Age Differences in Computer Input Device Use: A Comparison of Touchscreen, Trackball, and Mouse

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Age Differences in Computer Input Device Use: A Comparison of Touchscreen, Trackball, and Mouse

Ho-chuen Ng, Da Tao, and Calvin K.L. Or

Department of Industrial & Manufacturing Systems Engineering,
The University of Hong Kong, Pokfulam, Hong Kong
{hochuen,taodahuoniao,klor}@hku.hk

Abstract. This study examined age-related differences in user performance and preference with three computer input devices (mouse, touchscreen, and trackball) among older, middle-aged, and younger adults. Sixty-six participants were recruited and equally split into the three age groups. The results showed that age and input device had significant effect on task completion time and number of error. There were significant age-related performance differences in task completion time among the input devices. Ratings of users' preference indicated that the older adults preferred trackball to the mouse and touchscreen. Our findings suggest that the touchscreen could moderate only part of the age-related performance differences and conferred limited benefits to older adults. More research efforts are required to examine user characteristics, user perception on the use of the devices, and task requirements before we can determine the benefits of an input device for users in different ages.

Keywords: Age-related difference, input device, user performance.

1 Introduction

It is projected that the number of people aged 65 or older will increase from 524 million to 1.5 billion by the year 2050 worldwide [1]. This aging population is the fastest growing computer user group [2]. As the older adults are increasingly engaged in varied computer systems for social, recreational and healthcare purposes, more attention is being paid to the study of computer use by older adults, which is currently under-investigated.

One important issue facing the aging computer users is that almost any computer systems use a non-keyboard input device (e.g., mouse, trackball, and touchscreen) as one of the primary communication approaches between the users and the systems. Successful human-computer interaction may depend largely on users' ability to manipulate these input devices. However, given the age-related declines in functional and cognitive abilities, the older adults encounter many difficulties in using the devices [3]. Promisingly, the recently popularized touchscreen technology appears to hold the promise of addressing some of human-computer interaction issues related to age-dependent limitations [4]. Despite of its potential benefits, we know little about age-related differences in the use of the touchscreen compared with the use of other

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input devices. This paper presented preliminary results of a study that examined age-related performance differences with three widely used input devices: two indirect input devices (i.e., mouse and trackball) and a direct input device (i.e., touchscreen). The objective is to examine whether the touchscreen can moderate age-related performance differences, and to provide implications to optimize the selection and use of input devices for users with different ages.

1.1 Input Device Comparison

Non-keyboard input devices can be divided into direct input devices (require no movement translation between the user behavior and the device response, e.g., light pen and touchscreen) and indirect input devices (require a translation between the user behavior and the device response, e.g., mouse and trackball) [5]. Numerous studies have been conducted to compare user performance with different input devices. The majority of the empirical studies that compared mouse with other indirect input devices revealed that the mouse generally yielded superior performance in terms of speed, accuracy, and user preference, followed by the trackball [6-8]. Some early concerns also had much of an effort to examine the use of touchscreen [9]. Findings from several following studies suggested that the touchscreen appeared to confer more benefits than indirect input devices in some specific task situations [10-12]. For instance, Sears and Shneiderman found that the touchscreen yielded higher speed and fewer errors for larger size target selection in unimanual tasks compared with mouse, yet the users preferred mouse to touchscreen [10]. Forlines et al. suggested that the touchscreen outweighed the mouse in bimanual tasks performed on tabletops, while the mouse may be more appropriate for single-pointing tasks [12]. However, these generalizations and guidelines were drawn from studies where the input devices were evaluated for tasks in isolation and only by younger adults. The experience of the older adults as computer users may differ from that of the younger users when they interact with the input devices.

1.2 Age-Related Differences on Input Device Performance

Old adults are reported to have poor motion control with their functional and cognitive abilities decreased over times [3]. These changes may have negative impact on their ability to use input devices. A handful of studies examined the effects of age-related differences on mouse input performance. It was quite evident from the limited studies that the older adults experienced more difficulties in a wide-range of mouse control tasks compared with younger adults [13-15]. They committed more errors in target acquisition task [13]; yielded poorer performance in cursor control tasks [14]; and expressed higher ratings of perceived exertion after task performance [15]. A debate has since evolved with respect to the findings that the mouse, as the frequently used input device, might be problematic for the older adults.

