Improving users' emotional relationships with consumer electronics through enhanced interface design

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Abstract

While eager adopters of technology embrace its rapidly changing nature, many others are hesitant or actively resist using any innovative equipment unless they can see a direct benefit. All users can experience negative emotion towards technology, ranging from mild frustration to phobic reactions. These emotions are brought on by both the anxiety and fear of using technology and by poor interface design. Any human-machine interface requires consideration of all the human factors involved as well as the mechanics of the technology. Any physical, physiological and psychological constraints involved in interaction all need to be considered.

Two user case studies were conducted to assess the design of *myReader,* a new low-vision reading aid. A pilot study was conducted primarily to gather information to assist the company in its design of the control panel of the product. However, it also provided an opportunity to test methods for the more in-depth study. This main study provided further information for the company to refine the design and quantified the benefits of the new system over the old, through performance measures of reading speed and comprehension and subjective measures such as a physical comfort rating. The main study also provided a platform to investigate areas of product design that occasion negative reactions and improve user's emotional relationship through enhanced interface design.

The results of both the pilot study and the main study clearly illustrate that overall *myReader* offers a more pleasurable reading experience than existing closed circuit television (CCTV) technology. The user group appears to be more accepting of innovative technology when they can see it will improve their quality of life. The *myReader* unit takes a little longer to learn how to use than CCTVs but given the increased functionality this is not unexpected. An overall increase in reading speed was evident with *myReader*. However, experts had a slight but statistically insignificant decrease in reading speed, perhaps due to a negative transfer of skills. Comprehension was unaffected by the scrolling text and faster reading speeds, indicating there is no speed-accuracy trade off. The increasing reading speed over time suggests that further improvement in performance is likely with practice. Many of the physical requirements of CCTVs are reduced in *myReader* and participants reported less fatigue. Areas of the design that could be altered to improve the emotional relationship users have with the product are discussed. Early identification and elimination of design aspects that induce negative emotional responses can improve the emotional relationship with electronic products such as low-vision reading aids.

1 Introduction

Technology is becoming more and more pervasive and it is changing rapidly. While many people embrace these changes and eagerly adopt new technology, many others are hesitant or actively resist using any innovative technology. Less eager users can experience negative emotion towards technology, ranging from mild frustration to phobic responses. Even eager adopters experience feelings of frustration. For less eager users, these emotions are brought on by both the anxiety and fear of using technology and by poor interface design. Negative affect grows from, among other things, feelings of inadequacy, concerns of becoming addicted to technology and the incompatibility of the human-machine interface.

Any human-machine interface requires consideration of the human factors involved as well as the mechanics of the technology. Physical constraints, psychological constraints and the constraints involved in interaction all need to be considered. Physical constraints govern how people interact with machines. For example a person cannot bend their arm in a direction that the wrist, elbow or shoulder will not allow, therefore machines should be designed to avoid requiring any action that does not fit our physical constraints. Designers and engineers have become more aware of these physical constraints and can use tools such as anthropometrics to ensure the constraints are respected.

Psychological constraints also need to be considered. These constraints include the way people sense and process information from the environment, limited attentional and cognitive resources, memory limitations, emotions and motivation. Fundamental research into these processes is available, but this information is often overlooked by engineers and designers. While studying the fundamental psychological and physical elements is important, more emphasis needs to be given to research into the interaction of all elements of any human-machine system. Little consideration seems to be given to the unique mix of human and machine factors involved in interaction, and more awareness of interaction is needed to reduce negative experiences with machines. Studying users *in situ* can provide information to assist in designing machines that make the experience of interaction as intuitive and pleasurable as possible on a psychological as well as a physical dimension, but with an emphasis on interaction rather than considering fundamental elements in isolation.

The advent of the computer and internet spawned a plethora of research into how computer interfaces could be maximised to match the information processing constraints of people. Command line interfaces were changed into graphical user interfaces which required less cognitive workload. Other research centred on the concept of technostress or technophobia as it related to user's negative experience at a fundamental level. Further studies investigated how to change the way people think and behave in interactions with machines to reduce technostress.

While there is research and theory regarding the role that external factors such as the physical design of the user interface plays in causing stress or anxiety, most of the research in this area centres around interaction of a person and a computer rather than a person and consumer products, with a focus on the interaction with graphical interfaces of software products. While it could be argued that most consumer electronic products now contain computer components, much of the interaction is between a person and a physical product or hardware. More recently research has centred on creating products that elicit pleasurable experiences. This type of research focuses on ensuring pleasurable elements are included in design. However, little research has been done to eliminate elements that cause negative responses. Enhancing positive elements does not cancel out any negative elements of design.

Therefore, it is important to learn more about how an interface of a consumer product can be optimised to fit both physical and psychological constraints of users, with an emphasis on interaction. This information can be used to change the product rather than requiring the person to adapt their cognition or behaviour to fit the machine. Optimising human-machine interfaces is a vast area of research and indepth analysis is outside the scope of this thesis. Therefore, a case study of interaction with an electronic consumer product (low-vision reading aids) is used to investigate one element.

By taking a specific user group, the elderly, who are often regarded as being the most hesitant or resistant to technology and examining their specific needs we can gain more knowledge about how to optimise interface design to reduce negative affect. Many elderly people suffer from low-vision conditions and require low-vision reading aids. Therefore, by comparing learnability, usability and the pleasure of an existing and a redesigned low-vision reading aid, problems of interface design that can lead to negative emotions or technostress may be highlighted and recommendations made to the designers to change these elements.

The research detailed in this thesis was undertaken on behalf of a Christchurch based international electronics company that specialises in products for people with visual impairments, both blind and with low-vision conditions such as age related macular degeneration. Therefore, the research objectives were three-fold:

1. To investigate the positive and negative emotional relationships users have with this consumer product.
2. To determine aspects that were significant in affecting learnability, usability and pleasure in using the product.
3. To assist the company in the design of a more learnable, usable and pleasurable product.

These three objectives were achieved by conducting user studies to assess which elements of this product could be enhanced to reduce negative emotion. Objective measures quantified the performance differences between machines, and logging of button presses helped determine the optimum button configuration. Subjective measures helped identify whether users were eager adopters, hesitant users or resisters of technology, as well as which machine they preferred and what problems they encountered in using the product. This information along with analysis of video footage of the participant's interaction with the products helped identify changes that needed to be made in the product's design.

The following section puts this research into context, investigating the changing state of technology and human-machine interaction and detailing the role of physical and psychological human factors in interface design. An analysis of the user group then provides information about their defining characteristics which must be considered in designing a low-vision reading aid. This is followed by specific details of the research methods employed. Details of a pilot study are then explained in Sections 4 and 5.

The pilot study was conducted primarily to gather information to assist the company in its design of the control panel of the product under development. However, it also provided an opportunity to test methods for the more in-depth study detailed in Sections 6 and 7. This main study provided further information for the company to refine their design and quantified the benefits of the new system over the old. It also provided a platform, via user-studies, to investigate how to identify areas of product design that occasion negative responses. The concluding section highlights the outcomes and offers suggestions for future research. Appendices include a glossary of terms used in the thesis (see Appendix A), materials used in the studies and specifications of the low-vision reading aids assessed.

2 Research Context

2.1 Human Interaction with Technology

2.1.1 Technology Today

There is more technology in our lives today than ever before and its presence is only increasing. In a broad sense, 'technology' has come to mean any artefact made by people, anything not in its natural state that can be used to benefit human endeavour. Technology has been in existence for tens of thousands of years. For example, hand axes and spears date back 10,000 years and were made by our ancestors from sticks and stones to assist in hunting for food. Many of these artefacts have become so integrated into our lives we no longer think of them as technology. For example, lead pencils were a technological innovation, a revolutionary tool created by people to assist in their endeavours. However, in today's society technology is more prevalent than the stone axes and pencils of yesteryear. Every aspect of our lives now seems to be affected by technology in some way.

In the average New Zealand home, there is a proliferation of technologically advanced appliances, designed as domestic time savers. Microwave ovens cook food in a fraction of the time of conventional ovens and modern washing machines are far less labour intensive than the older wringer machines. In addition, the entertainment opportunities technology offers range from the ubiquitous television viewing experience to immersive role playing games that consume hour upon hour of leisure time. At work, multitudes of communication tools such as the internet facilitate global access to information unimaginable even 10 years ago. Activities such as banking have changed from taking actual cash to the person at the counter to virtual banking where coins and notes are a thing of the past. Booking airfares can now be done online via the internet, and there is no need to wait in line with a ticket to check in, just swipe your air points card through a machine and away you go. These experiences all require humans to interact with machines. The more effective the interface is between human and machine the better the user experience. In many aspects of our lives we are being encouraged and perhaps even forced to interact with machines.

2.1.2 Changing Nature of Technology

As pervasive as technology is today, it will only become more so in the future (Shneiderman, 2002; Vicente, 2003). The virtual reality of today is the reality of tomorrow as technological integration into every day life increases at a staggering rate. Smart home technology and cell phones are being used by everyday people, many of whom have disabilities such as low-vision and these products need to be designed to accommodate people's limitations. Smart homes, for example, are homes where a computer controls many of the appliances, security and air conditioning. All of these devices can then be manipulated remotely using cell phones or the internet. Current research into smart home technology will make them a reality in more countries in the next few years (Mori, Baba & Asaine, 2003). Alternatively, cell phones, initially just a portable phone, can now send electronic images and text messages and even access the internet from virtually anywhere, anytime.

More functions seem to be added daily to appliances, often providing functionality that is not necessarily needed (Fournier, Dobscha & Mick, 1998). The multiple features of highly complex products frustrate and overwhelm many consumers. These additional functions and features are often added without consideration of the user's specific needs. Many businesses add functions just to help maintain or gain market share because they believe that more functions will give the product a competitive advantage (Fournier et al, 1998). Technological innovations allow the introduction of novel attributes such as Global Positioning Systems (GPS) into cars (Mukherjee & Hoyer, 2001). In low complexity items novel attributes may assist in evaluation of the product, but in more complex products novel attributes may have a detrimental impact due to associated negative learning costs and consumer resistance of such technology (Mukherjee & Hoyer, 2001).

If people are unfamiliar with the novel attribute in a high-tech device it may dissuade them from purchasing (Mukherjee & Hoyer, 2001). Washing machines with "fuzzy logic" may be technologically more advanced, but if a consumer is unaware of what "fuzzy logic" is or the benefit it offers they may be less, rather than more, inclined to purchase such a product. For example, in a study of the effect of novel attributes on product evaluation, participants rated a high-tech product with novel attributes lower even if they were given information regarding the benefits of the new features (Mukherjee & Hoyer, 2001). Eager adopters of innovative technology, however, may buy products on the basis of how many novel attributes they have regardless of their practicality (Moore, 1999). Therefore, it is important to understand the needs of the user and their level of acceptance of innovative technology before including functions into products that may not be understood or used, and may ultimately influence consumer behaviour to the detriment of product sales.

While technology is likely to become more integrated into our lives, many problems with existing technology still have to be addressed to reduce negative emotion. Since the advent of video recorders over 20 years ago people have had problems programming them due to unintuitive interfaces (Norman, 1988). This is not due to a lack of technology to make the operation simpler; instead it is a lack of consideration for the user understands of how the machine works. Despite the problems to be overcome, some early issues with computers have been addressed. Programmers have addressed some of the emotion invoking issues associated with computers in the early days. For example, it is now less possible to lose files as safe guards such as the "undo" button in Microsoft Word have been built in. This function provides users with a way to recover from errors, reducing the fear of losing important information. There are still interface design problems that could be addressed by conducting user studies with non-expert users, but it is possible to identify what occasions negative responses and provide alternatives or safeguards.

2.1.3 Users of Innovative Technology

Nearly everyone in the Western world interacts with some type of technology everyday, highlighting a distinction between accepted technology such as the telephone and television, and innovative technology that is seen by some as more complex, modern or unfamiliar such as computers. While most people would say they are eager users of accepted technology, it has been proposed that there are three types of users of innovative technology (Weil & Rosen, 1997).

- Eager adopters (10-15% of population) are at the leading edge. They embrace all technology, find it fun to use, try to fix any problems and do not believe they are at fault for any errors that occur when using the system. They choose to buy products based on how many functions the product has and usually purchase early in the product's life cycle.
- Hesitant users (50-60% of the population) are those who want proof of the benefit and reliability of technology before using it. They will only consider purchases if they can see a need and may still not purchase or use a device because they are afraid to experiment with unfamiliar controls. Hesitant users believe they are possibly to blame when system problems occur.
- Resisters (30-40% of the population) are at the other end of the scale to eager adopters. These people avoid innovative technology at all costs due to overwhelming anxiety, concern or disregard for technology. They fear breaking modern technological devices, and if they have been able to get by without them they cannot see any need. Resisters are certain that any and all errors are their fault (Weil & Rosen, 1997).

Many hesitant users and resisters could benefit from using technology but choose not to for a variety of reasons. From this model it appears that up to 90% of the population is not eagerly embracing technology (Weil & Rosen, 1997). One extreme example of how people are actively avoiding and shunning technology is offered by the Lead Pencil Club. This is a group of neo-Luddites who are battling 21^{st} century technology by refusing to use computers, cell phones etc as their fore fathers in the 19^{th} century battled against the technology of the industrial revolution (Henderson, 1996). By knowing whether the user group is an eager adopter, hesitant user or resister, designers can adjust the complexity to suit the specific needs. For example if the user group of a product, such as a low-vision reading aid used mainly by the elderly, is likely to be hesitant or resistant then a less complex product would be more suitable.

2.1.4 Negative (E) Affect of Technology

Eager adopters, hesitant users and resisters are often forced to interact with technology in many facets of their lives, but not always with positive outcomes. Many people are suffering a variety of negative emotions that can be directly attributed to their interactions with technology. Weil and Rosen report that 30-80% of people have varying degrees of negative feelings towards technology (1997). Professionals and the uninitiated alike have problems with technology at some stage (Shneiderman, 2002). At the extreme, computers are outstripping public speaking and death for instilling fear in business people (Snyder, 1997). Even those who embrace technology in all its multitudinous forms experience some degree of stress. In a study of the feelings associated with interacting with technology, participants were asked to identify feelings from a list of 30 positive and negative adjectives. Despite choosing mainly positives, eager adopters also identified frustration as an emotion they experienced (Weil & Rosen, 1997).

Negative emotions associated with interaction with technology include estrangement, embarrassment, irritation and frustration. In the study mentioned above all user groups (eager, hesitant, resister) mentioned frustration, but it was more common for the resisters than for the other two groups. The eager adopters identified mainly positive emotions when considering their experiences with technology, the hesitant users had a mixture with negative more common, while resisters chose mainly negative adjectives from the list. These negative emotions do not seem to be abating (Weil & Rosen, 1997). For example, in 1993 a Dell Computer Corporation study of 1,000 adults and 1,000 students revealed that 55% were deemed "technophobic". Similarly, in 1995 an Associated Press poll of 1,000 people revealed almost 50% felt that technology was leaving them behind (Weil & Rosen, 1997). Given the stable numbers of people concerned about technology in this period of growth, it is likely that the level of technophobia has not decreased in the years since this research was conducted.

So what is technophobia? The term computerphobia was first used in 1981 to describe a nerve wracking fear of interacting with computers (Weil & Rosen, 1997). As with many types of stress, computerphobia can lead to physical symptoms such as rising blood pressure, disturbed sleep and indigestion. This phobia whilst not classified as a clinical disorder, does carry a clinical connotation. Technostress is a term first used in the early 1980s by clinical psychologist Dr Craig Brod to clarify the negative emotions resulting from interacting with technology (1984). Technostress and computerphobia quickly evolved into technophobia. Other terms such as technology related anxiety have also been used to define this phenomenon. These terms all have limitations. Technophobia for example, implies that fear is the only emotion experienced, and technology related anxiety implies anxiousness is the only emotion. For the purposes of this thesis technostress is used to cover the multitude of negative emotions caused by using technology. A comprehensive exploration of any of these terms is outside the scope of this thesis. However, it is clear from the literature that they exist and probably more so in the older population (Rosen & Weil, 1995), although this has been debated (Brosnan, 1998).

2.1.5 Reasons for Negative Affect

Thought Processes

Technostress can result from the constant bombardment of our senses by cell phones, pagers, computers and appliances and the associated thought processes. Privacy and security, our level of self-efficacy, resistance to change, and health and safety concerns all play a role in causing technostress. Feelings of a lack of privacy and security can cause stress when using technology and many people have a belief that technology is an invasion of privacy and that it reduces leisure time (Greenfield, 1999). For example, private conversations are often held in public places on cell phones and the work day no longer finishes at 5pm as business is conducted at all hours over the internet and telephone.

Fears also exist about the security of internet banking. While there are risks involved with online banking, these risks are also apparent when conducting transactions over the telephone in your own home. Other people experience a fear of being robbed while withdrawing money from money machines and therefore do not use them. These concerns are not directly related to the design of the product, but instead are based on our thought process regarding technology and the context in which they are used. For example, knowing that users of money machines are robbed more often at night, invokes a tendency to avoid using money machines at night.

Technostress can also result from feelings of being unqualified to use computers and people's beliefs that children are more proficient in operating computer equipment. This then turns into a fear of technology and avoidance at all costs (Snyder, 1997). Fears of being replaced by machines can impact on self esteem and this can be compounded if self-efficacy is already low (Weil & Rosen, 1997). Feelings of inadequacy from having to learn how to operate new appliances and software are symptomatic of technostress (US Congress, 1985). Technology often changes quicker than humans can adapt. People's behaviour, beliefs, habits and culture do not change as quickly as technology advances (Branaghan, 2001a). Feelings of shock and displacement result from these rapid changes (Weil & Rosen, 1997). People also experience pressure to maintain and update skills with technology in business (US Congress, 1985).

We also have health and safety concerns about technology's influence on our lives, including concerns regarding possible technology based addiction. For example, children spend large amounts of time on computers, which impacts on their health (Greenfield, 1999). Other health concerns include fears about the impact of radiation emissions from products such as microwaves and cell phone transmitter towers. Other reasons for avoiding technology have more to do with fear and circumstance than with the actual product design.

These include not being exposed to innovative technology, concerns about breaking equipment and for women there is possibly a belief that men can do it better. Many other people are just not interested in taking the time to learn how to use a product they can see no inherent value in.

Technology is pervasive and results in problems but there are ways to reduce the associated stress. Leading technostress researchers, Michelle Weil and Larry Rosen, produced a book with information on how to deal with stress associated with interaction with technology (1997). They explain that by using cognitive behavioural therapy (CBT), technostress can be countered by helping people change their thought processes regarding their interaction with technology. Their book provides coping strategies to deal with the problems such as lack of self-esteem, addiction fears, security concerns etc. Several other comprehensive reviews of computer phobia, technophobia and technology related anxiety also suggest treatment of the person as the solution (Brosnan, 1998: McInerney, 1997). Other ways to make technology use more "healthy" include learning how to use the OFF button on cell phones, restricting game playing time and ensuring a balance between interaction with people and interaction with technology (Greenfield, 1999). Methods of treating the symptoms rather than the cause are in line with modern clinical methodology. However, methods such as CBT do not eliminate the elements of poor interface design that lead to stress.

Product Design

As well as our thought processes, interaction of person and product is an integral factor in the cause of technostress and the basis of the research in this thesis. A better way to reduce technostress is to find exactly what actions cause the stress and address the product's design rather than requiring the person to adapt their thoughts and behaviour. Technology was designed by humans to assist humans. However, many machines require people to adjust the way they work to accommodate the limitations of the machine. Microsoft Word is a familiar example. While users may want to change formatting to suit their own needs, the default settings have to be undone before this can be achieved. This is changing the person to suit the tool which can have implications for the well being of the user. Human factors engineering is about changing the tool to suit the person (Galer, 1987). A mismatch between the users' needs and abilities and the design of the machine's interface are often the cause of technostress.

One example of how the design of computers directly results in negative affect is the feeling of frustration experienced when computers do not respond as quickly as we expect. In a survey of 6,000 computer users in the US it was reported that over five hours per week per person were wasted waiting for computers to perform the required action (Shneiderman, 2002). Negative affect, such as frustration, is often caused by time spent waiting for computers to perform background tasks such as loading pages. It is recommended to keep users informed of loading/wait times or distract them with other activities (Myers, 1985). Usability expert Jakob Nielson suggests "...the minimum goal for (website) response times should therefore be to get pages to users in no more than 10 seconds, since that's the limit of people's ability to keep their attention focused while waiting" (1997). Changing the machine (decreasing loading time) to suit the person's expectations will reduce frustration and the resulting technostress.

Technology can cause many minor and chronic frustrations during our daily interaction with machines. With the Accident Compensation Corporation of New Zealand's introduction of stress as a recognised illness, the impact stress has on our lives has been highlighted, with the result that stress reduction is an important area of current research (ACC, 2004). Tiny frustrations can have a cumulative effect on people's health (Selye, 1991; Smith, 1996). Being able to eliminate stress invoking actions from interaction with electronic equipment could assist in reducing overall stress. With technostress reportedly experienced by 50% of the population, it is a phenomenon that cannot be ignored (Brosnan, 1998). Finding ways to reduce negative emotions associated with interaction with technology is necessary. An individual's belief systems can be modified with CBT, but if the product interface more appropriately matches the needs of the individual there would be less need for CBT as interaction with machines would be more rewarding. A product that is easy to learn to use, performs well and is pleasurable to use will initiate less negative emotion. Technostress could be reduced by enhancing the interface design to better match the human factors of the system and by eliminating elements of the interface that occasion the negative emotions. The human factors that need to be considered will be explored in the following section.

2.2 Human Factors

2.2.1 Human-Machine System

To design the interface between human and machine, first we need to understand the interface's function. The nature of interaction with technology can be explained by looking at the entire human-machine system. A tool or any type of technology is made to help people in some endeavour. The immediate workspace, the context and environment a device is used in are all part of the human-machine system and must be considered when determining the appropriate design or selection of tools (Galer, 1987).

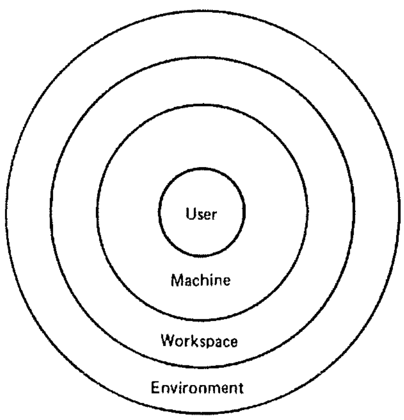


Figure 2.1: User centric model of interaction (from Galer, 1987).

Figure 2.1 illustrates a user centric system, involving the machine, the workspace and the environment. Interaction between people and technology involves communication of the user's intention and required actions to the machine. Somehow we need to communicate our requirements to the device and the device needs to communicate when it has achieved

achieved through an interface between the human and machine. Therefore, an interface is the boundary between person and machine, but also the place of interaction. If an interface is designed appropriately and the fit between the user and the product is good, then feelings of stress associated with using the product should be reduced.

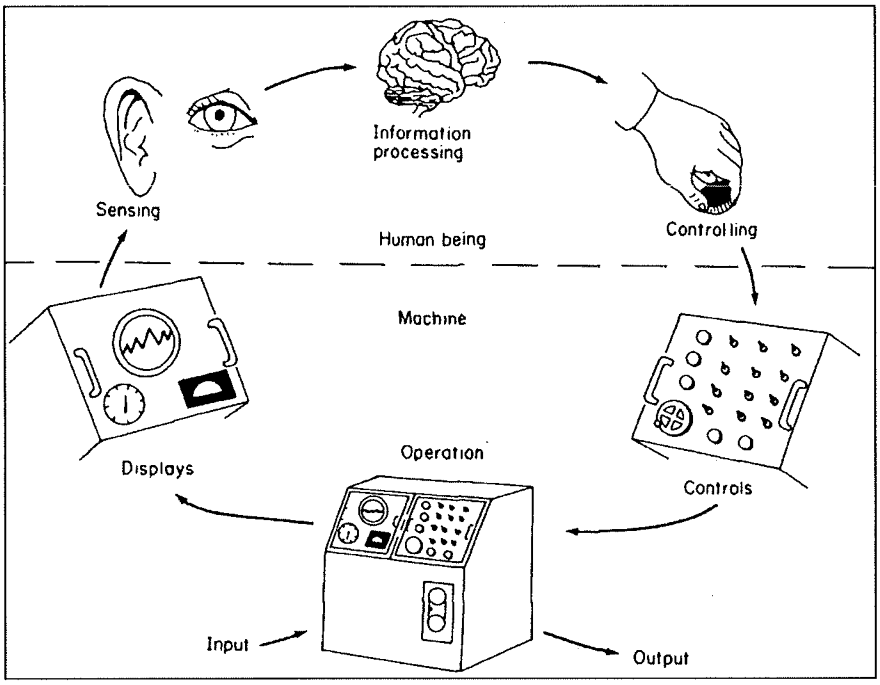


Figure 2.2: Elements of human machine interaction (from Chapanis, 1976, in Sanders & McCormick, 1993).

Thus, the interface between the machine and the human user needs to be designed to allow for input and output from both to be optimised for its own capacities and limitations. Figure 2.2 clearly illustrates the many elements involved in an interaction between human and machine. Human senses, brain processes and actions as well as the machine's displays and controls are all considerations in optimising interfaces (Sanders & McCormick, 1993). The mechanical and electrical workings and aesthetic design aspects of a product are the responsibility of engineers and designers. These engineers and designers cannot however, do their job without being aware of the physical and psychological limitations of the user, which dictate how the machine needs to present and receive information (Stanton, 1998). This can only be achieved by considering the specific user group's physical and psychological human factors of the system, which are detailed below.

2.2.2 Physical Constraints

The human body has limitations. For example, an arm can only bend in certain directions at the elbow. Buttons on a control panel need to be certain distances apart so the smallest and largest hands can use the panel. Lists of anthropometric data and ergonomic guidelines have been available for most populations for many years (Pheasant, 1996), including New Zealand. As Sanders and McCormick put it, "it is easier to bend metal than twist arms" (1993), therefore, consideration needs to be given to human capabilities, limitations and preferences. Physical aspects are important and have been considered, but they are not the focus of this thesis. Figure 2.3 illustrates some of the dimensions that require consideration when designing products for people. While ergonomic principles include the biomechanics and hard facts of product usability, the next section shows that psychology also has a major role to play in assessing and enhancing the positive emotional aspects of electronic equipment use.

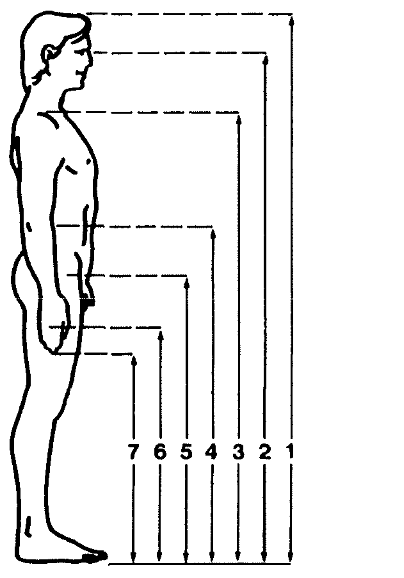


Figure 2.3: Anthropometric data is gathered from numerous parts of the body
(from Pheasant, 1996).

2.2.3 *Psychological Constraints*

There are numerous fundamental aspects of a person's psychology that require consideration when designing an appropriate interface. As can be seen in Figure 2.2, information processing functions play a major role in human-machine interaction. To optimise the interface designers must consider the psychological activities such as human attention, perception, emotion, motivation and memory. Humans have limited attentional resources and if demand is higher than supply we can suffer from overload and are no longer be able to perform tasks efficiently or effectively (Wickens, 1992). These resources include our existing knowledge, skills and experience. The demands are those involved in achieving goals to a specific standard (Stanton, 1998). If we are overloaded or have too little stimulation and are underloaded, we can more easily make mistakes than if we are in an optimal situation of attention load. Therefore we need to optimise the cognitive workload associated with human machine interaction to ensure attention is maintained but not overloaded. This can be achieved by ensuring human actions are intuitive and require enough workload to be engaging but are not over taxing.

People use cognitive categorisation to reduce the cognitive burden of distinguishing between the multitude of objects in the world (Medin & Ross, 1997). Designers and engineers should understand how people categorise and map information they extract from the real world so the interface design matches these processes (Norman, 1988). An example of a familiar, yet suboptimal interface is the dials controlling the elements on an oven top. Because of space requirements the dials are not laid out in direct relation to the spatial location of the elements on the stovetop. Because of this people often adjust the wrong dial because they try to map the location of the dials to the elements and there is a mismatch (Norman, 1988).

<u>Perception</u>

Given the human visual sensitivity, communicating information relies primarily on visual perception (Wickens, 1984). Labels, icons and words are often used to communicate visual information in interfaces. One advantage of using symbols or pictograms is that they cross language barriers. However, very few pictograms are universally accepted and even those that are typically understood may be interpreted incorrectly by some users. Also, symbols and pictograms cannot convey complex ideas (Pheasant, 1987). However, consideration needs to be given to how well these communication devices work for a chosen user population. For example, if a product is being designed for an older population it is important to consider whether this user group prefers textual rather than pictorial or iconic information (Stephens, Carswell, Delaine, 2000). Choosing the appropriate means of communication is further complicated by the fact that people with visual impairment have difficulty with complex type faces and graphics. Therefore, as elderly people prefer textual information (Sanders & McCormick, 1993) it would be appropriate to use text rather than symbols to convey the function of controls, and *sans serif* fonts in a mixture of upper and lower case letters, making textual labels easier to read (Vanderheiden, 1997; Pheasant, 1987).

Figure 2.4: Informal look at how computer terminology can be misinterpreted by lay people (source unknown).

Despite preferring textual information, older users may often be confused by many of the technological terms used today. The implications of words such as capture, live, navigate and translate will have less relevance to this user group than to engineers and computer scientists. These words are examples of specialised technological jargon, which for people outside the specific sphere where this jargon is used, have other meanings. Figure 2.4 informally illustrates how jargon can be misinterpreted by people unfamiliar with the terminology. Designers, engineers and consumers all have different goals, tools, philosophies and perspectives. They also have different ways of referring to the same concept or object. Different terms for the same item or similar terms for different items can cause problems in communicating needs between designers, engineers and users (McInerney, 2001).

A popular illustration of how jargon can be misunderstood is the error messages associated with many computer programmes (Shneiderman, 2002). Because so many people rely on manuals to teach them how to learn to use a product, jargon should also be eliminated from this information. Further, the reading level for manuals is recommended to be at a US sixth grade level (11-12 years old) (Rogers et al, 2001). Therefore, jargon should be avoided when conveying messages, especially for user groups unfamiliar with any specific terminology. Simple language should be presented in a format that any user can understand.

Memory

Memory also plays a role in human-machine interaction. There are limitations on how quickly people can learn and remember (Branaghan, 2001a; Weil & Rosen, 1997). Many products now have multiple functions and if matching of these functions to user expectations is not appropriate, performance is affected (Francis, 2000). In a study into multifunction displays it was determined that depth of hierarchical representation was better than breadth as target search takes longer in breadth (Francis, 2000). If too many high level options were offered (breadth) users were more confused than if more options were offered under fewer high level choices (depth). Therefore, if there are too many buttons with too many functions there can be problems due to the high memory load. If there are fewer buttons with more levels of functionality this is better. One goal of control panel design should be to reduce the number of buttons to assist users in remembering which control achieves what task. Additionally, arbitrary function allocation increases memory and processing load causing cognitive overload (Wickens, 1984).

The role of memory was fundamental in the move from command line operating systems such as MS-DOS, Linux and Unix which rely heavily on remembering commands, to graphical user interface (GUI) environments such as Windows (Olson & Olson, 2003). One way of assisting users is to design controls that have easily remembered and associated properties. For example, if there are multiple controls, colour coding or making the dials different shapes can prompt users rather than having to rely entirely on memory of what button performs what function (Sanders & McCormick, 1993). Users do find recognition easier than recall (Branaghan, 2001b).

2.2.4 "Pleasurability"

As well as the fundamental psychological aspects of the human, our desire to pursue pleasure and avoid pain is also relevant in product design. The emotional mind is quicker at responding than the rational mind (Goleman, 1995), suggesting that designers need to appeal not only to information processing, but also to the emotional aspects of the consumer. Usability engineering traditionally emphasises performance criteria exclusively. Only recently has user satisfaction been considered important (McDonagh, Bruseburg & Haslam, 2002; Tractinsky, Katz, Ikar, 2000). In the last few years emotional aspects of interaction and design have received growing recognition and prominence. In 1999 the first International Conference on Design and Emotion was held in Delft, Germany (Design and Emotion Society, 2004) and in 2001 the first Conference on Affective Human Factors was held (DPPI, 2004).

The emotional aspects of design, or "soft" functionality, include the emotional needs and other intangibles such as preference (McDonagh et al, 2002). There are numerous qualitative aspects that influence the emotional relationship of the user and product such as aesthetic appeal and whether the user identifies with the product (McDonagh et al, 2002). Therefore designers need to consider the functional, ergonomic and emotional components (McDonagh et al, 2002).

Figure 2.5: Mazda Mita car designed used Kansei Engineering principles
(from Nagamachi, 2003).

Emotional elements have been implicitly examined and considered previously but now their importance has become explicit. Since the turn towards designing pleasurable products, several strong themes of research have evolved. In Japan a design ethos, Kansei engineering, has emerged which embraces pleasurable design and is now synonymous with pleasurable products (Nagamachi, 2002). Using Kansei engineering principles involves evaluating products on a variety of dimensions assessing how pleasurable the product is. For example, a recent study investigated Kansei of food by comparing convenience-oriented feelings, health-oriented feelings and earnest-oriented feelings relating to menus (Kanda, 2003). Figure 2.5 illustrates an example of a Kansei product, the Mazda Mita roadster car that went through many research phases to determine how to make it more pleasing to consumers. Sensual aspects such as form, colour and texture were all assessed.

Designer Patrick Jordan also promotes using a framework of four pleasures (sociological, physiological, psychological and ideological) to identify what pleasurable aspects need to be included in product design (2000). While the concept of the four pleasures was first used by Lionel Tiger (1992), Jordan has made the concepts more widely known and understood. *Physio-pleasures* include all aspects relating to the body and pleasure derived from the senses, for example how well a camera would fit a user's hand. *Socio-pleasures* involve enjoyment gained from social interaction and status, for example whether the product makes other people aware of the social group the user belongs to. The *ideo-pleasures* are those associated with the user group's belief system, including aspects such as the environmental impact of a product. The *psycho-pleasures* relate to people's cognitive and emotional responses, for instance how cognitively demanding the product is to use. Once the target user group has been identified, their pleasure needs on all four dimensions are assessed. Then product benefit specifications targeting these specific needs are generated, for example a camera should feel good in the hand to create a positive and pleasurable experience (Jordan, 2000).

