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Effect of computer input device on speed and accuracy of older adults

Linda M. Phillips
San Jose State University

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EFFECT OF COMPUTER INPUT DEVICE ON SPEED AND
ACCURACY OF OLDER ADULTS

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Linda M. Phillips

December 2003

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Dr. Emily H. Wughalter

Dr. Anthony D. Andre

John H. Moses, M.S.
NASA Ames Research Center

APPROVED FOR THE UNIVERSITY

ABSTRACT

EFFECT OF COMPUTER INPUT DEVICE ON SPEED AND

ACCURACY OF OLDER ADULTS

by Linda M. Phillips

The purpose of this research was to determine whether significant differences exist in speed and accuracy (verified by number of errors) between two input device types, mouse and finger (on a touch screen), in a sample of adults between the ages of 65 and 80 years. User preferences for mouse and finger were also assessed in a 16-participant, one-day, 2 (Task Type: target selection and dragging) x 2 (Input Device: mouse and finger) fully within-subjects, repeated measures design study. The analyses revealed participants performed tasks faster and made fewer errors using a mouse input device than finger on touch screen. The participants reported the mouse required less force, less physical and mental effort to operate, and was more accurate for pointing than finger on touchscreen. Finally, participants reported a preference for the mouse overall for general comfort and ease of use.

DEDICATION

I would like to dedicate this completed project to my mother, Beverly A. Harrell, whose unconditional love, tireless support, and profound belief in my ability to succeed continue to inspire me daily toward achieving goals I never dreamt possible.

Thanks mom... I love you!

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And finally, a sincere thank you to my brilliant chairperson Dr. Emily Wughalter. Emily, I want to thank you for believing in me and taking me under your wing as you did. You revived my spirit and restored my faith in the profession of teaching. Your infectious optimism and inspired guidance has shown me that being a teacher is a gift to be shared... not an axe to grind.

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CHAPTER 1

Introduction

This introduction provides readers with information that describes the rapid growth of computer ownership and use over the last 10 years for adults between the ages of 65 and 80 years. Research is presented that examines problems inherent to older adults performing target selection, dragging, and scrolling tasks using a mouse input device. (Sikorski & Oppermann, 1996; Bow, Williamson & Wale, 1996; Worden, Walker, Bharat, & Hudson, 1997) Lastly, the introduction illustrates the importance for a continued interest in human computer research to address design challenges in support of an increasing older adult population. The purpose of this research was to determine whether significant differences exist in speed and accuracy (verified by average number of errors) between two input device types: mouse and finger (on a touch screen) in a sample of adults between the ages of 65 and 80 years. User preference for mouse and finger were also assessed by two pen and paper measures.

Early Internet demographers profiled computer users and consumers by gender, income, education, and race depicting the archetypical computer user as belonging to the “younger” generation. (Times Mirror, 1995; Yankelovich Partners, 1995) This limiting demographic appears to be changing however, to include a new group of users: adults over the age of 65 years. Within the last ten years, computer use and the Internet have become synonymous and indistinguishable from one another due to the technologically rich world we live in. As a result, it is nearly impossible to perform a simple examination of existing literature on conventional computer use and older adults without learning that a staggering 13 million plus users, over the age of 65 years, were using home computing

systems to access the Internet in 1999, nearly doubling the number from 1997. (Shapiro, 2000) The number of older adults using computers is clearly on the rise, in fact a collaborative study by Charles Schwab & Company and SeniorNet found that in 1998 four in 10, (40%) of older adults had personal computers at home compared to only 29 percent in 1995, and nearly eight in 10, (80%) reported using their home computers several times a week or more. (SeniorNet, 1998) Commerce Net (2002) has reported a tremendous increase in computer use and ownership among adults over the age of 65 years between 2000 and 2002, distinguishing this age group as the fastest growing sector of computer users and computer buyers. One characteristic is clear; freed from the constraints of raising a family and with more time of their own, adults over the age of 65 years are seeking activities that complement their desire to live life to the fullest and it appears that using computers, for a number of uses, is one of various avenues they are turning to in order to do so. (PC Magazine, 2002)

Home computing systems traditionally consist of a central processing unit, a keyboard, a monitor, and a hand-manipulated mouse. While users periodically require the support of a keyboard, the mouse is the primary input device used to execute precise movements essential to target selection or pointing tasks, dragging targets from point A to point B, and scrolling windows particularly on the Internet. The mouse, originally generated for a well-defined target market of younger users, has been shown to be problematic for older adults to use. (Sikorski & Oppermann, 1996) For example, a study testing signal, noise, and performance for older adults showed that the ability to make small precise movements decreased with age. (Welford, 1981) Older adults also move the

cursor slower, and show more difficulty landing on small targets than younger adults.
(Worden et al., 1997)

Depicted in Figure 1 are the results of a study that examined 120 adults over the age of 50 years in public libraries accessing the Internet who indicated that the most problematic computing tasks for them were scrolling windows and using the mouse.
(Bow et al., 1996)

Figure 1. Data from Bow, Williamson and Wale (1996) Internet study of mouse perception of degree of problem by input type.

Problem Statement

Older adult computer users represent an important and growing sector of the population, which will only increase in the coming years. Yet their requirements are not being considered in the design of computing hardware, and as a result, they often find

computers difficult to use. The surge in computer ownership and use in adults over the age of 65 years and the significant amount of research showing that older adults have problems using the mouse encourages research to evaluate alternative solutions for input devices for older adults. Human Computer Interaction (HCI) professionals routinely conduct research aimed at answering these types of questions in an attempt to facilitate design and evaluate the performance of information and communications systems, including input devices such as the mouse. Shneiderman (1993) pointed out that environmental engineers go to great lengths to pay respect to the diverse array of users across many populations when designing exterior surroundings, resulting in larger street signs and brighter traffic lights from which all ages can benefit. This same wide-ranging logic should apply to older adults, input devices, web design, and software interfaces as well, yet it does not seem to be the case. The purpose of this research was to determine whether significant differences exist in speed and accuracy (verified by average number of errors) between two input device types: mouse and finger (on a touch screen) in a sample of adults between the ages of 65 and 80 years.

Hypotheses

The following null hypotheses were tested for this study:

1. Input device would not affect speed and accuracy;
2. Task type would not affect speed and accuracy;
3. Input device (finger and mouse) and task type (target selection and dragging) would not interact to affect speed and accuracy;
4. Input device would not influence user preference.

Delimitations

This study was delimited to:

1. An adult sample between the ages of 65 and 80 years, as age is a significant feature of the study;
2. Adults who use computers at least three times a week, and navigate the Internet at least twice a month.

Limitations

The limitations of this study were:

1. Volunteer participants from the Alameda YMCA in San Jose, CA.;
2. Volunteer participants from The Villages Tennis and Racquet Club, an active senior retirement community in San Jose, CA.

Definition of Terms

A touch screen monitor is a direct manipulation input device. Touch screens detect and respond to touch from a finger, a stylus, or other pointing device. Software interprets the signal and performs the required operation. For the purpose of this study, an ELO Touch systems™ touch screen monitor was used (see Appendix A).

While touch screens are considered input devices by many researchers (Sears, Plaisant, & Shneiderman, 1992; Sears & Shneiderman, 1991; Deron, 2000; Valk, 1990), a finger touching the screen was really the true “input” device in this study and a touch screen is simply the conduit that displays the “output” from the input command. (Hinkley & Sinclair, 1999) For the purpose of this research, the participant’s finger was one of the two input device conditions. The second input device condition was a Hewlett Packard two-button mouse (see Appendix A).

The IBM Isotest software used for this study (see Appendix A) refers to simulated target selection tasks as “one-directional tapping”. For the purpose of this research, a more traditional term “target selection” was used.

“User performance is almost always measured by having a group of test users perform a predefined set of tasks while collecting speed and accuracy data”. (Nielsen, 1993, p. 192) For the purpose of this study the dependent measures were speed and accuracy. Speed was calculated by averaging total time to complete tasks as a function of target position, path length, and width. Accuracy was calculated by averaging the total number of errors as a function of target position, path length, and width. Two pen and paper instruments were administered, 1) a Usability Questionnaire for Mouse and Finger Input Devices (see Appendix B) and, 2) a Forced-Choice Preference Questionnaire (see Appendix C). Both were used to determine whether user preferences existed for one input device over the other.

Importance of Study

In view of the fact that older adults are the fastest growing group of computer users, the fastest growing group of computer buyers, and the fastest growing group of Internet navigators on the web (CommerceNet, 2002), it should come as no surprise that computer interface design and research is looking more closely at this expanding demographic, and rightly so. (Bohan, Chaparro, Fernandez, Kattel, & Choi, 1998; Chaparro, Bohan, Fernandez, Kattel, & Choi, 1999; Liao, Groff, Chaparro, A., Chaparro, B., & Stumpfhauser (2000); Bernard, Liao, Mills, 2001; Czaja & Sharit, 1998; Irizarry & Downing, 1997; Irizarry & Downing, 2001)

CHAPTER 2

Review of Literature

The review of relevant literature will make clear the advances of computer technology and its evolution over the last 50 years along with statistics in terms of the overall growing numbers of older adults in the population. Also discussed is the convergence of the computer revolution and the unprecedented number of older adults using computers, which is only increasing.

History of User Interface Technology

Perhaps a key turning point for older adults overcoming their fear of technology was the improvement of computer interfaces. Netscape and Microsoft (Internet Explorer) both offer simple point and click overlays for the Internet, making it easy to access the Internet and most service providers offer simple windows, bars, and pull down menus that are easy to understand, mimicking Microsoft's Windows' format. (Philbeck, 2001) While these design improvements have had profound effects on users of all ages, in terms of reduced learning times, faster performance on tasks, lower rate of errors, higher subjective satisfaction, and better human retention over time (Shneiderman, 1993), the traditional computing system paradigm (i.e., mouse, cursor and keyboard) has not changed much since the early 1980's. (Van Dam, 1997) According to Van Dam (1997), the history of user interfaces can be loosely categorized into four general phases, as follows:

Phase 1: In the early 1950's and 1960's computers had virtually no user interface. This was because there was no interactive capability, functioning rather by means of batch mode with punch card input and line printer output.

Phase 2: The early 1960's through the early 1980's brought computers up to an era of timesharing on mainframes and minicomputers using mechanical or "glass" teletypes (alphanumeric displays) enabling the first interface which users could interact with the computer by typing in commands with parameters.

