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TOUCHPAD-BASED
REMOTE CONTROL DEVICES

BY

NEIL ENNS

A thesis submitted in conformity with the requirements
for the degree of Master of Computer Science
Graduate Department of Computer Science
University of Toronto

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ABSTRACT

Touchpad-Based Remote Control Devices

Master of Computer Science, 1998

Neil Enns

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While the complexity and number of functions available in home entertainment systems has advanced over the years, the method by which these devices are controlled has remained relatively unchanged. The present research explores a new style of remote control that uses a touchpad, rather than buttons, to provide access to home entertainment appliances.

This study compares the usability aspects of a traditional buttoned remote to the new touchpad remote control design. The usability study, conducted with twenty participants, collected data through the use of questionnaires and post-test interviews.

The research found that the touchpad remote control was easier to use and was favoured by more participants in both daylight and dimmed light conditions. Seventy percent of the participants in the study said they would use a production version of the touchpad remote for their home television. In addition, 85% of the participants commented in post-trial interviews that the touchpad remote was easier to use in the dark.

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INTRODUCTION

Remote control devices were introduced in the 1930s as a mechanism for changing stations on radios. Since then, the popularity and complexity of remote controls has grown dramatically. Today, 97 percent of North American households own at least one remote control (Lowry, 1997), and the current generation of remotes allows users to control everything from televisions to thermostats. However, the design of remotes has changed very little since the mid-1970s. Today's units, much like early remote controls, consist of rows of tiny buttons, each with its own tiny label.

1

1.1 PROBLEMS WITH TRADITIONAL BUTTONED REMOTES

Traditional buttoned remote controls suffer from several disadvantages that limit their expansion for use in emerging technologies. One of these is a lack of scalability. Whenever a new feature is added to an electronic device, it usually requires adding a button to the remote control. With this approach, it is difficult, for example, to develop a five-device universal remote that does not consist of several dozen buttons. As well, these multi-function remotes are often hard for users to understand and use.

Another disadvantage of buttoned remote controls require television viewers to refocus their eyes from the screen to the remote and back whenever there is a need to find a particular remote control function. In daylight situations, this is a minor problem, but it can be a significant issue in low-light situations. Television

viewers are known to watch programs and movies in the dark, and in these lighting conditions, it difficult to see the button labels on traditional remotes.

Finally, and perhaps most importantly, current buttoned remote controls do not provide the range of input methods required by new technologies. For example, set-top boxes, one of these new technologies, combine the familiarity of television with the power of the Internet. These set-top boxes require that users have the ability to navigate web pages and compose electronic mail, all while sitting at a distance from the television. To accomplish these interactions, set-top boxes are often equipped with bulky wireless keyboards and button-laden remote controls – devices that do not lend themselves to flexible interaction styles.

The goal of this research is to develop a new remote control that addresses the above problems, while still maintaining an acceptable level of usability for the average consumer.

1.2 DEVELOPING A NEW REMOTE CONTROL DEVICE

Before starting the development of a new remote control, a complete review of the development of traditional buttoned remote controls was conducted. This review provided information on previous attempts at developing various styles of remote control devices. Additionally, a review of the academic research into the behaviour of television viewers was conducted, to gain an understanding as to how people use current remote control devices.

In the initial stages of this research, it was thought that a touchpad would be a good choice for an input mechanism in the new remote. A review of the re-

search into the usability of touchpads was conducted, to verify this assumption. Note, however, that while this review did show that touchpads would be a suitable method for a new remote, it did not prove that touchpads were the only viable solution.

Following this literature review, a prototype remote control was developed based on the information obtained during the literature review. This prototype incorporated a touchpad, menus that appeared on a television screen, and a single-stroke alphabet for data entry. The remote was then subjected to a usability study designed to answer the following questions:

- Do users find the new remote control simpler and easier to use than a traditional buttoned remote?
- Is the new remote control easier to use in low-light conditions than a traditional buttoned remote?
- If any usability advantages exist for the new remote control, are they large enough to entice users to switch to the new design?

The usability study did not attempt to investigate how well the new remote control design could be extended to interact with new consumer electronic devices. However, it is evident based on research conducted by Buxton et al. in 1985 and Brown et al. in 1990 that the new remote control design presented in this thesis is more extensible than traditional buttoned remotes.

1.3 THESIS OUTLINE

The remainder of this thesis describes in detail the development and testing of a new remote control. Chapter 2 provides background information on previous remote control designs and research studies. A description of the design issues for my new remote control, and a full description of the prototype developed, can be found in chapter 3. In chapter 4, a usability study conducted to test my prototype remote is described, and the results of the study are discussed in chapter 5. Finally, directions for future research and conclusions are presented in chapter 6.

PREVIOUS DESIGNS AND PAST RESEARCH

2

2.1 INTRODUCTION

Before designing a new device, it is useful to examine similar previously-developed products. The history of remote control devices is surprisingly rich and varied, dating as far back as the 1930s. This chapter takes a retrospective look at earlier remotes, as well as some of the newer devices currently under development. Past research into the use of remote controls and the behaviour of television viewers is also examined. In addition to remote controls, this chapter also presents previous research on touchpads and touch tablets.

2.2 THE HISTORY OF REMOTE CONTROL DEVICES

2.2.1 The 1930s: Radios and Carpets

One of the first remote controls was introduced in 1930 in an article that appeared in *The Canadian Magazine* (Relyea, 1930). The remote was for use with a radio, and consisted of a small motor and wiring inserted into the walls of a house. Through the system, users could switch to different radio stations and adjust the radio volume from any room. Interviews with users showed enthusiasm for the product – one commented: ‘there is the difference between cranking a car and stepping on the starter’. However, the remote was not free of design problems. For example, most homeowners were unwilling to tear up walls to run cables.

FIGURE 1: Diagram of an early remote control for radios

Electrical diagrams for a remote that solved this problem were published in a 1933 *Popular Mechanics* magazine (Anonymous, 1933). This remote used a simple solution to solve the problem of running wires through the walls: flat cables. By using flat cables, the wiring for the remotes could easily be hidden under living room rugs.

Despite the initial enthusiasm, remote controls did not become widely available. This was likely because their high cost during the depression era made them unaffordable for most people. Development of remote controls was also slow during much of the 1940s due to wartime activities.

2.2.2 The 1950s: The Arrival of Ultrasonics

Following the end of World War II and with the growing popularity of television, a flurry of remote control devices appeared on the market. Numerous articles touting new remote controls were published in magazines such as *Popular Science*, *Popular Mechanics*, and *Radio & Television News*.

Popular Science published plans for a remote that controlled channel selection, volume, and contrast; it could be built for under ten dollars (Baldwin, 1952).

The technology in this remote was not much more advanced than in the remotes of the 1930s. Other remotes included a unit from Admiral from 1956 that could change channels, control volume, and switch the television off and on. As an added feature, this remote skipped over channel numbers having no signal when changing channels up or down (Sheneman, 1956). This feature is still available on most televisions today.

As early as the 1950s, the usability of remote controls was not overlooked. *Consumer Reports* published an article in 1955 that compared nine remotes; a second article that compared an additional seven was published in 1956 (Anonymous, 1955). Of the sixteen remotes discussed in the two articles, two stood out: the *Sentinel* and the *Zenith Flash-Matic*. The *Sentinel* remote was notable because it included a speaker as well as standard television controls, a feature that never seemed to catch on.

The 1950s produced several interesting names for remote controls, including 'Lazy Bones', 'Magic Brain' and 'Remot-o-matic'.

The *Zenith Flash-Matic* was distinct, as it was the first available wireless remote control. The *Flash-Matic* remote was essentially a flashlight that was pointed at the corners of the television screen to activate television functions. Each corner of the screen was equipped with a photoelectric sensor that detected the flashlight. The upper-left sensor controlled channel up; the upper-right sensor controlled channel down; the lower-left sensor controlled power on and off and the lower-right sensor muted the audio. This remote shipped with Zenith televisions in 1956, but flopped. Viewers had difficulty recalling which corner corresponded to a particular function, and would, for example, turn off the television when they intended to switch channels. As well, the set had trouble with ambient

lighting – when placed in a sunny corner of a room, television functions would activate at seemingly random intervals (Anonymous, 1956).

Despite the problems with their initial wireless remote, Zenith would eventually become the leader in wireless designs. In June 1956 Zenith unveiled the *Space Command TV* that included the *Space Commander*, a four-button hand-held wireless remote that controlled volume, channel selection, and power by transmitting ultrasonic commands. Ultrasonic remotes became the standard until the advent of infrared in 1977.

The story of the development of the Space Commander system was told through interviews with Dr. Robert Adler in the August 27th, 1986 edition of the Chicago Tribune.

FIGURE 2: The *Sentinel* remote

FIGURE 3: The Zenith *Flash-Matic* remote

FIGURE 4: The Zenith *Space Commander* remote

2.2.3 The 1970s: Infra-red and Integrated Circuits

Perhaps the biggest advancement in remote control design to-date was the intro-

duction of infrared wireless remotes in 1977. General Electric was the first to introduce remotes using this technology, and GE's remotes were also among the first to use integrated circuits (Prentiss, 1977). The GE remote allowed viewers to change channels, adjust volume and turn the power off and on. A later design also allowed viewers to adjust colour, hue, brightness, and contrast.

With the introduction of infrared remotes, manufacturers had the ability to include a wide range of commands on the remote. Factors such as the number of wires that could fit into a cable or the number of distinct ultrasonic frequencies that could be generated no longer restricted development. By using several infrared LEDs, binary-coded decimal commands could be sent to the television allowing for an essentially unlimited number of remote commands (Prentiss, 1977). The removal of this limitation triggered a noticeable increase in the number of buttons on remote controls.

2.2.4 The 1980s: Buttons, Buttons and More Buttons!

The 1980s introduced people to everything from VCRs to window blinds that could be controlled by remote controls. Home automation was touted as the wave of the future, with remotes playing a central role in controlling all types of devices around the house (Anonymous, 1983).

Universal remotes were another advancement in remote design that was introduced in the 1980s. With so many electronic devices, it was not uncommon to find households with three or more different remote controls. The universal remote, which retailed for approximately \$100, could control several devices (such as a tele-

visions, VCRs, and tape decks) with a single remote (Cole, 1988). This style of remote remains popular today, and many new televisions and VCRs now come equipped with a universal remote.

The 1980s were also the decade in which remote control devices achieved wide acceptance by the general public. With a vast array of devices that were equipped with remote controls and the growing popularity of cable television, remotes quickly became a commonplace household item. A survey by *Channels* magazine in 1988 estimated that 75% of American households had a remote control (Burgi, 1988).

2.2.5 The 1990s: More of the Same

Remote controls have achieved widespread acceptance in the 1990s, with an estimated 97% of American households owning at least one remote (Lowry, 1997). Universal remotes are advertised as excellent holiday gifts, and cars with door locks that can be opened by remote are widely available. Entire companies are engaged in manufacturing and distributing universal and replacement remotes.

Despite their popularity, however, remotes have changed very little from those of the 1970s and 1980s. While today there are \$300 universal remotes that include LCD displays and illuminated buttons (see figure 5), these remotes are still just a large collection of buttons (Crosariol, 1996). Indeed, the ever-increasing numbers of buttons on today's remotes have led to a mini 'retro' movement toward replacement remote controls that consist only of volume, channel and power buttons (see figure 6).