Nowadays, touchscreen technology is becoming more available at a relatively low cost. As a direct input device, the touchscreen has many advantages over indirect input devices, such as easier hand-eye coordination, faster target acquisition, and less

cognitive demanding [5]. These advantages are expected to compensate for the limitation of other indirect input devices used by older adults [4]. A previous study suggested that a direct input device, light pen, could minimize the age-related performance differences and have generally more benefits to older adults [16]. However, it remains unknown whether the promising benefits of the light pen for older adults can generalize across other direct input devices, such as touchscreen. In addition, previous studies pointed out that direct input devices do not necessarily yield better performance in all circumstances, as they can have negative impact on computer tasks due to fatigue, inadvertent activation, or a lack of precision [5]. For example, Jastrzembski et al. compared task performance between direct and indirect input devices for different age groups [17]. They argued that the light pen yielded no superior performance than the mouse for older adults, and produced even worse performance at the first several task trials. Another study comparing task performance for a touchscreen and a rotary encoder found little benefits of the use of touchscreen by older adults [5]. Conversely, their results suggested that the task performance may be dependent on both the age of the user and the task requirements. Therefore, research efforts is needed to understand how the degree of directness of input devices and age-related differences interact with each other with regard to task performance; and how this interaction might vary upon different task scenarios.

2 Methods

2.1 Participants

Twenty-two younger (mean age=27 years), 22 middle-aged (mean age=56 years), and 22 older adults (mean age=69 years) were recruited in our study. Eligible participants were identified if they reported having normal or corrected-to-normal vision and healthy upper extremity function in a screening questionnaire. The study protocol was approved by the institutional review board of The University of Hong Kong and informed consent was obtained from all participants.

2.2 Materials and Tasks

The experiment was conducted in a university laboratory. Task scenarios were programmed using Visual Basic 2010 and performed on a Lenovo all-in-one touchscreen computer. The three input devices evaluated were a touchscreen, a trackball, and a mouse.

We designed three types of computer tasks that involved types of actions typically performed using non-keyboard input devices. Figure 1 presents a schematic representation of the three tasks. The point-and-click task asked participants to select a target square back and forth ten times between two squares on the computer screen. To select the target square, the participants needed to point to the target square (by moving the cursor with the mouse and trackball, or by using a finger) and click it (by pressing the left button on the mouse and trackball, or by pressing the target square on the touchscreen with a finger). The drag-and-drop task required participants to drag

six target squares into a fixed box at the center of the computer screen. To drag a target square into the box, the participants needed to select it and hold down the button or maintain pressure with the finger on the touchscreen until dragging the square into the box. The track-and-click task asked participants to track and click the eight squares by following a computer-generated, random sequence. The first target square in each task was indicated by yellow color. Once the participants accomplished all steps with the target square, a new target square with yellow color immediately appeared.

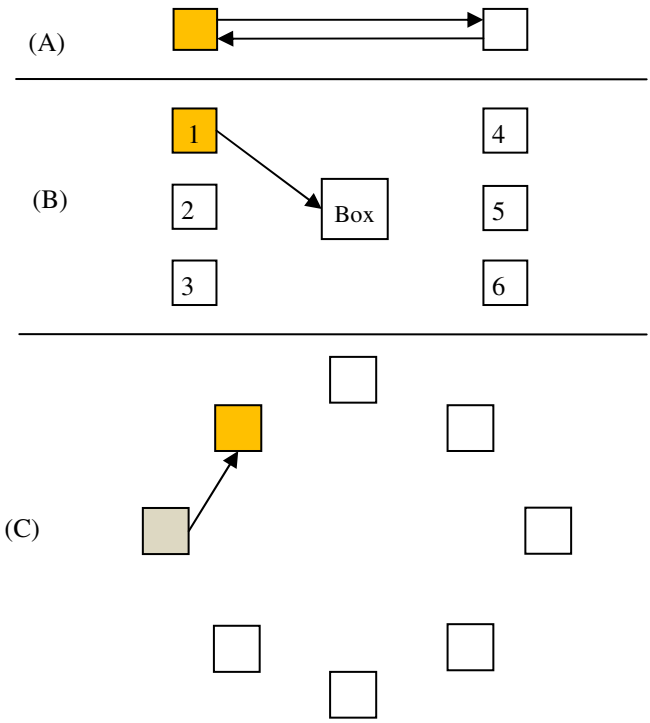

Fig. 1. Schematic representation of computer tasks: (A) point-and-click task; (B) drag-and-drop task; (C) track-and-click task

