates were also higher when using the uncommon datasets. Participants were all successful completing the count task when using the common datasets (STM1 and STM3), comparatively only 40% success rates were observed using the uncommon datasets.

	Common		Uncommon	
	% Correct	% Incorrect	% Correct	% Incorrect
Map Dataset	63.3	36.7	73.3	31.7
Search	90	10	100	0
List	20	80	50	50
Count	100	0	40	60
Estimate Direction	60	40	100	0

Table 4.10: Data Selection Crosstabulation Analysis of Task Success

Map Experience

Comparing tactile map experience with map reading task success rates using crosstabulation demonstrates that tactile map experience was not associated with task success (Table 4.11). When completing the count map reading task 50% of the novice participants successfully completed the count task whereas 100% of intermediate participants were successful.

	Novice		Intermediate	
	% Correct	% Incorrect	% Correct	% Incorrect
Experience	66.7	33.3	70.8	29.2
Search	100	0	87.5	12.5
List	33.3	66.7	37.5	61.5
Count	50	50	100	0
Estimate Direction	83.3	16.7	75	25

Table 4.11: Map Experience Crosstabulation Analysis of Task Success

Map Purpose

The crosstabulation analysis in Table 4.12 demonstrates consistent success rates across the search and list map reading tasks for each map purpose. Again, the count and estimate direction map reading tasks were unique to map purpose and therefore cannot be compared.

	Reference		Navigation	
	% Correct	% Incorrect	% Correct	% Incorrect
Map Purpose	70	30	66.7	33.3
Search	100	0	90	10
List	40	60	30	70
Count	70	30	-	-
Estimate Direction	-	-	80	20

Table 4.12: Map Purpose Crosstabulation Analysis of Task Success

Chapter Summary

Six participants took part in the interview sessions. Five participants took part in interview one, four original participants and one additional participated in interview two. Thematic analysis demonstrated that participants value tactile maps as they provide independence and improve spatial ability. When asked about data preferences all participants spoke about pedestrian crossings, intersections, and street/road names. All participants also discussed data currency, for example changing shop locations.

Usability studies revealed that all participants unanimously agreed they preferred STM2. STM2 contained high-value datasets identified during the initial interviews which were uncommon on the assessed accessibility maps. STM2 contained crossing information, traffic direction, traffic lights, curb cuts, roads, street/road names, and a 'you are here' location. This research did not involve enough participants to provide representative statistical analysis of response times (efficiency) and success rates (effectiveness), however the results suggest data selection, map purpose and map experience are not associated with tactile map usability.

Chapter 5

Discussion

This research investigated the data selection and tactile map preferences of blind and low vision participants. Using thematic analysis and usability, this thesis examples the results of 10 interviews with blind and low vision participants over two sessions. This chapter first discusses the value of tactile maps, then the data selection preferences of the interview participants. Participant preferences are analysed based on their past tactile map experience and map purpose. Then, the usefulness of data selection on tactile map usability is examined. The results are analysed by tactile map experience and map purpose.

5.1 Research Question One

What do blind and low vision tactile map users value about tactile maps?

5.1.1 Choice and Independence

The most prominent themes deduced from thematic analysis of participant responses to the initial interview questions were choice and independence. All participants wanted the freedom to choose what navigation tool they use. Participants did not suggest that tactile maps would be more useful than other navigation assistance (for example GPS). However, with the emphasis placed on the importance of choice, the blind and low vision individuals in this study were likely to value tactile maps as an alternative. Participants also value independence, in particular the satisfaction they gain by navigating independently and without assistance.

The importance of choice and independence is in line with the United Nations Convention on the Rights of Persons with Disabilities. Past research highlights the positive impacts on attitudes when individuals have autonomy and can choose (Collins & Hoyt, 1972; Goethals & Cooper, 1972; Linder et al., 1967). Two participants pointed out that choice extends beyond creating tactile products. These participants mentioned the community needs to be informed of their choices and the tactile products must be easy to obtain. The United Nations Convention (2006), Perkins (2001), and Lobben and Lawrence (2012) all state that for a product to be accessible it must be easy to access, reproducible, and provided at a low cost.

5.1.2 Spatial Ability

Participants also valued tactile maps because they are effective tools to improve spatial ability and to build cognitive maps. The two participants with the most tactile map experience stated that the tactile maps they have used made it easier for them to build a "mental image". All participants with previous tactile map experience compared their learning experience with tactile maps to GPS and/or audio assisted navigation. None of the participants discounted GPS or audio navigation aids, but saw tactile maps as additional support.

