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Long paper

Input devices for web browsing: age and hand effects

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Abstract The work reported in this paper examined performance on a mixed pointing and data entry task using direct and indirect positioning devices for younger, middle-aged, and older adults (n=72) who were experienced mouse users. Participants used both preferred and non-preferred hands to perform an item selection and text entry task simulating a typical web page interaction. Older adults performed more slowly than middle-aged adults who in turn performed more slowly than young adults. Performance efficiency was superior with the mouse for older adults only on the first two trial blocks. Thereafter mouse and light pen yielded equivalent performance. For other age groups, mouse and light pen were equivalent at all points of practice. Contrary to prior research revealing superior performance with a light pen for pure pointing tasks, these results suggest that older adults may initially perform worse with a light pen than a mouse for mixed tasks.

Keywords Age - Hand - Usability - Input device - Web

Introduction

The twenty-first century has seen the inception of nearly ubiquitous computing in developed countries. Indeed, the combination of less expensive and more powerful computer technology combined with the rapid adoption of high-speed communications networks will likely accelerate this trend and spread it to most nations. Because of the rapidly increasing aging population in America, a new set of challenges for human factors design of computer systems is arising. About 15% of adults aged 65 years or older reported having Internet access by the second half of 2000, compared to about 56% for the US population as a whole and 75% for those aged 18–29 years [18]. However, older adults may comprise one of the fastest growing segments of the estimated 80 million Internet navigators in the US, having jumped 47% as of 2004. Thus 22% of older adults are now online [13], and better design of interfaces and selection of input/output devices could certainly encourage greater adoption [12].

Traditional interaction techniques require a pointing device for menu target selection and for cursor positioning. These devices may be direct, meaning there is one-to-one mapping from the device to the screen, or indirect, meaning that the user must map the movement of the device in one plane (for instance, on a mouse pad) with the movement of a cursor on a different plane (the computer screen) [14].

Mice are the most common type of indirect positioning devices for most home and work computer systems. Research consistently reveals that older adults experience significant declines in spatial abilities [21] and are generally slower on translation tasks [19]. These age-related declines help explain why older adults experience more difficulties than younger adults using normal mouse settings, as standard mice employ greater acceleration and velocity in the plane of the screen versus the plane of the mouse surface. Indeed, Walker et al. [23] showed that novice older adults were less accurate using a mouse in a target acquisition task than their younger counterparts, as older adults exhibited more difficulty homing in on target and avoiding slip errors. Minor adjustments to acceleration profiles help minimize such performance differences between groups.

Given the decline in motor control and coordination of older adults, in addition to the greater likelihood of disabling conditions like arthritis or after effects from a stroke, older adults also exhibit other problems with aspects of mouse control, including clicking, double-clicking, and dragging [1]. Smith et al. [22] showed that cursor control tasks with a mouse are more difficult for older adults than younger adults, particularly in double-clicking tasks, as evidenced by longer movement times, more submovements, and more errors. Furthermore, Chaparro et al. [7] showed that older adults exhibited higher ratings of perceived exertion with the mouse than their younger counterparts.

Touch screens and light pens are examples of direct positioning devices. They provide a “where you point is where you go” (WYPIWYG) method of operation. Charness et al. [9] showed that a direct positioning device (a light pen) was generally faster than a mouse and age-related performance differences were minimized relative to the mouse in a pure pointing task, which involved pointing and clicking on the requested targets using the specified input device, and did not require the user to input data using the keyboard or to shift the hand from one device to another for any procedure to be completed. Thus, results provided some evidence that age differences in mouse use are partially accounted for by age differences in mapping operation efficiency. The study reported in this paper extends research by Charness et al. [9] to compare the usability of both direct (light pen) and indirect (mouse) pointing devices for young, middle-aged, and older adults in a mixed pointing and data entry task. This task required users to point and click to places on the screen with a given input device and to shift the hand to the keyboard to enter requested text. Such a task provides a more realistic model of the processes encountered within graphical user interfaces (GUI) during web navigation (e.g., typing a keyword into a search engine and then pointing and clicking on the hyperlinks of pages found).