FIGURE 5: The Marantz RC2000 remote

FIGURE 6: Universal Electronic's
URC-2010 remote control

2.3 EXPERIMENTAL REMOTE CONTROL DESIGNS

Even with the popularity of the buttoned remote controls described above, there is ongoing research into the development of other types of remote controls. Some of these have no buttons, and others make use of a limited number of buttons in innovative ways.

In 1992, a system was proposed that used multi-function buttons on a remote control to manipulate a set of on-screen menus (Kingham, 1992). The simplified remote consisted of 25 buttons, which allowed the user to change channels, switch television mode, adjust volume and turn the set off and on. The design rationale for this simplified remote included a reduction in the number of buttons, flexibility for supporting new television functions, and a more understandable interface for the viewer. Unfortunately, it appears that Kinghorn never constructed or tested his remote control.

ITT's Semiconductors Group took a similar approach in 1989 (Gosch,

1989). They designed a simplified remote that was shaped like a ballpoint pen and had a single button mounted on the side. By pressing the button, an on-screen menu was activated. An infrared beam inside the remote could then be used to position a pointer on the screen, with the button used to select the desired function. Simply bringing up the appropriate menu, then sweeping the remote control back and forth across the screen could adjust settings such as brightness, contrast, and tint. The design was intended to reduce the number of buttons typically found on remote controls and to allow for new features inherent in technologies such as High-Definition Television and the convergence of personal computers and television.

Another remote control that makes limited use of buttons is under development at the Himeji Institute of Technology, in Himeji, Japan. It consists of a pair of ski goggles used to hold electrodes in place against the head and a portable computer system. The remote control uses the electrodes to sense brainwave patterns and then converts them into signals to control household appliances. According to a CNN interactive article, tasks such as turning lights off and on can be mastered easily, but other tasks such as changing television channels require extra practice (Associated Press, 1997).

2.4 BEHAVIOURAL RESEARCH

Research into the use of remote control devices is widespread in the advertising and psychology fields. Advertising executives from television networks are interested in the use of remote controls and their effect on the television viewer's habits

(e.g., do viewers bother to watch commercials?). Psychologists are interested in the effect of different family cultures on television viewing behaviours (e.g., do men really hog the remote?). Manufacturers of televisions and remote controls also do research into remote control designs, in an attempt to discover new features worth adding to help differentiate their equipment from competitors’.

All these areas of research are worth examining as they provide insight into the behaviours of television viewers and the usage patterns for the various remote control commands. Knowledge of the different viewing patterns of television viewers and the frequency of button usage can assist in making informed design decisions when developing a new type of remote control device.

2.4.1 Electronic Monitoring of In-Home Television RCD Usage

Kaye and Sapolsky (1997) have conducted the most recent study on remote control device usage. They equipped 23 randomly selected households (40 adults, 4 children) with electronic monitoring devices that were attached to cable converter boxes. The devices monitored how often channel changing took place, the lengths of time channels were watched before a change is made, and in what time periods the changing occurred. In addition, subjects recorded their viewing times in a diary, and a post-experiment questionnaire was administered. Results from the study include the following:

- Subjects averaged 36.6 channel changes per hour (one channel change every minute and 38 seconds).
- Subjects overwhelmingly used a “rapid-fire” style of viewing. Eighty percent of

channel changes occurred when a channel was watched for less than 5 seconds.

- Subjects tended to do a large amount of rapid channel changing followed by extended periods viewing a single channel.

Kaye and Sapolsky did not publish several key pieces of information that could have been inferred from their data. For example, they did not discuss the time periods in which the channel changes occurred. Did the changes occur at the start of television programs, during commercial breaks, or within programs? In addition, due to the electronic nature of the study, channel changes were not categorised by intent (grazing or arrowing).

Grazing is the act of flipping through available channels to find something to watch.

Arrowing is when the channel up and down buttons are used to go to a specific station.

2.4.2 Delineating Grazing: Observations of Remote Control Use

In 1995, Eastman and Newton conducted a study in which they observed 146 households (253 adults) during three hours of prime time television for one evening. They recorded the number of operations, the types of operations, the time at which the operations occurred, and the type of program being watched when the operations took place. What is significant about this study is it was not based on a small sample of college students, as are most published remote control studies: instead, a large number of subjects from a variety of backgrounds was studied. This differs from many other remote control studies, where classes of psychology students were used as subjects. Further, the subjects did not record the data themselves; observers recorded the data.

This comprehensive study reported several results that can inform the design of a new remote control:

- Punching channel numbers directly and arrowing were almost equally used among all subjects, and neither style was significantly favoured over the other. Therefore, a new remote control design should include support for both types of actions.
- The majority of subjects (57%) never used the mute button. In addition, only 24% used it occasionally (1–3 uses during prime time). While this appears to indicate that a dedicated mute button could be removed from a new remote control design, this may not be the case. It may be that during the study, there simply weren't many of the normal interruptions (such as a telephone call) that necessitate the use of the mute button.
- 57% of channel changes were at the start and end of programs. Most viewers did not change channels during within-program commercial breaks, with most activity centred on the hourly and half-hourly breaks. A new remote control design, therefore, might consider using a more visually intensive interface since viewers are not likely to be preoccupied with watching a television program.

Punching is when the digit buttons on a remote are used to change directly to a channel.
Inserting is when two or more channels are watched at the same time

2.4.3 Measuring RCD Use: Method Matters

In 1993, Cornwell et al. conducted a study to illustrate how the methodology used to measure remote control usage can affect study results. They hypothesised that relying on self-reported data and university students for subjects can result in data that are inaccurate and that do not accurately represent the general population. Cornwell et al. then proceeded to conduct a study using electronic equipment (such as video cameras) that measured a variety of viewing activities. Results were

then compared to those from previously conducted studies. This study showed, as with the Eastman and Newton study, that remote controls were more likely to be used during a commercial than during a program.

2.4.4 Measurement of Mundane TV Behaviours

Similar in style to the Cornwell et al. study, a study conducted by Ferguson in 1994 examined the difference between actual and self-reported channel flipping frequencies. Ferguson studied 49 college students by observing them between 6:00 PM and 11:00 PM. Television channels were delivered through a cable converter box equipped with a hidden counter recording channel changes.

After a four-hour viewing period, subjects were asked about their channel changing habits. The responses were then compared against the actual data recorded by the hidden counter. Results clearly showed the problems with using self-reported data when attempting to determine actual remote control usage: 20.4 percent of subjects under-reported usage by a factor of eight, and 26.5 percent by a factor of five.

As this study and the Cornwell et al. study show, the population sample and reporting methods used in remote control studies are important. With this knowledge, any study to evaluate a new remote control design should carefully select the study participants and data collection techniques.

2.5 TOUCHPAD RESEARCH

While knowledge of the previous research of remote control devices is important

in the design of any new remote, in this case there are other areas also worth examining. As the new remote control design described in this thesis centres around a touchpad, past research on touch-based input devices is also worth examining.

Touch-based input devices have been available since the 1970s, when the first touch-sensitive computer screens were developed (Elo TouchSystems, 1998). Since then, a number of technological improvements have been made, and there are now several touch-based devices that use different techniques to sense finger location. Most touchpads today are of either the *capacitance* or *point-pressure* varieties (Blickenstorfer, 1996). The capacitance technology works by sensing distortion between electrodes on a grid underneath a membrane on the touchpad. This distortion is caused by a finger pressing on the membrane. Most touchpads on the market, including those illustrated in figures 7 and 8 below, use variations of this sensing technology. The drawback to this technology is that an actual finger must be used, and that moisture and oils on the finger can interfere with the sensing of the finger location and pressure. Point-pressure touchpads (see figure 9), in comparison, are essentially mini graphics tablets. These types of touchpads can be used with either a finger or stylus, and are not susceptible to interference from moisture and oils.

It is also worth noting a related technology: graphics tablets. These tablets operate with a stylus, rather than a finger, and typically use magnetic sensing technology, where magnetic fields are used to detect the location (and sometimes tilt) of the stylus in relation to the tablet. While tablets employ a different input method than touchpads (a stylus rather than finger), they often have similar inter-

action styles.

Many of these devices were developed for use in the graphics and computer-aided design communities. For example, graphic designers frequently use graphics tablets to draw digital artwork. Touchpads, however, were originally developed for use with air-traffic control systems to select aircraft from display screens (Ball et al., 1998). Since then they have been used in a variety of computing environments – most recently as input devices for mobile electronic devices.

FIGURE 7: The Cirque *GlidePoint* touchpad

FIGURE 8: The Synaptics T1002D touchpad

FIGURE 9: The Interlink *TrackPoint* touchpad

2.6 TOUCHPAD USABILITY RESEARCH

Despite their availability since the 1960s, relatively little research has been conducted on the usability of touchpads. While a thorough review of published work in the computing and engineering fields uncovered several papers on the usability of stylus-based input devices (such as touch tablets), relatively few papers were

found that discussed the usability aspects of touchpads. However, since the interactions styles of touchpads are very similar to their stylus-based counterparts, the research on stylus-based input devices is also applicable to new remote control designs.

The published research focuses mainly on the effectiveness of touch-sensitive devices (as opposed to focusing specifically on touchpads) as a replacement for other types of input devices, such as mice and trackballs. These studies usually compare a touch-tablet and one or two other input devices for pointing and graphics editing tasks. The studies relevant to the design of the new remote control design are described below.

2.6.1 Touchpads in Air Traffic Control Systems

One study, conducted by Whitfield et al. in 1983, and compared a touchpad-type device to a touch-sensitive monitor and a trackball for tasks such as menu selection and target acquisition. While the researchers chose these tasks because they were common in air traffic control systems, such tasks are also representative of the tasks done in typical graphical user interfaces. Results from this inquiry showed that users had lower error rates when using both the touchpad and touch-sensitive monitor, as compared to a trackball. The study also found that touch input surfaces give poor performance with high-resolution targets in demanding situations, but are acceptable for use with tasks that require coarse cursor positioning.

Given the date of this study, and the hardware used to develop the device, it is difficult to apply these findings directly to current touchpad devices. For exam-

ple, the resolution of both displays and touchpads has improved significantly since this study, and therefore the poor performance of the touchpad in this study may no longer exist in today's devices.

On the other hand, the tasks presented to the user in this study are similar to those of today's users. In this study's three experiments, users were asked to position a cursor over an illuminated item on-screen, and to then indicate their selection by pressing a button (for the trackball) or raising their finger (for the touchpad and touch-sensitive monitor). Since the touch devices available at the time were rudimentary in nature, it is significant that the prototypes still managed to outperform the more established trackball. With the improved resolution of today's touch devices, it is reasonable to assume that this finding still holds today.

2.6.2 Touchpads for Graphic Editing Tasks

A similar study by Epps (1987) compared two different styles of touchpads to two styles of joysticks, a mouse, and a trackball for graphic editing tasks. Participants in the study were asked to complete several basic graphics editing tasks, such as drawing a rectangle of a specified size, using each of the different input devices. Data were collected on the number of errors made and the time required to complete the tasks. Participants were also asked to rank the devices in order of preference for each of the tasks. The study showed that participants consistently performed tasks better with and preferred using a mouse or trackball. The study also found that touchpad performance was comparable to that of a mouse or trackball for coarse positioning tasks.