Designers need to identify the emotions they want the user to feel (Branaghan, 2001b). Methods such as subjective report, product personality profiling, mood boards and discussion or focus groups are advocated as user-centred design methods for gathering data to assess how the user feels about the product (McDonagh et al, 2002). While attempting to elicit positive emotions is the goal, designers must also identify and eliminate aspects of the interface that result in negative emotions. It is not sufficient to design a product using as many positive elements as possible. An emotional response based on the balance of positive and negative elements is not comparable to the physical metaphor of a set of scales being loaded down with positives to offset any negative elements. Negative elements in a design cannot be eliminated merely by adding more positives (Tubbs, 1991). Therefore, it is essential to identify aspects of design that elicit negative responses and alter the design to eliminate these. More attractive products, with added functionality that appeal to our ideological, social, psychological and physiological needs will only outperform other products if they are free of properties that induce negative responses.

2.2.5 Human-Machine Interaction Research

From the mid 1980s to the mid 1990s an abundance of research into human computer interaction (HCI) was conducted. However, much of this research was specifically in the HCI domain, not human-consumer product interaction and this trend appears to continue. For example, in a recent book on usability from the US Usability Professionals Association the majority of essays were related directly to the web and computers (Branaghan, 2001a). While the methods and ethos of HCI and interface design of consumer products are similar, specifics are needed for testing a physical interface to a consumer product. HCI research focuses on signal detection theory, cognitive ergonomics and behaviour. These are fundamental elements in isolation rather than a system of interaction. The emotional element of design is often overlooked and if it is considered, it is often done poorly (Yap & Smith, 2002). A study investigating emotion conveyance in web sites, found that many designers misinterpret users' emotions, believing they were appealing to specific emotions but respondents reported this was not the case. Research has also been conducted on how to design computers to recognise emotion (Picard, 1998), but not on how to reduce the negative affect associated with using them.

While extensive research has been conducted in HCI and designing pleasurable products, there is limited research on how to improve the emotional relationship with consumer electronics by identifying and eliminating aspects that elicit negative experiences. Research is also limited on dealing with a user population that is especially prone to technostress and who may have disabilities that restrict their ability to use technology. While literature is available on designing pleasurable products (Jordan, 2000), this is a relatively new field and mainly focuses on enhancing the positive, not eliminating the negative. Several tools have been developed to identify whether pleasurable elements are included in a product (Jordan, 1997). These tools provide little information regarding what may cause any negative responses and user-studies with direct subjective feedback, observation and objective measures are required instead. With little research to draw upon, methods for conducting research into enhancing interface design to eliminate negative experiences will have to be developed.

2.3 Interface Design

Quality interface design is essential for quality interaction and this can only be achieved by considering all human factors and the interaction specifically. Ignoring human limitations can have far reaching consequences for business, government and safety (Branaghan, 2001a). Technostress resulting from poor interface design can create high staff turnover, absenteeism, decreased productivity (Snyder, 1997). Poor design of US election voting papers had an impact on the outcome of the last election when poorly designed voting papers led people to make errors in their voting and made it difficult to tally the votes (Vicente, 2003). Poor product design can result in a negative impact on the market share the product gains, and whether it continues to be used by the purchaser. To avoid problems of poor interface, designing a product should be an iterative, user-centred process. Ideally, user-centred design involves user participation from concept generation to product launch and beyond (Peacock, 2002). This will ensure all human factors are considered, and negative reactions are eliminated, producing a pleasurable product which will in turn have positive benefits for all concerned. After all, the aim of technology is to assist and make a person's task(s) easier and this includes their emotions.

Table 2.1: Five fundamental fallacies that designers can experience (from Pheasant, 1996).

No.1	This design is satisfactory for me – it will, therefore, be satisfactory for everybody else.
No.2	This design is satisfactory for the average person – it will, therefore be satisfactory for everybody else.
No.3	The variability of human beings is so great that it cannot possibly be catered for in any design – but since people are wonderfully adaptable it doesn't matter anyway.
No.4	Ergonomics is expensive and since products are actually purchased on appearance and styling, ergonomic considerations may conveniently be ignored.
No.5	Ergonomics is an excellent idea. I always design things with ergonomics in mind – but I do it intuitively and rely on my common sense so I don't need tables of data or empirical studies

2.3.1 User-centred Design

Improving the relationship between people and technology can be assisted by utilising a user-centred design processes. Technology that is driven by users' needs rather than technology can overcome many of the problems already identified. Designers need to incorporate the requirements of the end-user as early as possible in the design cycle (Stanton, 1998). However, while designers and engineers have valuable insight into aspects of design, they can have fundamental gaps in their knowledge, often generalising what fits them to what fits a group that they have nothing physically, ideological, socially or psychologically in common with (Pheasant, 1996). A summary of the inappropriate assumptions that can be made regarding design is in Table 2.1. These fallacies highlight the need to incorporate human factors into the design process. Talking to users and observing them using the product for the tasks the product was designed for and in the appropriate context will help alleviate these assumptions (Pheasant, 1996). Design should also be an iterative process, incorporating user information into the design as the product develops (Jordan, 1998). Figure 2.6 illustrates an iterative design cycle with evaluation following each step. A good example of how user studies can feed into a cyclic design process is in the development of the Dyson vacuum cleaner, which went through much iteration with more than 5000 prototypes produced before being released into the market (Dyson, 2004).

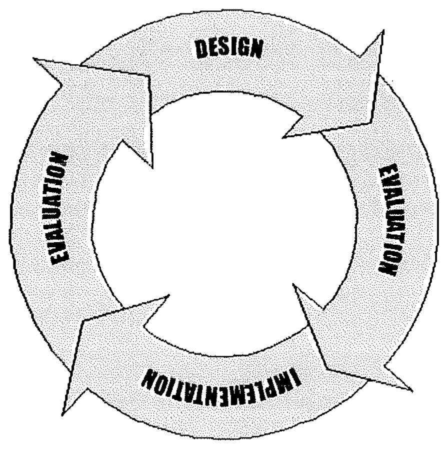


Figure 2.6: Iterative Design Process

An element of the design process that is particularly relevant to this research is the production of prototypes used in user studies. Prototyping is the technique of building a replica of a design concept. Prototypes come in different varieties, from paper prototypes to three-dimensional (3-D) prototypes that accurately replicate the look and feel of the product to a high level of fidelity (Sade & Battarbee, 2001). Paper prototypes are useful in early design phases but do not allow 3-D interaction (Sade & Battarbee, 2001) which is essential in determining emotional relationships. Paper prototypes are cheap to produce but are not as reliable as high fidelity models (Sade & Battarbee, 2001). 3-D working prototypes that may not be fully functional but contain many elements of the envisaged final product can assist greatly in developing a product concept (Ulrich & Eppinger, 2000). Prototypes should incorporate the physical dimensions and functions that will be utilised in the final product.

Details of physical dimensions (anthropometrics) and cognitive capacities are usually gathered for general use. To ensure realistic information about product use in the intended context, specific data needs to be gathered in a realistic environment (Kanis, Rooden & van Duijne, 2002). Conducting user studies in as realistic a situation as possible also assists with the ecological validity of any results. However, while a study in the intended environment provides real-world data, many variables are unable to be controlled (Mitropoulos & Muszak, 2001). *In situ* studies can be prohibitive due to time and resource constraints, but generally the information gained from *in situ* testing outweigh the negatives. For example, if a product has a large footprint and is tested in laboratory conditions, users may not be as aware of space considerations as if the product was tested in their home where they would normally use it.

2.3.2 Learnability

Assessing the learnability and usability of a working product or prototype if in an early design stage, is essential to determine how well the product fits the person. A user may never employ all functions but they need to become proficient with some very quickly to ensure they will use the product again (Branaghan, 2001b; Mitropoulos & Muszak, 2001). For example, users of low-vision reading aids are not casual users so need to be able to learn basic functions quickly or they may not use a reading aid again, despite its potential to assist with their quality of life. Problems identified in learning to use a product include not being able to remember the steps involved to achieve a goal. Appropriate and consistent metaphors help with learnability (Branaghan, 2001b). Domestic products need to be easily learnable as there is a lack of feedback regarding performance and a lack of formal training (Sauer, Wiese & Rüttinger, 2002). This is also true for accessibility products such as low-vision readings aids (Watson et al, 1997). Without formal training, mental models used to learn how to use an appliance rely on product information and design features (Sauer et al, 2002).

2.3.3 Usability

Trade reviews of products often do not test a product long enough to assess anything other than learnability, which is relatively simple to test (Branaghan, 2001b). However, usability of a product should also be assessed to determine the level of task performance. People have difficulty operating all manner of equipment and consumer products (Norman, 1988). International Standards Organisation's standard number 9241 states that usability is the extent to which a product can be used by a specified group of people to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context (ISO, 1998). Assessing usability is better achieved once users are proficient or have been trained and no longer show any improvement (Branaghan, 2001b). It is argued that usability would require performance to be free from stress inducing negative affect.

However, design decisions cannot be based entirely on performance. More often than not it is the subjective opinion of the consumer that sells a product and determines if it is used once it is in its intended location (Stephens et al, 2000). If users are told a product is easy to use and then have problems, they may blame themselves, feel embarrassed, not ask for help and may discontinue using the product (Rogers et al, 2001). While manufacturers can purport simplicity of a product, the actuality may be quite different. For example, in a study into a blood glucose monitor where it was suggested by the manufacturer that the product was "as easy as 1, 2, 3" it actually required 52 steps to operate (Rogers et al, 2001). In addition, 50% of people in the study relied on the manual for information on learning. Therefore, usability is also based on personal preference and perceived ease of use.

Errors

One especially useful usability measurement for improving design is error analysis. Repeated errors often provide more information than when tasks are performed correctly. By identifying and classifying errors in performance, the source of a problem can be determined (Vora, 2001). Error analysis can reveal both information about the user and aspects of design that cause negative responses. An isolated error with little consequence does not provide a lot of information. However, if errors or concerns are common among many users this suggests a mismatch of design and user group and these errors should be rectified to enhance the experience of using the machine.

One of the basic tenets of human factors is that errors classified as human error are often design flaws leading users to commit errors (Rogers et al, 2001). People often blame themselves if they make errors when in actuality it is more likely that the problem is one of design (Reason, 1990). Errors are either of omission where users omit a required step to perform a function, or errors of commission when users perform a function incorrectly (Norman, 1988). For example, an error of omission when video recording programmes on television would be to forget to turn the machine on. An error of commission would be selecting the wrong channel to record. User centred design can help identify whether errors of both omission and commission are user or design based and reveal ways to improve the design (Rogers et al, 2001).

2.3.4 Universal Design

As well as ensuring that products are learnable and allow users to achieve tasks efficiently, usability also involves users being able to access and use the controls. Therefore, it is also important to consider designing for the physical differences among people and specifically people who have disabilities. Disability means that these people are unable to operate in the world as it is (Vanderheiden, 1997). In some situations it is possible to change the person, such as with training or surgery; more often however this is not possible and assistive technology, such as prosthetics, reading glasses and assistive technologies, such as reading aids, are required (Vanderheiden, 1997). Products need to be designed so they are accessible by the widest proportion of the population. Design for people with disabilities should be a part of design rather than a special ad hoc consideration (Vanderheiden, 1997). To ensure that a product can be efficiently and effectively used by the majority of the target population it needs to be designed to maximise its universality. Cumulatively, people with disabilities make up 5% of the population (Vanderheiden, 1997) and in New Zealand this equates to 200,000 people.

One example of an element of universal design is that of handedness. For example, since 8-10% of the US population is left handed (Sanders & McCormick, 1993), it is important to ensure consumer products can accommodate left handers as effectively as right handers. While many younger people with a dominate left hand have adapted to using a right-handed mouse for computer operation, it is suggested that an older left hander is less likely to accept the frustration inherent in having to work around technology that does not accommodate their handedness. When designing for the elderly and for other less physically able users, consideration also needs to be given to reduced dexterity and strength (DTI, 2000). One benefit of universal design is that if the interface design accommodates people with limitations it is also likely to be easier to use for those without the same limitations, potentially reducing the risk of repetitive strain based injuries. In addition, it is more than possible that one day we might all end up needing to use specially designed equipment (Vanderheiden, 1997). Therefore, when looking at the design of a product, assessing whether it can accommodate left handers as well as right handers and is accessible for as much of the population as possible is important.

2.3.5 Marketability

A final consideration in the design of a product is how well it will sell. Usability considerations are now expected in consumer products, so another avenue for gaining market share is needed. Consumers are more discerning and the availability of a wider variety of similar products reflects this more astute nature (McDonagh et al, 2002). Consumers require products to not only be safe, efficient and economical, but also to be inspirational, enhance their lives, evoke emotion and satisfy dreams (Yap & Smith, 2002). Quality interface design that addresses usability and is pleasurable can provide the required edge in the market place. Product functionality is critical to product success (McDonagh et al, 2002). However, product appearance, materials, shape and form provide the first impression for the consumer. The emotional bonding with a product is therefore an effective indicator of the success of the product (McDonagh et al, 2002). Eliminating negative experiences will also help to ensure the product maintains market share.

2.4 Summary

With the introduction of computers, there is more and more human interaction with technology. There are varying levels of acceptance of technology with eager adopters, hesitant users and resisters of innovative technology. Many users experience negative affect when required to use unfamiliar or innovative equipment. The reasons for these negative experiences can either be due to the individual's thought processes or a poor interface between the user and the machine. Thought processes can be changed to some extent, but human factors such as the physical and psychological constraints of the user need to be considered when designing an optimal human-machine system to ensure a pleasurable experience. Research in HCI has predominantly centred on human computer interaction and enhancing pleasurable aspects in product design. More research is required into human-appliance interaction. It is however, important to assess the learnability, usability and marketability of the design to ensure quality interface design. In the next section the current research project will be outlined. In this research a specific user group (people with low-vision) and a specific product (a low-vision reading aid) will be used as a case study to identify how limitations of design can be identified through user-centred design techniques.

3 Case Study

3.1 Interface Design for People with Low-vision

The design of the interface between user and machine is of paramount importance to the learnability, usability and “pleasurability” of a product. User-centred design is essential to achieving this. It is evident that accessibility to products that will enhance quality of life is important for both people with disabilities as well as able-bodied people. Interface design for people with disabilities is important for mainstream products, but perhaps more so for purpose designed products. Therefore, investigation of the interface design of a low-vision reading aid provides a good platform from which to investigate interface design considerations. In turn we can investigate the emotional relationship users have with technology in general and reading-aids in particular.

3.1.1 Low-vision Population

As previously mentioned, the first step in designing an appropriate product interface is to identify the intended user population. In the US 35% of those over the age of 70 have some form of visual impairment, for those over 85 this figure jumps to 65% (Vanderheiden, 1997). The existing low-vision population is reported as 75% older users, 15% in employment and 10% in education (Lund & Watson, 1997). Low-vision is caused by a variety of conditions, including age related macula degeneration (ARMD), diabetic retinopathy, glaucoma, retinitis pigmentosa and cataracts. The result is foggy vision, dimness, distortion, spots, extreme near or far sightedness, visual field defects and tunnel vision.

ARMD is the major characteristic type of low vision condition. It results from a deterioration of the macula, the outermost layer of the retina (Cassel, Billig & Randall, 1998). ARMD affects in excess of 10 million people in the US alone (D'Amato & Synder, 2000). The early stages of ARMD involve blurring of detail in the central vision while maintaining good peripheral vision. This makes many regular tasks such as reading difficult. Other symptoms include a need for increased light for close work and kinks appearing in straight lines or edges (RNZFB, 2001). Functional limitations caused by visual impairment affect the ability to see visual inputs of most kinds. Hand-eye coordination tasks (e.g. using a computer mouse) are affected and documentation needs to be prepared with consideration of the visual constraints (Vanderheiden, 1997). Reading aid users with vision disorders other than ARMD are a minority, but still need to be considered during product design, either those specifically for people with low-vision or mainstream products.

Population projections indicate that in all Western countries the number of elderly individuals will increase, both in absolute terms and as a proportion of the total population. In New Zealand, for example, the proportion of the population aged 65 and over was 11% in 1991 and 12% in 2001, but demographic projections show that this will increase to approximately 25% by 2035, or 1.22 million individuals (Statistics NZ, 2003). This also applies in the US where the older population is set to double by 2030 (Stephens et al, 2000). Because of this trend, there is likely to be an increase in the occurrence of age related ARMD and the need for products specifically designed for this group.

Older people with visual impairment offer a suitable population to investigate emotional relationships with consumer electronics, due to their ability to be more aware of their limitations and the shortcomings of the products they use. In a recent study comparing preferences and context sensitivity to consumer products it was determined that older adults were more context aware than younger adults (Stephens et al, 2000). Those with sensory or motor impairment showed the greatest context sensitivity. Therefore, user studies should involve elderly participants as they are likely to understand the impact of the products. It is suggested that this is because older adults have had more time to become aware of daily situations, and those with impairments are more aware of user-friendly design features and finding alternate ways to achieve their goals (Stephens et al, 2000).

3.1.2 Low-vision Reading Aids

The needs of those with low-vision are varied, but one that is integral to quality of life is to be able to read and write. In the literate world, reading and writing abilities are important skills we are encouraged to learn and use from an early age (Underwood & Batt, 1996). If one is afflicted by low-vision the need to read and write is not lessened, just made more challenging. Many elderly people live alone and if they have low vision they either have to rely on other people to read them their mail or use one of the various tools available to help them. For example, hand-held magnifying glasses allow the user to magnify text and see as they sign their signature. However, magnifiers have low levels of magnification, have a limited viewing area and can be cumbersome to hold. Large print and talking books are commonly available through public libraries and organisations such as the Royal New Zealand Foundation of the Blind (RNZFB). There is a wide variety of talking books, however not all titles are available and printed material such as newspapers, or crosswords are rarely converted to tapes. Additionally, the voices or accents of the narrators can influence the enjoyment of "reading". Talking clocks, calculators and other items are also widely available from the likes of the RNZFB.

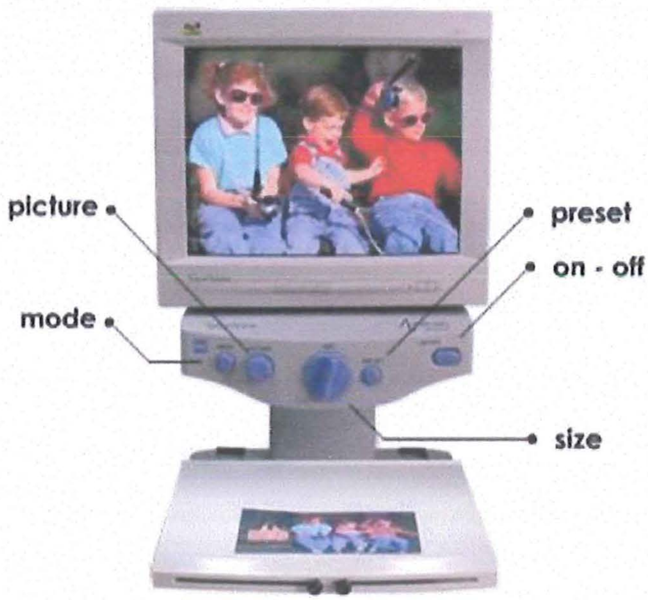


Figure 3.1: A SmartView 8000 closed circuit television video magnifier (from Pulse Data).

Existing Technology

One major innovation for people with low-vision is closed circuit television video (CCTV) magnifiers (see Figure 3.1). CCTVs overcome some of the limitations of hand held magnifiers by providing greater magnification and control, and offer access to almost all forms of printed material. CCTV uses a fixed zoom lens camera to display magnified text onto a computer or television screen. Text is placed under the lens and magnified and then displayed in real-time onto a screen. A light is located near the lens to illuminate the text. Users navigate the text with an x-y table that is moved under the camera to the required passage. The table moves along left and right (along the x axis) and backwards and forwards (along the y axis) and is usually moved with both hands[1]. As the magnified text is moved across the screen the beginning of the line goes out of view. Users must remember the beginning of the line they have just read so when they move the table back to the beginning they can reveal the next line when they move the page up.

A *size dial* adjusts magnification and a *picture dial* is used to select enhanced contrast, inverse video or false colours, if these are preferred and available on the model in use. False colour options provide different colours of text and background, for example white text on a black background, black text on an aqua background. Enhanced contrast offered by this function is especially important for poor quality print such as newsprint. Inverse video options (e.g. white text on a black background) are very important for many users who find a white background too bright to view for any length of time. Focussing is done either manually or automatically depending on the product and model. Some CCTVs also have controls for contrast and brightness. Writing is conducted in a similar way with text and pen under the camera[2].

Low-vision research suggests that typical tasks conducted using CCTVs include reading from books, magazines, newspaper articles and letters (Lund & Watson, 1997; Watson et al, 1997). People with low vision also use this technology to read bills, write cheques and

[1] Machines such as the Prisma do not have a table and pages must be moved manually under the camera.
[2] Machines such as the Esenbach have an additional swivelling camera that allows writing to be done in a more natural location, off to the side rather than directly in front of the user.

fill in forms. Many people with low vision have complimentary equipment for other tasks such as the aforementioned talking books and hand-held magnifiers (Cassel et al, 1998; Lund & Watson, 1997). Assuming that reading and writing are the major uses for the CCTV technology it is clear that adequate space for page turning and writing under the lens is important (Lund & Watson, 1997).

Despite their utility, CCTVs have several limitations. Discomfort can result from using the product for extended periods and viewing can be physically, visually and mentally exhausting. The physical requirements for dexterity and coordination to manipulate text under the camera are demanding. These needs can be further complicated among the elderly, the predominant user group, who may also have other health issues such as arthritis. The placement of the screen can also cause physical fatigue and stress. The screen is either included as part of the unit (on a platform above the lens), is a separate unit placed on top of the CCTV or is placed to the side of the machine. Few CCTVs have height adjustments[3]; therefore the screen is often at a suboptimal viewing height forcing the head to be tilted forward or backwards (see Figure 3.2). For those who place the screen to one side, twisting of the body or neck occurs as the hands moving the text are at angle to the screen.

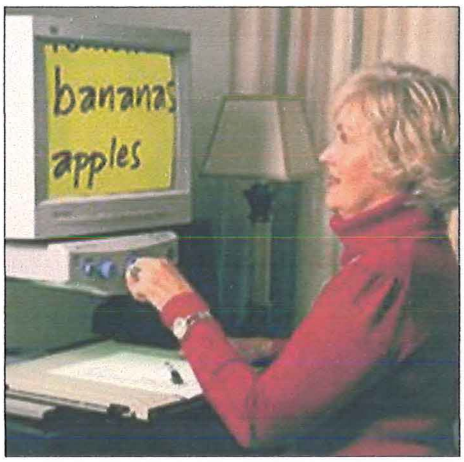


Figure 3.2: This user has her seat and screen adjusted appropriately, but because of the screen height poor posture if possible using CCTVs (from Pulse Data).

[3] During the thesis research, one participant noted that when she had an adjustable machine it dropped on her hand while she was trying to adjust it.

Visually, problems include the magnification of print imperfections, often resulting in fatigue when reading for comprehension. Further compounding this issue, the magnification required reduces the textual resolution and viewing text on a screen results in an increased visual load (Harpster et al, 1989). Motion sickness can also result from the movement of the text on the screen. Text is moved back to the beginning of the line very rapidly causing disorientation and resulting in "queasiness". Many people who could potentially benefit from using low-vision reading aids find this motion sickness too debilitating and refuse to use the machines. Users also need to remember the beginning of the previous line of text for long periods, which can cause a heavy memory load. CCTVs also require a lot of space, with a basic footprint of 355 mm x 457 mm added to by the room required to operate the x-y table (see Appendix B for specifications and Figure 3.3 for an illustration). If users have a screen beside the machine this calls for yet more space. Optimal operating room is a factor especially limiting for elderly people living in small apartments. The weight and size of the equipment also makes it difficult to transport or put away when it is not in use.

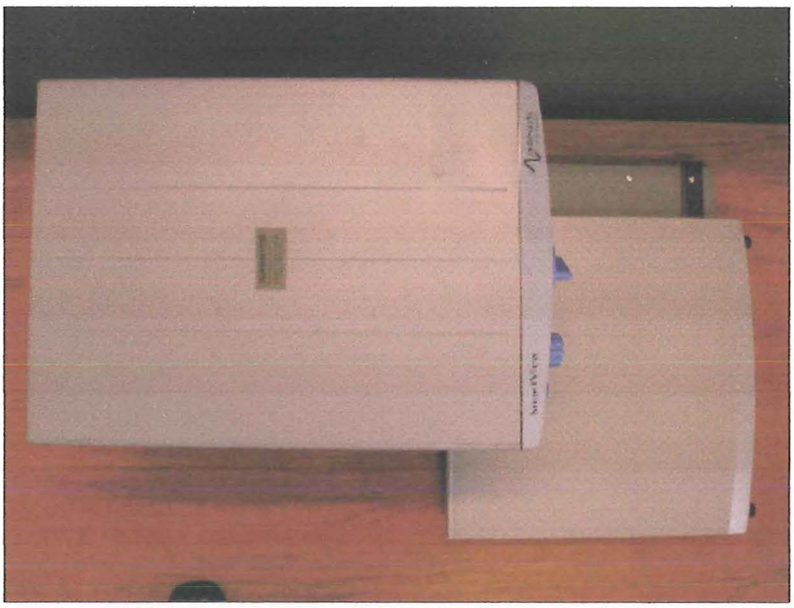


Figure 3.3: With x-y table fully extended the space required for a CCTV can be substantial.

Redesigned Technology

As detailed above, CCTVs have several limitations. The technology involved has also remained essentially unchanged for 20 years. However, technology is now available that may revolutionise the way people with low vision read and write and could eliminate many CCTV limitations. There is an increasing use of technology among the elderly which suggests they may be willing to embrace more technologically advanced alternatives (Brosnan, 1998). Optical Character Recognition (OCR) software has now progressed to a stage where it can enhance text to reduce visual fatigue. Processed text could be presented automatically, in either a single line or as a single column of text, eliminating the need for the x-y table and assisting with the flow of text. *Sans serif* fonts could be used to enhance the textual viewing experience. Synthesised speech could also be utilised, prolonging the life of the machine by accommodating worsening eye conditions.

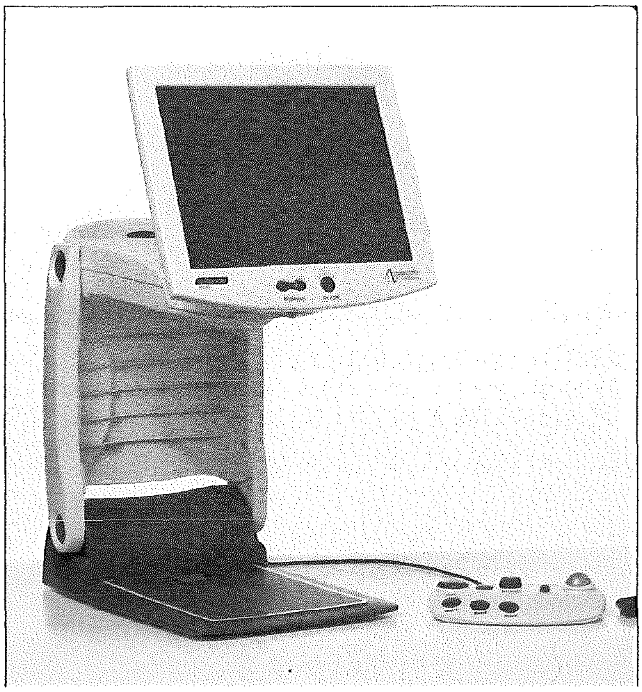
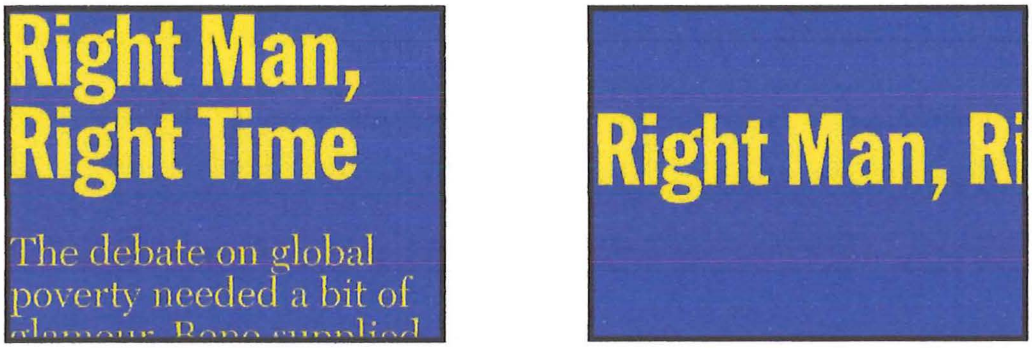


Figure 3.4: Prototype *myReader* low-vision reading aid with reader to the left and control panel to the right (from Pulse Data).

The *myReader*™ machine, a reading aid under development (see Figure 3.4), appears to overcome many of the limitations of CCTVs. *myReader* eliminates the x-y table of the CCTV machine by utilising processed text and automatic scrolling. The new product captures digital images of the target document, subjects the text to a variety of image enhancement and presentation techniques ensuring the content is presented to the user in an easily readable form. More specifically, *myReader* uses page segmentation to decompose a page into blocks, lines, words and letters and then rearranges them in various formats. In this way *myReader* is an advance over existing reading aids inasmuch as it reduces dexterity and coordination requirements, potentially increasing reading endurance and speed as well as improving functionality.



a) b)

Figure 3.5: *myReader* offers several modes of text presentation including a) Word-wrap mode and b) Marquee mode

To operate *myReader* users press the *start button*, text is scanned by an overhead camera and processed momentarily into a variety of formats including *wordwrap*, *marquee* or *rapid serial visual presentation* (RSVP) (see Figure 3.5 for examples). *Wordwrap* involves *myReader* processing and presenting the text in one single full-screen sized column that scrolls vertically. As magnification increases less words are presented on each line. *Marquee* presents the text in a single line of horizontally scrolling text. *RSVP* presents text one word at a time in the same location on the screen. *Image View* mode is used for reading material which is not able to be processed, such as graphs, tables and pages that are too complicated for the software to analyse successfully.

Figure 3.6: *myReader* control panel prototype #1 that was used for the pilot study
(from Pulse Data).

In the prototype used for this research, users had to press the *read button* to access processed text. Navigation of the processed text was then conducted manually via a *trackball* or automatically via a *speed dial.* These functions eliminate the need for manually moving an x-y table. *myReader* incorporates an auto focus system so no manual focusing is required. A live function, essentially the same as CCTVs, allows users to write and do manual tasks that need a live image such as viewing insects or can labels. *myReader* also has enhanced contrast, inverse video and false colour options, operated via the *picture dial.* Magnification is set using the *size dial* as on CCTVs. Figure 3.6 details how these controls were laid out on prototype control panel #1 used for the pilot study.

3.1.3 Low-vision Reading Aid Users

During the research detailed herein, *myReader* was in the middle stages of development with many major design decisions already made by engineers and designers with little consultation with the target market. One of the objectives of this research was to gather information regarding the user's specific needs and preferences to enhance the design as part of an iterative user-centred design process. CCTVs have a simple and learnable interface, and so any new product should maintain this. Increased functionality should not be at the cost of usability, learnability or pleasure. The goal then was to develop a new system that takes advantage of new technology, maintains the learnability of existing technology, improves usability in terms of reading speed and comprehension, reduces physical demands by eliminating the x-y table, and provides users with a pleasurable reading experience. To determine how best to achieve these goals the specific user considerations must be determined. Using Jordan's pleasure framework, the sociological, ideological, physiological and psychological needs of this particular user group can be used to determine elements for the best layout design.

Sociological

Sociological pleasures refer to those relating to relationships with others, to social settings and opinions. Meeting the challenges of day-to-day living can cause negative emotional reactions for people diagnosed with low vision problems (Flax, Golembiewski & McCaulley, 1993). Many people with low-vision conditions may suffer psychological symptoms due to the feelings of isolation and fear of further deterioration associated with their diagnosis (Flax et al, 1993; Cassel et al, 1998). Denial, anger, depression and feelings of social isolation are common. While the feelings follow a typical grief pattern, some people can become stuck in any one of these emotions and also have feelings of fear about their condition worsening. A sense of normalcy is important, since people do not want to be seen as different or a burden by their peers (Cassel et al, 1998). Due to feelings of isolation, products that can increase interaction with other people and reduce dependence are important. CCTVs are large and heavy and not particularly portable or storable. As many New Zealanders, young and old, spend their summers in holiday homes or caravans, a portable reading aid would further assist in improving social acceptance as users could take it on holiday and store it out of sight.

Facilitating the social aspect of reading is crucial. Low-vision reading aids, *myReader* in particular, may help by providing users information for discussion with their peers. Maintaining or improving quality of life is important; having the independence to read and write and having things to discuss will assist in facilitating social interaction. As people with low vision problems may already suffer from isolation, it is also important to ensure that any aids they use do not compound any feelings of social isolation, by making them feel different when people visit them in their homes and see the aids. Possessions communicate a symbolic expression of who people believe themselves to be (McDonagh et al, 2002). Reducing the clinical look of products will reduce feelings of social isolation caused by any perceived negative stigma of being "ill". However, as the main user demographic is older a more conservative look rather than one that is overtly modern may be a better option. Therefore, high contrast conservative colours should be used, avoiding clinical colours.

Ideological

Ideological factors are those pertaining to peoples' values and beliefs. While product function is important, the form of the product also plays a major role. It is proposed that this user population has a less consumer oriented value system than younger adults; as such they do not want to "waste" money. They often refuse to buy equipment that cannot be of benefit to other people once they die. Furthermore, they may have more environmental concerns. The environmental impact includes the chemicals used to produce a product, the energy consumption during use (which accounts for 80% of impact) and disposal (Sauer et al, 2002). Therefore, the use of renewable/recyclable resources used in manufacture and possible information on resale options are advocated for this population. The RNZFB does offer lease options that may partially address this issue. However, a lease over several years can ultimately cost more than a purchase.

Psychological

Many people with low-vision conditions may suffer a psychological impact due to the feelings of isolation and fear of further deterioration associated with their diagnosis (Flax et al, 1993; Cassel et al, 1998). As many of these users may already suffer from emotional difficulties due to their condition (Lund & Watson, 1997) and may have a tendency to be more prone to technostress (Rosen & Weil, 1995), they may also be more susceptible to frustration than other consumers. Therefore, it is important to reduce the chance of frustration by reducing the number of potential errors and making the control system as approachable as possible. Reducing frustration can be achieved by optimising the interface design.

People like to have control over what is happening to them and around them. Having a sense of control over computers can help reduce a sense of anxiety (Brosnan, 1998). With an automatic scrolling option a feeling of a lack of control may result. In addition, the saccades and regressive eye movements involved in reading require control over the rate of word presentation. Low-vision users make more saccades and regressive eye movements than normally sighted individuals (Lund & Watson, 1997). Therefore, the ability to easily override the automatic function and go back over missed or misunderstood words will address this. This is possible with *myReader* as the *trackball* can temporarily override the automatic scrolling function.