Mixed tasks usually involve interleaving the use of two input devices: a pointing device and a keyboard. Interleaving creates problems for touch typists because one hand must leave the home row key position to reach for a pointing device and then return to that position for further typing - the homing problem [5]. Previous research revealed that in computer text-editing tasks, approximately 360–400 ms were lost each way in “homing” between the mouse and keyboard [2, 3, 4]. Card and colleagues [5] incorporated these findings into a Keystroke Level Model that estimated times for specific tasks. For instance, a pointing task incorporates a pointing action (1,100 ms) and two homing actions (400 ms each), meaning that simple movements from the keyboard to the mouse and back take approximately 40% of the total time it takes to point to an object on the screen.

Further, Douglas and Mithal [11] argued that it is necessary to think of a "device context switching time" when conducting task analyses. This can be thought of as the total time it takes to mentally prepare and execute an action when the user changes from one input device to another (e.g., keyboard to mouse, or light pen to keyboard). They termed changing from selecting a target with a pointing device to entering data on a keyboard "mode-switching," and estimated that "homing" time accounted for 28% of the total time spent keyboarding. Thus, given the additional components involved in this mixed pointing and data entry task, a somewhat different pattern of results was expected than the one revealed by the pure pointing task used by Charness et al. [9]. In the current context, it was predicted that the advantage to using a direct positioning device, the light pen, would diminish.

In a survey of web use collected by Morrell et al. [16] older adults indicated that they were primarily interested in utilizing e-mail (95%), "window shopping" online (92%), checking weather reports (70%), locating coupons and special offers (57%), reading the newspaper online (56%), and obtaining health information (45%). These tasks clearly involve positioning a cursor on a menu item or hyperlink, clicking or double-clicking on the target selection, and placing the cursor inside a text box to allow data entry. Many web sites require users to enter such information as name and address, enter a password, type text into search engines, or point and click radio buttons to select options from a list. Thus, the experimental task in the conducted study was designed to be relevant to such real-life activities.

To determine the efficacy of any mode of data entry, the speed of entry and the error rate must both be taken into account. Older adults are expected to take longer than younger adults, due to the aforementioned age-related declines in motor control and coordination, in addition to effects of general slowing [20]. The question of interest then inquires whether performance differences using a light pen will still be minimized for older adults when the additional task requirement of data entry is involved. For this scenario, the user must pick up the device, point-and-click the screen target before and after each data entry, and place the device back down. Such activities require a greater amplitude movement for the light pen compared to the mouse, as the light pen must be moved from its position proximate to the keyboard to the surface of the screen. As a result, light pen efficiency with respect to speed may decrease for older adults, yet may still offer easier control, particularly when used in the non-preferred hand.

In addition to studying the efficacy of direct and indirect positioning devices for younger, middle-aged, and older adults in a task involving both pointing and data entry, performance differences with the preferred and non-preferred hand were also examined. The reason underlying the investigation of this factor is that older adults are more likely than younger adults to lose functionality of the preferred hand due to injury (e.g., musculoskeletal disorders) or disease (e.g., stroke, arthritis), and may be forced to train the non-preferred hand on tasks requiring fine motor control. Although it was expected that older adults would perform less efficiently than younger adults, and that the preferred hand would be superior to the non-preferred hand, it was considered particularly relevant to examine whether practice would interact with factors of age, hand, and device for the mixed pointing and data entry task. For instance, the age-complexity hypothesis postulates greater age differences in performance with more difficult tasks [6], and skill acquisition studies have shown greater performance gains by older adults across initial trial blocks [8]. Data could be used to provide recommendations for the type of input device to be adopted when people must switch to the use of their non-preferred hand.