Phase 3: In the early 1970's, Xerox Parc Research released the first "point and click" Window, Icon, Menu and Pointing device interfaces (WIMP) with graphical user interfaces.

Phase 4: The next generation of user interfaces in computer technology, which are beginning to emerge, moving beyond the traditional WIMP paradigm involve elements like virtual realities, head mounted displays, sound and speech recognition, limited artificial intelligence, and highly portable computers with cellular or other wireless communication capabilities. (Van dam, 1997) Current graphical interface designs based on WIMP interfaces lend themselves to expediency by allowing fairly non-trivial operations to be performed with a few mouse clicks (Worden et al., 1997), however, while pointing, clicking and scrolling are considered straightforward, effortless operations for most operators, older users exhibit unsteady motor control and hand-eye coordination problems that result in difficulty scrolling and using the mouse. (Bow et al., 1996)

Older Adults as Internet Enthusiasts

Early computer research typically used participants belonging to the younger generation. (Times Mirror, 1995; Yankelovich Partners, 1995) Perhaps this was due to a concern with psychological perceptions alleging negative attitudes toward older adults thereby disregarding them as potential computer users. (Kornbluh, 1984) Or perhaps

early researchers presumed situational barriers or accessibility issues discouraged older adults from using computers (Bow et al., 1996) and that younger adults had more opportunities to interact with computer-based technology than older adults did. (Krauss & Hoyer, 1984) Some early researchers even suggested that older adults may have more negative attitudes towards computers and other technologies than younger adults and are therefore less likely to use them. (Brickfield, 1984) However, despite these early notions of older adults and computer use, nothing could be further from the truth as according to eMarketer (2002) older adults are logging on to the Internet in record numbers. In 2000, almost 14 million older adults (17% of all Americans aged 55 years and above) were active Internet users and the number grew to 22 million by the end of 2002, accounting for 36% of all older adults. The number of older adults on-line daily is at 76%, compared to 68% of all on-line adults, adjusting what early Internet demographers' recognized as the "archetypical" user. (Jupiter, 2003)

Significant Amendments to Population Data

The influx of older adults using computers and the Internet can be attributed to the significant increase in the overall number of older adults in the US population in general. (SeniorNet, 2000) Since 1900, the overall percentage of Americans 65 years and older has more than tripled, going from 4.1 percent in 1900 to 12.7 percent in 1999. (US Bureau of Census, 2000) Each year the US population gets older, primarily because of the aging baby boomers, but also because of low fertility (birth) rates and an annual increase in life expectancy. (SeniorNet, 1999) A child born in 1998 can expect to live 76.7 years, about 29 years longer than a child born in 1900. The major part of this increase is due to reduced death rates for children and young adults. (US Bureau of

Census, 2000) Life expectancy at age 65 years increased by only 2.4 years between 1900 and 1960, but has increased by 3.5 years since 1960 and almost 2.0 million persons celebrated their 65th birthday in 1999 averaging out to 5,422 65th birthday celebrations per day. (US Bureau of Census, 2000) Figure 2 depicts a projected increase in frequency of adults over the age of 65 years from 1900 to 2030.

Figure 2. Population demographic of adults (65 years+) from 1900 to 2030, in millions. (US Bureau of Census, 2002)

In addition to an overall rise in the number of older adults in the population, the elderly population itself is increasing in age. Demographic trends associated with the aging of the Baby Boomer population, plus gains in longevity, will increase the 50 years and above market to over 106 million by 2015 when they will account for just over 45% of the adult population. (US Bureau of Census, 2000) According to the latest 2002 US Census Bureau, adults 50 years and above represent 79 million people, 28% of the total US population and 37% of the population over 18 years and up. The aging of the US

population will affect every aspect of the US society in one way or another, presenting challenges to policy-makers, families, businesses, and health service providers. (US Bureau of Census, 2000)

Research shows that behavioral and physiological declines inherent to aging influence computing tasks, specifically, mouse pointing and selecting tasks (Worden et al., 1997), computer related sensing ability (Welford, 1981), and in the precise motor skills required to manipulate mice input devices. (Meyer, Cohen, & Nilsen, 1994) In fact compared to young adults, older adults take longer to complete the same movement, and their movements are more variable, less smooth, and less coordinated than younger users (Seidler & Stelmach, 1996), and the loss of fine motor skills makes it difficult for older adults to position cursors on computer screens, particularly when interacting with small objects. (Chaparro et al., 1999)

HCI research is striving to improve upon the human-computer experience for older adults by designing research efforts addressing psychomotor limitations. Mouse manipulation seems to be especially problematic for older adults due to the precise motor movements required to coordinate a two-dimensional mouse on one-dimensional surface. (Meyer et al., 1994) For example, Bohan and Scarlett (2003) proposed dynamically enhancing target size as the mouse cursor approaches the target as a potential solution for older adult users, and Bernard et al. (2001) found that using larger (from 12-point to 14-point) on-line font increased legibility, reading time, and overall preference for older adults between the ages of 62 to 83 years ($M = 70$ years). While Walker, Millians, and Wordon (1996) examined mouse gain functions and cursor positioning for older adults and found computer users over the age of 50 years took approximately twice as long, and

made more than five times as many cursor positioning errors when moving icons on a computer interface as did younger adults. (Walker, Millians, & Wordon, 1996) The purpose, therefore, of this research was to determine whether significant differences exist in speed and accuracy (verified by number of errors) between two input device types: mouse and finger (on a touch screen) in a sample of adults between the ages of 65 and 80 years.

Age Related Computing Issues

Aging is an inevitable fact of life and slowing down, both cognitively and physically, is a natural byproduct of aging. As a result, questions have been raised on the effects age has on the ability to navigate complex paths and elaborate information networks on computers. (Meyer, Sit, Spaulding, Mead, & Walker, 1997) Cognitive processing for older adults, in general, tends to be slower than younger adults, often resulting in greater difficulty for memory related tasks (Danowski & Sacks, 1980), and a reduction in working memory, illustrated by poor performance using systems that require users to remember items from one computer related task to another. (Meyer et al., 1997) For example, Meyer et al. (1997) determined older adults navigating the Internet might have trouble remembering which pages they had previously visited, or trouble remembering how they arrived at a current page. In the same study, Meyer et al. (1997) examined the effects of age and training on efficiency and preferences in an Internet search activity and found that older adults were eventually able to complete most of the tasks, but took more steps to find the required information than the younger adults in the study, and that age related difficulties existed for older adults while operating scroll bars and image maps. These issues may prove problematic when attempting to perform

fundamental, low-level operations such as pointing, clicking and dragging as required to interact with direct manipulation interfaces. (MacKenzie, Sellen, & Buxton, 1991)

Age Related Interventions

Several studies have examined potential solutions to age related computing issues, for example, Worden et al. (1997) suggested providing "area cursors" and "sticky icons". Traditional cursors have a one-pixel "hot spot" point of activation, whereas Worden et al. "area cursor" was 12 by 12 pixel square that had 144 hot spots. The "sticky icons" enabled an automatic 30% reduction of the cursor's gain ratio as the cursor neared a target slowing it down to increase the success of target selection. The researchers in this study stated that cursor positioning among older computer users can be improved with area cursors and sticky icons, as older users position the cursor much more slowly than younger computer users and have greater difficulty making precise movements to small targets. The experiment examined 16 younger adults ($M = 23.4$ years) and 16 older adults ($M = 70.1$ years) across a seven-factor, mixed factorial design with within-subject variables constituting task types including movement distance, target width, and screen environment. The area cursor and sticky icons had no effect on accuracy, but improved speed of performance over the traditional pointer for both young and old users alike. (Worden, et al, 1997)

Another study suggested reducing the amount of screen text on the monitor by using multi-media presentations rather than text-only screens. (Ogozalek, 1994) In Ogozalek's study (1994) 64 older adults ($M = 71$ years) with no prior computer experience were asked to compare computerized information to words printed on paper with positive results in both performance and preference for the computerized

information over the text-only condition. (Ogozalek, 1994) Although helpful, Ogozalek's study did not address interaction issues inherent to older adults using a mouse.

A study by Zhao and Tyugu (1998) examined a "personalized browser". Zhao and Tyugu's objective was to design an "intelligent" browser that could adapt to any user based on their interactions with the browser. Three different user interface designs were developed for the browsers in the study. The first had five buttons: Back, Forward, Home, Bookmarks, and Exit. The second had the first five buttons plus an added E-mail button, and the third had all of the other buttons, plus an added History button. Zhao and Tyugu's results found that older adults preferred the simpler browser with fewer buttons, to the more complex browser. (Zhao & Tyugu, 1998) Chaparro et al. (1999) examined whether differences exist for performance and preference of two pointing devices (mouse and trackball) between older ($M = 70$ years) and younger ($M = 32$ years) adults. Participants in this study performed point-and-click and click-and-drag tasks and the results found no difference in performance between older and younger adults, but older adults preferred using the trackball to perform tasks to the mouse, suggesting that the prolonged use of the mouse might be associated with greater levels of discomfort for older adults computers and further suggested that the trackball may turn out to be a better input device for older adult computer users. (Chaparro et al., 1999)

These prior studies represent a sample of the research performed to improve upon the human computer interaction between older adults and computers. The purpose of the author's research was to determine whether significant differences exist in speed, accuracy (verified by average number of errors), and preference between two input device types, in a sample of adults between 65 and 80 years, in an attempt to improve

upon the traditional, albeit awkward and sometimes challenging, mouse input device. The alternative input device used in this research was a touch screen. The following section examines the technology behind touch screens and the research on the efficacy of touch screens as input devices.