It is important to remember that people generally have a limited cognitive capacity (Anderson, 2000). People not using cognitive skills may also lose capacity, therefore reading aids help maintain cognition by encouraging intellectual stimulation (Lund & Watson, 1997). Due to the age of this user group, cognitive capacity may be further reduced with learning and retaining skills more difficult than for younger people. Hiding infrequently used controls minimises clutter and confusion, making it easier to perform basic tasks (Jordan, 1998). Low-vision reading aids provide users with cognitive stimulation through increased capacity to read. *myReader*, with its increased functionality may in turn increase cognitive stimulation by encouraging reading but also because operating the machine will require use of cognitive functions that may be currently under utilised. Reducing the number of arbitrary allocations of function, multiple functions and hiding unused keys could help minimise the cognitive load. Reducing learning time is also important to reduce frustration.

Physiological

As the primary low-vision market group is older, co-morbidity is another issue that needs to be considered. As well as having low-vision, many older adults may suffer from arthritis, which can reduce joint movement and strength (DTI, 2000). Biomechanical considerations are important for any product, but perhaps more so for the elderly or physically impaired, due to the deterioration of physical capacity. User anthropometrics such as hand length, breadth and spread are important in determining the optimal design of the control panel (Pheasant, 1996). The smallest person needs to reach all the buttons while the largest hand must still be accommodated, therefore it is important to use the 5th percentile female and the 95th male percentile figures (Pheasant, 1996). Anthropometrics of an elderly user group are different than the younger population, usually with smaller dimensions. The control panel needs to accommodate as much of the intended population as possible and consider the above limitations.

The Department of Trade and Industry in the UK have formulated data of maximal force abilities for various demographics (2000). It is clear from this data that older adults have decreasing force abilities after age 50, with those over 70 having significantly less strength than younger adults. This includes both button pushing and wrist twisting actions, both of which are involved in operating *myReader*. In addition, if co-morbidity is apparent in the user population then reduced force requirements are more important. Therefore it is suggested that the force required for control operations such as button pushing and knob turning, be kept to a minimum to avoid users struggling with them[4]. It is however, important to ensure the buttons and knobs cannot accidentally be operated.

Prolonged screen viewing causes fatigue, sitting in suboptimal conditions can cause back and neck aches, sustained scrolling movement can cause injury, and wrist deviation can cause tendons to bunch when the wrist is bent. These factors can lead to repetitive strain injuries or exacerbate existing conditions (Sanders & McCormick, 1993). Strength is

[4] Recommended force requirement for pressing of buttons with index finger of the general population is 35N (Pheasant, 1987).

greatest when the wrist is in a neutral position (Pheasant, 1996). Therefore it is important to provide optimal conditions for sitting and viewing and avoid deviations and repetitive finger action when operating the machine. It is important to adhere to good ergonomic principles in the design of the set up of the system. In a study into CCTV use by veterans, poor ergonomics was cited as one of the main concerns and aspects that could be improved (Watson et al, 1997). Improving the ergonomics requires having an adjustable screen height to accommodate a variety of users and seating situations. The control panel needs to minimise wrist deviation, across body movements, and the need for users to have a twisted body position to view the screen. It is also important to provide users with information about optimum seating set up when they purchase or hire a reading aid.

As well as the appearance of the control panel, it must also feel good especially to a user group whose other senses are heightened (Magee & Milligan, 1995). Therefore it is suggested that the control panel offer a pleasant tactile and aural experience with soft formed rubber for buttons and less mechanical sounds as feedback. Another important consideration is the physical environment in which the machine will be used. As the major user population is older it would seem that many of them would live on their own and in smaller accommodation. The size of the equipment and its footprint are therefore important considerations. *myReader* does have a smaller footprint than most CCTVs and without the need for the x-y table and with the potential to use a liquid crystal display (LCD), space requirements are further reduced.

3.1.4 myReader Control Panel Design

One of the objectives of this research was to help optimise the physical layout of the control panel. The type, size and placement of input controls are important considerations for usability.

Controls

In the initial developmental stages of *myReader*, the company was unsure what type of control to use for navigation. Several options were considered including a track ball, joystick or four-way rocker. Determining which was more appropriate depends on several variables, including user preference and task achievement. These can be evaluated during user trials. However, after initial consultation with engineers and industry specialist it was decided to use a combination of a *trackball* and a *speed dial*. The company also decided to use a variety of different shaped controls for different functions, since varying the shape, type and size of controls improves the discriminability (Vanderheiden, 1997). Button shape can have a significant effect on a user's ability to locate and actuate them. The control panel shown in Figure 3.6 shows the different shapes of controls used.

Designers have a variety of information available regarding optimum sizing of buttons (Pheasant, 1987). However, the target user group are people with low vision, so the concept of enlarged buttons is supported to assist in location and activation. In addition, the larger the knob/dial the less force is required to operate it, which should assist users with reduced strength (Pheasant, 1987). A positive report of activation is necessary in push buttons and knob controls, to inform users when they have achieved the intended action (Sanders & McCormick, 1993). Due to the enhanced sensory input from touch in this user group and to reduce any mechanical feel, it was recommended that softer buttons would improve the emotional response of users. Concave buttons could also increase the ability of users to find the buttons easily as their fingers settle into the indentations (Vanderheiden, 1997). Finally, if users are tired, or have additional disabilities that reduce their cognitive performance it is useful to include any labels in a tactile format (Vanderheiden, 1997).

Colour

With low-vision users it is important that the colour of the controls is in high contrast to the control panel to aid location and activation. Yellow, orange and red are the most conspicuous against black (Pheasant, 1987). These colours should also be positive and stimulating. However, red is associated with some forms of colour blindness and should be avoided as red on black has been associated with reduced reading speed (Kleweno et al, 2000). It is suggested that yellow on black provides a high contrast for a majority of users (D'Amato & Synder, 2000) and also fits with a less clinical look, but is perhaps too modern for this demographic. Colour coding of controls is only recommended when operation is critical (Pheasant, 1987). In this instance the different shapes of controls, the placement and the labelling would make colour coding redundant and may negatively impact on the aesthetics, due to the combination of several different and potentially uncomplimentary colours.

Button Operation

On/off functions for each button are suggested as a better alternative to buttons that support toggling between modes. Clicking one button to activate a mode which is then turned off by clicking another button can cause confusion and requires users to make additional associations (Pheasant, 1987).

Placement

Optimum placement of controls is dependent on the frequency and sequence of their use. Having controls that are used regularly too far from the resting working position reduces efficiency, increases physical workload and can create frustration (Sanders & McCormick, 1993). While in existing technology the focus and magnification controls are those most commonly used (Lund & Watson, 1997), assessment of which buttons are used in the redesigned technology was part of the research documented here. Optimum placement of controls also depends on the order in which they are used. Sequential controls should be close together and be operated from left to right or top to bottom (Pheasant, 1987).

Ergonomists recommend that the placement of buttons be based on guidelines such as the frequency and sequence-of-use principle (Sanders & McCormick, 1993). Those buttons used most frequently should be placed as close as possible to the hands used to operate them. In addition, those used in sequence should be placed in sequence. Controls that are used sequentially should be placed in close proximity to each other in the order they are activated to allow quick and easy access (Sanders & McCormick, 1993). Determining the expected sequence and comparing this with the actual sequence can provide insight into required design adjustments as regular deviations from the expected sequence may reveal actions that are not intuitive.

3.2 Low-Vision Reading Aid Evaluation

3.2.1 Existing Low-vision Research

Most research regarding CCTV use has related to optimising character size and presentation methods (e.g. Ahn & Legge, 1995; Harland, Legge & Luebker, 1995; Lowe & Drasdo, 1990), and assessing the training and continued use of the equipment (Watson et al, 1997) rather than investigating optimal design. A thorough summary of previous research is available in Lund and Watson's (1997) book "CCTV". Previous low-vision research has used a variety of measures, including self-report and post-experience questionnaires and interviews. Objective performance measures have included analysis of user behaviour during use of the interface and assessing reading speed by averaging the number of words per minute from a set piece of text. Text comprehension has been assessed by asking questions about the text upon completion (Harland et al, 1995). However, proven evaluation methodologies for many of the variables under consideration in this thesis are scarce (Lund & Watson, 1997). Therefore, much of the methodology used here has been compiled from a variety of human factors, product design, technostress and low-vision areas and combines both objective and subjective measures.

3.2.2 Overview of Research Project

The multiple award winning, Christchurch based, international electronics company, Pulse Data International, employed the Human Interface Technology Laboratory NZ (HIT Lab NZ) to conduct an expert appraisal of the *myReader* control panel prior to its progression to the tooling phase. Tooling, the process of creating the tools used in production, takes place once the final design of a product has been confirmed. Pulse Data wanted a human factors analysis to be conducted prior to this phase, to ensure the tools would not have to be reworked if significant design flaws became apparent. Further research evolved from this initial evaluation. The research detailed in this thesis therefore has three phases;

1. An expert appraisal and task analysis (briefly summarised below)
2. A pilot study comparing performance of CCTVs and *myReader*, but specifically looking at *myReader's* control panel layout (the subject of Sections 4 and 5)
3. A main study comparing objective and subjective performance of CCTVs and *myReader* and assessing emotional relationships with technology (the focus of Sections 6 and 7)

<u>Expert Appraisal and Task Analysis</u>

Prior to any experimentation, an expert appraisal was conducted of the prototype control panel of *myReader*. Expert evaluation is a cost effective method for product evaluation and is often used for initial assessment of products that have progressed through development with little user involvement or human factors assessment (McQuaid & Bishop, 2003). An expert analysis involves a team of usability experts assessing a product to identify positive and negatives attributes of the design. The author, along with two other researchers from HIT Lab NZ, visited the offices of Pulse Data where the working prototype panel was assessed. Assessment involved discussing the intended functions of *myReader* with the design team and interacting with the prototype. A report from this evaluation was produced for the company detailing the strengths and several limitations identified (Harrison, 2003a).

Following the results of the expert evaluation, Pulse Data agreed that further investigation in terms of user studies was warranted. A rudimentary task analysis was then conducted to get a clearer picture of what CCTV, and potentially *myReader*, users do with their equipment (see Appendix C). This was a simple task analysis rather than a hierarchical task analysis (Stammers & Shepard, 1995). While task analysis usually involves spending time with users to assess specific activities, this was not possible in this instance due to the time constraints imposed by the company's production schedule. Instead information from a review of previous low-vision research (Lund & Watson, 1997) and Pulse Data staff experience was used. By conducting the task analysis an in-depth understanding of required actions to achieve goals was identified and possible errors highlighted. This information was later utilised in the design of the pilot and main studies.

Pilot Study

Nielsen (1993) states that most severe usability problems are revealed by as few as 4 or 5 participants, with diminishing returns when including more evaluators. Therefore a small scale study was undertaken to determine optimal configuration of controls prior to tooling commencing. The pilot study employed simplified techniques to compare performance between existing and redesigned technology and make recommendations on control layout. To determine the optimum button configuration, an analysis was conducted of the frequency and sequence of button use as well as a qualitative study of how buttons were used by real users. The prototype control panel's operating software included the facility to log all button presses. Evaluation of whether all of the buttons were required for efficient task performance was also assessed. Finally, the pilot study provided an opportunity to gather subjective feedback on the physical interface design. Methods utilised for the pilot study are detailed in Section 4, the results and discussion are in Section 5.

Main Study

While the pilot study provided valuable information on control panel layout, methodological limitations meant that it was not able to record performance measures that could be statistically analysed. Therefore, in the main study the focus was on assessment of learnability, reading speed, comprehension and endurance to determine if the redesigned product was in fact superior. Methods to assess the emotional relationship between participants and the products were also utilised. Methods for the main study are detailed in Section 6 with results and discussion in Section 7.

3.2.3 Experimental Approach

Due to the nature of the study, a combination of both objective and subjective measures was utilised. Objective methods provide quantifiable measures of performance, such as time taken to achieve competency, time to complete a task and number of correct responses to comprehension questions. However, not everything can be measured objectively and it is possible to gather more information than can easily be interpreted (Sinclair, 1995). Qualitative information is not necessarily accessible without subjective measures. For example, while anxiety has been measured using objective physiological correlates, if problems occur with equipment or the results are unreliable (as occurred in this research) subjcctive measures provide the ability to acquire data that is not necessarily obtainable otherwise (Sinclair, 1995). However, the reliability of subjective questionnaires is often in question as researchers cannot always know if everyone is scoring in the same way on a 7-point scale. They do have credibility when personal judgement is important (Sinclair, 1995). One of the limitations of subjective measures is the potential for bias. Users can prefer design features that actually hinder their performance (Stephens et al, 2000). Social desirability bias can downplay problems experienced as participants censor their responses (Kanis et al, 2002). Memory processes and rationalisation of answers can also affect retrospective reports (Kanis et al, 2002). The Hawthorne effect of results being influenced by the mere inclusion of the participant in a study may also be evident (Muchinsky, 2001). Therefore, triangulation of a variety of objective and subjective methods can ensure a more thorough understanding of the phenomena being studied (Sinclair, 1995).

Subjective Measures

Previous research into the emotional relationship between users and products have utilised a variety of questionnaires and surveys (see Brosnan, 1998; McInerney, 1997; Weil & Rosen, 1997). However, few have been widely used and many of them have had specific agendas. For example, the Pleasure with Product general index (Jordan, 1997) specifically addresses positive emotional elements without identifying what aspects of technology may cause negative emotions. One method that has revealed reliable results is one formulated by

Rosen and Weil (1995). This tool involves participants imagining their interaction with technology and choosing as many adjectives (from a list of 30) that apply to how they feel.

Objective Measures

Objective performance measures used in this study included assessing reading speed, comprehension (Harland et al, 1995) and time to achieve competency (Stanton, 1998). A comparison of endurance between machines was also used. Objective measures that could be used to assess negative responses include physiological measures such as heart rate, galvanic skin response and blood pressure. Many of these tools have been used in other research to assess workload and anxiety. For example, in a study into airplane pilot stress measures such as electro-myography (EMG), electro-encephalograms (EEG) and heart rate variability (HRV) were used in simulators (Watson, 2001). Despite the value of the research done in simulators, these researchers wanted to find a measure of stress that could be performed *in situ*. Therefore, they used EMG monitoring with chest electrodes on pilots during a long-haul flight. Major events that could have influenced physiological responses such as high stress take-off and landing situations were recorded on data files as they occurred and matched with heart rate data collected from the electrodes which provided good conductivity. Stressful events such as landing did result in observable differences in the pilot's HRV. As the pilot's workload increased, the variability in high frequency components reduced (Watson, 2001).

Measurement of HRV is a growing area of research both in medicine and psychology (Thayer, 2002). For psychology the link between emotional arousal and heart rate variability may be due to the association of the prefrontal cortex and amygdale being closely related to HRV (Thayer, 2002). HRV analysis is either determined in the time or sequence domain (Friedman et al, 2002). In the time domain, HRV is derived from interbeat intervals (heart period) or differences between adjacent interbeat intervals (heart rate). Frequency domain HRV uses spectral analysis and is computationally complex. The most reliable results have been gathered using electrodes (Friedman et al, 2002). In a study into the relaxation effects of different types of music (classical versus rock), heart rate was measured using a plethysmograph, plastic clip, placed on the ventral side of the finger (Burns et al, 1999). These clips were used as an alternative to electrodes as they were considered less invasive. However, the results from the clips were susceptible to motion and hand temperature, and proved to be less reliable than electrodes. In Burns et al's study there was little physiological evidence of a decrease in arousal to support the participants who reported feeling more relaxed (1999).

A visual field test provided further objective data. Central field loss was determined to be a possible confound for reading speed by Harland, et al (1998). They used medical reports to obtain low-vision diagnoses. This approach was deemed uneconomic for the research undertaken for this thesis. Therefore, after consultation with an optometrist to determine a viable alternative, an Amsler Grid test was identified as an economic alternative to assess whether the central field of vision was intact or damaged, for people with low-vision. The benefit of the Amsler Grid is its simplicity and that it can easily be administered by a layperson. The Amsler Grid is described in more detail in Section 6.2.2.

Inadvertent expressions such as gestures, postures, facial expressions and sighs can all be quantified and recorded during observation and may provide more relevant data than subjective retrospective reports (Kanis et al, 2002). When conducting observational studies it is recommended that the fewer interruptions the better (Drury, 1995). Only if the participant is visibly frustrated or the problem is common should the researcher intervene (Tamler, 2001). While a web camera could capture digitised footage, the image quality would be insufficient for content analysis. Combining video analysis of errors with data logs of button pushes also provided further objective data.

Think-aloud or verbal protocol analysis and workload assessment methods were considered for this research. With think aloud protocols, participants are required to verbalise explanations of their intention and actions, either as they perform tasks or retrospectively (Bainbridge & Sanderson, 1995). However, in this instance think aloud protocols were not used for several reasons. Firstly, if done concurrently verbalising their thoughts and actions could slow participant's reading (Harland et al, 1998), which could impact on the performance measures. Verbal protocol analysis could not have been done retrospectively as people with low vision would not have been able to "view" video footage of the interaction. In addition, think aloud protocols automatically indicate a research setting and may result in biases (Kanis et al, 2002). Finally, because people with low vision typically read significantly slower than normally sighted people they may also be embarrassed by the slowness of their reading. Assessing cognitive workload was also considered using measures such as the NASA Task Load Index (Hart & Staveland, 1988). However, due to reliability issues and the fact that many workload tools are designed for specific work situations rather than product interaction these were also discounted as suitable tools.

3.2.4 Scope of Thesis

Given the revolutionary design of *myReader*, it is evident that there are gaps in quantifiable research regarding performance of a low-vision reading aid of this type. This research project offered an initial opportunity to assess *myReader's* performance as a prototype after short duration exposure. Research regarding interface design, user preference and task achievement is lacking for consumer products in general, and for low-vision products specifically. This research provided a chance to offer design suggestions to reduce negative emotion associated with human-machine interaction and assess methods that could be valuable in assessment of other products. Low-vision research and human-machine interaction research reveals a large number of variables which could be considered when designing a product; from optimum text presentation mode to training methods.

This research does not attempt to specifically address any of the multitudes of individual fundamental issues associated with low-vision reading due to the time constraints of a Masters thesis. Instead, the case study focused on the applied issue of optimising the interface design of a low-vision reading aid to enhance the emotional relationship between users and the product. The research provided an opportunity to gauge the level of technostress evident in this population and determine whether this has an impact on interface design. By understanding how people interpret and use objects in their daily lives we are in a better position to design optimal devices to support their activities.

3.2.5 Research Objectives

Therefore, the research objectives were to

- Investigate the positive and negative emotional relationships users have with this consumer product
- Assess which aspects of the interface were significant in effecting learnability, usability and pleasurability
- Determine whether performance was better with *myReader* or CCTV
- Determine user preferences between *myReader* and CCTV
- Determine the correlation between usability and preference
- Assist the company in the design of a learnable, usable and pleasurable product.

In essence, the global hypothesis of the research project is that by considering the affective response to products, users' emotional relationships with, and the utility of, consumer electronics can be enhanced through improved interface design.

4 Pilot Study Method

The pilot study offered an opportunity to trial methods for the main study and gauge initial user feelings regarding the manufacturer's low-vision reading aid concept, *myReader*. However, the pilot study's main purpose was to assist the manufacturer in the development of the low-vision reading aid that incorporates functionality offered by new technology. Methodologies used for the pilot study follow those summarised in Lund and Watson (1997). The main objectives are summarised below with more details of the participants, materials, procedure and design in the following sections.

- *Control Panel Layout* – Frequency and sequence of use of the individual controls on the control panel were recorded and analysed to assist the manufacturer in deciding on optimum control placement.

- *Performance* – Quantifying the differences in participant performance for similar tasks with CCTV and *myReader* machines assisted the manufacturer in determining whether *myReader* achieved their goals of improving reading performance.

- *Universality* – The current button configuration on the control panel was assessed by analysing any difficulties experienced by users. This helped to ascertain if *myReader* presented any problems for left-handers specifically and users in general. This enabled the manufacturer to decide if redesign was necessary to accommodate left-handers.

- *Pleasurability* – Analysing data from post-test semi-structured interviews determined how the users felt about *myReader* in comparison to CCTVs. Additional information regarding their needs helped determine further suggested design changes. This enabled the manufacturer to ascertain whether users were comfortable with the product and whether development should continue.

4.1 Participants

Once University of Canterbury Human Ethics Committee approval was obtained, six participants were recruited from the manufacturer's Christchurch database of existing and prospective clients. They were all members of the RNZFB. Participants ranged in age from 31-83 with an average of 66.5 years. Two were males and four females. One of the males was left handed. Three were existing CCTV users (experts) and three were not current users (novices). Two had retinitis pigmentosa, one had glaucoma and three had ARMD. All participants received a small box of chocolates for their participation at the completion of all testing.

4.2 Materials

4.2.1 Telephone Questionnaires

Due to the dearth of reliable and valid questionnaires, one was created combining demographic information, technology exposure and level of comfort with technology, using both open ended questions and those using a 5 or 7-point Likert scale. See Appendix D for these questionnaires. Rosen and Weil's adjectives tool to determine user type by determining the relative number of positive or negative adjectives chosen (1995). The questionnaire was piloted in a study into the design of a wearable camera (Harrison, 2003b) and provided two measures of technostress;

- Firstly, a mean grade of technostress was determined by totalling the sum of the raw scores in individual items relating to respondents opinion of technology. A high score suggested a high level of technostress
- Secondly, a list of 30 adjectives (15 positive, 15 negative) was scored to provide a classification of whether participants were eager adopters, hesitant users or resistors (Rosen & Weil, 1995).

Questionnaires were user-group specific (i.e. expert or novice). For expert users the questionnaire included items regarding current use of existing CCTV technology, while the novice questionnaire related to use of other low-vision reading aids and where and for how long they envisaged using a CCTV, if they ever got one. Suggested responses were offered but questions were open ended to allow feedback and discussion.

Questionnaires gathered demographic information (age, sex, disabilities, handedness, profession, education, accommodation type) and included questions relating to the participant's eye condition (diagnosis and time since diagnosis). To trial questions relating to technostress the questionnaires used 7-point Likert scales to assess negative emotion regarding technology such as

"Have you ever felt frustrated when using a new electronic product?"

Aspects from Rosen and Weil (1995) were included, such as their measure of psychological reactions to computerised technology using a list of feeling adjectives. There were also questions to gauge technology exposure such as

"How many hours do you spend using a computer per week?"

In addition to the questionnaire, comments made during testing and post-test interview information provided additional subjective data. In post-test interviews, participants were asked to discuss the experience of using both machines. One of the final questions related to machine preference. Repeated errors and negative comments made during testing regarding frustrating functions were analysed to determine aspects of the interface that could be altered to enhance pleasurability. Pleasurability was determined from a combination of the subjective assessment of participants, problems encountered with actions and their willingness to continue reading (endurance).

4.2.2 Low Vision Reading Aids

Closed Circuit Television Video Magnifier (CCTV)

CCTVs use a fixed zoom lens to display magnified text onto a computer monitor or television screen. Text is placed under the lens and the text is magnified and displayed on the screen in real-time. Users navigate the text by means of an x-y table under the camera. A *size dial* changes magnification and a *picture dial* is used to for enhanced contrast, inverse video and false colours if these are preferred (see Section 3.1.2 for further details). For this experiment, experts used their own video magnifier and screen

(2 SmartView and 1 Aladdin). Novices used a SmartView 8000 (Figure 3.1) supplied by the manufacturer (see Appendix B for specifications) with a 19 inch Compaq monitor.

myReader

Because *myReader* is still in development and a fully functional product was unavailable for testing, a rapid prototype of the *myReader* control panel was used throughout the study (see Figure 3.6). The prototype was run on a Compaq laptop using simulation software developed in C++ by the manufacturer, using a Windows XP operating system. A 19 inch Compaq monitor displayed the text. Monitors were the same for both products for all participants, except one. Due to one of the participant's CCTV machine being unable to accept the monitor connection. The Aladdin Classic machine used by this participant combines the monitor and CCTV in one closed unit. No external monitor could be connected. This is considered only a minor limitation not affecting the primary goal of testing comfort and performance.

myReader eliminates the x-y table of the CCTV machine, instead utilising processed text and automatic scrolling. Navigation of the processed text is via trackball or *speed dial* rather than manually moving the x-y table. Text is scanned by an overhead camera and processed momentarily into one of the three presentation modes, *wordwrap*, *marquee* or *Rapid Serial Visual Presentation (RSVP)* (see Figure 3.5). Wordwrap involves the computer processing and presenting the text in one single full-screen sized column that scrolls vertically. As magnification increases fewer words are presented on each line. Marquee presents the text in a single line of horizontally scrolling text. RSVP mode is also available on *myReader*. However, Harland et al (1998) found this was not a preferred method of text presentation for low-vision readers. Therefore it was not tested as it is expected that few people will use this text presentation mode. While some buttons had multiple functions, only the basic function of the *start button*, *read button*, *auto button*, *size dial*, *picture dial*, *speed wheel* and *trackball* were tested as the simulation did not simulate all aspects of the intended product's performance (see Appendix B for details).

4.2.3 Data Logging

The control panel's simulation software included a data logging function, which allowed collection of the frequency and sequence of use of each button. The data logging software time coded every activation of individual controls, detailing the degree of change. For example, data regarding activation of the *picture dial* would indicate how many times it was activated, how far and in what direction it had been turned. A sample of the output from the software is in Figure 4.1. Errors in appropriate control selection were determined through matching video analysis and data logging to the task analysis. Data logging was only available for *myReader* as a hidden, embedded function of which participants were unaware. No data logging function was available for the CCTV machines. This was not necessary as the primary focus was determining optimum configuration of buttons on the *myReader* control panel, not redesigning the CCTV machine.

```
2003-08-04 13:39:22 Logging initialised
2003-08-04 13:39:22 Reading cleaned up image
c:\\hercules\\images\\test01.cleaned.bmp
2003-08-04 13:39:23 have bitmap
c:\\hercules\\images\\test01.cleaned.bmp
2003-08-04 13:39:23 Loading thresholded image
c:\\hercules\\images\\test01.thresholded.bmp
2003-08-04 13:39:23 Reading textbmp
c:\\hercules\\images\\test01.textbmp
2003-08-04 13:39:23 Entering pan mode
2003-08-04 13:39:43 Button Read Pressed
2003-08-04 13:39:43 Entering wordwrap mode
2003-08-04 13:39:58 Size changed by 1 size now=1.100000
2003-08-04 13:41:00 Picture knob changed to setting 5
2003-08-04 13:41:26 Mouse movement: x=-85, y=-93
2003-08-04 13:42:17 Key M Pressed Mode
2003-08-04 13:42:17 Entering marquee mode
2003-08-04 13:42:29 speed change 0,current= 0
2003-08-04 13:43:10 Key M Pressed Mode
2003-08-04 13:43:10 Entering RSVP mode
```

Figure 4.1 Sample of data logged by *myReader* simulation software

Frequency

Expected frequencies were determined by assuming one trial page and four test pages, given that this was approximately the average for the study. The *go/start button* would be used the same number of times as the number of pages that were loaded. The expected optimum *loading time* was the maximum suggested in the literature. The *read/page button* would be used the same number of times as the number of pages to access text from the overview of the page presented once the page was loaded. It was predicted that the *size dial* would only be used once to set font size to the user's preference. The *picture dial* would be automatically set by the computer and once for the user to set their preference. The *auto button* would be used twice as often as the number of pages, once to initiate scrolling and once to stop, plus perhaps once or twice more for stopping a page if required. It was unclear how often the *speed dial* or *trackball* would be used for navigation. The *write button* was inactive, so it was assumed it would not be used at all. Table 4.1 details the expected and actual frequencies.

Table 4.1: Expected frequencies of button presses of *myReader* assuming 1 training page and 5 test pages.

Controls	Expected Frequency	Details	
Go/Start	5	# of pages	
Loading	10 sec	Maximum	
Read/Page	5	# of pages	
Size	-	Unknown	Total movements
	1	Set up	Initiations - trial
	1	Fine tune	Initiations - test
Picture	-	At least 5 computer generated	Total movements
	1	Set up	Initiations - trial
	1	Fine tune	Initiations - test
Auto	15	2x # of pages + extra stopping	
Speed	-	Unknown	Total movements
	-	Unknown	Initiations - trial
	-	Unknown	Initiations - test
Trackball	-	Unknown	
Write	0	Inactive control	

Sequence

The designers of *myReader* envisaged that users would press the *go/start button* to capture and load an image. Once the overview of the processed text was displayed, they would press the *read/page button* to access the processed text, adjusting size and picture preferences before pressing the *auto button* to initiate automatic scrolling and adjusting the speed and back tracking using either the *speed dial* or the *trackball.* Table 4.2 details the expected sequence of control activation.

Table 4.2: Expected sequence of button presses with *myReader*

Goal	Action
Capture image	Go/ Start Button
Access text	Read/Page Button
	Size Dial
	Picture Dial
Initiate scroll	Auto Button
Adjust speed	Speed Dial
Back track	Trackball
Stop	Auto Button

4.2.4 Reading material

Five passages of text were chosen (see Figure 4.2 for an example): one for the training phase (a TIME magazine article) and four for testing. Two passages were selected from TIME magazine and two from the first Harry Potter novel (Rowling, 1997), offering participants a choice of reading material to suit their individual interests. None of the test passages of text were presented more than once to any of the participants.


GLOBAL AGENDA MICHAEL ELLIOTT

Right Man, Right Time

The debate on global poverty needed a bit of glamour. Bono supplied it

WHEN A CELEBRITY FINDS A CAUSE, CYNICISM IS the first reaction. There are exceptions, of course, like the work of Paul McCartney and Heather Mills on land mines. But often, we suspect that we're being conned—that film stars and musicians have calculated that supporting some benighted group is a way of redoubling our reverence for them. And we know that some causes—Tibet, HIV/AIDS—are frankly more fashionable than others. Offhand, I can't think of one celebrity who has dedicated time and money to reducing the number of deaths from diarrhea, a killer throughout the developing world and one easily treated by simple, low-technology interventions.

[illegible] burg will take stock of the progress toward the U.N.'s "millennium goals" to eliminate extreme poverty and increase access to education and health care.

But if these initiatives are to get anywhere and overcome the suspicions of those in Washington who are convinced there are no votes in foreign aid, they need a constituency. The poor of the world can't just rely on "the usual 'poverty is bad' liberals," notes Lucy Matthew, who works for DATA, the policy network that Bono founded.

The model for a new approach is Jubilee 2000, which campaigned with great success to reduce developing-world debt. Jubilee 2000 was based in Europe, not the

Figure 4.2: Sample of a TIME Magazine article use as training text for the pilot study.

Text was placed under the CCTV camera as in normal use. Text material for the prototype *myReader* was scanned, digitised and loaded onto the Compaq laptop prior to testing to avoid delays caused by the stage of development. These images were presented using the simulation software developed by the manufacturer and presented in either wordwrap or marquee mode depending on participant's preference. As testing was of a prototype, the research did not test full functionality. However, participants were informed that for the working product, text would be placed under a camera, scanned and processed. This may have influenced users' impression of ease of use as they did not see full functionality.

4.2.5 Comprehension Questions

Five open-ended questions were prepared for each of the four sets of test text. Figure 4.3 shows an example of the format of the questions, a full list of questions is available in Appendix E.

TIME Magazine Article #1

1. What did the reporter feeding the boy? – Dumplings
2. Which river did the boy cross to get to China? – Tumen River
3. What was the name that the boy agreed to being called? – Jae Young
4. How old was the boy? – 17 years
5. How many days did he walk from his village? One

Figure 4.3: Example of comprehension question used in Pilot Study

4.2.6 Post-test Interview

Four separate post-test interviews were used, one for the initial interview with each product and one for the final interview with each product. Each participant was given only two interviews, one for each product. Questions were all open ended and included asking about how tiring and how easy the product was to use and how the interface could be improved. For *myReader,* additional questions were asked regarding best/worst aspects and how the buttons felt to the touch in comparison to soft buttons on a television remote control. If it was called for, further discussion regarding the interaction was entered into.

In the final interview, participants were asked which product they preferred and why. They were also asked, if they were to do the tasks again, whether they would be comfortable having their heart rate, blood pressure or galvanic skin response monitored while undertaking these tasks. This was to determine if physiological measures would be feasible for the main study given the user group. See Appendix F for full list of questions.

4.2.7 Environment

Since all participants suffered some form of visual impairment, evaluation was conducted in participants' homes or place of work, eliminating travel problems for them. Testing in the location where the product would be used under normal circumstances also ensured ecological validity of the results. Due to the tiring nature of participation in the study, two separate visits were required: one for CCTV and one for *myReader*.

4.2.8 Observers

Several of the manufacturer's designers and engineers were involved in the data gathering stage as passive observers of the interaction. It was believed they would benefit from witnessing actual users *in situ*, and they may have been aware of issues the researcher did not detect, which could be fed back into the design process. Given the time constraints and study environment, only one observer attended each visit. Participants were asked prior to arrival if it were acceptable to them if other people were in attendance.

4.2.9 Video Analysis

Two small digital video cameras (Canon ZR-50 and Sony DCR-TRV33E) were used to gather footage for later analysis alongside the data logs. The first camera (#1) was set up on a tripod over the left or right shoulder of the participant (depending on the test environment) and directed toward the control panel and screen of the reading aid. Due to the height of the monitors on top of the CCTV, and seating arrangements, the full screen was not visible for some users. To ensure user intention and actions could be matched, a second camera (#2) was connected to a TV-PC converter to capture screen activity (see Figure 4.4). Footage from both cameras was later downloaded to a computer where it was compressed using Ulead MediaStudio 6.5 Director's Cut. During editing, camera #2's footage was overlaid on camera #1's allowing more rigorous video analysis. All interactions in this research were video recorded for later analysis. Coding of footage was based on categories from the task analysis, correlating intention with action and comments.

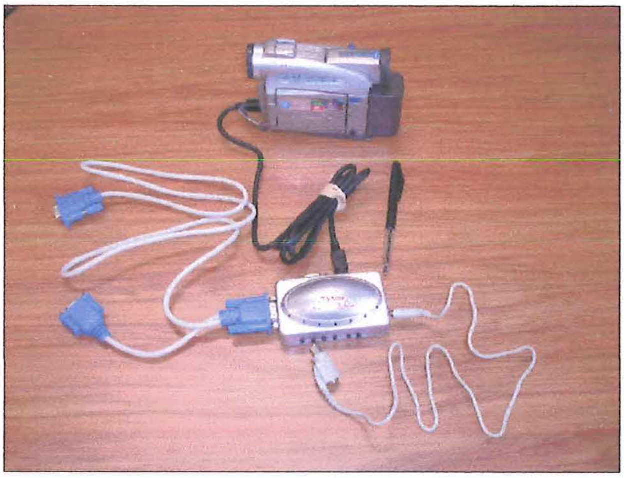


Figure 4.4: TV-PC converter used in to capture screen feed from monitor

4.3 Procedure

4.3.1 Telephone Interview

The researcher telephoned potential participants to discuss the project and confirm their willingness and ability to commit to 2-3 hours of data collection. This familiarised the researcher with the participant's individual requirements. Once recruited, participants completed the telephone questionnaire (see Section 4.2.1).

4.3.2 Set up

During the initial visit, an information sheet was read to participants and left with them if they had any questions (see Appendix G). The information sheet was printed in a bold 16 point sans serif font to assist participants if they had to read it later. They were then asked to sign a consent form (see Appendix H). Expert users were asked where they normally used their CCTV and novices were asked about a suitable testing area (see Table 4.3 for location).

