School of Information Systems

A Conceptual Multi-Modal HCI Model for the Blind

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This thesis is presented for the Degree of

Master of Information Systems

of

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Ian Blackburn   Date

Dedication

This thesis is dedicated to the lord Jesus Christ and to all who are blind and use Braille or Braille keyboard devices. May the research presented in this thesis lead to the development of better Braille keyboard devices.

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Abstract

The ability for blind people to read and write Braille aids literacy development. A good level of literacy enables a person to function well in society in terms of employment, education and daily living. The learning of Braille has traditionally been done with hard copy Braille produced by manual and more recently electronic Braille writers and printers. Curtin University is developing an electronic Braille writer and the research on an interface for Braille keyboard devices, presented in this thesis, forms part of the Curtin University Brailler project.

The Design Science approach was the research method chosen for this research because of the flexibility of the approach and because it focuses upon the building of artefacts and theory development. The small sample size meant that both individual interviews and a focus group were employed to gather relevant data from respondents. The literature review covers a variety of areas related to computer interfaces and Braille keyboard devices. A key finding is that the interaction paradigm for Braille keyboard devices needs to differ to interfaces for sighted individuals because of the audio, tactile and serial nature of the information gathering strategies employed by blind people as compared with the visual and spatial information gathering strategies employed by sighted individuals. In terms of usability attributes designed to evaluate the interface consistency was found to be a key factor because of its importance to learning and memory retention.

However, two main functions carried out on a computer system are navigating and editing. Thus the model of interface for Braille keyboard devices presented in this thesis focuses upon navigation support and editing support.

Feedback was sort from by interviews with individuals and a focus group. Individual interviews were conducted face to face and via the telephone and the focus group was conducted via Skype conference call to enable participants from all over the world to provide feedback on the model.

The model was evaluated using usability attributes. Usability was important to the respondents, in particular consistency, learnability, simplicity and ease of use were important. The concept of rich navigation and infinitely definable key maps were understood by respondents and supported. Braille output is essential including the ability to show formatting information in Braille.

The limitations of the research included the few respondents to the interviews and the choice to focus upon a theoretical model rather than implementing the model on an actual device. Future research opportunities include implementing the interface concepts from the model on to touch screen devices to aid further development of the interface and implementing the interface on a physical device such as the Curtin University Brailler.

Chapter 1: Introduction

1.1 Introduction

Without education and training, people (especially those who are blind) have little chance of obtaining meaningful employment. The Building Diversity Project, conducted by the Department of Training and Employment (2000) revealed that students with vision impairment have less opportunity to gain qualifications at vocational and tertiary levels compared with other students, due to the inexperience of educational institutions in catering for students with this type of disability. Furthermore, during 2007, Vision Australia conducted a survey of nearly 1900 working age vision impaired and blind individuals on their labour force participation and barriers to employment. The survey revealed that 26% of the participants were unemployed compared with a national average of 4.5%. However, this figure increased to 63% when discouraged workers were included, compared with a national average of 14% for sighted individuals (Vision Australia 2007).

A study by Ryles (1996) examined the relationship between Braille reading skills and employment, income, education and reading habits. Her study included only those congenitally legally blind between ages of 18 to 55 with no other disabilities. The 74 respondents either learned Braille as a primary medium as a child or learned it later in life as a result of either deteriorating sight or acquired blindness.

It is of interest that 32% of the respondents completed bachelor degrees and 23% had post graduate qualifications. 30% of those who learned Braille as a primary medium completed graduate degrees whereas only 13% of those who learned Braille later in life had completed graduate degrees (Ryles 1996). Additionally only two of the respondents completed doctoral degrees and these were respondents who learned Braille as their primary reading medium.

Related to this lack of opportunity is the increasing presentation of education materials in visual e-learning formats. Research undertaken by Armstrong, Murray and Permvattana (2006) found differences in the accessibility levels between low vision and blind students in Information and Communication Technology (ICT) courses that had been specifically converted for the vision impaired. It was found that the students who were totally blind had more difficulty accessing content than did those with some vision.

The researcher was born blind and has experienced the challenges of obtaining education and employment with no sight. Additionally, the researcher learned to read Braille as a first medium of writing and reading. Furthermore, the use of manual and later electronic Braille writing devices became essential skills for education and employment. The researcher has used both Braille and audio learning methods and like the findings of Murray (2008) found that his use of speech output aided the reading of large amounts of material but that Braille reading and writing are essential skills for in depth study of material. For example the researcher is able to remember phone numbers more accurately if he reads the number in Braille. Hearing the number does not produce the same long term memory retention that reading Braille does.

1.2 Demographics

Disability is a term that covers a wide range of conditions and combinations of conditions (Noonan 1999) including both physical and intellectual conditions. For example the 2003 Survey of Disability Ageing and Carers (SDAC) conducted by Australian Bureau of Statistics (ABS 2004), revealed that 20% of the population had a reported disability.[1] The gender distribution of disability is relatively even with 19.8% of the male population and 20.1% of the female population reporting a disability. Disability was defined as, "any limitation, restriction or impairment, which has lasted, or is likely to last, for at least six months and restricts everyday activities" (ABS 2004, p. 3). Examples range from hearing loss requiring the use of a hearing aid, difficulty dressing due to arthritis, to advanced dementia requiring full-time care. After removing the effects of different age structures, there was little difference between the 1998 senses data and the 2003 data. For example the disability rate was 20.1% in 1998 and 20.0% in 2003. Also the rate of profound or severe core-activity limitation remained fairly constant over this period; being 6.4% in 1998 and 6.3% in 2003.

Statistics from the SDAC report (ABS 2004) relating to employment are of particular interest. Of persons aged between 15 years and 64 years with a reported disability living in households, only 30% had completed year 12 of schooling and 13% a bachelor degree or higher. The proportions for those with no disability and therefore better opportunities were 49% and 20% respectively. The labour force participation

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[1] ABS (2003) did not provide a breakdown of disability statistics in such a way that meaningful information on visual impairment or blindness could not be extracted from the data provided.

rate of persons with a disability was 53% and the unemployment rate was 8.6%. Corresponding rates for those without a disability were 81% and 5.0%. The median gross personal income per week of persons aged between 15 years and 64 years with a reported disability living in households was $255, compared to $501 for those without a disability. Median gross personal income per week decreased with increasing severity of disability. The report shows that median gross personal income per week was lowest, $200 per week, for those with a profound core-activity limitation.

These results indicated that people with a disability are less likely to have the same levels of education, employment and income as people without a disability. Technological tools may aid these persons to participate more fully in society. It is the aim of this thesis to produce an interface to be employed on Braille keyboard devices that will enable them to function more efficiently as tools.

There are nearly 650 million people throughout the world experiencing disabilities of various types (WHO 2008). 180 million people have a visual disability and approximately 50 million are blind and cannot walk unaided (Resnikoff et al. 2004). The World Health Organisation anticipates that with normal population growth, the number of blind people will double within the next 25 years, providing more individuals who could benefit from Braille keyboard devices.

In Western Australia there are an estimated 22,500 vision impaired persons aged 18-65 (Australian Bureau of Statistics 1998). The definition of who is blind and who is vision impaired varies depending upon which source is consulted. For example

Retina Australia define legally blind “those whose visual acuity or sharpness (with glasses, if needed) is 6/60” (Retina Australia 2009, p. 1). Further they also state that “A person is "legally blind" if the combined visual field for both eyes is less than 10 degrees”. The Department of Social Security (2010, p. 1) uses the following guidelines and definition when determining permanent blindness when assessing the individual for disability support pension (DSP) or Age pension Blind (APB):

- *“Corrected visual acuity (1.1.V.50) on the Snellen Scale must be less than 6/60 in both eyes, or*
- *Constriction to within 10 degrees or less of arc of central fixation in the better eye, irrespective of corrected visual acuity, or*
- *A combination of visual defects resulting in the same degree of visual impairment as that occurring in the above points.”*

1.3 Impact of Types of Blindness

The preceding discussion indicates that people who have vision impairment may have differing degrees of sight loss which may extend to mild vision disability to total blindness. There are a variety of causes for vision impairment which will not be discussed in detail in this thesis but can be found in Appendix A. People may be born with a vision disability (congenital blindness) or may acquire the blindness or vision impairment later in life, either through an inherited condition or accident or due to other factors such as cancer.

This thesis does not investigate these causes; however, there is an impact on skill development depending upon onset of disability and severity of disability. As stated previously research by Armstrong, Murray and Permvattana (2006) found that those with total blindness had more difficulty in interacting with e-learning materials. However, Carmeni (1997, p. 97) indicates that there is a difference between Judo players with vision impairment and those with no vision. For example those with vision impairment may have more difficulty playing the sport during competitions than those with no sight. However, the vision impaired learn the skills and moves more easily than do congenitally blind students who, from his 40 years' experience teaching blind Judo players, have more motor and cognitive skill development issues than do those who have sight or who have vision impairment (Carmeni 1997, p. 88).

A study by Monegato et al. (2007) which compared the visuo-spatial mental abilities of those who were congenitally visually impaired and those who recently became visually impaired found that the former group performed quantitatively better in spatial memory tasks than did the latter group. Further, Monegato (2007) also found that those who were visually impaired performed better than congenitally blind individuals. However, the study also indicates that those who are congenitally blind demonstrate cognitive substitution where other senses are employed to compensate for loss of sight. Cognitive substitution as a concept will be considered later in this thesis in relation to the learnability of interfaces, as will the concept of cognitive load.

Another study by Brambring (2010) indicates that congenitally blind children learn at a slower rate than sighted children. He postulates that this is due to the use of visual cues by sighted children as opposed to cognitive skill used by blind children. For example "Sighted children can solve the task 'find two identical objects in a set of five objects' at about 26 months; "normally developing" blind children, not until about 42 months. The reason for this difference is that sighted children can recognize and compare all five objects at a glance. It is a task that makes relatively low cognitive demands on them. Blind children, in contrast, have to carefully feel all five objects one after the other before they can identify which two are the same—a relatively advanced cognitive achievement" (Brambring 2010, p. 1). This latter point also demonstrates the different information gathering strategies employed by sighted as compared to blind persons. In Chapter 3, in the discussion of graphical user interfaces it will be postulated that sighted persons can use a two dimensional information gathering strategy, whereas the blind use a serial information gathering strategy. This affects how they interact with computers and other systems. This thesis examines what functions should be employed in the design of an interface on a Braille keyboard device and will propose a set of supporting usability attributes designed to evaluate the functions.

1.4 Senses and Bandwidth of Information Transfer

Our technological age offers an abundance of devices which rely heavily upon images, 3-D graphics, employing features such as rotation, flashing and animation and which impose a low cognitive load on the individual. The use of pointing devices relies upon hand-eye co-ordination, and the reliance on visual output as well as visual input prompts and controls means that people who are blind are excluded from using many of these devices. Additionally, people who are blind are expected to interact with an increasingly complex technological environment where interfaces are usually designed for 'able-bodied' users (Keats and Clarkson 1998). It is suggested that people who are blind need multi-modal user interfaces to overcome their inability to use hand-eye co-ordination. Current practice suggests the blind require interfaces which utilize senses other than sight in order to communicate (for example see Chapter 3 which discusses the subject of multi-modal computer interfaces including screen readers for the blind). This is due at least in part to the varying volume of information input that can be processed by the senses. In computing, the speed of transfer of information is often called bandwidth. Vision can transfer the largest amount of information at any one time and has the largest bandwidth of communication of any sense. Bandwidth for sight has been estimated at around 10^6 bits per second (Kokjer 1987). Information bandwidth for the ear was given at 10^4 bits per second and for the skin (vibrotactile stimulation) was given at 10^2 bits per second (Murray 2008, p. 14).

Another way to compare the capabilities of the senses is to examine reading rates because reading is an example of a task that requires one’s full attention and requires the engagement of the senses. Users commonly achieve Braille reading rates of around 100 words per minute (Way and Barner 1997). This can be compared to an average visual reading rate of around 250 words per minute and preferred rates of around 200 words per minute of synthetic speech (Murray 2008). It is suggested by Murray (2008) that the performance difference between totally blind and sighted persons using computer interfaces may be related to both the differential between the bandwidth of transmission of sight compared to hearing and tactile but that interface design may also impede the efficiency of computer use by blind individuals. It may well be that the interaction paradigm which allows blind persons to perform best differs to that which allows sighted persons to perform well. The model of interface on Braille keyboard devices presented in Chapter 5 presents such a different interaction paradigm.

There is a two stage approach to seeing. First there is a breadth approach where the person takes in the whole scene. For example the person can look at the computer screen and get an overall picture of its contents. Then the person moves to the depth stage. At this stage the person focuses upon individual items to seek for the item of interest. Roth (Roth et al. 2000) terms this two-stage approach: ‘macroanalysis’ or the “where” stage and then a ‘microanalysis’ or “what” stage to gain more detail. The serial approach to information created by the use of screen readers inhibits this two-stage search process (Murray 2008).

1.5 Usability

The researcher evaluates the literature on usability and functionality in Chapter 3 and examines user-centred models to establish a set of usability attributes against which a linear or serial interface could be tested. The usability attributes included as part of the interface specifications presented in Chapter 5 were established through the triangulation of a review of the literature on usability, an examination of published reviews of Braille keyboard devices and a practical review of three modern Braille keyboard devices. The researcher will incorporate user feedback on the Venturer Model (the model developed in Chapter 5), desired functions and importance of usability attributes. This feedback is presented in Chapter 6.

1.6 Electronic Braille Keyboard Devices

An extensive literature review uncovered no existing models for evaluating Braille keyboard devices. The researcher wished to establish a set of functions that would allow tasks to be completed on an electronic Braille device as well as to establish a set of usability attributes that could be employed to evaluate these functions. Also the interaction paradigm underlying the function set needed to be established through an evaluation of literature on devices and real world evaluation of devices by the researcher. The limitation imposed by the researcher that he wished to evaluate devices in real world situations meant that devices available in Australia were tested and literature evaluating these devices was focused upon.

Historically, Braille input devices are not new. For example the Perkins Brailler (discussed in Chapter 3) is an early manual Braille writer. There are several early electronic devices with Braille keyboards, which are discussed further in the same chapter. Some of these include: Braille and Speak, Eureka A4 (Robotron Sensory Tools (1987) and the Mountbatten Brailler (Fraser 2009; Quantum Technology (2008). The Mountbatten Brailler is used as a learning aid to teach Braille and is adopted in many countries due to the fact that not only does it produce hard copy Braille but it also incorporates some computer features giving it a technological advantage over the manual writers. Students beginning on the Mountbatten Brailler are developing both Braille literacy and early or pre-computer skill which will help them when they progress to using computers later in education.

The Braille and Speak and Eureka A4 inspired many of the modern devices. An advantage of the Eureka A4 as it relates to the current thesis is that it was a PDA-like device which had a well-developed help system for its time (Robotron Sensory Tools 1987). The user could request the meaning of a function key prior to executing the function. From the point of view of a person without sight, this spoken help aided learning and memory retention. Both learnability and memorability are key usability attributes which may prove valuable for Braille keyboard devices and could support the evaluation of functionality on such devices.

1.7 The Curtin University Brailler

Curtin University is developing a modern electronic Braille typewriter with some Personal Digital Assistant (PDA) functionality which is based upon concepts found on the Eureka A4. Photos of the device are presented in Figure 1.1. The device has been designed to be light weight and portable and possesses the following design features:

- A small, lightweight design allowing the unit to be transported easily
- Robust Components to insure the reliability of the unit.
- Real-time forward and back translation of Braille.
- Synthesised Speech interface.
- LCD text display.
- USB functionality for expansion purposes.

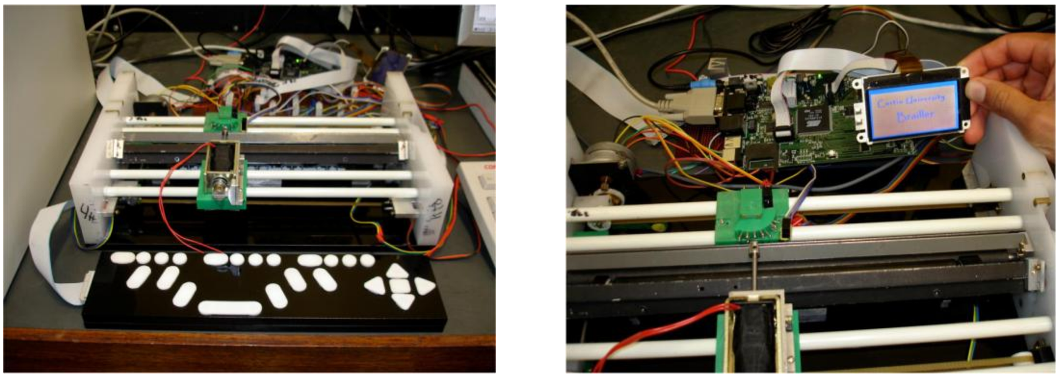

Figure 1.1: Curtin University Brailler

The key components in the Curtin University Brailler (CUB) Design are:

- Low friction, lightweight materials.
- Embossing & paper feed mechanism.
- ARM Micro Controller (Linux kernel).
- 24 key keyboard.
- FPGA for Braille translation and keyboard encoding.
- Doubletalk Speech Synthesis.
- LCD Screen.

The developers of the CUB have implemented a modified version of Linux which they call Skippy Linux which is designed to be small and to contain only the functions necessary to perform needed tasks.

This thesis presents research which is part of the Curtin University Brailler Project to design an interface model suitable for deployment on the CUB and to allow future development of interfaces for Braille keyboard devices. The primary research question to be investigated is: *What is the optimum functionality and interaction paradigm for a Braille keyboard device?* The secondary research question is: *What* *are the optimum usability attributes for a Braille Keyboard Device?* This research contributes to the body of knowledge about the needs of totally blind users of Braille keyboard devices, key usability factors for the design of such devices and provides a foundation for further research and practise in the design and development of such devices.

1.8 Structure of the Thesis

Chapter 1 presents some background to the research. Chapter 2 presents the research method and design of the project. The research questions are presented and the significance of the research is discussed.

The design science approach was adopted as the research methodology because the researcher sought to design an interface and interaction paradigm for a Braille keyboard device. The output of the research is an artefact (a theoretical model showing the components and their links). An artefact is a potential output of design science. The chapter also covers the theory behind the chosen data collection methods and also discusses the advantages of using focus groups in addition to individual interviews. The researcher used both individual interviews and a focus group to provide triangulation of data collection methods and to obtain a wider user perspective.

Chapter 3 presents the literature review, which provides background to the problem space outlined in Chapter 2 and includes such topics as:

- Usability Theory and Human Computer Interface Models are to guide the choice of usability attributes suitable for evaluating functionality of Braille keyboard devices.
- Guidelines for Good HCI design.
- Graphical user interfaces (GUI) and Problems with these Interfaces including a discussion of Ear cons and Icons. The problems faced by blind users of the internet are presented as an example of difficulties faced by the blind interacting with a two-dimensional presentation of information.
- Review of Research into Alternative Interaction Methods including Multi-modal Human Computer interaction. This includes Speak Serial interface and Haptic Technology Braille and Braille keyboard devices.

Chapter 4 presents the researcher's real-world practical evaluation of three modern Braille keyboard devices available in Australia. These devices were the same three devices investigated in the literature. The researcher sought to establish whether the previous review of the devices was accurate. The devices reviewed included: BrailleNote Empower 32 (produced by Humanware), PacMate (produced by Freedom Scientific) and BrailleSense (produced by HYMS Co). A key feature of this chapter is the discussion of the key maps for the devices. People who cannot see are unable to use a mouse or pointing device to successfully interact with the interface on a computer system and are largely restricted to using voice input or keyboard input. The result is that the key maps are extremely important. Each device has a unique key map and the chapter presents detailed tables of the command structures on the three devices.

Each device also possesses functions in common with others and which differ between devices. The differences in functions provided on devices allowed the researcher to establish a common set of functions to be employed on Braille keyboard devices. The strengths and weaknesses of each device informed the choice of functions to be employed and also confirmed some of the usability attributes established through the review of literature.

Chapter 5 presents the first version of the new Venturer Model showing the interface for an ideal Braille keyboard device. The chapter opens with a preliminary framework consisting of several tables and a diagram of the faceplate of a Braille keyboard device. The chapter seeks to present important functions of Braille keyboard devices and their links. The chapter also presents a few supporting usability attributes that may aid evaluation of the functions presented as part of the model.

Chapter 6 discusses the data collection and analysis of this data and presents the modifications to the Venturer Model. The processes used to obtain participants are outlined as is the number of participants. Effectively, five individuals provided significant feedback and thirteen respondents participated in a focus group. The interview questions asked of respondents were divided into categories. The chapter details the responses to the interview questions.

Chapter 7 presents the conclusion to the research and the limitations of the research. The chapter outlines how both functions and usability attributes needed to be modified when establishing the Venturer Model. The data collected were insufficient to present adequate discussion on usability attributes.

Chapter 2: Research Method and Design

2.1 Introduction

Having presented an introduction to the effects of blindness and a brief survey of this thesis the present chapter seeks to present the background to the research method employed in this thesis and the theory behind the research method used. Design Science was the research approach chosen for this project due to its focus on the design process and end product. The result of a design science project is a design of some kind, and all designs are based upon theorizing. Design science is appropriate for this research as it seeks to produce a conceptual interface for deployment on Braille keyboard devices, a design artefact.

This chapter first outlines the significance of the research and the subsequent selection of the topic. The topic leads to the research questions which are presented and explained. The theory behind the chosen research method (Design Science) is outlined, as are the data collection methods. Strengths and weaknesses of interviews and focus groups are presented in this section.

2.2 Choice of Topic

The researcher is totally blind and uses electronic Braille keyboard devices on a daily basis. The researcher prefers being able to input using Braille but discovered that there was no consistent use of functions on Braille keyboard devices produced by different manufacturers. Furthermore manufacturers differed in how they implemented the key maps on their devices and the researcher was unable to find any publications purporting to present a model for an interface to Braille keyboard devices. It was also noted that there was an absence of significant published quantitative research on the usability of Braille keyboard devices. The result of this was that each manufacturer produced a different physical device with some common features exhibited between devices.

Researchers such as Holbrook, Wadsworth, and Bartlett (2005) studied the use of Braille keyboard devices on the learning of children who were blind and others such as Davies (1996) focused on psychological developmental aspects of the children who were blind. These studies showed that the learning of children who were blind improved with the use of Braille and Braille keyboard devices. These studies, together with the experiences of other people who are blind that the researcher knew led the researcher to an investigation of the learning processes associated with Braille, which in turn led to an interest in the way the interfaces on Braille keyboard devices were developed.

2.3 Significance of the Research

Graphical User Interfaces (GUI’s) are common interfaces on computer systems. These interfaces, although they differ, possess commonalities; for example they display their information in areas called windows. Some elements of these commonalities include the use of icons, menu bars, the use of a pointing device and a status line (Apple 2010; Microsoft 2010). The operating systems also use similar concepts such as the use of function keys. Microsoft uses at least four such keys in addition to the keys called F1-F12; Control, Windows Logo, Alt and application keys. Apple use at least three keys, as function keys, apart from F1-F12; Control, Option and Apple logo. Further there are alphabetic keys that are associated with functions; for example the letter F is associated with the file commands, the letter S with save and the letter O with open. Each operating system ties these letters to function keys and these vary between operating systems (Apple 2010; Microsoft 2010). An outcome of such commonalities is that users of GUI’s can use the devices employing them as tools. Once one programme or device is learned skills learned can be transferred to other devices. The device can be used as a tool rather than the user having to expend cognitive effort in learning each new device.

Chapter 3 presents discussion of Braille keyboard devices and demonstrates the lack of commonality in design between these devices. Indeed it would appear that the manufacturers of these devices seek to differentiate them from each other (Freedom Scientific 2007; Humanware 2008c, HYMS Co. Ltd. 2008). Chapter 4 explains the differences and commonalities between three of the Braille keyboard devices available in Australia. The main commonalities relate to the Braille dot keys used for writing the Braille. A practical outcome of this research is presenting an interface that is focused on commonalities or which seeks to encourage designers of Braille keyboard devices to provide devices that can be used as tools and the interfaces learned and commands memorized easily.

Chapters 3 and 4 discuss the history of Braille keyboard devices and provide a practical review of three such devices. A factor which arises as a result of this discussion is that the interfaces demonstrate some non-intuitive features. Some devices, such as the Mountbatten Brailler (Quantum Technology 2008) used a confusing set of commands and non-verbal audio messages to communicate to the user. Basically the commands had to be learned. Chapter 3 provides some examples of Mountbatten commands.

Not only do some Braille keyboard devices demonstrate non-intuitive interfaces such operating systems as Unix also demonstrate confusing commands. For example:

```
ps -ef|grep "ora_"|grep $ORACLE_SID|-v grep| \awk '{ print $2 }'|-exec rm –f {} \;
```

(Scalzo, Burleson, and Callan, 2010)

When separated into its components this command becomes

```
ps –ef
grep "ora_"
grep $ORACLE_SID
grep -v grep
awk '{ print $2 }'
-exec rm –f {} \;
```

Even broken down like this the command is not intuitive to the person who does not know UNIX. It is shown in Chapter 3 that some of the Braille keyboard devices employ complicated commands that must be learned rather than being intuitive. This research attempts to provide a model and theoretical construct to aid designers of products for the blind to make intuitive devices which may be learned easily. Standardization and consistency of command sets will aid learning of devices and the teaching of how they are to be used as tools.

2.4 Research Questions

2.4.1 Primary Research Question

The primary research question to be investigated is:

What is the optimum functionality and interaction paradigm for a Braille keyboard device?

This question seeks to establish how the user will interact with the interface and the functions that should be part of an interface to be employed on an electronic Braille keyboard device. Such a device has a special keyboard termed a ‘Braille Keyboard’. Braille and Braille keyboard devices are discussed in Chapter 3. The functional requirements of an interface on a Braille keyboard device may well differ to those for a device produced for sighted users. It may also be the case that the interaction paradigm for the system and interface may differ. This question seeks to establish whether this is indeed the case.

Part of the test of the functionality of the interface will be a simulation of using the interface to access the Curtin University web page. Using the Internet is a common task to be employed on a computer device and so simulating accessing the internet with the Venturer Model interface developed in this thesis will help to establish the strengths and weaknesses in the design of the interface. The simulation will assume the use of Internet Explorer and compare the result to using Internet Explorer with JAWS screen reader used by end users who are totally blind. The results of the simulation test are reported in Chapter 6.

Interaction is the physical connection between the user and the system. It is what a user does to communicate with the system and what the system does or provides to the user to enable communication. Functionality is what the system can do. In technical terms functionality or functional requirements of a system are defined as: “the services the system must provide” (Dix, Finlay, Abowd and Beale, 1998, p. 182). Services provide ways for the user to interact with a system.

2.4.2 Secondary Research Question

The secondary research question is:

What are the optimum usability attributes for a Braille Keyboard Device?

Usability provides a support to functionality or the functions of a system. This question seeks to establish the appropriate set of usability attributes that complement the functionality established as a result of answering the primary research question.

Usability is defined by Dix, Finlay, Abowd and Beale (1998, p. 192) as “the effectiveness, efficiency and satisfaction with which specified users achieve specific goals in particular environments.” This definition contains terms which the authors define as follows:

- Effectiveness is defined as “The accuracy and completeness with which specified users can achieve specific goals in particular environments.”
- Efficiency is defined as “The resources expended in relation to the accuracy and completeness of goals achieved.”
- Satisfaction is defined as “The comfort and acceptability of the work system to its users and other people affected by its use.”

2.5 Research Methodology

"In general, a scientific paradigm is a whole system of thinking. It includes basic assumptions, the important questions to be answered or puzzles to be solved, and the research techniques to be used" (Neumann 2006, p. 82). Each scientific paradigm suggests differences as to what Science is and what questions should be asked. For example positivism has its grounding in the work of August Comte and John Stuart Mill and emphasizes discovering causal laws, careful empirical observations, and value-free research. A key aspect of this type of research is that it seeks abstractions from the real world and also emphasizes "early identification and development of research questions and hypotheses, choice of research site and establishment of sampling strategies" (Falconer and Mackay 1999, p. 287). Whereas interpretive science can be traced to German sociologist Max Weber (1864-1920) (Neumann 2006) and relates to the science of hermeneutics which is the detailed interpretation of texts or "the theory or philosophy of the interpretation of meaning" (Butler 1998, p. 286). A key concept of interpretive science is that values exist which influence choices.

If social events influence values and values influence social events, then it is important to value each person's view. The result of this is that surveys and the abrogation of data is less appropriate (Neumann 2006, p. 288). Further, the concept of the impartial observer is also inappropriate. Instead, the researcher is directly involved in the setting and does not formulate rigid hypotheses prior to collecting data (Falconer and Mackay 1999). Interpretive science is not necessarily always qualitative; indeed, qualitative research may be positivist, interpretive or critical (Falconer and Mackay 1999).

This research is mainly positivist because it seeks to answer pre-defined questions for a particular target group using a particular device but draws from both the positivist and interpretive paradigms.

2.5.1 Design Science Research Method

The research method chosen to undertake this research was the design science approach because the researcher sought to examine the functions to be included in a theoretical Braille keyboard device. The output of the research is an artefact (a theoretical model showing the components and their links). An artefact is a potential output of the design science approach.

The design science approach is historically positivist but other approaches are also possible. Additionally, design science consists of two main stages: build and evaluate (March and Smith 1995; Simon 1981). March and Smith stated "building is the process of constructing an artefact for a specific purpose; evaluation is the process of determining how well the artefact performs" (March and Smith 1995, p. 58). The approach seeks to determine whether built artefacts actually are usable. Evaluation is necessary to determine usability and usefulness. Usefulness is related to utility or the benefit of the artefact for the users. The secondary question for this thesis addresses usability.

Design science "is fundamentally a problem-solving paradigm. It seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished" (Hevner et al. 2004, p. 13). Further, in design science "building is the process of constructing an artefact for a specific purpose; evaluation is the process of determining how well the artefact performs" (March and Smith 1995, p. 258).

Venable (2006) considered the work of Hevner et al. (2004) and suggested a more inclusive name for Design Science, ‘Solution, Technology, Invention’ research, because this more accurately reflects what the researchers are doing. Venable explained the traditional design science approach, which focuses upon theory building and creating artefacts as outputs of design science, to link the four key elements of theory building, problem diagnosis, technology design and invention and technology evaluation (see Figure 2.1).

A central focus of the Venable method is ‘Theory Building’ and this process is highly iterative, with the opportunity to gradually build and refine theory as the research progresses. Other features of the design science diagram are arrows which are bi-directional, permitting iteration between the phases and providing a flexible research approach.

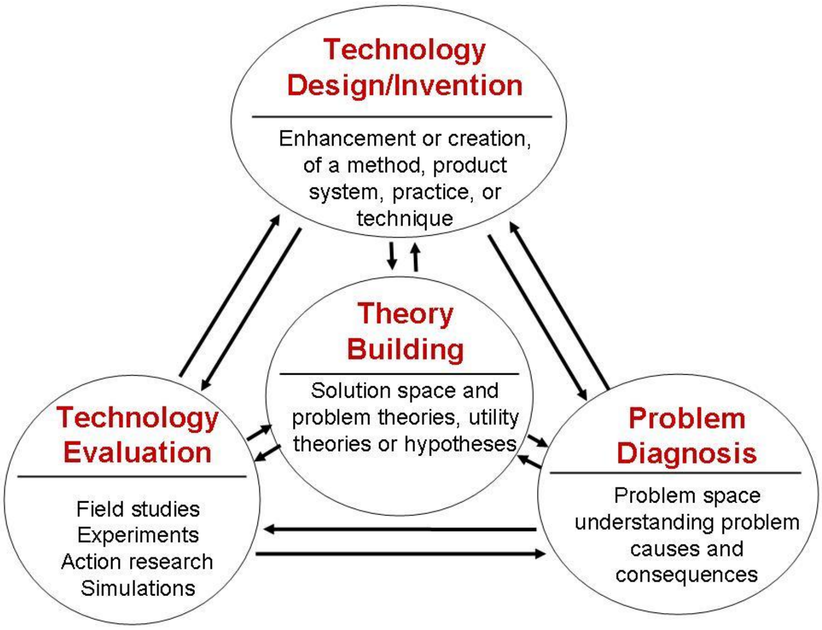

Figure 2.1: Design Science Framework (Venable 2006, p.17)

Since the focus of design Science is theory building it is important to understand the concept of theory. According to Kuechler & Vaishnavi (2010) there are two types of theory; kernel and design theories. Kernel theories relate to the natural sciences and are outside the design science framework but may influence design theory.

However, other authors, such as Davern & Parkes (2010) suggest that there is a potential conflict between theory building and the building of an artefact in terms of which is the focus and 'comes first'. The mark of good design science is in its rigorous evaluation of the artefacts developed (Livari 2007).

Theory building, in terms of utility theory is the central focus of Venable's (2006) framework diagram. According to this author the contribution to the knowledge base or theory may occur via an examination of the literature or through the development of the artefact. The development process itself contributes to the knowledge base.

2.5.2 Examination of the Venable (2006) Design Science Framework

The problem diagnosis phase usually occurs early in the design science process and is initiated for a particular problem and specific stakeholders. The concept of utility affects the concept of a problem space. Hence, a problem exists where known solutions either do not address the problem or address it ineffectively. Therefore the concept of usability directly impacts upon the concept of a problem space. Stakeholder views produce the utility or disutility of solutions, whether those solutions exist or are developed as part of the design science process.

The problem diagnosis phase may be considered to be a pre-cursor to design science research but may also be part of the flow process of the research. It involves analysing the problem space to gain an understanding of the broader problem space and to isolate problem areas for research. During this phase, the researcher may decide to focus only on part of an overall problem. Problem diagnosis also involves seeking out the opinions of the stakeholders who are directly involved in the problem space or in the research.

A major part of the problem diagnosis phase is identifying the causes of the problem and the resulting consequences. The researcher must understand that existing solutions may be a part of the problem or part of the solution. It may not be possible to separate out the cause and effect relationships.

The technology design/invention phase includes hypothesizing and designing solutions to address the problems identified in the problem space, and may involve the enhancement of a method or technique. This phase influences the utility of theories developed in the theory building phase. The design is tested and assessed with respect to how it addresses the problem identified in the problem space.

The theory-building phase, which is key and central to the Venable (2006) design science framework, has the following characteristics. It occurs before, during, throughout and at the end and as a result of design science research. Therefore, it is central to the design science approach. Hence, the centre of the diagram is ‘theory building’.

Theory building begins with the spark of an idea - a nascent concept for a not yet existing (or not yet applied) technology as the solution for a problem or type of problem. Moreover, this spark of an idea may come from:

- Recombining ideas and conceptualizations of problem spaces.
- Realising new possibilities for solutions.
- Recombining existing solutions or technologies.
- Imagining new technologies.
- Realising new applications for existing technologies.

Theory Building continues during the design and solution phases of the research. The result is that:

- Nascent ideas are fleshed out.
- New concepts and constructs are added to the solution space.

- Theories are refined depending upon the results of evaluation.

The key aspects of the technology design and invention phase include; hypothesizing solutions to address the problem space, the creation or enhancement of a method or product, system, practice, or technique. Conceptual diagrams or models are developed and converted into a more complete artefact. The artefact is tested (with stakeholders) for correct functioning to ensure it meets the requirements of the solution space. This may be a small refinement of an existing solution or an entirely new one.

When undertaking this type of research, the following general questions can be asked:

- Who are the stakeholders?
- What are the perceived undesirable implications generated by the problem?
- What are the perceived causes of the problem?
- Are there any solutions already existing?