This final result is worth noting as it echoes the findings of the Whitfield et al. study in 1983. The fact that this finding was obtained with more recent hardware, improved graphics displays, and similar tasks, makes the findings easier to apply to current touchpad devices. However, the study was only conducted with six participants, so it is debatable as to how representative the sample was of the general population.

2.6.3 Comparing Devices for Pointing and Dragging Tasks

A more recent study by MacKenzie et al. (1991) compared a magnetic tablet with stylus to a mouse and trackball for both pointing and dragging tasks. This study was significant as it included dragging activities as part of the tasks, which had been unexplored in previous research. Results indicated, as with the previous studies above, that users had better performance for pointing tasks using mice, with comparable user performance results using a tablet. The authors also commented that a tablet and stylus combination had the potential to perform better than a mouse when tasks included drawing and character recognition.

While the devices tested in this study did not include a touchpad, the tablet and stylus combination employs interaction methods similar to those of a touchpad. For example, in this study the dragging task with the stylus required the participant to exert pressure on the tablet with the stylus. This is essentially the same interaction used in the touchpad and finger combination. As such, the results from this study should be taken into consideration when evaluating the applicability of a touchpad for pointing and dragging tasks.

2.6.4 Issues and Techniques in Touch-Sensitive Tablet Input

In 1985, Buxton, Hill, and Rowley, published a paper outlining the issues surrounding the use of touch-sensitive tablets as input devices. The paper presents three distinctions between touch tablets and one button mice: the ability for touch tablets to signal events; their suitability for applications that require multiple point sensing; and the ability to apply tactile templates on top of touch tablets. A number of properties of touch tablets are presented as well, such as the lack of moving parts in tablets. Before constructing any device based on a touch-sensitive tablet or touchpad, the pros and cons of the properties presented in this paper must be carefully weighed.

2.6.5 User Comfort and Performance with Touchpads

A study published by Çakir and Unema in 1995 examined user comfort and performance when using a TrackPad touchpad on Apple PowerBook computers. During a one-day test, subjects were asked to complete a variety of Fitts's law tasks. The researchers measured user performance and biomechanical load. In addition, participants were asked to complete a post-test questionnaire to measure their general comfort when using the touchpad.

Çakir and Unema found that participants using the touchpad exhibited no progressive fatigue or increased muscle load from one task to the next, and that the physical interactions with the touchpad fell within the limits of the physiology of the human arm. In addition, the study found that after the training session study participants had already obtained touchpad performance equivalent to 65% of

their mouse performance. This increased to more than 90% after two hours of touchpad use, and to 100% after five hours of use. Their results conclude that touchpads can be used for everyday tasks without causing postural discomfort or fatigue.

The results showing touchpad performance reaching 100% of mouse performance are highly suspect. The tasks used in this experiment focused primarily on 'office tasks', such as selecting text, pointing at menu items, and pointing at virtual buttons. Nowhere in the paper are these tasks clearly outlined, nor are visual representations of the tasks included. Due to these omissions, is difficult to conclude from the task descriptions how closely they mirror the more standard tests typically used in measuring pointing device performance.

In addition, the measure of performance used in this study was solely based on speed, and did not take into account errors. This type of measurement is a poor indication of performance, as it is well established that the performance measurement for a task is dependant not only on speed, but on accuracy as well. While it was not available at the time, the results would have been more believable had had the data been analyzed using the methods detailed in the ISO 9241-9 draft standard for throughput measurement.

2.6.6 Selection Techniques for Touchpads

In a 1997 paper, MacKenzie and Oniszczak discuss the use of touchpads as a replacement for mice in desktop and mobile devices. They point out that while touchpads are widely available on mobile devices, they are not generally used on

The first mobile device to incorporate a touchpad was the Apple PowerBook 500, from Apple Computer.

desktop systems. MacKenzie and Oniszczak claim that this lack of desktop adoption is due to the difference in how mice and touchpads implement selection and positioning tasks. In a mouse, positioning is accomplished by physically moving the mouse across a mousepad, and selection is accomplished by pressing and releasing a mouse button. A touchpad uses a finger for positioning tasks, and either physical buttons placed near the touchpad or a “lift-and-tap” of the finger to implement selection. As MacKenzie and Oniszczak explain, the lift-and-tap method for selection has usability problems.

In an attempt to address the shortcomings of current touchpad selection techniques, MacKenzie and Oniszczak present a touchpad design, dubbed the “tactile touchpad” that incorporates a relay beneath a standard touchpad. They attempt to use the pressure-sensing capability of touchpads, coupled with the relay, to create a selection method that mimics the button press-release mechanism of mice. To perform a selection technique with the tactile touchpad, users simply apply pressure to the touchpad with their finger. Once a certain pressure threshold is registered by the touchpad, the relay is activated causing both auditory and sensory feedback in the form of a “click”. While pressure has often been discussed as a method for implementing selection in touchpads, the tactile touchpad design is innovative in that it couples the pressure with auditory and tactile feedback that is familiar to computer users.

While the design presented in the 1997 paper introduces a new variation on pressure-based selection with touchpads, when the paper was published no studies had yet been conducted comparing the tactile touchpad to the standard lift-and-

tap touchpads. A follow-up paper, published in 1998, remedied this by presenting findings from a preliminary study on the effectiveness of this technique compared to the two existing selection techniques.

MacKenzie and Oniszczak's study compared the tactile touchpad to a lift-and-tap touchpad and a touchpad with a selection button. The three devices were compared using a standard selection task, and the results were analyzed in the context of the ISO draft standard for throughput measurement (ISO 9241-9). In addition, the subject participants were surveyed following the discussion to gauge their perception of the speed and accuracy of the different selection methods, as well as their selection method preference.

The study found that the tactile touchpad was superior to both the lift-and-tap and button selection methods in terms of both throughput and movement time. While the error rate for the tactile touchpad was higher than for the other two selection methods, this was not generally noticed by the study participants. The authors of the paper speculate that this result may be due to the higher throughput of the tactile touchpad, as measured by the ISO standard.

THE TOUCHPAD REMOTE CONTROL DEVICE

3.1 INTRODUCTION

After examining the history of remote control devices (see chapter 2), it is apparent that their design has changed little since the 1950s. While the functionality of the remotes has advanced significantly, the basic design of the devices still depends on buttons. Buttons were a suitable interaction method when remotes provided a small number of commands, however they fall short with today's multi-purpose remote controls. The sheer magnitude of functionality in today's electronic devices results in remotes that are equipped with over fifty, often tiny, buttons.

Besides being complicated and intimidating, it is difficult to take a traditional buttoned remote control and use it to manipulate some of today's emerging technologies. For example, it would be quite difficult to type someone's email address into a television-based email program using a standard button-based remote.

This chapter outlines the development of a new style of remote control that addresses the issues mentioned above. First, the design choices reflected in my new remote control are described. This is followed by a complete description of my remote that takes into account the design ideas.

3.2 DESIGN DECISIONS

When developing any type of new device, there are often several viable methods for making it work. This section outlines the different methods considered for

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The Sony RMT-V5A remote has 82 buttons plus a jog/shuttle wheel.

each aspect of the new remote control design, and discusses the reasons for selecting each specific implementation method. A prototype system, built using the design decisions discussed below, is described in section 3.5.

3.2.1 Input Devices

In developing the new design, it was thought that input devices other than buttons may be suitable a remote control. Several options for an input device to replace the buttons were available, including a touchpad, joystick, trackball, and touch-tablet/stylus combination. For an input device to be suitable for the new remote control, it must allow users to easily point and select menu items, enter alphanumeric characters, and be durable enough to withstand the home environment. Of the four potential input devices, three did not meet all these requirements for the reasons discussed below.

While the studies reviewed in section 2.6 do not completely discount joysticks for pointing tasks, they do tend to indicate that trackballs and touchpads perform better for these tasks. In addition, empirical studies have shown that it is difficult to draw symbols, such as digits and letters, accurately using either a joystick or a trackball. Finally, both joysticks and trackballs are likely to break if dropped on the floor.

Magnetic tablets, while providing users with a good degree of pointing accuracy, require the use of a stylus to draw on the tablet surface. While this is not a problem in an office environment, it could pose problems for viewers in a home environment. One can imagine how easy it would be to lose the stylus between

sofa seat cushions, which would render a magnetic tablet remote control useless.

A capacitive or resistive touchpad, however, has none of these problems. The studies in section 2.6 showed that users achieve good performance using a touchpad for tasks requiring a moderate degree of accuracy (such as pointing to an on-screen menu item). In addition, commands can be drawn on a touchpad simply by using the tip of a finger, thus avoiding the problem of a lost stylus. Buxton et al. (1985) also note that touchpads can be molded into one-piece constructions, eliminating cracks where dirt can collect, and that they have no moving parts, which makes them suitable for environments where they will be subject to intense use. As anyone with a remote knows, they are subjected to a barrage of soda pop, chip crumbs, and are frequently dropped, thrown, or otherwise abused. For these reasons, the touchpad shown in figure 8 in chapter 2 was used as the new remote control design.

3.3.2 The Visual Interface

The buttoned remote controls available today typically use a rudimentary visual interface to indicate how the remote works. This interface is typically implemented using small text labels adjacent to each button on the remote. While this works fairly well when the remote only has a few buttons and is used in daylight situations, it breaks down in other circumstances. For example, finding a desired button among the 80 or more buttons on some of today's remote can be a frustrating task. Also, many people enjoy watching television with the lights off or dim, and it can be difficult to read the individual button labels in dimmed light

conditions. The other drawback to this type of visual interface is that it requires the viewer to shift eye focus from the television to the remote when locating a button on the remote.

A touchpad remote, however, is not limited to providing a visual interface on the remote itself. A variety of methods could be used, including an LCD screen placed on the remote control, using a touch-sensitive LCD, or displaying the interface on the television screen. Of these, the first two have usability issues similar to those of text labels on a buttoned remote. They require the viewer to refocus attention from the television to the remote when looking for a particular command.

The third option, displaying the visual interface on the television screen, is not limited by these problems. Because the menus are displayed in the same location as the television picture itself, the viewer does not have any refocusing problems. As well, the interface is equally usable when lights are turned off. For these reasons, an on-screen display for the visual interface was selected.

3.3.3 Providing Feedback

With any type of electronic system, there is a need to provide feedback to the user. This feedback is critical in keeping the user informed as to the state of the system, and whether the system is correctly responding to the commands communicated by the user.

Computer systems generally provide feedback to the user using auditory feedback (sound) and visual feedback (images). For remote controls intended for

use with a television system, it would be difficult to use auditory feedback due to the amount of ambient noise from both the television and other viewers. As a result, most television systems today use visual images displayed on the television for feedback.

Many of the visual feedback mechanisms used for traditional buttoned remote controls are suitable for use with a new remote control design. For example, buttoned remotes frequently display the channel number in the upper-right corner of the television as it is entered. This type of feedback is simple and straightforward, and common across most televisions available today. The new remote control should therefore, wherever possible, attempt to use the standard types of visual feedback in today's televisions.