Method

Design and subjects

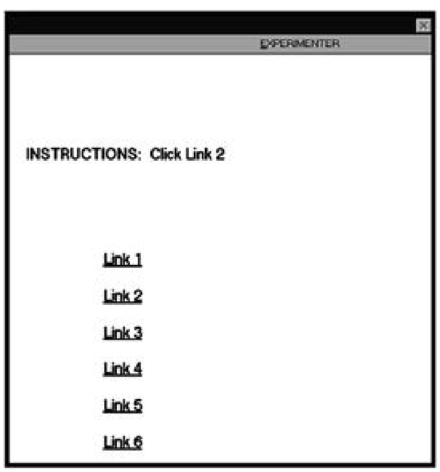
The design formed a 3×2×2×5 mixed model factorial. Age (young, middle-aged, or old) was a between subjects variable. People were selected for ages 18–25years, 45–55years, and 65–75years. Hand (preferred and non-preferred), device (mouse and light pen), and practice blocks (1 through 5) were within subject variables. Within each age group, 24 participants were presented with each of four conditions (preferred hand/mouse; non-preferred hand/mouse; preferred hand/light pen; and non-preferred hand/light pen) with the order of presentation counterbalanced across participants within age groups. All participants received five blocks of trials on each combination.

The young adults (*M*=21.7 years) were recruited from undergraduate psychology classes or the community and received either extra course credit or a stipend for their participation. The middle-aged adults (*M*=49.9 years) and older adults (*M*= 70.9 years) were recruited from the community and were paid a stipend for their participation. All were experienced mouse users in terms of the criterion of having at least 5 h of prior mouse use.

We gathered a large set of demographic and psychometric measures in two sessions that took place before the experiment as part of a larger project [*10*]. Participants were given both group-administered (session 1) and individually administered (session 2) tests of visual and auditory acuity, perception, memory, attention, and reaction time. The Grooved Pegboard (Lafayette Model 32025) test of manual dexterity was also administered in order to assess whether age-related differences in manual dexterity may mediate age-related differences in item selection and data entry performance.

Apparatus and materials

The experiment was conducted at PC workstations equipped with a FastPoint Technologies, Inc. light pen (donated by FastPoint) and a Microsoft Intellimouse mouse, a two-button mouse. The light pen was attached to a USB hub to the right of the computer for right-hand trials, and shifted to the left of the computer for left-hand trials. It has flexible cable and a clickable end point. It operates a software cursor via a device driver program that interacts with the graphics card to determine when a screen pixel is activated via the left to right and top to bottom scan pattern for the CRT. Pressing the tip of the light pen against the screen registers the equivalent of a mouse click using the device's driver. A program written in Visual C++ provided the item selection and data entry tasks using standard Windows controls such as drop down menus, point and click activation, and boxes with flashing cursor for text entry (see Fig. 1). Participants were prompted to enter password (all numeric), name (all alphabetical), and address information (alphanumeric). The controlling program also contained embedded sub-programs to measure handedness, preference and acceptability ratings, and workload.