2.6 Research Design

Design Science framework as a basis for the research in this thesis first involved establishing the problem space. The problem space was established both through; the researcher's own life involvement in being blind living in a world which relies largely on visual interaction, Braille literacy, experience with Braille writing devices and a review of literature on subjects related to blindness. A problem space was established and the process of theory building began.

The researcher examined three modern Braille keyboard devices (see Chapter 4) in order to clarify the problem space and to refine the researcher's understanding of the theory and technology invention phase. The researcher sought to understand the concepts behind the interfaces on different Braille keyboard devices in order that a set of functions could be established. The literature review provided an understanding of the concepts of usability and allowed the researcher to establish a set of usability attributes designed to support the evaluation of functions derived from the practical evaluation of the Braille keyboard devices. Usability attributes were incorporated in the technology evaluation phase of the research and stakeholders views on functions and usability attributes were also sought.

The feedback from stakeholders produced an iterative process in which the original model was modified to take account of user feedback. Utility was considered important in establishing functions.

It is important to note that the literature on Braille keyboard devices is limited and Chapter 4 presented such a review and provided triangulation with the author's review on Braille keyboard devices and modified the researcher's understanding of functions and usability. This was the first iteration of the problem space and was a direct result of the evaluation process. Stakeholder feedback of the model (presented in Chapter 6) provided further evaluation of the problem space and the theory building.

Although this thesis presents a model of interface on Braille keyboard devices the researcher sought to understand the concepts of human computer interaction (HCI) and to understand guidelines for good interface design. Chapter 3 considered various sets of guidelines for interface design with the researcher focusing on those presented by Schneiderman (1998). Chapter 3 provided an understanding of different interaction paradigms for computer systems, focusing on Graphical User Interfaces (GUI's) and alternative output modalities. The initial focus for the researcher was to understand the different ways that persons could interact with systems and to establish a different paradigm that did not rely upon a visual spatial method of interacting and which focused upon a serial method of interacting.

2.6.1 Unit of Analysis

The researcher interviewed 7 individuals and conducted a focus group consisting of 13 respondents. All focus group participants were blind and had used Braille keyboard devices and 5 of the interviewees had used Braille keyboard devices. Since the sample size was small, trends can be only tentatively established.

Small sample sizes may be used when studying populations of disabled persons. "For research focussing on users with impairments, it is generally acceptable to have 5-10 users with a specific impairment take part in a study. For example, in the recent proceedings of the ASSETS conference (well-accepted high quality conference on this topic), most of the research studies in which blind users had to be physically present to take part in the research had 15 or fewer blind individuals taking part in the research. This means that if a classic experimental design is used, that there will often be no more than one control group and one treatment group" (Lazar, Feng and Hochheiser 2010, p. 401).

The results reported in this thesis relied on feedback from a small sample size and it was not possible to present conclusive findings regarding usability attributes. Further, Lazar, Feng and Hochheiser (2010) indicate that research on populations with disabilities sometimes becomes exploratory in nature due to the small sample sizes. Also they point out that in many cases results reported will be of a qualitative nature rather than a quantitative nature.

2.6.2 Target Population and Sample

The researcher contacted various agencies for the blind throughout the world and four agencies agreed to publicise the need for participants. The researcher also advertised on e-mail discussion lists which targeted people who are blind. Although the researcher was unable to obtain information from the agencies or list owners on total subscribers or members, the researcher knew of fifty persons who were at least mildly interested in participating in the research. The researcher was able to obtain five participants from this process. The researcher then approached the Cisco Academy for the Vision Impaired at the Association for the Blind in Western Australia in order to obtain further participants. The result was that thirteen persons agreed to participate in a focus group out of the approximately 100 students enrolled in 2009 at the Cisco Academy for the Vision impaired. An additional two individual respondents also provided feedback. The result was a total of 20 participants.

2.6.3 Data Collection Methods

There were two types of data collected as a result of the interviews and focus groups. Some data was quantitative (such as the numbers of years of use of Braille keyboard devices), whereas other data was textual (in the form of comments on features present or desired). The sample size was small and although there may be some relationship between the responses, the sample size was not sufficient for statistical testing.

The method for obtaining the data from respondents was to record the interview or focus group session and then to type up the audio material. These interviews were semi-structured but the interviewee was free to comment on other aspects not covered by the interview question.

Focus groups were conducted with the assistance of the Cisco Academy for the Vision Impaired at the Association for the Blind of Western Australia. The group session was held using Ventrillo which allows multiple people to speak with each other as if they were in the same room. This focus group was recorded and the responses typed up. The focus group was less structured than the interviews and tended to discuss additional material not covered in the interview questions. This research was limited in that the researcher was not specifically looking for the conversational relationships between respondents but rather was seeking to establish consensus views and to establish divergent views and possible reasons for these views. The focus group provided valuable feedback on functions to be included on an ideal Braille keyboard device.

2.6.4 Research Instrument

Research instruments were discussed by Neumann (2006) including interviews. The researcher chose to use interviews and focus groups because both data collection methods have advantages for the interviewee and interviewer and triangulation of data collection methods would be evident because of the nature of the two methods.

The individual interview is designed to obtain individual attitudes, beliefs and feelings (Gibbs 1997). Further, “The interview is a structured conversation which introduces interviewer bias because the interviewer can guide participants” (Neumann 2006, p.

306). The bias introduced by this situation was desired by the researcher so that respondents could be guided to provide clarification when respondent was not clear or strayed from topic.

Additionally in the interview respondents are able to obtain clarification on points and the interviewer can record responses directly on a computer. Another advantage of interviews, which also applies to focus groups, is that respondents and interviewer are able to use non-verbal communication and this may aid or hinder responses depending upon the psychological makeup of respondents and interviewer. Blind participants are unable to see the other members of neither a focus group nor the interviewer and so this advantage of face to face interviewing is not present for such respondents.

Kitzinger (1995, p. 299) also compares focus groups with group interviews. She states that: “Focus groups are a form of group interview that capitalises on communication between research participants in order to generate data”. Focus groups explicitly use group interaction as part of the process. “People are encouraged to talk to one another: asking questions, exchanging anecdotes and commenting on each other’s experiences and points of view” (Kitzinger 1995, p. 299).

Group discussion is particularly appropriate when the interviewer has a series of open-ended questions and wishes to encourage respondents to explore the issues of importance to them, in their own vocabulary, generating their own questions and pursuing their own priorities. Furthermore, the dynamic interaction between respondents in a focus group produces dialogue which may be a source of data for analysis.

Moreover, focus groups have several sampling advantages. They:

- Do not discriminate against people who cannot read or write.
- Can encourage participation from those who are reluctant to be interviewed on their own.
- Can encourage contributions from people who feel they have nothing to say or who are deemed unresponsive.
- Allow the participants who are vocal to encourage others who are less vocal to participate.
- Participants can feel that they are actively involved in the analysis process (Kitzinger 1995, p. 300).

There are a few advantages for the respondents participating in focus groups and these relate mainly to the empowerment of respondents; they have the opportunity to:

- Be involved in decision making processes.
- Be regarded as experts.
- Work collaboratively with researchers.

Further, the focus group meeting can be an agent for change, particularly in action research or where the researcher identifies with the felt needs of the respondents.

There are disadvantages of such focus groups:

- When the majority view is put forward, those who do not share this view may be discouraged from participating or airing their views.
- Confidentiality of individual responses may also be compromised. How can the researcher stop participants sharing information shared at the session?

(Catterall and Maclaran, 1997, para 3.3)

All groups will be subject to group processes (Catterall and Maclaran, 1997, para 3.3). This means that even a group which is not specifically set up as a focus group will exhibit dynamic traits of a group. Furthermore, the authors suggest that it can be challenging to interpret the information generated by such focus groups. They point out that groups may differ depending upon the research objective and underlying philosophy of the research.

2.6.6 Reliability and Validity

The data collection techniques used in this research were designed to provide a stable, consistent and reliable mechanism for gathering data. The difficulties in obtaining respondents means that the sample size is small and therefore the issues related to small sample sizes discussed earlier in this chapter applied. The data presented is mainly qualitative and it proved impractical to apply statistical analysis to the data.

There are several issues associated with the validity of the results generated by having such a small sample size. Only tentative conclusions can be drawn. There were difficulties in communicating the need for participants to those who were blind and vision impaired due to the varying levels of cooperation within the organizations which serve the blind and vision impaired community throughout Australia and the world. The requests for participants were unevenly distributed throughout Australia and the world. Moreover, those who were interviewed may have preferred to participate in a focus group or fill in a survey sheet. Each person was offered the format of data collection they desired but the difficulty of transport may have persuaded respondents to participate in the interview rather than the focus group. Given the mobility difficulties faced by persons who are blind, the difficulties of distribution of requests for participants, and the difficulty of reliably assessing the actual numbers of persons who are blind, it is reasonable to assume that the responses obtained represent a sufficient sample of the opinions of people who are blind for the reliability and validity of this research to be accepted.

2.6.7 Triangulation

The researcher chose to test the same three Braille Keyboard Devices as were reviewed in Chapter 3 partly because this would provide triangulation between reviewer's opinions of Braille keyboard devices and the researcher's assessment of these devices in real world situations but there were also the cost considerations in obtaining devices unavailable in Australia. Further, the focus group and respondents who were interviewed also had used at least one of the three devices and in some cases more than one. This provides triangulation between three sources of opinion regarding functionality of devices and usability attributes for evaluating devices of devices.

Also, the use of two different data collection instruments (individual interviews and focus group) provided triangulation in data collection instruments and allowed for the advantages of these instruments to elucidate the data collected.

2.7 Conclusion

Design Science was the research method chosen to undertake this research because of its flexibility and focus upon the building of artefacts and theory. Interviews and focus groups were chosen in order to both provide an opportunity for individuals to express their opinion and for the advantages of group dynamics to influence the outcome of the focus group discussions. It was shown how the participants in focus groups were able to influence other participants which allowed a more inclusive set of data to be collected. The problems with the research included difficulty in obtaining respondents and the small sample size which is common in studies of this kind.

The model presented in Chapter 5 contributes to practice by presenting a model of interface for Braille keyboard devices. Part of the contribution of this research is the provision of a theoretical model that engineers and designers of Braille keyboard devices can employ in developing their products. Theory extension could occur when the model is extended and applied to different user groups such as the deaf or different technological environments such as the mobile environment where screen resolutions are small and the number of keys available for input is reduced compared to a full computer keyboard. Chapter 3 will examine the literature impacting upon the development of such an interface.

Chapter 3: Literature Review

3.1 Introduction

Having discussed the background concerning the impact of blindness in Chapter 1 and the research method and research questions in Chapter 2 this chapter presents an outline of the literature impacting upon the development of an interface and interaction paradigm for Braille keyboard devices. This chapter will:

- Outline the concept of Human Computer Interaction (HCI) and the alternative meaning of HCI.
- Present the concepts of functionality and usability and outline models of usability and design.
- Present a series of guidelines for good generic interface design.

The concept of Graphical User Interfaces (GUI's) is outlined with particular reference to difficulties of use faced by blind users. Additionally the different ways to interact with computer systems are presented in terms of multi-modal interaction methods.

The background to the development of Braille and electronic Braille keyboard devices is presented in order to not only demonstrate the key differences between devices, but also similarities between devices, to begin to establish the optimum function set, and to present a review of literature seeking to evaluate these devices.

Both designers and users of computer systems have goals they wish to achieve and it is not always possible to produce a theory to determine those goals. Given that goals exist the concept of a goal related overarching model may be presented.

3.2 The GOMS Model

The Goals, Operators, Methods, Selection or GOMS (Card et al. 1983) approach consists of the following four elements:-

- Goals - the state of affairs to be achieved or the user goals to achieve the desired task.
- Operators – actions which change the user’s mental state or the task environment. They also include actions that the software or system allows the user to take, for example button presses.
- Methods – procedures for accomplishing goals or learned sequences of sub-goals and operators that can accomplish a goal.
- Selection rules – drive the decision where more than one action can accomplish the goal. They are also the personal rules or sequences of actions that each person uses to accomplish particular tasks.

The GOMS model was proposed as an approach to HCI design. The model deals with user tasks which may be divided into four elements:

- The degree of direction the user has with goals.
- The degree of routine skill involved.
- The degree to which the user has control over the task.
- The degree to which there is a logical sequence in the tasks performed.

(John and Kieras 1996, p. 294).

Further, goal-directed tasks are the main types of tasks that may be processed with a GOMS approach. Additionally, GOMS cannot produce the goals itself. These goals must be developed through different methods, such as reviewing prior procedures or devices or interviewing stakeholders to establish the higher order goals are necessary.

Although this research uses a GOMS approach it assumes that higher level goals are determined and this is one of the reasons for determining the problem space initially. The problem space needs to be determined in design science research.

The GOMS approach is useful for engineering design when the cognitive processes or procedures for accomplishing a task need evaluation. GOMS can produce qualitative and quantitative results focusing on procedures (John and Kieras 1996).

Gong and Elkerton (1990) found that when computer manuals were goal and task-oriented and contained specific procedures new users performed more efficiently. Further, Baumeister and John (2000) reported that there were insufficient sophisticated tools available to allow GOMS to be implemented for complex design and the researcher needed to develop a set of user goals outside the GOMS process and that GOMS was more amenable to procedures.

3.3 The Computer Interface

Once the goals are determined it is necessary to understand the concept of the computer interface. "The user interface must be understood as part of a computational system with which a person enters in contact physically, perceptively and conceptually" (Carneiro and Velho 2004, p. 228). In computer science, the term ‘interface’ usually denotes the hardware and software components that allow users to interact with the computational system. Thus the concept relates to the physical things a user does with the hardware and software to accomplish goals. The result is that a user of a specific device with specific software will interact with the system in a particular way. This thesis presents some hardware and software specifications that engineers can use to develop Braille keyboard devices that can be used as tools to accomplish goals.

In support of the concept of an interface is that ‘interaction style’ is a term that refers to the way users interact with the computer system (Carneiro and Velho 2004). Tidwell (2005) in her book "Designing Interfaces" discusses various aspects of interface design including the diversity of interfaces and indicates that interfaces may contain many elements including visual layout of the information on the screen. An important element of her discussion is that applications are easy to use when they are designed to be familiar and intuitive to users. Furthermore, the concept of "familiarity" is important. Familiarity does not mean that an application or product is identical to another but it does mean that there are recognisable similarities between the new interface or product and existing interfaces or products that the user knows about. Indeed, Tidwell (2005) indicates that there are three broad components of user interface design. These are:

- Idioms - these are the large building blocks of user interface design.
- Controls - these are smaller building blocks.
- Patterns - these are the links between the first two elements and are the structure of the interface. There is an element of familiarity which is necessary, especially when designing for people who have no visual input because, if the new interface has similarities to what they already know, then the new command set will be more easily assimilated. Learnability and memorability and consistency become important factors in such design.

The discussion of patterns includes the concept of reducing cognitive overload. Cognitive overload is when the user is required to spend significant resources on learning the environment of the interface before s/he can use it (Tidwell 2005) or when the complexity of tasks exceeds the cognitive resources available during use of an interface.

3.3.1 Visual Layout and Elements of a Visual Hierarchy

Tidwell (2005) discusses the concept of visual layout which is composed of: hierarchy, flow and grouping. Although she explains these concepts in a visual way they are applicable to a non-visual interface design in terms of order, structure and grouping. The Venturer Model developed in Chapter 5 relies upon structure, flow and grouping of commands to produce ease of learning and consistency.

3.3.2 Human Computer Interface Theory

Effective communication demands that information is transferred between at least two entities and while technology provides many devices to assist this process the focus is on developing devices for the mass market. Groups who do not fit the mass market are often neglected. Murray (2008, p. 24) suggests that vision impaired and blind technology users are often neglected and require purpose designed communication output devices rather than purpose designed input devices.

The acronym ‘HCI’ may better relate to ‘Human Computer Interaction’ rather than to ‘Human Computer Interface’. Human computer interface tends to focus on a requirement for users to possess an ability to interact visually to enable effective communications with that computing device.

Murray (2008 discusses three primary implications of focusing upon 'Interaction' rather than 'Interface'. These are:

- The physical activity for most computing users is reduced to entering information as the end product of cognition whereas an interaction perspective demands a dynamic process of communication.
- By adopting the interaction perspective one may then consider activity with devices as tool use.
- The use of a tool would normally imply that the activity is directed towards achieving an objective through purposeful behaviour. Therefore, human computer interaction must be grounded in work practice.

There is a difference between interaction and interface. Murray (2008) explains this by indicating that the computer mouse is an interface device. This device is easier to use to select an onscreen object and initiate an activity than it is to remember a series of typed commands (interaction). Whilst this may be true for the majority of users, it is not true for all. The obvious exception is those who use text to speech (TTS) as the display modality. When utilising a screen reader with TTS output is serial i.e. all information is read as a sequential list unlike a standard visual display where information is displayed in two dimensions but randomly accessed. For a screen reader user, it is much easier to use a series of typed commands than to navigate a graphical arrangement of objects.

3.3.3 Usability Theory

The functional requirements of a system were discussed earlier, however, users will select systems that provide functions needed to do their tasks (Goodwin 1987). Further, “by comparing the list of functions requested by the users to the list of functions provided by the system, the designer knows how well the system will meet users' needs (Goodwin 1987, p. 229). Also, “There often exists a perception that the more functions are provided, and the more flexibility and the more complexity in the system, the better. However, for both discretionary and nondiscretionary users, the way in which the functions are implemented will have a significant impact on system usability” (Goodwin 1987, p. 229-30).

It is important to understand that usability is related to task performance and the nature of the people using the system. Furthermore, some of the factors affecting usability are organizational and may be beyond the designer's control. Such factors as; training, accessibility of computers, and the culture of the workplace or educational institution in which the person is functioning may not be considered by the designer.

Further, Goodwin (1987, p. 232) suggests that “designing a usable system requires understanding the intended users, their levels of expertise, the amount of time they expect to use the system, and how their needs will change as they gain experience”.

The secondary research question guiding this research relates to usability attributes and so it is important to understand the goals of usability and usability testing.

According to Preece, Rogers and Sharp (2007) the goals for usability may be defined as:

- Effective to use.
- Efficient to use.
- Safe to use.
- Have good utility.
- Easy to learn.
- Easy to remember how to use.

These goals, although different to the usability attributes discussed in the next section, bear some similarity particularly those related to learnability. Preece, Rogers and Sharp (2007) also define what they call user experience goals which enhance the usability attributes discussed in the next section. These experience goals include:

- Satisfying
- Fun
- Enjoyable
- Entertaining
- Helpful
- Motivating
- Aesthetically pleasing
- Motivating
- rewarding
- support creativity
- emotionally fulfilling

...and more

The secondary research question for this thesis focuses upon usability attributes for Braille keyboard devices and so the concept of usability needs to be understood. It is discussed by a variety of authors however, there is no consensus on the meaning of terms, nor what should be considered as usability attributes. Later in this chapter models for usability will be presented but they are limited and do not consider all factors. Furthermore, not all authors define the usability attributes they discuss and so the definitions provided by Alonso-Rios et al. (2010) will be used. The reason for using their definitions is that they attempt (unlike other authors) to provide a taxonomy of usability attributes rather than assuming the reader is familiar with definitions.

According to Alonso-Rios et al. (2010, p. 53) “no precise definition of the concept of usability exists that is widely accepted and applied in practice”. Additionally, the idea of usability stems from the concept of ‘user friendly’ which also is an ambiguous term but which can be defined as: “systems that have self evident interaction styles and are simple to use by a novice” (Alonso-Rios et al. 2010, p. 53).

Usability is defined by Alonso-Rios et al. (2010, p. 54) 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.” This definition can be broken down further as there are significant elements to this definition:

- Specified users refers not to all users but particular ones. For example people who are blind would constitute ‘specified users’.
- Effectiveness refers to “the accuracy and completeness with which users achieve specified goals.”
- Efficiency is the “resources expended in relation to the accuracy and completeness with which users achieve specified goals.”
- Satisfaction is the “freedom from discomfort and positive attitudes towards the use of the product.”

(Alonso-Rios et al. 2010, p. 55).

The six attributes of usability presented by Alonso-Rios et al. (2010, p. 55) are:

1. ‘Knowability’ is defined as the property by means of which the user can understand, learn, and remember how to use the system. This has 4 sub-attributes:
    a. Clarity is “the ease with which the system can be perceived by the mind and the senses”. It has three elements
        - Clarity of the elements, classified in turn in terms of formal clarity (capacity of the system to facilitate perception of individual system elements through the senses) and conceptual clarity (capacity of the system to facilitate comprehension of the meaning of the system elements).
        - Clarity of the structure, divided in turn into formal clarity (property of the system in terms of having its elements organized in a way that enables them to be perceived with clarity) and conceptual clarity (property of the system in terms of having its elements organized in a way that enables their meaning to be easily understood).
        - Clarity in functioning, referring to both the way user tasks are performed and the way system tasks are automatically executed”.
    b. Consistency is “system uniformity and coherence.
    c. Memorability is “the property of the system that enables the user to remember the elements and the functionality of the system”.
    d. Helpfulness is “the means provided by the system to help users when they cannot infer or remember how to use the system. For this attribute a distinction is drawn between two aspects:
        - ▪ Suitability of documentation content, that is, content should be useful and adequate, bearing in mind that it includes definitions, descriptions, and examples.
        - ▪ Interactivity of assistance, that is, the extent to which the help provided by the system responds to the actions of the user”.

2. Operability is “the capacity of the system to provide users with the necessary functionalities and to permit users with different needs to adapt and use the system”.
    a. Completeness is “the capacity of the system to provide the functionalities necessary to implement the tasks intended by the user”.
    b. Precision is “the capacity of the system to perform tasks correctly”.
    c. Universality is “the extent to which the system can be used by all kinds of users”. It is broken down as follows:
        - Accessibility is “the extent to which the system can be used by all kinds of users regardless of any physical or psychic characteristic they may have (e.g., disabilities, limitations, age, etc.). This attribute is subdivided into others in accordance with specific characteristics (visual, auditory, speech, motor, and cognitive)”.
        - Cultural universality is “the extent to which users from different cultural backgrounds can use the system”. We identify this attribute as having two features, namely, language and other cultural conventions (use of symbols, measurement units, numeric formats, etc.).
    d. Flexibility is “the capacity of the system to adapt and to be adapted to different user preferences and needs”. It has two distinct aspects:
        - Controllability is “the capacity of the system to permit users to choose the most appropriate way to use the system”. A distinction is drawn between two sub attributes:
            - Configurability, defined as the capacity of the system to permit users to personalize the system, with a distinction drawn between the configurability of technical aspects and of formal aspects.
            - Workflow controllability, defined as the capacity of the system to permit users to control tasks as they are implemented. This attribute includes controllability over the steps to be followed (i.e., the system permits alternative approaches to performing tasks) and enabling task reversibility (i.e., the system allows users to reverse actions).

    - ‘Adaptiveness’ is “the capacity of the system to adapt itself to user preferences and to different types of environments”.

3. Efficiency is “the capacity of the system to produce appropriate results in return for the resources that are invested.” Four sub-attributes are included:
    a. Efficiency in human effort
    b. Efficiency in task execution time
    c. Efficiency in tied up resources
    d. Efficiency in economic costs.
4. Robustness is “the capacity of the system to resist error and adverse situations. It is broken down into sub attributes as follows:
    a. Robustness to internal error.
    b. Robustness to improper use.
    c. Robustness to third party abuse.
    d. Robustness to environment problems.
5. Safety is “the capacity to avoid risk and damage derived from the use of the system”. It is broken down into the following sub attributes:
    a. User safety, defined as the capacity to avoid risk and damage to the user when the system is in use. Specifying risk or damage in more detail, we distinguish between notions such as physical safety, legal safeguarding, confidentiality, and the safety of the material assets of the user.
    b. Third party safety, defined as the capacity of avoiding risk and damage to individuals other than the user when the system is in use.
    c. Environment safety, defined as the capacity of the system to avoid risk and damage to the environment when being used.
6. Subjective satisfaction is “the capacity of the system to produce feelings of pleasure and interest in users”. It consists of two sub attributes:
    a. Aesthetics, defined as the capacity of the system to please its user in sensorial terms. Depending on the type of sensation, this attribute can be subdivided into visual, acoustic, tactile, olfactory and gustatory aesthetics.
    b. Interest, defined as the capacity of the system to capture and maintain the attention and intellectual curiosity of the user.

The above mentioned models and components of usability formed a foundation for the development of a set of usability attributes that guided the design of the Venturer Model described in Chapter 5.

3.4 Models of Usability

3.4.1 Model of Multi-Modal Interface Design for Universal Accessibility

One approach to Human Computer Interface (HCI) design for the disabled based upon communications channels has been presented by Obrenovic, Abascal and Starcevic (2007). This model is an all-encompassing model for multi-modal interface design for universal accessibility. In Obrenovic's view, modalities can be seen as communication channels between the computer and the user and any environmental constraints or limited user abilities are perceived as breaks or decreased throughput in these channels (see Figure 3.1).

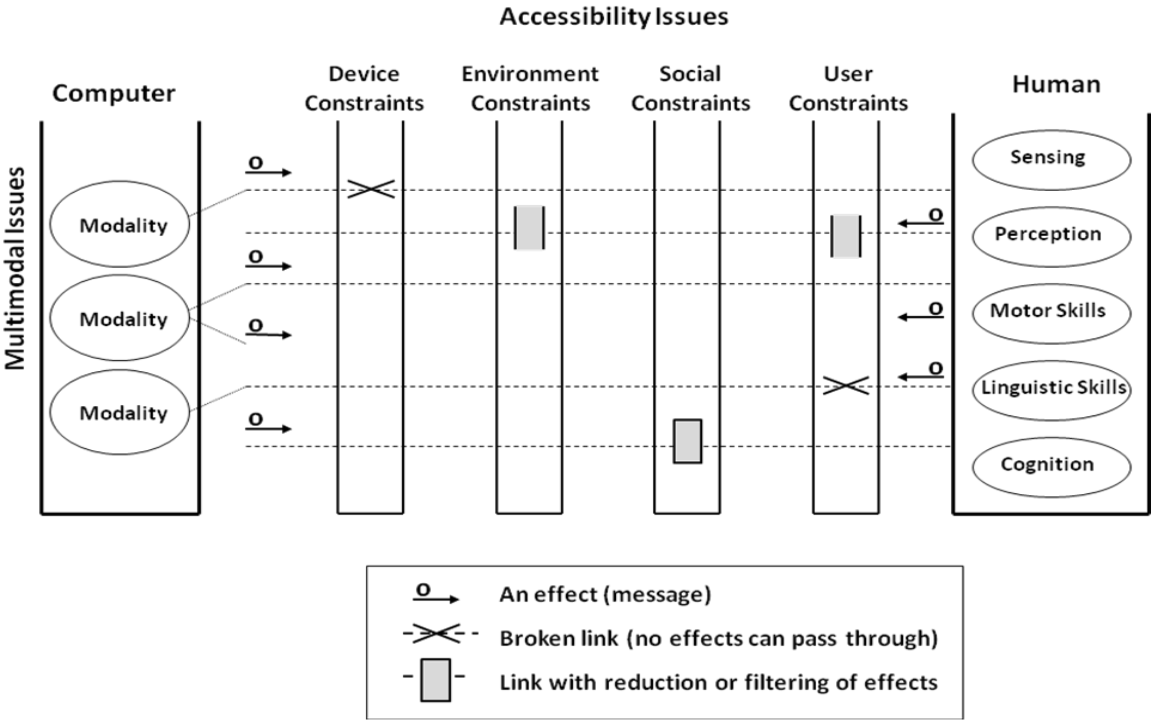

Figure 3.1: Model for Universal Accessibility (Obrenovic et al., 2007, p. 84)

This model for universal design, is composed of the following elements:

- Communication channels between the computer interface and the user in the areas of sensing, perception, motor skills, linguistic skills and cognition.
- Between the user and the computer system there are constraints in the form of; device constraints, environment constraints, social constraints and user constraints.
- Communication lines between the computer and the human pass through all the four constraint columns, and these lines can be; clear (message gets through), reduced, or broken for each of the human areas. For example, a

person who is blind would have a break in the perception line between the computer and the human in the user constraints column.

The universal accessibility model is a design-based model. This model is broad in its applicability to all disability groups. The current research applies only to the human elements of sensing and perception.

Obrenovic et al. (2007) describe a modality as a form of interaction designed to engage a number of human capabilities and these include; producing effects on computer users, or to process these effects. Indeed, they suggest there are both complex and simple modalities. A complex modality is one which comprises other modalities. Additionally, there are input and output modalities. The former require input devices that translate the user’s intentions or actions into code that the computer system can process. Output modalities take the response from the computer system and output them in a way with which the user can interact. With this in mind, there is a need to know the limitations of the user because then the output can be customized for the user based on his/her abilities. Some output modalities are simple and thus only one type of output can be generated. A complex modality would allow the system to output in more than one way affecting more than one sense (Obrenovic et al. 2007, p. 85).

Further, this universal accessibility model defines accessibility in terms of interaction constraints. These can be complex or simple. There are two types of simple constraints; user and external constraints. User constraints are user features, states and preferences. User features include the special abilities of the user and any disability the user has. The authors recognize that users have preferences and these illustrate how eager the user is to exploit the system with the abilities they have. External constraints include device constraints, environment constraints, and social context (Obrenovic et al. 2007, p. 85).

The Obrenovic model focuses on universal accessibility and this is designed to encompass accessibility for different types of needs and disabilities. As such this model is not directly applicable to the research at hand which on design constraints associated with Braille keyboard devices and user constraints of people without vision.

3.4.2 Usability Factor Model

A Usability Factor model was developed by Lauesen (2005, p. 24-5) that may be applied to the design of interfaces for non-sighted users. This model is both design and outcomes-based and contains six elements:

1. Fit for use (all user tasks can be supported).
2. Ease of learning (measured by task time).
3. Task efficiency (measured by task time completion); ease of remembering (measured by Task completion).
4. Subjective satisfaction (measured by interviews with stakeholders as task completion is not a suitable measuring method).
5. Understandability.

In discussing the strengths and weaknesses of her approach Lauesen (2005) suggested that conducting interviews may be an appropriate way to measure user satisfaction or to gain user opinion on a suggested model but results are not objective. Furthermore Lauesen (2005, p. 21) suggests that in designing and evaluating an interface there are; predicted problems, actual problems, false problems and missed problems.

Additionally, there are specific problems associated with usability in software and these include:

- Errors in the programme itself.
- Missing functionality which means that a user cannot carry out the task.
- The system may be difficult to use.
- Users may not be able to complete tasks or believe tasks are completed when they are actually not completed.
- The user may not work in an optimal way and may become annoyed at the system.
- The user may find a solution after many attempts (termed medium problem).
- A user may find a solution to a problem quickly.

(Lauesen 2005, p. 12).

3.4.3 Usability Attribute Model

Another framework, an outcomes-based usability attribute model, displays features that may be appropriate in formulating an interface for devices for those users without sight. Such a framework was devised by Adikari et al. (2006) consisting of three parts:

1. An Ishikawa diagram with spines representing seven attributes; efficiency, functional correctness, error tolerance, learnability, memorability, flexibility, and satisfaction.
2. A table with criteria to be measured for all seven usability attributes.
3. A conceptual user model containing seven user attributes; user needs and expectations, existing knowledge and skills, existing experience, user goals and tasks, physical attributes, cultural practice, and attitude information.

This model is displayed in Table 3.1 and Figure 3.2.

There must be flexibility built into the system which allows the users to undertake tasks in multiple ways or which provides multiple feedback to the users. The system must satisfy users and they must feel comfortable using the system. A key aspect of these elements is the fact that the system needs to be developed in such a way that users need to spend the least amount of time using help. Another key element is that no workarounds are needed. Workarounds are regarded by Adikari et al. (2006) as a negative element rather than being an exploratory means that enables users to become expert users.

Furthermore, Adikari et al. (2006) focus on the need for tasks to be completed in minimum time. This is related to a user becoming an expert and learning the system. A key element of ease of learning the system is that the user can determine the next action and the system presents clear instructions which enable this to occur.

Table 3.1: Conceptual Usability Attribute Model – Usability Attributes and User Attributes (Adikari et al., 2006, p. 431)

Efficiency	Functional Correctness	Error Tolerance	Satisfaction
E1-Task completion in minimum time	FC1-Task completion in minimum time	ET1-Appropriate error messaging for invalid conditions	S1-User desirability of the system and user tasks
E2–User tasks are not misleading	FC2-User tasks are appropriate, effective and match user needs	ET2-Ability to exit error conditions or unwanted states	S2-User opinion about user experience
E3-No workarounds are needed	FC3-User spends minimal time on 'Help'	ET3-No workarounds are needed	S3-User opinion about frustration or confusion

Learnability	Memorability	Flexibility	
L1-Clear visibility of current system status and a feel about what to do next	M1-No memory recall to carry out tasks	F1-Multiplicity of ways to carry out user tasks	
L2- User tasks are not misleading	M2- User spends minimal time on 'Help'	F2-User control of task performance	
L3- Task completion in minimum time			
L4- User spends minimal time on 'Help'			

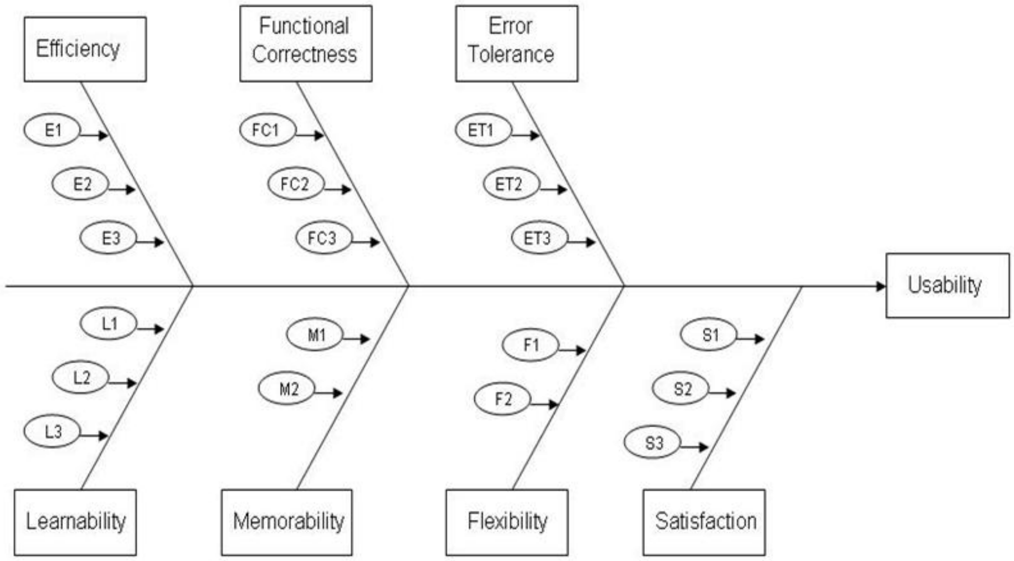

Figure 3.2: Conceptual Usability Attribute Model – Usability Attributes and User Attributes (Adikari et al., 2006, p. 431)

User Attributes are different to usability attributes because they are integral to users and thus are brought with users when they interact with user interfaces (Adikari et al. 2006). They recognised that users brought with them expectations and needs as well as cultural elements, a lot of existing knowledge and skills with computer and other systems, a set of goals they wished to achieve when using a system, and physical needs or disabilities.