Touch Screen Technology

Complexities have been found to exist for task performance while manipulating a two-dimensional mouse on a one-dimensional surface, (Meyer et al., 1994) and touch screens may have the potential to resolve these complexities. Interacting directly with a touch screen interface involves passing the finger (or other pointing device), over a vertical plane. This mode of interaction eliminates the need to synchronize a mouse and cursor in order to interact with a computer interface. Touch screens offer a natural mode of communication (touching) and are generally faster than other input devices given their one-to-one relationship between the user and the screen. (Albert, 1982) Touch screen interfaces enable users to directly touch and manipulate items of interest on the screen, making it by definition a truly “direct manipulation” interface. (Albert, 1982) Resistive touch interfaces allow all types of touch input devices to activate the screen, including fingers, fingernails, stylus, gloved hands, and credit cards, all the while maintaining tactile feel allowing users to control the way they interact with computer interfaces. (ELO Touch systems, 2000) Touch screens have been used with much success in public information kiosks, ATM machines, point-of-sale restaurant locations, and casino and gaming machines for years because of their ease of use. (ELO Touch systems, 2000) Touch input device interfaces are used in more applications than any other input device technology, such as hand-held computers, personal digital assistants (PDA), industrial

equipment, point of sale equipment, medical equipment, office automation equipment, and consumer electronics. (ELO Touch systems, 2000) Additionally, both the touch interface and its electronics are simple to integrate into imbedded systems thereby providing an efficient solution to the traditional mouse input device. (ELO Touch systems, 2000)

Furthermore, touch interfaces have been shown to be preferred to other input devices for novice users since they require little or no training. (Albert, 1982) Meyer, Cohen, & Nielsen (1994) compared five input devices: mouse, mouse pen, trackball, stylus, and touch screen on a series of goal-directed tasks using a drawing program. While Meyer et al.'s (1994) results indicated a significant effect of device on total time with the ordering of device performance from best to worst being mouse, mouse pen, trackball, stylus, and touch screen, when asked which device the participants preferred, 29% chose the touch screen (vertical orientation), 37% chose the mouse (horizontal orientation), 16% the trackball, 8% the mouse pen, and 5% for both the stylus and mouse pen. Meyer et al. (1994) also pointed out that the horizontal placement of input devices such as a mouse was favored over vertical placement, such as with a touch screen.

Valk (1990) compared task performance using a speech input device and a touch screen for the control of a batch process. A typical batch process involves adding ingredients to a container, mixing, heating and/or cooling, such as when combining ingredients for foods, drugs, and metals. (Valk, 1990) The task in Valk's experiment was to simulate making batches of ice cream. He studied 30 participants between the ages of 17 and 53 years ($M=35$ years); none of whom had previous experience with touch screens, speech input devices, or experience controlling a batch process. For the speech

input device condition, participants established voice patterns representing steps necessary to make a batch of ice cream for each of the following words: Valve 1, Valve 2, Valve 3, Mixer, Heater, Defrost, Valve 4, and Next. An identical process and instrumentation diagram was presented on a CRT display for the touch screen condition. Participants activated ingredient and process icons by touching them for the touch condition and saying the name associated with the ingredient/process aloud in the voice condition. Significant main effects for speed and total errors were found. Participants completed the task faster using the touch screen, and made significantly fewer errors with the touch screen, and participant opinions were significantly better for the touch screen over the speech input methodology. (Valk, 1990)

Advances in computer technology over the last 50 years have brought computers from batch modes and punch cards to easy-to-use, colorful, Windows-based interactive “point and click” graphical user interfaces. The advent of these accessible, user-friendly interfaces make computers easier for all users to operate and as a result have indirectly altered computer demographics to include adult users over the age of 65 years. While researchers appear to be embracing the significance of the growing elderly population using computers and the design challenges they present as indicated by the growing cache of institutes designed specifically to study age and technology suggest (Chaparro et al., 1999; Smith, Czaja & Sharit, 1999; Mead, Sit, Rogers, Rousseau, & Jamieson, 2000; Rogers, Hertzog, & Fisk, 2000; Liao et al., 2000; Bernard et al., 2001; Charness, Czaja, Fisk, & Rogers, 2001; Whittall & Grace, 2002), researchers, computer manufacturers, and retailers have yet to embrace touch screens as mainstream computer input devices. The purpose of this research was to determine whether significant differences exist in

speed and accuracy (verified by average number of errors) between two input device types: mouse and finger (on a touch screen) in a sample of adults between the ages of 65 and 80 years.

CHAPTER 3

Methods

This methods section contains information on participant demographics, instrumentation, experimental procedure, user tasks, experimental design, test parameters, and analysis of data. The purpose of this research was to determine whether significant differences exist in speed, accuracy and preference between two input device types: mouse and finger in a sample of adults between the ages of 65 and 80 years.

Participants

Participants, three males and 13 females, were recruited from the Central YMCA and The Villages Golf and Country Club, both located in San Jose, CA. Participants were recruited by responding to printed flyers (see Appendix D). Depicted in Figure 3 and Figure 4 are results of User Demographic Profile filled out prior to collection of speed, accuracy, and preference data for mouse and finger input devices.

Figures 3. Demographic data for all 16 participants, Part 1.

Demographic Profile Questions, Part 2

Figures 4. Demographic data for all 16 participants, Part 2.

Instrumentation

The following instruments were used in the study:

1. A flyer was designed and posted at the Central YMCA, and an image of the flyer was placed in The Villager, the official and legal communication medium for The Villages Golf and Country Club, San Jose, CA, for the purpose of recruiting participants (see Appendix D);
2. A Screening Questionnaire was administered to participants to insure they met the study's criteria; i.e., between the ages of 65 and 80 years, used a computer at least twice a week, and used the Internet at least twice a month (see Appendix E);
3. Participant Consent Forms were read and signed by each participant (see Appendix F);

4. An 8-item Demographic Questionnaire was used to collect information on age, computer use, computer experience, exercise habits, computer ownership, Internet purchasing habits, and touch screen experience (see Appendix G);
5. Verbal instructions were provided to participants outlining the experimental procedure, and what would be expected of them as part of their participation (see Appendix H);
6. An ELO touch screen was used for the finger input device condition. For consistency, an ELO Touch systems touch screen display was used for both finger and mouse conditions (see Appendix A);
7. A Hewlett Packard two-button mouse (model number M-S34) was used for the mouse condition (see Appendix A);
8. The software used was IBM Isotest-Input Performance Test Software, Version 0.94 Beta© Copyright IBM 2002. Isotest is a Java™ application for testing the performance of users on graphical input tasks with cursor control devices developed by Barton Smith at IBM Almaden Research Center in San Jose, CA. It was designed to be consistent with the recommendations of ISO 9241-9 Annex B, "Testing of efficiency and effectiveness" (See Appendix I);
9. Identical post-test Usability Questionnaires for Mouse and Finger Input Devices administered to participants to solicit feedback on perceived mental and physical fatigue, accuracy for pointing, and fatigue on specific areas such as fingers, wrists, hands, shoulder, and neck. Questions were based on ISO 9241, Part 9 Draft International standards for testing computer-pointing input devices (see Appendix B);

10. Post-test Forced-Choice Preference Questionnaire administered, asking participants to choose which input device (mouse or finger) was preferred to perform specific tasks, which was preferred for overall ease of use, and which was preferred for overall preference (Appendix C);
11. Data Collection sheet used to collect individual behavioral characteristics such as signs of effort, hesitation, and handedness (see Appendix I);
12. Debriefing Statement was read at the end of each participant's session explaining the purpose of the study (see Appendix K).

Procedure

Prior to any testing, San Jose State University's Institutional Review Board, Human Subjects approved of the method and design of the study (see Appendix L). Participants read and signed a Consent Form (see Appendix F). Verbal instructions were read aloud to each participant explaining the procedure of the study (see Appendix H). Participants were advised that the results of the study may be published but no personal information, such as their name, would be disclosed. Participants were instructed to work as fast as possible while trying to minimize errors. Participants performed two sets of tasks (target selection and dragging) using two input devices (finger and mouse). The target selection task simulated selecting icons on a Windows based graphical user interface. This task required participants to tap (for the finger input device), and/or click (for the mouse input device) on predetermined sized (in pixels) rectangular targets as they appeared on the screen until they were all selected. Then a second set of rectangular targets at a different angle and a different size would appear, and so on. This process was repeated until all conditions of target angles and sizes were met and the word "Finished"

appeared on the screen. The dragging tasks simulated dragging icons and scrolling windows. In this test, the participants were required to alternately drag rectangular targets of a predetermined size from a start point to a destination point and back again until all the targets for that condition were dragged. Once they had all been dragged, the next set of rectangular targets would appear (different angle and size) and the process was repeated until the word “Finished” appeared on the screen. Depicted in Figure 5 is an example of the target selection (tapping) task using the mouse input device; Figure 6 depicts the dragging task using the finger input device.

Figure 5. Example of target selection (tapping) task with mouse input device.

Figure 6. Example of dragging task with finger input device.

The workstation environments for both test locations were comparable, but not identical. Participants sat in an adjustable chair in both test locations and were instructed to adjust the chair to a comfortable height. The touch screen monitor was positioned in front of them on a table for one of the locations and on a desk for the other location. Participants were instructed to adjust the distance of the touch monitor closer or further from them, as necessary, to be comfortable. The touch screen was used in both finger and mouse conditions. A keyboard was not required and therefore not present, and the only other hardware used during the study was the mouse. Participants were not given any instruction as to which finger to use while performing tasks for the finger condition, nor were they given any practice runs before they started the tasks.

Task order was randomly assigned to participants. Order of input device was counterbalanced (i.e., participant 1 = finger/mouse, participant 2 = mouse/finger, participant 3 = finger/mouse, etc.) across all 16 participants. Once participants completed one set of tasks using one of the input devices they were asked to fill out a Usability Questionnaire (see Appendix B). They repeated the tasks using the remaining input device and filled out another, identical Usability Questionnaire. Once all tasks had been performed using both input devices participants were asked to fill out a Forced Choice Preference Questionnaire (see Appendix C), were debriefed (see Appendix K), asked if they had any questions, and thanked for their time.

Design

A 2 (Input Device: finger and mouse) x 2 (Task Type: target selection and dragging) fully within-subjects, repeated measures design was used. Test conditions for task types were defined by target width (w) in pixels, distance (d) between the centers of

the targets in pixels, and target angle (a) in degrees. The testing software, IBM Isotest, created one condition for each possible parameter of w , d , and a . The following condition parameters were used: $w = 10, 20, 40$ (pixels), $d = 125, 250, 500$ (pixels), and $a = 0^\circ, 45^\circ, 90^\circ$ (degrees), based on a recommendation by Barton Smith at IBM Almaden Research Center, the software designer. While any pixel size parameters could have been chosen, the basis for choosing the pixel sizes for this study were arbitrary, and fall within a range of standard sizes of icons and text size found in Windows based applications. Therefore, the fully crossed conditions were established by the following equation: $([3 \text{ widths} \times 3 \text{ distances}] \times 3 \text{ angles}) = 27 \text{ different conditions per trial set}$. Six trial sets for each condition were programmed in, producing 162 targets for each task type and input device combination: finger-target selection, finger-dragging, mouse-target selection, and mouse-dragging, for a total of 648 target hits per participant. Depicted in Figure 7 is the IBM Isotest's setup condition interface.