Research findings indicate that tactile maps can support a blind or low vision user's development of cognitive maps and improve the likelihood of successful navigation (Lobben, 2005; Lobben & Lawrence, 2012; Perkins, 2002; Siekierska et al., 2003). According to Parush et al. (2007, p. 240) and Ishikawa et al. (2008, p. 74), any individual who relies on GPS assisted navigation will have "reduced situation awareness" and "poorer topological accuracy".

5.2 Research Question Two

What are the data selection preferences of blind and low vision tactile map users?

During the initial interview, participants highlighted that crossing roads is often difficult. Teaching individuals how to cross intersections is a key orientation and mobility task in the blind and low vision community (Holloway, 2022). When asked about data selection preferences, participants placed the most emphasis on discussing street and road names, crossings, intersections, building uses, and the currency of data.

Participants felt that intersection and crossing datasets would be useful as they would enable them to identify where and how to cross a road safely. In addition, unable to read street signs, participants indicated they would use street and road names on tactile maps to confirm they were at the correct intersection or crossing. Participants expected to use the tactile maps in the environment or as preparation beforehand. Holloway (2022) found that tactile maps are commonly used to describe intersections to blind and low vision individuals. However, the medium through which they are created varies, for example, mobility instructors may use 3D printing, swell paper, Lego, or draw on the hand or on their back.

All participants preferred the same sample tactile map when asked to rank the provided samples. Consistent with the results of the initial interview session, this sample tactile, STM2, map contained a detailed description of an intersection, including streets and roads, street and road names, intersection type, crossing information, curb cuts, and traffic direction arrows.

Building uses were also valued by participants, however definitions of use varied. Examples of suggested building uses included significant landmarks the participant could use for reference and buildings of use to the participants during their journey. Participants were less concerned with having accurate representations of the building outlines on the tactile map. Survey participants in the study by Rowell and Ungar (2005) indicated that public buildings relevant to blind and low vision people may be valuable on a tactile map. However, their survey participants also stated that other buildings, which may be useful reference points for sighted people, are often not useful for blind and low vision navigators.

Little literature provides suggestions of useful tactile map datasets. Existing accessibility maps were investigated during this research, and the datasets that appeared on thirteen maps were listed to participants (Table 3.6). Detailed intersection and crossing information were often missing on these accessibility maps; pedestrian and traffic crossing datasets only appeared on two maps. Building uses appeared on eleven maps, notably however building outlines and uses are currently not included on tactile maps generated by TMAP, a product used in New Zealand.

The NSW Guide (2006) suggests that where possible land cover information should always be presented on tactile maps. When asked four participants indicated that this information may be useful. When conducting the usability map reading tasks, however, participants unanimously preferred the tactile maps without land cover information.

All datasets were selected by at least one participant in the initial interviews. Each participant envisioned different uses for the hypothetical tactile maps and a high variation in responses supports this assertion. Data selection is similarly wide ranging in the wider cartographic literature where authors argue data selection should be based on the map's purpose (Forrest, 1999; Robinson et al., 1995).

Creating tactile maps for blind and low vision individuals cannot be a 'lift and shift' approach, whereby a print map is converted into a tactile map. Data selection preferences elicited during this research indicate different considerations are required during data selection for tactile maps. The Braille Authority of North America (2012) recommends that significant generalisation is undertaken when constructing a tactile map as most print maps, designed for visual interpretation, contain too much detail. Gardiner and Perkins (2002) also contend that tactile map design requires "an extremely simplified version of a visual image" (p.1).

The data selection preferences found in this research are different to current accessibility maps, and literature recommendations. Inclusive design and user involvement is of value during map production. As literature lacks clear data selection recommendations the tactile map user, with practical first-hand experience, is best placed to influence tactile map design. This can occur before and during production. In 2005, Rowell and Ungar came to similar conclusions: they noted that tactile maps are unique, where they are influenced "by having to make decisions about what to include". The creation of print maps takes the opposite approach and is "influenced by a principle of what map information to leave off" (p. 1).

Data Currency

The currency of data was an unexpected theme identified during thematic analysis of participant responses. All participants mentioned spatial data currency. Some participants directly mentioned outdated tactile map products, others indicated they would like to be able to identify change information such as when intersections change or stores move. One participant stated they would find access to real-time spatial information such as traffic density useful. Currency is a known limitation of both tactile and print maps (Ducasse et al., 2015; Yatani et al., 2012). Tactile mapping research has identified how to automate production (Kazemi et al., 2004; TMAP, 2018; Wabiński & Mościcka, 2019) however the distribution of tactile map products remains an issue (Siekierska et al., 2003).