3.4.4 Advantages and Disadvantages of the Usability Attribute Model

The Usability Attribute model has advantages for the current research for the following reasons:

1. The model takes into consideration both tangible and intangible criteria.
2. The model hinges on examining the existing system in situ (in a practically applied environment).
3. The model is comprehensive in its coverage and ensures “user interactions are efficient, functionally correct, error tolerant, learnable, memorable, and satisfying”

(Adikari et al. 2006, p. 431).

Despite its advantages the Adikari et al. (2006) usability attribute model has two disadvantages in terms of designing interfaces for Braille keyboard devices:

1. The model only focuses upon usability and does not take in to account other factors relating to quality in design.
2. The model does not take in to account the special requirements of blind people, in terms of interacting with complex documents and web pages.

However the advantages easily outweigh the disadvantages and the model is highly relevant to the design undertaken in this research. This model will be used in Chapter 4 to provide a set of usability attributes against which the functionality of Braille keyboard devices can be evaluated.

3.5 Guidelines for Good Interface Design

Various authors have attempted to codify sets of guidelines that are suitable for designing computer interfaces such as the one presented in Chapter 5. Five sets will be examined in order to determine the most effective guidelines to aid in evaluation of Braille keyboard devices presented in Chapter 4 and the design of the Venturer Model in Chapter 5.

3.5.1 The Gestalt Principals of Interface Design

The Gestalt Principals of Interface Design are discussed by Lauesen (2005). The Gestalt Principals emerged in 1980 as a result of merging psychological theory with Interface design theory. There was a challenge to the concept of ‘Atomism’, which suggests that the whole can be composed of the elements alone. However, Gestalt theory suggests that the whole is more than the sum of its parts (Behrens, 1984). These Gestalt principals are directly related to visual presentation of data to the user. There are five principles that should govern good interface design:

1. The law of proximity – pieces that are close together are perceived as belonging together.
2. The law of closure – the area inside a closed line is perceived as a shape.
3. Law of good continuation – pieces on a smooth line are perceived as belonging together.

4. The law of similarity – things that look alike are perceived as belonging together.
5. Law of parallel movement – things that move in parallel are perceived as belonging together.

(Lauesen, 2005, p. 68).

3.5.2 Schneiderman Guidelines

The eight guidelines for good human computer interface design developed by Schneiderman (1998) and enhanced by Skaalid (1999) include:

1. Strive for consistency – This includes consistent actions in similar circumstances and identical terminology should be used throughout menus, prompts and help information.
2. Enable expert users to use shortcut keys.
3. Informative feedback – can include multi-modal options.
4. Dialogues should result in closure – this means that prompts and dialogue boxes should lead to an end result.
5. Error prevention – only allow certain types of information to be entered at prompts and use menus to aid selection.
6. Design the interface in such a way that the user can escape without saving changes.
7. Design the interface so that the user is in control of the system. This includes reducing the amount of information the user is expected to remember. A way to reduce memory load is to use menus and prompts.
8. Error prevention – design the interface around functional relatedness.

3.5.3 Preece Guidelines

Preece, Rogers and Sharp (2007, p. 3) in their book, “Interaction Design: beyond human-computer interaction”, developed what they termed “design and usability principles”. These principles are similar to those developed by Schneiderman (1998) and outlined above. However, they do differ and include two principles not included in the guidelines developed by Schneiderman (1998). The five principles are:

1. Visibility – This refers to the visual layout of the contents of the HCI.
2. Feedback – Do commands result in an appropriate response that confirms the command used and what it has accomplished?
3. Constraints – So errors can be avoided. A physical example would be disallowing a card to be inserted upside down.
4. Consistency.
5. Affordance – how intuitive something is.

The two principles termed “Visibility” and “Affordance” differ from the guidelines presented by Schneiderman (1998). They include the appearance of the interface and the visual relationships of the elements. This concept may be reinterpreted to relate to the relationships between the elements of the interface. The concept of relationships will be investigated in developing the Venturer Model in Chapter 5. Moreover, the concept of ‘affordance” is an interesting concept. It was decided that the idea of ‘intuitive interfaces’ was too broad a concept for the current research since it was difficult to determine what ‘intuitive interfaces’ meant in terms of specified users with specified technology.

3.5.4 Raskin Guidelines

The ‘Humane Interface’ presented by Raskin (2000) is based upon a series of principles and proposes that humans can only consciously do one thing well at a time, providing the example and explanation that most people can walk and speak with a companion simultaneously because the conversation is the only conscious task being undertaken. He suggests that after an initial learning phase, all interaction with the “Humane Interface” should become habitual and an unconscious activity because it has become an automated interaction. He further suggests guidelines to promote computing commands becoming habitual more quickly:

1. All modes should be eliminated.
2. The system should always react in the same way to a command.
3. Generate user modes errors.

Further, Raskin (2000) explains that modes are differing types of responses based on context and that receiving unexpected or different responses is undesirable. All responses should be predictable (therefore consistent) and based on context and the user should not have to pay attention to the system’s current mode. The user should only have to pay attention to content and only be alerted by the system to any user mode errors. Additionally, Raskin (2000) also recommends monotony and non-multiple command paths. The monotony of performing tasks in the same manner more quickly leads to learned response and therefore habitual responses. Interactions become unconscious.

The memorability of commands is improved by monotony and simplicity. This is particularly true for screen reader users as they generally rely on memorised series of commands to perform tasks. It is not efficient to explore menus and dialog boxes, as a sighted user would do, if searching for a particular command. This is due to the serialised output (or display) of Text To Speech (TTS).

3.5.5 Guidelines for Web Interaction for the Blind

Chapter 5 discusses the functionality of Braille keyboard devices and presents this in terms of the Venturer Model. A key functionality of such a device is the ability to navigate complex documents and this functionality is called ‘rich navigation’. When discussing the interaction of blind people with complex documents and the web Babu (2009) considers various issues relating to problems with cognition and considers various usability attributes. He considers that the Usability attributes; perceivability, understandability, operability and robustness represent suitable attributes in the context of non-visual Web interaction. He suggests the following guidelines for non-visual web interaction:

1. Perceivable: A blind user can perceive a Web interface element.
2. Operable: A blind user can operate an interface element.
3. Understandable: A blind user can understand all content and controls.
4. Robust: The screen reader can interoperate with every interface element.

3.6 Multi-Modal Computer Interfaces

Multi-modal interfaces are computer interfaces which produce an output that stimulates more than one physical sense and may have advantages from a design point of view because they can be used in environments where the senses are engaged in other cognitive tasks.

An example of a domestic appliance with an excellent multi-modal interface is the Fisher and Paykel GW512_300px2 automatic top loading washing machine. This appliance has a keypad with different shaped buttons for different groups of functions. These keys are well-spaced and differentiated both tactually and visually. Although the key arrangement is visually pleasing it also stimulates the sense of touch. The processor outputs visual information via lights and outputs unique audio tones for different states of the machine and error codes (Fisher and Paykel 2008). The sense of hearing is stimulated by the audio output, the sense of sight by the visual appearance and lights and the sense of touch is stimulated by the tactile nature of the buttons.

A theoretical example of a multi-modal interface design would be output of error states, which; displays a graphical icon or a message, produces tactile (perhaps vibrating) information and plays a unique error tone to warn the user.

3.6.1 Non-Visual and Multi-Modal Interfaces

Most people who are blind and who use computers use screen reading software linked to synthetic voice output and perhaps a Braille display. However, the screen-reading software and related hardware can only read and display text and is unable to access the rich content, that is, images and graphical features (Freedom Scientific 2008; GW Micro 2008d). The screen reading technology accesses such elements as the document object model structure elements and ALT tags associated with the graphic or image. In contrast to those who are totally blind, people with low vision rarely use Braille, as more of their sense of sight is available to them. Further, Vertanen and Kristensson (2009) analysed the use of audio input to a mobile device and found that users could input between 13 and 18 words a minute. However, this was using a predictive keyboard in addition to the verbal input. Typists can type faster than 18 words a minute.

Kennedy (2009) discusses the disadvantages of using speech input. He indicates that speech input has a high error rate and there is a need to spend time training the software. Further, Kennedy (2009) indicates that because of the limitations of speech recognition that people with mobility impairment to the hands or arms may derive benefit from the technology. Other groups such as those who have autism or who are dyslexic may also benefit. The author does not recommend the technology for blind users as their primary need is for output modalities rather than alternative input modalities.

Research into the development of multi-modal user interfaces, for blind people, is still in its infancy as the majority of research in this area concentrates on speech input and output (Christian 2001). Although the research into user interfaces by using modes other than vision is increasing, it has been predominantly focused on the needs of those with low vision rather than on the needs of people who are totally blind. Numerous tactile and haptic interfaces have been developed over the past decade in particular, but they are generally linked to specific standard operating systems such as Windows and are quickly superseded as the technology moves on. Indeed Murray (2008) when studying e-learning among blind and vision impaired students at the CISCO Academy examined the use of various means to convey information to students (both audio and haptic technologies were examined).

3.6.2 Graphical User Interfaces

Graphical User Interfaces (GUI's) for computers were first introduced in the 1980s but by the early 1990s, the popularity of the Windows Operating System made it essential to study this phenomenon, especially as it impacted upon people with disabilities. These graphical interfaces are based almost entirely upon a visual spatial model and upon visual metaphors and direct manipulation of objects. GUI's are easy to use because they present a consistent visual interface to a user who can use skills learned in one programme when using another (Carneiro and Velho 2004). The BrailleNote PDA device, produced for people who are blind by Humanware, presents a consistent multi-modal interface to the user that focuses upon audio and tactile output. This consistency aids in the learning and memorability of the interface. The graphical user interface is based on the acronym WIMP which stands for Windows, Icons, Menus and Pointers. These are the interaction styles for Microsoft Windows and focus on a visual interaction paradigm.

The most common interaction styles in modern computer and electronic interfaces are; menus, direct manipulation, form-fills, and natural languages. These styles are based on; direct manipulation of objects and are characterized by interpreting user actions, such as; move, select, drag and drop. They are also characterized by a set of unique visual representations of objects such as icons. They rely upon special input devices such as mice (Carneiro and Velho 2004).

3.6.3 Alternative Interaction Methods

Graphical interfaces perform well for those who are completely able-bodied but Keats, Clarkson, and Robinson (1998) consider that GUI’s are problematic for those with motor impairments particularly in relation to alternative devices such as the mouse. The authors considered that the implications for those relying on models of interaction for designing interfaces or usability tests, is not to rely on the accepted able-bodied models and ‘add a bit’, but to actually measure the differences in the interaction styles between users with different capabilities.

The United States National Council on Disability (NCD) (1996) warned of the coming difficulties with employment and education associated with graphical user interfaces but was largely ignored by the community. It is suggested that as society’s utilization of electronic devices increases, people who are blind may become more disadvantaged.

Fritz, Way and Barner (1996) explored various ways to impart graphical information to people who are blind. They focused on haptic and audio output to display scientific and graphical data to their research subjects. The researchers used raised line drawings similar to those which are produced by the Piaf device developed by Quantum Technology in Sydney (Quantum Technology 2007b).

3.6.4 Computer Interaction Without Sight

In discussing haptic sense Carneiro and Velho (2004) described haptic as directly related to the sense of touch. In humans, this sense has two independent components: cutaneous (e.g. pressure) and kinetic (e.g. position and velocity of joints) (Oakley et al. 2000). This rich set of sensorial mechanisms allows people to assess an object's dynamic and material properties, verify and monitor activities in progress, build mental models for invisible parts of a system, etc. Many experiments have been conducted to discover the strengths and weaknesses of the human haptic system (Carneiro and Velho 2004; Klatzky et al. 1985; Lederman et al. 1993; Lederman and Campbell 1982; Reed et al. 1996). These authors use diagrams to show the haptic devices available at the time they undertook their research and also discuss the exploratory procedures used by humans. Carneiro and Velho (2004) declared that haptic touch is the only sense that can allow two-way communication with the computer interface. They further suggest that incorporating some haptic concepts in human computer interaction devices can improve the interaction efficiency of all people using computer systems. The Nintendo WII game console has a variety of different controllers, which offer different forms of feedback to the user, which include haptic feedback on some games (Nintendo.com 2008). It is suggested that one advantage of incorporating haptic feedback is that those who are blind are more able to use computer systems if alternative methods of interacting with the system are provided.

Multi-modal computer interfaces are incorporated in to devices for the blind and the benefits were discussed by Jacobson (2002), in particular, Feature Recognition and Shape Tracing. The main thesis was: “Multi-modal interfaces promise to increase the reliability of data interpretation through redundancy of representation, increase the number of data characteristics that can be analysed simultaneously, and improve navigation through higher dimensional datasets. Redundancy differs from pure repetition, and means the display of identical or related information in different formats, such as text that relates to a map, or a verbal commentary that accompanies a film” Jacobson (2002, p. 10). Redundancy of representation of data is suggested as the main benefit of multi-modal interfaces. Jacobson (2002) suggests three advantages of employing redundancy in design of user interfaces:

1. The information presented by a computer to a user is less vulnerable to loss of attention by the user if it is provided in more than one way, using more than one sense.
2. Learning theory demonstrates more long-term memory retention if information is presented in different formats.
3. Information presented through different modalities allows a user to use, or adapt to, the format of information presentation style that suits his/her disability or individual cognitive learning style.

Universal design requires the designer to take into account the needs of a wider group of people with varying abilities when designing a computer interface. Jacobson (2002) suggested that there were three areas of research in the field of applied multimodal interface design but focused on non-visual interfaces for use by vision impaired people. Here, "through sensory substitution, access is provided to information that would normally be perceived visually or with limited vision”, thereby allowing alternative methods of perceiving content (Jacobson 2002, p. 1).

Apart from raised line drawings for the blind, current conventional techniques for displaying information non-visually rely mainly on synthetic speech and Braille. These methods are problematic, as they do not provide access to the structure of even the simplest information. The user is unable to form a holistic overview of the information being presented. This relates in part to the properties of human short-term memory, which mean that listeners are unable to hold in their minds enough information to make any non-trivial observations and this appears true whether listening to a reading of a table of numbers or trying to visualise a map from a verbal description (Jacobson 2002). The Venturer Model (discussed in Chapter 5) and the three Braille keyboard devices (discussed in Chapter 4) provide multi-modal output to the user which is designed to improve the experience of blind users of the technology.

The experiments conducted by Jacobson (2002) focused mainly on potential areas of research into multi-modal interfaces and focused on haptic devices and used students with full sight and included shape identification. Results centered on the exploration techniques employed by the participants. The results indicated that further study needed to be undertaken in the area of haptic representation of spatial information. Furthermore, Carneiro and Velho (2004) and Jacobson (2002) undertook laboratory experiments with subjects, but only Carneiro and Velho (2004) used subjects who were blind and who used haptic devices. Each researcher undertook different tests and had varying triangulation of subjects and/or tests but both researchers concluded that the use of haptic devices would improve the interface experience of people who were blind.

This and other research into multi-modal ways of interacting with a computer system addresses the different ways by which those who are blind interact with systems compared with those with sight. In discussions with Tim Noonan (a totally blind consultant in disability design who has experience in interface design[2]) the researcher discussed the different ways in which a person with sight interacted with a computer system compared with a person with no sight. Tim Noonan suggested that the most successful computer devices designed exclusively for the use of the blind work in a single dimension or list model. Why this should be the case was also discussed, but without any conclusive reason for this success. It would appear from discussions with Tim Noonan that people who are blind have less spatial awareness than those with sight. The feedback provided by Tim Noonan supports discussion in Chapter 1 where impact of blindness was highlighted.

One outcome of the difference between a visual spatial and serial audio interface is that there needs to be a method designed to compensate for the fact that the serial

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[2] Discussion with Tim Noonan on 28 October 2008. Consulting: www.timnoonan.com.au

Speaking: www.visionarycommunications.com.au interface cannot mimic fully a two dimensional interface - a concept that arises out of the difference is the concept of ‘navigation support’. An example where navigation support can be employed is within web pages. The web provides rich content with different media formats and with complex layout of information. Another example where navigation support can be helpful is with large and complex documents. Such documents as a long report or thesis contain different elements that could include; tables, images, headings, footnotes/end notes, style changes whereas web pages also include elements such as frames and anchors. Screen readers for Microsoft Windows (JAWS for Windows, NVDA, and Window Eyes) address the problem of providing a single dimensional interface to a two dimensional interface in different ways, however, some elements are similar. Both JAWS and Window Eyes (Freedom Scientific 2008; GW Micro 2008d) use an off screen model to allow users to navigate the rich content of complex documents including web pages by providing short cut (single letter) navigation to document elements such as tables. The concept of a browse mode and edit mode derive from the off screen model concept. A browse mode is considered in relation to the Venturer Model in Chapter 5.

Babu (2009) discusses some distinct issues faced by blind people in terms of navigation support and web pages. Navigation support is considered in Chapter 5 in relation to the Venturer Model. These include:

1. The fact that screen readers present information serially means users perceive only a small part of the whole content, and are largely unable to understand the contextual information.

2. Users cannot assess information which is part of graphical elements since screen-readers can only read out text. An image with inadequate alt text (alternative text) will be difficult to interpret for a blind user.
3. Inability to quickly scan a page makes locating goal-relevant information difficult.
4. When Web pages possess complex layout, screen-reader’s output may become ambiguous.
5. The command structure of screen readers focuses upon keyboard input and requires the user to remember a large number of keystrokes in order to interact efficiently with web page and graphical user interface items. The requirement creates a cognitive overload on the user. Thus the users spend their cognitive resources in trying to understand the interaction between the screen reader, Web browser, the Web site.

Navigation difficulties arise when users fail to determine:

1. Relationship between intended actions and system mechanisms.
2. Functions of a control.
3. Mapping between controls and functions.
4. Inadequate feedback for verifying outcomes of actions.

These inconsistencies in design and navigation correspond to two types of gulfs (Babu 2009, p.3):

1. Gulf of execution: This represents a mismatch between a user’s intentions and system’s allowable actions. Users have difficulty translating goals into actions.

2. Gulf of evaluation: This represents the mismatch between the system's physical representation and the user's ability to perceive and interpret it directly with respect to her expectation. This gulf is large if feedback is difficult to perceive, interpret and is inconsistent with user's expectation.

The following terms may prove helpful in understanding the difficulties of navigation support for systems designed for blind people (Babu 2009, p. 3):

1. Incongruence denotes blind people's difficulty in completing Web-based tasks due to gulfs of execution or evaluation.
2. The term dissonance may refer to difficulties resulting from a gulf of execution.
3. Failure may refer to difficulties resulting from a gulf of evaluation.

The researcher and Tim Noonan also discussed the concept of ear cons. An ear con may be defined as "non-verbal audio messages that are used in the computer/user interface to provide information to the user about some computer object, operation, or interaction" (Blattner, Sumikawa and Greenberg 1989, p. 13). Also discussed was the concept of multi-modal interfaces with the result that Tim suggested that the area of multi-modal interface research should be broadened to include ear cons and other innovative ways of interacting with computer systems.

3.6.5 Icons and Ear Cons

This section will cover the concept of ear cons as it relates to computer interfaces and Braille keyboard devices. The discussion will cover concepts related to icons because ear cons have properties that are similar to icons.

Ear Cons are audio messages which are used in computer interfaces to provide information and feedback to users (Blattner, Sumikawa and Greenberg 1989). Microsoft Windows uses some ear cons as alert signals. One way to understand ear cons is by comparing them to icons.

There are several major differences between icons and ear cons. An icon is both selectable and informational to the user. Ear cons serve only informational needs because once they have been provided they have already gone. Further, icons are permanent (or can be), whereas ear cons are only transitory. In interfaces, ear cons normally serve only to provide additional feedback to the user. This feedback complements the visual feedback provided by the system. Another advantage of icons is that they can present a large amount of information in a compact space. They cover both representational images and visual symbols (Blattner, Sumikawa and Greenberg 1989). Moreover, icons are responded to more quickly than is text (Blattner, Sumikawa and Greenberg 1989), however this finding may be related to the familiarity of users with Microsoft Windows rather than the properties of icons alone. There are three types of icons; representational, abstract, and semi-abstract (these are a combination of representational and abstract). The concept of “representational icons” is that the icon visually appears like the object or function it represents. One such example of representational icons is the Apple “deleted items” which is visually represented as a trash can.

Another concept is that of items and actions. Some icons visually appear like the object and have characteristics simulating actions. Clicking on these icons will perform the action on the selected object (Blattner, Sumikawa and Greenberg 1989). Abstract icons are composed of shapes and are known to the user because of their learned association. They are not intuitive, and semi-abstract icons are a combination of representational and abstract.

As ear cons are the audio counterpart of visual icons they have some characteristics similar to those outlined above for icons, but also possess unique characteristics associated with their audio (and not visual) nature. Representational ear cons are those ear cons that use naturally occurring sounds of objects or events. The items do not have to be perfect representations of the object or action, but must be sufficiently recognisable. An example of a representational ear con would be the sound of a door closing to represent the closing of a programme or file. Abstract ear cons are composed of tonal sounds that are generated sound schemes rather than being composed of naturally occurring sounds. Ear cons are composed of potentially three multi-level elements as follows:

1. Motives - “A motive is a brief succession of pitches arranged to produce a rhythmic and tonal pattern sufficiently distinct to allow it to function as an individual, recognizable entity. Rhythm is the timing and weighting of notes and the pitches must be in the same octave for the same motive. Additionally,

"A single-pitch ear con is any audio message composed of one note with the attributes of pitch, duration, and dynamics".

2. Modules – are built from motives and are the second level of complexity in relation to ear con development.
3. Families – are built out of modules and single motives. These are the most complex sets in ear con development.

(Blattner, Sumikawa and Greenberg 1989, p. 29).

There are distinct advantages of classifying audio objects according to this three-layered approach.

1. It is systematic, with well-defined elements that may be used to construct larger sets of ear cons. This systematic approach is straightforward and can be understood. The method allows for small modules or parts of the whole and this allows easy modification, future development and tailor ability.
2. The constructed motives may be transformed, combined or inherited. This allows for the creation of families of related motives.
3. Different families of motives will sound different.
4. The use of simple rhythm and pitch allows for implementation on systems with low specifications of hardware.

(Blattner, Sumikawa and Greenberg 1989, p. 29).

There are other characteristics of sound which affect ear cons (Blattner, Sumikawa and Greenberg 1989):

1. Timbre - Changing the wave form of the sound will change the tambour or quality of the sound.
2. 'Dynamics' refers to the variability in loudness of the ear con.

A method of forming hierarchical families of ear cons is proposed by (Blattner, Sumikawa and Greenberg 1989).

1. Computer messages must be classified into hierarchical trees of messages. This means related messages must be grouped.
2. Each family is assigned a unique rhythm and this becomes the signature for the family. It is analogous to a last name in a human family.
3. Ear cons which lie below a family name or rhythm are made up of two parts: the family rhythm and a set of pitches connected to the family rhythm.
4. Third level ear cons have the characteristics of the first and second levels and have a third entity composed of the second level set to a different timbre and a slightly higher pitch.

Microsoft Windows uses several informational ear cons including “new E-mail alerts” and “system crashes”. These informational messages have properties similar to textual information and are presented serially with the difference that textual information can generally be reviewed, but in these instances it is usually transient, in a similar manner to the audible messages of ear cons.

The Mountbatten Brailler used a great number of ear cons in its interface (Quantum Technology 2008). However, the device provided no context-sensitive help to aid the learning of the unique sounds. An innovative use of ear cons is found as part of the Emacspeak audio desktop application extension to emacs developed by T.V. Raman. Unlike screen readers that speak the contents of a visual display, Emacspeak speaks the underlying information. The system deploys the innovative technique of audio formatting to “increase the band-width of aural communication with changes in voice characteristic and inflection combined with appropriate use of non-speech auditory icons are used throughout the user interface to create the equivalent of spatial layout, fonts, and graphical icons so important in the visual interface. This provides rich contextual feedback and shifts some of the burden of listening from the cognitive to the perceptual domain” (Emacspeak 2009, n.p.).

Another innovative use of ear cons was developed by Andre Louis in his sound scheme for Windows. He is a musician who is blind and wished to provide a useful set of sounds that were assistive to users. His scheme provides unique sounds for almost every Windows event.[3] For example, a Window maximising sounds different from one closing; moving slowly with the cursor in a list view in “my computer’ sounds different if the user moves quickly across the same file list. The sounds are organised into families and motives.

3.7 Braille Writing Devices

3.7.1 Manual Braille Writing Devices

The Braille writing devices for the use of people who are blind usually have six dedicated dot keys for producing the Braille dots and a space bar and some means to backspace and change lines. This convention of nine dot keys which are dedicated to the writing and correction of the Braille is a standard adopted by most manufacturers of manual Braille writers and some manufacturers of electronic Braille keyboard devices. The Marburg Braille writer (Figure 3.3) has a fixed embossing head with a

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[3] Monday 20 April 2009 http://onj.andrelouis.com/44.1k.exe

movable carriage.[4]

Figure 3.3: Photo of the Marburg Braille Writer (The New York Institute for Special Education 2008)

Stainsby Braille Writer

One of the early Braille writers was the improved Stainsby Braille Writer manufactured (Figure 3.4) by V. L. Martin Co. Ltd., England London. This device was cumbersome to use and produced Braille vertically. One of its problems was that the dot keys for forming the Braille extended sideways rather than being placed at the front. The paper was clamped to a metal base that was hinged for storage.[5]

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[4] The American Printing house for the Blind (APH) has a Museum which houses a collection of approximately 35 Braille and other writers for the blind. The online version of the collection can be viewed at: http://sun1.aph.org/braillewriters/index.html.

[5] Interpointing or interlining models were available (American Printing house for The Blind, 2007).

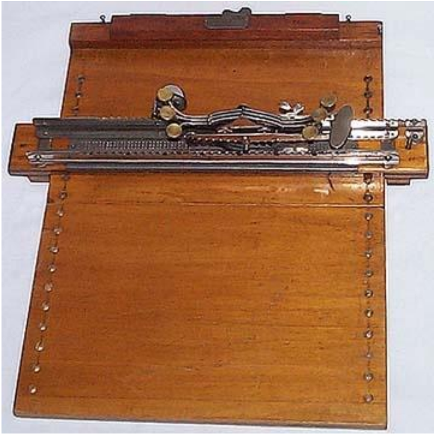

Figure 3.4: Stainsby Braille Writer (Vision Australia 2008)

<u>Perkins Brailler</u>

The Perkins Brailler (Figure 3.5) was first manufactured in 1951 and was designed by David Abraham and produced by Howe Press of Perkins School for the Blind Watertown, Massachusetts. The device is the most commonly used manual Braille writer in the world today and has a reputation for being durable and simple to maintain (American Printing House for The Blind 2007).

Figure 3.5: Perkins Machine (Adaptive Technology Center 2008)

The keyboard on this device serves as the standard for the Braille keyboard devices produced today.

Perkins.org released a new generation Perkins to the market in October 2008 (Figure 3.6). The company surveyed its user base and designed a new manual Braille writer which took into account the user needs. The new machine possessed a table for reading the Braille and front margin set levers, had a quieter operation and was lighter in weight (Perkins.org 2008).

Figure 3.6: The 2008 New Perkins (perkins.org 2008)

Until recently, blind children who were learning Braille used the Perkins Brailler as the primary tool for writing. A major disadvantage in this scenario is that the Perkins weighs in excess of 12 pounds and the required pressure on the keys to emboss paper is excessive for many young children (Quantum Technology 2007b).

3.7.2 Electronic Braille Keyboard Devices

Electronic Braille devices tend to have a limited number of dot keys available and therefore make use of ‘chorded’ commands and function keys to add functionality. The convention for invoking chorded commands on a Braille keyboard device is to hold down one or more of the function keys (either the backspace, enter or the space bar) and then press the dot keys representing a mnemonic letter command. An example would be space + f for find. Microsoft Windows employs several keys as function keys such as ctrl, shift, alt and the Windows logo key.

VersaBraille and Braillex

The 1970s saw computer technology begin to be used in devices for the use of people who are blind. Two such early electronic Braille keyboard devices were the VersaBraille (Figure 3.7) and the Braillex (Figure 3.8).

Figure 3.7: The Versabraille (CEPIS, 2007)

Figure 3.8: Papenmeier Braillex (Papenmeier 2008)

The Braillex was the first electronic Braille keyboard device that possessed Braille output although the VersaBraille, released soon after the Brailex, also had Braille output. Both of these devices initially relied upon tape drives but later models of the VersaBraille used floppy disks for storage. Both devices enabled a blind person to store information under a name and then retrieve it later. The refreshable Braille displays on these devices consisted of a number of Braille cells. The Braillex had an advantage of a serial port which enabled it to communicate with other computer devices. People who were blind took advantage of using the Braillex system because for the first time they could write, retrieve and read Braille without using paper.

Braille and Speak

Another early electronic Braille keyboard device was the Braille and Speak (Figure 3.9), produced by Blaizie Engineering in 1985 (Freedom Scientific 2008). The device provided mainly note taking facilities and synthesised voice output.

Figure 3.9: ***The Braille 'N Speak*** **(http://www.arkansasschoolfortheblind.org/images/brlnspeak.jpg)**

This device possessed a seven-key Braille keyboard and relied upon chorded commands to operate the device. Because of its limited keyboard the command structure was complicated (chorded commands had to be memorized) and the device possessed no built in help functionality.

Mountbatten Brailler

The Mountbatten Brailler (Figure 3.10) is an electronic Braille note taker and embosser with features that include an ergonomic keyboard, memory, speech feedback, and the ability to translate from Braille to print, and print to Braille and became available in 1991. The device was marketed as a Braillewriter and was intended to replace the Perkins Braille.[6]

Figure 3.10: Mountbatten Brailler System (Quantum Technology, 2008)

This electronic Braillewriter uses a unique Braille keyboard with several additional dot keys to allow commands (including chorded commands) to be initiated. Later models provided some context-sensitive help via a built-in speech synthesizer, however help was limited and the user was largely expected to learn the commands, chorded commands, and earcons in order to use the device efficiently.

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[6] The research and development of the Mountbatten Brailler was funded by a bequest in Lord Mountbatten’s will for the development of a modern, low cost, portable braillewriter. The prototype was developed at the Royal National College for the Blind in Hereford, England, and Quantum Technology, of Sydney Australia, subsequently began to produce the device (*Holbrook Wadsworth and Bartlett 2005)*.

Apart from chorded commands (which used spacebar with an alpha numeric key) the Mountbatten Brailler command sequences included text strings that are typed at the command prompt. The command prompt is initiated by pressing together the following keys; New Line key + Spacebar + F1 + F2. Text commands must be entered in a three stage process:

1. Press command key.
2. Type letter or number string.
3. Press enter key.

There are more than two hundred such commands, covering such areas as text formatting, file management, status commands and printing commands. Table 3.2 provides examples of these commands.

Table 3.2: Example Mountbatten Command Sequences

Command	**Explanation**
ADV	Advanced Mode
SPK R	Recorded Speech Output
SPK A	Speaks all keys
SPK C	Speaks only Errors and Prompts
TB	Tab
END	Close an open file
LMH	Set left margin to embossing head position.
LS n[m]	Line spacing (Default = 1)
PBELL [n]	Set page bottom warning bell to ring "n" lines before the end of page
MPR y [filename]	Print "y" multiple copies of the file named "filename"

The chorded commands use the spacebar as the function key. Table 3.3 provides examples of chorded commands.

Table 3.3: Example Mountbatten Chorded Command Sequences

Command	**Explanation**
Chord B	Backtab
Chord C	Carriage return
Chord E	End
Chord F	Line feed
Chord H	Help
Chord I	Indent
Chord P	Page eject
Chord R	Reverse Line
Chord T	Tab
Chord Z	Stop speech

Eureka and Aria

An innovative personal computer designed especially for the use by Braille users was known as the Eureka A4 (Figure 3.11). Robotron Sensory Tools produced this sophisticated personal secretary from 1986 but it has since been replaced by the Aria (Figure 3.12) which was first produced in 1996 but failed to be commercially successful.

Figure 3.11: Eureka A4 (Robotron Sensory Tools 2008)

The Eureka had a ROM-based CPM operating system, 128 K of ROM, 1 MB flash and a low power floppy disk drive produced by the Citizen Watch Company (Robotron Sensory Tools 2008). It had a serial port and a built-in modem that provided connectivity to the early IBM and Apple personal computers, as well as giving it the capability to work with the early bulletin boards.

Figure 3.12: Aria System (Robotron Sensory Tools 2008)

The Eureka A4 had significant advantages; the command structure was consistent across applications and the user could invoke spoken help on any of the eight function keys by holding down the space bar and pressing the function key. The Eureka was the first Braille keyboard device to offer this form of spoken help. This help was available at the main menu and at the menus for the applications within the Eureka. Eureka also possessed a “Where am I” help function invoked with space bar and dot key 4, many Braille keyboard devices have since adopted the convention of using the space bar to invoke spoken help. The Eureka A4’s unique keyboard consisted of three distinctive groups of keys, the seven-key Braille keyboard, eight function keys, and a set of cursor arrows. Function keys were placed directly above the Braille keys in a row from left to right 1-8. This meant that the user could reach up with the Braille writing fingers to reach the function key above a Braille key with F3 and F6 having raised dots to aid orientation. The 16 applications available in Eureka A4 are set out in Table 3.4.

Table 3.4: Applications available on Eureka A4 (Robotron Sensory Tools 2008)

Function key	**Application**
F1	Note taker
F2	Clock and calendar
F3	Calculator
F4	Communications
F5	Telephone directory
F6	Basic interpreter
F7	Music composer
F8	Disk directory
shift-F1	Word processor
shift-F2	Diary
shift-F3	Thermometer
shift-F4	Volt meter
shift-F5	Data base
shift-F6	Disk utilities
shift-F7	Run disk programme
shift-F8	Disk formatter

Note: Shift is the ‘home’ key centre button in the cursor pad.

Another feature of the key mapping adopted by Eureka is the placement of similar applications on the same function key for example, on the Eureka A4, the note taker and word processor are located on the same function key except for the addition of the shift key. The key mapping for this research will take into account the lessons learned from the Eureka and, as far as possible, will locate applications which are related to each other on the same function key or set of keys. Additionally the key mapping will consider the use of chorded commands and the use of function keys and cursor arrows.

PacMate

Freedom Scientific chose to develop the PacMate (Figure 3.13) in such a way that there is minimal modification to the Windows CE environment and thus off-the-shelf programmes may be installed. PacMate uses a 400 mhz processor, has 32 MB flash and 64 MB ram, two type 2 compact flash card slots and USB port. The keyboard on the PacMate has three distinct groups of keys, these are the nine-key Braille keyboard (six Braille writing keys, backspace key, enter key and space bar) eight function keys and the cursor arrows. The device can be connected to external devices via a serial and USB port and provides PC card storage options.

Denham and Leventhal (2003) reviewed The PacMate and considered that its command structure was confusing and not intuitive. In their view the learnability of the interface was reduced by the layered approach adopted by Freedom Scientific. This approach also necessitated a similar layered architecture with context sensitive help. Usability is compromised due to the inconsistent use of short cut key sequences and the confusing application of function keys.

Table 3.5 shows examples of the command structure for PacMate.

Table 3.5 PacMate Example Commands

Command	**Description**
Spacebar+c	determines key strokes to change a control within a dialogue box
Spacebar+h	provides information on current application, dialogue or window
Spacebar+t	opens on line help
Spacebar+p	opens the table of commands
Spacebar+w	gives a list of commonly used Windows keyboard commands
Spacebar+I then t	window title
Spacebar+k	keyboard help on/off toggle

Freedom Scientific placed the function keys above the Braille writing keys and chose to give them the same function key number as the corresponding Braille dot below them (see Figure 3.13). The placement of function keys does not follow that for a personal computer which may cause some confusion.