Figure 7. IBM Isotest software interface.

Target pixel size represented a range of distances across a typical Windows based graphical user interface for a 1024 by 768-pixel display. The display area was consistent for both input device conditions at 1024 x 768 pixels. The number of targets in each condition ($n = 6$) was an arbitrary number chosen by the principal investigator. The widths and distances of targets in pixels represented a Fitts' Index of Difficulty (ID) between 2.4 and 5.5 bits. This range was calculated by inserting the highest and lowest pixel ranges for w and d into Fitts' Index of Difficulty equation: $ID = \log_2 (2A/W)$, where A = amplitude (or distance) and W = width. An arbitrarily chosen number of four was chosen for the "random number seed". This feature insured that all 16 participants were presented with the same random order of presentation as the first participant. The test software, IBM Isotest© was developed by B. Smith and is consistent with testing criteria recommended by ISO Standard 9249-9 Annex B, for testing non-keyboard input devices (see Appendix B). The ELO Touch System's technology allowed for smooth conversion between touch and mouse clicks enabling the same computing system to be used for both task types. The touch screen's mouse button emulation mode was set to "drag, double-click". This is the standard setting and works with all normal interface actions such as selecting targets and dragging, according to the ELO Touch System software specifications (see Appendix A).

Analysis of Data

The dependent variables measured by the current research are speed and accuracy. Speed was calculated by averaging the total time on task (in minutes and seconds) across both input devices (finger and mouse) as a function of target position, path length, and width for target selection and dragging tasks. Accuracy was measured by averaging the

total number of errors. An error was defined as selecting outside of a targets perimeter for the target selection tasks, or releasing the target before the final destination point for the dragging task. A factorial analysis of variance (ANOVA) with repeated measures was performed using SPSS 11.0 for PC to compare sources of variability among input device conditions.

While inferential statistics identify significant differences and the presence or absence of interactions among independent variables, they do not consider important subjective data such as user preferences for various manipulations of the independent variables being tested. Descriptive measures of behavior are usually expressed by frequencies or the number of times an event occurs or action occurs, means or averages, and standard deviations or measures of variability. The current research solicited subjective measures of preference from participants in two ways. The first was a post-test Usability Questionnaire for Mouse and Finger Input Devices (see Appendix B). Identical Usability Questionnaires were administered to participants once they had performed target selection and dragging tasks using the mouse and finger input devices. The Usability Questionnaire for Mouse and Finger Input Devices was developed as two parts. Part one asked participants to rate finger and mouse input devices on (a) physical effort, (b) mental effort, and (c) accuracy for pointing, and part two asked participants to rate perceived levels of fatigue for (a) finger, (b) wrist, (c) arm, (d) shoulder, and (e) neck during target selection and dragging task performance. The Usability Questionnaire for Mouse and Finger Input Devices utilized Likert rating scales, ranging from 1 (effort/less fatigue) to 5 (more effort/more fatigue).

A second post-test measure, a Forced-Choice Preference Questionnaire, was administered asking participants to choose either the mouse or finger input device they preferred using to performing tasks, for overall ease of use, and for overall preference (see Appendix C). The Forced-Choice Preference Questionnaire utilized Likert rating scales, ranging from 1 (most preferable) to 5 (least preferable).

An Observational Data Collection sheet was filled out by the researcher for each participant while they performed tasks using both input devices (see Appendix J) to determine whether signs of effort, hesitation, posture, and handedness were evident. Simple frequency means were used to analyze all paper and pencil measures to determine whether trends existed in favor of one input device over the other.

CHAPTER 4

Results

The purpose of this research was to determine whether significant differences exist in speed and accuracy (averaged errors) between two input device types: mouse and finger (on a touch screen) in a sample of adults between the ages of 65 and 80 years. The goal of performing statistical analyses in experimental studies is to determine whether significant differences exist between the independent variables being manipulated. (Kepple, Saufley, & Tokunaga, 1991, p. 228) Two independent variables were manipulated in this experiment, input device with two levels (finger and mouse), and task type with two levels (target selection and dragging). The objective was to determine if participants performed target selection and dragging tasks differently, in terms of speed and accuracy, across two input devices: finger and mouse. Speed was measured by averaging the total time it took participants to perform tasks, and accuracy was measured by averaging total number of errors. An error was recorded when a participant selected outside of a targets' perimeter for the target selection task, or when a participant released a target outside its final destination point for the dragging task. An alpha level of .05 was used to determine statistically significant effects for all analyses. Mean speed results were recorded in minutes and seconds and errors were averaged across participants.

The independent variable: input device type (finger and mouse) was counterbalanced across participants; task type was randomly varied. Practice, or learning effects, can be problematic in repeat measure designs such that each participant is performing at all levels of all conditions. To determine effects of order of input device on the dependent variables speed and accuracy, two one-way ANOVAs were performed.

The ANOVA on speed revealed that speed was not significantly affected by order of input device, $F(1, 15) = .466, p = .506$. The ANOVA on accuracy revealed that accuracy was not significantly affected by order of input device, $F(1, 15) = .279, p = .606$. Depicted in Table 1 are the means and standard deviations for the effect of order effect of input device on speed and accuracy.

TABLE 1.

Means and Standard Deviations for the Effect of Order of Input Device on Speed and Accuracy Collapsed Across 162 Trials for 16 Participants

	<i>Means</i>	<i>Standard Deviations</i>
<hr/> Speed Analysis		
Finger	1.87	0.793
Mouse	1.58	0.729
Accuracy Analysis		
Finger	61.72	32.89
Mouse	1.58	0.729

Speed Analysis

Once it was determined that the order of input device did not significantly affect speed or accuracy, the next analysis conducted was a 2 (task type) x 2 (input device type) ANOVA with repeated measures on speed. Depicted in Table 2 is the ANOVA source table from the speed analysis.

TABLE 2.

Analysis of Variance Source Table for Speed as a Function of Task Type and InputDevice Type Collapsed Across 162 Trials for 16 Participants

<i>Source</i>	<i>df</i>	<i>MS</i>	<i>F</i>
Task Type	1	1.32	2.20
Input Device Type	1	4.86	10.66**
A x B	1	0.304	.755
Error	15	(0.403)	

Note. () = MSE; ** = $p < .05$

For the variable task type, no significant main effect was found for speed, $F(1, 15) = 2.20$, $MSE = .602$, $p = .158$. While it took participants less time to perform target selection tasks than dragging tasks, the difference in speed was not statistically significant. Table 3 summarizes mean and standard deviation (*SD*) values (collapsed across 162 trials) from the speed analysis. Depicted in Figure 8 is a graphical representation of these values to aid in the interpretation of Table 3.

TABLE 3.

Means and Standard Deviations for Speed as a Function of Task Type and Input Device
Type Collapsed Across 162 Trials for 16 Participants

	<i>Means</i>	<i>Standard Deviations</i>
Task Type (no main effect found)		
Target Selection	1.45	0.28
Dragging	2.00	0.98
Input Device Type (main effect found)		
Finger	1.98	0.96
Mouse	1.47	0.39
Interaction (no interaction found)		
Target Selection/Finger	2.22	0.23
Target Selection/Mouse	1.52	0.99
Dragging/Finger	1.78	0.31
Dragging/Mouse	1.37	0.96

Figure 8: Means (M) and standard deviations (SD) for speed in minutes and seconds, as a function of task type by input device type.

For the variable input device (finger and mouse), a significant main effect was found for speed, $F(1, 15) = 10.66$, $MSE = 4.57$, $p < .005$. Participants performed tasks significantly faster when using a mouse input device than when using a finger input device (see Table 3, and Figure 8).

The interaction of task type and input device type was not statistically significant for speed, $F(1, 15) = .755$, $MSE = .403$, $p = .399$. Although participants performed target selection tasks using the mouse faster than using their finger to perform dragging tasks, the difference in speed was not statistically significant.

Accuracy Analysis

Accuracy was measured by averaging total number of errors participants made performing tasks. A two-way ANOVA, task type by input device type, was performed on the variable accuracy. Depicted in Table 4 is the ANOVA source table for accuracy.

TABLE 4.

Analysis of Variance Source Table for Accuracy as a Function of Task Type and Input Device Type Collapsed Across 162 Trials for 16 Participants

<i>Source</i>	<i>df</i>	<i>MS</i>	<i>F</i>
Task Type	1	492.29	1.77
Input Device Type	1	50204.00	60.24**
A x S	1	1565.20	.699**
Error	15	(224.08)	

Note. () = MSE; ** = $p < .05$

For the variable task type (target selection and dragging), no significant main effect was found for accuracy, $F(1, 15) = 1.77$, $MSE = .279$, $p = .204$. Although participants made fewer errors performing target selection tasks than dragging tasks, the number of errors made was not statistically different. Table 5 summarizes the means and standard deviations (collapsed across 162 trials) from the accuracy analysis. Figure 9 is a graphical representation of these values to aid in the interpretation of Table 5.

For the variable input device (finger or mouse), a significant main effect was found for accuracy, $F(1, 15) = 60.24$, $MSE = 833$, $p < .05$. Participants made significantly fewer errors using the mouse input device to perform tasks than their finger.

TABLE 5

Means and Standard Deviations for Accuracy as a Function of Task Type and Input Device Type Collapsed Across 162 Trials for 16 Participants

	<i>Means</i>	<i>Standard Deviations</i>
Task Type		
Target Selection	28.01	36.81
Dragging	39.41	36.45
Input Device Type		
Finger	60.97	34.02
Mouse	06.45	07.68
Interaction		
Target Selection/Finger	69.40	26.90
Target Selection/Mouse	03.50	02.98
Dragging/Finger	54.00	37.20
Dragging/Mouse	07.90	09.11

Figure 9. Means and standard deviations for accuracy (depicted as number of errors) as a function of task type by input device type.