5.2.1 Map Experience

In addition, three participants with intermediate tactile map experience suggested tactile map floorplans. Intermediate participants had more prior experience with tactile maps and therefore also a variety of datasets, for example building floor plans. None of the novice participants mentioned floorplans. In this case, map experience appeared to be associated with data selection preferences, however more investigation with a larger number of participants is required in order to confirm this.

5.2.2 Map Purpose

All participants indicated they were more likely to use a tactile map when heading to a new or unfamiliar location. Participants indicated that as their spatial understanding and memory of a location improved, they may use the tactile map less often, unless this map was able to provide additional detail or peripheral information about the location.

In addition, most participants would prefer to use the tactile map for preparation before the navigation task. Therefore, during the initial interview, participants suggested that reference maps may be of most use to them. Participants noted they preferred to prepare and know their route prior to heading out, they also mentioned their hands may often be full, for example if they have a guide dog. These findings are similar to those of Rowell and Ungar (2005) whose survey participants stated they "would rather use [tactile maps] for general orientation rather than follow them closely for very specific navigation purposes" (p. 10).

These findings are important to tactile map designers as they enable data selection decisions. Knowing that blind and low visions individuals would prefer to use a map prior to navigation allows designers to construct larger maps and enables them to add additional detail to the map which may not have otherwise been possible.

5.3 Research Question Three

How does data selection affect the usability of tactile maps for those who are blind or have low vision?

Overall, the results show that varying map data was not associated with the efficiency (time taken) of a tactile map, when the map reading tasks were relevant to the data and the map purpose. However, participants completed the estimate direction map reading task quicker when using STM2. STM2 contained uncommon descriptive intersection datasets. Participants placed significant emphasis on these datasets during their initial interview sessions.

Some participants inferred a route whilst carrying out the estimate direction tasks. When using STM2 these participants quickly inferred they could navigate using the crossings. Some participants took longer to complete the estimate direction map reading task when using STM1, they noted there was no crossing information on this map which caused them some confusion when attempting to infer a route.

Data selection was not associated with the effectiveness (success) of a tactile map. On average most map reading task success rates were higher when using the uncommon datasets (STM2 and STM4) but these rates were not significantly higher. When performing the count map reading task, participants were more successful when using the common datasets on STM1 and STM3.

Participants unanimously concluded they preferred STM2, and they had the most positive comments (11) to make about this map. However STM2 also had the move negative comments. STM3 received the lowest participant ranking, the remaining two tactile maps were closely placed. These findings, despite being limited in significance due to the low sample size, uncover a clear need and want for detailed intersection information within the blind and low vision community. Crossing intersections is a key orientation and mobility training task (Holloway, 2022), in their initial interviews participants spoke at length about the difficulties of crossing the road, their preferences for STM2, a map containing descriptive intersection information, shows there is a need for improved accessibility to spatial data that describes intersections. This research echoes the concerns of Gardiner and Perkins (2002) regarding the lack of current literature providing data selection recommendations as participants preferred the uncommon datasets.

In the the sample tactile map preference rankings participants indicated they did not value the building use datasets as much as anticipated after the initial interviews. This finding contradicts initial data selection preference from interview one and highlights the importance of involving users at multiple points during tactile map production (Holmes, 2018; Kujala, 2003; Wilson et al., 1997). The second interview sessions established the importance participants placed on intersections, compared to other datasets. When using the maps, participants clearly identified the value of tactile maps at intersections. When discussing the building uses participants raised concerns about data currency (building uses changing) and relevancy (building uses relevant to each participant differed).

5.3.1 Map Experience

Map experience was not associated with map reading task speed (efficiency) or success (effectiveness). In addition, all participants preferred the same tactile map, STM2. The low number of participants and/or lack of experienced users with extensive knowledge of tactile maps may have impacted results. There is a lack of exposure to maps and cartographic products within the blind and low vision community and it can be difficult to locate experienced users from within a small target participant group (Higgins, 1999; Perdue & Lobben, 2016). Alternatively, it is possible that due to self-selection, experienced tactile map users were not keen to participate. Rowell and Ungar (2005) found experienced users do not find tactile maps particularly useful.