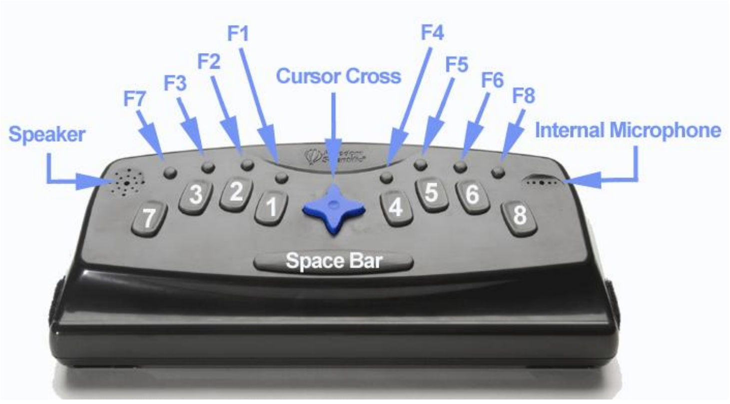

Figure 3.13: PacMate with Braille Keyboard and 40-Cell Braille Display (Freedom Scientific 2008)

BrailleNote

There are various models of the Braille Note family of PDAs designed for the blind and distributed by Humanware, although only the BrailleNote PK (see Figure 3.14) and Empower (see Figure 3.15) will be considered. The Empower is larger and provides more connectivity options and possesses a different command structure to the PK due to its use of ‘thumb keys’ rather than a joystick control. The placement of the Braille dot keys and space bar in relation to the Braille display on the PK could present problems for a new user.

Figure 3.14: BrailleNote PK (Humanware 2008b)

Figure 3.15: BrailleNote Empower with 32 Braille Cell Display (Humanware, 2008a)

A review of the BrailleNote PK undertaken by Denham, Leventhal, and McComas (2005a) indicated that the BrailleNote PK was the smallest PDA designed for the blind. The reviewers stated that the command structure and spoken help were consistent and helpful. Consistency is a key element in good interface design (Schneiderman 1998). The reviewers found several problems particularly with the e-mail feature, where they felt the command structure had been poorly executed. The review of these devices was conducted over five years ago and all have since undergone further development.

The BrailleNote family of PDAs use the Windows CE 4.2 Operating System. A key feature of these devices is that Humanware has chosen to run a specialized software supervisor, called KeySoft that acts in a similar manner to a task manager for all applications. This means that the user of a BrailleNote never interacts with the Windows operating system. There are different versions of KeySoft running on different models of BraileNotes due to the availability of Braille feedback and the different arrangement of function keys.

The developers of KeySoft adopt a different interaction paradigm to Microsoft windows. Keysoft relies upon menus, prompts and shortcut keys in its interface. The developers of the software have made consistency a high priority. Table 3.6 provides a sample of BrailleNote Empower key assignments.

Table 3.6: Sample commands for BrailleNote Empower BT32 (Humanware 2008c)

Command	**Action**
Spacebar+h	Help
Spacebar+o	Options Menu
Spacebar+i	Information
Spacebar+left thumb key	Rotates voice from on to ‘on’ by request to ‘off’
Spacebar+right thumb key	Turn Braille display ‘on’ or ‘off’
Spacebar+dot keys 123	Top of document
Spacebar+dot keys 456	Bottom of document

A feature of the keyboard layout of the BrailleNote is that functions that either return to the top or previous location are located on dot keys 1, 2 or 3 and functions that advance or increase are located on dot keys 4, 5, 6, and functions that read current items are achieved by holding down dot keys on both sides of the space bar at once. This design feature of functional relatedness ties in well with guidelines 7 and 8 of the interface guidelines developed by Schneiderman (1998). The system is also efficient for the user and commands can be learned easily. These aspects relate to usability attributes.

BrailleSense

A third Braille keyboard PDA (BrailleSense) is produced by HYMS Co. Ltd. The device has a nine-dot-key Braille keyboard and several function keys (F1-F4) as well as keys on the front panel to control the media player (see Figures 3.16 and 3.17).

Figure 3.16 The BrailleSense (GW Micro 2008)

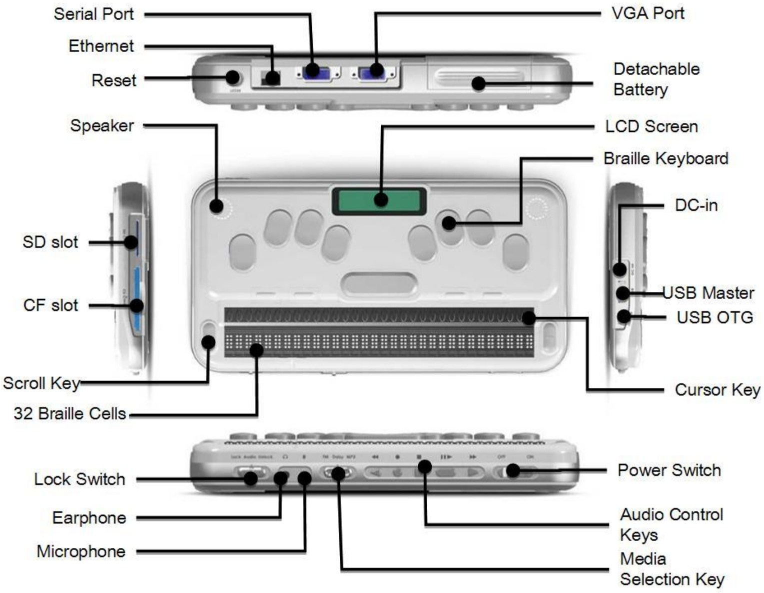

Figure 3.17: BrailleSense Plus (GW Micro 2008b)

A review of the BrailleSense undertaken by Denham, Leventhal, and McComas (2005a) indicated that the user manual was not clearly written and that audio help was not useful. They point out that the applications and interface for the BrailleSense are proprietary and that there is no spell checker within the unit. The reviewers found the unit to be unstable when surfing the Internet and in some other applications. The developers have adopted the convention of writing specialized applications for the blind.

This convention commenced with the Eureka A4 and is a convention adopted by Humanware with their BrailleNote family of PDAs. During tests conducted by Denham, Leventhal, and McComas (2005a,b), the BrailleNote products were rated highest. A key reason why the BrailleNote is easier to master is that the unit contains well developed help facilities with help information being specific to each prompt within the unit (Humanware 2008c).

The usability attributes discussed in this section will influence the design of the Venturer Model; in particular ‘Consistency’ and ‘Functional Correctness’ will be important considerations.

3.8 Braille Keyboard Devices as Learning Aids

The British Columbia Provincial Resource Centre for the Visually Impaired, Special Education Technology-British Columbia (SET-BC), and the University of British Columbia's Program in Visual Impairment initiated a research project in December 1998. The purpose of this project was to introduce the Mountbatten Brailler (MB) to children in early literacy programs and to provide training in the operation and use of the Mountbatten Brailler for both teachers and students.

A total of fifteen teachers and their fifteen students were included in the project with the project running over three years. The students were enrolled at regular schools and learning Braille, with each student having the support of a teacher trained in teaching blind students. Nine of the students had little or no useful vision and used Braille as their primary literacy medium, and six had varying degrees of useful vision and were learning to read and write in both Braille and print. Three of the fifteen students had additional identified disabilities. All the students had used the Perkins

Brailler as their primary writing tool for Braille before they entered the project. The study found that the use of the Mountbatten Brailler improved student literacy (Holbrook Wadsworth and Bartlett 2005).

Quantum Technology responded to a questionnaire which was related to this study where they discussed the merits of Braille writing, particularly the Mountbatten Brailler (MB) in learning literacy in blind people. They pointed out that the MB is used both as a Braillewriter and an aid to the teachers of the blind. The SET-BC project was one of the early studies that focused on Braille writing and literacy. The Quantum Technology response highlighted issues of repetitive strain injury, which they indicated was a problem with the long-term use of the Perkins Brailler (Quantum Technology 2007a).

3.9 Conclusion

This chapter presented a summary of the literature impacting upon the development of an interface and interaction paradigm for Braille keyboard devices. A key focus was to illustrate how the interaction paradigm for Braille keyboard devices for blind people needs to differ from that for people with sight. A key difference relates to the non-visual and serial nature of the interface for Braille keyboard devices compared to the two dimensional visual interface present in computer interfaces for sighted individuals.

The concept of an interface was introduced with a key finding that multi-modal interfaces promise to provide a better experience for blind users than a single modal interface. Further usability attributes and criteria were discussed and it was established that a variety of usability attributes should be considered in developing an interface suitable for deploying on devices with Braille keyboards. A key usability attribute to be considered is consistency. Consistency aids learning and memory retention. The chapter also discussed some unique problems faced by blind people accessing complex documents with complex structure. It was determined that web page navigation concepts found in such screen readers as JAWS and Window Eyes could aid the development of an interface for blind people because these screen readers provide navigation to elements of complex documents such as headings, tables, lists, frames, and font attributes such as bold text.

A review of several Braille keyboard devices available in Australia was also presented. The review revealed that the most highly regarded devices available in Australia were produced by Humanware. A key reason for this finding was the existence of context sensitive help and consistent keymapping on the devices.

Chapter 4 will now take the concepts introduced in this chapter and apply them to a practical evaluation of three modern Braille keyboard devices available in Australia. The usability attributes provided by Adikari et al. (2006) and the guidelines for interface design developed by Schneiderman (1998) will guide the review.

Chapter 4: Three Modern Braille Keyboard Devices

4.1 Introduction

The preceding three chapters have provided a background to the problem space, discussed the research method and data collection methods employed in this research and presented a review of literature focusing upon usability of systems and providing the history of Braille keyboard devices. Models for usability and a set of usability attributes designed to evaluate functions were also presented.

This chapter evaluates the three electronic Braille keyboard devices considered in Chapter 1. This will provide triangulation and establish whether the reviews of the devices conducted by Denham, and Leventhal (2003), Denham, Leventhal, and McComas (2005a) and Denham, Leventhal, and McComas (2005b) are still valid given the updates to the devices since the reviews. The chapter presents the functions that should be included in an interface for Braille keyboard devices and presents preliminary findings concerning an interaction paradigm for such devices. The evaluation of these devices will use two sets of criteria. The criteria for good interface design by Schneiderman (1998) will be used to establish how well the devices meet interface design guidelines and for usability the Usability Attributes presented by Adikari et al. (2006) will be considered (see Table 4.1). Restricting the evaluation of the devices to the usability attributes provided by Adikari et al. (2006) allowed the researcher to present findings on functionality and the interrelatedness of these functions more clearly. Chapter 5 presents the Venturer Model where additional usability attributes will be considered.

Table 4.1: Criteria for Evaluation

Good Interface Design Criteria (Schneiderman 1998)	**Good Usability Attributes Adikari et al. (2006)**
Consistency	Efficiency
Shortcut Keys	Functional Correctness
Informative Feedback	Error Tolerance
Dialogues result in closure	Satisfaction
Restricted types of information entered at prompts	Learnability
Use of menus	Memorability
Escape without saving	Flexibility
User is in control of the system	
Functional relatedness drives interface design	

There are three devices evaluated in this chapter. These are:

1. BrailleNote Empower 32 (produced by Humanware)
2. PacMate (produced by Freedom Scientific) and
3. BrailleSense (produced by HYMS Co., Ltd.).

The researcher studied these physical devices in 2009 and evaluated them by using applications on the devices. The focus was upon; the word processors, internet browsers, data bases, connectivity and file management. The same devices were also tested in October 2010 with the firmware updates applied.

The functions of the devices were evaluated by the researcher because each device possessed different sets of applications and methods of interacting. An application is a programme offering functionality to the user. Each device offered different ways to interact with it and so each had a different interaction paradigm. Each possessed a speech and Braille interface. The interaction paradigms differed on each device but all focused upon text; although the BrailleSense and PacMate offer a ‘Windows like’ interface.

There are two predominant tasks a blind user carries out on a computer device. These are navigating and editing. All the functions of devices can be seen as supporting either navigating or editing. Some functions support both main tasks. This thesis will use the term ‘navigation support’ and ‘editing support’ to describe these two main tasks. Navigating is ‘looking’ at the output of the device and moving around within its interface. Looking can include the use of alternative output modalities such as speech or tactile output. Editing is making changes to the content and moving and copying files and content. Playing an audio file itself would be considered navigating but creating a playlist of favourite songs would be considered editing.

4.2 BrailleNote Empower 32

The BrailleNote Empower BT32 uses text input and output modalities and provides three ways to interact with the user. These are:

- Prompts – requiring user response from the keyboard.
- Menus – user can interact with these via the keyboard.
- Short Cut Keys – User memorizes these to make interaction efficient and thus improves usability.

Whereas Graphical User Interfaces (GUIs) are based almost entirely on visual metaphors and direct manipulation of objects, the KeySoft User Interface (UI) on this particular device is based on menus, prompts and shortcut keys, including first letter navigation. GUIs are easy to use for those with sight because they present a consistent visual interface to a user who can apply skills learned in one programme when using another (Carneiro and Velho 2004). The BrailleNote PDA device is easy for people who are blind to master and use because KeySoft provides a consistent audio and tactile UI. Skills learned in one application can be applied to others. The consistent nature of the KeySoft UI on the BrailleNote Empower BT 32 fulfils the first guideline for good interface design proposed by Schneiderman (1998). Also, the interface presented to the user by KeySoft means that the system can be learned and memorized easily. A key element of the usability attribute model presented by Adikari et al. (2006) is that the system should be easily learned and commands should be easily memorized and be functionally related. Keysoft presents a consistent interface where commands are functionally related as the following discussion will show.

Keysoft was originally developed in the mid 1980's on the Epson HX 20, then ported to MS DOS, then to Windows, and finally to Windows CE. The initial development of KeySoft occurred within an environment prior to the widespread use of GUIs. The user interface development occurred within the constraints of a speak serial interface. Thus, the two-dimensional visual spatial metaphor of GUIs was replaced by a single-dimensional metaphor based around textual elements such as characters, words, sentences and paragraphs. Command control was accomplished through lists of functionally related items (menus). Where possible the new functionality of each new operating system was incorporated into the user interface of KeySoft as it was developed. All the commands can be seen as methods for moving back and forward through a list. The command sets provide different ways to achieve this but the underlying concept is a list related to a speak serial interface.[7]

A vital component of the KeySoft application is the help facility. A user of a BrailleNote BT can press the space bar and the letter H at any time to obtain context-sensitive help. The help provided includes displaying the menu or the options available at prompts. The help facilities are an integral aspect of the user interface. The help system is structured in such a way that it presents menus to the user. The maximum number of elements that a user of the help system needs to remember at any one time is three. Good interface design reduces the amount of information a user needs to retain in his/her memory (Schneiderman 1998). Reducing memory load improves the usability of an interface.

Humanware were cognisant of the lack of visual prompts which would remind the blind user of commands. They implemented a highly structured context sensitive help facility to overcome this limitation. Because the users of BrailleNote would be unable to refer to visual prompts on the screen, the developers of KeySoft made the conscious decision to make consistency an extremely important aspect of the design of KeySoft.[8]

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[7] Conversation with Tim Noonan on 28 October 2008. Tim is a Human Factors user interface designer, Consulting: www.timnoonan.com.au Speaking: www.visionarycommunications.com.au

[8] phone interview with Morris Sloan from Humanware on 2 June 2008

Further, Humanware made the design decision to produce a device which relied upon an interaction paradigm specifically for people who are blind based upon user needs rather than the needs of the operating system underlying the interface.[9] They recognized that the users of the BrailleNote could focus only on one piece of information at a time. This led to the implementation of a user interface within KeySoft which is based upon menus, prompts and shortcut keys. This design choice reflects good interface design (Schneiderman 1998). The choice to employ linked menus, prompts and shortcut keys also allows users to become experts and use shortcut keys. This is also a feature of the usability attribute model (Adikari et al. 2006).

The formatting of word processor documents is achieved through tagged mark-up of the text. An example of a tagged command is that a new paragraph is marked with a space, a $ sign, a letter p and a space. This is a convention used in Braille and originated with Braille translation programmes such as Duxbury (Christensen, Holladay, Leventhal and Navy 2010).

The concept of visual layout is unnecessary in the presentation of information to the user of a device without a screen. Tagged mark-up allows the experienced user to be aware of how the document will be printed.

The whole concept of What You See is What You Get (WYSIWYG) is unimportant on a device without a screen. The concept employed on the BrailleNote Empower BT 32 and other Braille Keyboard devices with Braille displays is What You Imagine is What You Get (WYIIWYG). This concept existed in such early MS DOS

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[9] phone interview with Morris Sloan from Humanware on 2 June 2008

word processing programmes as WordPerfect 5.1 (Jones 1991). Additionally WordPerfect 5.1 used text tags to indicate layout and text formatting.

The user of the BrailleNote Empower BT 32 will be reading the Braille on the Braille line. Humanware did not implement many ear cons in its interface. This may have been due to the origins of the Keysoft application or the limitations of Windows CE. Humanware also wished to allow users of the BrailleNote to use existing skills and knowledge of other Humanware products to aid in the learning of the device. Earlier Humanware products did not have many non-verbal cues or extensive use of ear cons.[10]

The interface on the BrailleNote devices was designed so that both very young people who were blind and people who lost their sight in later years could easily and rapidly learn to use them. This choice was made in order to target that user group. Further, Humanware also targeted new users of computer systems. Humanware wished to provide a device that would enable a new user of computer systems to carry out daily tasks such as keeping a diary and a structured contacts list. The BrailleNote was seen as an aid to the learning of computer systems, especially for young people who were blind who would learn to write Braille on the BrailleNote and then later learn to use a personal computer. The BrailleNote thus complemented the computer experience rather than competing with it or providing a personal computer.[11]

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[10] phone interview with Morris Sloan from Humanware on 2 June 2008

[11] phone interview with Morris Sloan from Humanware on 2 June 2008

The producers of the three electronic PDA devices reviewed in this chapter, all chose to offer a multi-modal option to people who were blind. The BrailleNote Empower BT 32 and PK offer both audio and tactile feedback to the user. Thus, more than one sense can be stimulated. This choice was made on the premise that the blind would interact better with a device offering both speech and Braille output. This choice is supported by research undertaken by Jacobson (2002) who discussed multi-modal computer interfaces. They suggested that multi-modal output would improve experience of blind users through redundancy of information pathways. The adoption of multi-modal output also meant that Humanware were conforming to Schneiderman's (1998) good interface design by providing informative feedback including multi-modal options.

Humanware also recognised the advantages of employing redundancy of design in computer interfaces. They were particularly aware of the advantages to long term memory retention if information were presented in more than one format. They were also aware that presenting information through more than one modality would enable users with different abilities to use the method that most effectively helped them to retain information. Offering both speech and Braille output enables users to use the output modality which suits them.

Additionally, the developers of the BrailleNote were aware of the limitations of audio memory as compared with visual memory and so made the design decision to offer Braille as a way of communicating the information to the user. Jacobson (2002) discussed the limitations of verbal memory when presenting their findings on haptic interaction. Jacobson suggested that providing tactile feedback would increase the memorability of information presented to users. Increasing the memorability of information improves usability (Adikari et al. 2006).

Because the BrailleNote has no dedicated function keys, commands are issued via chorded commands and via the four Braille thumb keys on the front of the unit. Many of the chorded commands are issued by holding down one of the three function keys (backspace, enter and spacebar) and then pressing a letter. The keyboard assignments were chosen so that no more than six keys would need to be pressed to invoke any of the common functions.[12]

There are two common exceptions to this rule. The first exception is the main menu command which is executed from anywhere in the system by depressing at the same time dot keys 123456+spacebar. The other exception is using eight-dot Braille entry where more than six dot keys have to be pressed to obtain some characters. The largest number of dot keys that are held down by a person writing Braille on a manual Braille writer is six dot keys.

Navigation within the menus on the BrailleNote Empower BT 32 is achieved by either pressing the space bar to advance through menus or backspace to cycle back through menus, or using space bar with dot key 1 to go back and space with dot key 4 to advance through menus. Items in menus are chosen by pressing the enter key. All menu items can be chosen with first letter navigation.

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[12] phone interview with Morris Sloan from Humanware on 2 June 2008

If first letter navigation is used, the sub-menu is displayed immediately. A key design feature of all menus on the BrailleNote is that each menu has only one item beginning with a particular letter. The main menu consists of the items listed in Table 4.2.

Table 4.2: Main Menu of BrailleNote Empower BT32 (Humanware 2008c, Humanware 2008d)

Menu Item	**Shortcut Key**	**Application**
1	W	Word Processor
2	P	Planner
3	A	Address List
4	E	Email
5	I	Internet
6	M	Media Centre
7	B	Book reader
8	S	Scientific Calculator
9	D	Data base Manager
10	G	Games
11	F	File Manager
12	U	Utilities
13	T	Terminal for Screen Reader
14	R	Remote Synthesiser
15	K	Keyboard Learn
16	Space+I	Information
17	Space+O	Options

Another important aspect of the design of the BrailleNote UI is the concept of independent navigation by the Braille display. This concept refers to the ability to move the Braille line to parts of the content independently of the voice cursor or the editing pointer. This allows the functionality of checking surrounding text without using the voice. The BrailleNote Empower possesses four dedicated Braille display navigation thumb function keys on the front of the unit. These keys are used to control the Braille display. Their description and function are shown in Table 4.3 from left to right:

Table 4.3: Description of BrailleNote Empower BT32 Thumb Keys (Humanware 2008d)

Braille Thumb Function Key Number	**Key Name**	**Key Description**
1	Previous	Escape from Menus
2	Back	Scroll Braille display back one width when reading
3	Advance	Scroll Braille Display one width forward while reading
4	Next	Select or Enter key

Another concept employed on the BrailleNote and other Braille keyboard devices is the ‘triplet’. Keysoft on the BrailleNote Empower BT 32 uses many such triplets. The three components of a triplet on the BrailleNote are back, current and forward. Back is associated with keys to the left of the space bar, current is associated with combinations of keys to the left and right of the space bar and forward is associated with keys to the right of the space bar.

The commands set out in Table 4.4 illustrate the Triplet concept. An important design feature of this command set is that these commands can be executed at any time to dynamically change the speaking voice or volume. Another aspect is that they are all chorded commands using the enter key as a function key. These commands are easily remembered and could be employed on any Braille keyboard device using a nine-key Braille keyboard.

Table 4.4: Command structure showing left and right keys (BrailleNote Empower KeySoft 7.5 context-sensitive help)

Command	**Action**
Enter+dot Key4	Speak Louder
Enter+dot Key1	Speak Softer
Enter+dot Key 5	Increase Speech Pitch
Enter+dot Key 2	Decrease Speech Pitch
Enter+dot Key 6	Speak Faster
Enter+dot Key 3	Speak Slower
Enter+dot keys 46	Increase Media Volume
Enter+dot Keys 13	Decrease Media Volume

The edit commands for the BrailleNote listed in Table 4.5 illustrate another important feature of the KeySoft command structure; that the commands are all chorded commands using the backspace key as a function key. The backspace key itself is an edit command because it is a destructive key. The designers made the decision to use the backspace key as the function key for chorded edit commands because of its functional relatedness to editing. Functional relatedness aids memorization of keystrokes and is an aspect of both the Adikari et al. (2006) usability attribute model and the guidelines for good interface (Schneiderman 1998).

Table 4.5: BrailleNote Empower BT32 edit commands (BrailleNote Empower KeySoft 7.5 context-sensitive help)

Command	**Function**
Backspace+dot keys 36	Delete Character under cursor
Backspace+dot Keys 25	Delete Word under Cursor
Backspace+dot Key 2	Delete Word before Cursor
Backspace+dot Keys 14	Delete to end of Sentence
Backspace+dot Keys 2356	Delete to end of Paragraph
Backspace+dot Keys 456	Delete to End of file
space+dot Keys 2346, dot Keys 14	Centre Line
Backspace+F	Find and replace

All the review commands shown in Table 4.6 control the reading of content (and use the triplet concept) but also may move the cursor. The feature of these commands, apart from the fact that all use the space bar as an function key to perform the chorded commands, is that keys to the left of the space bar all decrease the item and those to the right increase the item. One significant feature of this key mapping is that the keys to the outside of the unit perform the smallest units of movement and keys nearer the centre or nearer the space bar perform larger movements which is counter intuitive. Another aspect of the key mapping is that in order to read the current item, the space bar is held with dot keys to the left and right. Indeed, the keys held represent the dot keys for both decreasing and increasing the item. The logic behind this is that if a command is issued to both go back and to go forward simultaneously, the result is that the current item does not move[13]. The concept of smaller units of movement associated with Braille keys to the outside of the unit also applies to movement within programmes. For example, while navigating the calendar, the space bar can be pressed with dot key 6 to move forward a day and with dot key 3 to move back a day; space bar with dot keys 2 and 5 move a week at a time and space bar with dot keys 1 and 4 move a month at a time; space bar with dot keys 23 and 56 move a year at a time. This movement structure coincides with movement within the word processor.

Table 4.6: BrailleNote Empower BT32 review commands (BrailleNote Empower KeySoft 7.5 context-sensitive help)

Command	**Function**
Space+g	Go forward reading (continuous reading)
Backspace+Enter	Stop reading
Space+dot keys123	Top of file
Space+Dot keys 456	Bottom of file
Space+F	Find
Space+n	Find Next
Space+dot key3	Move back a character

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[13] phone interview with Morris Sloan from Humanware on 2 June, 2008.

Space+dot keys36	Current Character
Space+dot key6	Forward a Character
Space+dot key2	Hear and move Back a word
Space+dot key25	Hear Current word
Space+dot key5	Move and Hear next word
Space+dot key1	Move Back and hear previous sentence
Space+dot keys14	Hear current sentence
Space+dot key4	Move forward and read next sentence
Space+dot keys23	Move back and read previous paragraph
Space+dot keys2356	Read current paragraph
Space+dot keys56	Move to and read next paragraph

The applications within KeySoft provide unique commands to the user and use command concepts familiar to users of DOS systems such as WordPerfect 5.1. For example, the word processor in KeySoft allows text to be copied and moved. Text is first marked then actions are performed on marked text. These actions are performed through the block menu which is accessed by the space bar with the letter B. A beginning and end mark are set, and then the actions can be performed on the text.

Each version of KeySoft for each language has different key combinations for the scientific calculator. KeySoft on the BrailleNote Empower BT 32 is the only software package to provide country-specific calculator operators. This unique feature aids the learning of the calculator interface and the memorization of the command structure and also is consistent with the Braille with which the users would be familiar. This last item relates to the concept of existing skills and knowledge.

These aspects relate to consistency, the learning of the interface and the ability of users to memorize the commands, all of which are directly related to the items which comprise good interface design and usability as defined by Schneiderman (1998) and Adikari et al. (2006).

4.2.1 Strengths of BrailleNote Empower BT 32

A major advantage of KeySoft 7.5 on the BrailleNote Empower BT 32 is that the software presents a consistent audio and tactile experience to a user. This means that skills learned in one programme can be employed in others. The user does not have to learn a unique set of commands for each application. Consistency is a key element of Schneiderman's (1998) guidelines for good interface design. Consistency also leads to the ease of learning and memorization of commands which are important usability attributes (Adikari et al. 2006). The consistency particularly applies to navigation within the system and within documents and editing of work.

Further, the BrailleNote Empower BT 32 employs an integrated context-sensitive help system which is based on menus. The system is navigated in exactly the same way as any other menu system on the BrailleNote Empower BT 32. This leads to consistency of interface and ease of learning and memorization. The user enters the help command both to obtain help and to bring up the application menu. A user of the BrailleNote needs to remember only one command in order to find help at any menu or prompt. The excellent help facility aids memorization of the key assignments. This is because the sense of hearing and touch are stimulated with the correct commands.

Unlike Microsoft Windows which has many interaction styles, KeySoft 7.5 on the BrailleNote Empower BT 32 relies upon menus, prompts and short cut keys.

The BrailleNote Empower BT 32 possesses a nine-key Braille keyboard and no F1 type function keys. The advantage of this configuration is that the Braille writer does not have to move his/her hands from the Braille keyboard in order to activate any function on the device. Almost all commands require combinations of these nine keys. Further, the BrailleNote Empower BT 32 possesses dedicated Braille thumb function keys which control the independent movement of the Braille display and offer alternative navigation options but a user is able to invoke all these options using only the nine-key Braille keyboard. This keyboard functionality allows for multiple ways to execute commands which is an aspect of usability in the Adikari et al. (2006) model.

Backspace itself is a destructive key and so is used as the function key to initiate editing. The key sequences assigned to editing mimic reading commands to aid memory retention. Additionally, the backspace key is used on other Braille keyboard devices as a function key to perform destructive editing which means that a user familiar with Braille keyboard devices will be able to assimilate the functional relatedness of backspace with destructive editing. These aspects relate to the usability attributes, particularly user experience (Adikari et al. 2006).

Formatting in word processor documents is indicated with text tags on the Braille display. This method allows the Braille reader to notice the commencement of a text attribute or formatting command and to know when that text attribute is no longer applicable. The Braille formatting tags can be displayed to the user or not and they can be entered via the menu or manually entered into the text. This allows for maximum flexibility of use and allows the new Braille reader to become familiar with Braille reading and writing before learning the complex formatting commands. Flexibility is a usability attribute which may aid the evaluation of functions on a Braille keyboard device (Adikari et al 2006).

A further advantage of the key mapping on the BrailleNote Empower BT 32 is that it is based upon logical text units and the concept of triplets.

Additionally, the BrailleNote Empower BT 32 is customized for the language of the country in which it is being distributed. This means that where information is entered at prompts, such as in the Calculator, dot patterns familiar to the Braille reader are used to enter operators.

4.2.2 Weaknesses of BrailleNote Empower BT 32

The practical assessment of the device and a study of the user manual revealed the following issues with the software and key mapping on the device:

1. The BrailleNote Empower BT 32 does not possess F1 type function keys or a fn key to allow other keys to represent F1 function keys.
2. No way to access the main menu by pressing only one key.

3. There is not a dedicated application menu key, so there is no easy way to switch between applications, but this relates to the fact that the device is not a multi-tasking device.
4. The device has no running applications list based upon menus.
5. There is no easy way to remember a set of commands in order to efficiently read and navigate HTML elements.

The hardware disadvantages of BrailleNote Empower BT 32 include problems with outdated hardware. The problems include:

1. KeySoft 7.5 must be updated using a 500mb or less SD card (Humanware 2008c). These are becoming difficult to purchase.
2. The BrailleNote Empower BT 32 can supply a video stream to a monitor but has no built-in LCD display that a person with sight can observe when inputting data.

4.3 PacMate Omni

Because the PacMate is based on a windows platform Freedom Scientific recognised there would be challenges using standard windows applications on the PacMate Omni BX 400 so they provide several custom written applications which make the device easier to use. They provide a word processor with the ability to edit Braille files and the ability to translate files to and from Braille. They also provide a functional Calculator which overcomes the problems of using the Calculator which is part of the pocket PC suite of programmes.

The word processor provided allows a user to spell check work; this is not a function available in Pocket Word (Freedom Scientific 2008c). Furthermore, Freedom Scientific recognised that the blind would require this functionality, particularly because many people who are blind do much of their ‘reading’ through listening, and hence frequently are not aware of the spelling of everyday words.

Table 4.7 shows the more common key assignments on the PacMate Omni BX 400, which is the latest model of the PacMate and was released in 2007. One of the key issues with this key mapping relates to the need to mimic Microsoft Windows functionality on a device with a limited number of keys. Although there is some logic to the key mapping, such as the use of triplets, the logic is different. For example the Tab and Shift Tab commands are created in such a way as to minimize movement of the hands. The left and right functionality is employed but the functional relatedness with the shift key (dot key7) is not maintained. This presents a problem of lack of consistency and may not demonstrate good design of an interface as determined by Schneiderman (1998).

Table 4.7: Key assignments for PacMate Omni BX (Freedom Scientific 2007, Freedom Scientific 2008c)

Function Key / key press	**Meaning**
F1	Esc / close
F2	Alt key / menu bar
F3	Fs Calc
F4	Windows logo key or start menu key
F5	List of running applications / recent applications key. This is similar to the task bar in MS Windows.
F6	FS Edit

F7	Stopwatch
F8	File Explorer
F1+F2	Activate left soft key
F4+F5	Activate right soft key
F1+F4	Announce current soft key assignments
F3+F7	Decrease system volume
F6+F8	Increase system volume
Space+F1	Refresh screen
Space+F2	Context menu key also used for “tap and hold)
Space+F3	Calendar
Space+F4	Say time and date
Space+F6	In box
Space+F7	Contacts
Space+F8	Tasks
Dot key7	Backspace
Dot key8	Enter (also used for tap)
Space+dot keys12	Shift+tab
Space+dot keys45	Tab
Space+dot keys68	Stop speech
Space+dot keys23	Ctrl+shift+tab
Space+dot keys56	Ctrl+tab
Space+dot keys13	Home
Space+dot keys46	End
Space+dot keys123	Ctrl-home or beginning of document
Space+dot keys456	Ctrl-end or end of document

Because Freedom Scientific chose to use a standard Pocket PC environment, the PacMate Omni has a start menu, a key that performs the Windows logo key function, an application menu that mimics the function performed by the alt key in Windows to bring up the application menu. The PacMate Omni BX 400 also possesses other characteristics similar to those of the Windows environments.

A list of the items in the PacMate Omni start menu is given in Table 4.8.

Table 4.8: Start menu on PacMate Omni (Freedom Scientific 2008c)

Item Number	**Item Title**	**Item Description**
1	Today	Allows user to configure how the today screen looks. The today screen is the Pocket PC version of the Desktop on Windows XP
2	Active Sync	Allows PacMate to communicate with other computers
3	Calendar	
4	Contacts	The Address List
5	In Box	Goes to In Box
6	Internet Explorer	Web Browsing
7	Tasks	
8	Windows Media	Windows Media Player
9	Programmes	The list of installed programmes
10	Settings	Allows the user to configure how PacMate sounds and behaves
11	Find	
12	Help	On line help

Not all the programmes on the PacMate Omni BX 400 start menu are accessible. Table 4.9 provides comments on the programmes.

Table 4.9: Comments on the list of programmes on PacMate Omni (Freedom Scientific 2007)

Programme Number	**Programme Name**	**Comment**
1	Calculator	The Calculator which is shipped with Pocket PC
2	File Explorer	Similar to Windows Explorer
3	FS Calc	A Calculator provided by Freedom Scientific
4	FS Edit	A word processor provided by Freedom Scientific, contains spell checker and convert utilities to Braille
5	Game	Not Accessible
6	MSN Messenger	
7	Pictures	Not accessible
8	Pocket Excel	Accessible
9	Pocket MSN	
10	Pocket Word	No spell checker
11	Stop Watch	Provided by Freedom Scientific

An excellent feature of the PacMate Omni is the concept of a programmes list which effectively is a menu and can be navigated in the same way as a menu. A programmes list or menu is also available on the BrailleNote but the PacMate has the advantage that the programmes list or start menu is located on one dedicated function key (Freedom Scientific 2007; 2008a). Good interface design (Schneiderman 1998) suggests that expert users should be able to use shortcut keys. PacMate allows for first letter navigation in the programs list but does not employ unique letter designations for all items in this list.