Table 4.3: Location of testing

Participant	Study Location
1	Living room table
2	Bedroom table
3	Living room table
4	Living room table
5	Study
6	Workplace - Office

Testing in their homes or offices presented some problems as many CCTV users are elderly and live in small apartments. Therefore, equipment set-up had to be adapted to the individual conditions and Figures 4.5 and 4.6 offer schematics of a typical set-up. Given the visual impairment of the participants, an explanation of the equipment and its purpose was given as it was being assembled.

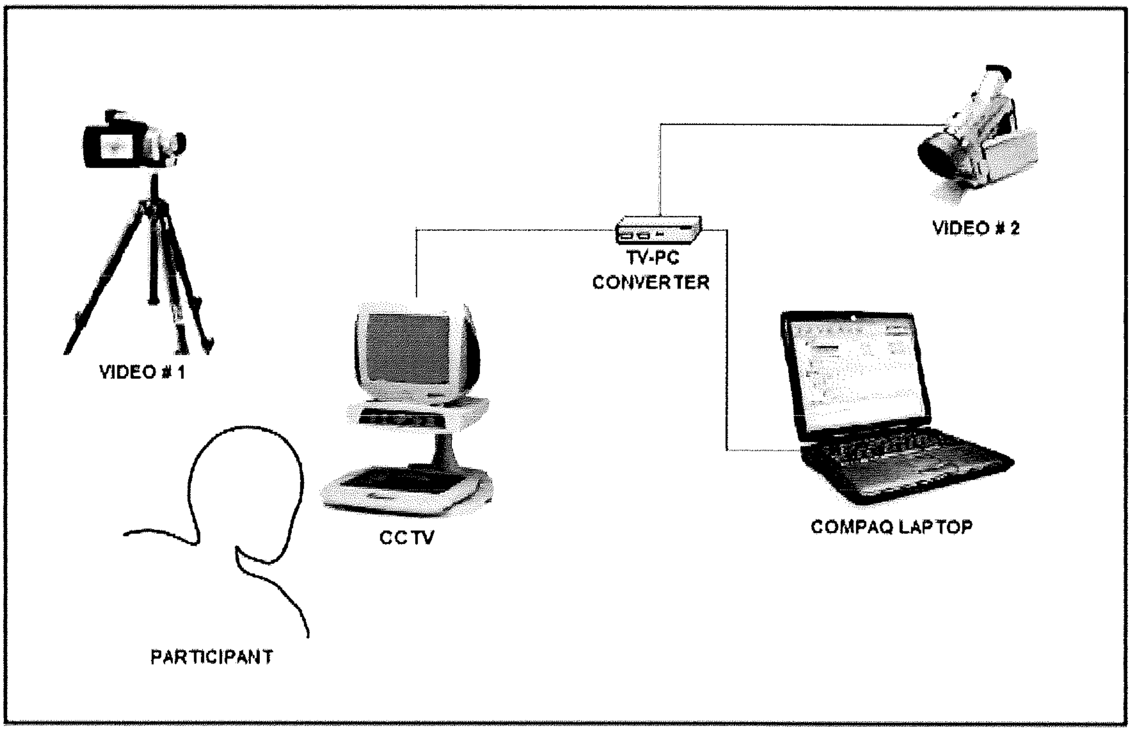


Figure 4.5: Schematic of experimental set-up for CCTV testing.

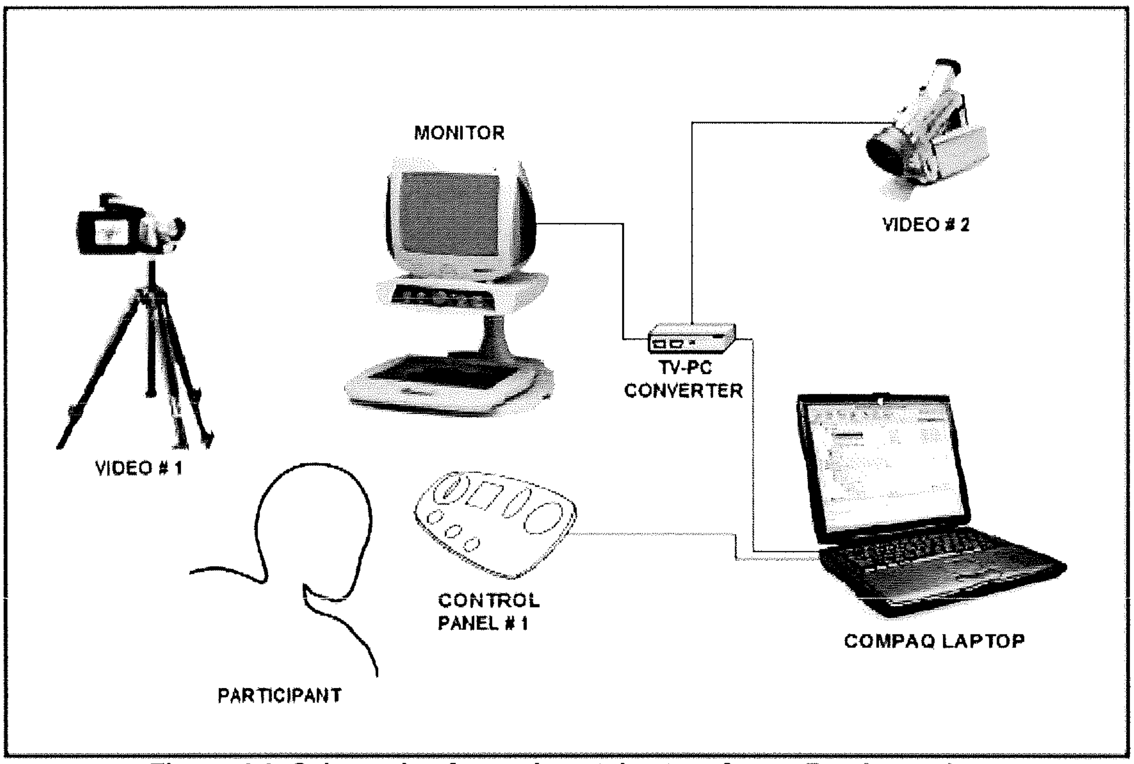


Figure 4.6: Schematic of experimental set-up for *myReader* testing

4.3.3 Training Phase

Once equipment was set up, participants were familiarised with it. For the CCTV equipment, experts went straight to the testing phase. After the training piece of text was placed under the camera, novices were instructed how to move the x-y table, how to adjust the size and change the false colours that were available. They were asked to select a magnification and colour combination that suited them. Their viewing distance from the screen, magnification, colour choices and seating were self-determined. They were then given several minutes to practice reading the text.

For the *myReader* prototype, the simulation software was initialised by the researcher. Both novice and expert CCTV users were asked for their first impression of the panel. They were then instructed in the primary function of each of the buttons on the control panel (see Appendix I for protocol). The training text was placed under the camera to indicate how it would operate in a working product. Participants were then asked to get familiar with the controls. The two text presentation modes (wordwrap and marquee) were also introduced and participants were asked to choose their preferred mode. They were then invited to ask questions, which were answered.

4.3.4 Test Phase

For each machine, participants were asked how they were feeling and if they wanted to continue with the testing phase. Once the participant stated they were familiar with the equipment and happy to continue, the testing phase was explained and commenced. Participants chose either one of the chapters from Harry Potter or one of the TIME magazine articles and were asked to read at their normal reading speed. Participants were also informed they would be tested on their comprehension at the end of 10 minutes.

At 2-minute intervals the researcher stopped the participant to determine how far into the text they were and asked participants to assess their level of fatigue to estimate their endurance. A stop watch was used to record reading speed. After 10 minutes the comprehension questions were asked to assess understanding of the material read. The number of questions asked depended on how far through the text they were.

Following the comprehension questions, the brief semi-structured post-test interview was conducted. If an observer was present and had questions, these were asked as the researcher packed up the equipment. Upon completion of the initial test, the final test was scheduled. After both texts were complete, participants were given a box of chocolates and thanked for their time.

4.4 Design

4.4.1 Conditions

As mentioned previously, reading material was chosen by the participants on the basis of preference. The comprehension questions were specific to the chosen text and were asked in the same order each time as they related to sequentially occurring pieces in the text. The order of exposure to the machines was counter balanced.

4.4.2 Control Panel Layout

Frequency and sequence of use of the individual controls on the control panel were recorded by means of the data logging software embedded in the prototype. This data was analysed in conjunction with video footage, matching intention with action. The expected frequency and sequence of use was determined from the task analysis and compared to the observed frequency and sequence of use. The data logs were converted into Excel spreadsheets, then, as the video was viewed, errors were hand coded into this spreadsheet alongside the corresponding control activation. Data logging recorded activation frequency for each control, sequence of use and loading time for the pages of text. The total number of times each control was activated was calculated. This was then broken down into how many times users initiated the control in the training phase and in the test phase. The focus was on *myReader* so no coding of CCTV tests were conducted.

4.4.3 Performance

The pilot study involved 6 participants and this was insufficient to obtain statistical significance for any of the performance measures. However, quantifying the differences in participant performance for similar tasks with CCTV and *myReader* machines was undertaken to assist the manufacturer in determining if *myReader* achieved their goals.

Reading Speed

Participants read their chosen text for 10 minutes. At 2-minute intervals, the place they had reached in the text was recorded, by asking participants to point to it on the screen. At the completion of testing, average reading speed was determined by counting the number of words read per minute and averaging this over the time they read for. If participants exceeded 8 minutes but were unable to reach 10 minutes, a comparison of reading speed was made at 8 minutes for both machines.

Comprehension

Comprehension was indexed by the percentage of correct answers for all questions asked, as some participants did not reach a place in the text where five questions could be asked.

4.4.4 Universality

The current button configuration on the control panel was assessed by analysing any difficulties experienced by users, for example, if users were inadvertently bumping controls, found the panel uncomfortable if there was no place to rest their wrist. This helped to ascertain if *myReader* presented any problems for left-handers specifically and users in general. This enabled the manufacturer to decide if redesign was necessary to accommodate left-handers.

4.4.5 Pleasurability

Participants were asked in the final post-test interview which machine they preferred and why. Information from the telephone questionnaires helped identify the ideo, socio, physio and psycho pleasure needs this user group has.

5 Pilot Study Results and Discussion

The pilot study revealed several areas where the design of the product could be adjusted to better match the users' needs. These are summarised in Table 5.1 and detailed in the following sections. It was clear that those tested preferred *myReader*, despite having some difficulties with initial use. The pilot study methodology also had several limitations which may have affected the outcome of the performance measures, including the small sample size not allowing statistical analysis of results.

Table 5.1: Summary of design suggestions for the company following the pilot study.

- Use of user-centric wording instead of "loading" advocated
- Text to be presented at the same size, including titles, to avoid repeated size adjustments
- Use alternative means to highlight different aspects of the text
- Loading time should be kept below 10 seconds
- Distraction or feedback should be provided to reduce frustration with loading delay
- Extra room on edges of control panel for holding and to avoid bumping *size dial*
- More space required for wrists to rest to eliminate hovering and poor wrist placement
- Allow more space for access to the *speed dial* to avoid bumping the *trackball*
- Tighten up the *size dial* to make it more difficult to bump
- Alter the *size dial* to allow entry to adjusted text to embrace intuitive actions
- Allow movement of the *trackball* to mimic text mode (vertical wordwrap – horizontal marquee) and direction (stroke left to scroll left – stroke up to scroll up)
- Alter direction of *speed dial* to reduce errors in activation
- Provide tactile feedback on *speed dial* when stop reached to avoid backtracking
- Continue to allow *speed dial* to back track
- *Speed dial* to have smaller increments to allow finer adjustment
- Use the *go/start button* to initiate scrolling rather than *auto button*, to eliminate need for one button
- Continue to allow *speed dial* to initiate scrolling
- Provide margins in wordwrap mode to assure users that all text is on screen
- Processing of text needs to eliminate fuzzy letters in text to avoid distraction
- The labels on the controls need to be bigger and bolder or alternate identification used
- Raised dots on buttons could be eliminated as they did not aid location
- High contrast of colours of the panel and controls needs to be maintained
- Dials are needed on the screen to allow for brightness and contrast adjustments
- *myReader* screen needs to be height adjustable to ensure good posture
- Provide information regarding good seating arrangements

5.1 Control Panel Layout

The pilot study revealed that the expected and observed frequency and sequence of use did not entirely match. Loading time was longer than recommended, the size dial was used more frequently due to confusion regarding accessing the processed text, participants did not initiate scrolling in quite the way expected and several people used buttons they had been informed were inactive.

During the pilot study, the simulation software logged the occurrence of button pushes. However, the computer automatically adjusted some buttons, and other events were a series of continual movements rather than discrete actions by the user. Because of this, the analysis includes both the overall movements and single initiations that may have included numerous data events. As statistical analysis was not possible given the small sample size, results and discussion have been combined in this section. Table 5.2 details the expected and actual frequencies discussed.

Table 5.2: Comparison of expected and average actual frequencies of button presses of *myReader* assuming 1 training page and 4 test pages.

Controls	Expected Frequency	Mean Actual Frequency	Range	Details
Go/Start	5	8.8		
Loading	10 sec	11.2 sec		
Read/Page	5	8.5		
Size	-	271.3		Total movements
	1	4.8		Initiations - trial
	1	22.3		Initiations - test
Picture	5	30		Total movements
	1	6		Initiations - trial
	1	4.5		Initiations - test
Auto	15	15.7		
Speed	-	158.7		Total movements
	-	3.8		Initiations - trial
	-	20.8		Initiations - test
Trackball	-	8522.2		Total movements
Write	0	1		

5.1.1 Frequency of Use

Capturing Text

The *read/page button* was designed to access the processed text and to return to the overview of the page layout. This was used less for this task than expected because it was not used for checking; instead it was only used for accessing the processed text. This suggests that the overview of the page may not be a necessary element. An additional question was added to the main study post-test interview to determine if the overview was a useful function. One participant's score was higher than the others, which raised the average.

Accessing Processed Text

The *go/start button* was designed to load the pages. This would mean that it would be activated once for each page. The button was used on average 8.83 times, suggesting errors in usage as there was an average of only 4.33 pages. Most of these activations were to initiate and cease scrolling as the prototype software allowed the *go/start button* to initiate scrolling and people continued to use it rather than the *auto button.* Two users intuitively went to the *go/start button* suggesting that "start" implies start for whatever action they were trying to achieve. This provides evidence that jargon and ambiguous terms should not be used for this demographic.

Loading

Despite text being pre scanned and loaded onto the laptop, the programme still requires time to load the processed text for presentation. As text for CCTVs is presented instantaneously, loading time is an aspect of important consideration for *myReader* designers. *Loading time* was determined as the time between the *go/start button* being pressed to "all buttons being released," a software command recorded in the data logs. The actual loading time varied from 3 seconds to 20 seconds with an average of 11.3 seconds. Several negative comments were made regarding the length of time pages took to load. In addition, two users were confused and did not understand what was happening when the message "loading" appeared on the screen. While the word "loading" offered feedback that the computer was working this did not appear to mean much to the elderly participants, further highlighting the need to eliminate jargon and provide additional information.

Size Dial

Once the processed text was loaded and had been accessed by pressing the *read/page button*, users could then adjust the size and colour preferences. It was envisaged that the *size dial* would only be utilised initially to set the user's preferred reading size. The actual usage of this dial was considerably higher than envisaged, with the dial being adjusted on average 27 times. This is not the degree of adjustment but how many times a user initiated movement with the dial.

The placement of the *size dial* also caused accidental bumping when the control panel was held in the hands or the left hand rested near the dial (see Figure 5.1 a and b). One participant did rest her hand on this dial throughout the testing, increasing the occurrence of activation. This indicates that more room is required on the edge of the control panel for hands to rest.

a) b)

Figure 5.1: Bumping of the size dial occurred during testing when participants rested their left hand by the size dial, a) and b) illustrate how this could occur.

All participants used the *size dial* more often than expected, adjusting it throughout testing. This high level of activation could be due to any one of several reasons. Text and heading sized differed and users adjusted more than expected to ensure they could read both.[5] The novelty of the experience may also have influenced usage. Most of the initiations during testing were erroneous and not for fine tuning. All but one participant incorrectly used the *size dial* to access text when they should have pressed the *read/page button*. This suggests an intuitive link between seeing the overview of small text and changing the size to read, highlighting the superfluous step of having to press another button before users can read the text. Participants did learn that this was not the appropriate action, but in some cases this took several trials, which increases learning time. Providing functions that take advantage of people's intuitive actions reduces learning time and frustration. The size dial was used more frequently than expected. However, with more room for resting hands and greater familiarity there would be less activation. Therefore, its placement away from the navigation controls seems appropriate.

Picture Dial

The *picture dial* has a default setting and it was envisaged that the dial would be set to the user's preference once and default to that setting when each successive page was loaded. Therefore, once the user set their preference it was expected that there would only be one software-generated occurrence for each page. The results show that users used the *picture dial* more frequently than this, both in trial and test situations. This could be due to negative transfer as some expert users of older CCTVs did adjust settings with their machines on a regular basis. Alternatively, unfamiliarity with the product, uncertainty of the optimal setting of the novelty of the function could have been responsible. These results may change with extended exposure, participants would become more familiar with there being no need to continually adjust these settings. There was only one occasion when a participant mistook the *picture dial* for the *size dial*. While the *picture dial* was used more than expected, comparison of video footage and data logs suggested this was due to setting up and familiarisation and therefore its placement further from the navigation controls appears appropriate.

[5] In future models, software will alter the document's text to ensure all text is the same size, highlighting titles through other means.

Initiating Scrolling

The *auto button* was expected to initiate the automatic scrolling and would therefore be used once to start and once to stop each page. Additional use would be made if users wanted to stop scrolling for other purposes. In actuality, the average use was 15.67. One participant's score was excessively higher than the others. Removing this score, the average decreases to 5, a figure lower than expected, suggesting users actually initiated scrolling using the *speed dial* and *go/start button* instead of with the *auto button.*

The *speed dial* was designed with the primary function of adjusting the speed once automatic scrolling was initiated by pressing the *auto button.* This would result in a variety of adjustments depending on user's speed preference and the complexity of the text. Due to prototype software allowing it, the *speed dial* could be, and was, used to initiate the automatic scrolling. It was also used to back track when a word had been missed. As a result, this control was used more than expected. Usage varied from 37 to 509 movements in total. As this was the most frequently used control it needs to be as easy to access as possible. Because of some bumping of the *trackball* while using the *speed dial* a recommendation was made to increase spacing between these two controls. In addition, most users made errors when trying to use the *speed dial* to initiate scrolling, having to make corrective actions. Altering the direction of *speed dial* could help reduce errors of this type.

Navigation

The most frequently used controls were the *speed dial* and *trackball* as was expected due to their use in navigation. However, the total number of movements recorded for the *trackball* was not the number of activations. Most of the *trackball* movements were not user generated. The sensitivity of the *trackball* to movement of the panel meant that very small movements resulted in *trackball* events being recorded in the data log. Bumping of the *trackball* was also evident when using the *speed dial* suggesting bumping. As mentioned, allowing more room to access the *speed dial* could overcome this. Placement of the *speed dial* and *trackball* close to fingertips conforms to appropriate design considerations.

Write Button

Participants were informed that the *write button* was inactive before trials and testing began. Therefore, no presses of this button were expected. Two participants did not press the button at all, two others pressed the button once and the final two pressed it twice, suggesting some confusion regarding appropriate actions. Video analysis revealed that these erroneous activations were due entirely to uncertainty regarding which button to press to achieve the desired action. This highlights a need to simplify the controls by eliminating unnecessary buttons or providing larger labelling to assist with location of the controls. It also supports the concept of using different shaped controls to aid identification.

5.1.2 Sequence of Use

The average actual sequence of use rarely matched the expected sequence (see Table 5.3). This may be due to participants getting familiar with the equipment, trying things out and being unsure of each button's allocated function. In addition, the software allowed actions that were unexpected (e.g. the *speed dial* and *go/start button* initiating scrolling as well as the *auto button*).

Table 5.3: Expected and average actual sequence of button presses with *myReader*

Goal	Expected Sequence	Average Actual Sequence
Capture image	Go/ Start Button	Go/Start Button Size Dial
Access text	Read/Page Button Size Dial Picture Dial	Read/Page Button Size Dial Picture Dial
Initiate scroll	Auto Button	Go/Start Button or speed dial
Adjust speed	Speed Dial	Speed Dial
Back track	Trackball	Speed Dial
Stop	Auto Button	Go/Start Button

It was evident that user's automatic response when shown a screen of the whole page of text (the default overview mode that appears once the image is loaded) was to increase the size using the *size dial* rather than using the *read/page button*. Several users also

chose the *go/start button* to initiate scrolling instead of using the *auto button*. This suggests that "start" is an intuitive word for initiating scrolling.
Despite the numerous *trackball* movements recorded (attributed to control panel movement and high sampling rate of the data logging software) the *trackball* was used little for navigation and most participants preferred to use the *speed dial*. If the *auto button* was eliminated the sequence of use, once user's set their preferred size and picture settings, would be as simple as 1, 2, 3;

1. *go/start button* to load
2. *size dial* to access text
3. *speed dial* or *go/start button* to initiate scrolling

The *speed dial* would be used to control scrolling and the *go/start button* would be used to cease scrolling.

The control panel layout does not support this sequence of use with the *go/start button* in the bottom left hand corner, the *size dial* in the top left hand corner and the *speed dial* on the top just in from the *trackball* on the far right of the panel. As several changes were recommended which would affect the function of the buttons and as designers believed that users would have to take their hands away from the *speed dial* to turn pages or place new text under the camera, this discrepancy was not addressed here. In addition, the numbers 1, 2, 3 were allocated to the *go/start button*, the *read/page button* and the *auto button* respectively. This fits the expected but not the observed sequence of activation.

5.2 Performance

Due to the small sample size it was not possible to obtain statistical significance for either reading speed or comprehension. However, simple analyses were done to identify whether one machine performed better than the other.

5.2.1 Reading Speed

Reading speed was assessed by averaging the individual words read per minute. As is evident in the Table 5.4, reading speeds using *myReader* were below those for CCTVs. No consistent trends were evident, highlighting the shortcomings of such a brief testing period (see Figure 5.2).

Table 5.4: Average reading speeds per participant.

Participant #	**1**	**2**	**3**	**4**	**5**	**6**
CCTV	73.7	136.6	120.7	30.7	52.7	160.8
myReader	42.9	131.8	28.1	30.4	28.8	83.3

While all *myReader* reading speeds were below those for CCTV, this is only one of the elements that index performance. With a more thorough training period and a check on competency before initiating testing, it is believed the differences would be reduced. In addition, using the same piece of text for all participants will help reduce any confounding effects of text complexity. While training and familiarisation are options to increase reading speed under test conditions, the CCTV research indicates a limited amount of training is given in use of this equipment (Watson et al, 1997). Therefore, it is important to make the product as easy to learn and use as possible. Exploiting the intuitive actions of users could reduce the cognitive load needed to remember arbitrary actions. For example, it is clear that users intuitively changed the size when the overview was presented to them, rather than pressing another button to access the processed text. Learnability or time to achieve competency was tested in the main study to allow assessment of performance to be conducted from a more level platform.

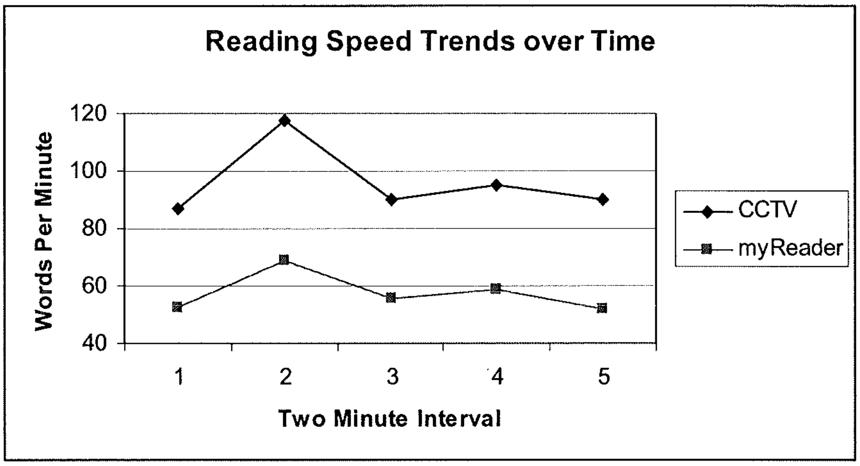


Figure 5.2: Comparison of reading speeds between CCTV and *myReader* at two minute intervals.

5.2.2 Comprehension

Comprehension was assessed using five questions relating to the piece of text they read. The questions were very specific and some people never reached the place in the text where the answers were mentioned. Because of this, the scores presented in Figure 5.3 are a percentage correct of those they were able to answer.[6] If we remove this score, comprehension on *myReader* appears to be on a similar level with CCTVs. No degradation in comprehension suggests that there are no ill effects of using *myReader* on this dimension.

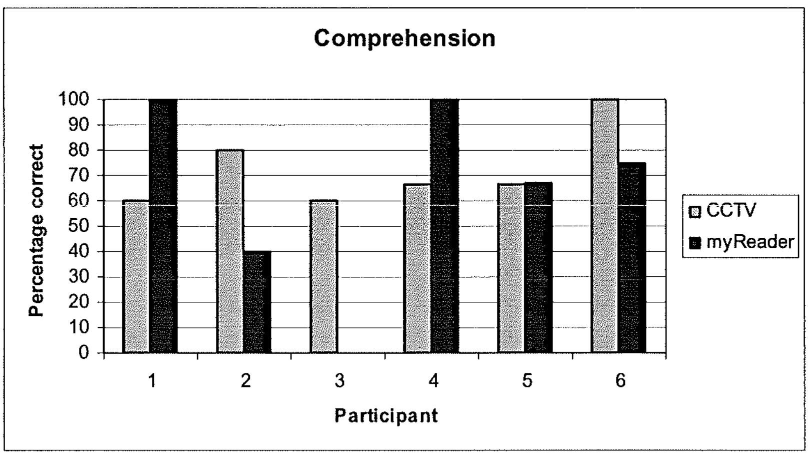


Figure 5.3: Comprehension scores based on the percentage correct out of the number participants could possibly answer.

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[6] Participant 3 was unable to answer any comprehension questions in the *myReader* trial as they did not reach the place in the information the first question related to.

Comprehension may have been affected by several aspects. The format of the questions required participants to recall from memory aspects that may not have been prominent. In addition, some participants did not reach the place in the text that contained the information for the questions. Therefore, several less specific, multi-choice comprehension questions per page were used in the main study. In addition, participants may have had previous knowledge of the text used due to the recent high profile of *Harry Potter* (1997). Text complexity between Harry Potter and TIME also varied, potentially affecting comprehension. In order to minimise these limitations, text for the main study was more thoroughly analysed and no choice was offered to ensure consistency to provide a better measure of overall comprehension.

5.3 Universality

The one left-hander tested had no more problems than right-handers did when operating the control panel. As several of the participants used their left hand for operating the controls, results are likely to be robust despite there being only one left-hander in the pilot study. Two participants rested the control panel on the desk/table for the duration of the trial. The remaining four held the panel with both hands either in their lap or just above the desk surface. At least two users, who held the panel at the top corners of the panel, bumped the *size dial*, at the top left. When one participant asked who changed the size, she answered herself by saying "I did accidentally and didn't know it."

Force requirements appeared to be appropriate with little or no problem being displayed by any of the users in pushing buttons or turning dials. However, the *size dial* and *trackball* may need to be tightened up to avoid being bumped. Screen height was an issue for two novice users. The researcher had to move the monitor to eye height for one participant who believed he was unable to continue otherwise. It was recommended that the *myReader* screen be adjustable to ensure good posture. Other considerations include the inappropriate seating used by many existing users. It is therefore important to provide users with information of optimum seating adjustment. This could be included in user manuals.

Hand size did not appear to present a problem indicating a well-proportioned panel. However, several participants did display hovering behaviour indicating a lack of comfort at resting their wrists on the panel. Hovering of the whole hand, wrist or some fingers was evident in most tests. Two participants who exhibited nervousness about operating the control panel had their hand hovering above the panel throughout testing rather than resting anywhere (see Figure 7.9 for illustration). While two participants rested their wrists in their laps while reading, none of the others found an uncompromised resting place, exhibiting deviation and flexion (Pheasant, 1996). In one instance of operating the *speed dial*, the user's pinky, ring and middle fingers were splayed above the *trackball*, indicating insufficient room to rest them. The left-handed participant's fingers were hovering over the *picture dial*. More room for the *speed dial* could reduce this. Wrist movements were not always optimal with some deviation and flexion, which could, over time, result in symptoms of repetitive strain injuries. All but two participants operated the controls with both hands indicating that single-handed operation was not optimal. This appears to be due to the distance between buttons operated in sequence, i.e. *go/start button* and *speed dial* and the desire not to bump the other buttons.

5.4 Pleasurability

Pre-test questionnaires, observations during testing, post-test interviews and video analysis of interaction with specific attention to errors and comments, supported the objective measures above and provided further insight for enhancing the design. As well as assessing user preference and common errors, Jordan's framework of four pleasures revealed additional information regarding sociological, ideological, psychological, and physiological aspects which are detailed below.

5.4.1 Preference

Subjective feedback from comments and post test interview suggested that users were more satisfied with the new concept, both physically and emotionally. Five out of the six participants preferred *myReader*. Less physical fatigue using *myReader* was reported as well as less eyestrain. However, they did seem to experience difficulties with initial use of the control panel, finding it difficult to remember which button was used for what function. When asked if she wanted to adjust the size, one participant stated, “I’m afraid to as I have forgotten which button.” Comments included concern about the “fuzzy bits in the words not so good.” This related to the initial image processing used in the simulation and was rectified for the main study. There was also concern expressed that in wordwrap mode not all the words were being presented as there was no on screen feedback such as margins, with text extending right to the edges of the screen. Participants stated they could not read the labels because they were too small. There was also concern about words from a caption in one of the TIME magazine articles being difficult to read and frustration about titles being in a different size than the body of the text.

One other area of design that was tested was whether participants preferred buttons made of hard or soft material. A remote control device was used as an aid when participants were asked which they preferred in the final post-test interview. Only one person preferred the soft buttons. However, it is argued that the remote control did not provide a good comparison to determine preference of button material. Several participants had memories of negative experiences with remote controls, commenting on this. These previous negative experiences may have influenced their choice. Soft buttons of the same size as those proposed for *myReader*’s control panel would be a better comparison. However, the company chose not to pursue this as an option in the main study.

5.4.2 Sociological

All participants stated that they would like to be able to read as they did before their sight became impaired. One would have liked to be able to read and mark his race book. Two would like to do crossword puzzles again. They all stated that these aspects would enhance their quality of life. No decision had been reached on colours of the product, therefore it was recommended that clinical colours should be avoided and high contrast conservative colours be used to avoid any social “illness” stigma. All participants stated they liked the contrast and colours of the prototype control panel (black with light blue controls). One stated he did not particularly enjoy black but appreciated the contrast offered. Participants expressed enthusiasm for the potential portability of *myReader* given its compact nature.

5.4.3 Ideological

The river stone metaphor of the prototype panel #1 provided good aesthetic appeal. Participants commented positively regarding the compact and attractive nature of the product. No negative feedback was received regarding the materials used in the product or any potential impact the product would have on the environment.

5.4.4 Psychological

One participant exhibited outward frustration and three participants mentioned a lack of confidence in being able to use the product on first sight. For example, one participant said, "I'm not good enough"… for it to go fast enough for reading to be engaging. Being made more aware of the ability to easily override the automatic function and go back over missed or misunderstood words could address the issue of feelings of lack of control. Most participants used a combination of the automatic scrolling and manually overrode this to backtrack using the *speed dial.* This product will provide users with cognitive stimulation that comes from reading and pursuing other hobbies. Reducing the number of arbitrary allocations of function and hiding infrequently used controls such as the picture dial, could reduce cognitive overload. The number of errors apparent in this study indicated that remembering which function was allocated to which task was difficult for most users. Utilising the intuitive actions of the users may reduce this, i.e. using the *size dial* to access the adjusted text and using the *go/start button* to start automatic scrolling.

It was evident from the way some users initially approached using the *trackball* (twisting it like a knob) that it was a novel concept for them. One thing that was evident from corrective movements was that users were trying to mimic the direction and mode of the text with their movements. People were stroking left to make the text go left when in marquee mode and stroking down to make the page come down. It is therefore important to allow movement of the *trackball* to mimic text mode (vertical wordwrap – horizontal marquee) and direction (stroke left to scroll left – stroke up to scroll up).

5.4.5 Physiological

The physiological issues were discussed in Section 5.3 under universality.

5.5 Limitations

The pilot study provided an opportunity to trial experimental methods and highlight aspects of the control panel design that could be enhanced. As is often the case with pilot studies, several methodological limitations were identified. Most of these have been mentioned throughout the above discussion, several others are detailed below.

Considerable "noise" was evident in the data. Any movement of the control panel caused recording of *trackball* movement. In addition, data was logged linearly rather than cumulatively so several lines of data were recorded for one activation of controls such as the *speed, size* and *picture dials*. Numerous lines of data for the same control were evident in a single second. Adjustments to the software for the main study were made to avoid this and assist with analysis.

Participants were not tested on their level of competency with the equipment prior to testing commencing. Not ensuring all participants had basic skills could have affected performance. To reduce this effect, a longer trial period preceded testing in the main study and all participants were required to achieve a set level of competence before proceeding with the testing. Changing pages, loading software and participants stopping to interact with the researcher and observer may have influenced the reading speed results. A more rigorous timing regime was used in the main study to enable statistical significance to be drawn from results.

Due to the small sample size, statistical analysis revealed no significant results regarding any interactions between product type, user type, eye condition or age. There was however, sufficient information gathered from the six participants to provide data for tooling work to commence and some trends to become evident. The results showed that there was a difference between the reading speed and comprehension for CCTVs and *myReader*. Both were slightly lower for *myReader* and novices appeared to do better with CCTVs than with *myReader*. With a larger sample, more rigorous methods and more training, this may change. It is however, important to consider that previous research in CCTV use reveals that little training is given (Watson et al, 1997) and learnability is an aspect that needs to be addressed.

No trends were apparent in reading speed in the pilot study, perhaps due to the length of testing. For the main study, testing was to continue for 30 minutes or until participants reported being too fatigued to continue. As is apparent in the main study results, this was not possible as most participants had difficulty completing 10-minute tests. Interruptions due to changing pages, loading software, equipment failures and participants stopping to interact with the researcher and observer were also unavoidable. However, a more rigorous timing regime was used in the main study to mitigate the effects of interruptions. Having different observers, and on occasion no observer, may also have influenced the results. No observers will be present in the main study. In addition, not all the actual functions of *myReader* were available for either the pilot study or main study, which limits the range of results.

It was not possible to address all the pilot study limitations, including issues of endurance, interruptions, varying environmental conditions and Hawthorne effects. However, knowledge gained from the pilot study did assist greatly with formulating the method for the main study. Table 5.5 summarises the changes made to the methodology and the control panel following the conclusion of the pilot study.

Table 5.5: Summary of changes made to method for the main study.