2.3 Procedures

Each participant started the experiment by signing a consent form and completing the screening questionnaire. The experimenter gave them brief instructions on how to use the input devices and how to complete the tasks. Following a brief practice session in order for them to get familiar with the input devices, the participants were presented with main experimental tasks. They were asked to click a start button on the center of the computer screen to initiate the task performance. The order of input devices and tasks were counterbalanced across participants for each age group. However,

participants completed a session of all three tasks with the same input device before they continue to use another input device. Each session lasted about 10 minutes with 3-minute breaks between the sessions. A total of approximately 40 minutes were required to complete the experiment. Participants were asked to respond as quickly and accurately as possible. After the completion of all tasks, an overall preference rating scale was administered. This scale asked participants to rank their input device preference on a 3-point scale (1 for the most preferred, 2 for the second preferred, and 3 for the least preferred).

2.4 Experimental Design

This study utilized a 2×3 mixed factorial design, with age as the between-participant variable, and input device as the within-participant variable. Dependent variables were task completion time, frequency of error, and users' preference. The task completion time referred to the total time to complete a task. Frequency of error was calculated by the number of errors made by participants in a task. Error in the point-and-click task and track-and-click task was defined as any target selection outside the actual target square, while error in the drag-and-drop task occurred when the participants failed to drag a target square into the box or drop the target during the dragging process.

Repeated measures analyses of variance (ANOVAs) were used to analyze the effects of age and input device on user performance and preference. Post hoc analyses were performed using Tukey-HSD procedure with p-value=0.05.

2.5 Hypotheses

The hypotheses shown below aimed to examine the effects of age and input device on the user performance and preference.

Hypothesis 1. The older adults will have longer task completion time and commit more errors than that of other age groups.

Hypothesis 2. There will be differences in task completion time and frequency of error among different input devices.

Hypothesis 3. The touchscreen will moderate the age-related differences on task completion time and frequency of error.

Hypothesis 4. The older adults will prefer touchscreen to the mouse and trackball.

Hypothesis 1 was based on previous evidence that the older adults encountered more difficulty in computer tasks; Hypothesis 2 was based on the nature of the difference among the input devices; and Hypothesis 3 and 4 were based on anticipated benefits of the touchscreen for the older adults.

3 Results

A total of 594 dataset (66 subjects×3 input devices×3 tasks) were collected in this experiment. Table 1 and 2 show the effects of age and input device on mean task completion time and mean frequency of error, respectively. The median for task

performance time is also presented in Table 1. The results are also illustrated graphically to facilitate interpretation of the tables. The sphericity assumption for the within-participant variable was violated. Thus, adjustment values of the degree of freedoms were applied.

Table 1. Mean task performance time (seconds) by age and input device in different tasks

	Older			Middle-aged			Young		
	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD
Point-and-click task									
Mouse	18.3	18.9	5.3	11.6	13.0	4.3	7.9	8.3	1.4
Touchscreen	8.2	9.0	2.8	7.7	8.5	2.9	5.3	5.7	1.3
Trackball	25.0	27.1	7.4	16.6	18.3	6.0	12.7	12.5	3.6
Drag-and-drop task									
Mouse	16.6	26.1	24.8	12.0	13.2	5.3	7.4	7.7	1.5
Touchscreen	16.0	18.9	7.9	10.0	13.6	9.6	8.2	9.8	4.8
Trackball	28.2	48.8	65.3	19.1	25.7	19.4	13.4	15.6	8.9
Track-and-click task									
Mouse	12.0	14.0	5.3	8.6	9.8	2.5	6.3	6.6	0.9
Touchscreen	7.4	7.3	1.8	6.4	6.7	2.0	4.3	4.7	1.2
Trackball	18.8	21.2	7.0	12.3	14.6	4.8	9.7	10.0	1.6

Table 2. Mean frequency of error by age and input device in different tasks

	Older		Middle		Young	
	Mean	SD	Mean	SD	Mean	SD
Point-and-click task						
Mouse	0.4	1.3	0.2	0.4	0.2	0.2
Touchscreen	0.3	0.5	0.1	0.2	0.2	0.4
Trackball	1.0	1.9	0.3	0.4	0.2	0.3
Drag-and-drop task						
Mouse	2.5	3.0	1.0	1.2	0.5	0.7
Touchscreen	3.1	3.0	1.8	2.9	1.6	3.6
Trackball	5.0	5.7	3.9	7.4	2.3	2.8
Track-and-click task						
Mouse	0.3	0.5	0.1	0.2	0.1	0.2
Touchscreen	0.0	0.1	0.1	0.5	0.3	0.5
Trackball	1.0	1.6	0.2	0.2	0.1	0.1