One major feature of the design of interface implemented on the PacMate Omni is an unconnected layered approach for command sets which proved difficult to use in real-world conditions. It was difficult to obtain relevant help because the help system is also based upon this layered approach. The usability attribute of learnability (Adikari et al. 2006) is not supported by this approach.

The researcher is familiar with JAWS for Windows and so during testing was able to adapt to the layered approach. A user would need to be familiar with Windows concepts in order to know which layer to access.

The PacMate is designed to have the least impact on a user familiar with Windows and JAWS. However, a new user of computers or a young person may find the “learning curve” associated with learning the screen reader along with the operating system significant. Usability will be compromised for those who are not familiar with Microsoft Windows and JAWS. Consistency is compromised by the implementation of the layered approach on PacMate.

Like the BrailleNote Empower BT32, the PacMate device also includes the ability to make changes to the voice settings from anywhere. The command to enter the dialogue box is space+s. Any changes made in this dialogue box are not permanently saved. A JAWS user will be familiar with temporary and permanent voice settings. Permanent changes can be made through the settings dialogue box accessed via the start menu. Freedom Scientific use dialogue boxes throughout the interface to mimic a Windows interface and makes the learning and memorization of commands easier for a person familiar with Microsoft Windows.

Because a person who is blind cannot see the screen on a computer system, keyboard commands need to be implemented that allow the user to read logical text units on the screen. The commands need to allow reading the following; characters, words, paragraphs or sentences. The following commands have been implemented on the Braille keyboard of the PacMate Omni to enable reading of logical text units (see Table 4.10).

Table 4.10: Reading and navigating commands (Freedom Scientific 2007)

Description	**Command**
Prior Character	Space+DOT Key3 or LEFT ARROW
Move to and read the Next Character	Space+DOT Key6 or RIGHT ARROW
Read the Current Character	Space+DOT Keys36
Read the Current Character Phonetically	Space+DOT Keys36 twice quickly
ASCII Value of Current Character	DOT Keys 3-6 CHORD three times quickly
Move to and read the Prior Word	Space+DOT Key2 or DOT key 2+LEFT ARROW
Move to and read the Next Word	Space+DOT Key5 or DOT Key5+RIGHT ARROW
Read the Current Word	Space+DOT Keys25

Spell Current Word	Space+DOT Keys25 twice quickly
Move to and read the Prior Line	Space+DOT Key1 or UP ARROW
Move to and read the Next Line	Space+DOT Key4 or DOWN ARROW
Read the Current Line	Space+DOT Keys14
Move to and read the Prior Sentence	DOT Key4+LEFT ARROW
Move to and read the Next Sentence	DOT Key4+RIGHT ARROW
Read the Current Sentence	DOT Key4+LEFT+RIGHT ARROW
Move to and read the Prior Paragraph	DOT Key1+UP ARROW
Move to and read the Next Paragraph	DOT Key1+DOWN ARROW
Read the Current Paragraph	DOT Key1+UP+DOWN ARROW
Page Up	DOT Key2+UP ARROW
Page Down	DOT Key2+DOWN ARROW
Move to Beginning of Line	DOT Key3+LEFT ARROW
Move to End of Line	DOT Key3+RIGHT ARROW
Move to Top of File	Space+DOT Keys123 or DOT Key 3+UP ARROW
Move to Bottom of File	Space+DOT Keys456 or DOT Key3+DOWN ARROW
Read from Beginning of Line	DOT Keys37+LEFT ARROW
Read to End of Line	DOT Keys37+RIGHT ARROW
Read Selected Text	DOT Keys45678

Read the Top Line of the Active Window or Dialog	DOT Keys27+UP ARROW
Read Bottom Line of the Active Window	DOT Keys27+DOWN ARROW

Freedom Scientific has implemented multiple ways to execute some of these reading commands. The usability attribute ‘flexibility’ or the ability to execute commands with different keystrokes or methods may be important in terms of evaluating functionality on Braille keyboard devices. The use of the cursor arrows will be more familiar to the JAWS user. The implementation of multiple ways to achieve functions means that the user of a PacMate Omni can use the commands that best suit his/her own learning style or ability. Further, the edit commands shown in Table 4.11 have also been implemented. Many of these commands assume that the user has firstly selected items.

Table 4.11: Sample of Edit commands available on the PacMate Omni (Freedom Scientific 2007)

Description	**Command**
Find	SPACE+E, F
Find Next	SPACE+E, N
Replace	SPACE+E, R
Undo	SPACE+E, U
Set Mark	SPACE+E, M
Select to Mark	SPACE+E, S
Quick Select Word	SPACE+Q, W
Quick Select Sentence	SPACE+Q, S
Quick Select Line	SPACE+Q, L
Quick Select Paragraph	SPACE+Q, P
Quick Select Entire Document	SPACE+Q, D

The quick select keys all use the letter q. These commands have been chosen to aid memory retention. However, whether the quick or edit layer commands are used, the same number of keystrokes need to be executed in order to perform the action. The ability to use shortcut key sequences is an important aspect of good interface design (Schneiderman 1998).

The reading commands assigned in FS Edit are illustrated in Table 4.12, however there are a few issues related to these commands. Because the PacMate runs JAWS for Windows, the current character or word commands can be executed twice in succession in order to hear the phonetic spelling of characters. Furthermore, the multiple key presses used to achieve phonetic spelling is a concept with which users of screen readers for Windows will be familiar. Familiarity with a concept means that the user will be bringing that knowledge and skill to the learning process associated with the interface. This is important in relation to usability attributes (Adikari et al. 2006).

FS Edit allows the user to invoke a continuous Braille mode. This enables a user to read a Braille file on the unit in a continuous way without having blank areas on the Braille display. Also, FS Edit allows a user to spell-check a document. The spell checker is launched by typing space+dot keys16. Dot keys 16 are the dots for the "CH" sign and CH are the first letters of the word "check".

Table 4.12: Reading Commands in FS Edit (Freedom Scientific 2008c)

Keystrokes	**Function**
Space+dot keys36	Read and hear current character
Space+dot key3	Read and move to previous character
Space+dot key6	Move to and read next character
Space+dot keys25	Hear current word
Space+dot key2	Move to and hear previous word
Space+dot key5	Move to and hear next word
Space+dot keys14	Hear current line
Space+dot key1	Move to and hear previous line

Space+dot key4	Move to and hear next line
Up arrow	Move to and hear previous line
Down arrow	Move to and read next line
Left arrow	Move to and hear previous character
Right arrow	Move to and hear next character

Freedom Scientific provided FS Calc as a scientific calculator that the users of PacMate Omni could use. An advantage of using FS Calc is that the user may save work as a text file and then later print the file containing all calculations. Basic arithmetic functions are entered as computer Braille and are summarised in Table 4.13.

4.13: Example of Basic Arithmetic Functions in FS Calc (Freedom Scientific 2008c)

Dot Key Pattern	**Arithmetic Symbol**
Dot keys346	+
Dot keys36	-
Dot keys16	*
Dot keys34	/

One of the significant problems with these keyboard combinations is that they relate to computer Braille. A person familiar with literary Grade 2 Braille would not associate these key combinations with literary mathematical signs. The BrailleNote on the other hand, is customised for the various countries and the arithmetic signs are entered as dot combinations related to the literary Braille math code for the country where the BrailleNote is supplied. This makes the learning of the interface easier.

The ease of learning of the interface and the ability of the users to memorize commands is important to usability as defined by Adikari et al. (2006).

Freedom Scientific also implemented letter and shortcut keys to enhance the functionality of FS Calc. The concept of using abbreviations or letter commands was introduced on such devices as the Braille and Speak and Eureka A4 which employed many letter or abbreviated commands in its metric conversion formula (Robotron Sensory Tools 1987). Table 4.14 shows a list of shortcut keys used in FS Calc. These shortcuts are available within FS Calc after pressing space+dot keys146.

Table 4.14: Shortcut FS Calc keys (Freedom Scientific 2008c)

Letter key	**Function**
M	Modem connection
H	Clear history
V	Clear variables
O	Load history from a file
S	Save history to a file

FS Calc also employs letter commands, in the form of abbreviations or arguments. These are entered at the calculator prompt. The basic structure of a FS Calc command is: Name of the operator (first argument, second argument)

An example command is:

Pwr(5,2)

Where:

PWR means to the power of,

5 is the first argument and 2 is the second argument.

Therefore, the structure is: operator, followed by (, followed by first argument, followed by a comma, then the second argument and finally a). The equation is entered by pressing the enter key which is dot key8.

The above equation is 5^2 or 5 squared which equals 25.

4.3.1 Strengths of PacMate Omni BX 400

PacMate is a true multi-tasking Windows Mobile 6.0 PDA and as such any application which can be installed on Windows PDAs can be installed on the PacMate.

The PacMate provides a set of cursor arrows which allow users to move within text by elements they will be familiar with if they are Windows users. The movement by logical text units is not considered as important as being able to move in a way similar to the way a blind person reads information on a Windows computer. This relates to consistency and existing skills and knowledge which have been pointed out above as being important usability attributes (Adikari et al. 2006). The cursor arrows also allow the user to employ the keyboard commands which are most familiar to Windows users. Those blind people who are familiar with using computers will be comfortable with this arrangement.

A key advantage of the PacMate is that the designers developed a device that has the least impact on a user of Windows. However, a user not familiar with Windows might find the interface challenging to learn because s/he will need to learn the screen reader commands and the multiple interaction styles associated with Windows as well as the correct help command to execute to obtain correct context-sensitive help. The usability attributes of learnability, efficiency, and memorability are compromised by this choice.

The PacMate device has a dedicated applications menu key and relies upon function keys to access Windows functionality. Additionally, the online manual is written in HTML code and can be accessed using the same commands as those used on web pages. However, this feature is not unique to PacMate and indeed other Braille keyboard devices such as the BrailleNote also have an HTML online manual. Moreover, the reading commands on the PacMate are similar to those on the BrailleNote. This would facilitate the transfer of existing skills and knowledge between PacMate and BrailleNote users.

An advantage of the cursor arrows is that they provide an alternate way to read characters. However, the key mapping on the PacMate results in the same number of keys being pressed for word reading whether or not the user users the arrow keys. The PacMate uses space with dot keys1 and 4 for moving up and down lines but a user can also use the up and down arrow keys for this purpose. Therefore, space with dot keys1 and 4 could be used for sentence navigation. This would allow the PacMate reading commands to be improved and for them to be more similar to those of the BrailleNote, thereby making it easier for a BrailleNote user to become familiar with the PacMate reading commands. Such a change would mean that existing knowledge and skills could be more easily transferred between PacMate and BrailleNote.

A key advantage of the PacMate Calculator is that the user can save work as a text file which can be shown to a teacher if needed.

4.3.2 Weaknesses of PacMate Omni BX 400

PacMate is a true Windows PDA and as such the user must be familiar with all the interaction styles associated with Windows mobile devices. The keyboard assignments reflect a Windows philosophy and the eight function keys (F1-F8) serve to both run applications and to invoke Windows functionality. PacMate offers three ways to access help. These different methods of accessing help all access different types of help and are confusing. A user must be aware of which type of help they are seeking so they can use the correct command to bring up the relevant help. A new user might not know which type of help to request. This complexity reduces the ease of learning of the PacMate interface and the memorability of commands. Ease of learning and memorability of commands are usability attributes (Adikari et al. 2006).

Further, the user of PacMate must be aware of Windows applications that do not work on the PacMate. The key assignments to adjust the volume and other speech parameters on the PacMate involve chorded commands using the F1-F8 function keys alone. The key assignment to decrease system volume is to hold the F3F7 keys, and to increase system volume, the user holds the F6F8 keys.

A disadvantage of the interface design on the PacMate is the concept of a layered approach to commands. With practice, a user becomes familiar with what layer to request. The unconnected nature of the layers generates the need for a help system.

A disadvantage of the PacMate keyboard assignments for editing is that the user must press space with E for the edit layer then press another key combination. PacMate provides quick edit commands but they all require the user to press space with Q then another letter. These letters are not first letter designations and appear to have been assigned randomly. This approach is not consistent with the usability attribute ‘consistency’.

The PacMate also uses a confusing series of commands to select items. The space bar is used as the function key for selecting. The BrailleNote uses a block menu to invoke the selecting commands. There does not appear to be an easy-to-remember pattern in the PacMate selection commands. A confusing pattern makes it more difficult to remember the commands and this lack of ease of learning and memorizing of commands is not consistent with usability.

The PacMate Omni BX 400 does not offer a built-in LCD or a series of unique Braille symbols to identify formatting attributes; nor does it offer a help system based upon integrated menus. The PacMate does not assign a group of keys to media functions. Finally, a disadvantage of the PacMate calculator commands is that simple operators must be entered in computer Braille. The interface is not customized for different languages.

4.4 BrailleSense

The Korean government acknowledge the need for a Braille note taker suitable for Korea’s blind people and so it provided funding to a non-profit organization to develop the core technology for a Korean Braille note taker. Then in 1999, HYMS

Co. Ltd. (formally known as HYMS Technology), a Korean company used that core technology to develop the Braille Hansone. The Braille Hansone became known as the BrailleSense.

The original development company undertook research by visiting all the schools for the blind in Korea and interviewed both teachers and blind students to determine their usability requirements for a Braille note taker. The Braille Hansone was first supplied in 2002 to all the schools for the blind in Korea (http://www.braillesense.com/). Then in 2004, GW Micro partnered with HYMS Co. Ltd. to further develop the interface for the Braille Hansone and to provide an interface suitable for the American market. The BrailleSense, which was the updated Braille Hansone for the American market, became available in 2005.

The BrailleSense has a 32-cell Braille display with accompanying cursor routing keys and keys at each end of the display which are used to advance the Braille. These buttons act like scroll buttons and are in two parts. Pressing the upper part will scroll the display back and pressing the lower part will advance the display (HYMS Co. Ltd. 2008).

The BrailleSense has three distinct groups of keys:

- Nine-key Braille keyboard.
- Four F1 type function keys. Two function keys are to the left and two are to the right of the space bar and in line with it. From left to right they are; F1, F2, F3, and F4. The four function keys are mapped so they provide the

functionality needed to mimic the actions performed by the standard Windows function keys (ctrl, alt and windows logo key).

- Dedicated function keys on the front of the unit which control the media player.

The hardware configuration of the BrailleSense includes the following:

- Operating system: Windows CE 5.0
- Flash memory: 8GB
- RAM: 128MB
- CPU: Intel PXA270
- Keyboard: Braille keyboard with Perkins-style, 4 function keys, 32 cursor routing keys, 4 scroll buttons, 5 audio buttons
- Additional button and switch: key lock switch, audio mode switch, reset button
- Braille display: 32 refreshable Braille cells
- Video output: VGA output, LCD
- Network: 10/100 based Ethernet
- Wireless: WLAN b/g, Bluetooth
- Interface: USB OTG, USB, serial (RS-232C) port, CF slot, SD slot
- Sound: Internal stereo speakers, stereo headphone jack
- Voice recording: Internal microphone, external microphone jack.

A key feature of the BrailleSense is that it is a true multi-tasking device allowing the user to run up to seven programmes at once. Additionally, the user interface of the BrailleSense is based on a Windows like interface but relies mainly upon menus, prompts and shortcut keys in a similar way to the BrailleNote. The user interface includes multi-modal output which stimulates more than one sense. A key aspect of this output is a series of letter symbols which appear upon the Braille display to indicate Windows controls. Further, HYMS Co. Ltd (2008) provides a key mapping that maps Windows keystrokes to the Braille keyboard.

Table 4.15 shows the keyboard layout for the BrailleSense keys mapped to the corresponding Windows keys and shows that HYMS have adopted multiple ways for users to execute commands which is consistent with usability. The multiple ways allow users with different user experience to use the way which works according to their existing skill.

Table 4.15: Keyboard Layout for the BrailleSense Keys Mapped to corresponding Windows Keys (GW Micro 2008c; HYMS Co. Ltd 2008)

BrailleSense key combination	**Windows key combination**
F1	Windows logo key or start menu key
F2 – alternative combination is space+m	Acts as the alt key – brings up menu bar
F3 or space+dot keys 45	Tab key
Space+F3 or space+dot keys12	Shift+tab
F4 or space+e	Esc key
F2+F3	Alt-tab
F1+F2	Page up
F3+F4	Page down
F1+F4	Running applications or task list
Space+z	Alt-F4 close application
Space+dot key 1	Up arrow

Space+dot key 4	Down arrow
Space+dot key 3	Previous character
Space+dot key 6	Next character
Space+dot keys 126	Page up
Space+dot keys 345	Page down
Space+dot keys 16	Home key
Space+dot keys 46	End key
Space+dot keys 123	Ctrl-home
Space+dot keys 456	Ctrl+end

A key feature of the F1 key on the BrailleSense is that it functions similarly to the Windows Logo key the F1 key can be used as a function key to provide shortcut access to the applications on the BrailleSense. For example, holding down F1 and pressing the letter B will open the web browser from anywhere in the BrailleSense. Each programme on the BrailleSense has a unique first letter for its name (HYMS Co. Ltd. 2008). The BrailleNote also provides a mechanism similar to that provided on the BrailleSense for launching applications, but the BrailleNote system is more complex and the BrailleNote does not have the ability to multi-task. Using the F1 or start menu key in this manner allows the users of the BrailleSense to use existing skills and knowledge gained from using Windows computers in the learning process. This ability relates well to usability (Adikari et al. 2006) where user experience, ease of learning and the ability to memorize commands are important components to usability.

Table 4.16 shows the Programmes available on BrailleSense. The BrailleSense presents the user with menus which contain items that can be accessed with shortcut keys. Some items and menus such as the options menu can be accessed from anywhere within the BrailleSense. The options menu is accessed with the space+o combination. This is a convention adopted from the BrailleNote as is the space+h for help menu. The command structure from the BrailleNote and some Windows concepts enables HYMS Co. Ltd. to take advantage of the ability of the users to learn and memorize commands.

Table 4.16: Programmes on BrailleSense Main Menu (GW Micro 2008c, HYMS Co. Ltd 2008)

Item number	**Programme**
1	File Manager
2	Word Processor
3	Address Manager
4	Schedule Manager
5	E-mail
6	Media Player
7	Web Browser
8	Daisy Player
9	Bluetooth Manager
10	MSN Messenger
11	Database Manager
12	Utility
13	Option Settings
14	Help

A user of the BrailleSense is able to change the volume, speed, and tone of speech used on the device at any time. (The space bar, enter and backspace keys are used as function keys). The common aspect of these commands is that functions that decrease the item are associated with function keys to the left of the space bar and functions that increase an item are associated with function keys to the right of the space bar. This association with left and right of the space bar is a concept similar to that of the triplet concept from BrailleNote Empower BT 32.

HYMS Co. Ltd. has implemented two different methods for entering upper case characters when writing computer Braille. The user may enter capitals by first typing space+u (for upper case) and then typing the upper case character. This is identical to the method used on the BrailleNote Empower BT 32.
Example command (at sign):
First method

- Type space+u
- The dot key4.

Method two

- Hold down the dot key7 (the backspace key) with the dot keys for the letter (or symbol) that needs to be upper case.

The @ sign would be entered as dot keys47.

There is also similarity in the way that the one-handed mode works in the BrailleSense and the BrailleNote. Both devices provide for this functionality. Once it is established through the menus, the one-handed mode is implemented in the same way on each device. The space bar is pressed before and after any command needing a space in the combination.

The applications on the BrailleSense are structured similarly to those of MS Windows. For example, the file manager is based on a structure of an address window or bar and a list view with accompanying menu structure and shortcut keys. Additionally, the BrailleSense contains two types of lists with which a user can interact. These are menus and list views. The commands shown in Table 4.17 are available in either menus or lists.

Table 4.17: Commands available in menus and lists (HYMS Co. Ltd, 2008)

Item	**Function**	**BrailleSense Keystroke**
1	Move to the previous item	Up arrow (space+dot key1) or up scroll button
2	Move to next item	Down arrow (space+dot key4) or down scroll Button
3	Move to the beginning of a list	Ctrl+home (space+dot keys123)
4	Move to the end of a list	Ctrl+end (space+dot keys456)

Table 4.18 illustrates that HYMS Co. Ltd. have provided multiple ways for the user to execute file management commands on the BrailleSense. In particular, they have assigned common navigation features to various combinations of the four function keys. This is a feature that could be implemented on an interface to be employed on new Braille keyboard devices. All these aspects show similarities between BrailleNote and BrailleSense and how HYMS Co. Ltd. have tried to implement a system that draws on the greatest amount possible of existing knowledge and skills.

This should enable users to more quickly learn to use the BrailleSense. It also shows attention to good interface design as presented by Schneiderman (1998). Furthermore, a key feature of the command sequences used in the file manager is that many of the shortcut keys are executed using the enter key as a function key.

Table 4:18: Sample list of file manager commands (HYMS Co. Ltd 2008)

BrailleSense key combination	**Function**
Enter+s	Send to
Enter+c	Copy
Enter+x	Cut
Enter+v	Paste
Enter+d	Delete
Enter+n	New document
Enter+f	New folder
Enter+t	File conversion or translation
Enter+a	Select all
Enter+z	Zip utility
Enter+u	Unzip utility

A significant problem with the key mapping of the BrailleSense is that the developers have not been consistent in implementing shortcut keys. For example, the backspace key is used for the function key to bring up menu items but the enter key and space bar are used as function keys to invoke shortcut keys. The user must learn which of these two keys to use as a function key with the first letter of the sub-menu to be chosen. For example; the function key combination to open a new document is enter+n. The function key to activate the *save as* dialogue is space+s. The lack of consistency in the key mapping reduces the memorability of the assigned key combination. The lack of consistency in key assignments does not demonstrate good interface design (Schneiderman 1998).

Three aspects of the key mapping on BrailleSense relate to usability (Adikari et al. 2006). These are:

- The commands are difficult to learn and memorize.
- There is lack of consistency.
- Efficiency is reduced if users cannot learn the commands.

Both the reading and editing commands employed on the BrailleSense are similar to those employed on the BrailleNote. Like Humanware, HYMS Co. Ltd. have chosen to use the backspace key as the Function key with combinations for editing logical text units. They tied the destructive functionality of the backspace key with the dot key patterns associated with editing logical text units because of the functional relatedness of the backspace key. An exception to this is the command for deleting the current letter. Instead of using backspace+dot keys36 for the deleting command, they have chosen to use the dot key pattern for the letter D for delete.

The address manager on the BrailleSense is similar to that on the BrailleNote except the navigation keys are different. An important feature of the address manager on the BrailleSense is the ability to move to any of the 23 fields in address manager by pressing a cursor routing key above the corresponding Braille cell on the Braille display. For instance, if a user wishes to enter information in the last name field, s/he presses the cursor routing key above the Braille cell no.1 (HYMS Co. Ltd. 2008).

This is an excellent feature but it relies upon the user being familiar with the order of fields in the database.

Table 4.19 shows moving commands within the address manager. The combinations are different from those employed on the BrailleNote and are related to MS Windows keys. There is also more functionality provided by this keyboard mapping than exists on the BrailleNote. Moreover, the dot keys to the left of the space bar perform functions of going back in the list or reducing the size of an item and those to the right of the space bar increase the function or move to a later item.

Table 4.19: Move Commands in BrailleSense Address Manager (HYMS Co. Ltd, 2008)

Function	**BrailleSense key combination**
Move to a previous field in a record	Space+dot key2
Move to the next field in a record	Space+dot key5
Move to the first field in a record	Home (Space+dot keys13)
Move to the last field in a record	end (Space+dot keys46)
Move to the previous record	up arrow (Space+dot key1)
Move to the next record	down arrow (Space+dot key4)
Move to the first record	ctrl+home (Space+dot keys123)
Move to the last record	ctrl+end (Space+dot keys456)
Move to previous same field different record	Space+dot key3
Move to next same field different record	Space+dot key6

The BrailleNote planner and the BrailleSense Schedule Manager have exactly the same key assignments for moving around the calendar. Further, the BrailleSense has a web browser which has key combinations allowing the user to navigate the structural elements of web pages. These key assignments include those to allow users to move between; controls, links, frames, tables and headings. There are also dedicated keyboard shortcuts for navigating within tables.

4.4.1 Strengths of BrailleSense

The hardware advantages of the BrailleSense include:

- Dedicated keys to control the media player.
- Detachable, user replaceable battery. The advantage of this is that the user does not have to return the unit to a manufacturer in order to get the battery replaced.
- Built-in LCD display to display content from the device. This allows sighted users to enter information into the BrailleSense or to read information entered by a blind person and may assist the deaf blind with communication and adds functionality to the device.
- Of the three devices reviewed, BrailleSense has the most connectivity options.
- The BrailleSense function keys are assigned to Windows operations. The page up and down commands F1+F2 and F3+F4 are easy to use and are associated with the function keys to the left and right of the space bar. Also, these key combinations are consistent with the convention of using keys to the left of the space bar to move back or up in a document and those to the right to move forward or down.

The software and interface advantages of the BrailleSense include:

- Multi-tasking ability
- Relies on; menus, prompts and shortcut keys with dialogue boxes.
- The F1 key acts similarly to the Windows logo key and is used as the function key to open applications from anywhere in BrailleSense.
- The navigation and editing commands on the BrailleSense are almost identical to those on the BrailleNote Empower BT 32.
- The BrailleSense also adopts a single method for obtaining help and to access the options menu.
- User can modify speech settings on the fly.
- One-handed mode is operated in the same way as it would be on the BrailleNote.
- Both BrailleSense and BrailleNote allow the user to move to the beginning or end of a list with space+dots123 or space+dots456.
- BrailleSense uses space with dot key1 or 4 to move back or forward in a menu. This is consistent with their use of these commands to mimic the arrow keys on a PC. The BrailleNote use of backspace and space means the user is pressing only one key to move within menus. A set of cursor arrows provides one key press to achieve movement within menus. The user of a BrailleSense can use the scroll buttons to move within menus, thereby needing to press only one key.
- The key combinations used to navigate in the file browser are assigned to various combinations of the four function keys. Within the file browser, the enter key is used as the function key to invoke file management commands.

- If BrailleSense possessed a number of additional function keys, these could be assigned to these commands. However, the developers of BrailleSense and BrailleNote were mindful to minimise the movement of the hands while using the devices. They assigned commands in such a way that a user could use the devices without taking his/her hands from the keyboard.
- The reading commands are almost identical to those of the BrailleNote except that the BrailleNote uses space with dot keys 1 and 4 to move by sentence rather than by line. The BrailleNote combination is so similar to the BrailleSense combination that the BrailleNote combination could be adopted.
- The BrailleNote planner and BrailleSense scheduler have identical key mappings for moving around the calendar.

4.4.2 Weaknesses of BrailleSense

The BrailleSense is a Windows device with a Windows-like interface. The interaction styles are less than for Windows but the commands available are extensive. A new user has the advantage that most commands are available from menus as well as being available through shortcut keys.

The information provided by HYMS Co. Ltd in relation to destructive editing related to current items only. The BrailleNote editing commands are similar and provide more functionality.

4.5 Evaluation Summary

Table 4.20 gives a summary of the findings of this review of three Braille keyboard devices. The table shows the functions on the device which are implemented well. The table also shows which functions are implemented poorly and which functions are lacking from the design.

This chapter assessed the functions only according to the usability attributes, which are integral to the Adikari et al. (2006) model. The summary does not include usability attributes not included in the usability attribute model developed by Adikari et al. (2006). A finding of this review was that the usability attribute called ‘consistency’ stood out as the primary usability attribute for evaluating interfaces and the functions within these interfaces on Braille keyboard devices.

Table 4.20 shows that:

- The best presented functions of the BrailleNote Empower BT 32 include; navigation support, editing support and help based upon menus.
- BrailleNote Empower BT 32 does not have the following features which are possessed by one or both of the other devices reviewed; multi-tasking, a list of running applications based upon menus, one key to access programme menus and function keys, nor an easy way to access HTML elements. The device also does not have a built-in LCD display.
- The PacMate Omni BX has the following features; multi-tasking, one-key access to the menu of programmes, and function keys.

Table 4.20: Summary of findings from review of three Braille keyboard devices

Braille Keyboard Devices Evaluated	**Available Functions on Device**	**Missing Functions on Device**
BrailleSense	Navigation Support Editing Support Multitasking Built in LCD Menus of programs access with one key Unique Braille Symbols (Formatting) Function keys Media Keys	*?Windows Based device* *?commands are difficult to learn* *?Help Based on Menus*
BrailleNote Empower 32	Navigation Support Editing Support Help based on Menus	*?Multitasking* *?List of Running applications based on Menus* *?Menus of programs access with one key* *?Function Keys* *?No easy way to access HTML elements* *?Built in LCD*
PacMate Omni	Multitasking Menus of programs access with one key Function Keys	*??Navigation Support* *??Editing Support* *?Limited to windows Based* *?Three types of help* *?Difficulty accessing the list of commands* *?Editing functions are complex* *?Commands are difficult to remember* *?Built in LCD* *?Unique Braille Symbols (Formatting)* *?Help based on menus* *?Media Keys*
Legend: *? The feature is missing from the model.* *?? The feature although present is poorly presented.*		

- The device does not have the following features possessed by one or more of the other devices reviewed; poorly implemented navigation and editing support, built-in LCD, unique Braille symbols representing text formatting, three interaction styles, and help based upon menus, or dedicated media keys.
- The BrailleSense has the following features; multi-tasking, built-in LCD, menus and programmes are accessed with one key, unique Braille symbols showing formatting, function keys and dedicated media keys.

With regard to ratings of Functions on Braille keyboard devices, Tables 4.21-4.23 have exactly the same structure. Column one contains the usability attributes from the (Adikari et al. 2006) usability attribute model and column two and subsequent are the functions established by this review. Functions were assessed by the usability attributes in column one.

The assessment of the devices was based upon an assessment of the user manuals and audio tutorials as well as tests of the devices in real-world situations. This enabled the claims of the manufacturer to be tested by the researcher and a comparison could thus be drawn between documented claims and actual user experience.

The rating scale used in the tables is as follows:

1 = this device does not possess this Function.
2 = this device possesses this Function but the implementation is poor.
3 = this device possesses this Function and it performs well.

Table 4.21: Usability Attributes and Functions of BrailleNote Empower 32

Usability Attributes **(Adikari et al. 2006)**	**Navigation Support**	**Editing Support**	**Menus of program access with one key**	**Multi-tasking**	**Function Keys**	**Built in LCD**	**Unique Braille Symbols (Formatting)**	**Help based on Menus**	**Media Keys**
Learnability	3	3	1	1	1	1	1	3	1
Memorability	3	3	1	1	1	1	1	3	1
Flexibility	1	3	1	1	1	1	1	3	1
Satisfaction	3	3	1	1	1	1	1	3	1
Efficiency	3	3	1	1	1	1	1	2	1
Functional Correctness	3	3	1	1	1	1	1	3	1
Error Tolerance	2	2	1	1	1	1	1	3	1

Table 4.22: Usability Attributes and Functions of PacNote Omni

Usability Attributes **(Adikari et al. 2006)**	**Navigation Support**	**Editing Support**	**Menus** **of program access with one key**	**Multi-tasking**	**Function Keys**	**Built in LCD**	**Unique Braille Symbols (Formatting)**	**Help based on Menus**	**Media Keys**
Learnability	2	2	3	3	2	1	1	1	1
Memorability	2	2	3	3	2	1	1	1	1
Flexibility	2	2	3	3	2	1	1	1	1
Satisfaction	2	2	2	3	2	1	1	1	1
Efficiency	2	2	3	3	2	1	1	1	1
Functional Correctness	2	2	2	3	2	1	1	1	1
Error Tolerance	2	2	3	3	3	1	1	1	1

Table 4.23: Usability Attributes and Functions of BrailleSense

Usability Attributes **(Adikari et al. 2006)**	**Navigation Support**	**Editing Support**	**Menus** **of program access with one key**	**Multi-tasking**	**Function Keys**	**Built in LCD**	**Unique Braille Symbols (Formatting)**	**Help based on Menus**	**Media Keys**
Learnability	3	3	3	3	3	3	3	1	3
Memorability	3	3	3	3	3	2	3	1	3
Flexibility	1	3	3	3	3	3	3	1	3
Satisfaction	3	3	3	3	3	3	3	1	3
Efficiency	3	3	3	3	3	3	3	1	3
Functional Correctness	3	3	3	3	3	3	3	1	3
Error Tolerance	2	2	3	3	3	3	3	1	3

Each Braille keyboard device possesses more or less of the functions listed across the top row of Table 4.21. For the functions which the BrailleNote Empower BT 32 actually possesses the user interface is effective. The usability attributes that are rated highest for the BrailleNote Empower BT 32 include; learnability, memorability, satisfaction, efficiency and functional correctness. The BrailleNote Empower BT 32 performs adequately for error tolerance, but scores low on flexibility. It may indeed be the case that flexibility and consistency counter each other. This is an area for future research.

Table 4.22 shows that for the nine functions present on Braille keyboard devices, the PacMate Omni BX generally shows poor implementation of its functions. This assessment is based upon the score of 2 for most functions when plotted against the usability attributes.

Table 4.23 reveals that the BrailleSense presents the functions with the highest score of any device.

4.6 Preliminary Functions for the New Model

The review of the three Braille keyboard devices produced the functions used in the above tables. Additionally, the literature review revealed several models of usability and design which could have been used to evaluate the functions. The researcher determined that the Schneiderman (1984) guidelines for good interface design and the usability attribute model developed by Adikari et al. (2006) were adequate to evaluate these devices.

The best implementation of functions varies across devices. Table 4.24 shows from which device the implementation of functions will be drawn when creating the Venturer Model. The Venturer Model will be presented in Chapter 5.

Table 4.24: Useful Functions for the new Venturer Model

Functions Present on Braille keyboard Devices	**Device (s) from which feature will be drawn in the New Model**
Navigation Support	Braille Note Empower 32 BrailleSense
Editing Support	Braille Note Empower 32 BrailleSense
Menus of Program Access with One Key	PacMate Omni BrailleSense
Multi-tasking	PacMate Omni BrailleSense
Function Keys	BrailleSense
Built in LCD	BrailleSense
Unique Braille Symbols (Formatting)	BrailleSense
Help Based on Menus	Braille Note Empower 32
Media Keys	BrailleSense

4.7 Conclusion

Although many usability attributes were highlighted as the devices were evaluated consistency became a preeminent usability attribute. Furthermore, the BrailleNote Empower BT 32 and BrailleSense possessed the most complete implementation of functions in their interfaces and so their implementation of key maps and interaction paradigms will guide the development of the interface model in Chapter 5. No Braille keyboard device reviewed used extensive use of earcons but non-verbal prompts should be considered when designing an interface for Braille keyboard devices to improve the user experience and to alert the user.

Although all functions identified in the prior analyses are important, navigation support and editing support will be focused upon in the development of the Venturer Model. The review presented in this chapter, when considered along with the literature review, indicates that navigation support needs to be expanded to consider the concepts of:

- Rich Navigation - to include such elements as navigating tables, headings, forms, frames and other content in complex documents.
- Textual Navigation – including; characters, words, sentences, paragraphs and sections.
- Menu Navigation – including; previous item, next item, chose item, move to next menu level.
- System Navigation – navigating the screen and operating system.

Chapter 5: The Venturer Model

5.1 Introduction

This chapter discusses the interface model developed for deployment on Braille keyboard devices. Chapter 3 presented a review of literature impacting the development of such a model and Chapter 4 presented a practical evaluation of three modern Braille keyboard devices which focused upon usability and drew upon the usability attributes from Adikari et al. (2006), as well as focusing on good interface design as presented by Schneiderman (1998). The model presented in this chapter will draw from the literature discussing the difficulties faced by blind people interacting with visual interfaces and the experience of previous researchers so that an alternative interaction paradigm can be shown.