- A larger sample was used for statistical analysis to be undertaken (from 6 to 45)
- During the training phase, participants had the opportunity to activate controls as they were explained to reinforce memory of actions
- Participants were tested for competency before test phase commenced
- No choice of text was offered to avoid prior knowledge or varying complexity
- A more rigorous timing protocol was used to mitigate interruptions
- A more general set of multi-choice questions was used to reduce memory confounds
- Data logging software adjustments reduced noise making data analysis easier to analyse
- Blurry words were enhanced to assist users with reading
- "Loading" was changed to please wait
- The direction of the *speed dial* was reversed
- The *auto button* was eliminated
- The *speed dial* was moved to allow more room for operation
- The *trackball's* movement was altered to mimic text mode
- The prototype panel II was made larger to provide more wrist room
- A discrete stop point was included in the *speed dial*
- Margins were provided in wordwrap mode to provide feedback that all text was presented
- The *go/start button* was not able to be used for initiating scrolling

5.6 Conclusions

The pilot study provided a valuable opportunity to observe actual users interacting with the prototype control panel and to trial methods for the main study. A variety of information was gathered to generate the list of design suggestions (see Table 5.1) to assist with optimal placement of controls on the panel, to optimise the user experience and quantify the differences in performance between *myReader* and CCTVs. Users reported a positive response to *myReader*; however performance did not entirely reflect this with reading speed and comprehension scores slightly lower on *myReader* than CCTV for both novices and experienced CCTV users. Addressing the limitations of the pilot study was intended to provide a more thorough picture in the main study, which is detailed in the following sections.

6 Main Study Method

The main study method changed slightly to utilise information gained during the pilot study. These changes addressed some of the pilot study limitations (see Table 5.5) and incorporated changes made to the control panel design by the company.

The major objectives of the main study were:

1. *Impression of Technology* – Quantify users' feelings about technology in general by analysing their response to the telephone questionnaire, ascertaining whether they were eager adopters, hesitant users or resisters of technology
2. *Learnability* – Compare participants' time to achieve competency between *myReader* and CCTV
3. *Usability* – Quantify users' reading speeds, endurance and comprehension with *myReader* by comparing participant performance on similar tasks
4. *Pleasurability* – Determine user preference and comfort levels from responses to post-test interviews and from video analysis, and to assess endurance and anxiety and by utilising Jordan's four pleasures framework
5. *Control Panel Design* – Reaffirm control layout through analysis of common errors and concerns
6. *Marketability* – Gather consumer demographic data that the company can use for marketing

6.1 Main Study Participants

None of those involved in the pilot study were tested in the main study. Low-vision participants were recruited from RNZFB members in both Canterbury and Otago and from a marketing list of the manufacturer's. Control participants included residents of private retirement villages and personal contacts of the manufacturer's staff, low-vision participants and the researcher. Participation complied with regulations of the University of Canterbury Human Ethics Committee. At the completion of all testing, participants received the choice of either a box of scorched almonds or a large block of chocolate as thanks for their involvement.

Potential participants were screened using the following criteria:

- Participants had to be fluent speakers of English to avoid language difficulties impeding reading performance
- They had to have no upper body motor deficits to avoid problems with the manual navigation required for the CCTV machine[7]
- They needed to have attended school until the age of 15 to avoid any difficulties with reading and comprehension
- Control participants were matched in age with low-vision people to within 12 months
- Control participants were required to have the visual acuity to be able to legally drive a motor vehicle in New Zealand
- All participants were required to be of sound mind and suffer from no disorders such as dementia. If they were able to follow the flow of conversation during the telephone conversation they were considered of sound mind.

Participants included 15 expert users of existing CCTVs (experts), 14 people with low vision who were not current users and those who had only recently begun using or rarely used CCTV machines (novices) and a matched age group of 15 people who met the above criteria (control). Study participants were 15 males and 29 females, ranging in age from 35 to 90 years old (average 73).[8] Unfortunately, no participants were left handed. However, seven participants stated they were ambidextrous and two who stated they were right handed operated all controls with their left hand.

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[7] Several participants had arthritis which was acceptable.

[8] A 9 year old, who did not meet the criteria, was tested to determine if younger people had any difficulties using the system, but his data has not been included in any analysis.

Table 6.1: Breakdown of numbers in each group who completed the questionnaires and those who completed tested.

Group	# recruited	# completed all testing
Expert	15	13
Novice	14	11
Control	15	14

While responses to the questionnaires of all 44 participants are included in the data analysis, several participants were unable to complete the testing (see Table 6.1 for summary). Three participants were unable to participate in the testing due to the severity of their eye conditions (1 expert and 2 novices). One participant was recruited but suffered a detached retina before testing could begin. One participant's eyesight was so severely limited that he was unable to read words of any size, he experienced difficulties with the *serifs* joining the letters together and resulting in an inability to distinguish the individual letters. One participant was unable to commence testing due to a belief that reading was just too difficult. No performance analysis was possible for these three participants.

Three other participants were unable to complete both tests (1 novice, 1 expert and 1 control), two of these completed the *myReader* component but found the *CCTV* component too difficult or uncomfortable. One was unable to complete the *myReader* component. These three participants' results were excluded from the performance analysis, as only one reliable reading rate could be obtained.

6.2 Main Study Materials

6.2.1 Telephone Questionnaires

The telephone questionnaire remained the same as in pilot study with the addition of a questionnaire specifically for the control group, which captured the same demographics, technology exposure and technology related aspects as for the experts and controls (see Appendix D for details).

6.2.2 Amsler Grids

One addition to the pilot study materials was the introduction of the Amsler Grid test (see Appendix J for details). This simple test assesses if the central field of vision is intact (CFI) or lost (CFL) and can be easily administered by a layperson. This was tested as CFL was determined a possible confound for reading speed by Harland, et al (1998). Acuity was not assessed as users were encouraged to use any corrective lenses they would normally use for reading and this was allowed for both tests.

6.2.3 Heart Rate Monitor

The other addition to Pilot Study materials was a heart rate monitor. Recording heart rate could most reliably be achieved using chest sensors, but as this equipment was difficult to source, overtly invasive and could cause additional confounding anxiety this approach was disregarded. Finger-clip sensors were another alternative considered, but it was believed these would restrict participant's movements, potentially influencing product interaction, which was of primary importance to the study. Intended to gather physiological data relating to anxiety, it was determined that recording heart rate using a sports monitor would be the least invasive approach.

A modified Polar™ heart rate monitor (see Figure 6.1) that recorded the beat-to-beat data required to see heart rate variability and reactivity was used (Polar, 2003). Normal sports monitors measure beat-to-beat but only record five-second averages, which would not provide high enough resolution data (Lam, Chase & Shaw, 2002). The equipment used included a sports watch that receives a radio frequency signal from a chest strap worn by participants. Good skin conductivity is required to allow transmission of data. The watch was modified and attached to signal processing hardware that converted the data for direct download to a laptop via a USB connection.

Figure 6.1: Modified polar sports heart-rate monitor, including chest strap, watch and signal processing hardware.

Prior to the commencement of the main study the heart rate equipment was tested on two people in their late 50s to determine if it was sensitive to changes in anxiety levels and whether good readings could be gathered under non-controlled conditions. Both people achieved good conductivity providing good readings and exhibited an increase in heart rate when subjected to answering complex mathematical equations.

6.2.4 Low Vision Reading Aids

CCTV

As for the pilot study, novices and controls used a SmartView 8000 supplied by the company and experts used their own machines. See Table 6.2 for details of these machines.

Table 6.2: The type of CCTVs used by experts in the main study.

MACHINE	NUMBER
SmartView	7
Aladdin	3
Prisma	1
Voyager	1
Eschenbach	1
	13

myReader

Following the pilot study, several alterations were made to the prototype control panel. The *auto button* used to initiate scrolling was eliminated and scrolling was initiated via the *speed dial.* The *auto button* was renamed "next" and was inactive in the simulation, but would be used in the finished version to scroll down the screen one page at a time, as an alternative to automatic or manual scrolling. The *write button* was renamed *live button* to more accurately reflect its function of accessing real-time, live view of material placed under the camera. Changes were also made to the simulation software. These included introducing margins in wordwrap mode and cleaning up "fuzzy" images. More details of changes are listed in Table 6.3.

Table 6.3: Summary of changes made to control panel and software for the main study.

- "Please Wait" used instead of "Loading" when *myReader* processing text
- "Write" renamed "Live" to more accurately reflect function
- Control panel #2 was bigger to reduce hovering and poor wrist placement
- More space allowed for access to the *speed dial* to avoid bumping the *trackball*
- Movement of *trackball* changed to mimic text mode (vertical wordwrap – horizontal marquee) and direction (stroke left to scroll left – stroke up to scroll up)
- Direction of *speed dial* altered to reduce errors in activation
- Tactile feedback on *speed dial* provided to indicate when stop reached to avoid backtracking
- *Speed dial* allowed to back track
- *Speed dial* to have smaller increments to allow finer adjustment
- *Speed dial* allowed to initiate scrolling
- Margins provided in wordwrap mode to assure users that all text is on screen
- Fuzzy letters in text eliminated to avoid distraction
- "Noise" reduced in data logging software to aid analysis
- Raised dots on buttons eliminated as they did not aid location
- High contrast of colours of the panel and controls maintained

In addition to the changes to the control panel (see Figure 6.2), a Viewsonic 17-inch LCD was used to display text, to more closely simulate the final product that incorporates an LCD screen (see Figure 3.4). As in the pilot study, the screen used for *myReader* should have been used for both products to ensure visual characteristics were the same for all participants. However, because most of the expert participants used CCTV machines that were unable to accept the screen connection (i.e. those using televisions as a screen or Aladdin machines which are closed units) it was not possible to use the LCD screen when testing CCTV.

Figure 6.2: *myReader* prototype control panel #2 used in the main study

6.2.5 Reading material

In the pilot study, participants were given the option of either a TIME Magazine article or a chapter of a Harry Potter book (Rowling, 1997). This revealed potential limitations of possible prior knowledge (given the recent release of the Harry Potter movies) and complexity of words (Time article). Therefore, no choice was offered in the main study. Research suggests that reading materials used in this type of study should be aimed three grades below the ability of the participants (Harland et al, 1998). Extracts from "Swallows and Amazons" (Ransom, 1982) were used due to the potential appeal to this age group having originally been published in the time of their youth. The language intended for a reading age of 12 years was simple and easy to understand. There was however the possibility the material may have been too simplistic and not engaging enough.

Three passages of text were chosen; one was used for all participants for the training phase (Chapter 1). The other two (Chapters 2 and 4) were counterbalanced between the two test tasks (see Section 6.4.1). No passage of text was presented more than once to any participant. A stopwatch recorded time to achieve competency and reading speed.

First Chapter
Page 1
1. Where would the children sleep if they weren't allowed to sleep in tents on the island?
a) on the boat
b) in a cabin
c) camp on shore **
d) under the trees

Figure 6.3: Example of the multiple-choice comprehension questions used in the main study.

6.2.6 Multi Choice Comprehension Questions

In the pilot study, it was determined that because of highly variable reading speeds some participants did not reach the place in the text relating to some questions. In addition, the format of the questions required participants to call on short-term memory rather than comprehension to answer. To avoid this, three multiple-choice comprehension questions were prepared for each page (approximately 200 words) following the model of Harland et al (1998). Multi-choice questions included the target, no more than one implausible answer, and one or two plausible distracters (see Figure 6.3). They were carefully prepared to ensure they could not be answered using general knowledge. See Appendix K for a full list of questions.

6.2.7 Post-test Interview

As with the pilot study, four separate post-test interviews were constructed, one for the initial visit and one for the final visit. Each participant completed one interview for each product. There were only minor adjustments from those used in the pilot study, including eliminating the question regarding preference for softer buttons and including a question relating to the relevance of the overview mode. See Appendix L for full list of questions.

6.2.8 Environment

As in the pilot study, testing for all participants was conducted in their own home or workplace, on two separate occasions. No observers were present except when members of the participant's family were in attendance.

6.2.9 Video Analysis

Two cameras and a TV-PC converter were used, as in the pilot study. Once all tests for all participants were complete and video had been edited, coding commenced. A programme developed by the HIT Lab NZ in Visual Basic was used to synchronise video tape and data logging and facilitate coding (see Figure 6.4). *myReader* video analysis involved coding using the categories in Table 6.4. The participant's **intention** was determined by the researcher on the basis of the action required to achieve the next task. **Hesitation** was coded if the participant took longer than 5 seconds to initiate a required action. Motivation was considered **autonomous** if their action was achieved without any consultation, **prompted** if the researcher reminded the participant there was an action to be taken and **directed** if the researcher instructed the participant in the action. Data logging recorded the frequency of activation for each control, sequence of use and loading time for the pages of text. Action was determined from these data logs with confirmation from the video footage.

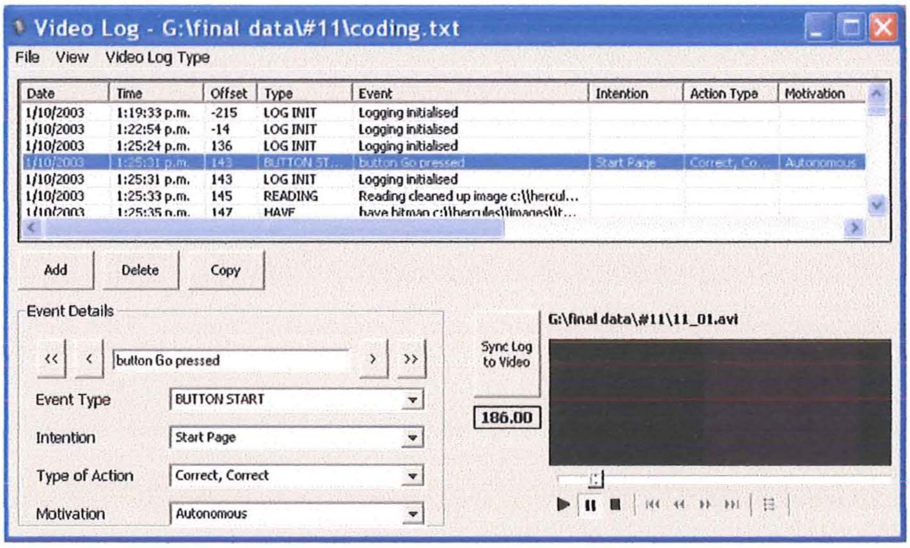


Figure 6.4: Screen shot of video analysis tool used for coding interaction in the main study.

No computer generated data logging was possible with the CCTV machines due to the nature of the product. Hand coding of all actions, such as left to right movement of the x-y table, would have been outside the timeframe of a Masters thesis. However, once the training phase was complete and participants were reading using the x-y table for navigation there were few errors possible. Possible errors included losing their place in the text, moving the page outside the camera's viewing zone, moving the table to the left when they intended moving it to the right, not realising they had come to the end of the page. Therefore, video analysis for the CCTV involved viewing video to determine if any of these errors were visible and logging these using the same HIT Lab video coding software. In addition, "posture" and "hands" were recorded on the same dimensions as for *myReader* (see Table 6.4). This postural information would be used for use in determining the comfort score (see Section 6.4.5).

For both machines it was not possible to code some aspects, as a verbal protocol analysis would have been required to determine all actions. One example of an aspect which could not be coded without participant input was when participants back tracked; it was possible they were either re-reading something (the more likely alternative) or getting lost.

Table 6.4: Categories used for coding video of interaction with the control panel

Intention			Motivation	Action	Finger	Posture	Hands	Expression
Start page	Correct	Correct	Autonomous	Start page	L/R thumb	Leaning forward	Both on panel	Positive
Access text		Hesitation	Prompted	Access text	L/R pointer	Leaning back	Left by size dial	Negative
Adjust size		Correction	Directed	Adjust size	L/R middle	Neck bent back	In lap	
Adjust colour	Error	Button	Researcher	Adjust colour	L/R ring	Neck bent forward	Both on table	
Initiate scroll		Direction		Initiate scroll	L/R pinky	Twisting to screen	Chin on hand	
Move forward		Software		Move forward		Reaching out	Wrist hovering	
Move back		Bumping		Move back		Wrist bent		
Slow scroll		Action		Slow scroll				
Stop scroll				Stop scroll				
Manual move				Manual move				

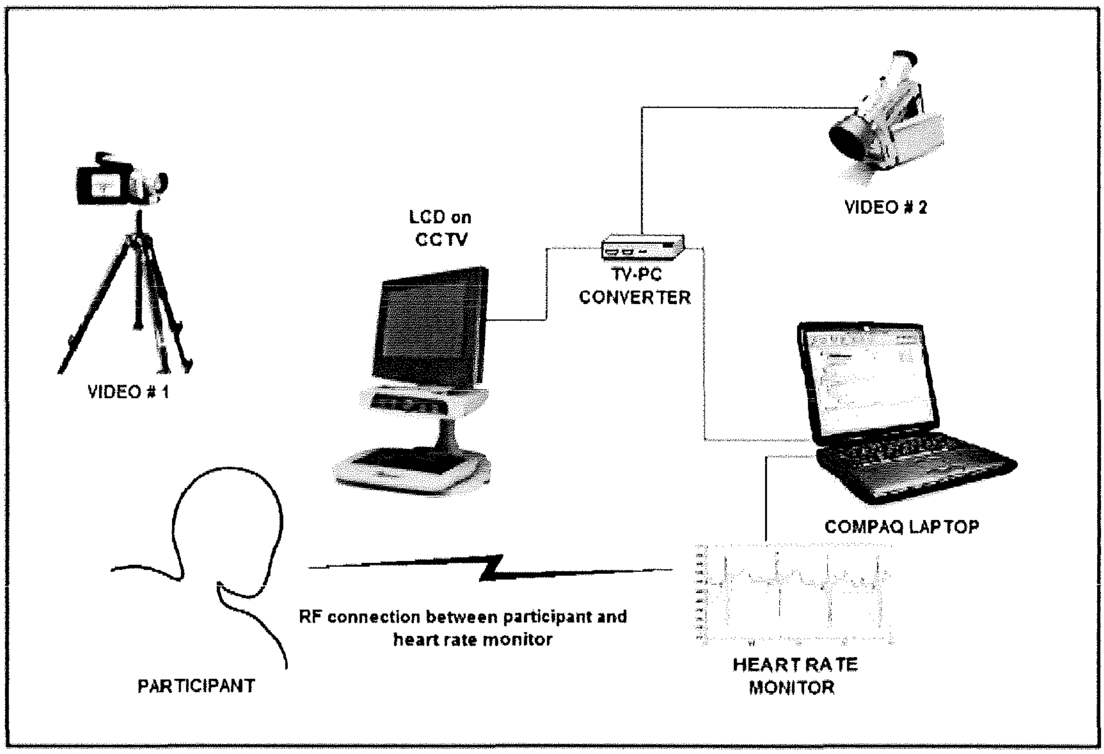


Figure 6.5: Schematic of experimental set-up for CCTV testing for main study, incorporating heart rate monitor

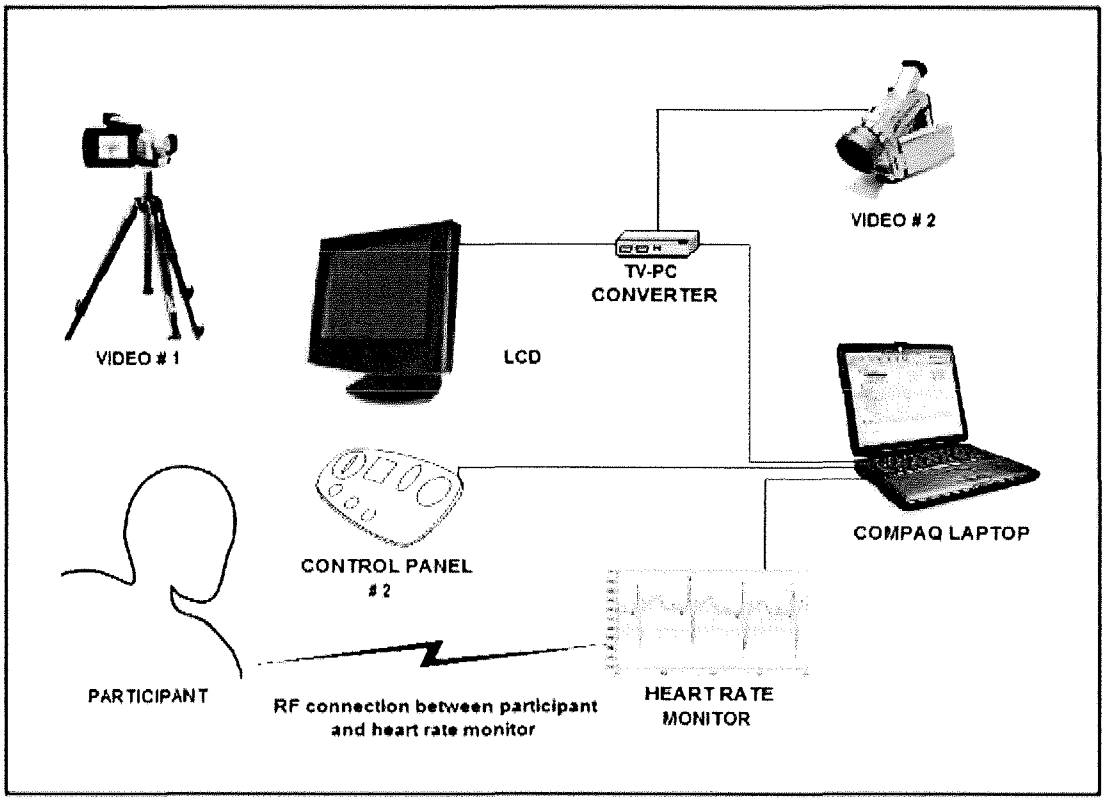


Figure 6.6: Schematic of experimental set-up for *myReader* testing for main study, incorporating heart rate monitor

6.3 Main Study Procedure

6.3.1 Telephone Interview

Unlike the pilot study, participants were not volunteers and had to be recruited. The researcher telephoned potential participants to discuss the project, screen them for suitability (see Section 6.1) and determine if they were willing and able to commit to 2-3 hours of research. This allowed the researcher to become familiar with the participant's individual requirements. The questionnaire was administered verbally during the recruitment call, and the initial visit time and date were set.

6.3.2 Set-up

As in the pilot study, participants were read an information sheet and required to sign a consent form before any testing commenced. The Amsler grid test was then administered. The chest strap of the heart rate monitor was put on and the equipment was set up ensuring video and heart rate synchronicity to assist with later analysis (see Figures 6.5 and 6.6 on previous page).

6.3.3 Training Phase

Once the equipment was set up, participants were familiarised with the equipment. CCTV experts were asked to read two paragraphs and identify the controls before proceeding to the testing phase. The training page was placed under the camera and novices and controls were instructed how to move the x-y table, how to adjust the size and change the false colours that were available. They were asked to select a magnification and false colours that suited them. The viewing distance from the screen, magnification, colour choices and seating were self-determined. Participants were then asked to read two paragraphs of text and identify the controls as per the protocol in Appendix M.

For the *myReader* prototype, the simulation software was initialised by the researcher. Both novice and expert CCTV users were instructed in the primary function of each of the buttons on the control panel (see Appendix M for protocol). Some of the controls will eventually have secondary functions, but these were not available in the prototypes. The training text was placed under the camera to simulate how *myReader* would operate. Participants were then shown how each control worked using the training page to view the results of their actions. Participants were required to load a page using the *start button*. Once the page was loaded and the overview of the page was presented participants were required to access the text using the *read button*, adjust the size to their preference using the *size dial*, select their preferred picture settings using the *picture dial*, initiate and stop scrolling using the *speed dial* and move the text with the *trackball*. They were informed that the "next" and "live" buttons were inactive for this test. Two text presentation modes (wordwrap and marquee) were also introduced and participants were asked to choose which they preferred. Participants were invited to try the buttons at their own speed, but were prompted by the researcher if they were unsure. They were asked to read two paragraphs of the training text to become familiar with the controls. If participants had questions, these were answered.

As this part of the testing measured learnability of the product, the time taken to achieve competency was recorded. After they completed navigating around and reading two paragraphs of text, participants were checked for competency (see protocol). The researcher asked a predetermined set of questions requiring participants to locate and identify the individual controls on the product. If they were unable to do this 100% accurately they were given further time to familiarise themselves with the product and retested on their knowledge of the controls. They were then asked again if they were ready to begin the test or required more time for practice. Participants were given as much time as they required to achieve competency.

6.3.4 Test Phase

Once participants achieved competency and consented to continue, they were required to begin the testing phase. This involved loading, accessing and silently reading the set piece of text. They were asked to read at their normal speed and told that they would be given several multiple-choice comprehension questions at the end of each 10-minute period. Participants were free to use either the *trackball*, *speed dial* or a combination to navigate text. Participants chose their preferred magnification, picture settings and text presentation mode. A stopwatch was used to time participants following a strict timing protocol, including stopping the timer when page end was reached, the participant stopped to ask questions, if there were faults with the simulation or other interruptions. At 2-minute intervals, the researcher asked the participant to stop reading and indicate how far they were in the text by pointing to the place on the screen. The reading rate was determined from this.

It was envisaged that participants would read for longer than the 10 minutes used in the Pilot Study. This would have provided a measure of difference in endurance and offered more opportunity to identify emergent reading speed patterns, such as increasing speed with greater equipment familiarity or decreasing speed as fatigue increased. However, it became evident after the first few tests that reaching 10 minutes with either machine was difficult for some participants. Throughout the study, some participants were visibly tired, complaining of sore eyes and expressing reluctance to continue. Encouragement had to be issued and if participants needed to stop, they were given a short break to recover. These breaks usually lasted less than 2 minutes. If they believed they were unable to continue, they were not forced to and all but one person reached 10 minutes. Once participants reached 10 minutes reading time or their endurance limit, the comprehension questions for the piece of text were asked.

Upon completion of the reading task and comprehension questions, the post-test interview was conducted. Participants were thanked for their time. The second session was confirmed and followed the same structure but involved a more in-depth interview than for the first product they were tested on.

6.4 Main Study Design

A counter balanced, repeated measures, between and within-group design was used. Table 6.5 details the independent, dependent and other variables investigated in the study.

Table 6.5: Variables analysed in the main study

VARIABLE	TYPE	LEVEL
Independent	User	Expert Novice Control
	Product	CCTV *myReader*
	Eye condition	Central Field Loss (CFL) Central Field Intact (CFI) Control (CTL)
Dependent	Objective	Competency – *Learnability* Reading Speed – *Usability* Comprehension – *Usability* *Endurance – *Pleasurability* *Heart Rate – *Pleasurability*
	Subjective	Preference – *Pleasurability* Physical Comfort – *Pleasurability* Impression of Technology Common Errors
Other	Impression of Technology	User Type Exposure to Technology Comfort with Technology Comfort with *myReader*
	Control Panel Design	Common Errors
	Marketability	

*No results available

6.4.1 Conditions

The order of product exposure and text exposure were counterbalanced. The schedule was predetermined and participants were assigned to the next available participant number as they were randomly recruited. The order of recruitment calls depended on where testing was being conducted (i.e. Christchurch, Ashburton or Dunedin), availability of the participants and availability of names. For exposure to word presentation modes for *myReader*, all participants were offered the wordwrap mode initially as this is the software's default mode. They were then shown the marquee mode, asked to try it out, and asked which they preferred. If there was no strong preference, they were taken back into wordwrap and asked again. Counterbalancing of conditions is detailed in Table 6.6.

Table 6.6: Sample of counterbalancing of conditions for the main study

	Initial Product	Final Product	Initial Document	Final Document
# 1	1	2	1	2
# 2	1	2	2	1
# 3	2	1	1	2
# 4	2	1	2	1
# 5	1	2	1	2
# 6	1	2	2	1
# 7	2	1	1	2

6.4.2 Impression of Technology

User Type

User type was determined from responses to the list of 30 feeling words (Rosen & Weil, 1995). The number of negative and positive words chosen was averaged to determine if participants were *eager adopters*, *hesitant users* or *resisters* of technology.

Comfort with and Exposure to Technology

The comfort and level of exposure was determined from a composite score based on the responses to related questions in the telephone questionnaires.

Reasons for Avoiding Technology

Participants were also asked several direct questions relating to reasons for avoiding technology and were invited to offer alternative reasons to those mentioned.

6.4.3 Learnability

Competency was assessed by timing how long participants took to achieve a predetermined level of ability using the machines. The overall time taken to achieve competence was used as a measure of learnability. Because experts' time to achieve competency would be less than non-experts (novices and controls) their time to achieve competency with CCTV would be excluded from analysis and for *myReader* their data would be analysed against a combined non-experts time.

6.4.4 Usability

Reading Speed

Participants read as much of the text as they could for as long as they could, usually 10 minutes. At 2-minute intervals, the place they had reached in the text was recorded, by asking participants to point to it on the screen and say it out loud. At the completion of testing, average reading speed was determined by counting the number of standard words read per minute and averaging this over the time they read for. The number of standard words in a passage was determined by dividing the total number of characters (including spaces and punctuation) by six (Carver, 1990). This differed from the method used in the pilot study when words were merely counted.

Comprehension

Comprehension was indexed by the percentage of correct answers for all comprehension questions asked, as some participants did not reach a place in the text where five questions could be asked.

6.4.5 Pleasurability

Pleasurability was determined from a combination of participant's preference, their physical comfort, common problems encountered with actions, their willingness to continue reading (endurance) and heart rate variability. In a post-test interview, participants were asked to discuss the experience of using both machines. Common errors and negative comments regarding frustrating functions were analysed to determine aspects of the interface that could be altered to enhance pleasurability.

Preference

Participants were asked in the final post-test interview which machine they preferred and why. This provided a subjective measure in itself and one that was compared to performance.

Physical Comfort

A comfort score was based on subjective ratings made by the researcher using data from video analysis and scores from the post-test interview. Scores were on a 20-point scale; ranging from -10 = very uncomfortable, 0 = neutral up to 10 = very comfortable. The number of negative aspects was subtracted from the number of positive aspects (see Table 6.7) to determine the comfort score. So, if a participant had the maximum negative factors with no positives they would score -10. If they had the maximum negative factors and 2 positives their score would be -8. A specific negative or positive aspect was counted only once even if data included more than one mention of the same aspect.

Table 6.7: Scoring template for comfort rating.

POSITIVE	NEGATIVE
Did not need to stop	Needed to stop
Leaning back	Leaning forward
Neck in neutral position	Neck either bent forward or back
Arms at good angle	Arms extended
No body twist	Body twist
Hands away from controls	Both hands engaged
Hands and fingers relaxed	Hands or fingers hovering
No statements of frustration	Statements of frustration
No statements of discomfort	Statements of discomfort
No statements of fatigue	Statements of fatigue
Post-test fatigue score low	Post-test fatigue score high

Endurance

The length of time participants read before reporting fatigue was intended to determine endurance. In addition, decreasing reading speeds over time would indicate fatigue. However, due to the reasons mentioned previously, participants were reluctant or unable to continue past 10 minutes and quantifiable data was unavailable.

Physiological Measure of Anxiety

The physiological measure of HRV was to be related to subjective measures to determine level and direction of arousal. However, due to difficulties gathering quality data, this data was unreliable.

The Four Pleasure Needs

The socio, ideo, psych and physio pleasure needs identified in Section 3.1.3 were revisited to assess if these had been met.

6.4.6 Control Panel Design

Common Errors and Concerns

Video analysis and notes taken during testing provided information about common errors made by participants. This helped identify any areas of the control panel design that required further work by the company.

Frequency and sequence of use with control panel #2 were measured during the main project and will be utilised to refine a second-generation design if significant changes are required. However, this information was not analysed for this thesis and does not appear to differ greatly from the pilot study results.

6.4.7 Marketability

Demographics were gathered from telephone questionnaires to assist the company with marketing this product. In addition, information on user preference of picture settings, existing CCTV use patterns etc may also be beneficial for determining future products.

7 Main Study Results and Discussion

7.1 Conditions

Results

The order of exposure to the product and text was counter-balanced as detailed in Section 6.4.1. No order effects were found in statistical analysis of learnability, reading speed or comprehension.

Participants chose their preferred text mode (wordwrap or marquee), picture settings, speed and size. Participants often varied their speed and size during testing so only text mode and false colours were recorded. Table 7.1 is a summary of the number of participants who chose wordwrap or marquee mode of text presentation. Despite all participants seeing wordwrap first, due to this being the default setting, participants had a quick and strong preference for one or the other. No effects were apparent between text mode and other variables.

Table 7.1: Text mode preference by group.

	WORDWRAP	MARQUEE
Expert	6	7
Novice	7	4
Control	14	0

A 2 x 3 x 3 Chi^2 analysis of low-vision groups and picture settings for both CCTV and *myReader* revealed a significant effect of group with novices preferring black text on white background and experts preferring white text on a black background ($\chi^2(12)=45.4894, p=0.000009$). Black text on an aqua background was the only other false colour chosen regularly with 3 experts and 3 novices choosing this combination when using *myReader* while choosing more traditional black and white combinations with CCTVs. Table 7.2 summarises the colour preferences for all groups. However, performance measures were not significantly affected by picture setting choice.

Table 7.2: Colour settings chosen for testing in main study, by group.

	EXPERT		NOVICE		CONTROL	
	CCTV	*myReader*	CCTV	*myReader*	CCTV	*myReader*
Black on White	2	2	11	7	8	6
White on Black	10	8	0	1	1	1
Black on Aqua	0	3	0	3	3	5
Other	1	0	0	0	2	2
Total	13	13	11	11	14	14

Control participants (CTL) were eliminated from analysis of classification of central field using the Amsler Grid as their eyesight should not have influenced their performance. Very few people were classified as CFI resulting in cells with low frequencies (see Table 7.3), and no effects were found between central field and any of the performance measures or group.

Table 7.3: Central field classification,
CFI = central field intact, CFL = central field loss and CTL = control.

	CFI	CFL	CTL
Expert	2	11	0
Novice	4	7	0
Control	0	0	14

Discussion

Experts and novices were allowed to choose their own size and picture settings so as not to influence reading speed by forcing sub optimal viewing conditions on them. However, by not assigning participants to conditions, there were insufficient people in each of these conditions for statistical analysis to be conducted for several variables. It is also important to note that the three groups had unequal numbers (experts $n=13$, novices $n=11$, control $n=14$), but this was accounted for during analysis. None of the conditions mentioned here had a statistically significant impact on any performance variables, suggesting counter balancing was effective. The preference of the majority of experts choosing white text on a black background is consistent with this combination being less tiring and reducing glare (Lund & Watson, 1997). Most novices and controls preferred the traditional black text on a white background and many stated that this was what they were used to. Black text on an aqua background was another popular choice for both novices and controls, offering slightly less glare than a white background.

7.2 Impression of Technology

As the emotional relationship users have with technology is one of the focuses of this thesis, before investigating the results of the main study, let us first look at the impression this user group had of technology. By having an idea of how they are likely to interact with the technology, we can perhaps better understand the results that follow.

7.2.1 User Type

Results

Statistical analysis of user type was not always possible, as some cells had insufficient sample sizes. However, analysis of the percentages of people in each group who were a particular type reveals several interesting points (see Table 7.4).

Table 7.4: Number and percentage of technology user type by group.