3.3.4 Menu Styles

The new remote control described in section 3.5 includes on-screen menus to access many of the television's functions. Several menu styles could be used in the on-screen displays, including drop-down menus (illustrated in figure 10) and pie menus (illustrated in figure 11).

Drop-down menus, while they are fairly well recognized and understood by the public, require a fine degree of pointing accuracy. As described in section 2.6, touchpads do not give users good performance for tasks that requiring this degree of accuracy. As a result, drop-down menus would likely be difficult to use in a new remote control.

Pie menus differ from drop-down menus in that they require less precise

pointing accuracy to manipulate. Simply moving a cursor in one of the eight main compass positions selects the menu item. Their advantage lies in the fact the user is only required to move the cursor into the desired menu section; the cursor does not have to be moved a specific distance. However, pie menus do have a disadvantage in that they are not widely used in general-purpose graphical user interfaces, and users of consumer electronic devices may be unfamiliar with their operation. However, I believed that the usability advantages of a pie menu, especially when coupled with a touchpad, were significant enough to outweigh the disadvantages of the unfamiliarity of the menus.

In an attempt to adapt the design of the pie menu more to the rectangular television screen, and to allow the text of the menu to more easily be read from a distance, the menus used in the system were displayed on a grid rather than as pie wedges. While the 'grid menu' illustrated in figure 12 is visually different from a pie menu, its interaction methods remain the same.

FIGURE 10: Selecting an item from a drop-down menu.

FIGURE 11: Selecting an item from a pie menu.

FIGURE 12: Selecting an item from a grid menu.

3.4.5 User Input

There are several options to consider when selecting a method for allowing users to communicate commands to a new input device. Two, voice recognition and character recognition, are worth considering for a new remote control device.

Voice recognition software is now commonly available for consumer devices. IBM's VivaVoice technology can be used to enter text on Windows based computers, for example. Other consumer devices, such as Microsoft's AutoPC, use voice recognition in more consumer-oriented devices like car stereos. The major advantage of voice recognition is its simplicity: the user simply has to speak commands. However, there are problems associated with employing voice recognition in the home entertainment environment. For example, it is considered quite rude to talk while others are watching television. Most notably, it would be difficult for a voice recognition system to distinguish between the voice commands voiced by the user and the sounds coming from the consumer devices themselves (such as sound from the television or music from a stereo).

Character recognition, however, does not suffer from this drawback. It has

been widely adopted as the input method of choice for new devices such as Microsoft's Palm-Size PC and 3COM's PalmPilot. As these devices have shown, character recognition is accepted by users as a simple and easy to learn input method. For these reasons, character recognition was selected as the input method for the remote control device described herein.

3.5 THE PROTOTYPE SYSTEM

To demonstrate the new concept remote, a prototype television and remote control were programmed using a *Windows95*® system. To allow people to compare the new touchpad remote design to traditional buttoned remotes, support for standard universal remotes was also included in the prototype. The functions supported by the prototype television and its interactions are discussed below, while specific details on the hardware in the prototype system are described in appendix A.

3.5.1 *Single-Stroke Symbols*

As discussed in section 3.2.1, symbols can be drawn directly onto a touchpad with a finger. These symbols, which can take the form of familiar alphanumeric characters, can then be interpreted in software with a stroke recognition algorithm to activate a specific television function.

The prototype remote supports an alphabet of 20 single-stroke symbols, each of which is used to accomplish television viewing tasks. As the viewer draws the symbol on the touchpad, displaying the symbol on-screen provides visual feed-

back. After the viewer lifts their finger from the touchpad, the symbol is interpreted and the associated television command is activated. The supported symbols are illustrated in figure 13.

In 63 BC, a freed slave of Cicero invented a shorthand similar in style to the single-strokes used in figure 13. The shorthand was used for over 1,000 years to record the minutes of the Roman senate. (Panati, 1984)

FIGURE 13: Supported single-stroke commands.
The dot indicates the starting point for drawing the symbol.

The symbol for the number four differs slightly from the standard '4' character, as this is a single-stroke alphabet. To draw a normal '4', two strokes would be required.

The symbols '0' through '9' allow viewers to change channels simply by drawing the desired channel number. For example, drawing the symbol '2' followed by the symbol '7' changes the television to channel 27. Single-digit channel numbers can be entered as either a double-digit channel number (e.g. '07' for channel seven) or as a single digit (e.g. '7'). When a single digit is entered followed by five seconds of inactivity, the system assumes a single digit channel number and changes the channel accordingly. This length of delay was selected by observing several randomly selected people changing channels with various delay settings.

The symbol 'm' toggles the volume mute off and on. The lines drawn

northeast and southeast provide channel up and channel down support respectively, changing up (or down) to the next available television channel. A line drawn to the west causes the television to switch back to the last channel that was active.

The VCR can be controlled by the last six symbols in figure 13, and the command executed is indicated beneath the symbol. These symbols posed a design problem, as many of the obvious symbols (such as 's' for stop) were similar in shape to other symbols (such as '5' for changing channels). To solve this problem, new symbols that were not specifically related to the associated functions were used for the stop, power, and record commands.

3.5.2 On-Screen Menus

Several television functions, such as on-screen channel lists and program guides, require complicated interactions that cannot be reduced to a single symbol. To access these functions, the touchpad remote uses the on-screen grid menus described in section 3.3.4. These menus allow access to up to eight functions on a single level.

To display the menu, a finger is placed on the touchpad and not moved for three seconds. The delay length was set by observing several randomly selected people using the remote to display the menu with different delay settings. After this delay, the menu appears on the television screen. The viewer moves a highlighted square around the menu by moving a finger on the touchpad. Lifting the finger off the touchpad selects the highlighted menu item. To close the menu without selecting a function, viewers can either select the centre item from the

menu or move their finger to one of the edges of the touchpad and release.

For cases where eight menu items are not enough or cases where having functions grouped by type makes sense (VCR commands, for example), sub-menus are supported. Sub-menus function identically to regular menus, and are displayed when an item linked to the sub-menu is selected from a higher level menu. The VCR menu from the prototype system, an example of a sub-menu, is displayed in figure 17.

3.5.3 Slider Menus

Certain television functions, such as volume and brightness, are typically set by adjusting the value between a minimum and maximum value (between 0 and 100 percent with volume, for example). The prototype system provides a slider similar to those found on many commercial televisions (see figure 16).

Once the slider is displayed, usually by selecting a function from one of the on-screen menus, the value can be adjusted simply by moving a finger on the touchpad remote. To increase the slider value, the finger is moved to the right. Similarly, the finger is moved to the left to decrease the slider value. In the event the viewer's finger reaches the edges of the touchpad before the slider value has reached the maximum (or minimum), pressure-controlled velocity movement has been implemented. By holding the finger at the edge of the touchpad, the slider will continue to increase (or decrease) at a rate determined by the amount of pressure exerted by the finger on the touchpad. Vertical movement of the finger is ignored.

3.5.4 Vertical Scrollable Menus

Some newer television functions, such as on-screen channel guides and electronic program guides, are usually displayed using a scrollable menu. The prototype television includes an on-screen channel guide which is implemented using a generic vertical scrollable menu, shown in figure 17.

The menu allows viewers to move a selector up and down a list of menu items. When displayed, the currently viewed channel is highlighted and displayed in the centre of the menu. Sliding a finger up or down moves the selector up and down, respectively. Once the desired menu item is highlighted, lifting the finger off the touchpad activates it. Should the viewer's finger reach the top or bottom edges of the touchpad, the vertical scrolling menu behaves much like the sliders described in section 3.5.3. By holding the finger at the top or bottom edge of the touchpad, the selector will continue to move up (or down) at a rate determined by the pressure exerted by the finger on the touchpad.

FIGURE 14: The television's main menu

FIGURE 15: The television's VCR menu,
accessed by selecting the VCR item from the menu in figure 14.

FIGURE 16: The volume slider

FIGURE 17: The television's channel menu

The vertical menu also scrolls when there are more items in the menu than will fit on the television screen. When the selector is moved to the top (or bottom) of the menu, and the finger continues to move up or down (or maintains pressure at the touchpad edges), the list will scroll up or down. Horizontal finger movement is ignored.

3.5.5 Supporting Traditional Remotes

The prototype system described above can be operated with both the new touchpad remote control and a traditional buttoned remote control. The support for the buttoned remote was included to allow people to try the system's user interface with both types of remote controls, and to then evaluate the design of the touchpad remote. While any universal remote could theoretically be supported with the system, the interactions were mapped to the buttons available on a Universal Electronics *All-In-One* URC-5061 remote. This remote, shown in figure 18, has all the buttons typically found on a traditional remote.

Changing channel numbers on the prototype system with the buttoned remote is accomplished by pressing the buttons labeled '0' through '9'. Pressing the buttons corresponding to the first and second digit in the channel number changes to the desired channel. Single-digit channel entry is accomplished by either entering the individual digit (such as '7' for channel 7) and waiting for a few seconds, or by entering '0' followed by the single-digit channel number. The channel up and channel down buttons can also be used to change channels, and they move up and down to the next channel with a valid signal respectively.

FIGURE 18: The Universal Electronics One-For-All URC-5061

VCR commands are accessed by pressing the various VCR buttons on the remote, which include power, play, stop, fast forward, rewind, pause and record. The record button must be pressed twice to activate recording, which acts as a safety to prevent the accidental recording of programs over important tapes.

The on-screen menus are also accessible using the standard remote control device. Pressing the 'menu' button displays the on-screen menu. The channel up and down and volume up and down buttons are bi-modal, and in the 'menu' state are used to move the selector up, down, left and right around the menu. To activate the highlighted menu item, the 'mute' button is pressed.

Slider menus (such as volume) are manipulated by pressing the volume up/down buttons on the standard remote control device. Pressing volume up increases the slider position by one increment, pressing volume down decreases the slider position by one increment. For the volume slider, the viewer can simply press volume up or down and the slider will automatically be activated. To manipulate other sliders (such as brightness), the slider must first be selected from an on-screen menu.

The vertical scrolling menus are manipulated by pressing the channel up and down buttons on the standard remote control device. Pressing channel up moves the selector up by one menu item and pressing volume down moves the selector down by one menu item. To select the highlighted menu item, the 'mute' button is pressed.

THE USABILITY STUDY

Even the best planned designs developed by well trained and experienced usability specialists can be rejected soundly by the general population, for reasons so varied that no designer could possibly anticipate them all. When the newly designed item, be it a computer interface or a doorknob, is intended for people with a wide variety of skills and backgrounds, a thorough examination of the usability aspects of the device is especially necessary. Failure to do so can result in a rejection of the device by the general population, not because of inelegant design but simply because the device doesn't work the way people expect.

To ensure the touchpad-based remote control device provides simple and direct interactions for typical television viewing activities, a usability study was conducted. The study compared the newly developed touchpad remote with a more traditional buttoned remote control design. Details of the study are presented below, and the results are presented in chapter 5.

4.1 PARTICIPANTS

Twenty participants were recruited through advertisements posted to various University of Toronto electronic mailing lists and newsgroups. The first ten male and female respondents were selected to participate in the study. The twenty volunteers had a varied background of television viewing habits, as summarized in table 1. More information on the demographics of participants was gathered than needed for the purposes of this study. This data is available on file with the researcher.