Earlier sections discussed the tasks that can be carried out on a computer device, showing that the two overarching tasks are editing and navigating. Functions that could be employed on an interface for Braille keyboard devices were identified in Chapter 4. It was also found that ‘consistency’ is the primary usability attribute effecting the evaluation of the three devices reviewed. The literature review and analysis of current Braille keyboard devices also established that an interaction paradigm not relying upon visual elements appears to be more appropriate for Braille keyboard devices.

The preliminary framework for the Venturer Model consists of:

- The function set (Table 5.1),

- A diagram of the physical device showing keys (Figure 5.1) and
- Hardware functionality such as a Braille display and LCD screen.

The usability attributes intended to support the functionality and evaluate it are presented in Table 5.2.

5.2 Venturer Model Function Set

Table 5.1 shows the functions to be included and explained for the Venturer Model. The key elements are:

- The headings reflect two primary functions 'editing support' and 'navigation support'.
- The rest of the table shows the functions as they affect editing support and navigation support.

Table 5.1: Functions for Braille Keyboard Devices

Editing Support	**Navigation Support**
Unique Braille Symbols (Formatting)	Unique Braille Symbols (Formatting)
	Menus of program access with one key
	Multi-tasking
Function Keys	Function Keys
Built in LCD	Built in LCD
	Help based on Menus
	Media Keys
Non verbal messages (earcons)	Non verbal messages (earcons)
	Voice Commands

Table 5.2 shows usability attributes that complement the function set in Table 5.1.

Table 5.2: Usability Attributes Supporting Functionality

Interface	**Hardware & Software**	**Measures**
Consistency	Device Robustness	Productivity
Efficiency	Device Portability	Satisfaction
Functional Correctness	Device Safety	Easy to Use
Error Tolerance	Software Stability	
Simplicity		
Learnability		
Memorability		
Flexibility		
Accessibility		

5.2.1 Venturer Model Usability Attributes

Table 5.2 shows the Usability Attributes established as a result of reviewing the factors deemed important by other researchers (Chapter 3), evaluation of modern Braille keyboard devices (Chapter 4), feedback from respondents (Chapter 6) and considering the researcher's own experience being blind and using Braille. The researcher's definitions of each attribute and the significance of these for the development of an interface for Braille keyboard devices follows.

Interface Attributes

'Consistency' is the uniformity of the system and the coherence of the command sets. In terms of physical design for Braille keyboard devices it relates to the uniformity of the key shapes and relationships between keys. For example Figure 5.1 shows similar shapes for the Braille writing keys (dot keys 1237 and 4568; it also shows similar shapes for the function keys F1-F4. Consistency in physical design is important for blind users because they will be exploring the device via the sense of touch. Related shapes and definite key arrangements may assist the blind to orientate to the keyboard and other physical aspects of the device.

Uniformity in the system refers to uniformity in the interface presented to the users. Discussion in chapter three and elsewhere regarding consistency revealed its relatedness to the memorability and learnability which are other usability attributes.

‘Efficiency’ relates to the physical and mental resources a user commits in using a system; the lesser resources used the better or more efficient the system. Efficiency is related to other usability attributes such as learnability. The interfaces on Braille keyboard devices need to be designed to have some efficiency within command structures. The nature of interfaces on Braille keyboard devices involve sequences of commands and if command sequences are related (for example in the Venturer Model the reading and editing commands are similar but use different function keys to initiate the commands) then the user more easily remembers the commands. Thus efficiency can be related to memorability.

‘Functional Correctness’ This is also known as functional relatedness and refers to function sets having relationship with each other. The Venturer Model displays functional relatedness with the editing support and in particular the editing commands which use the backspace key as the function key to initiate commands.

Functional relatedness also allows the user to remember and learn commands more easily. For example the reading commands and editing commands are very similar in the Venturer Model allowing the user to memorize the relationships rather than every keystroke. Patterns are built up in the user's mind and may be recalled when attempting to undertake a task such as deleting a word.

'Error tolerance' relates to the ability of the system to deal with incorrect or accidental user input and the ability to properly inform the user of error states or incorrect input. Blind users using Braille keyboard devices with physical keys and even devices based on touch screens are likely to input incorrect information due in part to the fact that they are touching the device and are relying upon feedback to inform the user that the correct type of input has been made. For example a prompt to set the time may ask 'computer Braille is required; enter hour in 24 hour two digit format' which means that the user must enter numbers in the lower registry on the Braille keyboard. An error tolerant system would ignore input from key presses which don't include these four dot keys (dot key 2,3,5,6).

'Simplicity' relates to the simplicity of the software command structures. Because the blind user cannot see the screen and therefore has no visual prompts to remind them the system needs to offer a simple interface to aid learning the system. More experienced users can then access complex interface elements.

'Learnability' relates to how easy a system of commands is to learn. It is important for blind individuals to be presented with a system that demonstrates consistency and which deals with errors well in order for the blind users to easily learn the system.

‘Memorability’ relates to the interface design in terms of how easily commands are memorised. Blind users will have no screen to provide them visual feedback or prompts and so the commands and sequences of key commands need to be designed to be memorized. Thus memorability is related to consistency and functional relatedness.

‘Flexibility’ is the ability of the system to provide multiple ways for the user to interact with the software but it also includes the ability of the system to output in more than one way. Because the blind are restricted to touch and audible feedback a system that is flexible should address their needs for multiple output modalities.

‘Accessibility’ is the ability for the system to be used by people with differing physical or mental needs. A device targeted for the blind needs to take their needs in to account over and against those of the rest of society. In terms of Braille keyboard devices accessibility would relate to the ability for users of different skill levels to use the device. It is intended that a Braille keyboard device have both simple and more complex functionality, with simple functionality requiring the least number of key commands and complex key presses. Within the blind user group the needs of sub-groups such as deaf-blind persons need to be taken in to account and provided for in the design. For example the ability to receive feedback via Braille output is important for this user group as indicated in the feedback provided in Chapter 6.

Hardware and Software Attributes

‘Device Robustness’ relates to how much physical handling a device can take before breakage. The term covers such areas as the physical design of the case, key switches, any lid or case and if the device is to be used on a surface if the device has non-slip feet. Blind users use the sense of touch to use devices and they need to be robust enough to take significant handling and use. One of the reasons given by respondents for not providing a built in LCD display was that they (see Chapter 6) felt that LCD displays were fragile and devices containing them were thus not robust enough.

‘Device Portability’ relates to how portable the device is. This is important if a device is to be one that a user carries around with them such as a diary. People with sight can use their mobile phones for many mobile applications such as diaries, calendars and address books. The blind can now also use mobile phones with speech output however if Braille is implemented as an output or input modality the size of the device or the portability of the combined device and Braille display is not as good as it would be because of the extra Braille display that is not needed if a person can see the screen. Braille PDA’s are generally larger than those for sighted users and are thus not as portable as regular PDA’s.

‘Safety’ relates to how safe the device is to use. Designers need to design the physical device in such a way that there is not any physical danger to users. A few years ago a digital talking book player was released on the market that had been poorly designed that if the player fell from a table for example and hit the floor it would break open and electrical parts were exposed causing danger to a blind person who potentially could come in contact with the electricity source (personal written notification from Vision Australia).

‘Software Stability’ is also known as the robustness of the software system. It relates to whether the system is itself stable enough and does not internally crash or crash because users inputted incorrect information. Blind users are often very reliant upon electronic aids because they are unable to use physical instruments such as pads and pencils they rely upon electronic diaries and other devices which need to be reliable.

Measures

‘Productivity’ relates to the work output produced when using the device. If blind people are to compete in the society their tools must provide them an interface and physical design that allows them to be as productive as their peers even if the methods used are different. The nature of serial output as compared to a visual spatial output for sighted users limits the productivity of any device or interface designed for blind people. Productivity needs to be considered so that the disadvantages of serial output modalities can be reduced and productivity for the user improved.

‘Satisfaction’ relates to the feeling of wellbeing in the user. It is contended (but not proven in this thesis) that a feeling of wellbeing aids memorability and learnability of systems because it is contended that relaxed users more easily learn.

‘Easy to Use’ is similar to ‘simplicity’ but is a measure of how easy the system is to use based upon the circumstances of the blind user. If other usability factors are present then the system will be easy to use, resulting in good productivity and satisfaction.

Adikari et al. (2006) developed a Usability Attribute model discussed in Chapter 3 which focused upon usability including factors of efficiency, functional correctness, error tolerance, learnability, flexibility and satisfaction. However, this model did not consider hardware issues nor did it distinguish measures for usability. The Venturer Model, on the other hand has divided the usability attributes in to three areas. These include usability attributes related to the interface, hardware and software considerations for the device and measures for usability. The concept behind measures for usability is that if usability attributes related to interface and to the hardware design of the device are met then the measures for usability will produce a positive outcome. For example if all the other factors are fulfilled the user will be productive and will find the system easy to use and will be satisfied with the use of the system.

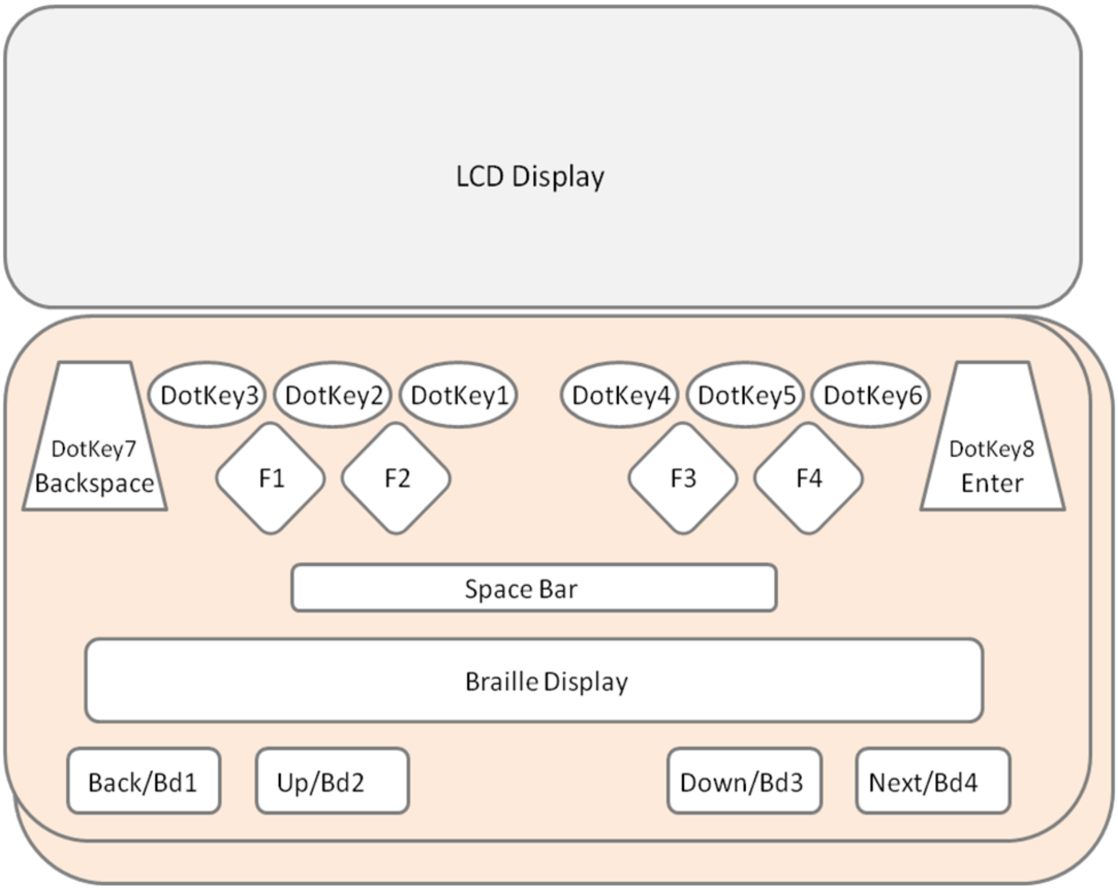
The concept of simplicity is important because not all users are at the same level of development and a simple to use system can be learned and commands memorized easily when compared to a complex one. Simplicity is improved if information is presented to the user. For example in GUI’s icons are present which remind the user of tasks or items that can be accomplished. Consistency of interface presentation aids memory learning and ease of use. Ease of use is a measure for usability.

Adikari et al. (2006) did not discuss hardware considerations as this was not part of the scope of their usability model. This is not a significant issue in regard to usability depending upon the device to be assessed and the environment in which the device is to be used. If a device is to be used in a noisy, dangerous or dirty environment the specifications for hardware design will differ. For example the design for a mobile phone would have to consider the portability of the device, the robustness of the physical device and the safety of the device usage.

Whilst other hardware considerations are important only those that relate directly to use of these by blind users and directly link to interface factors are included in this discussion.

5.2.2 Physical Device Features

The third part of the initial framework as illustrated in Figure 5.1 shows that the related key groups have unique shape and colour contrast (for example the Braille writing keys have one shape). This allows the new user to quickly identify key functions by their shape as well as position on the face of the unit. The figure also shows the Braille Display and the LCD screen. This figure can be referred to when reading this chapter with its key maps.



F1 Main Menu Key F2 Application Menu Key F3 Rich Navigation Key F4 Dismiss/Quit/Escape

Figure 5.1: Functions on the Venturer Model

5.2 Navigation Support

‘Navigation Support’ is an overarching function which relates to reading content and navigating within the system and does not include making changes to the system and possesses sub-categories which will be discussed below.

5.2.1 Reading

Reading is an essential part of navigation and hence is a sub-category of ‘navigation support’. It includes the ability to read content of documents and screen elements. In terms of the Venturer Model the term reading relates to the concept called 'Textual navigation' which is the concept that navigation should be based on logical text units such as characters, words, sentences and paragraphs and is related to ‘unique symbols formatting’. In the table there are three commands for reading characters and three for reading words. The commands to read current word and current character would allow multiple presses. The first press would speak current character or word and the second press would speak military spelling for the characters. This allows the blind person to distinguish difficult-to-hear characters such as ‘m’ and ‘n’. Table 5.3 shows the structured reading commands showing the triplet concept introduced in Chapter 4.

Table 5.3: Reading Commands

Command	**Function**
Space+g	Go forward reading (continuous reading)
F3+F4	Stop reading
Space+dot keys123	Top of file – speak word
Space+Dot keys 456	Bottom of file – speak word
Space+F	Find - provides prompts to user
Space+n	Find next – provides prompts to user
Space+dot key 3	Move back and read character
Space+dot keys 36	Read current character
Space+dot key 6	Move forward and read character
Space+dot key 2	Hear and move back a word
Space+dot keys 25	Hear current word

Space+dot key 5	Move and hear next word
Space+dot key 1	Move back and hear previous sentence
Space+dot keys 14	Hear current sentence
Space+dot key 4	Move forward and read next sentence
Space+dot keys 13	Read from beginning of line to cursor position
Space+dot keys 1346	Read current line
Space+dot keys 46	Read from cursor to end of line
Space+dot keys 23	Move back and read previous paragraph
Space+dot keys 2356	Read current paragraph
Space+dot keys 56	Move to and read next paragraph

5.2.2 Independent Navigation with the Braille Display

The three devices reviewed in Chapter 4 all offer ‘independent navigation with the Braille display’ which means that the user can independently move the Braille line to a place different from the voice or editing cursor. Therefore there are four cursors active on a Braille keyboard device;

- Braille Cursor.
- Voice cursor.
- Editing cursor.
- System cursor- on graphical device this is the mouse cursor.

The default is usually for the voice and Braille cursors to follow or track with the system cursor and when the editing cursor is available to track this instead. Screen readers such as JAWS and Window Eyes tie the mouse cursor to the editing cursor when the latter is present (Freedom Scientific 2008d; GW Micro, 2008d). However ‘independent navigation with the Braille display’ allows the Braille line to move independently of the other cursors. Furthermore ‘independent navigation with the Braille display’ is related to ‘unique symbols formatting’ which display formatting information on the Braille line.

Movement of the Braille display can be controlled by four keys. Each device reviewed in Chapter 4 had unique movement keys for the Braille display. The approach adopted here (see Table 5.4) is to use the convention developed by ALVA BV (2005).

Table 5.4: Braille Thumb Key Functions

Thumb Key (BD)	**Function**
BD1	Back - move Braille display back a whole display length
BD2	Up - move display up vertically to the next line keeping same column position. This key is also used to move vertically up in a spreadsheet or table. The key is also used as shortcut for back or up in a menu
BD3	Down - move vertically down in text keeping same column position. The key is also used to move down a column in a spread sheet. The key is also used as shortcut to move to next item in a menu
BD4	Next - move one complete Braille display width within text
BD1+BD2	Move Braille display back half a Braille display width in text
BD3+BD4	Move Braille display forward half a Braille display width within text
BD2+BD3	Shortcut to Braille menu

The Braille navigation keys on the front of the unit are used to achieve these commands and so the function 'independent navigation with the Braille Display' is related to the hardware keys shown in Figure 5.1. The set of Braille display key commands shown in Table 5.4 presents a consistent navigation experience for the blind user, can be learned, is productive and memorized. Importantly, the shortcut key to access the Braille options is associated with the Braille display keys. This is functionally correct. The Braille menu would include such items as;

- The ability to re-assign the Braille keys to left- or right-handed mode.
- Change cursor shape (dot pattern for cursor).
- The ability to change the Braille translation table for contracted and computer Braille.
- Ability to display or not the formatting information in Braille.
- Ability to write a custom Braille table.

5.2.3 Menu Navigation

The function called ‘navigation support’ includes ‘menu navigation’ which relates to other functions such as 'Menus of programmes accessed with one key' because accessing menus with one key is learnable, productive, and efficient and can be executed by persons with dexterity issues. Furthermore ‘menu navigation’ is related to ‘help based on menus’.

The BrailleNote Empower BT 32 uses the backspace key as the key to move back up a menu, the space bar to advance to the next item in a menu and enter key to select an item in a menu. This method of navigation is chosen for the Venturer Model because menu navigation can be achieved with one finger commands. In addition, the Braille display keys bd2, and bd3 are used to move back and forward through menus respectively. Providing more than one way to achieve a function allows users to choose the method which suits them and supports usability by allowing users to use existing knowledge and skills and use commands which are consistent with their experience. This is particularly the case when accessing the help feature which is also based upon menus and therefore aids ‘memorability’ and ‘learnability’ which are supporting usability attributes.

There are two different keys to access menus in the design presented in Figure 5.1; for example F1 brings up the list of potential programmes and the user manual. These programmes may be in nested menus. The office applications would be in their own sub-menu and the utilities in another. The F2 key brings up an application programme menu from which menus related to the currently focused programme can be accessed.

5.2.4 Rich Navigation

'Navigation support' includes 'Rich Navigation' which is a concept related to the movement between different elements on a web page or complex document. The function includes the ability to move between tables, frames, headings, lists, figures and headers.

Screen readers such as JAWS and Window Eyes (Freedom Scientific 2008d; GW Micro 2008d) use an off screen model which allows users to navigate elements on web pages and complex documents. There are thus two modes:

- Browse mode – the user is accessing a copy of the web page or complex document and cannot edit it but is able to move between different elements of the content by using single letter keys.

- Edit mode – the user can make changes to the content but is unable to use the single letter navigation keys.

Table 5.5 presents the ‘rich navigation’ short cut keys used in the Venturer Model. The table shows the F3 key (Figure 5.1) is to the right of the spacebar and is used as the access key for rich navigation elements. If browse mode is turned on then the F3 key does not need to be held while pressing keys listed in Table5.5. This allows for efficient navigation of elements and may produce higher productivity and satisfaction for users.

Table 5.5: Rich Navigation Key Assignments

Key	**Action**
F3+b	Browse mode on
F3+m	Browse mode menu
Space+e	Exit browse mode
F3+V	Next visited Link
F3+Shift+v	Prior visited Link
F3+u	Next unvisited Link
F3+Shift+u	Prior visited Link
F3+h	Next heading
F3+Shift+h	Prior heading
F3 + one of; 1, 2, 3, 4, 5, 6	Move to heading at that level. Example F3+2 - move to heading at level 2
F3+Shift + 1, 2, 3, 4, 5, 6	Move back to heading at that level
F3+P	Next paragraph
F3+Shift+p	Pryor paragraph
F3+F	Next form field

F3+Shift+f	Prior form field
F3+B	Next button
F3+Shift+b	Prior button
F3+L	Next List
F3+Shift+l	Prior List
F3+Q	Next block quote
F3+Shift+q	Prior block quote
F3+T	Next table
F3+Shift+t	Prior table
F3+x	Move to text that is not a button
F3+Shift+x	Previous text that is not a link
F3+M	Next frame
F3+Shift+m	Prior frame

Where 'shift' means dot key7 or backspace key.

There is a need for the system cursor to be tethered to the browse mode cursor because when browse mode is turned off the edit cursor will be in place for user editing of documents. Browse mode menu (F3+m) brings up a browse mode menu populated with the different types of items on the web page or in the document. The user moves through the menu using the space bar and backspace or uses first letter navigation to move to a type of item they are interested in. They press ‘enter’ and then use menu navigation commands to move to the desired item. This provides an alternative to the quick letter keys or the F3+ letter keys and informs the user of all types of items on the page or in the document. This ability of F3+m may improve usability of the system because the amount of information users need to remember is reduced, may aid in learning, increases flexibility, may improve user satisfaction with the use of the Internet or documents, may produce higher productivity for web searching and may increase efficiency for some users because it offers alternative methods for achieving the same result.

5.2.5 System Navigation

‘Navigation support’ also includes ‘system navigation' which includes all aspects of interacting with the underlying operating system. Such tasks as file and folder manipulation and setting the system time and date are included in this function. ‘System navigation’ is related to 'menus of programmes accessed with one key', 'function keys' and 'help based on menus'.

System features would be accessed in a variety of ways including shortcut keys for commonly used tasks. For example F1 would be the access key used for accessing system tasks. This key is the main menu key if pressed by itself, but if held down and then used with combinations of keys on the Braille keyboard, then access to categories of 'system navigation’ would be possible. This is similar to the way that Microsoft Windows uses the Windows logo key with letter keys to achieve system tasks. An example of how this feature might be utilised is given in Table 5.6.

A key aspect to the function 'system navigation' should be the concept of different levels of access to the system. The screen reader called Window Eyes, produced by GW Micro offers an interface allowing three different levels of access to commands (GW Micro 2008d). The programme offers: beginner, intermediate and advanced levels of access to the command sets. 'Beginner' is the most basic level and offers fewer menu items than does 'intermediate' which offers less menu item choices than does 'advanced'.

Table 5.6: Example of Key Assignments for System Navigation

Key	**Function**
F1+f	File and folder menu
F1+c	Connectivity for ports and Bluetooth and Internet
F1+d	Date and time features

'System navigation' should include access to a command prompt to enable advanced users to perform advanced system setting including file management. The ELBA produced by Papenmeier (2008) offers a command prompt and access to advanced features. The ELBA uses Linux for its underlying operating System.

5.2.6 The Voice Menu

The menu controlling the characteristics of the voice would be connected with the main menu of the system. The enter key could be used as the access key to provide shortcut access to speech feature adjustment. Table 5.7 shows example commands to adjust speech parameters.

This example key assignment uses similar concepts to the editing and reading commands in that keys to the left of the space bar reduce the item and those to the right increase the item. The implementation of the voice adjustment supports usability in that it aids ‘memorability’, ‘learnability’ and ‘flexibility’, when connected with the media keys.

Table 5.7: Example of Voice Adjustment Key Assignments

Command	**Action**
Enter+dot key4	Speak louder
Enter+dot key1	Speak softer
Enter+dot key5	Increase speech pitch
Enter+dot Key2	Decrease speech pitch
Enter+dot key6	Speak faster
Enter+dot key3	Speak slower
Enter+dot keys46	Increase media volume
Enter+dot keys13	Decrease media volume

The Media Keys perform some similar functionality to the shortcuts above and if no other media is playing then the front panel keys could be configured to adjust the speed of the voice.

5.2.7 Editing Support

The next function of an ideal Braille Keyboard Device is the function called 'Editing support' this function includes commands to delete and move content in the programmes and within the operating system itself. The chosen editing commands use similar key sequences to the reading commands. The commands use the same logic as the reading commands that keys to the left of the space bar move up or back and those to the right move forward or down in a document. Further, if keys to the left and right of the space bar are depressed together the current item is deleted. Thus the usability attributes of ‘learnability’, ‘memorability’, ‘satisfaction’, ‘efficiency’ and ‘functional correctness’ are supported.

Functional correctness is illustrated by the destructive nature of the backspace key as it relates to the destructive nature of editing itself. The format menu is accessed with the backspace+dots2346 which is an arbitrary combination identical to the BrailleNote Empower BT 32 command to access the format menu (HumanWare 2008c). This adopted key sequence aids 'memorability', 'learnability' for those users familiar with BrailleNote Empower BT 32 key sequences. The format menu is navigated like other menus including the ability to use first letter navigation. The format menu should include a page layout menu, font menu and paragraph alignment. The suggested commands are those shown in Table 5.8.

Table 5.8: Editing Commands

Command	**Function**
Backspace+dot key 3	Delete prior character
Backspace+dot key 36	Delete current character
Backspace+dot key 6	Delete next character
Backspace+dot key 2	Delete prior word
Backspace+dot keys 25	Delete current word
Backspace+dot key 5	Delete next word
Backspace+dot key 1	Delete prior sentence
Backspace+dot key 14	Delete current sentence
Backspace+dot key 4	Delete next sentence
Backspace+dot key 23	Delete prior paragraph
Backspace+dot keys 2356	Delete current paragraph
Backspace+dot keys 56	Delete next paragraph
backspace+dot keys 123456	Delete entire contents of file
Backspace+dot keys 13	Delete from beginning of line to cursor

Backspace+dot keys 1346	Spell check
Backspace+dot keys 46	Delete from cursor to end of line
Backspace+dot keys 2346	Format menu
Backspace+b	Block menu on
Backspace+f	Find and replace
Backspace+u	Undelete

The block commands menu allows for larger amounts of text to be deleted than the shortcut keys and allows ‘independent navigation with the Braille display’ to move to the end of the block. The block commands menu would contain all related block commands, including the ability to launch spell checker for the selected block. The block commands menu concept relates specifically to the usability attributes of ‘efficiency' and 'flexibility' but may relate to user ‘satisfaction’ for some users.

Four of these commands need further discussion. The spell check command is arbitrary and would need to be learned as it has no counterpart in reading commands. The find and replace command is similar to the find command and is tied to the destructive backspace key for functional correctness. The format menu would contain the page layout menu, font menu and paragraph alignment menu. The alignment includes heading alignment. The format menu also contains a link to the Braille format options. The Braille format options relate to the function called 'unique symbols formatting'.

The undelete command would allow for the un-deleting of the last action and depending upon the operating system allow for more than one reversal of action.

There should be an option to allow the voice to speak content to be deleted and this is likely to be contained in a settings area or in the voice menu.

5.2.8 Unique Symbols Formatting

The use of Braille is important to those who are blind and those who are both blind and deaf. The deaf blind need to be aware of formatting through the Braille since the synthesised speech cannot be heard. Formatting that needs to be conveyed includes such formatting as bold, centre, justified and other information such as font sizes. Unique formatting tags provide this certainty to those who are deaf and blind and to those who are just blind.

There are two aspects to formatting in Braille. First, there is the concept of mark-up. Mark-up tags are where unique symbols mark the commencement of a text attribute or a formatting command and unique symbols identify changes in these attributes. The other way to identify text attributes is to allow the Braille display to display only text attributes and not display text content. This option would work best if the speech is turned on so that the user hears the text content and can feel the Braille display to determine text attributes of particular letters.

Marking of a character position on the Braille line is accomplished by unique combinations of the eight dots available in each computer Braille cell. There are 256 combinations available from eight dots including the null position with no dots raised. Table 5.9 shows examples of formatting symbols; for example, a bold and underlined character could be represented by dot 12. This type of display of formatting information might reduce errors and so is related to the usability attribute 'error tolerance'.

Table 5.9: Examples of Formatting Attributes

Dot pattern	**Meaning**
	No formatting
Dot1	Bold
Dot2	Underline
Dot3	Strike through
Dot4	Reverse video

The concept of text tags is important. Text tags are unique symbols or groups of characters that mark the commencement and end of different paragraph formatting attributes. Products such as the Versabraille used text tags but these were mainly used to identify layout such as new paragraphs. Companies such as Duxbury Systems introduced unique symbols for mark-up when producing paper-based Braille with computers (Duxbury Systems 2008). These symbols initially used the $ sign as a commencement character. After the $ sign came one or more letters or numbers to identify the text tag. Other systems such as WordPerfect 5.1 for DOS introduced the concept of beginning and ending tags to the computer user. It is from these two systems that the following suggestions are made.

Text tags reduce ambiguity for the reader but require the reader to imagine what the document will look like once printed. A person who is blind cannot see the layout or document as a whole; hence, unique symbols defining layout formatting are related to the usability attributes of 'memorability', 'flexibility', satisfaction', 'efficiency', and reduce the amount of errors. Table 5.10 shows some possible formatting commands.

Table 5.10: Formatting Symbols

Unique symbol	**Explanation**
$l	New line
$p	New paragraph (hard return)
$b	Commencement of bold
$/b	Bold off
$u	Underline on
$/u	Underline off
$c	Centre
$l	Left aligned
$j	Justified text
$r	Right aligned
$fs followed by a number in the lower registry like computer Braille	Font size followed by a number
$ft	Font type
$+dots748	Cell boundary in spreadsheet

There are some important characteristics of these symbols. First, they must be surrounded with a single space on each side. Second, the attribute is turned off with the symbol with an / as the second character. The ability to display these symbols would be an option within the Braille menu.

5.2.9 Multi-Tasking

Multi-tasking will be implemented and the user will be able to switch between open applications. F1 is the main menu or programme key. Press and hold F1 and press the backspace key (dot key 7) immediately to its left which will initiate the menu of running applications. The menu is navigated in the same way as other menus. If an application has more than one document open, then a sub-menu for that application will be available from the running applications list. This sub-menu will contain the open documents for that application. Additionally F1+F2 will cycle between all open documents and F1+F2+backspace will cycle back through the list of open applications. The BrailleSense approaches this problem in a similar manner (GW Micro 2008c). There are two ways of accessing running applications and documents and one way is similar to the method used with Microsoft Windows. These options aid flexibility and ease of learning. Thus this implementation relates to the following usability attributes 'learnability', 'memorability', 'flexibility', 'satisfaction' and 'efficiency'.

5.2.10 Built-in LCD

The Built-in LCD function is mostly used for interaction with those with sight and relates to the following usability attributes 'flexibility' and ‘efficiency’, measured by 'satisfaction' and ‘productivity’.

5.2.11 Help Based on Menus

Context-sensitive help can be based upon menus. This provides a consistent interface and reduces the amount of information the user is expected to retain in memory at any one time. The system aids learning and memory retention and eventually produces an efficient user because s/he has been reminded often of command sequences. The system also helps to reduce errors because the user can obtain useful help at any prompt and explore other help information via the help menu. A help system based on menus relates to the following usability attributes 'learnability', 'memorability', 'error tolerance' and efficiency' measured by satisfaction' and ‘productivity’.

5.2.12 Media keys

Dedicated media keys allow the user to control the media player while using other applications. This function relates to the following usability attributes 'flexibility' and ‘efficiency’, measured by ‘productivity and 'satisfaction'.

5.2.13 Function Keys

The concept of 'function keys' relates to the keys on the device that perform functions or tasks. Broadly speaking, there are four groups of such keys on this theoretical Braille keyboard device. The first such group comprise the 'backspace key', ‘Spacebar’ and 'enter' key. These keys form part of the nine-key Braille keyboard. The 'Braille display’ keys (BD) are related to Braille functions and the media keys are related to media events. The true function keys are the keys F1-F4. The discussion here relates to these keys only. The 'function keys' F1-F3 were discussed throughout this chapter. F4 is defined as the esc key. There is one other function related to this key - the function 'key definition'. This concept relates to the ability to assign functions to keys on the device. F4 has been reserved for this function by choosing to redefine it in the main menu. 'System navigation' is tied to the function called 'key definition'. The way 'System Navigation' is tied to 'Function Keys' is through the ability of the system to assign tasks to keys or key combinations. Theoretically, allowing 'key definition' allows any key or key combination to be assigned to any function or letter providing there is no clash of key assignment with another function. The assumption is that the user does not require the original key assignment and can thus assign a new assignment to the key. Thus a user may decide that the original function assigned to F4 (escape) can be performed with the alternative key sequence (space+e). Thus F4 could be assigned the function 'fn' similar to a laptop computer. With F4 assigned to the 'fn' function, the user then has at least eight keys which can be function keys. These are dots 1-8. Therefore, the F4 key 'fn' key would be held down with one of the dot keys 1-8 and additionally any of the other function keys F1-3, either singly or together. This assignment gives more than 24 separate tasks that could be assigned. This function adds flexibility to the command structure, may increase efficiency, and may also lead users to be more satisfied with the system because they are able to customise the interface to meet their needs.

The result is that the function 'key definition' is related to the function 'function keys' and the usability attributes, 'flexibility' and 'efficiency' measured by ‘productivity’ and ‘satisfaction’.

5.2.14 Non Verbal Messages

The concept of earcons was discussed in chapter three with a recommendation that this function should be part of an interface for Braille keyboard devices. Such messages could include alert messages when incorrect information is typed at a prompt or error tones associated with accessing disks or content. The power of the device and operating system may influence the variety of earcons used. If non-verbal messages are employed the function would relate to ‘editing support’, ‘navigation support’, ‘system navigation’, and would relate to the usability attributes ‘efficiency’, ‘memorability’, ‘learnability’, ‘consistency’, and ‘error tolerance’ and measured by ‘productivity’ and ‘satisfaction’.

5.2.15 Voice Commands

Voice commands may be implemented depending upon the hardware and software limitations of the system. Text input via spoken input is not suggested; rather it is proposed that voice commands be permitted for example to invoke the menu, access a contact or to turn off the unit. This would be similar functionality to a mobile phone. ‘Voice commands’ are related to ‘navigation support’ and may be related to the usability measure ‘productivity’.

5.3 Summary and Key Relationships

This chapter presented the details of an interface Model for Braille keyboard devices focusing upon functions and usability of the system. Table 5.11 shows the main functions and their key relationships.

Table 5.11: Key Relationships Between Functions

Item	**Other related items**
Navigation Support	Reading, menu, rich navigation, browse mode navigation commands, and system navigation
System navigation	Voice menu.
Editing Support	Editing commands, unique symbols for formatting
Multi-tasking	
Built in LCD	
Help based upon menus	
Media Keys	

Function Keys	
Non Verbal Messages	Editing support, navigation support, system navigation
Voice Commands	Navigation Support

The following discussion expands on the relationships between functions within the interface presented in this chapter.

- 'Navigation support ' is related to 'reading commands', which is in turn related to 'textual navigation'. 'Textual navigation' is related to 'unique symbols formatting'.
- 'Navigation support' is related to the function called 'independent navigation with the Braille display', which is itself related to the diagram showing the front panel keys.
- 'Navigation support' is related to the concept 'menu navigation' which is related to 'menus of programmes accessed with one key' and 'help based on Menus'.
- 'Navigation support’ is also related to the concept 'rich navigation' and 'system navigation'.
- ‘System navigation’ is related to the functions 'menus of programmes accessed with one key', 'function keys', 'help based on menus', voice menu and 'media keys'.
- 'Editing' is related to the concept of a formatting menu. The 'format menu' has sub-menus called 'page layout menu', 'font menu', 'paragraph alignment menu', and the 'Braille format menu'.

