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Research on Interactive Device Ergonomics Designed for Elderly Users in the Human-Computer Interaction

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Abstract

In the era of aging society in China, focusing on the issue that it is difficult for elderly people to operate a variety of computing devices with the physiological and psychological changes brought by the aging, a research for ergonomics of interactive devices was put forward for elderly user groups. The research studied the performance of elderly people using the mouse, stylus and touchscreen to perform two-dimensional pointing tasks, compared with younger people, in the computer user interface by controlled experiments, measured the movement time and hit accuracy, and also investigated the subjective experience when they used the three input devices for completing two-dimensional pointing tasks. Experimental data analysis showed that elderly people spend more time than younger people to complete the pointing tasks with any of the three input devices, Fitts' law still hold when the elderly people used mouse, stylus and touchscreen to perform the two-dimensional pointing tasks, and the use of touchscreen can achieve higher performance with the target size should not less than 80 pixels (about 11.2 mm) for both elderly and younger people. Elderly people can benefit more from the touchscreen than younger people.

***Keywords**: Human-Computer Interaction (HCI); Fitts' Law; Elderly people; Ergonomics; Input device; Pointing task*

1. Introduction

China is a large country with 1.3 billion people. At the end of the 20th century, the population over 60 years old accounts for more than 10% of total population, China has formally entered the aging society[1]. Aging problem will become a very important livelihood issue and challenge, and it also brings huge opportunities. One of which is to nurture and develop the market of information technology products for the elderly people, enable them to have convenient, comfortable and colorful life. However, current information technology products have been intentionally or unintentionally designed for younger people with high computer skills, the elderly people are marginalized. Meanwhile, due to the changes and differences in physical, psychological conditions and knowledge level, elderly people often feel helpless under complex interactive environment, and have huge psychological barrier. It is difficult for them to learn seemingly simple operations for younger people[2]. Statistics indicate that about half of the elderly people (about 60 million people) have varying degrees of "technology phobia"[3] in China, they have many embarrassing problems when facing with diversified electronic device in the market, they are unable to use computer, cannot to send short message or use ATM machine. In developed countries, many retired people or people who are about to retire are well educated, and have rich computer knowledge and operational experience. Although they are technically skilled in operation, they have to face the physical and psychological changes caused by aging, such as decrease of hearing and vision, slow action, poor flexibility, reduced coordinating ability and memory decline[4]. These problems have brought difficulties for them to operate interactive

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device. In order to solve these problems, we need to figure out the problems and differences of existing interaction devices and interaction techniques designed for elderly people and younger people, analyze the differences, and make suitable device and interface design for elderly users.

In this paper, the elderly people who live in a community of Beijing are taken as research subject, the typical pointing operation in computer graphical user interface is taken as research task, common mouse, stylus and touchscreen are used as input device. The paper studies the operating performance of elderly people in using these three kinds of input device to perform desktop pointing task, explores their subjective user experience, takes younger people (undergraduates) as reference in experiment, and strive to find more suitable device and interface design elements that can meet the needs of elderly people.

2. Related Work

2.1 Definition of Elderly People

Since 1994, United Nations World Health Organization has set criteria to classify age group: people aged below 44 are younger people, people aged between 45 and 59 are middle-aged people, people aged between 60 and 74 are young-elderly people, people aged between 75 and 89 are the elderly, people aged above 90 are long-lived elderly people. In China, according to second rule of the Protection of the Rights and Interests of Elderly People: "The elderly people specified in this law refer to citizen aged above 60". According to the above criteria, we define the elderly users of our study as people who are more than 60 years old.

2.2 Introduction to Fitts' Law

Paul M. Fitts investigated the motion feature of motion time, range of motion and motion accuracy in human’s operation process, and established the famous Fitts' Law[5]. After that, many researchers in HCI made revisions over it; the common expression of Fitts’ law is Mackenzie’s Shannon formulation in (1):

$$MT = a + b \log_2 (A/W + 1) \quad (1)$$

Fitts’ law predicts the Movement Time (MT) required to acquire a target of size W at a distance A in a reciprocally pointing tasks, where a and b are empirical determined constants; $\log_2 (A/W + 1)$ represents the difficulty index of the tasks (Index of Difficulty, ID). Fitts’ Law states the linear relationship between movement time (MT) and the difficulty index of the tasks (ID): the more difficult the task is, the more time it will take.