Screen 1

Screen 2

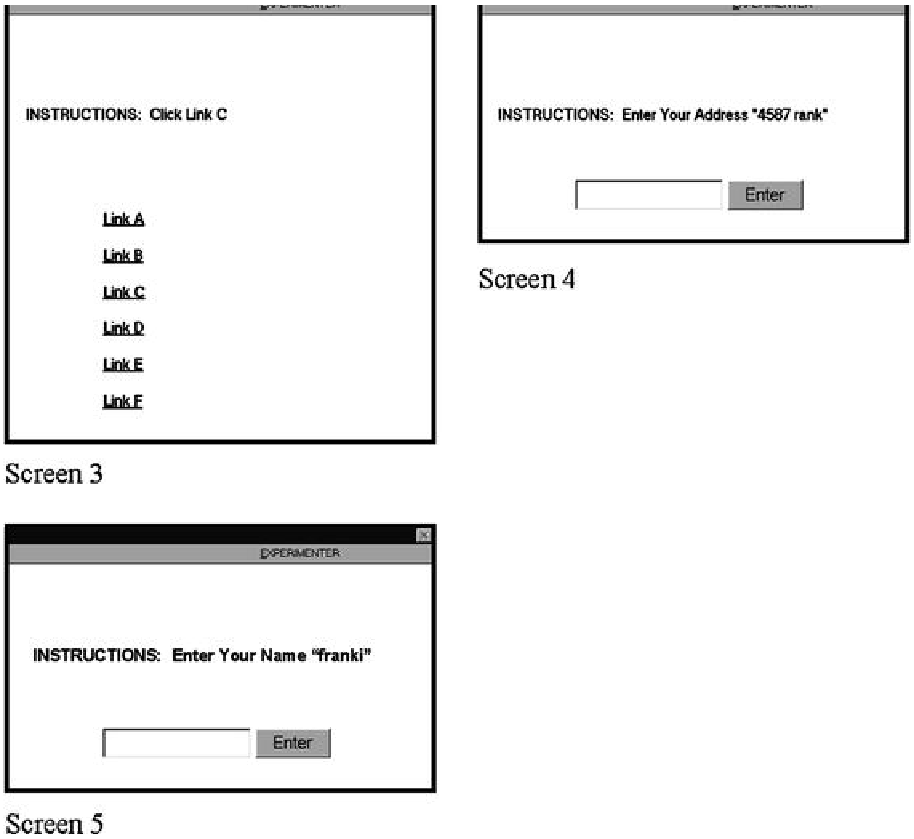


Fig. 1 Partial images of successive screen displays for the mixed pointing and data entry task

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Trials were initiated when a participant clicked on the "start" button for an initial screen that was shown maximized on a 19" Gateway VX 900 monitor set to a resolution of 1,280×1,024 pixels. That label was then replaced with a screen indicating which of six underlined words (e.g., Link 1, Link 2, Link 3, Link 4, Link 5, Link 6) was to be selected. When the correct word was clicked, the next screen provided the instruction to enter a password (e.g., 456987) and provided a text box that had to be selected in order to enter text. After entering the text, the participant clicked the Enter button to the right of the text box. The next screen again instructed the participant to click one of six underlined links (e.g., Link A, Link B, Link C, Link D, Link E), and when this was accomplished the next screen appeared instructing the participant to enter an address in a text box (e.g., 4587 rank). When the text was entered, the participant used the pointing device to click the Enter key. Response times and error data were recorded, and a message box provided trial reaction time feedback.

The Edinburgh Handedness Inventory [17] was embedded in the general experimental program and was run first to allow for quick determination of a participant's preferred hand. Two 10-point rating scales were also embedded in the program to measure "Acceptability" and "Ease of Use" of a given input device at the end of a trial block, for instance following completion of a block of trials with the preferred hand using a mouse. Finally, a workload inventory (NASA-TLX) was included in the program. A computer-administered version of the NASA TLX (Task Loading Index) Scale [15] required the participant to rate task workload on a number of dimensions. The entire task was administered, comprising two parts, paired comparison of dimensions (e.g., whether mental or physical workload was greater) as well as ratings of the degree of workload for each dimension. The combined workload rating was used in the analyses.

Procedure

Each individual experimental session began by asking participants to complete the Edinburgh Handedness Inventory. The computer scored handedness items and provided feedback (via a message box) that indicated the "preferred hand." For all but five participants this was the right hand (one younger adult was completely neutral, three middle-aged adults were left handed, and one older adult was left-handed). Next, participants were given instructions about the item selection and text entry task. Participants were told to move the cursor over the "start" button and click it, which would change START to the sequence of screens shown in Fig. 1. All participants were instructed to respond as quickly as possible. They were told that the message box located below the pushbutton would provide feedback about their performance in hundredths of a second. At this point, participants were encouraged to ask questions. If participants had no questions, they proceeded to the practice block where they practiced three trials for each condition, starting with their preferred hand. Throughout practice, message boxes instructed participants when to change the device or the hand they were using.

After practice, the main experimental trials were presented. At the end of each block participants were asked to rate the acceptability and ease of use for the particular hand and device condition on a ten-point scale. After completing five blocks, participants responded to the NASA-TLX for the hand and device condition that they just completed. This process was repeated for each of the remaining three experimental conditions. Participants were then paid for their participation and debriefed.