- The Braille format menu is related to the function called 'unique symbols formatting'.
- ‘Built-in LCD’ is not directly related to other functions.
- ‘Help based on menus’ is not strongly related to other functions.
- ‘Media keys’ is not strongly related to other functions.
- ‘Key definition’ is related to the function ‘function keys'.

The usability attributes which most influenced the design of this interface included Consistency, Efficiency, Functional Correctness, Error Tolerance, and Memorability. Each attribute was related to more than one function and relationship between functions. For example:

- ‘Navigation support’ may be related to the usability attributes ‘consistency’, ‘functional correctness’, 'memorability' and 'learnability'.
- ‘Editing support’ may be related to the usability attributes ‘learnability’, ‘memorability’, ‘efficiency’, and ‘functional correctness’.
- ‘Unique symbols formatting’ may be related to the usability attributes 'learnability', 'memorability', 'flexibility' and 'efficiency'.
- ‘Built in LCD’ may be related to the usability attributes ‘flexibility’ and 'efficiency'.
- ‘Help based on menus’ may be related to the usability attributes 'learnability', 'memorability', ‘'efficiency' and 'error tolerance'.
- ‘Media keys’ may relate to the usability attributes 'flexibility' and 'efficiency'.
- ‘Key definition’ may be related to the usability attributes 'flexibility' and 'efficiency'.

5.4 Conclusion

The Venturer Model is presented in this chapter and showed the key relationships between the functions in table 5.1. A key finding of the chapter is that a model for Braille keyboard devices needs to focus upon textual navigation and editing. Other functionality needs to be considered such as providing non-verbal messages and possibly speech input facilities. The next chapter will present analysis of the data collected in the evaluation of this model.

Chapter 6: Data Collection and Analysis

6.1 Introduction

The Venturer Model was presented in Chapter 5 and this chapter presents data collected from respondents and analysis of this data to determine the fit of the Venturer Model to the user community. The chapter first discusses the research participants, including the numbers of participants and the reasons for choosing interviews and focus groups over other data collection methods. Chapter 2 discussed the theoretical background to the different data collection methods and this chapter has the focus of explaining why the two data collection methods were chosen for use with the particular population studied. The discussion focuses on the particular problems associated with collecting relevant data from those who are without sight. The interview and focus group questions were categorized into five areas. The respondents raised other areas of concern which did not fit within these categories.

The data collected and the analysis of the data allowed the researcher to determine and present the strengths and weaknesses in the Venturer Model and determine how well the research has met the research questions. Modifications to the original Venturer Model will be presented and the final model will be released.

6.2 Research Participants

6.2.1 Obtaining Participants

The researcher prepared a letter requesting participants (see appendix D) which was distributed in 2008 to agencies providing services for or which represented people who are blind throughout the world requesting their assistance in distributing the interview questions and associated Participant Information (see appendix B). The response to this process was not very effective as Table 6.1 shows.

Table 6.1: Agencies Approached to Advertise Need for Participants for Study

Agency Approached	**Number of Participants Gained**
The Royal National Institute of Blind People (formerly Royal National Institute for the Blind) London	0
Canadian National institute for the Blind	0
Vision Australia	0
Association for the Blind Western Australia	1
Total	1

A key reason for approaching agencies representing people who are blind in different countries was that the researcher wished to seek feedback from respondents from a variety of countries and with a variety of experience with different Braille keyboard devices. The researcher was aware that a limited number of Braille keyboard devices were available in Australia and that different devices were popular in different countries thus reducing bias in the feedback provided by respondents and to improve validity and reliability of the results generated.

However, as Table 6.1 shows only one response was obtained from advertising with agencies for the blind around the world so the researcher decided to advertise directly on email discussion lists targeted at blind people who had an interest in technology and who were likely to be computer literate. Two email lists were targeted; The BrailleNote discussion list moderated by Humanware and VIP-l which is an email discussion group targeted to blind people in Australia and surrounding regions. Table 6.2 shows the number of persons who responded to the request for participants and the actual numbers who completed the interview. The numbers who completed the interview were significantly less than those who originally expressed interest in the study.

Table 6.2: Response to Advertisement on E-mail Discussion Lists

E-mail List Name	**Number of Persons Who Expressed Interest in Study**	**Number of Persons Who were Interviewed**
BrailleNote Discussion List	20	3
VIP-L	10	2
Totals	30	5

Of the 31 persons who were interested in participating in the research only 6 actually completed an interview. An additional person offered to provide feedback to the researcher, however, this person provided feedback on the model and did not complete the interview questions.

There were two main reasons why people did not wish to be interviewed. These included that the person did not feel their skills were sufficient to provide useful feedback and that the researcher was unable to get people to respond to follow up email correspondence. Five completed interviews were not considered sufficient to provide reliable feedback and so a focus group was organized through the Cisco Academy for the Vision Impaired (based at the Association for the Blind in Western Australia). The result was that a focus group (comprising thirteen individuals) was held in March and April 2009. The opportunity to carry out focus groups in addition to interviews was welcomed by the researcher because group dynamics could occur in a focus group as compared to individual interviews. Chapter 2 discussed the relative advantages of interviews and focus groups.

An advantage of employing Cisco Academy students for this research was that they were; computer literate, interested in computers, understood interface concepts and had used a variety of access solutions. Another advantage of using the Cisco students was that the researcher could target a population which was likely to be distinct from the population targeted by the requests to blindness agencies. In addition to western countries the Cisco students include those from countries such as India, Egypt and Pakistan.

6.3 The Interview Questions by Category

Respondents were asked a total of 22 questions which were targeted at issues and divided in to 5 categories. Appendix B presents the interview instrument in its entirety, including consent form, data sheet and interview questions. The appendix also provides the legends used to aid respondents to answer questions. The questions are included in the data presented below for clarity. The categories in to which questions were divided included:

- Demographics - included questions 1 and 4.
- Use of computer Systems - included questions 2 and 3.
- Use of Braille devices - included questions 5-10.
- Functionality of Braille devices - included questions 11, 12, 14-19.
- Usability - included questions 13 and 20-22.

6.3.1 Demographics

The information collected from respondents which related to demographics only included their gender, experience with computer systems and with Braille and Braille keyboard devices. Table 6.3 shows the gender split for individual respondents and for the focus group. More females than males participated in this study.

Table 6.3: Gender Split for Respondents

Gender	Individual Interviews	Focus Group
Male	2	5
Female	4	8

Tables 6.4 -6.25 present summaries of the respondents' answers to the questions. Some respondents chose to not answer some questions and not all respondents made comments, resulting in tables not displaying the same number of answer columns. Tables 6.4-6.25 are presented in landscape format and are grouped together for efficient presentation.

Table 6.4 presents the responses from five of six individual interviews with respect to their computer and Braille experience. The sixth individual did not provide sufficient information on this subject. There are respondents with more than ten years' experience with computer systems and with more than twenty years' experience with Braille.

The focus group had a similar range of experience with computer systems and Braille keyboard devices. During the focus group conference call I was able to discern six of the thirteen individual voices and therefore could provide structured feedback from those individuals. The other feedback from the focus group participants was combined into general feedback because I was unable to differentiate all the voices. Table 6.5 illustrates this.

The experience of both individual respondents and the focus group would indicate that they should be able to provide useful feedback given that years of experience relates to competence.

The computer interface was discussed in Chapter 3 and was shown to relate to both hardware and software specifications. Also the concepts of hierarchy, flow and grouping were shown to be important in terms of developing an interaction paradigm for Braille keyboard devices.

Various types of operating systems were discussed in the literature review; focusing upon graphical user interfaces due to their popularity and ease of use for sighted users. The difference between a visual spatial and a speech interface relying upon serial output was also discussed. There are a variety of challenges faced by blind persons interacting with a system designed for a visual spatial interaction paradigm when the interaction methods available to the blind are serial in nature. The concept of multi-modal computer interfaces was discussed earlier and was found to be of potential value in providing a more complete experience for blind users. The three devices discussed in Chapter 4 all provide multi-modal output as does the Venturer Model discussed in Chapter 5.

Table 6.6 shows the feedback from respondents who were individually interviewed regarding what they felt made operating systems easy to use. Table 6.7 shows the feedback provided by the focus group regarding what makes operating systems easy to use.

Both the individual respondents and focus group participants answered with a range of functionality and usability criteria. Consistency, a good help system, logical arrangement of related functions and simplicity were highlighted. Although the comments did not say directly the concept of first letter navigation is implied by some of the comments. Many of these criteria were implemented in the Venturer

Model. The comment on the search facility in Vista may require further development for the Venturer Model.

Table 6.8 shows the feedback provided by individual respondents who were interviewed about what made operating systems difficult to use. The key aspects of the feedback provided in this table are that for the respondents who understood what was asked the overall concept of GUI’s was confusing. Also, respondents recognised the need to use keyboard short cuts and the difficulty of having to learn the screen reader at the same time as learning the operating system. The lack of consistency was also highlighted. This is one of the reasons why consistency of commands and functionality is important in the Venturer Model.

6.4 Use of Braille Devices

The history and advantages of Braille are discussed in Appendix C and Braille keyboard devices are discussed in Chapter 3. All Braille keyboard devices have six dot keys for entering the Braille and all possess other keys for performing functions such as spacebar, new line, and backspace. Chapter 3 discusses the history of these devices and Chapter 4 evaluated three such devices in terms of functionality and usability. The assessment was based upon the researcher’s experience with the devices.

Table 6.9 shows the feedback on the use of Braille keyboard devices provided by individual respondents. There were only five responses regarding the use of Braille so the results need to be interpreted tentatively. Braille reading was more important than writing and the whole concept of Braille input as a modality needs investigation.

Table 6.4: Computer and Braille Experience of Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Demographics	1. How many years' experience have you with using different types of computer operating systems?	Primary Research Question	Respondents have had more than ten years of experience with systems so should be able to comment on model.	20 years	16 years.	13 Years	Two decades of use at least.	17 Years
	4. How many years have you been using Braille and Braille keyboard devices?	Primary Research Question	Although respondents experience varies some have had more than 15 years' experience – their feedback probably useful	16 years for Braille (no answer for Braille Keyboard Devices)	Around 32-33 years	Braille: 14 devices: 9 or 10	I have very little experience in real world use but I have used trialed several systems in the past.	17 years

Table 6.5: Computer and Braille Experience of Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5	Answer 6
Demographics	1. How many years' experience have you with using different types of computer operating systems?	Primary Research Question	Respondents have had more than ten years of experience with systems and three have had up to twenty years' experience so should be able to comment on model.	20	20	20	18	15	10
	4. How many years have you been using Braille and Braille keyboard devices?	Primary Research Question	Although respondents experience varies three have had more than 30 years' experience – their feedback probably useful	17	10	30	53	50	N/A

Table 6.6: What makes Operating Systems Easy to Use: Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Use of Computer Systems	2. What aspects of the way you used the operating systems made these operating systems easy to use?	Primary Research Question	User comments were a range of functionality discussion and usability problems. Consistency, logical commands and context sensitive help were important. The Venturer Model took Consistency as the primary usability attribute and is placed above the two	Some were easier than others to use, I have found so far that the easiest OS to use are Windows XP, MAC OSX and devices running Keysoft	When I first started using computers, I was using MS-DOS-based programs – mainly WordPerfect 5.1 and MS-DOS itself. I only had access to speech output at that time, not refreshable Braille. Being totally reliant on speech output from the screen reader, and being a somewhat reluctant computer user, I was only using the very basics of the screen reader I had at home, which was different to that used by the Association for the Blind for their computer training. I was getting by with WordPerfect navigation commands, arrow keys and very	layout/structure input methods (qwerty or Braille) output (speech or Braille) compatibility with screen readers (JAWS)	Logical arrangement, consistency of functions, friendly interface.	Well I like operating systems with a bit of help in them. With context sensitive help. For example like the Eureka. If you didn't know what a function key meant you could hold down space and press the function key. With the Braille companion and BrailleNote you can press the help key and find out

			columns of Table 5.1 to show this importance.		basic screen reader knowledge. Consistent screen lay-out and simple menus made this easier. When I later had access to a Braille display on loan for home use, I still didn't have to worry too much about screen reader commands; and on the laptop I was using for my second uni course, I didn't even have speech, just the Braille display, and I was able to do what I needed to do just fine. (In fact the Braille display and laptop were purchased by the uni precisely to facilitate greater access to study, which had been especially frustrating for me as I was studying languages and had been checking my work on my home computer by navigating through it letter by letter with speech alone.)			what to do at any time.

Table 6.7: What makes Operating Systems Easy to Use: Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5	Answer6
Use of Computer Systems	2. What aspects of the way you used the operating systems made these operating systems easy to use?	Primary Research Question	The focus of the comments related to logical commands, the use of different ways to interact with the system from the use of short cut keys to the use of menus. These criteria were incorporated in the Venturer Model. Simplicity as a usability attribute was not considered in the Venturer Model and this may well be a fault of the model structure.	The design is important; the interface needs to be simple with logical layout of commands with logical chorded commands. The function key assignments were also logical in the Eureka and I was able to call up help on any key.	I have been using computer systems for 20 years and the short cut keys made it easy. A problem with the Eureka was that it was not very robust to use the system.	Remembering a large number of keystrokes is tough for a lot of people so having the option of tabbing if you can’t remember a keystroke is good.	A command system is more efficient if you know the commands but there are people who have trouble remembering the commands. One thing that has made the victor reader stream so popular is that a complete brain dead idiot can drive the thing because all the menus and stuff are exceedingly simple. You lose a lot of functionality as a result. I would like to be able to bust open a command prompt but the device is exceedingly simple to use. Simplicity of design is important because not everyone is a tech wiz in the blind community.	If you have the two options available: menus and short cut keys, it makes the device more accessible to people of all levels of ability. You have to take in to account differing abilities in the blind community. For example you need to consider people with impaired motor skills and incorporate command sequences that are easy to use.	I really like the search box on Vista I like the search box popping up. What makes it intuitive to use is being able to go in to the start menu and being able to just type and have whatever I am typing bring up choices based on this.

Table 6.8: What makes Operating Systems Difficult to Use: Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Use of Computer Systems	3.What aspects of the way you used the operating systems made these operating systems difficult to use?	Primary Research Question	The key aspects of these comments relate to the nature of GUI’s, need to learn screen reader along with OS, irregularities in commands and lack of context sensitive help. The Venturer Model addresses this by making consistency a high priority and as far as possible making the command sequences functionally related. For example tying the editing to backspace key.	I didn’t find many difficulties except having to learn a lot of different keystrokes when working with MAC OSX	I didn’t find many difficulties except having to learn a lot of different keystrokes when working with MAC OSX	Windows, in contrast to the DOS environment, required far greater interaction with a screen reader just to navigate some of the dialogs and even perform tasks which were otherwise only achievable with a mouse. I didn't like Windows. I only started learning it at the Association (before I decided to go back to uni for my second degree) because of the supposedly better job prospects, but at home I happily kept using WordPerfect. I only switched to Windows later because I wanted to eventually use the Internet at home and the laptop which had been on loan to me had to be returned any way. I avoided using the Jaws	Irregularities in the way an OS is arranged.	Graphical user interfaces. Just getting the concept of them because a screen reader is just so different to how a sighted person would use them. Sometimes getting the overall concept of how the operating system works makes it difficult to learn to use. This is particularly important when there is no effective context sensitive help. Also there is the problem for the blind that when they go to learn a new operating system they must learn to use the access solution as well

						cursor wherever possible, and again, with a Braille display, when I did need to explore the screen without moving the cursor, I could get away with this for the most part, though the inherently complex, layered nature of Windows made this more difficult – especially as I didn't have access to specific training on the screen reader’s functions in conjunction with refreshable Braille. Even now, I have found that in some applications/dialogs, I can't necessarily scroll the Braille display to other parts of the screen not accessible with the application cursor, and the Jaws cursor doesn't necessarily enlighten me any further.		as the operating system at the same time. Every access solution has a different approach to how they access the operating system.

Table 6.9: Use of Braille: Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Use of Braille devices	5. Would you consider yourself an expert Braille reader and writer? Rate this from 1 having no using Braille to 5 being an expert reader and writer of Braille.	Primary Research Question	Most respondents were expert with Braille	4	Experience using Braille to 5 being an expert reader and writer of Braille. 4-5 (I'm less proficient with Unified English Braille Code at present).	4.5	2	5
	6. On a daily basis how much time (in terms of hours or minutes) would you spend reading Braille?	Primary Research Question	Two of the respondents only used Braille for more than two hours. From this feedback Braille output as a function would be considered to be unimportant to be included on a Braille keyboard device.	2 hours	3-4 hours	No answer	Less than 5 minutes	5 minutes
	7. On a daily basis how much time (in terms of hours and minutes) would you spend writing Braille?	Primary Research Question	Writing Braille was perceived as less important by these respondents than reading it. The option of Braille input needs to be considered in relation to qwerty keyboard options.	30 minutes maybe	It varies from a few minutes to an hour or more.	anywhere from 1 to 2 hours	Less than 5 minutes.	About three minutes

Table 6:10: Braille Keyboard Devices used by Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Use of Braille devices	8. How many years' experience have you using electronic Braille keyboard devices?	Primary Research Question	Four individuals respondents had used Braille keyboard devices for more than 10 years	Ten years	18 years	9 or 10 years	Infrequent trial over 2 years.	17 years
	9. Which electronic Braille keyboard devices have you used?	Primary Research Question	Two significant observations are that the respondents had nearly all used Eureka A4 and BrailleNote products. This may influence their feedback and the use of the Braillenote Products influenced the development of the Venturer Model. Perhaps the concept of arrow keys needs to be introduced on Venturer Model.	Eureka BrailleNote PK and Empower Brailliant 40 cell Mountbatten brailler	Eureka, Braille-n-Print, Keynote (just tried these out once); Braille-n-Speak, BrailleMate, BrailleLite (tried them a couple of times at expos); Mountbatten Brailler, BrailleNote.	Braille Light and BrailleNote	BrailleNote, PK, Empower.	Eureka, BrailleLight, BrailleCompanion
	10. Which Electronic Braille keyboard device do you currently use?	Primary Research Question	Three respondents currently use BrailleNote products.	Brailliant BrailleNote PK BrailleNote Empower	BrailleNote BT32 (Classic, not Empower).	BrailleNote Empower BT	Nil, but looking into my options for future purchase.	BrailleCompanion

Table 6.11: Braille Keyboard Devices used by Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3
Use of Braille devices	8. How many years' experience have you using electronic Braille keyboard devices?	Primary Research Question		17 years	10 years	
	9. Which electronic Braille keyboard devices have you used?	Primary Research Question	Eureka A4 and BrailleNote products are prominent	Braille companion, BrailleNote Empower and PK	Eureka A4 BrailleNote Empower and PacMate	Eureka A4
	10. Which Electronic Braille keyboard device do you currently use?	Primary Research Question	Eureka A4 and BrailleNote products are prominent	BrailleNote Empower and PK	BrailleNote Empower and PacMate	

Table 6.12: Why Braille Output is Important - Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	11. How important is it to you that your Braille keyboard device offers both speech and Braille output? Rate from 1 being not important to 5 being extremely important.	Primary Research Question	Respondents rated speech and Braille and their feedback reflects this. An interpretation is that Braille output aids speech output.	2	5 I wouldn't have even considered it if it didn't offer Braille output.	speech: 2 Braille: 5	I would rate this as a 5 as my skills with Braille are rusty. Voice would fill in the gaps	4
	12. Why is it important to you that your Braille keyboard device offers Braille output?	Primary Research Question	All responses preferred Braille. Reasons included privacy, blind deafness and preference.	Because Braille is my preferred medium of interacting with a computer	I longed for access to refreshable Braille ever since I first experienced it at the Technology Outlook expo, having been frustrated with the inefficiency of managing my written output with speech output on the computer. Even when handling material in	I have a hearing impairment, so listening to in it one ear while listening to other things in the other ear is not an option. Braille also makes editing easier; there	Able to use the device discretely. Able to use the device with a great degree of privacy.	It offers more flexibility and offers a different kenos thetic experience to speech output. For some things Braille

					English (never mind other languages), I function much better with access to Braille output, just as I was much better off when I had access to study materials in Braille (before I even got involved with computers). When I taped lectures, I still went through them again later and made my notes on the Perkins. When the BrailleNote came along, it represented, for me, a huge step forward because of the Braille output and portability being combined in a quiet note taker, which was even more convenient than the laptop and Braille display I was using during my second degree.	are certain errors, such as punctuation, that are much easier to detect when reading.		is not very good. For instance when you need to read lots of text speech is faster. If you want to work silently Braille is very good for that. It is also good for determining layout and fonts.

Table 6.13: Why Braille Output is Important – Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5	Answer6
Functionality of Braille Devices	11. How important is it to you that your Braille keyboard device offers both speech and Braille output? Rate from 1 being not important to 5 being extremely important.	Primary Research Question	All responses were five and all appreciated Braille output.	5	5	5	5	5	5
	12. Why is it important to you that your keyboard device offers Braille output?	Primary Research Question							

Table 6.14: What makes Braille Keyboard Devices Usable - Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	14. What aspects of the command structure on your Braille keyboard device do you appreciate?	Primary Research Question	Individuals provided reasons related to usability such as consistency, logic, learnability, often used functions restricted to one key presses,	No Answer	Simplicity, logic, consistency, learnability.	simplicity usually often used commands only require one keystroke	Menus	I appreciate it when they are consistent and they are intuitive. I don’t like using spacebar with SH for spell checker for no apparent reason. I like it when commands are consistent from one programme to another. This was the case in eureka where F6 and F7 always did the same thing. It is the same in the BrailleCompanion where you can use space with H to get help at any time. Space and W gave the key announce mode.

Table 6.15: Importance of Multi-tasking – Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	15. How important is it to you that a Braille keyboard device offers multi-tasking? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	For respondents who understood the question they considered that multi-tasking was important	5	5 I didn't really pay much attention to that aspect, but I found it a pain when I wanted to switch back into an email I was writing on the BrailleNote, only to find myself either in the inbox or in the email header. I don't need 8-10 (or even 5-6) applications open at once, but it would be great if I could at least get back to the right spot in an email from, say, the word processor, address list etc, and vice versa.	3	Multi tasking I would rate 5.	I don’t really know but it is important to be able to quickly get access to information from different files.

Table 6.16: Importance of Multi-tasking – Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	15. How important is it to you that a Braille keyboard device offers multi-tasking? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Most rated important	1	4	5	5	5

Table 6.17: Use of Function Keys – Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	16. What functions if any would you assign to function keys on a Braille keyboard device?	Primary Research Question	Answers varied including task switching and returning to main menu	Not really worried I find them easy to use as it is.	Perhaps inputting of 8-dot Braille, or switching between 6-dot and 8-dot Braille; or perhaps options which would allow the user to uninstall/remove programs he/she doesn't need and gain greater memory (this should even be looked at as an option within the setup process, whether this is done via function keys or otherwise).	No answer	Flipping between open programs. One touch printing/saving.	One to return to main menu, I might use them to open commonly used programmes, I don’t really know.

Table 6.18: Use of Functions Keys – Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4
Functionality of Braille Devices	16. What functions if any would you assign to function keys on a Braille keyboard device?	Primary Research Question	Answers varied including running the media player and the concept of infinitely definable key map	personally I think if you start to use fn key with letter commands you are overloading the user interface and you will confuse the users. If you were going to have a system like that I would want it to be infinitely customisable. That is that the entire key map should customisable and you should be able to say what every combination will do.	infinitely customisable function keys and key map	I would like separate function keys.	I prefer to use single function keys. The limitation is that you are limited to the number of function keys on the device.

Table 6.19: Dedicated Media Keys – Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	17. How important is it to you that a Braille keyboard device possesses keys dedicated to operating the media player? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Most respondents did not support the use of separate media keys.	1	2 I would rather that the media player is, in the first instance, fully functional – eg can handle a wide range of formats – whether downloaded or streaming, otherwise there is little point in having this application in the first place, or at least one should have the option of uninstalling/removing it. The BrailleNote has an FM radio and the media player can apparently handle wma and wav formats as well as mp3, but I suspect it still wouldn't handle some of the streams I listen to on the PC (even the ones which are in those formats), and I was disappointed with the reception on the FM radio.	1	Dedicated Media Player keys are essential. I'd rate this as a 5.	1

Table 6.20: Dedicated Media Keys – Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4
Functionality of Braille Devices	17. How important is it to you that a Braille keyboard device possesses keys dedicated to operating the media player? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Respondents supported infinitely definable key map rather than dedicated media keys	Personally I am sick and tired of every device being able to play multi-media. We need customizable key maps.	Rather than thinking of the media buttons as media buttons rather think of them as one touch buttons to commonly used programmes or customizable function keys or have an infinitely definable key map.	Also I agree that rather than being hard wired to the media player they should be part of the infinitely definable key map.	I agree with infinitely definable key map.

Table 6.21: Use of Built-in LCD and Braille Symbols showing Formatting – Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Functionality of Braille Devices	18. How important is it to you that a Braille keyboard device possesses a built in LCD display? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Individuals did not consider it important that a built in LCD was present.	1	1	1	I rate this as a 3. It all depends upon what information the display shows.	2 They are very fragile
	19. How important is it to you that a Braille keyboard device possesses unique Braille symbols showing formatting information? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Not all rated rich formatting information highly	2	5	5	I'd rate this as a 3. Voice indicators would be useful too	2

Table 6.22: Use of Built-in LCD and Braille Symbols showing Formatting – Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4
Functionality of Braille Devices	18. How important is it to you that a Braille keyboard device possesses a built in LCD display? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Focus group did not consider it important that a built in LCD was present.	1 not important it might get broken.	1 don’t have a built in LCD at all.	1 don’t have a built in LCD	1 don’t have a built in LCD but rather have a external device that can be plugged in or provide a video port.
	19. How important is it to you that a Braille keyboard device possesses unique Braille symbols showing formatting information? Rate from 1 being unimportant to 5 being very important.	Primary Research Question	Most rated Braille symbols showing formatting information highly.	5 If you are going to implement a system to show mark-up then you need to be using something that is standard such as xml or tec or latex. Also when are the text tags stripped out of documents? Personally I would push for a type setting type of language or mark-up. You would want to be able to	the ability to turn off the display of formatting would be good	it is very important for blind people to know about formatting documents and to know how they are formatted. It is important to have access to the ability to format a document yourself because if you are competing in the sighted world you need to	The device needs to be extensible and customisable. You need to be able to plug in modules when they get written in the future.

				do the formatting programmatically rather than wysiwyg.		be able to do all those things.	

Table 6.23: Consistency and Help Facilities - Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Usability	13. How important is it to you that the keyboard commands on your Braille keyboard device are consistent? Rate from 1 being unimportant to 5 being extremely important.	Secondary Research Question	Consistency was rated 5 by all	5	5	5	5	5
	20. The BrailleNote Help system is based upon menus. How would you implement a help system on a Braille keyboard device?	Secondary Research Question	Respondents would use menus and implement it similarly to BrailleNote products	Not Sure	I would also use menus, and prompts, and make it very context-sensitive.	In a similar fashion, with both a table of contents and an index. I might also add a search page, like in help for computer programs.	Menus seems logical to me. Or one dedicated help key.	I would just rip it off the BrailleNote

Table 6.24: Interacting with Device and Documents – Interviewees

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5
Usability	21. How important is it to you that a Braille keyboard device has limited ways of interacting with it. Rate from 1 being unimportant to 5 being very important.	Secondary Research Question	Responses varied; some supported limiting input modalities and others wished to have many ways to interact with the system.	3	4	No Answer	5	I think users should have a choice with how they interact with a device. For an advanced user they should be able to interact with the command prompt and run say ‘bash scripts’. For the novice user they should not be confronted with too many options

	22. How important is it to you that you can easily move between different types of objects within a document or web page? Rate from 1 being unimportant to 5 being very important.	Secondary Research Question	All respondents agreed that rich navigation was important.	5	5	5	5	5

Table 6.25: Providing Layout Information via the Braille Display – Focus Group Members

Category	Interview Questions	Matching with the Research Question	Adding the characteristics for Venturer Model	Answer1	Answer2	Answer3	Answer4	Answer5	Answer 6
Usability	21. How important is it to you that a Braille keyboard device has limited ways of interacting with it. Rate from 1 being unimportant to 5 being very important.	Secondary Research Question	Respondents wished to have many ways to interact with the system.	1	1	1	1	1	1
	22. How important is it to you that you can easily move between different types of objects within a document or web page? Rate from 1 being unimportant to 5 being very important.	Secondary Research Question	All respondents agreed that rich navigation was important.	5	5 we need as many accelerators as we can get. We are already handicapped in our ability to access information in a timely fashion	5 you need as much information as possible with as many accelerators as possible.	5 It is very important that we can move around documents in a structured way.	5	5

Table 6.10 shows the use of different Braille keyboard devices by individual respondents. Table 6.11 shows the responses of respondents from the focus group to Braille keyboard device use. Although the number of years of use of Braille keyboard devices varied among respondents most had used devices for more than ten years and most had used Eureka A4 and BrailleNote products. Some had used other products and currently use other products. The Venturer Model was influenced heavily by the BrailleNote products but the feedback indicates that some concepts should be drawn from the design of the Eureka A4 in modifying the Venturer Model.

6.5 Functionality of Braille Devices

Table 6.12 shows the individual responses on why Braille output is important. Table 6.13 shows the importance of Braille output to the focus group participants.

The feedback, particularly from the focus group indicates that Braille feedback is important and that the reasons that it is important to people vary from blind deafness to privacy and providing a different experience to users. These reasons support the inclusion of Braille feedback in the design of the Venturer Model presented in Chapter 5.

Table 6.14 illustrates the responses on what makes Braille keyboard devices usable.

The provided feedback on what makes Braille keyboard devices easy to use mainly focused on usability concerns such as; consistency, learnability, simplicity, often used commands restricted to one key presses.

Table 6.15 shows the individual respondents feedback on importance of multi-tasking. Table 6.16 shows focus group feedback on multi-tasking. Most respondents recognised the importance of multi-tasking and their feedback supports the inclusion of this function in the Venturer Model.

Table 6.17 shows individual responses regarding use of function keys. Table 6.18 shows focus group feedback on the use of function keys. Each respondent provided different functions to be assigned to function keys including running the media player and task switching. They introduced a concept called infinitely definable key map. The concept of running the media player from function keys crosses over with another function on the Venturer Model called media keys. The concept of a command prompt and infinitely definable key map needs to be investigated further.

Table 6.19 shows the feedback from individual respondents on the use of separate media keys. Table 6.20 shows feedback from the focus group regarding separate media keys. There was cross over from this feedback and the feedback on function keys. The concept of infinitely definable key map was prominent.

Table 6.21 provides feedback from individual respondents on LCD and Braille formatting symbols. Table 6.22 Shows focus group feedback on the use of built in LCD and Braille symbols showing formatting information. Feedback on providing a built in LCD indicates that it should not be provided. Rather the ability to plug in an external device is preferred. In terms of Braille symbols displaying formatting information the focus group preferred this function over the individual respondents. Further, the focus group discussed the implementation of formatting information.

6.6 Usability

The concept of usability was discussed in Chapter 3. This is related to task performance and the nature of the users of the system. Furthermore, it was shown that the research in the area of usability is not conclusive and that varying elements can be considered as usability attributes according to the researcher. The researcher drew from the literature on usability and upon his own experience in generating the list of usability attributes shown in Table 5.2 and also during evaluation of the Venturer Model.

Table 6.23 shows individual respondent feedback on consistency and help facilities. The individual respondents and focus group all agreed that consistency was an important usability attribute to be included. This is why it appears at the top of Table 5.1 to show its importance and relatedness to the model. Its placement also shows its importance in design. The individuals all agreed that the help system should be based upon menus or implemented similarly to that on the BrailleNote products.

Table 6.24 provides individual respondent feedback on interacting with device and documents and Table 6.25 shows the focus group feedback. There was a difference between the individual respondents and focus group with respect to their view on limiting input and other modalities on the Braille keyboard devices. The individuals were more likely to support limiting the functionality of the device by limiting input and other modalities. Both focus group and individual respondents all agreed that rich navigation was important.

6.7 Summary of Findings from Tables

More females than males participated in the study and all respondents had more than ten years' experience with Braille keyboard devices. Additionally, respondents had used the Eureka A4 and BrailleNote Products. This may have influenced results but it also indicated to the researcher that more features of the design of Eureka A4 need to be incorporated in the Venturer Model.

Many of the difficulties respondents faced with operating systems related to the nature of GUI's and this influenced the choice to develop the Venturer Model interface in a way that avoided windows conventions. Usability was important to respondents, in particular consistency, learnability, simplicity and ease of use were important. The concept of rich navigation and infinitely definable key map also became important points in the feedback as was the displaying of formatting information on the Braille display.

Functionality that respondents did not support being included in Braille keyboard devices included a built in LCD and dedicated media keys. However, multi-tasking was supported as was the use of function keys. Consistency was regarded as the primary usability attribute and there was a difference between individual respondents and focus group regarding limiting input and other modalities on the device with the focus group much less supportive of limiting functionality.

6.8 Additional Functions on Venturer Model

The focus group discussed a wider range of material than did the individual respondents including the hardware specifications of the device. For example they discussed how the user would know if the device was on or off. Table 6.26 shows feedback on hardware.

Table 6.26: Focus Group Feedback on Hardware Specifications

Hardware specifications discussed	**Answer1**	**Answer2**	**Answer3**
On / Off Status of Device	The problem of the state of the device, whether it is on or off can be solved by using a strait switch.	An on/off switch is a good idea but the user needs to have a way to know if the unit is on or off.	
Physical Robustness of Device	One of the devices with different modes of operation is the Mountbatten Brailler but one of its faults is that it is not robust.	if we are going to have a lid instead of a LCD display then it needs to be robust	It is important that the device has multiple ports for transferring information

The Focus group indicated that robustness of design was important including letting the user know the status of the device.

Table 6.27 shows focus group feedback on the use of Braille as an input modality.

Table 6.27: Use of Braille as Input Modality: Focus Group Members

	Answer1	Answer2
Braille Input Modality	I have only used the Eureka as a Braille input device. I prefer to touch type because I can touch type much quicker than I can Braille.	using Braille as an input method is very inefficient. Trying for example to get a backslash in on the Braille keyboard is something I don't enjoy much. If you are programming inputting the extended punctuation is quite nasty. I know Braille keyboards are smaller but it is a slower input method and you would want alternatives.

Several members of the focus group questioned the whole concept of using Braille as an input modality; however, feedback shows that respondents preferred to read Braille rather than writing it. Appendix C provides the advantages of Grade II Braille and Chapter 1 provides a brief introduction on the importance of Braillle for literacy and the employment outcomes for blind people.

6.9 Testing the Venturer Model with the Curtin Web Page

One of the objectives of this thesis was to examine the functions that should be provided on Braille keyboard devices. The concepts of rich navigation and short cut keys were introduced in Chapter 5 in relation to the Venturer Model. The model was designed to enable blind people to use their Braille keyboard devices as tools. A common task employed on a computer system is using the internet. Therefore, in order to test the functionality provided by the Venturer Model, with particular focus on the task of Internet use, a blind user of the Internet was asked to simulate using the Venturer Model commands found in Chapter 5 to go to the Curtin University web page and perform a few tasks.