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Button-based remote controls are an example of a device with inelegant design that is widely accepted by the general population.

	MALES	FEMALES
Light viewers (0 to 3 hrs)	5	4
Medium viewers (4 to 6 hrs)	2	2
Heavy viewers (7 or more hrs)	2	2
Frequent remote usage	7	7
Moderate remote usage	0	0
Light remote usage	2	1
18 to 24 years old	0	4
25 to 34 years old	5	2
35 to 49 years old	4	1
50 to 65 years old	0	1

TABLE 1: Study participant demographics

Participants were paid a \$10 honorarium for taking part in the study, and were reimbursed for public transportation costs to and from the research site. Snacks and beverages were also provided.

Ginger ale and sour cream and onion chips were the most popular snacks and beverages during the study. The Diet Coke was never opened.

4.2 APPARATUS

To test the touchpad remote control design, the prototype system user interface (described in chapter 3) and hardware (described in appendix A) were used. To hide the fact that the system was not an actual television, the computer monitor was placed on a regular television viewing stand with the computer case placed off to the side. As well as the computer, a Sony VCR was connected to the system and placed on a shelf above the monitor to allow participants to view videocassettes.

As mentioned previously, the study used both a touchpad remote and a buttoned remote. To prevent bias in the results, the remotes were simply referred to as 'remote A' and 'remote B' respectively. Since the touchpad remote was new to

all participants, a guide to the single-stroke commands was placed on a table near the participants. Similarly, the individual buttons on the button remote were labeled.

For details on the various electronic components and connections used to construct the prototype hardware, software and remotes please see appendix A.

4.3 METHOD

The usability study was a 2x2 design, with the remote control and the room lighting (either daylight or dimmed light levels) as the conditions. During the study, all windows in the room were covered with heavy black cardboard and duct tape. The daylight conditions were then simulated by illuminating the room with four 100-watt overhead lights. Dimmed light conditions were simulated by turning off all the lights in the room, leaving a pitch black room illuminated only by the television. Four trials were run during each session, with the remote used alternating after each trial and the lighting condition alternating after the second trial. The initial remote and lighting conditions were randomly assigned to each participant.

At the start of the session, the participants received instructions on how to operate the two remote controls. As well, they were given time to play with the two remotes to make sure they understood their operation. Following the practice time with the remotes, the participants proceeded to complete the four trials. Each consisted of the following tasks, which were performed by the participants as the researcher read them aloud:

- Change to channels 10, 49, and 26 by using the digit strokes (remote A) or numbered buttons (remote B).
- Change to channel 29 by using the channel up stroke (remote A) or button (remote B).
- Change to channel 20 by using the channel down stroke (remote A) or button (remote B).
- Adjust the volume up by a few increments.
- Mute the television.
- Change to channel 8.
- Change to the TV5 station by using the channel menu.
- Using either the appropriate stroke (remote A) or button (remote B), turn the VCR on, start the tape playing, stop the tape, start the VCR recording, stop the tape, and turn the VCR off.
- Using the television menu, turn the VCR on, start the tape playing, stop the tape, start the VCR recording, stop the tape, and turn the VCR off.

4.4 DATA COLLECTION

In any usability study, the collection of data is of paramount importance. A usability study can have a wonderful array of tasks that explore all aspects of a design, but if there are no data to examine, when all is said and done, the study is useless.

This user study employed a number of different data collection methods to get feedback from the participants on the touchpad remote control. During the

trials, the participants were encouraged to make comments on their likes and dislikes of the remote control designs. Following the trials, a questionnaire was administered to collect quantitative data on these likes and dislikes. As well as the post-trial questionnaire, participants were asked a series of questions following the trials to start the conversation flowing.

In addition to data obtained from the participant directly (through questionnaires and interviews) other information was collected through more indirect means. The software controlling the prototype maintained a log of all commands used by the participants, down to the individual button presses and drawn symbols. As well, an assistant observed physical aspects of how the participants used the remote controls. The questionnaires and interview questions used during the study are included in appendix B.

RESULTS AND DISCUSSION

5

5.1 INTRODUCTION

This chapter outlines the results of the previously described study, with particular emphasis on the comments made by the study participants. Usability studies frequently reveal design issues that even the best interface designer could not anticipate, and the study described in chapter 4 is no exception. These comments provide excellent insight into the usability issues of the current design of the touchpad remote.

Where necessary, quantitative results will be used to reinforce the comments made by the participants. Complete tables of all quantitative results are provided in appendix C; only those qualitative results that were very similar to or very different from the participants' comments are discussed below. In addition, the reader is reminded that the range of answers for each question covers both input devices. Thus, a mean of responses closer to 1.0 to a question indicates the touchpad remote, a mean of 3.0 indicates neither the touchpad remote nor the button remote, (i.e. neutral) and a mean of responses closer to 5.0 indicates the button remote. For example, in table 2, the mean of 4.4 to the question '*which remote did you find more difficult to use for entering direct channel numbers when the lights were off?*' indicates that the button remote was more difficult.

While future research directions are not typically discussed as part of study results, the nature of the findings lends itself to looking at the current research and

future steps simultaneously. Due to the large number of results from the study, they will be broken down and presented on a feature-by-feature basis, following an introductory review of the participants' general impressions of the touchpad remote.

5.2 OVERALL IMPRESSIONS

Despite its prototype status, the majority of participants favourably received the touchpad remote, with 70% of the participants saying they would choose a production version of the touchpad remote for their home television system.

The most overwhelming benefit of the touchpad remote, however, was not for any one particular task but rather for a particular study condition. Eighty-five percent of participants stated during interviews that the touchpad remote was easier to use in dimmed light conditions, compared to the buttoned remote. Many of these participants also mentioned that the touchpad remote could be used without having to refocus their eyes from the television to the remote and back.

'This is very hard because I can't see it.' 'I can't see anything.' 'I can't even bloody well see it.'

— Typical comments from participants trying to press buttons in the dark.

5.3 OVERALL USABILITY ISSUES

Even with the encouraging results outlined above, the study participants raised several usability issues.

One is that, in its current form, the touchpad remote requires two hands to operate (one to hold the remote, and another to draw the command). This is different from the typical buttoned remote, which is usually used with one hand. While the remote could be rested on a couch or slouched stomach instead of held

'With this I can eat the carrot at the same time!'

— Subject 9, on munching snacks and using the buttoned remote.

in-hand, participants almost exclusively held the remote in their non-dominant hand and drew commands with their dominant hand. When asked during interviews, however, participants said that the two-handed nature of the current design would not prevent them from using or buying a touchpad remote. Even so, it would be worth investigating different forms for the remote that could be used with one hand.

Another usability issue raised by participants concerned the button-free nature of the touchpad remote. Many of the participants missed having quick, easily accessible buttons for some television functions (such as channel up and down). One possibility, suggested by several participants during the interviews, was a hybrid remote that incorporated both a touchpad and a few select buttons. Other participants, when asked if they would prefer a remote of this style, agreed that it would be nice to have buttons for functions like channel up and down, and volume up and down.

5.4 DIRECT CHANNEL CHANGING

Of the various individual tasks the participants performed during the study, direct channel changing resulted in the strongest positive response.

When participants were asked to select two tasks for which the touchpad remote was their preferred input device, 60% chose direct channel number entry as one of the two tasks. The desire to use the touchpad remote for this channel-changing task was largely due to its ease of use in dimmed light conditions (although some participants admitted in interviews that a certain novelty factor was

involved as well). Many participants commented that they liked not having to look down at the remote to try and find individually numbered buttons, as with traditional buttoned remotes.

Other participants liked the touchpad for direct channel changing because of a perceived increase in the speed with which they could change channels. There was a slight difference in channel changing speed between the touchpad and buttoned remotes in the study, since the prototype touchpad remote did not include infrared transmission functionality. In a production system, this speed difference would likely be non-existent.

5.4.1 Usability Issues

One minor usability issue that cropped up while observing direct channel changing tasks was problems with the stroke recognition algorithm in the prototype. The algorithm to convert the symbol drawn by the viewer into a character that could be understood by the computer was fairly rudimentary and relatively unforgiving. In several cases, a very nicely drawn number (usually a '2' or a '5') failed to be interpreted correctly by the algorithm. This caused some initial confusion for several of the participants, although they adapted quickly to the style of symbols expected by the system, and as shown in table 2 participants actually found the touchpad remote a bit easier than the buttoned remote for direct channel changing.

	DAYLIGHT	DIMMED LIGHT
Difficulty	3.3	4.4
Device preference	2.5	2.3

TABLE 2: Mean post-test questionnaire results for questions 1–4, part A.

As seen in table 2, the mean answer of 4.4 for the dimmed light condition indicates that participants found the buttoned remote quite difficult for direct channel changing. The table also shows a slight preference for the touchpad remote in both light conditions.

5.5 ON-SCREEN MENUS

Using the on-screen menus was another task where participants clearly preferred the touchpad remote to the buttoned remote. When participants were asked to select two tasks for which the touchpad remote was their preferred input device, 55% chose on-screen menus as one of the two tasks, placing it just behind direct channel entry in order of preference. This preference was likely due to both the on-screen menu implementation and the touchpad remote – participants indicated they liked the way that movements of the finger on the touchpad were mapped directly to the movement of the selection highlight in the menu. In contrast, the buttoned remote was labeled as ‘too confusing’, likely because it used bimodal buttons for its menu interactions (as described in section 3.6.5). This confusion is also apparent in the participants’ post-test questionnaire responses (see table 3), although it doesn’t show as strongly as in the participants’ comments.

	DAYLIGHT	DIMMED LIGHT
Difficulty	3.4	3.6
Device preference	2.7	2.2

TABLE 3: Mean post-test questionnaire results for questions 1–4, part G.

As the users commented on the difficulty of using the buttoned remote to manipulate the menu, the table corroborates this with mean answers of 3.4 and 3.6, indicating the button remote was more difficult, in both lighting conditions. In addition, the table shows a slight preference for the touchpad remote in daylight conditions, and a stronger preference for the touchpad remote in dimmed light conditions.

As well, interacting with the sub-menus (used in the prototype system to provide an additional access method for VCR commands) posted no problems for the participants. They easily discovered the sub-menus and their operation on their own, even though the sub-menus were not demonstrated during the initial learning sessions.

5.5.1 Usability Issues

Despite the general acceptance of the on-screen menus and the touchpad interactions used to manipulate them, the menus did prove to be problematic for many of the participants. One major usability issue was the method of displaying the menus on-screen. The current design requires the viewer to place a finger on the touchpad without movement ('dwell') for three seconds before the menu displays. This design, however, did not take into account the motor skills of the users: many

of the participants would move their fingers very slightly on the touchpad during this three-second wait, thus preventing the menu from appearing. In addition, these slight wiggles were often interpreted as a '1' by the stroke recognition algorithm as a digit for a direct channel change, further confusing the participants. The prototype did have provisions in its design to try and eliminate this jiggle effect by implementing a movement threshold, but the study shows that the threshold was likely set too low. Future designs should investigate other mechanisms for displaying the menu or an improved dwell detection algorithm.