The interaction of task type and input device type was statistically significant for accuracy, $F(1, 15) = 6.98$, $MSE = 224$, $p < .05$. Participants were significantly more accurate performing target selection tasks using the mouse, and significantly less accurate performing dragging tasks with their finger (see Table 5). This finding is consistent with literature that reveals users perform target selection tasks more accurately using the mouse, than when performing other task types using other input device types. (Mack & Lang, 1989; Mackenzie et al., 1991; Cohen et al., 1993; Chaparro et al., 1999; Smith, Ho, Ark & Zhai, 2000) Depicted in Figure 10 is the interaction of task type and input device type for accuracy. Note the disparity in the large number of errors made while using the finger to perform dragging tasks (left side of figure) versus the smaller number of errors made while using the mouse to perform target selection tasks (right side of figure).

Figure 10. Interaction of task type by input device for accuracy.

User Preference Analysis

While inferential statistics attempt to identify significant differences and the presence or absence of interactions among independent variables, they do not consider important subjective data such as how participants feel about tasks they performed or whether or not preferences exist. Identical Usability Questionnaires for mouse and finger input devices were administered after each set of tasks was performed using each input device (see Appendix B). Depicted in Table 6 are means and standard deviations from the Input Device Evaluation Questionnaires. These values are also depicted graphically in Figures 11 and 12 to aid in the interpretation of Table 6.

TABLE 6.

Means and Standard Deviations From Input Device Evaluation Questionnaires Across All Participants. Collapsed Across 162 Trials for 16 Participants (Likert Scale: 1 = Very Easy to 5 = Very Hard)

	<i>Finger</i>		<i>Mouse</i>	
	<i>Means</i>	<i>Standard Deviations</i>	<i>Means</i>	<i>Standard Deviations</i>
Part 1- Usability Ratings				
1. Mental effort	3.44	0.96	3.06	0.57
2. Physical effort	4.25	0.93	2.81	0.83
3. Accuracy for pointing	4.69	0.70	2.31	1.08
Part 2 - Fatigue				
4. Finger	4.44	0.81	2.38	1.20
5. Wrist	4.19	1.22	2.69	1.35
6. Arm	4.50	1.03	2.38	1.15
7. Shoulder	3.75	1.61	2.25	1.24
8. Neck	3.31	1.35	2.13	1.36
9. General comfort	2.81	1.11	3.00	0.89
10. Overall ease of use	4.25	0.75	1.81	1.13

Figure 11. Results of Usability Questionnaire for Mouse and Finger Input Devices, Part 1.

Figure 12. Results of Usability Questionnaire for Mouse and Finger Input Devices, Part 2.

A Forced-Choice Preference Questionnaire (see Appendix C) was administered once participants completed both sets of tasks using both input devices. This measure asked participants to choose one input device (finger or mouse) which they preferred to perform the target selection tasks, dragging tasks, their preference for general comfort engaging with the input devices, and overall ease of use. Figure 13 depicts results from the Forced-Choice Preference Questionnaire.

Figure 13. Results from Forced Choice Preference Questionnaire on specific tasks, overall ease of use, and overall preference.

The researcher collected observational data on individual behavioral characteristics such as signs of effort, hesitation, and handedness while participants performed tasks using both input device types. In this study, 15 of 16 participants were right handed, four participants switched hands at least once during task performance due to arm fatigue while using the touch screen and none of the participants switched while

using the mouse. Twelve of the 16 participants showed signs of hesitation such as pausing, head movement to see where their finger was touching on the screen while performing tasks using the touch screen, while only two participants showed outward signs of hesitation while performing tasks using the mouse. Of 16 participants, 14 showed outward signs of frustration such as moaning, asking how much longer, shaking out their hand, looking at their watch while performing tasks using their finger on the touch screen, while only two participants appeared frustrated performing tasks using the mouse. Depicted in Figure 14 are the results of observational data on switching hands due to fatigue, and signs of hesitation and frustration.

Figure 14. Results from observational data collected from participants on switching hands due to fatigue, and signs of hesitation and frustration.

Summary

The following provides a summary of the ANOVA results as a function of the hypotheses proposed and user preference data from the current experimental study. Input device type (finger and mouse) was counterbalanced across participants during the study, but task type (target selection and dragging) was not. Therefore, the initial analysis was to determine whether order of input device type used to perform tasks influenced the outcome on speed or accuracy. An ANOVA revealed that neither speed, nor the number of errors made, was significantly affected by the order of input device.

The hypothesis proposing that input device type would not affect speed was rejected. Participants performed target selection and dragging tasks significantly faster using a mouse input device ($M = 1.47$, $SD = 0.39$), than using a finger on touch screen ($M = 1.98$, $SD = 0.96$). The hypothesis proposing that task type would not affect speed was accepted. Although participants performed target selection tasks faster ($M = 1.45$, $SD = 0.28$) than dragging tasks ($M = 2.00$, $SD = 0.98$), the difference in speed was not significant. The hypothesis proposing that input device and task type would not interact to affect speed was accepted.

The hypothesis proposing that input device type would not affect accuracy was rejected. The number of errors participants made while using the finger input device to perform tasks ($M = 60.97$, $SD = 34.02$), was significantly higher than when using the mouse input device to perform tasks ($M = 6.45$, $SD = 7.68$).

The hypothesis proposing that task type would not affect accuracy was accepted. While participants made more errors performing dragging tasks ($M = 39.41$, $SD = 36.45$) than target selection tasks ($M = 28.01$, $SD = 36.81$), the difference in the number of errors

made was not statistically significant. The hypothesis proposing that task type and input device type would not interact to affect accuracy was rejected. Task type interacted with input device in that the number of errors made was dependent upon the type of input device used as it varied across task type. Participants made more errors using the finger input device to perform dragging tasks ($M = 69.4$, $SD = 26.9$), than while using the mouse to perform target selection tasks ($M = 3.5$, $SD = 2.98$).

The hypothesis proposing that input device would not influence user preference was rejected. The Input Device Evaluation Questionnaires (see Appendix C) revealed that participants reported that the mouse required less force, was smoother to operate, required less mental and physical fatigue, and was more accurate for pointing than their finger on touch screen. Participants also reported more physical and mental fatigue using their finger on the touch screen than the mouse. And finally, 15 of the 16 participants reported they preferred performing tasks using the mouse better than using their finger on the touch screen. Overall, participants reported that they preferred the mouse input device for comfort ($M = 3.00$) over the finger ($M = 2.81$) but only by a small margin, whereas the difference in preference for overall ease of use was significantly more pronounced for the mouse input device ($M = 4.25$) than for the finger ($M = 1.81$).

CHAPTER 5

Discussion

In this study speed and accuracy were evaluated across two input devices, mouse and finger (on touch screen) in a sample of adults between the ages of 65 and 80 years. Speed was measured by averaging total time on tasks and accuracy was measured by averaging total errors across sixteen participants, as a function of input device used.

A review of relevant literature revealed that between 1989 and 2003 a number of studies examined the efficacy of input devices such as mice, touch pads, tablets, touch screens, trackballs (finger-ball and thumb-ball), and isometric joysticks revealing as many results as devices tested. (Mack & Lang, 1989; MacKenzie et al., 1991; Meyer et al., 1994; Lee, 1997; Chaparro et al., 1998; Chaparro, Bohan, Scarlett, Fernandez & Choi, 1999; Hinckley & Sinclair, 1999; Chaparro et al., 1999; Smith et al., 1999) Some researchers speculated that using touch screens was a more “intuitive” direct manipulation technique, supporting the “natural” human response to touch objects of interest (Lee, 1997), while others countered saying mice were superior... or trackballs were superior. The literature in effect reports that each input device possesses a unique set of characteristics, advantages and disadvantages. Therefore, categorically endorsing one input device as superior to all others at this point, for any age group, would be imprudent. This disparity can be attributed to any number of things inherent to experimental research such as variable test conditions, user demographics, task categories, interface test environments, and anticipated degree of accuracy. Upon observing the disparity of results for this experiment, several factors were reviewed. This was done for two reasons. First, to determine whether these factors could have

contributed to the difference in results between performance and preference thereby qualifying them as limitations, and second to avoid repeating them in future studies.

Of first concern was the touch screen used in the study. It was speculated that the touch screen's core technology might have been outdated. As a result, a phone call was placed to ELO Touch systems in Fremont, CA, (the touch screen manufacturer and who donated the unit for the study) on April 12, 2003 to determine the integrity of the technology. After explaining the motivation for the question, the ELO technician verified the touch screen technology associated with the unit used in the study "had not changed much at all" from those currently on the market. So it appeared that the underlying technology did not qualify as a limiting factor.

Another concern was the touch screen's grainy display. Grainy displays can be attributed to many things, one of which is dot pitch. Dot pitch determines how sharp the displayed image will be. The dot pitch is measured in millimeters (mm) and the smaller the dot pitch number, the sharper the image. In desktop monitors, common dot pitches are .31mm, .28mm, .27mm, .26mm, and .25mm (techweb.com/encyclopedia). The dot pitch of the ELO touch screen used in the study was 0.28, putting it well within the range of standard monitor displays, and thus disqualifying dot pitch as contributing to the grainy display. Having ruled out dot pitch, it was thought that perhaps the resistive technology, which makes it possible to engage targets through the sense of touch, was making the display appear grainy.

Touch screens have a glass panel with a resistive metallic. A thick polyester cover sheet is tightly suspended *over* the glass and transparent insulating dots are used to prevent the two surfaces from contacting each other until the screen is touched with a

pointing device, such as a finger or stylus. The cover sheet has a hard, durable coating on the outward-facing side and a conductive metallic coating on the inward-facing side.

Like most monitors, touch screen displays look and feel hard to the touch, but unlike regular monitors, touch screens have a exterior hard coating, a conductive cover sheet, separator dots, and resistive coating lying between what the user is seeing and what is being displayed, thereby accounting for the grainy appearance in this study and qualifying it as a limiting factor.

Another limiting factor was fingers lifting off the screen during dragging tasks resulting in “dropped” targets. Most Windows environments allow users to drag icons or scroll screens for a determined distance. If the user “drops” the target or stops scrolling the page, the item usually stays where it was dropped. The Isotest software did not afford this allowance. If a target was dropped, it jumped back to the start point. This feature was inconsistent with typical Windows operating system environments, tended to frustrate users, and was considered a significant limitation to this study.

While seven of 16 participants reported having used a touch screen prior to the study, none of them used one as their primary input device. This resulted in an inequitable skill set between mice and touch screens qualifying it as a limiting factor to the study.