The test was conducted as a simulation to establish whether the number of keystrokes needed to navigate the Curtin home page was similar or very different to that for JAWS for windows 12. The findings were that the user was unable to work out how to get to the address bar or to type in a web address. This was a flaw in the design of the Venturer Model. The user was unable to remember all the keyboard commands they needed to perform tasks and this made it difficult for the user to perform efficiently. Finally the user assumed they were on the requested Curtin University web page seeking to find the link for oasis login. With JAWS the user used the insert+F7 command to get a list of links and used first letter navigation to move to oasis and pressed enter to activate the link. With the Venturer Model the user chose to use the find command Space+f because there was no listed links list command.

Next the tester wished to find a staff member. This time the JAWS and Venturer Model find commands were used to find the word staff and the link was activated. The letter E was used to find the edit field to enter data in. Because the exercise was a simulation it became difficult for the tester to remember how to move between elements on the web page with the Venturer Model. The tester agreed that the Venturer Model provided internet functionality but that it was limited and that the explanation of how to use the commands was less than perfect and that the model needed development and implementation on a real device for proper testing.

6.10 Strengths of Venturer Model

The preceding discussion regarding functionality on the Venturer Model highlighted some strengths in the design. These strengths are outlined below.

- The respondent feedback was extremely limited due to numbers of respondents who provided feedback. Therefore, the statements concerning the strengths of the Venturer Model drawn from what respondents indicated need to be judged as tentative results and not conclusive.
- The Venturer Model provides a consistent user experience and respondents agreed that consistency was an overarching usability attribute.
- Braille support was provided thus providing a multi-modal output for users. Formatting information can be displayed on the Braille line giving deaf blind users as well as others tactile feedback on formatting.
- Navigation is achieved through menus, prompts and short cut keys.
- The editing commands are similar to the review commands aiding learning and memorization of key commands.
- Key definition is permitted allowing users to define meaning of key assignments.

6.911 Weaknesses of Venturer Model

The feedback provided by the individual respondents and the respondents who participated in the focus group revealed significant problems with the Venturer Model. Many of these problems relate to the keymap and neglected commands whereas others related to design choices by the researcher. The highlighted weaknesses in the Venturer Model design included:

- Lack of attention to design features present in Eureka A4 such as neither arrow keys nor use of a numeric pad to provide users familiar with MS Windows the ability to transfer skills and knowledge gained from use of that platform.
- Poor explanation of how to use internet.
- No proper definition of infinitely definable key map as respondents wished.
- The hardware description lacked a discussion of the status of the device (turning it on an off) and possibility of cover over keyboard for protection.
- No proper discussion of QWERTY input option as some focus group respondents wished. Some Focus group Respondents discussed whether Braille input should even be considered.
- There was no discussion of the portability of the venturer system in terms of size or weight. This may be due to the fact that the Venturer Model is only a abstract model and has not been deployed on an actual device.

6.12 Releasing the Venturer Model

The feedback provided by respondents which is presented above allows the following modifications to be suggested for the Venturer Model.

- An optional USB numeric keypad containing the following keys: left arrow, right arrow, up a line, down a line, page up, page down, home, end, *,/, an extra enter key and the – and + keys that can take on their own function or be used as function keys to modify the meaning of other keys on numeric pad. This could allow for a JAWS screen reader implementation of commands.
- Although the focus group members recommended the LCD be removed and replaced by a hinged lid to cover the keyboard, the researcher recommends

that the LCD be retained for use by sighted colleagues and associates who may interact with the blind user.

- A tutorial produced to give step by step instructions how to complete simple tasks with the Venturer Model such as how to enter data in to the address book or use the internet.
- A HTML based help system to complement the context sensitive help system and this needs to be accessed from the main menu.

6.13 Conclusion

The data presented in this chapter is limited due to the very few respondents who participated in the interviews and focus group. Any conclusions regarding the suitability of the Venturer Model for blind users need to be tentative. The Venturer Model demonstrates consistent use of commands but the command sets have some missing functionality. Although the interface may be easily learned by a user of BrailleNote Products functionality provided by Eureka A4 needs to be considered in order to modify the model and allow for additional one keypress functionality. The simulation using Venturer Model with the internet revealed some problems with the command set; mainly the lack of development of the interface. Although the data questioned both functionality and usability the data did not provide sufficient information to modify Table 5.2 listing the usability attributes.

Chapter 7 presents the research findings and conclusion.

Chapter 7: Research Findings and Conclusion

7.1 Introduction

This chapter presents a summary of the research conducted in this thesis and discusses whether the data and Venturer Model presented supports the research questions. The significance of the research is then discussed in terms of the practical and theoretical contributions to the knowledge base and how research presented in this thesis will benefit blind people. The limitations of the research presented in this thesis are then discussed followed by future research possibilities which flow from the research presented in this thesis. Future research in the areas of touch screen technology and the use of keyboards with limited keys will be canvassed before the conclusion.

7.2 Summary of the Research

The researcher is blind and uses electronic Braille keyboard devices on a daily basis. The researcher has an interest in how blind people learn and process information. While undertaking a specially developed CISCO course for blind people at Curtin University the researcher was exposed to a variety of devices produced by the Curtin University Centre for Assistive Technology including the Curtin University Brailler (see Chapter 1). The researcher was interested in this project because it sought to produce a low cost electronic Braille writer which could aid the development of literacy among blind people by promoting the development of Braille skill. Braille literacy affects employment, income, education and reading habits of blind people

(Ryles 1996). Chapter 1 details other studies such as that conducted by Vision Australia which revealed a high level of unemployment amongst blind persons (Vision Australia 2007).

The researcher's experience with electronic Braille keyboard devices revealed that each device possessed a different approach to interface design which made the learning curve associated with each interface significant for blind users. The researcher wished to address this problem by investigating interfaces on Braille keyboard devices to establish a usable interface which could be deployed on the Curtin University Brailler.

The research questions for this study are:
The primary research question to be investigated is:
What is the optimum functionality and interaction paradigm for a Braille keyboard device?
The secondary research question is:
What are the optimum usability attributes for a Braille Keyboard Device?

The Design Science framework (see Chapter 2) was chosen as the research method because of the flexibility of the research method and because it focuses upon the building of artefacts (in many different forms) and the development of theory. Individual interviews and a focus group were used to gather a user perspective on interfaces of current equipment studied and the interface developed in this thesis. Chapter 2 explains the reasons for the choice of two data collection methods and provides a background to the use of small sample sizes for groups such as populations of disabled persons.

The literature review in Chapter 3 provided a background to the development of an interface for Braille keyboard devices. Three Braille keyboard devices available in Australia were studied in detail in Chapter 4; these were the same three devices reviewed in Chapter 3 at a higher level. Some of the important aspects which were covered in Chapter 3 included the differences in the way sighted people use interfaces as compared to those without sight. A key aspect to this was the serial nature of information gathering employed by blind people as compared to the visual spatial method of information gathering employed by sighted persons. Much of the discussion of Graphical User Interfaces presented in Chapter 3 was presented to highlight the issues faced by blind persons using these interfaces. Models for usability and a preliminary set of usability criteria were established from a review of literature on usability and user centred models.

Chapter 4 delivered a practical evaluation of existing models on Braille keyboard devices conducted by the researcher. The limitations of this evaluation included limiting the usability attributes against which the interfaces were evaluated to only the seven usability attributes provided by Adikari et al. (2006).

Chapter 5 sought to incorporate lessons learned regarding usability and functionality from the literature review and the practical evaluation of the devices from Chapter 4. The result was that the researcher established Braille keyboard device functions and usability attributes in Tables 5.1 and 5.2 and Figure 5.1 to constitute the preliminary framework for the new model (Venturer Model) presented in Chapter 5. This model focuses upon the main functions of a computer system; functional support and editing support and the usability of the system.

Having presented a model in Chapter 5 it was necessary to evaluate the model and so an analysis of the data collected by individual interviews and focus groups was presented in Chapter 6. The Venturer Model needed modifications as determined by the feedback provided by respondents. However, further testing, evaluation and enhancement of the Venturer Model would need to be carried out once the hardware with which it will integrate (The Curtin University Brailler) is finalised.

7.3 Matching Results with Research Questions

The research questions are presented and explained in Chapter 2 and the data relating to these questions are presented in Chapter 6.

With respect to the first research question: '*What is the functionality and interaction paradigm for a Braille keyboard device?'* functionality and interaction mechanisms for several Braille keyboard devices were studied and evaluated. As time has progressed technology these Braille keyboard devices were found to not fully meet the needs of current blind users as previously highlighted.

The data collected from respondents supported extra functionality on Braille keyboard devices than the researcher proposed for the Venturer Model. Such functionality as an 'infinitely definable key map' should be included. Additionally, the respondents also suggested that some functionality included in the Venturer

Model should be removed. For example the respondents wished the built-in LCD to be removed and replaced by the ability to connect an external LCD instead. Figure 5.1 shows the original hardware specifications for the Venturer Model including the presence of a built in LCD. The recommended removal of the built in LCD was not implemented due to the interaction with sighted persons who may need to see the word at hand. A separate and optional USB numeric keypad was recommended based upon the functionality provided by other computer device manufacturers and the mapping of these keys into essential functionality.

With respect to the second research question '*What are the optimum usability attributes for a Braille Keyboard Device?'* the attributes were developed based upon an investigation of various Braille keyboard devices, the factors recommended by other internationally respected researchers, the feedback provided by respondents and the researcher's own experience with these devices and his understanding of the needs of blind users. As the goal was to develop asset of usability attributes these investigative methods produced the set of usability attributes presented in Chapter 5.

The researcher focused on consistency, learnability and memorability in designing the Venturer Model as these are foremost factors of importance for blind users.

7.4 Significance of the Research

The research presented in this thesis has presented a model of an interface on Braille keyboard devices (Chapter 5) which could be deployed on devices such as the Curtin University Brailler. Chapter 3 in discussing manual Braille writing devices discussed how the Perkins Brailler is still the Braille writer used most commonly in the instruction of Braille. However, it may be important to develop electronic Braille writers similar to the Mountbatten Brailler which was also discussed in Chapter 3. Interfaces for these devices need to be developed and the research in this thesis is presented to inspire and guide designers of new Braille keyboard devices. New Braille keyboard devices can be used to teach Braille skills because the user of the device is writing Braille and if Braille output is provided then they learn to read it also.

7.5 Braille Literacy

Chapter 1 discussed the importance of Braille literacy to the employment and education outcomes for blind people. For example a study by Ryles (1996) examined the positive relationship between Braille reading skills and employment, income, education and reading habits. Furthermore, Blake (2003) discusses the importance of Braille literacy amongst blind people and indicates that literacy involves the ability to acquire information, communicate with others and the ability to gain access to written information. The information which is communicated needs to be stored so that it can be referred to again later, "thus for the blind person, literacy involves all methods of acquiring, storing, and accessing information and all methods of communicating one's own ideas, opinions, and needs" (Blake 2003, p.1). There are three levels of literacy: emergent which relates to basic concepts learned at a pre-school level, basic literacy occurs during school years where spelling and grammar and other structural elements are learned and functional literacy refers to the literacy experiences involved in daily life, such as filling out a job application, keeping an address book, and labelling items.

There are counterparts to these in terms of illiteracy - for example: “Functional illiteracy refers to being unable to use reading and writing to meet one's everyday needs. Marginal illiteracy refers to being unable to use print at all. General literacy refers to the use of literacy to improve the quality of life for oneself and others” (Blake 2003, p.1). Additionally the Canadian National Institute for the Blind (2011) supports the development of Braille literacy for improving the lives of blind people in terms of employment, education and daily living skills. They suggest that “aside from using Braille to read all kinds of textbooks and documents, Braille is useful in a variety of other ways:

- Braille can be used at home to label, for example, CDs, clothes, thread, spices, cans of food, and computer disks.
- People who read Braille can play card games such as bridge and board games such as Scrabble.
- At school, a student who is visually impaired and knows Braille can take notes with Braille and scan the text to find the relevant part, and re-read homework assignments before handing them in.
- Braille readers can look things up and go back and forth in the text more easily.
- Children can write personal messages and leave notes for parents and caregivers in Braille.
- Braille can be easily read by sighted people with some Braille training.
- And, of course, there are computer programs that transcribe Braille to print or vice versa.” (http://www.cnib.ca/en/living/braille/literacy/).

It is important to understand that if Braille is used on a Braille keyboard device with Braille output then very few system resources need to be used because there is no dynamic translation of the Braille input to a format (e.g. ASCII code) for storage.

Furthermore in 1989 the United States blindness agencies agreed on the following statement: “If a child has a visual impairment and if literacy skills are to be taught, the child should, if the parent or parents want this to be done, be taught to read and write Braille by a certified teacher competent to teach Braille literacy skills to the blind. If a dispute arises between the parent and the LEA [local education agency] regarding the appropriate reading medium, both print and Braille shall be taught until the dispute is resolved through the IEP process” (Spungin 1996, p. 273).

The research in this thesis focused upon the interface for electronic Braille keyboard devices which can be used in the teaching of Braille to blind people. Devices that are made intuitive and easy to use may be learnt more easily. The learning of Braille aids literacy development amongst blind people as discuss in Chapter 1 and Appendix C.

7.6 Limitations of the Research

The research in this thesis only sought to develop a theoretical interface to be employed within Braille keyboard devices and did not seek to fully develop and implement such an interface on a real device. Furthermore, the researcher was only able to obtain a small sample size of blind participants who took part in the interviews and focus group designed to evaluate the interface, function set and usability attributes for evaluating the model. The conclusions regarding the function set and usability attributes need to be strengthened by additional application and evaluation.

A fuller research project would have produced an actual device running the proposed interface and tested it with a larger sample size and asked more targeted questions of respondents. A prototype physical interface together with a more detailed set of questions could have produced more effective data on usability of existing interfaces on Braille keyboard devices and the researcher then could have more effectively modified the Venturer Model.

Ideally completion of the development of the Curtin University Brailler device would have permitted a more robust application and testing of the Venturer Model and this is recommended for future research.

7.7 Future Research

One of the first areas for research which flows from the research conducted in this thesis is to implement the interface on an actual device. A device such as the Curtin University Brailler possesses a Braille keyboard for input. From the researcher’s point of view there are some advantages in using a physical keyboard:

- It is a physically defined device with keys in defined locations.
- It is similar to existing Braille keyboard devices.
- Users are used to interacting with physical keyboards on computers and other devices.

Companies such as Apple have developed accessibility solutions for use on touch screen devices such as the iPhone, iPad and iPod. These solutions include using predictive text (http://www.apple.com/accessibility/resources/iphone.html). An area of future research may be to implement the Venturer Model interface on a touch screen device such as an iPad and use predictive text to establish the position of the hands on the device. A minimum of 18 cm wide for the area to place the fingers would need to be provided. This is established by placing the fingers on a surface in a Brailling position and measuring the minimum distance from smallest finger to smallest finger of other hand. This measurement assumes the researcher's own hand size and does not allow for numeric pad or extra keys to the right and left of the Braille writing keys.

An advantage of using a touch screen device to implement the model on relates to construction costs. A variety of keyboard layouts can be imposed on the touch screen and tested with the respondents.

Designers such as T. V. Raman work in the area of touch screen interfaces. Raman has developed a dialler for the Android platform that allows him to place his finger on the touch screen, the software interprets this as a number 5 key and he can move his fingers in the direction of other keys on a numeric pad and raise the finger when the desired number is spoken by the phone (New York Times 2009).

A similar system could be employed on a touch screen device so that Braille could be input and different key assignments could be tested. If function keys were desired then the finger could be run across the top edge of the touch screen with the interface speaking the function key number and the person raising the finger when the correct function key is reached. Thus the scan codes would be sent upon the upstroke of using the touch device. Perhaps a physical keyboard could be implemented on the production device because of the user's familiarity with physical keyboards. The future may see blind people becoming more familiar with touch screen devices as the iPhone, Microsoft mobile platform and the Google Android systems become more commonplace in society.

7.8 Conclusion

Although the research conducted in this thesis was limited due to small sample size the research contributes to the development of electronic Braille keyboard devices which can aid Braille literacy development among blind persons. Braille literacy is important for education, employment and daily living independence. The Venturer Model interface developed in this thesis provides a more consistent approach to functionality and Braille keyboard device interfaces. The Venturer Model will benefit from being implemented on a physical device in the future and tested with a larger number of blind participants. Future research includes using touch screen technology to test the interface and the development of interfaces using few keys to be deployed in situations where the user has a small device.

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Appendix A - Examples of Eye Conditions

There are a variety of conditions causing vision impairment or total blindness. Murray (2008) discusses a variety of these conditions in the appendix to his thesis, as does Vision Australia (2010).[14]

Age-Related Macular Degeneration (AMD) occurs in elderly people and is the leading cause of vision impairment in these persons. The condition results in reduced central vision which makes close up work difficult. 15 Vision may fail slowly or quickly depending upon the type of AMD. The condition is genetic and may be exacerbated by smoking.

Charles Bonnet Syndrome may be experienced by those with AMD and is characterised by the presence of complex visual hallucinations. People may see detailed images of people, buildings or simple patterns of straight lines. People who have Charles Bonnet Syndrome are aware that these images are not real. The condition is more common in those who lose their sight later in life and can affect people other than those with AMD. The condition often appears after a period of

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[14] The fact sheets from Vision Australia have been used to compile this appendix and discuss a variety of different eye conditions and indicate their causes and some effects of the conditions. The information provided is limited and is designed to be understood by the general public and to inform users and to point them to Vision Australia for extra help.

[15] Vision Australia also present information on their web site about various vision conditions. This web site can be accessed at

http://www.visionaustralia.org.au/info.aspx?page=795#contentstart worsening sight and is common in people with age-related macular degeneration. The visual hallucinations usually stop within a year to 18 months.

Diabetic retinopathy is related to diabetes and occurs when the tiny blood vessels inside the retina at the back of the eye are damaged. This can seriously affect vision and in some cases may even cause total blindness.

Common symptoms include:

- Blurred or distorted vision that makes it difficult to read standard print, watch television or see people's faces.
- Increased sensitivity to glare and difficulty seeing at night.

People who have diabetes are at risk especially if they have:

- High blood-sugar levels or poorly managed diabetes.
- High blood pressure, particularly if they also have kidney disease.
- A long history of the illness.

Laser and other surgical procedures can be conducted to treat diabetic retinopathy. This slows progression of the disease and decreases the risk of vision loss.

Glaucoma is a condition associated with pressure in the eye. It is characterised by damage to the optic nerve that causes peripheral vision loss.

Glaucoma often has no symptoms. However, common signs include:

- Severe pain and vision loss.

- Blurred vision, or seeing coloured rings around lights.
- Nausea and vomiting.

Those most at risk include people who have:

- A family history of the eye condition.
- Diabetes.
- An injury to the eye.
- Used steroids regularly over a long period of time.

Glaucoma can be treated with laser work, medication or surgery. Early detection and treatment of this condition can prevent or delay vision loss.

Cataracts are a clouding of the cleared lenses of the eye and result in the following symptoms:

- Blurred vision.
- Glare sensitivity.
- Distortion or double vision in the affected eye.
- A feeling of looking through a veil or curtain.

Leber's Congenital Amaurosis is an inherited condition which is present from birth. The extent of vision loss varies, but it can be quite severe and a baby may be born with very poor vision or may even be totally blind.

Retinitis Pigmentosa (RP) is a genetic eye condition that causes the light-sensitive retina, located at the back of the eye, to degenerate slowly and progressively. The condition can vary greatly. While many people with RP retain limited vision throughout their lives, others will lose their sight completely.

Generally, symptoms develop between the ages of 10 and 30. Some of the first signs may include the following:

- Difficulty seeing at night (night-blindness) or in dimly lit areas.
- A narrowing field of vision.
- Light and glare sensitivity.

RP is a hereditary disease that occurs in people that have a family history of the condition and can affect males more than females. Furthermore, there is currently no standard treatment or therapy for RP.

Other causes of vision impairment are not related to problems with the eyes themselves For example Cortical Visual Impairment (CVI) is a temporary or permanent visual impairment caused by damage to the visual cortex or posterior visual pathways of the brain.

Appendix B - The Interview Questions

This appendix outlines the research instrument, including the questions asked of respondents and provides an explanation for their use. Some questions were asked in different ways in order to test feedback from respondents. The current research employed interviews and focus groups in order to provide triangulation of data collection and to take advantage of the different data to be collected by varying data gathering instruments.

Cover Letter to Respondent

Dear,

My name is Ian Blackburn; currently I am a Master student at Curtin Business School - Curtin University of Technology. I am conducting research in to Braille Keyboard devices.

Your assistance in this research is greatly appreciated and is crucial toward the success of its findings. This interview only takes a maximum of 45 minutes to complete. If you feel uncomfortable in answering certain questions, please feel free to disregard them.

All answers received will be held as strictly confidential, and there will be no material published to identify you or your organization. Please refer to the information sheet attached for further details.

If you have any enquiries, do not hesitate to contact myself by email at I.Blackburn@Curtin.edu.au. Alternatively, feel free to contact my supervisor Dr. Tomayess Issa Tomayess.Issa@cbs.curtin.edu.au.

Thank you in advance. You have contributed greatly to the field of IS research.

Yours faithfully,

Ian Blackburn

Curtin University of Technology Participant Information Sheet

My name is Ian Blackburn; currently I am conducting research on Braille Keyboard Devices.

Purpose of this Research

This project seeks to produce an interface, in the form of a model for Braille Keyboard devices that takes in to account the unique user needs of the users of these devices. The research will identify the key functions to be employed on a ideal Braille keyboard device by establishing the strengths and weaknesses of three modern Braille keyboard devices and examining usability attributes.

Your Role

Participants are requested to answer questions regarding the use and usability of current Braille Keyboard devices and relate experience using other computer systems.

Interview Length

The interview process will take approximately 45 minutes.

Consent to Participate

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality

The information you provide will be kept separate from your personal details, and I will only have access to this besides my supervisor. The interview transcript will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for one year, before it is destroyed.

Further Information

If you would like to ask further information about the study, please feel free to contact me by email: I.Blackburn@Curtin.edu.au Alternatively, you can contact my supervisors by email on Helen.Armstrong@cbs.curtin.edu.au .

Consent Form

Project Name: A conceptual multi-modal HCI Model for Braille Keyboard Devices

Organization Name: ____

I, ___________________________ have read the information on the attached letter. Any questions I have asked have been answered to our/my satisfaction. I agree to participate in this research but understand that I can change my mind or stop at any time.

☐ I understand that all information provided is treated as confidential.

☐ I agree for this interview to be taped or recorded.

☐ I agree that research gathered for this study may be published provided names or any other information that may identify me/us is not used.

Name	Signature
Date	
Investigator	Signature

The Interview Questions

The interview instrument consisted of 22 questions.

Some questions have a table following them which provides the reader with a set of categories to choose from when answering questions. The tables also provided a way for the researcher to categorise varying answers.

1. How many years' experience have you with using different types of computer operating systems?

This question uses years of experience as a surrogate for expertise. It assumes that the user will become more familiar with the system with use.

2. What aspects of the way you used the operating systems made these operating systems easy to use?

Legend for question 2: What Made Operating Systems Easy To Use

Legend ID	**Meaning**	**Venturer Model Feature ID number**	**Venturer Model usability Attribute ID Number**
0	No useful feedback or comment		
1	Navigation keys	8,9,10,11	
2	Consistency	1	
3	Simple menus		
4	Braille display output	12	
5	layout/structure		
6	input methods (qwerty or Braille)		
7	output (speech or Braille)		
8	compatibility with screen readers (JAWS)		
9	Friendly Interface		1,2,4
10	Context sensitive help		
11	Single key press for help		
12	Run command line		
13	Short cut or accelerator keys for common tasks		

This question seeks to elucidate the beneficial functions of operating systems and to establish if there were any interaction paradigms recognised by respondents.

3. What aspects of the way you used the operating systems made these operating systems difficult to use?

Legend for question 3 Aspects of Operating Systems Which Made Them Difficult to Use

Legend ID	**Meaning**
0	No Feedback
1	Learn Many Keystrokes
2	Layered nature of Windows
3	Lack of specific training with the screen reader an Braille display
4	Lack of keyboard shortcuts
5	Incorrectly labelled or unlabelled screen elements
6	Irregularities in the way an OS is arranged
7	Lack of context sensitive help
8	Must learn access solution at same time as operating system
9	Each screen reader tackles the access problem differently – limited duplication of keystrokes
10	belief that typing Braille was faster than typing on QWERTY keyboard

This question seeks to elucidate the difficulties faced by people who are blind using computer operating systems.

4. How many years have you been using Braille and Braille keyboard devices?

This question is a double barrelled question which may confuse the respondent. The question uses years of experience as a surrogate for expertise. It complements the next question.

5. Would you consider yourself an expert Braille reader and writer? Rate this from 1 having no experience using Braille to 5 being an expert reader and writer of Braille.

This question seeks to establish the expertise of respondents.

6. On a daily basis how much time (in terms of hours or minutes) would you spend reading Braille? Responses are given in minutes.

Again this question complements the above two questions.

7. On a daily basis how much time (in terms of hours and minutes) would you spend writing Braille? Answers were expressed as minutes.

This question seeks to determine the expertise and comfort of the respondent with Braille and the use of the Braille keyboard.

8. How many years' experience have you using electronic Braille keyboard devices?

This question uses year as a surrogate for experience and clarifies the answer given in the previous question.

9. Which electronic Braille keyboard devices have you used?

Legend for question 9 Braille Keyboard Devices Used by Respondents

Legend ID	**Braille Keyboard Device**
0	No device
1	Eureka A4
2	BrailleNote PK
3	BrailleNote Empower
4	Mountbatten Brailler
5	Braille-n-Print
6	Keynote
7	Braille-n-Speak
8	BrailleMate
9	BrailleLite
10	BrailleCompanion
11	BrailleSense
12	BrailleNote Classic

This question seeks to determine depth of experience with different Braille keyboard devices and their interfaces.

10. Which Electronic Braille keyboard device do you currently use?

Legend for question 10 Braille Keyboard Devices Currently used by Respondents

Legend ID	**Braille Keyboard Device**
0	No device
1	Eureka A4
2	BrailleNote PK
3	BrailleNote Empower
4	Mountbatten Brailler
5	Braille-n-Print
6	Keynote
7	Braille-n-Speak
8	BrailleMate
9	BrailleLite
10	BrailleCompanion
11	BrailleSense
12	BrailleNote Classic

This question complements question eight and seeks similar information as a clarification.

11. How important is it to you that your Braille keyboard device offers both speech and Braille output? Rate from 1 being not important to 5 being extremely important.

This question was double barrelled but sought to focus on Braille output as many Braille keyboard devices come with speech output as default but users can purchase Braille output options. The question sought to see if Braille output was very important in terms of a function of a Braille keyboard device that should be offered.

12. Why is it important to you that your Braille keyboard device offers Braille output?

Legend for question 12 Why Braille Output

Legend ID	**Meaning**
0	No Comment
1	Prefers Braille
2	Hearing impairment
3	Detect errors with Braille
4	Use device with privacy
5	Flexibility
6	Different kenos thetic experience

This question complements question 10.

13. How important is it to you that the keyboard commands on your Braille keyboard device are consistent? Rate from 1 being unimportant to 5 being extremely important.

This question seeks to determine how important the usability attribute “consistency” is to the respondent.

14. What aspects of the command structure on your Braille keyboard device do you appreciate?

Legend for question 14 Respondent Feedback

Legend ID	**Respondent Answer**
0	No Comment
1	Learnability
2	Memorability
3	Flexibility
4	Satisfaction
5	Efficiency
6	Functional Correctness
7	Error Tolerance
8	Textual navigation
9	Menu navigation
10	Rich navigation
11	Screen navigation
12	Independent navigation with the Braille Display

This question seeks to determine what key commands and ways of using the device help the user. This question is designed to obtain new commands or new ways of using the system that the researcher did not include.

15. How important is it to you that a Braille keyboard device offers multi-tasking? Rate from 1 being unimportant to 5 being very important.

This question asks directly about a function to be provided on an ideal Braille keyboard device.

16. What functions if any would you assign to function keys on a Braille keyboard device?

Legend for question 16 Functions Assigned to Function Keys by Respondents

Legend ID	**Meaning**
0	No comment
1	Does not know what to assign to function keys
2	Switching between 8 and 6 dot Braille
3	Uninstalling programmes
4	Task Switching
5	One touch printing
6	One touch saving
7	Return to main menu

This question seeks to obtain user feedback on key assignments which can inform the Venturer Model.

17. How important is it to you that a Braille keyboard device possesses keys dedicated to operating the media player? Rate from 1 being unimportant to 5 being very important.

This question asks directly about a Function to be included on an ideal Braille keyboard device.

18. How important is it to you that a Braille keyboard device possesses a built in LCD displays? Rate from 1 being unimportant to 5 being very important.

This question asks the respondent about a function to be included on an ideal Braille keyboard device.

19. How important is it to you that a Braille keyboard device possesses unique Braille symbols showing formatting information? Rate from 1 being unimportant to 5 being very important.

This question asks directly about a function to be included in an ideal Braille keyboard device.

20. The BrailleNote Help system is based upon menus. How would you implement a help system on a Braille keyboard device?

Legend for question 20 Ways to Implement help System

Legend ID	**Meaning**
0	No comment
1	Not sure
2	Menus
3	Prompts
4	Search prompt
5	Contents page
6	Dedicated single help key

This question asks directly about a function to be provided on an ideal Braille keyboard device.

21. How important is it to you that a Braille keyboard device has limited ways of interacting with it. Rate from 1 being unimportant to 5 being very important.

This question asks about the usability attribute “ease of use”.

22. How important is it to you that you can easily move between different types of objects within a document or web page? Rate from 1 being unimportant to 5 being very important.

This question asks about the function “rich navigation” which is a part of “navigation Support” which is a function to be included in an ideal Braille keyboard device.

Appendix C - The Braille System

The writing code used by people who are blind is called Braille after Louis Braille who lived in the 19th century.

Figure C.1: Louis Braille, inventor of the writing code for the blind (Adaptive Technology Centre 2009)

This tactile and raised dot code for writing used by people who are blind varies around the world and there is no one standard code for the presentation of information to people who are blind. There are different codes for different languages and for different subjects. For example, there is a different code for the presentation of mathematics compared with that for literature or chemistry. The focus here will be on Braille as a medium for presenting information to people who are blind and use Braille keyboard devices.

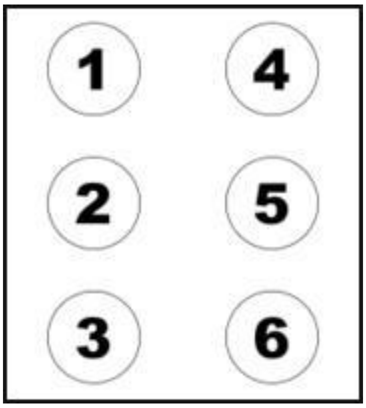

Figure C.2: Braille Cell with Dots Numbered (Adaptive Technology Centre 2009)

Originally, Louis Braille's first Braille cell was six dots high by two wide however this proved impractical as a reading system. Nowadays, the modern Braille cell is arranged in two columns of three tactile dots (8 dot Braille exists but is not commonly used) as depicted in Figure C.2. However, computer Braille has a cell consisting of two columns of four tactile dots with dots being slightly larger and more widely spaced than paper-based Braille. There is no official international standard for the size of Braille cells and each manufacturer of Braille production devices chooses a unique specification (Royal National Institute for the Blind 2008).

The period from 1825 to 1835 appears to be the period of innovation in the production of writing codes for the use of people who are blind. However, there was much dissention concerning the correct writing method and (Irwin 1955) discussed the controversy surrounding the various writing methods for people who are blind. He pointed out that material was published in English in both the United States and Britain although each used different English Braille codes. Additionally Lorimer (1996) discusses and evaluates the various problems and solutions faced by the blind when writing, including the following issues; the size and shape of the characters, the presentation in terms of clarity of line and space, the use of stenographic, and phonetic and letter-by-letter systems. Some codes discussed included; New York and Howe types and English Braille (Lorimer ,1996).

There are basically two main Braille codes taught to blind people, termed grade 1 or grade 2 Braille. Grade 1 Braille is termed ‘alphabetic Braille’ or ‘uncontracted Braille’ and consists of the letters of the alphabet, punctuation symbols and the number sign. It has 180 rules (Miller and Rash 2001).

Grade 2 Braille is also termed ‘contracted Braille’ and consists of the alphabet plus 189 one cell and two cell contractions representing various combinations of letters. Contracted Braille, with 450 rules, is a more complex system of letters plus whole word and part word contractions. Grade 2 Braille is regarded as the standard form of literacy for blind individuals and it is endorsed for its space-saving properties and for increased reading speeds achieved by accomplished readers (Miller and Rash 2001).

Miller and Rash (2001) conducted a survey of teachers of the blind. Of their 16 respondents, all had experience with teaching grade 1 and 2 Braille to students and the findings showed that respondents supported the use of grade 1 Braille for young beginning readers and for those who have had advantageous blindness. Other groups who benefit from the use of grade 1 Braille include; students with English as a second language, deaf blind and those who have additional learning disabilities.

The following were observed to be advantages of using grade 1 Braille over grade 2 Braille:

a. Uncontracted Braille works well with phonics-based reading programs, which are found in many elementary classrooms. Uncontracted Braille provides 1-

to-1 correspondence and promotes letter/sound associations, important components of literacy instruction. The use of contractions does not reinforce basic phonics skills.

b. When students use uncontracted Braille, they can participate in reading lessons with their sighted classmates. They can use the same reading materials as their peers, only in a Braille format.
c. Because there is a letter-to-letter correspondence between uncontracted Braille and print, it is easier for sighted peers, parents, siblings, and teachers to learn to read uncontracted letters.
d. Because the rules of spelling are the same in uncontracted Braille and print, students can sound out and spell words at the same time and in the same way as their classmates.
e. 39 of the 50 most common words in English have contractions when written in Grade Two Braille. Many also include lower cell signs.
f. Uncontracted Braille can promote greater speed and fluency in reading.
g. Uncontracted Braille can promote more interaction with peers.
h. Uncontracted Braille facilitates a quick transition from print to Braille for adults and adventitiously blind students
i. Uncontracted Braille can be a successful approach to reading for students who later transition to the use of contracted Braille.
j. Fewer reversal errors have been reported when using uncontracted Braille, especially for those students who use uncontracted Braille for a longer period of time before they transition to contracted Braille.
k. Uncontracted Braille works well with a linguistic approach to reading.
l. Uncontracted Braille works well with ESL students and foreign languages.

m. Uncontracted Braille works well for students using dual media for literacy, such as those students who use print but need Braille as well.
n. Uncontracted Braille can work well with deaf blind students because finger-spelling does not correlate with Braille contractions.
o. Because it matches print letter for letter, students can use uncontracted Braille in a variety of board games (Monopoly, Scrabble), card games (Uno), and leisure activities with sighted friends and family members (Adkins 2004).

Appendix D - Letter Requesting Participants for Study

Dear

I am a masters research student at Curtin Business School; Curtin University of Technology in Western Australia who is undertaking research in to the design of interfaces for Braille keyboard devices. In particular I am seeking user feedback from experienced computer users who have experience using Braille keyboard devices and other computer systems.

I am seeking participants who have these skills and who would be willing to be interviewed regarding their computer and Braille experience. Participants may choose to be interviewed in person, by phone / Skype or participate in a focus group. It is estimated that participants will need to set aside approximately 45 minutes to complete the interview.

I would be most grateful if you could advertise my need for participants in your client news letters or email discussion groups.

Yours sincerely

Ian Blackburn
Email: i.blackburn@curtin.edu.au