3.1 Effect of Age on User Performance

The ANOVA results indicated that there was a significant main effect of age on task completion time, $F(2, 63) = 13.931$, $p<0.001$, and on frequency of error, $F(2, 63) = 4.785$, $p=0.012$, respectively (see figure 2). Post hoc Tukey HSD multiple comparisons tests showed that the older adults were slower than the middle-aged ($p<0.01$) and younger adults ($p<0.01$), and yielded more errors than the younger adults ($p<0.5$).

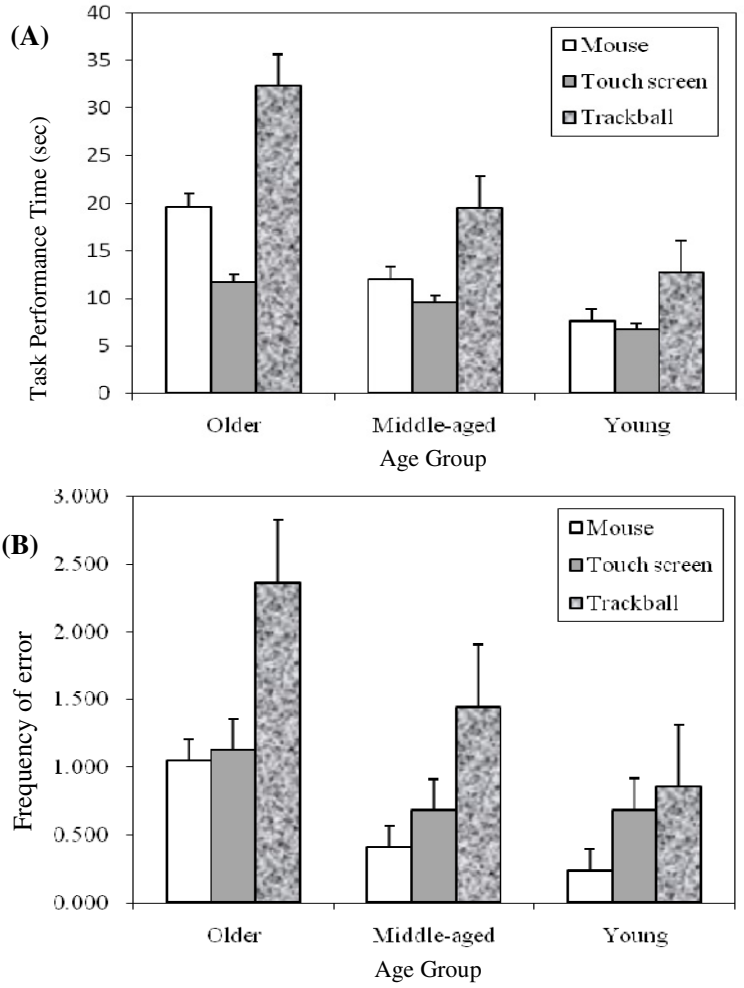

Fig. 2. Age-related differences in performance: (A) Device by age interaction for mean task completion time; (B) Device by age interaction for mean frequency of error

3.2 Effect of Input Device on User Performance

There was a significant main effect of input device on task completion time, $F(1.119, 70.482) = 43.766$, $p<0.001$, and frequency of error, $F(1.462, 92.091) = 10.478$, $p<0.001$. The touchscreen was the slowest input device, followed by the mouse and trackball (p's<0.001). Using the trackball yielded the highest frequency of error compared with other input devices (p's<0.05). The results also indicated that the interaction between age and input device on task completion time was significant, $F(2.238, 70.482) = 5.332$, $p=0.005$. The older adults had comparable speed with other age groups using the touchscreen, while they were much slower than other age groups

using the mouse and trackball (Figure 2A). The frequency of error, however, had no differences across input devices for the age groups (Figure 2B).