	EAGER		HESITANT		RESISTER		TOTAL
	#	%	#	%	#	%	
Expert	4	***31***	8	62	1	8	13
Novice	3	27	7	***64***	1	9	11
Control	3	21	7	50	4	***29***	14
	10	26	22	58	6	16	
Population %		10-15		50-60		30-40	

Overall this sample has a higher than previously stated percentage of eager adopters and fewer resisters (Rosen & Weil, 1995). This is because the experts (31%) and novices (27%) have a much higher than average percentage of eager adopters, slightly higher than average percentage of hesitant users (62 and 64% respectively) and a much lower percentage of resisters (8 and 9% respectively) than the controls. The percentage of people in the control group in each of the three user types almost matches that of the population, with eager adopters fractionally higher (21%) and resisters marginally lower (29%). Experts make up the highest percentage of eager adopters, novices have the highest relative percentage of hesitant users and the control group has the highest number of resisters.

Discussion

This sample's spread of technology user type appears slightly different from previous studies (Rosen & Weil, 1995). As is to be expected the control group almost matches the population percentage ranges identified previously. This is a good indication that the sample chosen matches the norm. What is more interesting is that these percentages suggest that the sample of people with low-vision (experts and novices) is more accepting of technology than the general population. This demographic may therefore be more resilient to complex technology than the general population. If novices do not have as much need for low-vision reading aids as experts, it may be because their eyesight is not as bad or because they have support people living with them as was often the case for this sample. This would mean that the greater the need for technological assistance the greater the acceptance of technology. This may assist designers who can incorporate more complex factors. However, it is important to note that many people surveyed had difficulty imagining using technology and may have been more inclined to a neutral or positive response, which may have influenced results.

7.2.2 Comfort with and Exposure to Technology

Neither comfort with technology nor level of exposure to technology had an effect on performance or preference. These two aspects were measured using responses to the telephone questionnaire. It was apparent that many of these people did not use innovative technology and therefore some of the questions regarding comfort were not applicable. This may be part of the reason for the insignificant results. The responses did identify that the majority of participants were not exposed to technology and many participants stated they did not actively avoid use but did not actively pursue it either. Often people stated that their eyesight was the only reason they felt nervous/anxious or frustrated when interacting with technology. One third of the 44 people surveyed had a cell phone, mostly for emergencies.

7.2.3 Reasons for Avoiding Technology

Telephone questionnaires revealed that this sample had several reasons for not using technology. The most frequently cited reason was that their eyesight made it difficult to use a large variety of equipment, especially money machines, EFT-POS facilities and other appliances with small buttons with small labels. Designers of this type of equipment may need to conduct more user studies using a low-vision sample to reduce the frustration and fear felt by these people. Many others suggested they did not actively avoid technology but had limited opportunity to use this type of equipment due to financial or other reasons. Several people commented that as they had no need for "modern technology" they just did not use it. For example, one participant suggested that they had fared perfectly well without a microwave so why bother getting one. This supports the findings that those who do have specific needs are more inclined to learn how to use equipment that can help them. Others suggested that they just did not want to waste the time learning how to use modern gadgets. Only one or two people were concerned about electrical or radiation emissions from electronic equipment and this was mainly related to microwave ovens and cell phones.

7.3 Learnability

Results

Learnability results show that *myReader* took longer than to learn how to use compared to a more traditional CCTV. As experts' time to achieve competency on their own CCTVs was negligible, they were removed from the analysis of the comparison of learnability between CCTV and *myReader*. Table 7.5 details the mean (M) time to achieve competency for non-experts as well as the standard deviation (SD).

Table 7.5: Descriptive statistics for time to achieve competency.

	EXPERT		NOVICE		CONTROL	
	M	SD	M	SD	M	SD
CCTV	-	-	4.71	1.25	3.73	0.96
myReader	13.20	4.06	11.53	3.20	8.91	2.36

A 2 x 2 ANOVA with repeated measures on product (CCTV versus *myReader*) and with group (novice versus control) as a between-participant factor, revealed a significant main effect of time to achieve competency ($F(1, 23) = 138.86, p = 0.00$), with an increase from CCTV to *myReader.* There was also a main effect of group on time to achieve competency, with time significantly longer for novices than the control group, ($F(1, 23) = 7.1171, p = 0.01$). There was no interaction effect (see Figure 7.1).

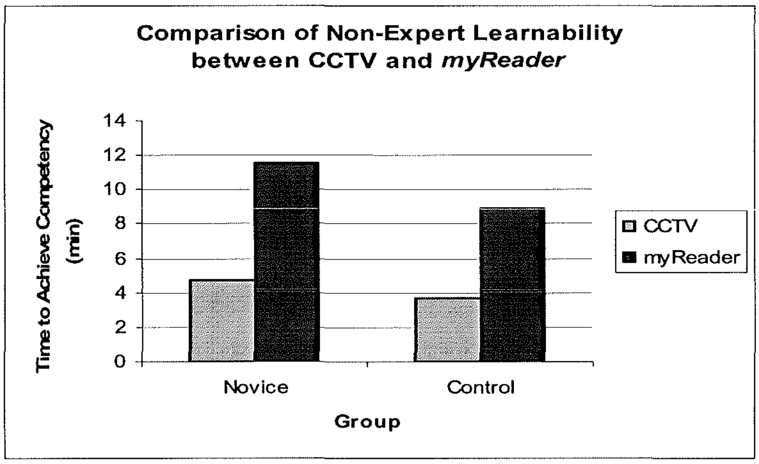


Figure 7.1: Average time to achieve competency for novice and control groups (non-experts) with CCTV and *myReader.*

A t test also revealed a significant difference in learnability for *myReader* between non-experts (novice and control, M=10.06, SD 3.01) and experts ($t(36) = 2.70, p=0.01$). As shown in Figure 7.2 below experts took significantly longer than non-experts to achieve competency.

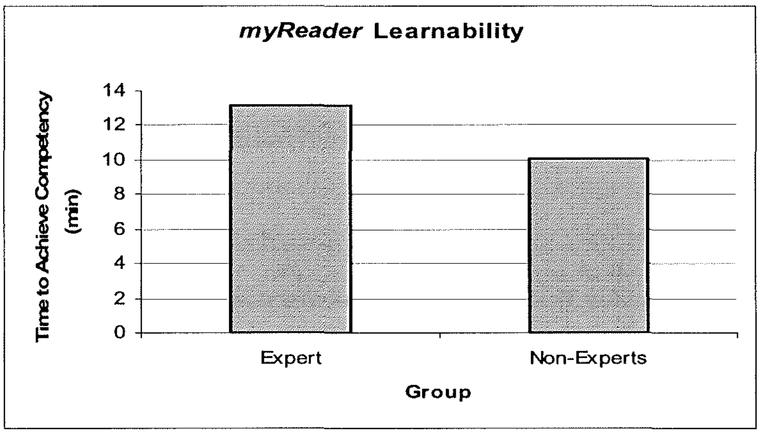


Figure 7.2: Average time taken to achieve competency for experts and non-experts (novice and control) with *myReader.*

Discussion

It was expected that *myReader* would take longer to learn than CCTVs given the increased functionality and complexity of the interface. Indeed, time taken to achieve competency was significantly greater for *myReader* than for the CCTV machines for non-experts. However, just over 10 minutes to learn how to use the functions tested in this experiment is very reasonable, considering how long people spend learning how to use complex technology such as cell phones and how many hours they will use reading aids.

The significant difference between experts and non-experts in time to achieve competency with *myReader* could suggest a negative transfer of skills for experts from CCTV to *myReader*. However, while the difference was statistically significant, three minutes is not a large difference, especially when considering the SD of 4.06 minutes. Training time was only long enough to learn how to navigate around and read two paragraphs of text and identify each of the operational controls. It is suggested that any negative transfer of skills would be mitigated with increased exposure to *myReader*.

The control group achieved competency quicker than novices. One possible reason for this is that control subjects could all read the labels on the control panel. The labels may have prompted them to the required actions, relying on identification rather than memory. Low-vision users may have had to rely more heavily on memory. Several low-vision participants commented that the labels on the control panel were too small to read. However, iconic labels were removed for Prototype #2 and making labels bigger is not possible due to space and aesthetic reasons. The different shapes of the controls were designed to aid memory.

Competency times may also have been affected by the time taken to load pages in the simulation. In the pilot study, the average loading time was 11 seconds; in the main study loading time was much higher with times of up to 50 seconds observed. Results reinforce the need to reduce loading time. As the company's project team is aware of the need to reduce loading time to 10 seconds, competency times for the fully functional product should be lower.

Competency was recorded with a stopwatch, which was stopped when there were interruptions. Having a second researcher present to record time may be a better alternative than relying on one person to make observations and take notes, provide training to participants and record time. Minute analysis of video would be required for second accuracy and was not possible given the time constraints of the project.

The design of the product will be modified to eliminate certain steps required to initiate reading, which may further improve learnability. However, learnability may be influenced by additional functions once the product is fully operational, as only the basic functions of the machine were tested in this study. Results do suggest that most users would be able to load and read documents in a very short period of time. Given the lack of training offered in the use of existing low-vision reading aids (Watson et al, 1997) this is an important element of design.

7.4 Usability

7.4.1 Reading Speed

Results

There was an overall improvement in reading speed of 18% for *myReader* with novice's speed 8% faster than with CCTVs and the controls reading speed with *myReader* was greater by 25%. The only group whose speed was lower with *myReader* was the experts, by 3%. A 2 x 3 ANOVA with repeated measures on product (CCTV and *myReader*) with group as a between-participant factor revealed a significant main effect of reading speed, $F(1, 35) = 13.787, p = 0.00071$; main effect of group $F(2, 35) = 75.443, p = 0.00000$ and an interaction effect $F(2, 35) = 13.767, p = 0.00004$ (see Table 7.6 for descriptive statistics).

Table 7.6: Summary of descriptive statistics for reading speed.

		CCTV		*myReader*	
	n	M	SD	M	SD
Expert	13	44.54	19.51	40.07	19.75
Novice	11	67.99	29.02	74.39	35.87
Control	14	158.23	46.73	219.33	53.54

As was expected and is evident in Figure 7.3, the control group influenced these results and are not the target market for this product. Therefore, analysis of the experts and novices was conducted. A 2 x 2 ANOVA with repeated measures on product (CCTV and *myReader*) with group (novice and experts only) as a between-participant factor revealed only a main effect of group, $F(1,22) = 7.8581, p = 0.01$, with novices being faster overall than experts.

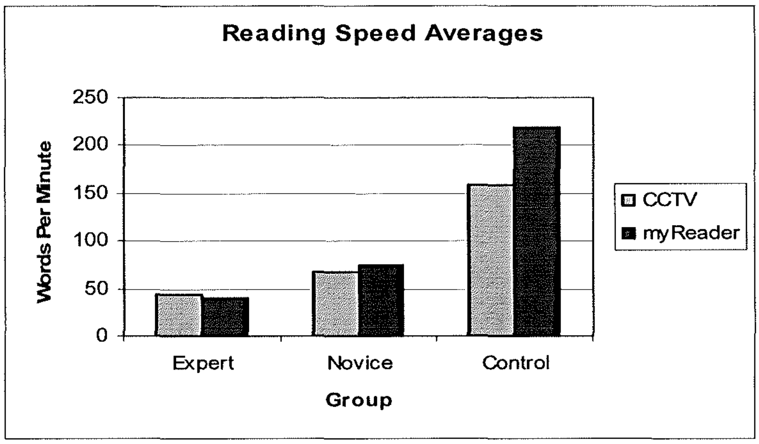


Figure 7.3: Average reading speed as words per minute by group.

Analysis of average words per minute for each 2-minute interval for the experts and novices revealed a significant main effect of an increasing reading speed over time ($F(4, 88)=3.3826, p=0.01269$). Reading speeds did not differ significantly between the products, but did differ between groups ($F(1, 22)=8.6899, p=0.00744$) with novices faster than experts. There were also significant interaction effects between time and group ($F(4, 88) =4.6286, p=0.00194$), and time, product and group ($F(4, 88) =2.6403$, $p=0.03901$). Figure 7.4 shows the trend for novices and experts and the control group trends, which also increased over time, are shown in Figure 7.5 over the page.

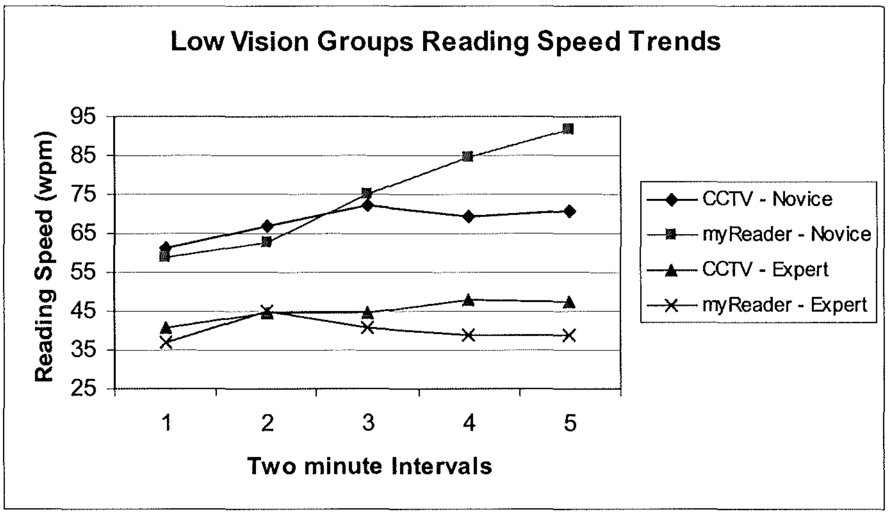


Figure 7.4: Reading speed trends for low-vision groups.

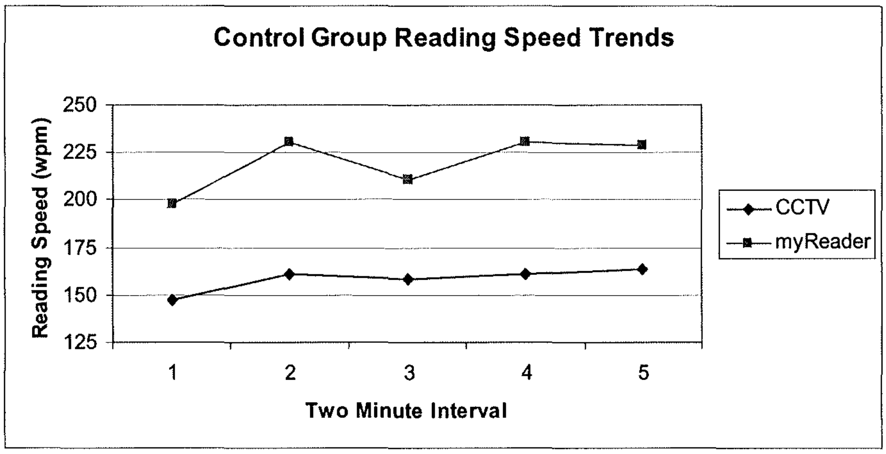


Figure 7.5: Reading speed trends for control group.

Discussion

Those unfamiliar with CCTVs (novices and controls) show an improvement in reading speed after a relatively short exposure. Experts showed a slight decrease in reading speed from their familiar product to the novel *myReader*, which may be due to negative transfer of skills. It is suggested that additional time spent becoming familiar with the machine may improve an expert's reading speed with *myReader* reading.

The trend of increased reading speed over time suggests a learning effect is apparent. This supports the concept that with further exposure experts may also show an increase in reading speed, mitigating any possible negative transfer of skills. The lack of a decrease in reading speed over time is also an indication that participants were not becoming fatigued. Therefore endurance may in fact be improved with *myReader*, although this would require further investigation.

The reading speeds in the main study were different from those in the pilot study, where both novices and experts speed decreased. Ensuring competency was reached prior to testing, using a standard word-per-minute measure rather than simple words per minute and including a control group are the most likely reasons for the differences in reading speed from the pilot study to the main study. While some of the speeds for the control group were higher than those found in previous research, most were comparable (Harland et al, 1998).

7.4.2 Comprehension

Results

The average percent of correct comprehension scores for CCTV was 65% and 66% for *myReader* (see Table 7.7 for descriptive statistics). A 2 x 3 ANOVA with repeated measures on product with group as the between-participant factor did not reveal any significant differences in the level of comprehension between machines. Post hoc analysis revealed that only the control group differed significantly from the other groups in level of comprehension (see Figure 7.6).

Table 7.7: Summary of descriptive statistics for percentage of correct comprehension questions.

	CCTV		*myReader*	
	M	SD	M	SD
Expert	63	24	61	24
Novice	65	12	64	17
Control	68	19	73	19
	65		66	

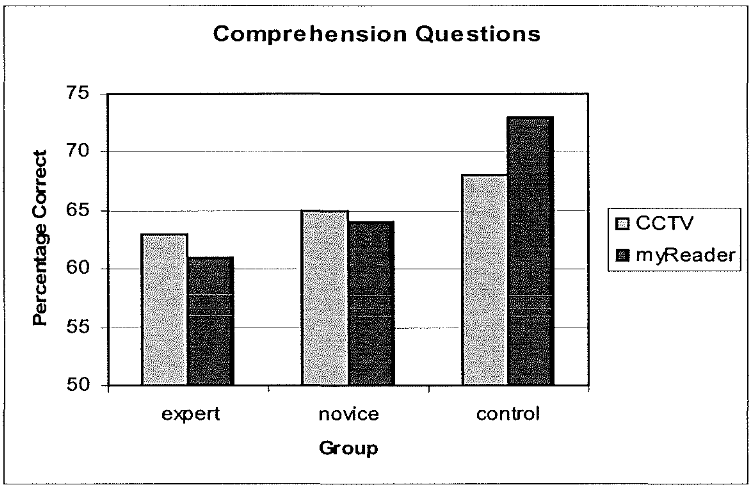


Figure 7.6: Percentage of correct comprehension questions by group.

Discussion

Although, there was no increase in overall comprehension from CCTV to *myReader*, as the manufacturer had hoped, there was also no degradation. Control participants were reading significantly faster with no degradation in comprehension. The combination of static comprehension results with increased reading speed, over all groups, suggests there was no speed accuracy trade off evident with *myReader*. This supports the increased functionality of *myReader*.

The overall level of comprehension achieved was not as high as levels reported in the Harland et al (1998) study. However, 70% comprehension is considered a good level and these results are only fractionally lower (Smith, 2002). Comprehension levels were similar in the pilot study suggesting that the main study results may indeed be an average level of comprehension for this sample and the changes made to the comprehension questions used in the pilot study had little impact. Colours of text and background can impact on comprehension levels (Smith, 2002). But, as mentioned previously no significant differences were found in picture setting choice. Investigating optimum choice of false colours may be an option for future fundamental research.

Because it was not possible to determine how far participants would reach in 10 minutes, the questions could not be counter-balanced. Instead, questions were chosen by the researcher on the basis of where participant's had reached in the text. Analysis of responses to the most commonly asked multiple-choice questions revealed that all but two of them were answered correctly more often than not. Multiple errors on a single question could suggest a poor question. Alternatively as the control group did better than novices, who in turn did better than experts it is possible that eyesight played a role in the level of comprehension.

7.5 Pleasurability

7.5.1 Preference

Results

Of the 38 participants who completed testing, 11 preferred CCTV (29%) and 27 preferred *myReader* (71%). The four participants excluded from performance data analysis because they could not complete testing all preferred *myReader* (see Figure 7.7). However, a Chi^2 analysis of preference of product was not significant.

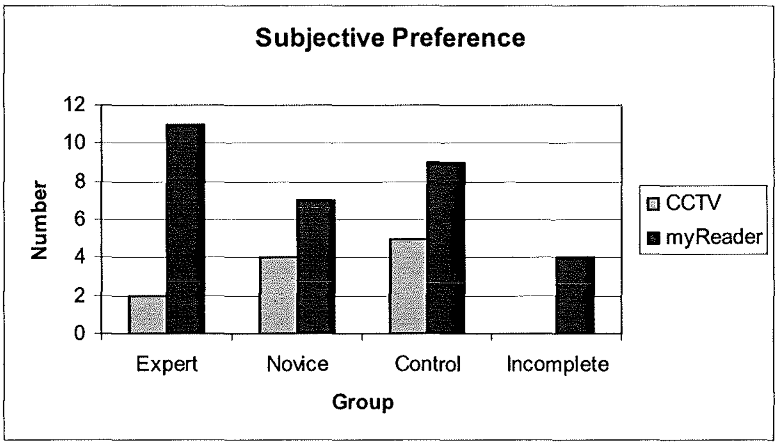


Figure 7.7: Frequency of preference for CCTV or *myReader* by group.

It is however evident that a large majority preferred *myReader*. The group with the greatest preference for *myReader* was the experts, with 85% of them preferring this product. As well, 64% of both the novice and control groups showed a greater preference for *myReader*.

A significant interaction was observed between preference and comprehension $F(1, 36) = 7.2736$, $p=0.01058$, with participant's who preferred one particular machine also performing better with that machine. However there was no interaction between preference and reading speed, in 2 (preference) x 2 (product) repeated measures ANOVA, with group as a between-participant factor.

Discussion

The high percentage of people preferring *myReader* supports the findings of the pilot study that *myReader* is the strongly preferred machine. Experts preferred *myReader* more often than other groups, perhaps because they have a greater need for this product. While novices and controls had a preference for *myReader*, it was less than the experts. Post-test comments regarding why participants preferred a particular machine were analysed. Comments all fitted into 9 categories (see Table 7.8). While some participants mentioned several reasons, coding was based on the primary comment. Some participants had no specific reason and have been coded as "just did."

Table 7.8: Coding of reasons for preference.

	myReader	**CCTV**
Simpler to use	6	4
More compact	5	1
Just did	5	1
Scrolling	4	0
Reduced dizziness	3	0
Reduced movement	3	1
Greater range of options	1	0
Familiarity	0	2
Greater control	0	2
	27	11

These reasons strongly support the automatic scrolling, reduced size, reduced physical requirements and lowered dizziness. It could be argued that those stating *myReader* was easier to use may have been referring to any number of factors. Despite further queries, these people were unable to give a definitive reason for their statement. Those that preferred CCTV because of greater control, support the theory that people do like to feel in control.

The interaction between comprehension and preference suggests that participants were aware of what was easier for them. This was not, however, supported by any significant effects between preference and reading speed. Indeed, 2 of those stating they preferred CCTVs reported discomfort during its use, and none when using *myReader*, highlighting the limitations of subjective assessment. In addition, many of the experts who stated they preferred *myReader* did not do as well in the performance measures.

7.5.2 Physical Comfort

<u>Results</u>

A 2 (product) x 3 (group) one-way ANOVA revealed a significant main effect of product (F (1, 35) =45.861, p=0.00) and group (F (2, 35) =3.6632, p=0.03593) with no interaction effect. Average scores by group are shown in Figure 7.8 with descriptive statistics summarised in Table 7.9.

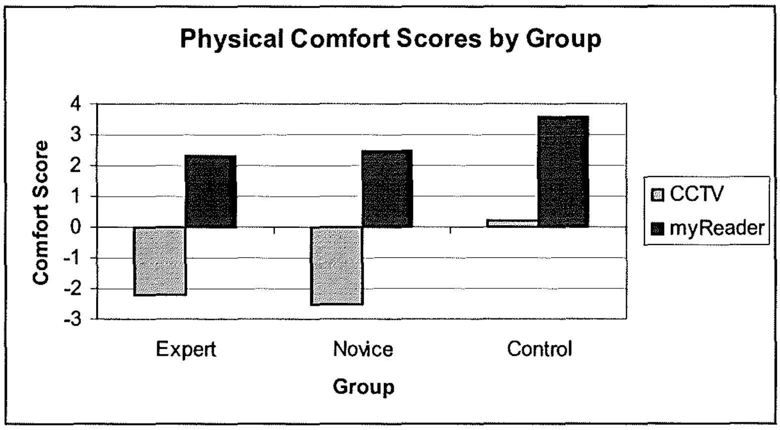


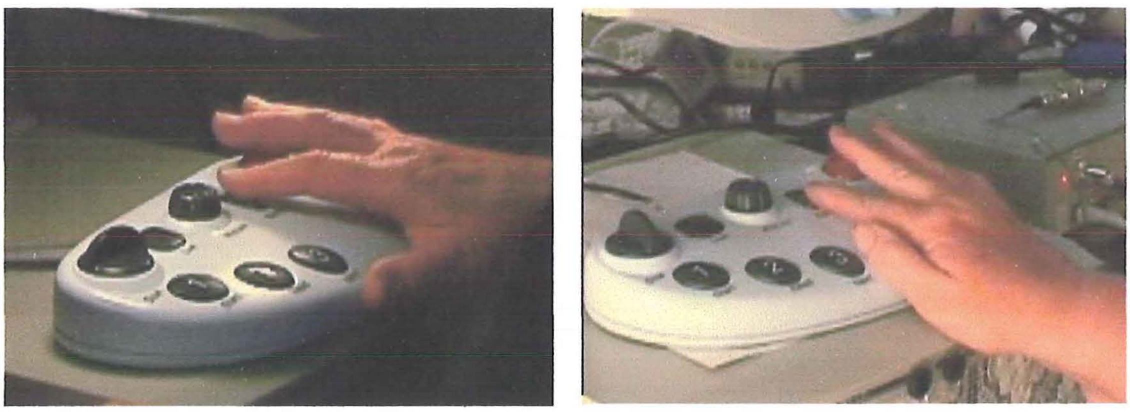
Figure 7.8: Comparison of subjective physical comfort ratings by group.

Table 7.9: Summary of descriptive statistics for physical comfort scores.

	EXPERT		**NOVICE**		**CONTROL**
	CCTV	*myReader*	CCTV	*myReader*	CCTV
N	13	13	11	11	14
Mean	-2.23	2.31	-2.55	2.45	0.21
Minimum	-8	-3	-7	-4	-2
Maximum	4	10	1	8	5
Std.Dev.	3.24	3.54	2.42	3.93	1.81

Discussion

The physical comfort score was a rating of participants' physical response to each machine, from -10 being the worst possible rating to +10 being the highest. Results suggest that *myReader* is an improvement over the physical requirements for CCTVs. However, there is still some room for improvement as only one participant received a score of +10 for physical comfort with *myReader*. Most participants were still operating *myReader* with both hands, having their hands hovering over the controls, reaching and reporting frustration. Figure 7.9 a and b illustrate hovering over controls. There was certainly less body twist apparent with *myReader*, less arm fatigue as hands could be relaxed, less occurrence of the neck being bent either forward or back. There were no reports of nausea or dizziness as was the case with CCTVs. Participants were also reporting less eye fatigue and had to stop less often.



a) b)

Figure 7.9: Several participants were unable to find a comfortable position when operating the speed dial with hovering fingers resulting, a) and b) illustrate this behaviour.

7.5.3 Endurance

As the physical requirements for *myReader* were expected to be reduced and posture improved, endurance was expected to increase. Only 2 of the 42 people tested were willing to continue after 10 minutes with either product, indicating endurance did not increase. However, many participants reported being less fatigued at the completion of testing with *myReader*. One participant struggled to complete the CCTV test, stopping several times. At the completion of the *myReader* test, the participant was pleasantly and openly surprised that 10 minutes had passed, commenting that "I could read a book like this." In addition, the reading speed trends show no decrease, a good indicator of fatigue.

It is suggested that being observed may have reduced participants' willingness to continue reading. If participants had a longer time to use the machine on their own endurance may increase, but further testing would be necessary. In addition, participants' motivation to read their own letters and books may be greater than reading an arbitrarily assigned story. Beta testing of a working *myReader* prototype is planned. This testing will involve obtaining a base-line measure of performance, leaving the equipment with participants for 4 weeks and then retesting to determine if gaining greater proficiency may also increase the length of time users are comfortable reading at one sitting.

7.5.4 Physiological Measure of Anxiety

One measure used in this study yielded no usable data. Out of 38 participants usable heart rate data for both machines was gathered for only 4 users. Several people were unwilling to have their heart rate monitored, good results were recorded for one test but not the other for some people. For several other participants no recording was possible either because of equipment faults or a lack of conductivity between the participant's skin and the chest strap. Women wearing powder, very hairy chested men, one with a sunken chest and people who did not perspire did not provide quality readings. While a damp face cloth was used to moisten the skin and the chest strap to encourage conductivity, this did not help in some situations. In addition, those who leant forward to the screen often had variable readings because of an intermittent connection.
While heart rate variability data was not usable in this study it is a good measure of anxiety (Watson, 2001) and should not be discounted for future research in this area. However, from this study it is clear that using a sports chest strap has its limitations and an alternate method for ensuring conductivity is essential. Electrodes attached to the chest offer the most reliable data, but it was not possible to use this equipment here. It was clear from feedback that once it was on, the chest strap was not invasive at all, once it was on. Many participants were so comfortable that when asked to take the strap off

they commented that they had completely forgotten about it. On one occasion, the strap was left on a participant after the researcher had packed everything up and left! It was not until the researcher contacted the participant that they realised they were still wearing it.

7.5.5 The Four Pleasure Needs

Revisiting the sociological, ideological, psychological and physiological requirements of this specific user group reveals that many of these aspects have been considered in the design of the control panel. On the sociological dimension, *myReader* does appear to assist in maintaining and improving user's quality of life by allowing easier reading. In the telephone questionnaires, 99% of participants stated that their existing machines provided them with independence, which they valued very highly. As *myReader* is preferred their reading experience will be further enhanced. Avoiding using clinical colours and a clinical look could help reduce negative stigma of the product. The final product is an almost grey-blue colour with highly contrasting black controls. This departs from the clinical grey or white of existing CCTVs and all but one participant said they liked the colours used. The compact nature of the product also lends itself to portability, offering more freedom for users.

Ideologically, the aesthetic appeal of the product lies in its organic form, with rounded edges and drawing on the metaphor of a river stone. All but one participant liked the shape and look of the product. None of the participants mentioned concerns regarding the environmental impact of the product. However, many were aware of the potential cost. Including information about buy-back schemes, RNZFB hire schemes and possible donation in the product's literature may help this user group.

With regards the psychological concerns, conducting user testing has identified actions that caused negative emotions (see Section 7.6.1 on common errors). Many of these have been addressed, enhancing the pleasurable experience of using *myReader*. Two participants who preferred CCTVs noted that greater control was their reason for their preference, highlighting this as a design consideration. The trackball is designed to override the automatic scrolling function to allow backtracking, providing some degree of control. However, users found discontinuing the automatic scrolling problematic, with several participants becoming visibly agitated when they could not remember how to stop the text from scrolling. It was suggested that a *stop* function be added to the *speed dial* so when users want to stop they depress the wheel rather than scrolling it to the stop location. This would provide a greater sense of control and is planned for future models.

Figure 7.10: A participant has to steady the control panel while adjusting the picture dial.

On the physiological dimension, *myReader* will suit the use of a height-adjustable LCD screen. The space required to use *myReader* is also less than for CCTVs with no x-y table. In addition, the reduced dexterity requirements will allow a wider group of users to enjoy reading again. Many of the ergonomic issues surrounding poor posture associated with CCTVs have therefore been addressed. This is supported by the improved physical comfort ratings. However, several participants did have difficulty with turning the *picture dial*, so decreased force requirements were recommended for this dial. While this is a factor under consideration by the company, technical realities mean this will not happen for the product's initial release. Figure 7.10 illustrates how one participant had to hold the control panel to activate the picture dial.

7.6 Control Panel Design

7.6.1 Common Errors and Concerns

Analysis of data logs, observations during testing and later video analysis revealed several common errors and concerns when operating *myReader*. These were the result of a mismatch between the control panel's design and the constraints of the user (see Table 7.10). Several recommendations were made to the company to change the interface design to eliminate the requirement for some of these actions and adjust the design to better match the physical and psychological considerations of the user. To eliminate or reduce the occurrence of these errors and the associated negative response the user's goal and the required action need to match. Each common error, the possible reasons for it and alternatives to reduce the problem are discussed below.

Table 7.10: Summary of common errors and concerns with *myReader* and percentage of users experiencing them.

COMMON ERROR	EXPERT	NOVICE	CONTROL	TOTAL %
Size dial instead of read button	6	7	8	55
Wrong direction with size dial	4	3	5	32
Query about whether all text presented	2	2	1	13
Wrong direction with speed dial	7	8	9	63
Not a fine enough speed adjustment	5	2	1	21
Bumping read button	2	1	0	8
Bumping size dial	6	5	3	37
Bumping trackball	5	5	3	34
Next button for next page	2	3	5	26
Unsure what to do at end of page	7	7	9	61
Not knowing how to stop	5	4	5	37
Picture dial too stiff	4	2	3	24

<u>Size Dial</u>

More than half of the participants at some stage during training or testing adjusted the *size dial* before they accessed the processed text. On the screen they could see an overview of the page which was too small to read. The overview was a function that engineers had thought useful but study participants found frustrating. Remembering an additional step made the action too complex and participants made repeated errors in executing this step. This is a mismatch between user expectations and required actions that elicited a negative response. Increasing the size of the text should be an intuitive action when presented with text that is too small. However, the machine required that they press the *read/page button* before they could adjust the processed text. Some users kept trying to change the size or tried to initiate scrolling. As there was no feedback regarding what to do next, these users were often stumped and unsure how to proceed.

It was recommended that an alternative method of accessing text be found. It was suggested to the company that the additional step (having to press the *read/page button*) be eliminated. If users pressed the *start button* and processed text was automatically presented this would reduce the frustration associated with having to remember an arbitrary action. Alternatively if text could be accessed by adjusting the size dial this would match their actions. The final product will have an alternate means of accessing text, although the specifics have yet to be decided.

The *size dial* had free movement both clockwise and anti clockwise with no physical feedback from the dial when the extremes had been reached. Even though the directions used in the *size dial* match the norm (anticlockwise to decrease and clockwise to increase) many users were still having difficulties. Several users continued to turn the dial anticlockwise for longer than a minute despite the lack of change of text on the screen providing visual feedback. This suggests the visual feedback was insufficient. By including physical feedback in the dial indicating the extremes, users may more quickly realise they need to turn the dial in the opposite direction.

Borders

In the pilot study several participants expressed concern that all the text was not being presented on the page when using the wordwrap mode of text presentation. The software for the pilot study ran text to the extreme edges of the page. The software was adjusted to provide space on either side of the text to indicate a border. However, in the main study several participants continued to query whether all text was on the page. Providing borders that are similar to page borders may help reassure users. An outline in the colour of text may help users conceptualise a page.

Speed Dial

In the pilot study participants made repeated errors in selecting the direction for the *speed dial*. The direction was changed for the main study to match the industry standard. However, participants continued to make these errors in the main study. While participants had problems initiating the automatic scrolling because they were pushing the *speed dial* in the wrong direction, they received sufficient and timely feedback from the display and quickly adjusted their actions.

The direction of the *speed dial* now fits with industry norms, and was easily learned; therefore, no further adjustment was recommended. One other common concern was that the *speed dial* needed finer adjustments. Several participants found the slowest speed too slow and the next speed just a little too fast. It was only at the slow speeds that this fine adjustment was necessary but it did cause concern and frustration. The company have included finer adjustments at lower speeds.