2.3 Current Situation of Domestic and Foreign Researches

The earliest studies on various interactive device ergonomics can be traced back to 1978, and were published by Card and other scholars, who argued that the operating performance of mouse is better than joystick[6], this was the first application of Fitts’ Law in HCI field. Since then, many studies have shown that mouse is better than other input devices[7], but in the researches on the usability of input device, subjects are often younger users. The researches on the usability of input device designed for elderly users began in the late 1990s. The body flexibility and coordination of elderly people dramatically deteriorates with the increase in age[8]. Elderly people’s hands are the most important part for operation, but each joint of hands will gradually become rigid and inflexible, even shake. Therefore, they are prone to make operational errors when operating small products, especially some ingeniously designed product interfaces. Numerous studies have compared the ergonomics of users of different ages in using different input device to perform interface tasks. The results of comparative study on the using portable computer's two cursor control devices –touchpad and trackpoint to carry out pointing and dragging tasks indicate that age effect significantly affects ergonomics, middle-aged people (40-65 years old) take significantly longer time to complete the task than younger people[9]. When using two different input devices--mouse and stylus to select menu, Charness et al. found that using stylus can reduce the impact of age difference on ergonomics, the results indicate that it is more suitable for elderly people to use stylus to pointing task[10]. In addition, some researchers consider that when carrying out long-time frequent repetitive operations, it is more suitable for elderly people to use track ball than mouse[11].

Many scholars of HCI made great efforts in designing relevant interfaces about elderly people's moving skills, and created many new operating techniques. Most techniques focus on how to improve the performance of selecting target task. For example, Worden et al.[12] proposed "area cursor" (the trigger point has certain area, rather than the cursor with just one pixel) and "sticky icons" (the icon that can reduces the moving speed of cursor when cursor passes by the icon), improve elderly people's ability of locating cursor. The study found that the elderly user's efficiency is increased by 50%, and the design is also beneficial for younger people, although it is significantly effective for elderly people. Hwang et al.[13] proposed the technology to pull the object near the cursor: proxy target, its aim is to make it easier for elderly people to select various texts or icons on computer screen. Moffatt et al.[14-17] made empirical research on how elderly people, middle-aged people and younger people perform multi-dimensional click operation and select menu items, in order to find out the problems of existing interface operation techniques, and design interactive technology that is suitable for elderly users based on the analysis.

It can be seen from the above analysis that the performance of elderly people in using ordinary input device to operate computer interface is much poorer than the younger people, but the results of different researches support different input devices[18]. Besides, these researches often select old people who have experience of using corresponding input device (such as mouse) as subjects, but ignore the inexperienced subjects, and most Chinese elderly people belong to this group. In addition, previous studies mainly use mouse, stylus, trackball and other indirect input devices, with the development of computer technology, touch-control technology has gradually entered people's work and living areas, the ergonomic problem of new direct input device needs to be explored.

3. Experiment Design

3.1 Subjects

The subjects of this experiment consist of 6 younger people and 6 elderly people. Younger people are female college students aged at 22-24, their vision or corrected vision are normal, and are right-handed users. They have experience with mouse and touchscreen, but no experience in using Wacom stylus. The elderly people are 6 healthy members aged at 60-70 who are randomly selected by "Jin Hui Jia" community service center, including 5 female members and 1 male member. Their vision or corrected vision are normal, and are right-handed users. They have experience in computer use about 1-2 times each week, and also have experience in using mouse and touchscreen, but no experience of using Wacom stylus. Before officially carrying out the experiment, each subject will practice in advance, until they believe that they can officially start the experiment.

3.2 Experimental Task

The experiment task is two-dimensional pointing tasks as shown in Figure 1. When the mission starts, the center of the screen displays a black solid circle, subject uses certain input device to click the solid circle, when the circle is hit, it starts timing. Then the solid circle disappears from the screen, another hollow circle (target) appears randomly on any places of the screen. Subjects are asked to use the input device to quickly and accurately click the target. When the target is hit, the timing ends. If the target is not hit correctly, the computer will make a sound "beep", and records the error. Next, the black solid circle appears on the center of the screen again, subjects just need to repeat the above steps until the task is completed.

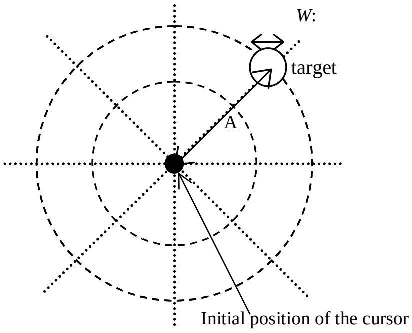


Figure 1. Two-dimensional Pointing Tasks

3.3 Apparatus

The display device used in this experiment is Microsoft Surface Pro3, the screen size is 12 inches, resolution is 2160x1440, equipped with Windows 8.1 operating system, the experimental program is developed by Java. Input device includes Logitech M215 Wireless Optical Mouse, stylus with Wacom tablet (model: PTH-451) and the touchscreen of Surface Pro3.