The continuous duration of the tasks and the resultant fatigue factor was considered, as well. The experimental design called for target dimensions of $[3 \text{ widths} \times 3 \text{ distances}] \times 3 \text{ angles} = 27$ different conditions per trial set. Six trial sets for each condition were programmed in, producing 162 targets for each task type and input device combination: finger-target selection, finger-dragging, mouse-target selection, and mouse-

dragging, for a total of 648 target hits per participant. While a large amount of data was collected, the tradeoff was a mismatch between the experimental environment and ecological validity thereby qualifying the continuous nature of the tasks and the resultant fatigue also a limiting factor to this study.

Three different target sizes were used in the study, 10, 20, and 40 pixels. While no analyses were performed to determine whether differences existed for speed and accuracy between the three target sizes, participants clearly had a harder time performing target selection and dragging tasks using the smaller targets (10 and 20 pixels), versus larger targets (40 pixels). This could have been due to one of two factors: 1) targets chosen for the study were too small and not representative of typical Windows interfaces and/or web page environments, or 2) fingers obscured the targets. Target sizes used in this study were recommended by Isotest software designer Barton Smith, and were said to be comparable to typical Windows interfaces and/or web page environments. In order to determine whether the targets used in the study were representative of Windows interfaces and/or web page environments, a comparison was made to targets on Yahoo's Mail Page. The problem was that the Isotest software allowed only one value of a target's size to be assigned. For example, while most icons are defined by two values (740 X 48) the Isotest software only allowed one value to define target size. So, rather than guessing the second value in order to make exact pixel size comparisons, the study's' targets were converted from pixels to millimeters and matched up to three targets on Yahoo's Mail Page, as follows:

1. 10 pixel targets = 10 x 3 mm targets ("Canada" link);
2. 20 pixel targets = 17 x 6 mm targets ("Sign In" icon);
3. 40 pixel targets = 33 x 11 mm targets ("Forgot your Password" link).

This comparison reveals that targets used in this study were within a representative range of sizes typically used on a common web interface, thereby disqualifying target size as a limitation to this study. Depicted in Figure 15 is a screenshot of Yahoo's Mail Page with comparable targets/icons circled and numbered (respectively) approximating target sizes used in the study.

Figure 15: Target size comparisons to common icons and text links on Yahoo Mail Page (millimeters $\approx$ target sizes).

While it has been shown that targets used in this study were comparable to typical web interfaces, participants have traditionally had difficulty acquiring targets using their fingers on touch screens due to fingers obscuring targets on touch screens. (Shneiderman, 1993) Figure 16 depicts a participant struggling to acquire a target and Figure 17 depicts a participant's finger obscuring 10, 20, and 40-pixel targets used in this study.

Figure 16: Participant struggling to acquire a target.

Figure 17: Target/finger comparison to 10, 20, and 30-pixel size targets.

Implications

The results of the current research found that the mouse significantly affected speed and accuracy, and participants preferred the mouse to perform the tasks presented in this study. Participants performed tasks faster and made fewer errors performing tasks using the mouse than when using their finger on a touch screen. While the implications of this study revealed the mouse to be superior in user preference, speed, and accuracy, it cannot conclusively implicate the mouse as the superior input device without considering the limiting factors discussed.

Future Research

It is recommended that research continue addressing issues inherent to this study, such as imprecise target selection and the inability to successfully drag targets from one location to another without dropping them. To date, this age group of users (between 65 and 80 years) has not been examined performing target selection and dragging tasks using touch screen and mouse input devices. To further this research, an older adult sample should be examined again addressing the following modifications:

1. Use a touch screen with a less grainy appearance;
2. Use a touch screen that's angle can be adjusted to a more horizontal plane;
3. Reduce the number of continuous tasks, or introduce more variety in task type;
4. Use software that does not "drop" targets in an attempt to more accurately emulate true graphical Windows based interface environments;
5. Choose participants with equivalent mouse and touch screen experience.
6. Provide a practice session.

Conclusion

While participants in this study performed tasks faster, made fewer errors, and preferred the mouse overall to the finger and touch screen for target selection and dragging tasks, many limiting factors were present which may have contributed to, or detracted from, this study's results. Below is a summary of touch screen pros and cons. While this edited list was taken from SAP Design Guild Guidelines (Waloszek, 2000), they apply to this research as well.

Touch Screen Pros and Cons

Pros:

1. Direct: Offers a direct relationship between hand and cursor movement;
2. Keyboard: no keyboard is necessary for applications that need menu selections only saving desk space.

Cons:

1. Precision: Imprecise selection due to finger size and imprecise target positioning;
2. Clarity: Problems with clarity due to grainy screen;
3. Fatigue: Strained arm, neck, and shoulder muscles from using vertically placed screen;
4. Sitting Position: Participants had to sit close enough to the screen to be within an arms length away;
5. Dirt: The screen got dirty from fingerprints;
6. Finger Obscuring Targets: Participants' finger obscured parts of the screen.

Design Recommendations

As Shneiderman (1993) pointed out, environmental engineers go to great lengths to pay respect to the diverse array of users across populations with design challenge solutions such as accessibility ramps and auditory stoplights. It follows that human factor engineering should assume these challenges in research and design efforts too, as the surface of this issue has only just been scratched. In fact, research shows that one of the main reasons older adult users have been underrepresented in computing is that until recently, hardware and software design have not been designed to accommodate them. (Bucar & Kwon, 1999; Shneiderman, 1998)

Designing a cabinet or desk that can accommodate an embedded, “drop-in” touch screen rendering its orientation to a more horizontal plane versus the traditional vertical plane may address the issues of fatigue. Enabling users to rest their arms on a desk or pad, rather than extending their arms out in front of them for extended periods of time may reduce load to the upper extremities, such as the shoulder, neck, and arm.

While this study’s main focus was to test hardware (input devices), it would be imprudent to ignore potential software enhancements when designing for an older adult population. Many design recommendations have been put forth specifically addressing impairments in vision, speech and hearing, psychomotor skills, attention span, and memory for older adult users and designers should apply these same guidelines to older adult users, such as those proposed by the World Wide Web Consortium’s Web Accessibility Initiative. (World Wide Web Consortium, 1999) While these guidelines are intended to assist in a variety of disabilities and impairments, they are useful

considerations for designers of all populations, and are certainly appropriate for touch screen software design, as well:

1. Provide equivalent alternatives to auditory and visual content;
2. Provide redundant cues rather than relying on color alone;
3. Provide context and orientation information;
4. Provide clear navigation mechanisms;
5. Ensure that documents are clear and simple.

An even more extensive set of design recommendations for addressing impairments in vision, speech and hearing, psychomotor skills, attention span, and memory exists (Hawthorn, 2000) and should also be acknowledged when designing computer interfaces intended for older adult users.

1. Keep the design simple, clear, and consistent;
2. Slow down double-click speed;
3. Use straightforward, germane icons and images;
4. Use short lists rather than long paragraphs of text.

This study serves as one of many efforts being made to carry on one the most important goals of HCI researchers: to improve upon the human-computer interaction experience. This research will benefit older adult users, and consequently benefit everyone in the HCI community, as we all will eventually be older adult computer users.

References

- Albert, A. (1982). The effect of graphic input devices on performance in a cursor positioning task. *Proceedings of the Human Factors Society 26th Annual Meeting*, 54-58. Santa Monica, CA: The Human Factors Society, Inc.
- Bernard, M. L., Liao, C. H., & Mills, M. M. (2001). The effects of font type and size on the legibility and reading time of online text by older adults. *Proceedings of CHI '01*, 175-176.
- Bohan, M. Chaparro, A., Fernandez, J., Kattel, B., & Choi, S.D. (1998). Cursor-control performance of older adults using two computer input devices. *Advances in Occupational Ergonomics and Safety*. X. S. Kumar (Ed). Washington DC: IOS Press.
- Bohan, M., & Scarlett, D. (2003). Can Expanding Targets Make Object Selection Easier for Older Adults? *Usability News, Newsletter, Software Usability Research Laboratory*, Wichita State University
http://wsupsy.psy.twsu.edu/surl/usability_news.html
- Boritz, J., Booth, K. S., & Cowan, W. B. (1991). Fitts's law studies of directional mouse movement. *Proceedings of Graphics Interface '91*, Toronto: Canadian Information Processing Society, pp. 216-223.
- Bow, A., Williamson, K., & Wale, K. (1996). Barriers to public Internet access. *Communications Research Forum 1996: Papers*. Canberra: Bureau of Transport and Communications Economics and the Media and Telecommunications Policy Group, RMIT, 36-50.

- Brickfield, C. (1984). Attitudes and perceptions of older people toward technology. In *Aging and Technological Advances*, (pp. 31-38). New York: Plenum Press.
- Bucar, A. and S. Kwon (1999). Computer Hardware and Software Interfaces: Why the Elderly Are Under-Represented as Computer Users. *CyberPsychology & Behavior*, 2 (6), 535-543.
- Chaparro, A., Bohan, M., Fernandez, J.E., Kattel, B., & Choi, S.D. (1999). The Impact of age on computer input devices: Performance and preference. *The International Journal of Industrial Ergonomics*, 24, 503-513.
- Chaparro, A., Bohan, M., Scarlett, D.S. Fernandez, J.E., & Choi, S.D. (1999). The effect of age on computer input device use: Performance and ratings of perceived exertion. *SAE Technical Paper Series*.
- Charness, N., Czaja, S., Fisk, A. D., & Rogers, W. (2001). Editorial. Why Gerontechnology? *Gerontechnology*, 1, 85-87.
- Cohen, O., Meyer, S., & Nilsen E. (1993) Studying the movement of high tech rodentia: Pointing and dragging. *Adjunct Proceedings of the INTERCHI '93 Conference on Human Factors in Computer Systems*, 135-136.
- Commercenet.com. (2000). <http://www.wilsonweb.com/webmarket/demograf.htm>
- Czaja, S. J., Blascovich, J., Hammond, K., & Joyce, J. (1987). Attitudes of the elderly towards computer technology. *The Journals of Gerontology*, 53B, 5. 329-40.
- Czaja, S. J., & Sharit, J. (1998). Ability-performance relationships as a function of age and task experience for a data entry task. *Journal of Experimental Psychology: Applied*, 4, 332 - 351.