Bumping

Following the pilot study the *speed dial* was moved and more access room allowed. The control panel became slightly larger to accommodate the physical constraints of the user. Despite these changes, several buttons were bumped during the course of the main study; mainly the *read button*, *trackball* and *size dial*. Three participants who used their left hand to operate the speed dial rested their left wrist on the *read button* (see Figure 7.11 for examples). Because they were unaware they had activated any controls they exhibited uncertainty as to what had happened and developed a lack of trust in the product.

Despite moving the *speed dial* and Prototype #2 having a bigger area, several participants still bumped the *trackball*, indicating more room is required. Figure 7.12 illustrates how this bumping may occur. The *size dial* was also bumped on numerous occasions, most often when participants had their left hand resting by the *size dial*.

a) b)

Figure 7.11: At least 3 participants operated the *speed dial* with their left hand. Their left wrist then bumped the *read button,* a) and b) illustrate this behaviour.

It was recommended that more room be provided to operate the controls and changes be made to the layout of the buttons to accommodate these concerns. The final control panel is however smaller than either Prototype 1 or 2. While the *size dial's* profile has been lowered to reduce bumping, there is less room for operating the *speed dial* which may result in bumping the *trackball* with nowhere for the left wrist to rest if operating the speed dial left handed. Beta testing will reveal whether bumping the *trackball* and *read button* still occurs in the final product. The company will then need to decide if an alternative design is necessary.

Figure 7.12: While operating the *speed dial* several participants bumped the *trackball.*

Jargon

User comments revealed that frustration due to a lack of understanding of some terminology used in labelling controls and simulation software notices. In the pilot study, while the computer processes the text the message "loading" appeared. This was changed to "please wait" which was better received. The control labelled "next" was also misunderstood causing some frustration. While participants had been informed that the *next button* was inactive, when they came to the end of a page and wanted the next page several people pushed this button with statements such as "...but I want the next page..." when told it was incorrect.

On the final product the *next button* allows users to move text one screen at a time rather than using the *speed dial* or *trackball* to navigate[9]. However, it is clear that the *next button* caused some frustration when its function did not meet the expectations of the user based on the terminology "next". Another control that caused minor confusion was the *picture dial.* The function of the *picture dial* is to alter the colours. Due to the product being sold in the United States the word "colour" would have to be spelled differently and "picture" was seen by the company as a more universal word. Unfortunately, some people could not remember how to access the processed text when presented with the overview, and for them "picture" meant changing the picture rather than colours. Determining optimum language to be used on controls for this population is a possible area of future research.

Many users had a problem when they came to the end of the page. Some did not know they had reached the end of the page, while and others were unsure what to do next. Those who were not aware they had reached the end of the page could not understand why the text had stopped scrolling, implying that participants were so immersed in reading the text that and were confused. Alternatively, this could be associated with memory requirements of learning the appropriate actions involved in loading a new page. A cue at the end of each page prompting users about the next action would be appropriate. When *myReader* is first turned on, a message states "place your reading material and press start." A similar message could also be placed at the end of each

[9] Several participants did mention they preferred to read one page at a time, but this was not tested in either of the studies documented here.

scanned page to prompt users. While this may only be necessary during learning, it is believed the redundant information would cause no negative effect. As other messages relating to paragraph end, section end and image are to be included, a message stating <page ends – place new text> may be appropriate. As this demographic prefers textual to iconic information, symbols should be avoided to convey this type of message.

7.7 Marketability

Demographic information and details relating to current use patterns of CCTVs was gathered during both studies. Table 7.11 summarises the type of data collected. This anonymous information will provide the company with data that can be used in marketing as well as enhancing future iterations of the product. For example, the colour preference of participants in this study may assist the company in choosing colours to incorporate or leave out of future products. Feeding these results and those regarding performance with *myReader* back into the design cycle can increase the product's usability and marketability.

Table 7.11: Summary of information collected for Pulse Data.

- Picture setting preference
- Text presentation mode preference
- The CCTVs in use by experts
- Technical problems experienced with CCTVs
- Activities undertaken using CCTVs
- Where in the house CCTVs are used
- Participant demographics
- Use of talking books

8 Conclusion

8.1 Overview of Results

The results of both the pilot study and the main study clearly illustrate that overall *myReader* offers a more pleasurable reading experience than existing CCTV technology. The user group appears to be more accepting of innovative technology when they can see it will improve their quality of life. *myReader* takes a little longer to learn how to use than CCTVs but given the increased functionality this is not unexpected or unacceptable. With an average time to achieve competency of just over 10 minutes, the decrease in learnability is not unreasonable. An increase in increased reading speed is evident with *myReader*. However experts exhibited a slight but statistically insignificant decrease in reading speed with *myReader*. Comprehension is unaffected by the scrolling text and faster reading speeds, indicating there is no speed-accuracy trade off. The increasing reading speed over time suggests that further improvement in performance is likely with practice and prolonged exposure. Many of the physical requirements of CCTVs are reduced in *myReader* and participants reported less fatigue. There are however areas of the design that could be altered to further improve the emotional relationship users have with the product.

8.1.1 Impression of Technology

Based on technology user type, the participants in this study almost match the norm, offering a good sample. Participants with low vision were, in general, more likely to engage with technology than the control group, perhaps only if this compensated for their disability. Those with a support person or those not interested in reading were less likely to engage. Experts were more accepting of technology because they could see a direct benefit to them of learning to use innovative technology such as computers. It would appear that in general this sample has less exposure to innovative technology than the population in general, due in large part to choice. Whether choice is avoidance because of technostress or for other valid reasons is not possible to determine from the results and may be a possible area for future research.

8.1.2 Learnability and Usability

Any new product takes time to learn how to use. CCTVs have a very simple and easy to learn interface. *myReader* incorporates more complex functionality and as such takes longer to learn. Expert CCTV users took longer to learn how to use *myReader*, but as this was only a few minutes more than novices and controls, the additional time is negligible. Several aspects of the design could be enhanced to increase learnability by utilising intuitive actions and matching the needs of the user with the abilities and requirements of the machine. Only the primary functions of the machine were tested in these experiments and added functionality of the fully operational product may further impact on learnability. Results do suggest that most users would be able to load and read documents in a very short period of time. *myReader* allows users to achieve their goal of reading more efficiently and enjoyably than with CCTVs. Comprehension is not adversely affected by improved reading speed and the majority of users reported preferring the automatic scrolling to using the x-y table of CCTVs. Levels of fatigue were less with *myReader* and the increased reading speed over time suggests endurance may be improved, this will, however, require further research for confirmation. However this will require further research to confirm.

8.1.3 Pleasurability

The majority of participants preferred *myReader* to CCTVs, with those most in need of the technology showing greater levels of acceptance. Physical comfort ratings were higher for *myReader*, with it's design addressing many of the limitations of CCTV. Improved posture, reduced dexterity needs, and decreased spatial requirement are the greatest contributors to *myReader's* enhanced physical comfort ratings, by improving posture, reducing dexterity needs and reducing space requirements. Using Jordan's four pleasure needs framework it was clear that many of this user group's needs have been addressed, suggesting that *myReader* has a high level of pleasurability. Reliable HRV data was not obtained using the methods detailed, but a physiological measure of anxiety could be utilised in future research to determine positive or negative arousal when interacting with the product.

8.1.4 Control Panel Design

Several common errors and concerns highlighted areas of the design that could be enhanced. Eliminating an unnecessary step when accessing text could make remembering how to operate *myReader* easier. Incorporating physical feedback in the *size dial* at the extremes of adjustment could assist users in identifying when they are turning the dial the wrong way. Using the concept of a page outline by incorporating physical borders in wordwrap mode could reassure users that all text is presented. Finer adjustments of automatic scrolling at the lower speeds would enhance user's reading experience. More space on the control panel to operate controls and rest the wrist could reduce accidental bumping. Having a prompt when users have reached the end of a page would lessen memory load. Also incorporating an immediate stop function in the *speed dial* (i.e. press in once to stop rather than having to reverse scroll) would provide users a simple escape route. Some users had problems with turning the *picture dial*, so if the resistance in this was lowered this problem may be eliminated.

8.2 Implications of Findings

The design of *myReader* has been enhanced because of user feedback and this research has expanded the database on the relationship between interface design and negative affect towards consumer electronics. User-centred iterative design is supported by the findings with several changes having been made to the product. Methods for identifying user type and aspects that elicit responses could be applied in other situations.

8.2.1 myReader

The research revealed that *myReader* is widely accepted among the target user group. Many of the CCTV limitations are overcome and the product appears to be usable and pleasurable. Findings from the study were devolved to the project team as production progressed. The benefit of this was twofold. Firstly, designers and engineers received early positive reinforcement that their product was of benefit to the target market. Feedback such as this can provide encouragement for staff when motivation wanes (Muchinsky, 2000), such as in the final stages of production. Secondly, the project team received information about areas that caused users problems and required enhancement. Receiving this information before the product was released allowed changes to be made without any negative effects on the potential market from teething problems. Results will also be used by the company in marketing the product.

Table 8.1: Summary of design changes to *myReader* control panel.

- "Please Wait" used instead of "Loading" when *myReader* processing text
- "Write" renamed "Live" to more accurately reflect function
- Progress indicator displayed on screen while *myReader* processes text
- Read/Overview button renamed read for simplicity
- Profile of *size dial* lowered to reduce bumping
- *Auto button* eliminated
- Movement of *trackball* changed to mimic text mode (vertical wordwrap – horizontal marquee) and direction (stroke left to scroll left – stroke up to scroll up)
- Direction of *speed dial* altered to reduce errors in activation
- Tactile feedback on *speed dial* provided to indicate when stop reached to avoid backtracking
- Stop function to be added to *speed dial* involving depressing dial†
- *Speed dial* allowed to initiate scrolling
- *Speed dial* has smaller increments to allow finer speed adjustment
- *Speed dial* allowed to back track
- Next function incorporated to scroll a screen at a time
- Visible margins provided in wordwrap mode to indicate all text is displayed*
- Message at the end of the page to prompt users†
- Fuzzy letters in text eliminated to avoid distraction
- Raised dots on buttons eliminated as they did not aid location
- High contrast of colours of the panel and controls maintained
- Controls all the same colour

* Changes to be made prior to product release
† Changes to be made in future models

8.2.2 Iterative User-Centred Design

The benefits of the iterative user-centred design are evident. The design of the *myReader* control panel evolved throughout this research with three iterations (see Table 8.1 for summary of the changes made). Many of these changes were made entirely based on feedback from the intended target user group as well as a group of matched age controls who experienced similar problems. Without the user studies, some of the problems experienced may not have been identified until after the product was released. The three prototype panels are illustrated in Figures 8.1-8.3 below.

Figure 8.1: ***myReader*** **control panel Prototype #1**

Figure 8.2: ***myReader*** **control panel Prototype #2**

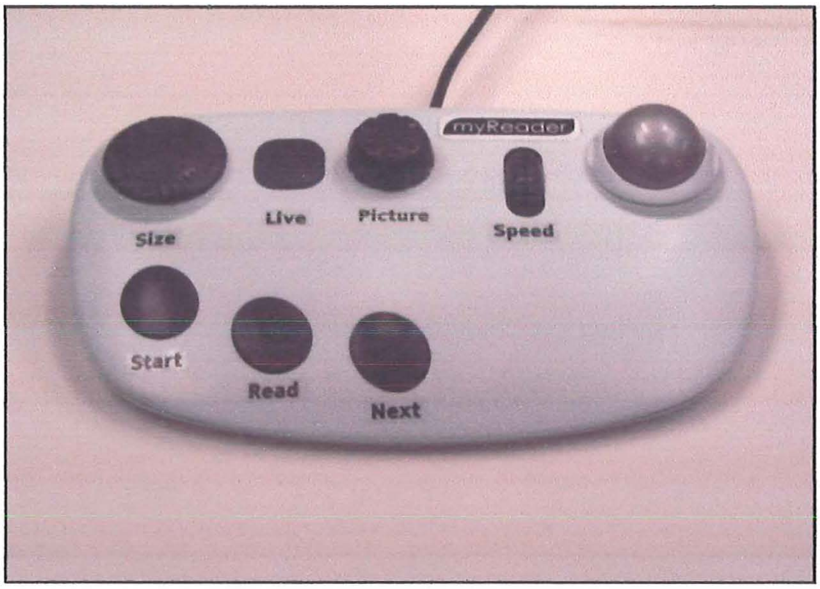


Figure 8.3: *myReader* control panel Prototype #3

Briefly, Prototype #1 had multi coloured buttons and iconic labels. In Prototype #2 the controls were all the same colour as the differing shapes of controls was sufficient to aid identification. Labels were made textual as several of the icons were unidentifiable by participants. Prototype #2 was slightly bigger with more room for access to the *speed dial,* as the *trackball* had been bumped during the pilot study. The *write button* was renamed *live* to more accurately reflect its function. The *auto button's* function was redundant as users could initiate scrolling using the *speed dial.* Therefore, this button's function was changed to allow users to advance one screen of text at a time and renamed *next.* It was inactive during testing. The final iteration, Prototype #3, is smaller than both previous prototypes with the size dial's profile being lowered to avoid bumping.

8.2.3 Application of Findings

This research investigated a sample of older New Zealanders in their interaction with low-vision reading aids. As well as the specific findings for the design of *myReader,* the results suggest that actions that cause negative reactions from users can be identified using observation and analysing common errors and concerns. While the results may not be entirely generalisable to other aspects of consumer electronic interaction, the results do suggest that similar methods could be used in other situations to identify actions that cause negative reactions.

Identification of the user type provided a measure of how eagerly participants accepted technology. In general, this group almost matched the norm, but the low-vision groups more eagerly accepted technology. The control group provided more of a hesitant user's perspective. Knowing whether people are eager, hesitant or resistant users of innovative technology can also help with training (Weil & Rosen, 1997). While a physiological measure of anxiety was not achieved in this research, with alternate equipment a quantifiable measure may further assist identification of anxiety provoking actions.

By assessing user's actions, negative experiences can be identified and consumer electronics can be designed to reduce negative affect by eliminating these actions. It is argued that interface design does affect a user's emotional relationship with a product and this relationship could be improved. Participants were excited about using *myReader* due to the improved usability. They did display concern and negative emotions when exposed to counter intuitive actions. By retesting some of these participants once final changes have been made, a measure of improvement in their impression of the technology could confirm an enhanced emotional relationship with the product.

CCTVs have a simple and easily learnable interface. *myReader's* interface is more complex and does take a little longer to learn. This would imply that interface design does affect learnability. In this instance however, the difference in time to achieve competency was expected and acceptable given the increased functionality. The reduced physical requirements for *myReader* suggests a more usable and pleasurable product. If users prefer a product, this has implications for continued use and marketability. Several expert users who participated in the study had reading aids that they did not use. Several novices had previously tried machines but chose not to purchase one due to the discomfort they experienced. As the majority of participants preferred *myReader* this would imply they are more likely to continue to use it. They are also more likely to buy and to recommend the unit to other people with low vision.

8.3 Qualifications of Experiments

The pilot study provided an opportunity to trial methods for the main study and several changes were made as a result. As with any research, further possible enhancements were revealed as the study progressed in methodology. Other limitations such as the realities of industry-based research were also highlighted.

8.3.1 Methodology and Equipment

The benefits of having an objective physiological measure of anxiety are well documented (e.g. Watson, 2001). However, conducting user testing in people's homes presented challenges to gathering quality HRV data. Alternative equipment or more highly controlled conditions would be required to gather HRV data. Automatic recording of timing by test equipment could reduce potential experimenter error. However, it would be difficult to achieve as the machine could not detect when someone had stopped reading or was talking. Additionally, CCTV machines cannot record timing of interaction such as the data logging software incorporated in the prototypes used in the studies.

Other possible biases identified included experimenter bias and a Hawthorne effect. Conducting a rater reliability check was not possible due to training time that would have been involved. While it may have been possible to have someone from the company who had an understanding of the product, this was not done due to time constraints. Participants were unaware of the specific objectives of the study which may have mitigated any Hawthorne effects.

Because several variables were self determined there were too few participants in some groups, reducing the number of statistical analyses that could be conducted. A more controlled testing regime may eliminate this effect, but could confound results in different ways by forcing suboptimal conditions on participants. Finally, the reliability of subjective measures could also be a limitation of the studies (Stephens et al, 2000). Several participants reported being uncomfortable when using CCTV but stated they preferred it. However, the triangulation of a variety of subjective and objective measures should have mediated this effect.

8.3.2 Reality of Manufacturing

Ideally, user-centred design involves user participation from concept generation to product launch and beyond (Peacock, 2002). By having users and human factors analysts involved early in the design cycle costly changes to a product can be avoided by identifying problems before making large investments into prototype production. The reality is that human factors analysts are often brought into the design process once many design decisions have been reached and time and much money have been invested. In this instance, the expert evaluation was conducted on a prototype that was scheduled for tooling in less than 4 months. This meant that if there had been major changes needed there would have been a greater cost associated than if such changes were made before the prototype was built.

This research was industry based with direct interaction with the company. This interaction provided first-hand experience of the realities of trade offs that are sometimes necessary when designing a product. On several occasions there was a gap between optimum design recommendations and what was economically, mechanically or managerially possible. For example, while it was suggested that the control panel allow more space for access to controls and for resting wrists the final product was actually smaller than Prototype #2 due to a company decision to keep the panel as small as possible. Another example is the technical reality of incorporating hard stops as feedback on the size dial to avoid turning in the wrong direction. This is not possible as the size dial is a relative control. When *myReader* is switched off, it remembers the user's size setting. If the dial is accidentally knocked or the user's grandchildren come along and play with the control panel, it still comes up with the user's preferred size next time it is switched on. Also, the user might have different size settings in different modes, e.g. Live Mode has a minimum magnification of 2.5x, while the Reading and Viewing Modes have a minimum magnification of 0.7x. An absolute size control wouldn't allow this (Pulse Data, 2004).

One other reality of conducting the research in conjunction with a company was the mismatch of the company's and the researcher's requirements. The product tested did not incorporate all functions that will be available in the final product. This was all that was available for testing but may impact on performance measures. In addition, the company's deadlines often dictated the testing schedule.

8.4 Future Research

Due to the lack of research in many areas of low-vision interaction with electronic equipment, there is an opportunity for a variety of further evaluation work to be conducted. There is also room for further research into reducing negative responses to innovative technology. An investment in research in both areas would have flow on effects for product development, such as reducing the cost of prototype production while at the same time increasing usability. In addition, publications resulting from any research could improve manufacturer's in-house knowledge of the specific needs of people with low-vision and those that are hesitant users of resisters of technology.

There is scope for more applied research on *myReader* specifically but also for low-vision users of mainstream innovative technology. Evolutionary research into the development of low-vision reading is possible and there is also plenty of room for fundamental research that would aid in measuring and enhancing low-vision reading aid use as well as enhancing interface design for everyone.

8.4.1 Applied

Responses to the telephone questionnaire highlighted the problems that both people with low-vision and the control group had with mainstream electronic products, by identifying several products they avoid or have difficulties operating. This is one area where applied research could be conducted. In addition, further applied research regarding *myReader* is possible. This thesis covered only a fraction of the testing that could be conducted to ensure the quality of interface design of products such as this. Longer term assessment of performance, user testing of the on-screen interface and alternate input/output methods are also potentially beneficial for *myReader's* development.

Interface Design of Mainstream Electronic Products

Only one third of the sample used in this research owned a cell phone, arguably a mainstream consumer product. Reasons for avoiding using technology ranged from having no interest to a belief that technology caused dementia in a relative. What is clear from the results of this study is that most people at some time do experience negative feelings when thinking about or interacting with technology. While choice may be a valid reason for avoidance, further investigation of aspects of interface design that cause technostress would be beneficial, not only for users but also for manufacturers.

Longer Term Testing of *myReader*

Efficiency of use needs to be conducted once users have had an opportunity to become proficient (Branaghan, 2001b; Mitropoulos & Muszak, 2001). As we have already seen an improvement in performance from CCTV to *myReader* one would expect a greater improvement once proficiency is reached. The company has further research planned for *myReader* to assess usability over a longer period of time.

Alternate Input/Output Modes

Currently, *myReader* has only one way to input information and one output mode. Users place text under a camera (input) and information is displayed visually (output). Alternate input and output modes may be considered for future models and could help a wider section of the population by accommodating the personal preference for auditory rather than visual information. As mentioned previously, incorporating voice recognition and auditory output extends the life of a low-vision reading aid. Other alternative input mechanisms that could be investigated include incorporating gesture, foot pedals or perhaps a touchpad. Alternative output other than visual and auditory could include haptic buttons that vibrate and Braille arrays, however both of these options would suit only a small percentage of the user group.

myReader Software and On-Screen Interface

The software and the on-screen interface combine with the control panel to comprise *myReader*. Each of these elements is vital to quality interface design. The research detailed in this thesis assessed only the control panel, with some assessment of the on-screen interface. The software was not assessed. Table 8.2 details a list of potential issues that should be considered.

Table 8.2: Questions to be answered regarding software and on-screen interface of *myReader*.

- What occurs as each button is pressed and how fast is the response?
- What default settings will be used (most recent, regular)?
- How much text can be captured at once?
- Can the system enlarge other onscreen documents (web and word)?
- How simple is the system to install, navigate and learn?
- Are optional functions hidden from novice users to avoid confusion?
- Are their more advanced options for more advanced users?
- Can the software adapt to user performance over time?
- How easy is it to upgrade software?
- Are users informed of system status when background tasks are being performed?
- Are the software and hardware specialist items or can they be used for other tasks?
- How many low vision users or care providers would already have a computer?
- Could software be integrated into existing systems to reduce costs to health care providers?
- Is training incorporated into the software to teach user how to use system?
- How often will the software crash and how long will it take for the system to reboot?
- How difficult is it for users to undo the last operation or switch out of a mode they entered by mistake?

8.4.2 Fundamental

Because this research was an applied case study, many of the fundamental factors were not assessed specifically and warrant further research. The user studies discussed in this thesis were conducted primarily to assess the design of the product and enhance the emotional relationship by reducing actions that caused negative responses. Several variables were self determined rather than controlled, such as font size, false colour choices. Future studies could specifically investigate these variables to find the optimum choice.

Fundamental research in any of the following areas may provide information to further enhance low-vision reading and to more closely analyse aspects of technostress.

- Reliable methods for measuring heart rate variability for *in situ* user testing
- Other physiological measures of anxiety

- Comparisons of performance between people with different vision conditions
- Optimal fonts and font sizes for specific vision conditions
- Optimal false colours for specific vision conditions
- Optimal choice of text presentation mode for specific vision conditions (wordwrap, marquee, RSVP)
- Pictogram comprehension

8.4.3 Evolutionary Research

There are several interesting far reaching and innovative research ideas that could also be explored in the low vision reading aid area. While these ideas may not have immediate commercial value, they may lay the foundation for future leading edge products. Some possibilities are discussed below.

- A more naturalistic interface design – People with low vision want to lead quality lives without being seen as different. A more book like presentation system could allow this. In addition it is less physically demanding to read a book sitting back in a chair. As low-vision users often require a close viewing distance, tablet technology could allow a more book-like presentation medium. By loading a book or article onto the hard drive, users could then sit or lie back and relax to read it.
- Portable system – By incorporating the *myReader* software into a PDA or tablet computer system, books or newspapers could be uploaded to be read or listened to on the bus or while waiting.
- Virtual Retinal Display – There is potential for the Virtual Retinal Display to enhance the quality of life of people suffering from low vision by allowing images to be projected directly onto areas of the retina not already degraded by ARMD (Kleweno et al, 2000).
- Interaction with other devices – Programmes are available for visually impaired computer users. The integration of *myReader* technology into mainstream computers may offer an alternative to these programmes and may assist people who prefer visual to auditory information. Facilitating low-vision users' access to the internet is another potential area of research.

8.5 Conclusions

myReader is now in production and is due to be released onto the world market in May/June 2004. Prior to its release, beta testing will be conducted with several low-vision people. A baseline level of performance will be gathered and a working *myReader* will be loaned to them for 4 weeks. During this time they will be required to keep a diary of their use of the machine, any problems they have and their feelings associated with its use. At the end of 4 weeks, a researcher will collect the machine and test the participant's performance again, then compare this to the initial test. It is expected that there will be an increase in reading speed and endurance as users become familiar with the controls and functions of *myReader*. Further independent analysis of performance is planned for later in 2004.

The first objective of this research was to investigate the positive and negative emotional relationships users have with low-vision reading aids and *myReader* in particular. Participants did prefer *myReader* to existing reading aids, with many users indicating a positive emotional relationship with the product. This was especially so for expert CCTV users who were aware of the limitations of their own machines. The second objective was to determine aspects that were significant in affecting learnability, usability and pleasurability. Several actions that caused a negative emotional response were identified and recommendations were made to the company to make adjustments. The final objective was to assist the company in the design of a more learnable, usable and pleasurable product.

Comparing performance and preference between the existing reading aid and a redesigned reading aid indicates that the new system is an improvement over the old as well as being more pleasurable to use. Physical demands are reduced with the elimination of the x-y table, and the option of using an LCD. Having greater magnification minimises visual load and the mental fatigue of remembering previous lines is eliminated with scrolling text. Results also suggest that users who are most in need are more likely to eagerly adopt the technology as they are aware of the benefits of the increased functionality and welcome the learnable, usable and pleasurable machine.

Results support the process of user-centred iterative design of the interface of a low-vision reading aid. By analysing common errors, actions that result in frustration and actions that rely heavily on memory, several aspects of the design that needed altering to better match user requirements were identified and modified. This research has assisted the company in reducing actions that cause negative emotions due to a mismatch between the requirements of the machine and the constraints of the user. Many people with low vision may yet again be able to experience the pleasure of reading with the benefit of equipment that has been developed and evaluated with a user-centred focus.

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Appendix A – Glossary

Aesthetic	In accordance with the principles of good taste
Affect	A broad class of mental processes, including feeling, emotion, moods, and temperament
Ambidextrous	Able to use both hands equally well
Amsler Grid	A tool testing the central field of vision, that is often self - administered
Anthropometrics	Measurements of the bodily form, particularly the proportions and relative frequency of occurrence of physical characteristics
ARMD	Age Related Macular Degeneration
Biomechanics	The measurement of bodily movement and dynamics
CBT	Cognitive Behavioural Therapy
CCTV	Closed Circuit Television
Cognition	General concept embracing all forms of knowing
Eager Adopter	Embracers of technology as they find it enjoyable to use. Make up 10 – 15% of the population
Ergonomics	The scientific discipline concerned with the understanding of interactions among humans and other elements of a system
False colours	Combination of colours of text and background not normally associated with text which enhance contrast
GUI	Graphical User Interface
Haptic	The sense of or ability to touch
Hawthorne effect	The tendency of people to work harder when experiencing a sense of participation in something new and special
HCI	Human Computer Interaction
Hesitant User	Users requiring proof of technological benefit and reliability before use. Make up 50 –60% of the population
HIT Lab NZ	Human Interface Technology Laboratory, New Zealand

HRV	Heart-rate variability
Human factors	An applied branch of psychology and engineering concerned with the problems of machine design, working conditions, skills, learning ability and efficiency
Iconic	Pictorial representation of a concept
Innovative technology	Artefacts that attempt to improve on existing, mainstream technology
Interface	Place or piece of equipment where interaction occurs between two systems, processes or entities such as a machine and a person
Inverse video	Function of reversing text and background colours
LCD	Liquid Crystal Display
Luddite	A band of English artists (1811 – 16) who raised riots for the destruction of machinery; or a person similarly engaged in seeking to obstruct progress
Macula	The region of greatest visual acuity in the retina
MS-DOS	Microsoft Software Corporation disk operating system that is primarily command line driven
myReader™	Low-vision reading aid in development by Pulse Data International Ltd
Noise	Spurious data causing interference
OCR	Optical Character Recognition – software that translates hard copy to digital form
Pictogram	Pictorial symbol or representation of a concept
Pleasurability	The ability of an artefact to elicit a positive emotional response
Prototype	Trial model of a design concept
Resister	Avoiders of innovative technology due to overwhelming anxiety, concern or disregard for technology. Make up 30 – 40% of the population
Retina	The layer at the back of the eyeball with light sensitivity
RNZFB	Royal New Zealand Foundation of the Blind

Saccades	Brief rapid movements of the eye between fixation points
Sans serif	Form of print face without serifs such as arial
Serif	Cross line finishing off a stroke of a letter, as in T
Tactile	*see* haptic
Trackball	A ball mounted in a stationary housing and rotated to control a pointer on a computer screen
USB	Universal Serial Buss
x-y table	The platform used to place text on the CCTV system allowing viewing through the X & Y axes

Appendix B – Product Specifications

SmartView

8000

technical specifications

Product
- Height 11"/280mm
- Width 14"/355mm
- Depth 18"/457mm
- Weight 28lbs/13kgs
- Operating temperature range 10 to 40°C
- Storage temperature range -20 to 60°C
- Operating humidity range 20% to 95%
- Storage humidity range 10% to 95%

Transportation Box
- Height 16.5"/420mm
- Width 22.2"/565mm
- Depth 19"/480mm
- Weight 41.1lbs/18.5kgs
- Weight by volume 43lbs/19.5kgs

General
- Auto focus
- Sturdy smooth ball bearing X/Y moveable table
- ISO9000 certified quality
- Maximum monitor weight supported 99.2lb/45kgs
- Smart KeyPad/PC access
- External camera input

XY Table
- Dimensions 14" x 14"/355mm x 355mm
- X dimension travel +/- 5.4"/135mm
- Y dimension travel 11.4"/290mm
- Height of XY table 2"/50mm
- Margin stops at left and right
- Friction pad adjustments
- Working space (height) 6"/153mm

Optics
- 60Hz colour camera
- Glass optics lens
- Magnification range ratio 15:1
- Magnification range - 15" display 3x to 45x
- Magnification range - 17" display 4x to 59x
- Magnification range - 19" display 5x to 67x
- Magnification range - 21" display 5x to 74x

Magnification depends on make of monitor model used

Illumination
- Two user-replaceable fluorescent lamps
- Average lifetime of bulb 10,000 hours (manufacturer's specification)
- Wattage of bulb 7W

Power Supply
- Input voltage 100-240 V AC
- Frequency 50-60Hz
- Input current 3.6 to 1.5A
- Connector IEC with separate cable
- Wattage usage 360W

Controls
- Zoom (size) control with an audible freeze focus setting
- Two preset size settings
- Picture mode (photo, positive, negative)
- On/off switch
- User selectable foreground/background colours adjustment
- Contrast adjustment using keypad
- Smart KeyPad
- Footswitch

Image Choices
- Positive or negative image display
- User selectable foreground/background colour display (16 std VGA colour combinations)
- Selectable photo mode for enhanced viewing of colour images (high contrast VGA)
- Full colour display

Video
- Video output VGA
- Camera resolution (pixels) 510 x 490 (VGA equivalent)
- External camera/TV input

Connections
- VGA output
- Computer video (VGA) input
- IEC input for main power
- IEC output for power supply to monitor
- Footswitch input
- Smart KeyPad input
- External video input

PC Compatibility
- Connects to desktop, laptop or notebook computer with VGA display
- Displays PC & camera images alternately
- Displays PC & camera images simultaneously
- SVGA video modes supported for split screen operation:
  640 x 480 @ 60, 72, 75, 85, 90Hz
  720 x 400 @ 70Hz (DOS)
  800 x 600 @ 56, 60, 72, 75, 85, 90Hz
  1024 x 768 @ 60, 70, 75, 85Hz
  1152 x 864 @ 60, 75Hz
  1280 x 960 @ 60, 75, 85Hz
  1280 x 1024 @ 60Hz

Display Selections
- Full screen camera
- Full screen PC view
- Horizontal split-screen
- Vertical split-screen

On Screen Display
- 4 sizes of on-screen display characters
- Line markers and blinds
- Date and time display
- 4 function calculator with memory
- Camera adjustable bright & colour settings

Optional Accessories
- Carry bag

Standards and Approvals
- EMC
- FCC 47 Part 15:1994 Class B
- CE
  CISPR22:1997
  EN50082-1:1998
  ENV 50204:1996
  IEC61000-4-2:1998
  IEC61000-4-3:1996
  IEC61000-4-4:1995
  IEC61000-4-5:1995
  IEC61000-4-6:1996
  IEC61000-4-8:1993
  IEC61000-4-11:1994

Electrical Safety
- AS/NZS 3260:1993

Appendix C – Task Analysis

SmartView 8000	
Task	**Feedback**
Setup	
Turn on machine – press on/off button	Visual and Auditory - Monitor turns on with a click and light turns on
Select text to read	
Place text face up on x-y table under camera	
Loosen table controls on front and side of table	Tactile - Table movement loosens
Move table so top of text is on screen	Visual - Text appears on screen
Adjust margins using table controls	Visual and Tactile - Table does not move past margins of page displayed on screen
Adjust size using size dial	Visual - Text is enlarged or reduced on screen
Adjust contrast and colours with picture dial	Visual, Tactile and Auditory - Colours change on screen, dial clicks
Adjust inverse video if required using mode buttons	Visual – black on white text becomes white on black text (auditory warning if button not released, no tactile or auditory feedback of activation)
Reading	
Move table under lens to the end of the line	Visual – display on text
Move table back to beginning of line	
Move table away from body to move to next line	
To back track, reverse table movement	
At the end of page either turn page of book or remove text from under camera and place new text	

Appendix D – Telephone Questionnaires

Telephone Questionnaire Participant # ____________________

Thank you for agreeing to be part of this study, which I am doing for Pulse Data.
This is part of a HITLabNZ project at the University of Canterbury.
It will form the basis of my masters thesis.

I'm going to ask you a series of questions and I'd like you to answer all of them, even if some of them sound similar answer them all.
Is it convenient to go through the questions now?
(If no) Would you like to make a time that is more convenient?
Feel free to give me comments if you have further information to add
If you have any questions just stop me and ask

Experts

What do you use your CCTV for?

Reading / Writing /
Other - please state ____________________

What do you read?

books / letters / bills / course notes /
other -please state ____________________

What else would you like to be able to do with your CCTV?

____

How often do you use your CCTV?

daily / weekly / occasionally / rarely / never

How long, at one sitting, do you usually use your CCTV?

>5 min / 5-10 min / 10-20 min / 20-30 min / < 30 min

How long have you owned your CCTV for?

________ years ________ months

Where do you use your CCTV?

____

Where else would you like to use your CCTV?

____

Does your CCTV share its monitor with a Computer?

yes / no

What, if anything, limits your use of your CCTV?

____

What do you most like about your CCTV?

____

What do you most dislike about your CCTV?

____

What do you wish your CCTV could do?

____

What problem(s) have you had with your CCTV?

____

Have you read the manual that goes with your CCTV?

yes / no

Do you believe you are aware of all the functions on your CCTV?

yes / no

Do you use all the functions on your CCTV?

yes / no

If no to any of the three previous questions please explain why not

____

<u>Novice</u>

Do you own a reading aid of any kind?

If yes

State what kind ______________________________

And use current user questionnaire substituting their reader for SmartView

Do you have any software on your computer for enlarging text?

If yes

State what kind ______________________________

If you had a reading aid, what do you think you would use it for?