Results

Errors

As is the case in normal computer menu use, if errors were made before selecting the correct menu item, participants continued until the correct item was acquired. If errors were made on data entry, however, those errors were saved to file but not corrected at time of entry. Analyses of errors were conducted. An error was defined as the case where a mouse click or light pen touch occurred on a non-target item before the target item or wrong text was entered. Using analysis of variance (ANOVA), only a significant effect of device (F (1, 69)=3.6, MSE=17.9, $p<0.01$) was found, with slightly more errors for the light pen than the mouse (0.71 vs. 0.21 errors). However, such errors were very infrequent considering that participants completed 120 trials with each hand.

Target acquisition time

Analysis of variance was used to evaluate the median task completion time per screen. Medians were chosen because of the extended response times observed on some trials coupled with the small number of trials per block which made outlier trimming procedures difficult to implement. Overall, younger adults were fastest (3,257 ms), middle-aged adults were slower (4,716 ms), and older adults were slowest (6,656 ms) for the tasks. Main effects of hand, $F(1,69)=9.18$, MSE=29634540; trial block, $F(4,276)=38.85$, MSE=47685644; and age, $F(2,69)=18.52$, MSE=1395286748, were statistically significant ($p<0.05$). Three two-way interactions were statistically significant: block by age, $F(8,276)=2.95$, MSE=3625418; hand by device, $F(1,69)=6.99$, MSE=3021986; and device by block, $F(4,276)=3.1$, MSE=1877732.

However, these effects were mediated by two three-way interactions: hand by device by block, $F(4, 276)=2.91$, MSE=1974039, and age by device by block, $F(8, 276)=2.24$, MSE=1354697. The hand by device by block interaction, shown in Fig. 2, indicates that the light pen minimized differences across preferred and non-preferred hands, and revealed greater gains in both the preferred and non-preferred hand across trial block. Moreover, efficiency with the light pen in the non-preferred hand achieved equivalent performance to the mouse in the preferred hand by the end of Block 3 (*t*(142)=1.39).

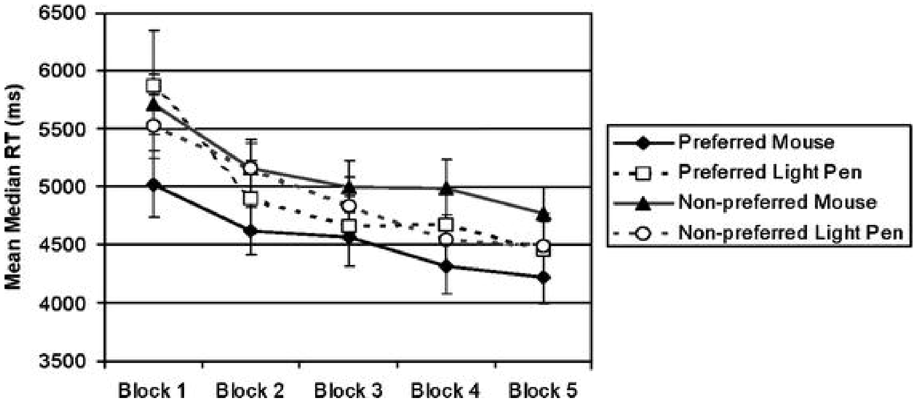

Fig. 2 Response times by hand, device, and block

The age by device by block interaction, displayed in Fig. 3, shows that older users performed worse with the light pen compared to the mouse only at Block 1 (*t*(46)=3.3) and Block 2 (*t*(46)=2.6), and hence, gained more with the light pen over trial blocks (1,850 ms) than younger (626 ms) or middle-aged (1,193 ms) groups. Other age groups showed equivalent performance with mouse and light pen at all points in practice and showed uniform gain across trial blocks.