- Danowski, J.A., & Sacks, W. (1980). Computer communication and the elderly. *Experimental Aging Research*, 6, 125-135.
- Deron, M. (2000). *How important is visual feedback when using a touch screen?*
Retrieved June 12, 2003 from <http://psychology.wichita.edu/surl/usabilitynews/2w/touchscreen.htm>
- Douglas, S. A., Kirkpatrick, A. E., & MacKenzie, I. S. (1999). Testing pointing device performance and user assessment with the ISO9241, Part 9 standard. *Proceedings of the ACM Conference on Human Factors in Computing Systems - CHI '99*, pp. 215-222. New York: ACM.
- ELO Touchsystems, 2000. *Literature On-line*. Retrieved June 16, 2000 from <http://www.elotouch.com/support/lit.asp>
- eMarketer eGlobal. *Demographics and Usage Report*. Retrieved January 24, 2002 from http://www.gii.co.jp/english/em9210_demographics_usage.html
- Hawthorn, D. "Possible implications of aging for interface designers." *Interacting with Computers* 12(5) (April 2000): 507-528.
- Hinckley, K. & Sinclair, M. (1999). Touch-sensing input devices. *Proceedings of ACM CHI 99 Conference on Human Factors in Computing Systems*, 223-230.
- Irizarry, C., & Downing A. (1997). Computers enhancing the lives of older people, *Australian Journal on Ageing* 16 (4) 161-165.
- Irizarry, C., & Downing A (2001) Use of the Internet by older rural South Australians, *Australasian Journal on Ageing* 20 (3) 153-155.

Jupiter Online Behavior & Demographic Report, Demographic Profile: Older Adults

Online. Retrieved March 16, 2003 from Jupiter <http://www.jupiterdirect.com/bin/report.pl/86121/939>.

Kepple, G., Saufley, W. H., & Tokunaga, J. (1991). *Introduction to design and analysis*. (2nd ed. p. 228) W. H. Freeman and Company, New York.

Kornbluh, M. (1984). Computer and telecommunications applications to enhance the quality of life of our elderly citizens. Congressional Research Service, Library of Congress, Washington, D.C.

Krauss, I. K., & Hoyer, W. J. (1984). Technology and the older person: age, sex and experience as moderators of attitudes towards computers. *Aging and Technological Advances*, 349-350. New York: Plenum Press.

Lee, A. (1997). The human factors of touch input devices. *Beta Research Inc.* Los Gatos, California.

Liao, C., Groff, L., Chaparro, A., Chaparro, B., & Stumpfhauser, L. (2000). A comparison of website usage between young and the elderly. *Proceedings of The Human Factors and Ergonomics Society 44th Annual Meeting*. San Diego, CA: The Human Factors Society, Inc.

Mack, R., & Lang, K. (1989). A benchmark comparison of mouse and touch interface techniques for an intelligent workstation windowing environment. *Proceedings of the Human Factors Society, 33rd Annual Meeting*. Santa Monica, CA: The Human Factors Society, Inc.

- MacKenzie, I. S., Sellen, A., & Buxton, W. (1991). A comparison of input devices in elemental pointing and dragging tasks. *Proceedings of the ACM Conference on Human Factors in Computing Systems - CHI '91*, 161-166. New York: ACM.
- Mead, S. E., Sit, R. A., Rogers, W. A., Rousseau, G. K., & Jamieson, B. A. (2000). Influences of general computer experience and age on library database search performance. *Behavior and Information Technology*, 19, 107-123
- Meyer, B., Sit, R., Spaulding, V., Mead, S., & Walker, N. (1997). Age group differences in World Wide Web navigation. *CHI '97 Electronic Publications: Late-Breaking/Short Talks*. Retrieved September 10, 1999 from <http://www.acm.org/sigchi/chi97/proceedings/short-talk/bm.htm>
- Meyer, S., Cohen, O., Nilsen, E. (1994) Device comparisons for goal-directed tasks. *CHI '94 Conference Companion Proceedings*, 251-252.
- Nielsen, J. (1993). *Usability engineering*. Boston; Academic Press. p.192
- Ogozalek, V. (1994). A comparison of the use of text and multimedia interfaces to provide information to the elderly. *Proceedings of the CHI '94 Conference Companion on Human Factors in Computing Systems*.
- Pearlman, G. (2001). Usability Test Consent Form. Retrieved from the World Wide Web April 19, 2002 from <http://www1.acm.org/~perlman/useval/consent.html>
- Philbeck, J. (2001). *Cybersociology Online Magazine*. Retrieved from the World Wide Web October 12, 2001 from <http://members.aol.com/Cybersoc/is2joyce.html>.
- Rogers, W. A., Hertzog, C., & Fisk, A. D. (2000). Age-related differences in associative learning: An individual differences analysis of ability and strategy influences.

Journal of Experimental Psychology: Learning, Memory, and Cognition, 26, 359-394.

SeniorNet. (1999). Profile of older Americans: SeniorNet Research Reports. Retrieved from the World Wide Web on December 9, 2001 from <http://www.seniornet.org/research/aoa.shtml>.

SeniorNet. (2000). Profile of older Americans: 1999. *SeniorNet Research Reports*. Retrieved from the World Wide Web October 11, 2001 from <http://www.seniornet.org/research/aoa.shtml>.

SeniorNet. (1998). Research on seniors' computer and Internet usage: report of a national study. *SeniorNet Research Reports*. Retrieved from the World Wide Web April 15, 2002 from http://www.seniornet.org/research/rsch_0998.html.

Sears, A., Plaisant, C., Shneiderman, B. (1992). A new era for high-precision touchscreens, *Advances in Human-Computer Interaction*, vol. 3, Hartson, R. & Hix, D. Eds., Ablex 1-33.

Sears, A., & Shneiderman, B. (1991) High Precision Touchscreens: Design Strategies and Comparisons with a Mouse. *International Journal of Man-Machine Studies*, 34(4): 593-613.

Seidler, R., & Stelmach, G. (1996). Motor performance. *Encyclopedia of Gerontology: Age, Aging, and the Aged*. San Diego: Academic Press, Inc. pp. 177-185.

Shapiro, P. (2000). Computer Use and the Elderly. Retrieved February 2, 2003 from http://www.user-groups.net/Library/Phil_Shapiro/Elderly.html

Shneiderman, B. (1993). *Sparks of Innovation in Human-Computer Interaction*, Ablex Publishers. Norwood, NJ.

- Shneiderman, B. (1997). Direct manipulation for comprehensible, predictable, and controllable user interfaces. *Proceedings of IUI97, 1997 International Conference on Intelligent User Interfaces, Orlando, FL, January 6-9, 1997*, 33-39.
- Shneiderman, B. (1998). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Reading, MA.: Addison-Wesley, 1998.
- Sikorski, M., & Oppermann, R. (1996). Computer-based support for exploratory learning. *Arbeitspapiere No. 998. German National Research Center for Information Technology GMD, Sankt Augustin, Germany*.
- Smith, B.A., J. Ho, W. Ark, & Zhai, S. (2000). Hand Eye Coordination Patterns in Target Selection. *Proceeding of the ACM Symposium on Eye Tracking Research & Applications*, Palm Beach Gardens, FL, USA, November 6th-8th 2000.
- Smith, M.W., Czaja, S. J., & Sharit, J. (1999). Aging, Motor Control, and the Performance of Computer Mouse Task. *Human Factors*, 41, 389-397.
- Times Mirror. (1995). Technology in the American household: Americans going online. The Pew Research Center for The People and The Press. Retrieved May 19, 2000 from <http://www.people-press.org/tech.htm>.
- US Bureau of Census (2000). Resident population of the United States: middle series projections, 2015-2030, by Age and Sex. Retrieved June 12, 2001 from <http://www.census.gov/population/projections/nation/nas/npas1530.txt>.
- Van Dam, A. (1997). Post-WIMP User Interfaces. *Communications of the ACM* 40 (2), 63-67.

- Valk, M. (1990). Comparing touch screen to speech input in the control of a simple batch process. *Proceedings of the Human Factors Society 34th Annual Meeting*. Santa Monica, CA: The Human Factors Society, Inc.
- Walker, N., Millians, J. & Wordon, A. (1996) Mouse gains functions and cursor positioning: performance of older computer user. *Proceedings of the Human Factors and Ergonomics Society*. Santa Monica, CA: The Human Factors Society, Inc.
- Welford, A. (1981). Signal, noise, performance, and age. *Human Factors*, 23, 97-109.
- Whittall, D., & Grace, D. (2002). Bridging the technology gap: enhancing communication between residents in a nursing home with local community school children using the Internet. *Geriaction* 20 (4). pp.15-17.
- Worden, A., Walker, N., Bharat, K., & Hudson, S. (1997). Making computers easier for older adults to use: area cursors and sticky icons. *Proceedings of the CHI '97 Conference on Human Factors in Computing Systems*. New York: ACM.
- World Wide Web Consortium. *Web Content Accessibility Guidelines 1.0*. May, 1999.
- Retrieved October 5, 2003 from <http://www.w3.org/TR/WAI-WEBCONTENT/>.
- Yankelovich Partners. (1995). *The Yankelovich Cybercitizen Report*. Yankelovich Partners, Atlanta.
- Zhao, Y., & Tyugu, E. (1998) Toward a personalized browser for elderly users. *Proceedings of the 4th ERCIM Workshop on User Interfaces for All*, Stockholm, Sweden 19-21.

APPENDIX A

Instrumentation

I. ELO CRT Touch screen

Model: Touch computer Celeron 466 or Pentium III550

Display size and type: 15.0" (381 mm) diagonal active matrix color TFT LCD

Optimal resolution: 1024 x 768 (XGA)

Colors: 262,000, 6-bit gray scale

Viewing angle: Horizontal $\pm 60^\circ$ or 120° total; vertical $\pm 45^\circ$ or 90° total

Display response time: 20 ms rise time; 30 ms fall time

Backlight lamp life: 40,000 hours at maximum brightness.

II. CPU - Gateway Solo 5300 Portable Laptop

Model: Solo 5300

Processor: Intel® Pentium™ III Processor

Memory: 128 MB RAM

Hard Drive: 10GB Hard Drive

Floppy Drive: Modular 1.44MB 3.5

Operating System: Microsoft® Windows® Millennium Edition (ME)

III. Application Software: Elo Touchsystems TouchTools for Windows® 2000 and

IBM, Isotest-Input Performance Test, Version 0.94 Beta© Copyright IBM 2002

IV. Hewlett Packard two-button mouse, model number M-S34

V. Participant Recruiting Flyer

VI. Consent Form (Pearlman, 2002)

VII. Participant Screening Criteria

- VIII. User Demographic Profiler
- IX. 13-Item Device Assessment
- X. Forced-Choice Preference Questionnaire
- XI. Verbal Instructions
- XII. Debriefing Statement
- XII. Data Collection Sheet

APPENDIX B

Usability Questionnaires for Mouse and Finger Input Devices

Input Device: Mouse

Please circle the number that best applies.