Another major usability issue uncovered in the study was the mysterious 'disappearing blue square'. As described in section 3.5.2, the on-screen menus included a mechanism for closing the menu without making a selection. This 'cancel' functionality was implemented by making the edge regions of the touchpad into a cancel area. Removing the highlighted selection indicator from all the menu items provided visual feedback. This created confusion for many of the participants. Participants generally expected the menu to be mapped to the entire touchpad, so that moving all the way to the left edge of the touchpad, for example, would move the selection into to the left-most column of the menu. Because of the cancel function, however, this would in fact cause the selection highlight to disappear from the screen.

'Something is going on...daddy? mommy?'
— Subject 13,
after the highlight
square disappeared.

5.6 THE CHANNEL MENU

A relatively new innovation in television, the on-screen channel menu included in the prototype system piqued the interest of several of the study participants. Some

of the infrequent television viewers mentioned how useful it would be on their home television set. While the comments were generally positive about the concept of a channel menu, the participants identified many usability issues in the current design. Despite these issues, however, participants indicated a preference for the touchpad remote for accessing the channel menu (see table 4).

		DIMMED
	DAYLIGHT	LIGHT
Difficulty	3.4	3.8
Device preference	2.2	2.0

TABLE 4: Mean post-test questionnaire results for questions 1-4, part D.

As seen in the above table, the mean responses of 2.2 and 2.0, for the two light conditions respectively, indicate a fairly strong preference for the touchpad remote. This corroborates the responses given by the participants during interviews.

5.6.1 Usability Issues

The channel menu differs from other user interface elements in the touchpad remote since it requires the viewer to move a cursor a precise distance to select a menu item. Pointing tasks of this type are not unusual in graphical user interfaces (selecting an item from a menu, for example), but design decisions and the form of the touchpad remote resulted in numerous usability problems. When programmed, the menu was designed so that its scroll speed was proportional to the pressure of the finger at the touchpad edges. However, in the touchpad used in the study, pressure is inferred from the amount of surface area of the finger on the pad.

In other words, the more finger area pressed to the touchpad surface, the 'harder' the finger is pressing on the pad.

This works reasonably well at the centre of the touchpad, but the beveled case of the remote made it difficult to control the amount of finger area on the touchpad at the edges. As a result, the scrolling speed of the menu was unpredictable, and viewers became confused when the menu scrolled too quickly. Often, in an attempt to slow the scrolling, the viewers would lift their finger off the touchpad completely, causing the menu to select an undesired channel number, resulting even more confusion.

Another issue with the channel menu was a lack of visual feedback while viewers were moving their finger on the touchpad. The channel menu as implemented only provided feedback when the finger had moved enough to cause the selected menu item to change (which caused the selection highlight to move to the next menu item). Without any visual feedback indicating the distance the finger had moved between two menu items, viewers would frequently overshoot the desired menu item. A possible improvement would be to draw a trail on-screen, indicating the distance travelled by the finger.

Finally, it was pointed out by a couple of participants that there was no mechanism to hide the channel menu without selecting a menu item (as is possible with the other on-screen menus). This could be solved by allowing the viewer to move off the menu by moving their left or right on the touchpad.

5.7 CHANNEL SURFING COMMANDS

Besides direct channel number entry, televisions typically provide channel up, channel down, and previous channel functions to change channels, and the touchpad remote is no exception. Viewers frequently use these commands to scan through the available channels, and as such should be straightforward and require little viewer effort to activate typically use these functions.

Despite the simple strokes used to access these functions in the touchpad remote, they received a somewhat lukewarm reception from the participants. As shown in table 5, participants did not indicate a strong preference for one style of remote over the other, except in dimmed light situations.

Even though the post-trial questionnaire did not indicate any strong preference, some participants did voice a specific device preference during interviews. Some of the participants preferred the touchpad for the channel up and down commands because of a perceived speed advantage, largely due to the inherent infrared transmission delay of the buttoned remote. Others preferred the buttoned remote because of its layout of the channel up, channel down, volume up, volume down, and mute buttons. This lack of a specific device preference also showed in the post-test questionnaire results (see table 5). Participants did not find either device much more difficult to use than the other, and only showed a preference for the touchpad remote in the dimmed light conditions.

	DAYLIGHT	DIMMED LIGHT
Difficulty	3.0	3.3
Device preference	3.1	2.4

TABLE 5: Mean post-test questionnaire results for questions 1–4, part B.

The above table corroborates the lack of specific device preference for channel up and down tasks found during post-test interviews. All means fall roughly around 3.0, indicating neither the touchpad nor the buttoned remote. The only exception is that participants seem to have a preference for the touchpad remote in dimmed lighting conditions.

5.7.1 Usability Issues

The straight-line strokes to access the three channel changing commands suffered from a usability problem not unlike the dwell issues described for the on-screen menu (see section 5.5). Observations during the study showed that some participants would draw the strokes with a slight swooping motion at the start, which prevented the stroke recognizer from correctly interpreting the command drawn. Most of the participants eventually learned to draw the strokes without this starting swoop, and none of the participants mentioned this as a problem during interviews. As with other recognition issues, this could be solved in a production version of the touchpad remote by using a more robust and forgiving recognition algorithm.

The only other usability issue that surfaced was with the direction of the channel down stroke. Six of the participants first tried drawing the channel down

stroke to the south-east as opposed to the south-west. In retrospect, placing the channel up and down strokes on the same axis makes sense, as it allows the hand to move smoothly along a single axis. In a future version of the touchpad remote, this mapping should be seriously considered.

5.8 THE VCR COMMANDS

During the design stage of the touchpad remote, it was difficult to develop strokes to assign to the various VCR commands. The symbols selected for the prototype seemed straightforward at the time. However, as the usability study showed, participants had a great deal of difficulty in correctly accomplishing the VCR tasks.

Despite this confusion, many participants still preferred the touchpad remote to the buttoned remote for VCR commands. Many of the participants commented on how fun it was to draw the stop command (often referred to as ‘the fish’). Participants also indicated quite strongly in the post-trial questionnaire that the touchpad remote was easier to use for VCR commands in dimmed light conditions (see table 6).

	DAYLIGHT	DIMMED LIGHT
Difficulty	3.2	4.0
Device preference	4.1	2.0

TABLE 6: Mean post-test questionnaire results for questions 1–4, part 1.

As can be seen in the above table, the mean of 3.2 indicates participants found neither remote more difficult than the other in daylight conditions. In fact, the mean of 4.1 indicates a pretty strong preference for the buttoned remote in

daylight. This, however, changed in the dimmed light conditions, where participants clearly found the buttoned remote more difficult (mean of 4.0) and clearly preferred the touchpad remote (mean of 2.0)

5.8.1 Usability Issues

As mentioned previously, the symbols selected to represent the VCR commands were chosen to match the starting letter of the associated VCR function ('R' for rewind, for example). This mapping, however, ran into problems with commands that started with the same letter, for example play and power, and rewind and record. More than half of the participants mixed up the VCR commands, drawing 'P' instead of 'W' for power, for example. Participants also had the basic problem of recalling exactly what the possible symbols were, and it was not uncommon to see people squinting at the symbol reference card for help. Clearly, the symbols overloaded the short-term memory of the viewers. Of the commands, it is worth noting that the alphabetic symbols (such as the 'fish' for stop and backward 'N' for record) were the most easily remembered.

A patent has been granted in the United States for a 26-letter single-stroke alphabet that consists entirely of alphabetic symbols.

When asked what might help reduce the confusion with the VCR symbols, most of the participants said 'more learning time' – allowing the symbols to move from short-term memory to long-term memory. Many indicated that with three or four more runs through the trials they would easily remember the right symbols to use. Other participants mentioned that a small reference sticker pasted to the touchpad remote would also help. Participants were also asked if having alphabetic symbols for all the VCR commands would reduce the confusion, but most

said that more learning time would be more helpful.

Despite the participants' lukewarm response to the idea of all alphabetic symbols, it is worth further investigation. Another solution to this problem may be to only use on-screen menus for the VCR commands, as they are used much less frequently than the channel changing commands. However, this would require testing in a follow-up user study, as many participants stated that they would never use the on-screen menus for VCR commands if buttons or symbols were also available.

5.9 VOLUME CONTROL

The volume control was another function of the touchpad that was generally panned by the study participants. The design tested did not include a volume up or down stroke; instead, a slider provided control of the volume level. In fact, a volume up and down stroke turned out to be the most frequently asked for addition to the touchpad remote, requested by half the participants. This also showed in the questionnaire results, where participants indicated that it was more difficult to change volume with the touchpad remote, even in low light conditions. Participants also strongly indicated a preference for volume up and down buttons in daylight situations (see table 7 below).

A mute command was also included in the television, and this function was much better received than the volume slider. Many participants said how they enjoyed drawing the 'M' command on the touchpad remote. In terms of difficulty, however, participants did not identify in the questionnaire any particular remote as

being more difficult (see table 8).

	DAYLIGHT	DIMMED LIGHT
Difficulty	2.0	2.5
Device preference	4.2	3.3

TABLE 7: Mean post-test questionnaire results for questions 1–4, part E.

	DAYLIGHT	DIMMED LIGHT
Difficulty	3.1	3.2
Device preference	2.7	2.3

TABLE 8: Mean post-test questionnaire results for questions 1–4, part F.

As indicated in the interviews, table 7 also shows the difficulty participants had in changing volume with the touchpad remote, in both daylight and low-light conditions. The strong preference for the buttoned remote in daylight conditions, indicated by an mean answer of 4.2, is also evident.

Table 8 shows the overall lack difference between the two remote designs for muting the television. As shown by the means of 3.1 and 3.2, for the two light conditions respectively, participants did not find any particular design of remote more difficult than the other. Participants, did, however, indicate a noticable preference for the touchpad remote in dimmed light conditions.

5.9.1 Usability Issues

The vast majority the participants had difficulty getting used to the pressure-sensitive nature of the volume control. Many participants used the very tip of their finger to enter commands on the touchpad, which translated to minimal amounts

of pressure on the touchpad. Since the speed of the volume slider was directly related to the pressure of the finger on the touchpad, this caused the slider to move very slowly for many of the participants. Frustration was common, with many participants believing the remote was broken or that they were doing something wrong.

Several participants, during the post-trial interviews, suggested solving this problem by removing the pressure-sensitive nature of the slider control and simply mapping the width of the touchpad to the width of the volume slider. Another option would be to increase the sensitivity of the slider to pressure, especially for the lower pressure values.

CONCLUSIONS AND FUTURE RESEARCH

6

This thesis describes a new type of remote control, one that uses a touchpad for user input instead of the buttons found on most remote controls today. The usability study and results, presented in chapters 4 and 5, allow for conclusions to be drawn regarding the usefulness of this new remote control design. However, as with any research, the usability study opens the door to many new research opportunities. In this chapter, major conclusions based on the usability study results are presented, and ideas for future research projects are described.

6.1 CONCLUSIONS

Results allow conclusions to be drawn on the effectiveness of the new design. Some of these conclusions show the promise of the touchpad remote; others indicate areas of disadvantage in the new design.