Reading / Writing /

Other - please state ______________________________

What do you think you would read?

books / letters / bills / course notes /

other -please state ______________________________

What else would you like to be able to do with a reading aid?

____

How often do you think you would use it?

daily / weekly / occasionally / rarely / never

How long, at one sitting, do you think you could use it?

>5min / 5-10 min / 10-20 min / 20-30 min / < 30 min

Where do you think you would use it?

____

Do you think a reading aid should share its monitor with a Computer?

yes / no

Expert, Novice and Control

How often do you use a computer?

daily / weekly / occasionally / rarely / never

How many hours per week would you spend working on a computer (excluding games)?

0-5 5-10 / 10-20 / 20-40 / more than 40

How often do you play computer or video games?

daily / weekly / occasionally / rarely / never

How many hours per week would you spend playing games on a computer or games console?

0-5 5-10 / 10-20 / 20-40 / more than 40

How often do you use a mobile phone?

daily / weekly / occasionally / rarely / never

How often do you use a video player for watching movies?

daily / weekly / occasionally / rarely / never

Do you personally use the record button for recording programmes with your VCR?

daily / weekly / occasionally / rarely / never

Do you personally use the programming timer record function on your video recorder for recording programmes?

daily / weekly / occasionally / rarely / never

Does anyone in your house use this function for themselves or on your behalf?

spouse / child / flat mate / nobody / other

In the following questions technology and electrical/electronic equipment refers to any products containing electrical and computer technology for instance computers, computer games, video recorders, cellphones, ATM machines, internet/email, Personal Digital Assistant (PDA), remote controls, etc.

Have you ever felt anxious when using electronic equipment?

never / once or twice / occasionally / regularly / always

If yes, which product(s)? ______________________________

Have you ever felt nervous about using a new electronic product?

never / once or twice / occasionally / regularly / always

If yes, which product(s)? ______________________________

How much do you agree or disagree with the following statements:

a) I feel comfortable using new electronic products

1	2	3	4	5	6	7
Agree						Disagree

b) I have felt nervous using unfamiliar electronic products.

1	2	3	4	5	6	7
Agree						Disagree

Please rate your current attitude toward technology.

positive / slightly positive/ neutral / slightly negative / negative /

Please rate your current level of anxiety about using technology.

low / mild / neutral / moderate / high

Suppose that someone gave you a new computerised gadget that did lots of things. As you are learning to use it which of the following do you think you would think and/or feel? Circle as many as are relevant

angry	eager	overwhelmed
anxious	enthusiastic	pleased
calm	excited	proud
capable	frustrated	relaxed
concerned	incompetent	stupid
confident	irritated	successful
delighted	jubilant	triumphant
discouraged	miserable	uneasy
dispirited	nervous	unruffled
dumb	overjoyed	worried

How comfortable do you feel using new electronic products?

very / reasonably / OK/ slightly uncomfortable / anxious

Has anxiety about electronic equipment stopped you from trying to use it?

never / once or twice / occasionally / regularly / always

If yes, which product(s)? ______________________________

Have you avoided any particular technology because you were concerned about breaking it?

never / once or twice / occasionally / regularly / always

If yes, which product(s)? ______________________________

Have you avoided using any technology through choice because it is not easy to use?

never / once or twice / occasionally / regularly / always

If yes, which product(s)? ______________________________

Have you avoided using any particular type of technology because it is not easy to understand?

never / once or twice / occasionally / regularly / always

If yes, which product(s)? ____________________

Have you been frustrated with using any particular electronics due to difficulty of use?

never / once or twice / occasionally / regularly / constantly

39a If yes, which product(s)? ____________________

Have you avoided using technology through choice because you are concerned about electrical or radiation emissions?

never / once or twice / occasionally / regularly / always

40a If yes, which product(s)? ____________________

Please list any other reasons you have for choosing not to use technology?

____

Expert and Novice

What is the cause of your Low Vision?

____

How long since your diagnosis?

years ____________________

Expert, Novice and Control

Do you have any other disabilities?

If yes, please state? ____________________

Gender? ____________________

What is your age? __________ years __________

What is your profession?

student / retired / other -please state ____________________

What kind of accommodation do you live in? ____________________

Which of your hands is dominant? Left / Right / Both

What is your highest educational qualification?

none / secondary school / polytech / university / postgraduate

Appendix E – Pilot Study Comprehension Questions

TIME Magazine Article #1

6. What did the reporter feeding the boy? – Dumplings
7. Which river did the boy cross to get to China? – Tumen River
8. What was the name that the boy agreed to being called? – Jae Young
9. How old was the boy? – 17 years
10. How many days did he walk from his village? One

TIME Magazine Article #2

1. Who is the bookmakers favourite to win? – Allinghi
2. What country, other than New Zealand, outside US has hosted the America's Cup? – Oz
3. Dennis Conner is competing in his 8^{th}, 9^{th} or 10^{th} campaign? – 9^{th}
4. How old is the event? – 151 years
5. How many former Team new Zealand members will be involved with other teams? – 26

Harry Potter Chapter #1

1. What is Harry's aunt and uncle's last name? – Dursley
2. What kind of bird upset Mr Dursley? – an owl
3. What was Harry's cousin's name? – Dudley
4. What was peculiar about the cat at the end of the street? – it was reading a map
5. What were the people wearing that caused Mr Dursley concern? – cloaks

Harry Potter Chapter #2

1. What was the name of the giant that Harry dreamed of? – Hagrid
2. What did the owl bring and drop on Hagrid? – a newspaper
3. Can you name one thing other than keys that were in Hagrid's pocket? – slug pellets, string, mint humbugs, teabags, knutts.
4. Where did Hagrid take Harry first? – Gringots the wizard's bank
5. What did Hagrid want a slice of? Harry's birthday cake

Appendix F – Pilot Study Post-Test Interviews

Post Test Interview - Initial
CCTV
How tiring did you find reading that article?
very tiring / slightly tiring / neutral / easy / not at all tiring
How easy is this product to use?
How easy are the buttons to use?
Left handers - do you have any problems using this product?
Do you have any suggestions about how to improve the interface of this product?
Do you have any other comments to make about the control panel or the study?
Are you still happy for us to come back again for the next round?

Post Test Interview - Initial
myReader
How tiring did you find reading that article?
very tiring / slightly tiring / neutral / easy / not at all tiring
How easy is this product to use?
How easy are the buttons to use?
What was your first reaction to the control panel?
Do you think your opinion changed once you used it?
Do you like the look of the new product?
What do you think about the placement of the buttons?
Left handers - do you have any problems using this product?
Would it be better to have the trackball somewhere else on the panel?
What are the best aspects of the control panel?
What are the worst aspects of the control panel?
What did you think of being able to see the whole page at once?
Do you have any suggestions about how to improve the interface of this product?
Do you have any other comments to make about the control panel or the study?
Are you still happy for us to come back again for the next round?

Post Test Interview - Final
CCTV
How tiring did you find reading that article?
very tiring / slightly tiring / neutral / easy / not at all tiring
How easy is this product to use?
How easy are the buttons to use?
Left handers - do you have any problems using this product?
Do you have any suggestions about how to improve the interface of this product?
Do you have any other comments to make about the control panel or the study?
Do you prefer these buttons or these?
soft/ hard
Why?
Which did you find easier to use?
CCTV or *myReader*
If you were to do the tasks again, would you be comfortable having your heart rate, blood pressure and galvanic response monitored while under taking these tasks?

Post Test Interview - Final
myReader
How tiring did you find reading that article?
very tiring / slightly tiring / neutral / easy / not at all tiring
How easy is this product to use?
How easy are the buttons to use?
What was your first reaction to the control panel?
Do you think your opinion changed once you used it?
Do you like the look of the new product?
What do you think about the placement of the buttons?
Left handers - do you have any problems using this product?
Would it be better to have the trackball somewhere else on the panel?
What are the best aspects of the control panel?
What are the worst aspects of the control panel?
What did you think of being able to see the whole page at once?
Do you have any suggestions about how to improve the interface of this product?
Do you have any other comments to make about the control panel or the study?
Do you prefer these buttons or these?
soft/ hard
Why?
Which did you find easier to use?
CCTV or *myReader*
If you were to do the tasks again, would you be comfortable having your heart rate, blood pressure and galvanic response monitored while under taking these tasks?

Appendix G – Information Sheet

Pulse Data Product Assessment
HIT Lab NZ

Thank you for considering being part of this study, which Chandra Harrison is undertaking as part of her Masters thesis for Pulse Data as part of a Human Interface Technology (HIT) Lab NZ project at the University of Canterbury, under the supervision of Drs Mark Billinghurst and Dean Owen. The study proposes to:

- Assess your reading speed and comprehension using current and redesigned low vision reading aids
- Assess your level of comfort using technology in general
- Assess your level of comfort using this technology
- Evaluate your preference for the interface design of the new product

The study will be conducted in your home on two visits of approximately 90 minutes each, once with the existing low-vision reading aid and another visit with the redesigned product. Prior to the visits, you will be asked to complete a questionnaire over the phone. During the initial visit your eyesight will be tested with an Amsler Grid. During each visit you will be given instruction on how to use the product being tested. You will then be given a piece of text to read and your performance will be recorded. At the end of each session, the researcher will spend a few minutes asking you some questions relating to the text you have read and how you felt about the product. Throughout the training and test, your heart rate will be monitored. A video camera and tape recorder will also be used to allow the researchers to gather as much information as possible through later analysis of video footage and audiotapes.

All your personal details will remain confidential and your name will not be associated with any particular piece of data. The information will be coded to ensure your anonymity. All information collected from the questionnaires, monitoring, video analysis, the tasks and in the discussion at the end will form the basis of a Masters Thesis and will be used to provide a report to Pulse Data. It may also form the basis for other publications arising from this research project. All information will be kept in a securely locked filing cabinet and all information with you name on it will be destroyed after the completion of the project.

If you are interested in the results of the study, a summary of the report/thesis can be provided to you. If you are willing to participate, please read the following and sign it.

If you have any queries about the study please do not hesitate to contact

Chandra Harrison: email: chandra.harrison@canterbury.ac.nz : Phone: 3642987 ext 3070
or
Dr Mark Billinghurst: email: mark.billinghurst@hitlabnz.org :Phone: 3662403
or
Stewart Pegg: email: stewartp@pulsedata.com :Phone: 3844555

Appendix H – Consent Form

Pulse Data Product Assessment
HITLabNZ
Consent Form

I have read the information above and agree to participate in the study as described.

I understand that I may ask further questions at any time. I understand that I have the right to withdraw from the study at any time and to decline to answer any particular questions. I agree to provide information to the researcher on the understanding that my name will not be used. I agree to be video and audio taped.

Name: ______________________________

Signature: ______________________________

Date: ______________________________

Appendix I – Pilot Study Protocol

Greeting
Hi Mr or Mrs X (participant) I'm Chandra, I spoke with you on the phone the other day. This is X (observer) who is going to help me set up the equipment for the study I told you about.

Information
This study will help PDI to design the best product for your peers. We are testing the hardware not your performance and we really appreciate your involvement. I have an information sheet here for you to keep which has my contact details on it and the basic information about the study. All your details will be kept completely anonymous. We will put a number on all your forms and the information about who belongs to each number will be destroyed so no one will be able to trace your details. All the information will be kept in a locked filing cabinet at the university and only myself and my supervisor will be able to access it. If you are happy to participate could I get you to sign this consent form?

Setup
Where do you normally use your reading aid?
Or
Can we use your kitchen table?
Can we go all through there now and set up, it shouldn't take us too long.

myReader
We are connecting up your monitor to the video recorder so we can record what's happening on the screen. <set it going> The camera is to record what your hands are doing and which buttons you are pushing. <set it going> The tape recorder is so we can keep a record of what questions you ask. We want you to make as many comments about what you are doing as possible. <set it going> The laptop is to record some data about how *myReader* works. <set it going>

CCTV
We are connecting up your monitor to the video recorder so we can record what's happening on the screen. <set it going> The camera is to record what your hands are doing and which buttons you are pushing <set it going> The tape recorder is so we can keep a record of what questions you ask. We want you to make as many comments about what you are doing as possible. <set it going>

Training Phase
myReader
So, here is the product we are actually testing.<Place control panel on CCTV table> What is your first impression? <Let them play with it>

On the top left is the size dial, just like on the CCTV. Next to that is the "write" button. It doesn't work at the moment but will allow you to write on documents or do hand crafts. Next to that is the settings dial, which combines a couple of modes of the CCTV, it controls the colour and contrast. On the top right is a track ball. This replaces the xy table. In between the trackball and the settings dial is the speed dial, which controls how fast the text will scroll on the screen, but we can come back to that. On the bottom row on the left is the new page/start button. You press this button each time you put a new page under the camera then it processes it. Next to that is the overview/page view button. This one is if you want to have a look at the whole page to get an idea of where you are up to. Next to that is the auto button. Once everything is set up you press this button to set the reading scrolling automatically. You can control how fast it goes with the speed dial and if you want to back track or jump ahead you can just use the track ball.

What do you think? Would you like to have a go? <Place controller in neutral location>

OK, we can use this brief Time magazine as a trial run just so you get comfortable with the control panel. <place document under camera>

If you get yourself comfortable and put the control panel where you want it and there is one more function I would like to show you. You can either have the words flowing in a single column down the page like this <show word wrap mode> or from left to right like this <M x2>

Which would you prefer? <Mx3 to get back to word wrap>

OK, why don't you just have a little bit of a trial with the control panel before we get started with the tasks proper.

OK, shall we get started

CCTV – only for Novices
Now I want you to spend a little time helping you get familiar with the product. I've put a piece of text under the camera and I'll take you through what all the buttons do.

The size dial
The Contrast Button
The xy table

Testing Phase
We are going to ask you read a piece of text for a while and we will just be sitting here and taking notes about how the equipment performs. We want you to read in the way you would normally and we want you to take your time and not feel pressured.

First of all make yourself comfortable. Feel free to move your chair or any of the equipment around if you need to and use whatever controls you need. Get as comfy as possible and settle in to read for as long as you feel happy.

Every couple of minutes I'm going to ask you to stop and I just want you to tell me where you are up to and just let me know how you are doing. Then I'll get you to carry on reading for 10 minutes or until you get tired. Once you tell me you have had enough we'll turn the reader off and just have a little chat about the experiment, is that Ok with you?

Just remember, we are just here to observe how you use your reader so while we want you to ask questions we would encourage you to try to find the answers yourself first. Have you got any questions before we start? Are you happy to get started?

That's great, now let's get on with the reading task. I have either a Time magazine article or a chapter from one of the Harry Potter stories, which would you prefer? I'll just put that into the machine. Now I just want you to settle in and start reading these articles. Have you got any questions before we start?

Don't interfere unless users become visibly upset and ask for assistance

Every 2 minutes - Can you just stop for a second and tell me where you are up to? And how are you feeling? Thanks carry on.

Post-test
Once they report having reached their endurance limit, or if participants exceed 10 minutes thank them for their effort, reassure them they have done great. Ask comprehension questions for the articles they read. Then conduct post-test interview, pack up equipment and

Thank you so much for your help with this. We'll just pack away this equipment now

You said that you'd be free X at X o'clock, is that still OK? Great, I'll see you then. In the meantime, if you have any questions about any of this please don't hesitate to ring me on the number on the information sheet I've given you.
Or
Thank you so much for helping with this study. If you have any questions or want to hear how the study went just let me know.

Appendix J – Amsler Grid Information

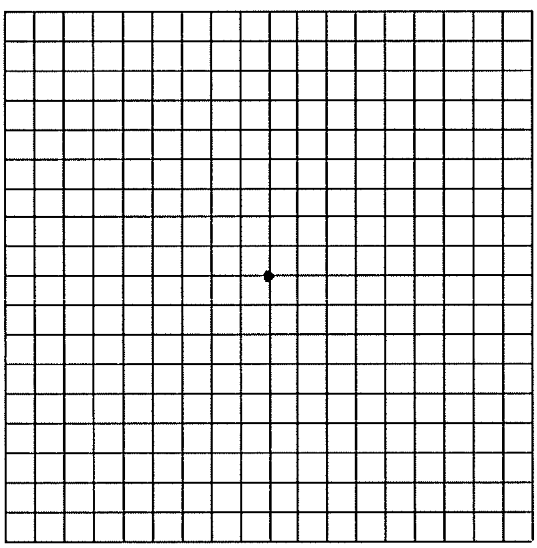
Grid (Figure 1 below) is held out at 30cm and throughout the test participants must try to focus on the spot while trying to see the whole of the grid.

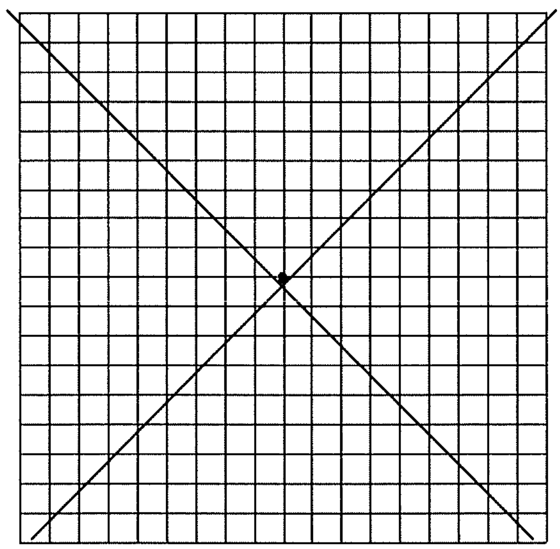
1. Do you see the spot in the centre of the chart?
   a) Perfectly well – no central scotoma – go onto question 2.
   b) Yes but it is blurred – relative scotoma – go onto question 2.
   c) No – absolute scotoma – use crossed chart (Figure 2 below) – ask again

2. Keeping your gaze fixed on the spot in the centre, can you see the four corners of the big square? Can you also see the four sides of the square? In other words can you see the whole of the square?
   a) Yes – go onto question 3
   b) No – one corner is cut off or one side – they have exterior scotoma

3. While always keeping the gaze fixed on the spot in the middle, do you see all the grid lines intact? Are there interruptions in the network of squares, like holes or spots? Is it blurred in any place and if so where?
a) Is the spot clearly defined
b) Is it completely blurred – absolute scotoma
c) do white lines show through – relative scotoma
is the blurring equal everywhere or are some parts more blurred than others

4. Always keeping your gaze fixed on the spot in the centre so you see all the lines, both horizontal and vertical? Are they straight and parallel? In other words is every small square equal size and perfectly regular?
If report any abnormalities then have metamorphopsia





Appendix K – Main Study Comprehension Questions

<u>First Chapter</u>
Page 1
1. Where would the children sleep if they weren't allowed to sleep in tents on the island?
   e) on the boat
   f) in a cabin
   g) camp on shore **
   h) under the trees

2. Which child got in the way while they put up the tents?
   a) Vicky
   b) Roger
   c) John **
   d) Holly

3. What were the tent ropes tied to?
   a) rocks
   b) sails
   c) trees **
   d) poles

Page 2
1. What did John want to use as a tent?
   a) sails and oars **
   b) mothers old tent
   c) bed sheets

2. What did Titty borrow from the nurse?
   a) a blanket
   b) a ground sheet
   c) Vicky **
   d) a tent

3. What did John want to use as a mattress
   a) foam rubber
   b) rugs **
   c) bracken

Page 3
1. What did mother suggest instead of rugs for mattresses?
   a) blankets
   b) pillows
   c) haybags **

2. What was Roger's title on the boat?
   a) captain
   b) boy **
   c) able seaman
   d) mate

3. What kind of boat was Swallow
   a) a yacht
   b) a sailing-dingy **
   c) a trailer sailor

Page 4

1. How big was Swallow?
   a) 10 feet
   b) 11-12 feet
   c) 13-14 feet **
   d) 15 feet

2. What was painted on the boats stern?
   a) Queen Elizabeth
   b) Swallow **
   c) Susan

3. What colour was the first flag?
   a) blue **
   b) green
   c) yellow

Page 5

1. Where was mother brought up?
   a) near Auckland harbour
   b) near Lyttleton Harbour
   c) near Sydney Harbour **

2. Who got the sail ready?
   a) Queen Elizabeth
   b) Mate Susan **
   c) Captain John

3. What colour was the sail?
   a) blue
   b) white
   c) brown **

Page 6

1. Which way were the crinkles supposed to go on the sail?
   a) cross ways
   b) up and down **

2. Who cast off from the jetty?
   a) Queen Elizabeth
   b) Mate Susan **
   c) Captain John
   d) One of the crew

3. Where did the crew stay during cast off?
   a) on the jetty
   b) in the bow of the boat
   c) in the bottom of the boat **
   d) on the pier

Page 7

1. Why was swallow's trial sail a short one?
   a) they had to get back for tea
   b) they had to make haybags and get stores **
   c) Roger wanted to sail in the field

2. What was the picture that Titty put on the sail?
   a) a swallow **
   b) a haystack
   c) knickerbockers

3. What colour was the flag?
   a) Blue with a white swallow
   b) white with a blue swallow **
   c) yellow

Page 8

1. What did Roger want a big tin for?
   a) Sugar **
   b) Tea
   c) Salt
   d) Cake

2. Who was to be the surgeon on the trip?
   a) Titty
   b) John
   c) Susan **
   d) Queen Elizabeth

3. What did Titty want to use to treat any ailments they had?
   a) medicine
   b) ointment
   c) herbs and natural remedies

Second Chapter
Page 1
1. Who was the last of the children ashore?
   a) Titty
   b) Susan
   c) Roger
   d) John **

2. Why was Titty concerned about leaving the stores on the beach when they first went ashore?
   a) savages
   b) tidal waves **
   c) earthquake
   d) someone might take them

3. Who handed the stores out of the boat?
   a) Titty
   b) John **
   c) Susan
   d) Roger

Page 2
1. What did Roger find in the trees?
   a) Natives
   b) a fireplace **
   c) birds
   d) matches

2 What didn't the children find on the island?
   a) Natives **
   b) a fireplace
   c) spare firewood
   d) a big pine tree

3. What wasn't at the fireplace?
   a) spare firewood
   b) a ring of stones
   c) matches **

Page 3
1. What did Titty think happened to the natives?
   a) they left the island
   b) they were killed and eaten by other natives **
   c) they were hiding on the island

2. After deciding to set up camp by the fireplace what was first thing the children did?
   a) tie up the tent
   b) gather stones for the tent
   c) build a fire
   d) collected the tent bundles from the beach **

3. Once the tents were up what did Susan start to think about?
   a) home
   b) her mother
   c) dinner **

Page 4

1. What did Roger go off to do once the tents were up?
   a) play
   b) gather firewood **
   c) fill the kettle
   d) look for a better landing place

2. What did Susan go off to do once the tents were up?
   a) play
   b) gather firewood
   c) fill the kettle **
   d) look for a better landing place

3. What did John go off to do once the tents were up?
   a) play
   b) gather firewood
   c) fill the kettle
   d) look for a better landing place **

Page 5

1. Why couldn't Susan help John put swallow into the new harbour?
   a) she couldn't leave the cooking **
   b) she didn't want to
   c) Titty wanted to go instead

2. What did John find at the south end of the island?
   a) a fireplace
   b) a tall pine tree
   c) a secret harbour **

3. Why had John missed the new harbour when they sailed passed?
   a) it was hidden by overhanging hazel trees
   b) he wasn't paying attention
   c) rocks had hidden it from view**

Page 6

1. Who helped John put Swallow into the new harbour?
   a) Susan
   b) Titty **
   c) Roger

2. What did Susan lend John when they went to put Swallow in the new harbour?
   a) her whistle **
   b) an oar
   c) a sail

3. What did Titty do while John rowed to the new harbour?
   a) helped him row
   b) sat in the stern of the boat **
   c) stayed at the campsite

Page 7

1. How did John attract the others attention once Swallow was safely in the new harbour?
   a) he called out
   b) he sent Titty to get them
   c) he whistled using Susan's whistle **

2. What was Titty doing at the front of the boat while John steered her into the new harbour?
   a) keeping an eye out for rocks **
   b) rowing
   c) looking for the others

3. What was John concerned about as they heading into the new harbour?
   a) hitting rocks **
   b) that they wouldn't find the others
   c) the wind coming up

Page 8

1. What did the children find painted on the tree in the new harbour?
   a) people's names
   b) the harbours name
   c) a white cross **

2. Who did Titty think had put the cross on the tree?
   a) Roger
   b) Natives **
   c) John

3. Why did Susan have to run off when they were tying up the boat?
   a) the kettle would be boiling **
   b) the eggs would be ruined
   c) the fire was out

Appendix L – Main Study Post-Test Interview Questions

<u>Post Test Interview - Initial</u>

CCTV

How tiring did you find reading that story?

very tiring / slightly tiring / neutral / easy / not at all tiring

How easy is this product to use?

no problem / easy / neutral / tricky / hard

How easy are the buttons to use?

no problem / easy / neutral / tricky / hard

Left handers - do you have any problems using this product?

Do you have any suggestions about how to improve the interface of this product?

Do you have any other comments to make about the control panel or the study?

Are you still happy for us to come back again next time?

<u>Post Test Interview - Initial</u>

myReader

How tiring did you find reading that story?

very tiring / slightly tiring / neutral / easy / not at all tiring

How easy is this product to use?

no problem / easy / neutral / tricky / hard

How easy are the buttons to use?

no problem / easy / neutral / tricky / hard

What was your first reaction to the control panel?

How do you feel about the product now?

Do you like the look of the new product?

What do you think about the placement of the buttons?

Left handers - do you have any problems using this product?

What are the best aspects of the control panel?

What are the worst aspects of the control panel?

What did you think of being able to see the whole page at once?

Do you have any suggestions about how to improve the interface of this product?

Do you have any other comments to make about the control panel or the study?

Are you still happy for us to come back again for the next round?

<u>Post Test Interview - Final</u>

CCTV

How tiring did you find it reading that story?

very tiring / slightly tiring / neutral / easy / not at all tiring

How easy is this product to use?

no problem / easy / neutral / tricky / hard

How easy are the buttons to use?

no problem / easy / neutral / tricky / hard

Left handers - do you have any problems using this product?

Do you have any suggestions about how to improve the interface of this product?

Do you have any other comments to make about the control panel or the study?

Which did you prefer to use?

SmartView or Hercules

Why?

<u>Post Test Interview - Final</u>

myReader

How tiring did you find it reading that story?

very tiring / slightly tiring / neutral / easy / not at all tiring

How easy is this product to use?

no problem / easy / neutral / tricky / hard

How easy are the buttons to use?

no problem / easy / neutral / tricky / hard

What was your first reaction to the control panel?

How do you feel about the product now?

Do you like the look of the new product?

What do you think about the placement of the buttons?

Left handers - do you have any problems using this product?

What are the best aspects of the control panel?

What are the worst aspects of the control panel?

What did you think of being able to see the whole page at once?

Do you have any suggestions about how to improve the interface of this product?

Do you have any other comments to make about the control panel or the study?

Which did you prefer to use?

SmartView or Hercules

Why?

Appendix M – Main Study Protocol

Greeting
"Hi Mr or Mrs X (participant) I'm Chandra, I spoke with you on the phone the other day about the research I'm doing. Can I come in and set up."

"We are testing the hardware, not your performance and we really appreciate your involvement. I have the information I read out to you on the phone the other day on a sheet for you to keep. It has my contact details on it and the basic information about the study. Would you like me to read it through again for you or shall I just leave it for you to read over later? OK I've put it xxx"

"Now I just want to reiterate that all your details will be kept completely anonymous. We will put a number on all your forms and the information about who belongs to each number will be destroyed so no one will be able to trace your details. All the information will be kept in a locked filing cabinet at the university and only myself and my supervisor will be able to access it. The study is part of my thesis and will help PDI to design the best product for your peers."

"Where can we set up / do you normally use your reading aid? Can we go through there now and set up, it shouldn't take too long."

"If you are happy to participate could I get you to sign this consent form? Thanks."

Or
"Hello again Mrs X, its Chandra. I've come to test the other machine today. Is it still OK with you? Great, shall we get straight into it. There is no eye test today but I will need you to put the heart rate monitor on again. Are you still OK with that?"

Heart Rate Monitor
What I would like to do now is confirm that you are happy to have your heart rate monitored while we do the study. The first thing we need to set up then is the heart rate monitor. This chest strap goes on under your clothes next to your skin and the strap does up with a push and a twist. <warm up strap with hands, moisten if needed and put strap on>.

Amsler (experts and novices only)
OK, the next thing is the Amsler Grid test. Have you done one of these before? Great/no problems. Its very easy, all you have to do is hold this piece of paper out at 30cm and I'll ask you a couple of questions. Throughout you must try to focus on the spot while trying to see the whole of the grid.

1. Do you see the spot in the centre of the chart?
Perfectly well – no central scotoma – go onto question 2.
Yes but it is blurred – relative scotoma – go onto question 2.
No – absolute scotoma – use crossed chart – ask again

2. Keeping your gaze fixed on the spot in the centre, can you see the four corners of the big square? Can you also see the four sides of the square? In other words can you see the whole of the square?
a) Yes – go onto question 3
b) No – one corner is cut off or one side – they have exterior scotoma

3. While always keeping the gaze fixed on the spot in the middle, do you see all the grid lines intact? Are there interruptions in the network of squares, like holes or spots? Is it blurred in any place and if so where?
a) Is the spot clearly defined
b) Is it completely blurred – absolute scotoma
c) do white lines show through – relative scotoma
is the blurring equal everywhere or are some parts more blurred than others

4. Always keeping your gaze fixed on the spot in the centre so you see all the lines, both horizontal and vertical? Are they straight and parallel? In other words is every small square equal size and perfectly regular?

If report any abnormalities then have metamorphopsia

That's great. Now I'd like to set up the equipment

Set up equipment
I'm connecting up the monitor to a video camera so we can record what's happening on the screen. The other camera is to record what your hands are doing and which buttons you are pushing. Then I need to make sure that they are synchronised and set them going <set it going> The laptop is to record your heart rate <set heart rate software going> and to record what the machines are doing <set simulation software going>

Training Phase
Now I want you to spend a little time getting familiar with the product. I've put a piece of text under the camera and I'll take you through what all the buttons do.

CCTV Novice
The size dial here adjusts the size of the print on the screen
The mode button changes the polarity so you can have white text on black
The contrast dial changes the colour setting
The xy table helps you move the text up and down and sideways
The markers can be set like this to help you find keep the margins.

CCTV Expert
Your machine looks as though its all going. Would you like to practice at all or are you happy just starting the test straight away? Great, what I'd like you to do is get yourself comfortable

myReader
<Place box on table> Inside this box on the table in front of you is the product we are actually testing. What I'd like you to do is take the panel out of the box and put it wherever you feel comfortable with.

Now I want you to spend a little time getting familiar with the product. I've loaded a piece of text onto the screen and I'll take you through what all the buttons do. On the bottom row on the left is the start button. You press this button each time you put a new page under the camera then it processes it. If you could press that now you'll see what I mean.

Next to that is the overview/page view button. This one is to go from seeing the whole page to actually reading. You can see the whole page there now and if you press that button, see you go into the page. You can use this whenever you want to have a look at the whole page to get an idea of where you are up to.

Once you are into the text you'll need to adjust the size. On the top left is the size dial, (just like on the CCTV). If you'd like to try it and make the text the right size for you.

Next to that is the "write" button. It doesn't work at the moment but will allow you to write on documents or do hand crafts. We will just ignore this button for today. Next to that is the picture dial, which combines a couple of modes of the CCTV, it controls the colour and contrast. If you'd like to try it now and find the right setting for yourself.

Great, now there are two ways of moving through the text. Firstly, on the top right is a track ball. This replaces the moveable table on the CCTV and allows you to move around the page. Why don't you give that a go and see how the text moves.

The other way of moving around the text if to set it scrolling automatically. In between the trackball and the settings dial is the speed wheel, which controls how fast the text will scroll on the screen. Give that a go now. OK, speed it up, now slow it down and then bring it to a stop.

There is one more thing that the product can do. You can either have the words flowing in a single column down the page like this <show word wrap mode>.
Or from left to right like this <M x2> Which would you prefer? <Mx3 to get back to word wrap>

What do you think? Would you like to have a practice by yourself? This is just a chance for you to get familiar with the product so feel free to play with whatever you want and ask questions if you have any. Great, what I'd like you to do is get yourself comfortable and then find your way to the beginning of the page and try and read the first couple of paragraphs to yourself and then let me know when you've finished that. Away you go.

Competency Test
After they complete two paragraphs - That's great.

CCTV expert
Now, because you've been using a CCTV for a while I just want to test that you know what all the buttons and things are for before we get started. So can you show me where the :-
Size dial is
Picture knob
What does this button do? (mode)
How does the table work?

CCTV Novice
I just want to test that you know what all the buttons and things are for before we get started with the actual test. So can you show me where the :-
Size dial is
Picture knob
What does this dial do? (mode)
How does the table work?
Can you set the margins?

myReader
OK, before we go any further I'd just like to see if you can remember where everything is and what they do. So can you show me where the:
Size dial is
Picture knob
Start button
Overview button
What does this button do (write button which doesn't work)
Show me the two ways to move the text (speed and track ball)

If they can't correctly identify all controls ask them to read another two paragraphs.

That's great. How did that go for you? Would you like to try a little bit more to get used to the buttons and things? Or would you like to start on the test itself?

That's great. How did that go this time? Would you like to try a little bit more to get used to the buttons and things? Or would you like to start on the test itself?

Testing Phase
Now I'm going to get you to read a piece of text and I will just stand here and take notes about how the equipment performs.

I would like you to try to read this story as you would normally. I also want you to read for as long as you feel comfortable. If you get tired or have had enough please let me know because I want make sure that you only read for as long as you are comfortable.

Every couple of minutes I'm going to ask you to stop the scrolling, stop reading and I want you to tell me where you are up to and just let me know how you are doing.

Every ten minutes I'll ask you a couple of quick questions about what you have just read to make sure that you've taken in what you've been reading. Once you tell me you have had enough we'll turn the reader off and just have a little chat about the experiment, is that Ok with you?

Just remember, we are just here to observe how you use your reader so while you can ask questions, but we would encourage you to try to find the answers yourself first.

Have you got any questions before we start?

Make yourself comfortable and feel free to move your chair or any of the equipment around if you need to and use whatever controls you need to achieve the tasks we have for you. Get as comfy as possible and settle in to read for as long as you feel happy.

Are you ready?

Don't interfere unless users become visibly upset and ask for assistance

That's great, now let's get on with the reading task. If you get stuck try to figure it out first, but if you can't let me know and I'll help. OK, I'll just get the text started and now its all up to you.

Every 2 minutes – Can you please just stop for a second and tell me where you are up to? Thanks carry on.

Every 10 minutes – comprehension questions

Timing
Start timing only once they start scrolling. Stop timing whenever they finish a page or stop to ask a question. ***Pay attention***. Once they report having reached their endurance limit, or if participants exceed 45 minutes thank them for their effort, reassure them they have done well.

Post Test
Conduct interview, pack up equipment.

"Thank you so much for your help with this. I'll just pack away this equipment now."

Check about follow up appointment. "Can we make another appointment now? Great, I'll see you then. In the meantime, if you have any questions about any of this please don't hesitate to ring me on the number on the information sheet I've given you." Thank Participant again.