Map experience appeared to be associated with time taken to list features on the tactile maps. Intermediate users were able to list the tactile map features faster than novice users. Analysis (section 4.4.3) showed map experience also appeared to be associated with a user's ability to successfully complete the count task. It is not surprising that intermediate users performed better during some map reading tasks as these participants were more likely able to use past experiences to interpret the sample tactile maps (Crowley & Siegler, 1993; Groen & Parkman, 1972; Siegler, 1987; Siegler & Lemaire, 1997; VanLehn, 1988). The novice users were more likely to construct solutions based on misconceptions and not successfully complete the map reading tasks due to their reduced experience (Anderson & Leinhardt, 2002; VanLehn, 1988). This was observed in our results, 36% of the questions answered by novice users were incorrect, intermediate participants were incorrect 29% of the time.

5.3.2 Map Purpose

Map purpose was not associated with the overall usability, effectiveness or efficiency of the sample tactile maps presented in this research. The map satisfaction rankings, presented in section 4.4.1, demonstrate that data selection was associated with sample tactile maps preferences more than map purpose. All participants preferred STM2, a navigation map. Only one participant listed the other navigation map, STM1 as their second preference. Most participants listed STM4 as their second preference. STM4 was a general reference map containing similar datasets to STM2. Participants valued the data displayed on each map more than their purpose. This research questions the common belief that data selection depends on map purpose as participant preference maybe more driven by datasets (Forrest, 1999; Robinson et al., 1995).

Chapter Summary

Blind and low vision individuals value the choice, independence, and improved spatial ability that tactile maps provide. Intersections and road crossings can be a difficult task for blind and low vision navigators, spatial information describing intersections is of value to these navigators. When assessing the sample tactile maps, all participants preferred STM2, this map contained: streets and roads, street and road names, intersection type (traffic light), crossings (traffic lights), curb cuts and traffic direction indicators. Due to the low number of participants, statistically, data selection, map experience, and map purpose were not associated with tactile map usability. However, data selection is important as participant data selection preferences did not vary across experience levels or map purpose.

Chapter 6

Conclusion

Data selection is an integral generalisation step, failure to select the correct data may result in confusion and navigation failure (Agrawala & Stolte, 2001). Literature states that data selection depends on the map's purpose, design, scale, and level of detail (Forrest, 1999; Robinson et al., 1995). Tactile maps require substantial simplification, therefore data selection is crucial (Gardiner & Perkins, 2002; Mulíčková & Štampach, 2016). Current tactile map standards and guidelines provide numerous recommendations on symbology, labelling, and printing, however, they lack guidance on data selection (Gardiner & Perkins, 2002). Often sighted tactile map makers must instead rely on the advice of their users.

Thematic analysis enables researchers to define and organise themes within their data (Braun & Clarke, 2012). In the blind and low vision community thematic analysis has identified common outdoor difficulties (Riazi et al., 2016) and transport issues (Gallagher et al., 2011). Thematic analysis has the potential to reveal unknown insights about tactile mapping and improve data selection. Usability studies provide a structured approach to improving product design and can be used alongside thematic analysis to refine and confirm results (Dumas & Redish, 1999).

Two interview sessions were used in this study to understand the data selection preferences of blind and low vision navigators. The initial interview: 'Part One: Experiences and Opinions' found that blind and low vision individuals value tactile maps despite the availability of other navigation aids such as GPS. Participants valued the choice and independence provided by tactile maps and the improved spatial ability gained when using tactile maps.

Participants agreed that tactile maps describing intersections in detail would be beneficial. All participants described the difficulties they face when attempting to cross intersections safely and efficiently. Specifically, participants mentioned that knowing the type of intersection, type of crossing, and street and road names would be useful. The intermediate participants, with more experience with tactile maps, indicated that tactile floorplans and indoor maps would also be useful.

Participants indicated they would prefer to use tactile maps to learn about a location in preparation for a navigation task. Some participants mentioned they have their hands full and therefore using a tactile map during navigation would not be possible, for example, if they had a guide dog or cane. All participants indicated they were more likely to use a tactile map if they were heading to an unfamiliar location. Some participants indicated that they would still use tactile maps as a location became more familiar to them, if the tactile map was able to provide a navigator with detailed or peripheral descriptive information, such as side-streets and/or alternative routes.

Four sample tactile maps were presented to participants during the second interview session. Participants were asked to carry out several simple map-reading tasks. Usability analysis of results demonstrated that data selection is not associated with tactile map usability (when the map reading tasks are relevant to the data selected). Data selection did appear to be associated with participants' performance during the estimate direction map reading task. Estimate direction was the most complicated map reading task as the process involved establishing a relationship between two features. Some participants took longer to estimate directions as they established direction by inferring a route between the two locations. Participants voiced frustrations when attempting to infer a route using the maps containing common data due to the lack of information describing how to cross the intersection.