6.1.1 The Touchpad Remote Is a Viable Alternative to Buttoned Remotes

While a preference for the touchpad remote was expected, the strength of this preference was not anticipated. Seventy percent of the participants in the study said they would use a production version for their home television. This result, when based on a prototype system after only two trials, is especially encouraging. With the viability of a touchpad remote proven, it can be concluded that the door is now open to developing a variety of exciting functions in all types of electronic devices, not just televisions.

6.1.2 The Touchpad Remote Is Easier To Use In Low Light Conditions

During post-trial interviews, 85% of the participants commented at least once on how the touchpad remote was easier to use in the dark. This is useful in situations where the television is being watched with the lights off (when watching rented movies, for example). Even in daylight situations this is an advantage, as the television viewer does not have to change eye-focus from the television to the remote control and back. Thus it can be concluded that a major advantage of the touchpad remote is its eyes-free operation.

6.1.3 The Touchpad Remote is not Suitable For All Viewing Activities

One goal of the usability study was to determine whether a touchpad is a suitable input device for all the common television viewing activities. As the results showed, this was not the case. While participants clearly preferred the touchpad for activities like direct channel entry, it was not as well accepted for arrowing tasks (such as channel up, channel down, volume up and volume down). While this lack of acceptance is likely due in part to the interactions used in my implementation of the touchpad remote, the consensus from the participants during interviews was that they preferred a button-style interaction for these types of tasks.

In general terms, activities that required the manipulation of complex on-screen controls, such as sliders and menus, were better suited to the touchpad remote. Tasks that involved repeated entering of the same command, such as channel up and volume up, were better suited to the button remote.

6.1.4 The On-Screen Menus Are A Viable Way of Hiding Seldom-Used Functions

The design goals of the touchpad remote were to create a device that could control a variety of electronic devices, without the need for a multitude of buttons. The usability study shows that television viewers do not mind using on-screen menus for little-used functionality, with 55% of participants listing it as one of their preferred tasks on the touchpad remote. However, for more frequent tasks, such as executing VCR commands, participants indicated that they preferred more direct interaction styles, such as the symbols. So, in this case, it is clear that it was not the touchpad itself that was the problem, but rather the implementation of the specific commands.

6.2 FUTURE RESEARCH

As with any study, the conclusions often lead to new areas of inquiry, as suggested below.

6.2.1 Hybrid Remotes

Many of the study participants mentioned that a remote consisting of both a touchpad and buttons might be more viable than one solely equipped with a touchpad. A research project where a hybrid remote is constructed and then compared to a touchpad- and button-only device would be worth pursuing.

Another hybrid remote that would be worth testing is one that includes a touchpad as well as a jog/shuttle wheel for VCR commands. The jog/shuttle wheel would perform better than the touchpad remote for these commands, and would

function well in low-light conditions. A drawback to this type of design, however, is its inclusion of an input method which does not extend very well to multiple tasks. While the jog/shuttle wheel is well suited to the VCR tasks, and may work well for channel selection tasks, it does not extend well to techniques such as menu item selection and text entry.

One other hybrid remote possibility is one that combines a touchpad with a game controller device, providing access to Internet, television, and gaming activities at the same time. This style of remote could outperform the touchpad remote for the specific interactions that electronic games require. However, as with the jog/shuttle hybrid, this remote would have a large amount of hardware dedicated to very specific tasks.

6.2.2 Exploring the Touchpad Remote Shape

The form of the touchpad used in this research was designed originally for use in regular computing applications where the touchpad is usually placed on a solid surface. This is different from traditional buttoned remote controls, which are usually held in-hand. As the usability study showed, the shape of the touchpad remote prototype was uncomfortable to hold for many of the viewing tasks, and difficult to use with a single hand. In addition, the users expressed their disappointment with the aesthetics of both the touchpad and the buttoned remote controls. Research should be conducted in association with an industrial engineer to design a prototype that is pleasing to look at and hold, and which lends itself well to the tasks performed by television viewers.

One possible shape, suggested during a group research meeting, would be that of a watch. Technology is available that would allow a watch to be constructed that includes a touch-sensitive surface and an infrared transmitter. While watches that function as remote controls have existed for many years, they have depended on buttons for their input methods, limiting their extensibility. A watch that incorporates both these technologies could be used to control a wide range of household appliances through single-stroke commands entered via the watch face (see figure 19). In addition, such a watch would be extensible, and could also handle tasks such as text entry and menu navigation.

Another possible shape, suggested by a study participant, would be an egg-shaped device with a small touchpad at the tip (see figure 20). Similar in shape to the Gyropoint input device from Gyration, Inc., this style of device could easily be held with one hand, and might incorporate a touchpad at the base of the egg and a button or two on the side. While this shape does exist, as with the watch design it has never been used in conjunction with a touch-sensitive input mechanism to give a wide range of interaction methods.

FIGURE 19: A watch with a touch-sensitive surface and infrared transmit capabilities.

FIGURE 20: An egg-shaped touchpad remote control

During the spring equinox, it is said that an egg will stand on its small end. Although some people have reported success, it is not known whether such results were due to the equinox or to the peculiarities of that particular egg. (American Egg Board, 1998)

6.2.3 The User Interface Elements

As the usability study showed, the basic user interface elements employed in the prototype system showed promise for a production system. However, these elements were only initial implementations, and future prototype systems should work at making the elements more robust and responsive to user input. For example, the symbol recognition algorithm could be expanded to recognize a variety of different renditions of the digit strokes. The on-screen menus could also be improved by fixing the 'disappearing blue square'.

Before building the next complete prototype, it would be worth conducting an informal study to see if the simple fixed-rate scrolling method results in fewer problems for the viewer than a velocity-based scrolling method. In a future prototype of the touchpad remote, decisions will have to be made regarding the velocity-based nature of some of the user interface elements. It is still unclear as to whether problems with the underlying touchpad technology were the cause of the poor acceptance of the velocity interactions in the touchpad remote tested in this study.

6.2.4 In-Home Trials

The research did not allow participants the opportunity to try the touchpad remote as part of their regular daily viewing activities. Therefore, it would be worthwhile to construct a new prototype touchpad remote that could be attached as an add-on to any television system, much like a cable converter or VCR. Several of these prototypes could be constructed and distributed to study participants, al-

lowing them to use the touchpad remote at home in a normal viewing environment. This would provide useful information as to how well a touchpad remote works in a multi-user environment.

FIGURE 21: Sketch of a home entertainment system equipped with a touchpad remote receiver box (located below the television on the stand).

6.2.5 Applications for People With Disabilities

The research presented in this thesis focused on moving the visual interface for the television from the buttoned remote to the screen. This was largely accomplished by adding more computer-like functionality to the television, through allowing a variety of graphical interface elements to be used for on-screen display. The touchpad in this study simply acted as an input device to these on-screen elements.

With the functionality now on-screen, there is the potential to use a variety of other input devices besides a touchpad. This is especially advantageous for people with disabilities, as the on-screen elements can now be manipulated using input devices tailored to the disabled individual. For example, someone without motor control in their arms could use a blow-tube or mouth stick to select items from the menus. A joint research project with people from the physiotherapy field,

that explores some of these other mechanisms for interacting with the on-screen menus, would be worth considering.

6.2.6 Text Entry Tasks

For a remote to be usable with the wide range of information appliances that are appearing on today's market, it is essential that it be able to support basic text entry tasks. For example, a remote that does not allow a user to enter text on a World Wide Web search page is not useful at all. While the prototype remote described in this thesis does not include text entry capabilities, it would be fairly simple to extend its functionality to permit some method of entering text. A worthwhile research project would be to construct a prototype system that includes this functionality, and adds text entry capabilities to the touchpad remote. This functionality could be added in a number of different ways, such as additional single-stroke characters, character recognition software, or an on-screen soft keyboard. A comparison of this remote and another input mechanism (perhaps a wireless keyboard) could be conducted, to see if users prefer the shape and interactions of a touchpad remote.

6.2.7 Testing With Emerging Technologies

While not specifically measured during the usability study, it is clear that the touchpad-based remote control is much more extensible than traditional buttoned remote. In addition, this work did not attempt to measure the usability of the touchpad remote in the context of some of the latest emerging information

appliances, such as set-top boxes, Internet-ready game consoles, and home automation systems. Even though some of these technologies, such as game consoles and home automation systems, have been around for years, they are only beginning to be used in conjunction with more traditional consumer devices such as televisions and stereos.

A future study could investigate the applicability of a touchpad-based remote control (or hybrid remote) as a central input device for all these consumer devices. It is my belief that a touchpad remote would significantly simplify the task of designing a remote that could be used for the diverse input requirements for this range of devices.

As well, a remote that made use of the emergence of new, compact, touch sensitive mobile devices (such as Microsoft's Palm-Size PC and 3COM's PalmPilot) would be worth testing. This style of remote could make use of menus on the device itself, through touch-sensitive LCD displays, as opposed to the on-television menus used in the touchpad-based remote control device. Advantages to this on-remote display include the remote's ability to be used for devices situated away from the television set. As well, the remote could employ virtual input devices as described by Brown et al. (1990) to interact with the controls for the various electronic devices. A remote control using this type of touch-sensitive LCD, on-remote display, and minimal buttons has recently been introduced by Microsoft and Madrigal. A comparison of this new remote control to the touchpad remote described in this thesis would also be worth undertaking.

HARDWARE IMPLEMENTATION

A.1 INTRODUCTION

The prototype system used for the usability study described in chapter 4 was assembled using a variety of off-the-shelf hardware components. This appendix outlines the various hardware components used, and provides some basic details on the programming utilities used to access the hardware functionality.

A

A.2 HARDWARE SPECIFICATIONS

The prototype system was based on a Pentium™ 120MHz computer, with 32MB of memory. A *tv-tuner* card from ATI Technologies (Thornhill, Ontario, Canada) was added to the base computer system to allow television signals to be displayed within specially designed Windows® applications. To provide access to videocassette functions, such as playing tapes and recording television programs, a Sony SLV-R5UC VCR was connected to the television tuner card.

While programming libraries were provided with the tv-tuner card to allow Windows programs to control the tuner settings, the VCR had no such libraries. To control the VCR, an IR Jukebox 100S infrared transmitter/receiver card from Dan-craft Technologies (Inglewood, CA) was attached to the serial port of the computer. This card was used to learn the infrared commands for the VCR, and to then send them back to the VCR as required. The touchpad remote was implemented using a T1002D touchpad from Synaptics (San Jose, CA).

A.3 SOFTWARE SPECIFICATIONS

A Windows95® application was written to read data from the touchpad, interpret the data, and then control the TV-tuner card and VCR. The application was written in Microsoft® *VisualC++*® 5.0, using the Microsoft Foundation Classes.

The stroke recognition sub-system of the application was based on code written by I. Scott MacKenzie, with the algorithm loosely based on one published in US patent number 559665.

QUESTIONNAIRES AND INTERVIEW QUESTIONS

B.I PRE-TRIAL SURVEY

The following questions were used to gather basic information from study participants. This information included demographic information, ownership of electronic devices, and television viewing habits.

B

B.1.1 Demographic Data

What is your age? (Possible ranges: less than 18, 18–24, 25–34, 35–49, 50–64, and 65+)

What is your gender?

What is your occupation?