3.3 User Preference

Table 3 shows the distribution of the users' device preference. There were significant differences in the users' device preference among the three age groups, $F(2, 63) = 4.99$, $p=0.001$. With regard to the older adults, the trackball was most preferred (45%), followed by the touchscreen (32%) and mouse (23%). Sixty-four percentages of the middle-aged adults preferred using the touchscreen to using the mouse or trackball, while 27% of them rated mouse as the most preferred input device. The younger adults had comparably favorable preference for the mouse (45%) and trackball (45%). They also had least preference on the trackball (86%).

Table 3. Distribution of user preference by age (indicated by percentage of the participants)

	Most Preferred			Second Preferred			Least Preferred		
	Mouse	Touchscreen	Trackball	Mouse	Touchscreen	Trackball	Mouse	Touchscreen	Trackball
Older	23%	32%	45%	41%	36%	23%	36%	32%	32%
Middle-aged	27%	64%	9%	41%	23%	36%	32%	14%	55%
Young	45%	45%	10%	50%	45%	5%	5%	9%	86%

4 Discussion

This study examined age-related performance differences on the use of three input devices. This proposition was largely driven by the rapid diffusion of computer systems designed for improving older adults' well-beings in their workplace, healthcare, and personal life [3, 18]. The results from this experiment provided evidence that age-related differences and the nature of input devices accounted for the observed differences in task performance. The touchscreen could moderate part of the age-related performance differences.

Hypothesis 1, which tested the effect of age, was supported. The older adults were slower and had less accurate performance than younger participants regardless of input devices and tasks. This finding was intuitive and consistent with previous studies [13-16]. As commonly acknowledged, the reason could be largely attributed to the older adults' deteriorative abilities in spatial perception, memory, and motor skills [3]. Another reason may lie in the fact that the older adults were less educated and less experienced in computer tasks. Lack of computer knowledge and unfamiliarity with the input devices may therefore result in poor computer task performance.

Hypothesis 2, which examined the effect of input device, was supported. Our results indicated that using the touchscreen was significant faster than that of the

mouse and trackball. The touchscreen and mouse yielded fewer errors than the trackball. This findings was partly incongruent with previous studies [9, 11], reporting that the touchscreen was the fastest but the least accurate input devices. This discrepancy may be accounted by the differences in task design between previous studies and our study. For example, our study only evaluated computer tasks in a stationary environment, while Yau et al. study involved tasks in both motion and stationary situations by simulating workplace environment on a ship [11].

With regard to Hypothesis 3, the significant interaction between age and input device indicated that although the older adults were slower using the mouse or trackball, they had comparably fast speed with other age groups using the touchscreen. The result was similar to that in Charness et al. study, which suggested that the direct input device, light pen, could minimize age-related differences in task completion time [16]. The reason could be attributed to the aforementioned advantages of the direct input device, which make the devices less cognitively demanding in task performance [5]. This merit is especially beneficial to older adults who were susceptible to the age-dependent declines in cognitive ability. However, this interaction was not significant on frequency of error. Therefore, hypothesis 3 was not fully supported. It meant that the touchscreen could moderate only part of the age-related differences in task performance. One possible explanation is that more physical efforts and unnecessary body movement may be required, and more fatigue may occur when the older adults use the touchscreen. This could increase the likelihood of error commitment.

Hypothesis 4, which examined the effect of age on users' device preference, was not supported. Interestingly, although the older adults were faster and made fewer errors with the touchscreen, they preferred the trackball to other input devices. As mentioned above, the differences in users' perception on using different input devices may serve as one possible reason of this counter-intuitive result. It is true that using a trackball requires less physical efforts through rolling a ball held in a socket than that of holding and shuttling a mouse across the working area or stretching the arm to point and press the touchscreen with a finger. Moreover, the trackball is less likely to be affected by the limited range of wrist movement than other input devices. Therefore, using the trackball may reduce strains on the hand and wrist, leading to better user experience. This explanation may be confirmed by observing users' task behaviors and by assessing users' subjective perception, such as perceived exertion, fatigue, mental efforts, and ease of use in using the input devices.

5 Conclusion

This study provided new insight into the evaluation of age-related performance differences in computer tasks by examining three widely used input devices among older, middle-aged, and younger adults. The experimental results showed that older adults were likely to be affected by their age-related declines in functional and cognitive abilities, resulting in poor task performance. The results also confirmed that the touchscreen could moderate part of the age-related performance differences and

confer benefits, though limited, to older adults. However, the findings also indicated that no input device could yield universally better performance in both of user performance and user preference. The selection of input device may be largely optimized by taking the user's characteristics, their subjective perception, and the task requirements into account.

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