1. The force required for actuation was:

1	2	3	4	5
Too low		Neutral		Too high

2. Smoothness during operation was:

1	2	3	4	5
Very rough				Very smooth

3. The mental effort required for operation was:

1	2	3	4	5
Too low				Too high

4. The physical effort required for operation was:

1	2	3	4	5
Too low				Too high

5. Accurate pointing was:

1	2	3	4	5
Easy				Difficult

6. Operation speed was:

1	2	3	4	5
Too fast				Too slow

7.	Finger fatigue:				
	1	2	3	4	5
	None				Very high

8.	Wrist fatigue:				
	1	2	3	4	5
	None				Very high

9.	Arm fatigue:				
	1	2	3	4	5
	None				Very high

10.	Shoulder fatigue:				
	1	2	3	4	5
	None				Very high

11.	Neck fatigue:				
	1	2	3	4	5
	None				Very high

12.	General comfort:				
	1	2	3	4	5
	Very Uncomfortable				Very Comfortable

13.	Overall, the input device was:				
	1	2	3	4	5
	Very Difficult				Very Easy

Input Device: Finger

Please circle the number that best applies.

1. The force required for actuation was:

1
Too low

2

3
Neutral

4

5
Too high

2. Smoothness during operation was:

1
Very rough

2

3

4

5
Very smooth

3. The mental effort required for operation was:

1
Too low

2

3

4

5
Too high

4. The physical effort required for operation was:

1
Too low

2

3

4

5
Too high

5. Accurate pointing was:

1
Easy

2

3

4

5
Difficult

6. Operation speed was:

1
Too fast

2

3

4

5
Too slow

7.	Finger fatigue:				
1	2	3	4	5	
None					Very high

8.	Wrist fatigue:				
1	2	3	4	5	
None					Very high

9.	Arm fatigue:				
1	2	3	4	5	
None					Very high

10.	Shoulder fatigue:				
1	2	3	4	5	
None					Very high

11.	Neck fatigue:				
1	2	3	4	5	
None					Very high

12.	General comfort:				
1	2	3	4	5	
Very Uncomfortable					Very Comfortable

13.	Overall, the input device was:				
1	2	3	4	5	
Very Difficult					Very Easy

APPENDIX C

Forced-Choice Preference Questionnaire

Instructions:

Please circle the input device you preferred most for the following:

1. Selecting targets	Finger	Mouse
2. Dragging targets	Finger	Mouse
3. Overall ease of use	Finger	Mouse
4. Overall preference	Finger	Mouse

APPENDIX D

Participant Recruitment Flyer

Attention Computer Users!

Are you between the ages of 65 and 80?

Do you use a computer at least twice a week?

Do you use the Internet or email twice a month?

If so, you are invited to participate in a 45-minute study intended to help
make computers easier for adults over the age of 65...

Guaranteed to be Fun & Easy!

As a token of our appreciation for your time you will
receive a box of See's Candy!

Study will take place here at the YMCA

Please call:

Linda Phillips @ (xxx) xxx-xxxx

To set up an appointment today!

APPENDIX E

Participant Screening Criteria

1. Are you between the ages of 65 and 80?

Yes _____ No _____

2. Do you use a computer at least twice a week?

Yes _____ No _____

3. Do you use the Internet at least twice a month?

Yes _____ No _____

APPENDIX F

Usability Test Consent Form (Pearlman, 2002)

Our group is studying how people use computers to access information. This will help us understand how to make information more useful to people. To do this, we need the help of people like you, so that we can observe people while they do particular tasks with computers. We will ask you to perform a series of tasks using two different input devices, which will involve your use of some computer software. The observations that we make will be of considerable importance. The test itself might be very easy or very difficult.

Before we start, we will tell you as much as we can about the test and our procedures, but we won't give you information that might affect how you do the tasks. After everything is finished, we will be happy to answer any other questions you have. We want your participation to be a cooperative venture with us in adding to our understanding of how to make computers easier to use. In addition, we are required to get your written consent to participate. If you agree to help us, you will be asked to sign the form. If you have any questions about this document, please ask us.

Test Description: The test we will ask you to do has the following purpose and procedures:

1. You will be asked to fill out a demographic survey.
2. You will be asked perform a series of tasks using a mouse and your finger on a touch screen.
3. You will be asked to think aloud so we can interpret what you are trying to do.

Participant Initials _____

4. The time it takes you to complete each task will be recorded, so you should try to work efficiently.
5. Do not worry if you cannot complete a task.
6. You will be asked some questions about the test.
7. No Risks: There are no risks to you involved in this test.
8. Questions: We will answer any questions you have about the test, except information that might affect your performance, which may be withheld until we are done. After the experiment is over, we would like you to not discuss the experiment with others who might participate because it could affect their performance.
9. Voluntary Participation: Although it is important to us that you finish the test because our observations may not be useful unless we have a complete set, you may leave at any time before or during the test if you feel uncomfortable.
10. Confidentiality: Any public presentations or published reports of the results using your data will not include any means of identifying you, in order to provide confidentiality and privacy. We would be happy to provide to you any published reports on this work.
11. Non-Disclosure: You may observe valuable proprietary information that we are maintaining as a trade secret. By signing below, you agree not to disclose any aspect of this test to anyone or use the information in any way.

Participant Initials _____

12. Evaluation of Hardware or Software, not users: Finally, it is not you who is being evaluated in this study; it is the computer hardware or software that is being evaluated, so there are no right or wrong ways for you to perform.
13. Questions About the Research: You may address questions you have regarding the research to Linda M. Phillips at (408) 292-6334.
14. Complaints About the Research: If you find you have any issues or complaints about the research you may direct your questions to Emily H. Wughalter, Ed.D. Professor of Human Performance and committee chairperson for this study at San Jose State University at (408)-924-3043.
15. Questions About Research Subjects' Rights: If you have any general questions regarding research subjects' rights or experience and research-related injury you may contact Nabil Ibrahim, Ph.D. Associate Vice President for the Graduate Studies and Research at San Jose State University, (408) 924-2480.

Participant Name (Printed)

Date

Participant Name (Signature)

Date

Principal Investigator (Printed)

Date

Principal Investigator (Signature)

Date

APPENDIX G

User Demographic Profile

Instructions: Please circle the best answer for each of the following questions.

- 1) My age is between:
a) 65-70 Years b) 71-75 Years c) 76-80
- 2) I use computers to:
a) E-mail b) Shop online c) Word Processing d) Other _____
- 3) I exercise regularly:
a) Yes b) No
- 4) When I exercise I:
a) N/A b) Walk c) Treadmill d) Swim e) Other _____
- 5) I own a computer:
a) Yes b) No
- 6) I have made purchases on the Internet using my credit card:
a) Never b) 1-5 times c) 6-10 times d) 11+ times
- 7) I believe the level of my computer experience is best described as:
a) Beginner b) Intermediate c) Expert
- 8) I have used a touch screen:
a) Yes b) No

APPENDIX H

Verbal Instructions

Thank you for participating in this study. This is considered a true scientific, experiment. As such, I must read these instructions to you and every participant so each person gets the exact same instructions. The purpose of this experiment is to see how easy or hard it will be for you to perform simple target selection and dragging tasks using your finger on a touch screen and a mouse. You will be given a few minutes to practice both tasks before each trial to familiarize yourself with the tasks. I will explain both tasks and will clarify the instructions as often as you need to hear them. I cannot help you do the tasks or tell you how to do them once the trials begin.

For the target selection task, two targets will appear on the screen a red target and an outline of a target. You touch (finger condition) or click (mouse condition) on the red target. Once you touch or click on a pre-determined number of red targets another set of targets appear, differing in size, angle, and width between targets. You will repeat the process of touching or clicking on the red targets until you see a message saying "Finished". This is not a race, but please work as fast as possible while trying to minimize error.

For the dragging task, two targets will appear on the screen, a red target and an outline of a target on the other side of the screen. You will drag the red target to the outline target with either your finger (finger condition), or with the mouse (mouse condition). Once you drag a pre-determined number of red targets to the outline targets another set appears, differing in size, angle, and width between targets. You will repeat the process of dragging the targets back and forth across the screen until you see a

message saying “Finished”. Again, this is not a race, but please work as fast as possible while trying to minimize error.

APPENDIX I

Isotest-Input Performance Test, Version 0.94 Beta© Copyright IBM 2002

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This Limited Use License Agreement (Agreement) is between You and International Business Machines Corporation (IBM) through its Almaden Research Center, 650 Harry Road, San Jose, California 95120-6099, to allow You to receive a copy of IBM's experimental Java application for testing user performance on input devices, together with associated documentation (hereinafter collectively referred to as "Software").

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APPENDIX J

Data Collection Sheet

Legend:

Frustration = F

Hesitation = H

Handedness = H

Task No. Signs of Behavior

1.Finger condition	
2.Mouse condition	

Other observed Behaviors:

APPENDIX K

Debriefing Statement

I would like to thank you for participating in this experiment. The purpose of this research was to evaluate performance and preference on target selection and dragging tasks for two types of input device, touch using finger and mouse for adults between the ages of 65 and 80 years. Thank you again for participating.

APPENDIX L

Human Subjects Institutional Review Board Approval Letter

**San José State
UNIVERSITY**

**Office of the Academic
Vice President
Associate Vice President
Graduate Studies and Research**

One Washington Square
San José, CA 95192-0025
Voice: 408-924-2480
Fax: 408-924-2477
E-mail: gstudies@whoo.sjsu.edu
<http://www.sjsu.edu>

To: Linda M. Phillips
117 S. Morrison Street
San Jose, CA 95126

From: Nabil Ibrahim,
AVP, Graduate Studies & Research

Date: September-17, 2002

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Effect of Input Device on Speed and Accuracy in Older Adults."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond September 17, 2003 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

The California State University:
Chancellor's Office
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Fresno, Fullerton, Hayward, Humboldt,
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Monterey Bay, Northridge, Pomona,
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