B.1.2 Ownership of Electronic Devices

How many televisions do you own?

How many VCRs do you own?

How many stereos do you own?

Do you own a satellite dish? If so, what provider?

How many computers do you own?

Do you have Internet access from home? If so, who is your service provider?

How many remote controls do you own that controls your television, your VCR or both?

Do you subscribe to cable? If so, which provider?

Which cable packages do you subscribe to?

Do you have remotes for any other devices, such as a garage door opener or stereo?

If so, how many and for what devices?

B.1.3 Television Viewing Habits

When watching television, would you say you use your remote frequently,
sometimes, or rarely?

When you sit down to watch television, how often do you know exactly what you
want to watch? (Possible answers: almost every time, about $\frac{3}{4}$ of the time,
about half the time, about $\frac{1}{4}$ of the time, less than that, don't know)

When you sit down to watch television, how often do you flip around to find
something to watch? (Possible answers: almost every time, about $\frac{3}{4}$ of the
time, about half the time, about $\frac{1}{4}$ of the time, less than that, don't know)

When looking for something to watch, do you flip through all the available
channels, or just to specific channels that interest you?

Do you ever watch more than one program at the same time? If so, how many can
you follow at the same time?

When watching a specific program, do you ever change channels during the
program (at commercial breaks or otherwise)? If so, why?

On a typical weekday, how many hours do you spend watching television?

On a typical weekend day, how many hours do you spend watching television?

On a typical weekday, how many hours is the television on (whether someone is
watching it or not)?

On a typical weekend day, how many hours is the television on (whether someone is watching it or not)?

On a typical weekday, during what time periods do you typically watch television?

(Possible answers: 6–9 AM, 9–noon AM, noon–3 PM, 3–8 PM, 9–11 PM)

On a typical weekend day, during what time periods do you typically watch

television? (Possible answers: 6–9 AM, 9–noon AM, noon–3 PM, 3–8 PM, 9–11 PM)

When watching television, do you typically watch many channels (more than 3) during a single sitting or just a few (3 or less)?

How many channels do you regularly watch? What are they?

How many movies do you rent per month?

How many programs do you record per week?

What type of television programs do you watch? (Possible answers include: news, sports, game shows, sitcoms, movies, documentaries, dramas, variety shows, nature/science programs, home improvement shows)

B.2 POST-TRIAL QUESTIONNAIRE

After the study participants had completed all four trials, a post-test questionnaire was used to gather raw data on their thoughts on the new remote control design.

The questionnaire consisted of the questions that follow.

Question 1: When doing each of the activities below, please indicate which of the two remotes you found *more difficult* to use when the lights were *on*.

	REMOTE A WAS MORE DIFFICULT		NEITHER ONE NOR THE OTHER		REMOTE B WAS MORE DIFFICULT
a) Change channels by entering the channel	1	2	3	4	5
b) Change channels by moving up or down a	1	2	3	4	5
c) Return to a previously watched	1	2	3	4	5
d) Select a channel with the channel	1	2	3	4	5
e) Change the volume	1	2	3	4	5
f) Mute the television	1	2	3	4	5
g) Select an item from the menu	1	2	3	4	5
h) Play a tape in the VCR using the menus	1	2	3	4	5
i) Play a tape in the VCR using symbols/buttons	1	2	3	4	5

Question 2: When doing each of the activities below, please indicate which of the two remotes you found *more difficult* to use when the lights were *off*.

	REMOTE A WAS MORE DIFFICULT		NEITHER ONE NOR THE OTHER		REMOTE B WAS MORE DIFFICULT
a) Change channels by entering the channel	1	2	3	4	5
b) Change channels by moving up or down a	1	2	3	4	5
c) Return to a previously watched	1	2	3	4	5
d) Select a channel with the channel	1	2	3	4	5
e) Change the volume	1	2	3	4	5
f) Mute the television	1	2	3	4	5
g) Select an item from the menu	1	2	3	4	5
h) Play a tape in the VCR using the menus	1	2	3	4	5
i) Play a tape in the VCR using symbols/buttons	1	2	3	4	5

Question 3: For each of the activities below, please indicate which of the two remotes you would be *more likely to use* in situations where the lights are *on*.

	MORE LIKELY TO USE REMOTE A		NEITHER ONE NOR THE OTHER		MORE LIKELY TO USE REMOTE B
a) Change channels by entering the channel	1	2	3	4	5
b) Change channels by moving up or down a	1	2	3	4	5
c) Return to a previously watched	1	2	3	4	5
d) Select a channel with the channel	1	2	3	4	5
e) Change the volume	1	2	3	4	5
f) Mute the television	1	2	3	4	5
g) Select an item from the menu	1	2	3	4	5
h) Play a tape in the VCR using the menus	1	2	3	4	5
i) Play a tape in the VCR using symbols/buttons	1	2	3	4	5

Question 4: For each of the activities below, please indicate which of the two remotes you would be *more likely to use* in situations where the lights are *off*.

	MORE LIKELY TO USE REMOTE A		NEITHER ONE NOR THE OTHER		MORE LIKELY TO USE REMOTE B
a) Change channels by entering the channel	1	2	3	4	5
b) Change channels by moving up or down a	1	2	3	4	5
c) Return to a previously watched	1	2	3	4	5
d) Select a channel with the channel	1	2	3	4	5
e) Change the volume	1	2	3	4	5
f) Mute the television	1	2	3	4	5
g) Select an item from the menu	1	2	3	4	5
h) Play a tape in the VCR using the menus	1	2	3	4	5
i) Play a tape in the VCR using symbols/buttons	1	2	3	4	5

Question 5: For each of the activities below, please indicate *how comfortable your hands and fingers felt* while using *Remote A*.

	Very uncomfort- able		Neither comfort- able nor uncomfort- able		Very comfort- able
a) Change channels by entering the channel	1	2	3	4	5
b) Change channels by moving up or down a	1	2	3	4	5
c) Return to a previously watched	1	2	3	4	5
d) Select a channel with the channel	1	2	3	4	5
e) Change the volume	1	2	3	4	5
f) Mute the television	1	2	3	4	5
g) Select an item from the menu	1	2	3	4	5
h) Play a tape in the VCR using the menus	1	2	3	4	5
i) Play a tape in the VCR using symbols/buttons	1	2	3	4	5

Question 6: For each of the activities below, please indicate *how comfortable your hands and fingers felt* while using *Remote B*.

	Very uncomfort- able		Neither comfort- able nor uncomfort- able		Very comfort- able
a) Change channels by entering the channel	1	2	3	4	5
b) Change channels by moving up or down a	1	2	3	4	5
c) Return to a previously watched	1	2	3	4	5
d) Select a channel with the channel	1	2	3	4	5
e) Change the volume	1	2	3	4	5
f) Mute the television	1	2	3	4	5
g) Select an item from the menu	1	2	3	4	5
h) Play a tape in the VCR using the menus	1	2	3	4	5
i) Play a tape in the VCR using symbols/buttons	1	2	3	4	5

B.3 INTERVIEW QUESTIONS

After the study participants had filled in the above post-trial questionnaire, the following interview questions were used to start a discussion of various usability aspects of the touchpad remote control.

Is there anything you would change about how *remote A* works?

Is there anything you would change about how *remote B* works?

Name 2 activities where you preferred using *remote A* to *remote B*. Why?

Name 2 activities where you preferred using *remote B* to *remote A*. Why?

When using *remote A*, did you have difficulty recalling which symbols were associated with each command?

If you could choose between using *remote A* or *remote B* to control your home television and VCR, assuming they were production versions, which would you choose? Why?

Overall, which remote did you find easier to use? Why?

Overall, which remote did you find more comfortable? Why?

Overall, which remote did you prefer? Why?

QUESTIONNAIRE RESULTS

Question 1: When doing each of the activities below, please indicate which of the two remotes you found *more difficult to use* when the lights were *on*.

Activity	A	B	C	D	E	F	G	H	I
Males	3.4	3.0	3.6	3.3	2.2	2.9	3.2	2.9	3.0
Females	3.2	3.0	3.6	3.4	1.7	3.2	3.6	7.1	3.3
Both	3.3	3.0	3.6	3.4	2.0	3.1	3.4	3.5	3.2

TABLE 9: Mean results for post-trial question 1.

Question 2: When doing each of the activities below, please indicate which of the two remotes you found *more difficult to use* when the lights were *off*.

Activity	A	B	C	D	E	F	G	H	I
Males	4.1	3.4	3.6	3.7	2.3	2.9	3.4	3.1	3.5
Females	4.7	3.2	4.2	3.9	2.6	3.4	3.8	3.9	4.5
Both	4.4	3.3	3.9	3.8	2.5	3.2	3.6	3.5	4.0

TABLE 10: Mean results for post-trial question 2.

Question 3: For each of the activities below, please indicate which of the two remotes you would be *more likely to use* in situations when the lights are *on*.

Activity	A	B	C	D	E	F	G	H	I
Males	2.3	3.5	2.6	2.2	3.1	3.3	2.6	2.7	3.1
Females	2.4	2.7	2.2	2.2	4.1	2.7	2.5	2.4	2.7
Both	2.5	3.1	2.3	2.2	4.2	2.7	2.7	2.8	2.6

TABLE 11: Mean results for post-trial question 3.

Question 4: For each of the activities below, please indicate which of the two remotes you would be *more likely to use* in situations when the lights are *on*.

Activity	A	B	C	D	E	F	G	H	I
Males	1.9	2.5	2.0	2.1	3.5	3.0	2.4	2.4	2.7
Females	1.4	2.3	1.8	1.9	3.3	2.2	2.2	1.9	1.9
Both	1.5	2.4	1.7	2.0	3.3	2.3	2.2	2.1	2.0

TABLE 12: Mean results for post-trial question 4.

C

Activities:
A – change channels by entering the channel number
B – change channels by moving up or down a channel at a time
C – return to a previously watched channel
D – select a channel with the channel menu
E – change the volume
F – mute the television
G – select an item from the menu
H – play a tape in the VCR using the menus
I – play a tape in the VCR using symbols or buttons

Question 5: For each of the activities below, please indicate how comfortable *your hand and fingers felt* while using *remote A*.

Activity	A	B	C	D	E	F	G	H	I
Males	4.3	4.0	4.3	2.7	2.6	4.1	3.3	3.1	3.8
Females	3.9	4.2	4.6	3.7	3.2	4.6	3.8	3.6	3.9
Both	4.1	4.1	4.5	3.2	2.9	4.4	3.6	3.4	3.9

TABLE 13: Mean results for post-trial question 5.

Question 6: For each of the activities below, please indicate how comfortable *your hand and fingers felt* while using *remote B*.

Activity	A	B	C	D	E	F	G	H	I
Males	4.3	4.0	4.3	2.7	2.6	4.1	3.3	3.1	3.8
Females	3.9	4.2	4.6	3.7	3.2	4.6	3.8	3.6	3.9
Both	4.1	4.1	4.5	3.2	2.9	4.4	3.6	3.4	3.9

TABLE 14: Mean results for post-trial question 6.

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COLOPHON

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For an excellent introduction to typography, read The Elements of Typographic Style by Robert Bringhurst (Vancouver: Hartley & Marks, 1997)