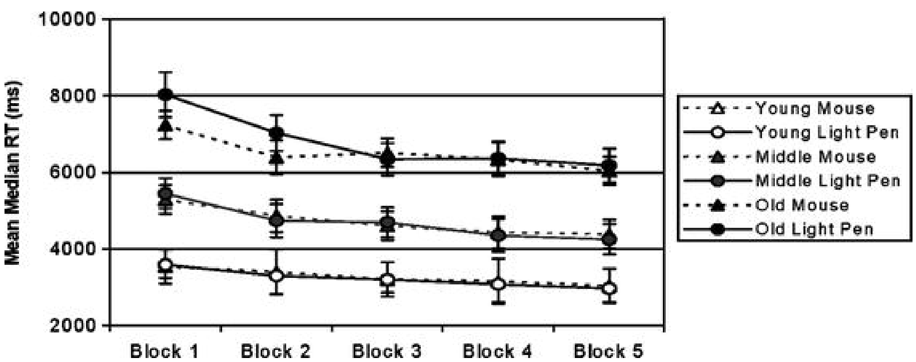

Fig. 3 Response times by age, device, and block

Analyses of data for manual dexterity, laterality of handedness, acceptability and ease of use ratings for type of device, and TLX workload indices showed no main effects of age or interactions with age so those results are not discussed here. (Previous findings in a pure pointing task indicated a preference for the mouse when using the preferred hand, but for the light pen when using the non-preferred hand [9]. This study revealed a significant interaction of hand by device (*F*(1,69)=6.89, MSE=7.39, *p*<0.02) showing that users rated the mouse as easier and more acceptable to use than the light pen in both the preferred and the non-preferred hand. This finding fits with prediction because activities associated with a mixed pointing and data entry task require a greater amplitude movement for the light pen compared to the mouse, and user satisfaction may therefore decrease.)

Discussion

This study investigated performance of young, middle-aged, and older adults on an ecologically valid computer task requiring participants to interleave two types of input devices, a pointing device and a keyboard, in order to complete an item selection and data entry task. Thus, rather than merely comparing the efficacy of a direct versus an indirect positioning device, the conducted experiment sought to test the efficacy of such devices on more complicated, realistic procedures than have been analyzed in past research. These results speak directly to operations encountered frequently in GUIs and navigating the World Wide Web. More specifically, the task that was employed mimics the procedure for completing fields in web-based forms that may require the user to select a hyperlink or radio button (e.g., male or female) or to position the cursor in a box to enter text (e.g., username, password, credit card number, search engine keywords or phrases).

This study revealed a somewhat different pattern of results than past research utilizing pure pointing tasks [*9*]. While the prior study showed a strong advantage for a direct positioning device, the light pen, over a mouse even for experienced mouse users when data entry was not involved, this study demonstrated that in mixed pointing and data entry tasks, the light pen may be less efficient than the mouse for older adults early in training. Due to the nature of the task, requiring the user to switch between the pointing device and the keyboard to successfully complete each trial, this finding was not unexpected. The mouse is close to the keyboard and requires a short travel distance to shift the cursor position on the screen. The light pen, though also close to the keyboard, must be lifted and moved a much greater distance to the screen to accomplish the same cursor movement. However, following a few blocks of practice, the light pen can achieve equivalent performance to the mouse, and may achieve superior performance in the non-preferred hand with sufficient practice.

Given that this task mimics typical web navigation and data entry (e.g., in an Internet commercial transaction), these results can provide useful guidelines for older adult users. This study may help provide estimates, as a function of age, for how much training should be expected to achieve satisfactory performance with a new input device or to control an input device with the non-preferred hand.

For instance, the results obtained indicated that older adults need to practice two full trial blocks, approximately 15 min, to achieve equivalent performance with the light pen as with the well-practiced and familiar mouse. The results also revealed that performance with the mouse in the non-preferred hand did not differ from performance in the preferred hand after the third trial block, which translates to approximately 30 min of practice for older adults. Even at the end of training, a difference of 552 ms existed between hands using the mouse. The light pen, however, required only one block of training, approximately 10 min for older adults, to achieve equivalent performance to that of the preferred hand. Given that older adults have the most to gain from practice with a device, as seen in the age by trial block by device interaction, these findings support instructing older adults to persevere with a new device. The device by hand by trial block interaction suggests that all age groups would benefit from using a light pen when forced to switch to the non-preferred hand. Further, with minimal light pen practice in the non-preferred hand, approximately 15 min, users can reach near-equivalence to performance with the mouse in the preferred hand.

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