In this research, tactile map experience did not appear to be associated with map reading task performance. As noted in the discussion chapter, this research only included novice and intermediate participants, no experienced participants took part. It may be possible that this finding would be different if the results were able to compare the time taken and success rates of novice and experienced tactile map users.

All participants unanimously agreed they preferred SMT2. STM2 contained streets and roads, street and road names, intersection type, crossing, curb cuts and traffic direction arrows. The sample tactile map participant preferences aligned with the data selection preferences obtained during the initial interview. Participants preferred the uncommon datasets, these contained detailed intersection information. Across both navigation and general reference map purpose, participants remained consistent in their preferred spatial datasets (uncommon). This suggests that it is not always correct to assume map purpose drives data selection decisions, and, in some instances, it might be possible to standardise data selection.

6.1 Recommendations

There are several practical recommendations that can be made based on the findings of this research. **First, blind and low vision participants should be included in the design of tactile maps.** This research clearly demonstrates the value of inclusive design to both the blind and low vision community and the tactile map designer. **Frequent user involvement is recommended for tactile map makers (and cartographers constructing print maps).** When standards do not contain the necessary information for data selection, the involvement of map users will ensure the appropriate data is selected.

Blind and low vision navigators would benefit from tactile maps that can be used for route planning purposes prior to the navigation task, for example at home. Participants indicated they were more likely to use a tactile map if it was of a location unfamiliar to them and contained relevant and detailed intersection information, such as street and road names, crossings, and intersection types. Participants also indicated they may find building uses helpful; participants varied in their definitions of building uses and the results of the usability tests suggests this information was not as useful as initially thought.

Making street and road names signs more accessible at pedestrian crossings and intersections would be useful for blind and low vision navigators. Participants spent a significant about of time discussing intersections and the difficulties they can face crossing them. An example of accessible street signage may be adding braille and large print street labels to the posts at hand and eye level. In addition, detailed intersection information is useful for blind and low vision navigators. **Tactile maps should include data such as street and road names, intersection type, and crossing information.**

Participants valued the choice and independence tactile maps provide. Participants were successful in interpreting the sample tactile map products and completing some common and simple map reading tasks. Tactile maps therefore remain effective tools which can be used to convey spatial information to blind and low vision navigators, particularly in new, unfamiliar, or changing environments.

6.2 Future Research Directions

This research demonstrated the use of inclusive design, thematic analysis, and usability studies to understand tactile map data selection preferences of blind and low vision navigators. To further identify how spatial data can be improved for the blind and low vision community, future research recommendations are made below.

All participants mentioned the currency of spatial data and its limitations during their initial interview session. The currency of data was not evaluated in this research. Future research might investigate techniques to communicate changing spatial information to blind and low vision navigators. Issues relating to the currency of data are not limited to tactile mapping, they exist also in the print and digital space. Researching how often spatial datasets need to be updated in order to be considered current would be beneficial to numerous spatial organisations and disciplines.

This research highlighted the lack of information about data selection within tactile mapping standards. To complement the abundance of research recommendations into tactile map symbology and printing standards, future research may investigate creating tactile map data selection guidelines given a map's purpose. This research demonstrated one avenue to effectively make data selection decisions when the cartographer has no lived experience of the maps use or purpose. Future research should investigate other methods and evaluate if alternative methods generate different, better, or more detailed results.

The value of a 'building uses dataset' was inconsistent in this research. At first, building uses were identified as highly valuable to participants during their initial interviews. However, building uses were not often discussed in the second interviews, instead participants almost entirely discussed intersections. Future research might make a detailed investigation into this finding, analysing the value, purposes and relevance of a building name and use datasets.

6.3 Concluding Remarks

This research aimed to provide insights into the value of tactile maps and spatial data within the blind and low vision community. All participants in this research indicated they valued the choice, independence and improved spatial ability tactile maps provide. Data selection was not associated with tactile map task performance. However, participants indicated they preferred crossing and intersection information such as crossing type, intersection type and streets and road names. This is as opposed to reference information such as land-cover or building outlines. Participant preferences did not change when the map purpose was altered.

The recommendations that emerged from this research were: (1) include participants in the design and testing phase of the tactile product lifecycle, this will ensure the correct datasets are selected. (2) Create tactile maps that can be used prior to the navigation task, (3) make street and road name signage more accessible, and (4) include detailed crossing information, streets and road names, and label building uses where practical and relevant. Taken together, this research on data selection hopes to pave the way for future research on tactile maps and encourage others to use inclusive design to help empower blind and low vision navigators.

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