3.4 Experimental Parameters

In this experiment, we design 3 kinds of target distance *A* (200, 390 and 580 pixels), 3 kinds of target size *W* (40, 80 and 120 pixels); 8 directions (hereafter referred to *D*), which are top, top-right, right, bottom-right, bottom, bottom-left, left, top-left in the clockwise direction. The measurements of experiment include the average movement time (*MT*) of moving the cursor from the screen center to the targetand the accuracy of hit. The order of 3 kinds of input devices is balanced by Latin Square among the subjects. The total number of pointing in the experiment is

3 (Amplitude)x

3 (Width)x

8 (Direction)x

3 (Input Devices)x

12 (Subjects)

=2592 pointing tasks

4. Data Analysis of Younger People Experiment

4. 1 Analysis of Movement Time (*MT*)

SPSS software is adopted to make ANOVA variance analysis of *MT*, the results indicate that *MT* is significantly affected by input device ($F_{2,10}$=31.696,p<0.001), *ID* ($F_{8,40}$=116.682,p<0.001), Direction ($F_{7,35}$=3.200,p=0.01), the interaction of input device and *ID* ($F_{16,80}$=4.454,p<0.001), the interaction of input device and Direction

($F_{14,70}$=4.389,p<0.001), and the interaction of *ID* and Direction ($F_{56,280}$=1.802,p=0.001). There is no significant interaction effect of input device, *ID* and Direction (p=0.123) on *MT*.

The average movement time for touchscreen, stylus and mouse are 745.6ms, 1019.4ms and 979.1ms respectively, as shown in Figure 2. Analysis of pairwise comparison shows that the younger people spend significantly less time with touchscreen than mouse and stylus (p<0.002) in the pointing tasks, but there is no significantly difference of *MT* induced by mouse and stylus (p=0.206). Using touchscreen is 26.9% and 23.8% faster than stylus and mouse respectively. In terms of *MT*, touchscreen is the optimum choice for younger people.

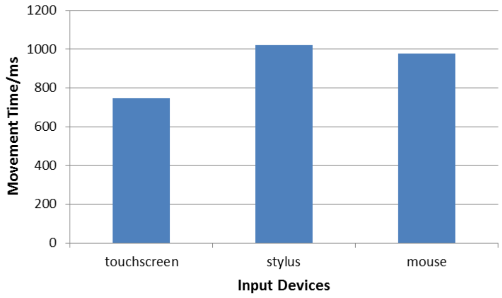


Figure 2. Movement Time with Three Input Devices for Younger People

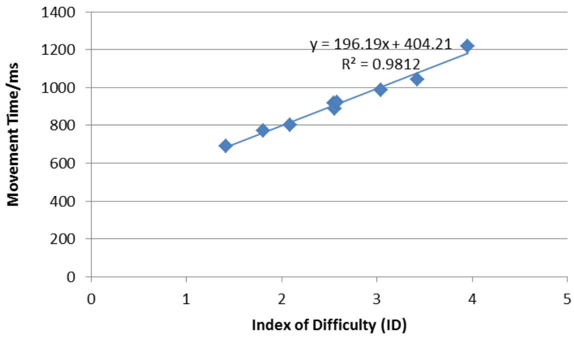


Figure 3. The Linear Regression between Movement Time and ID for Younger People

MT is linearly related to *ID* with higher fitness (R^2=0.981), which indicating that Fitts' Law is still suitable for younger users in two-dimensional pointing tasks, as shown in Figure 3.

The order of *MT* values from low to high for all directions is: bottom-left (*MT*=885.2ms), left, top-left, top-right, right, bottom, top, and bottom-right (*MT*=979.4ms). Further analysis of pairwise comparison shows that there is no significant difference of *MT* values in the top-right, right, and bottom-direction (p> 0.134), and no significant difference of *MT* in the top-left, left and bottom-left direction (p>0.074). That is, when the target is located in the second quadrant of the screen (bottom-right), it will take a long time to click the target.

The effect of directions on *MT* for different input devices is indicated in Figure 4. *MT* induced by touchscreen is smaller than that by stylus and mouse for all directions. Data analysis also found that moving direction has no significant effect on *MT* when using stylus and mouse as input device (p=0.089), that is, younger people will not be affected by the location of targets when using these two kinds of indirect input devices to perform pointing tasks; and when using touchscreen, the *MT* of bottom right is significant longer than other directions, this is because all the subjects are right-handed users, the targets appeared on the bottom right direction may be blocked by user's right hand to some degree, thereby increasing the time to find target object.

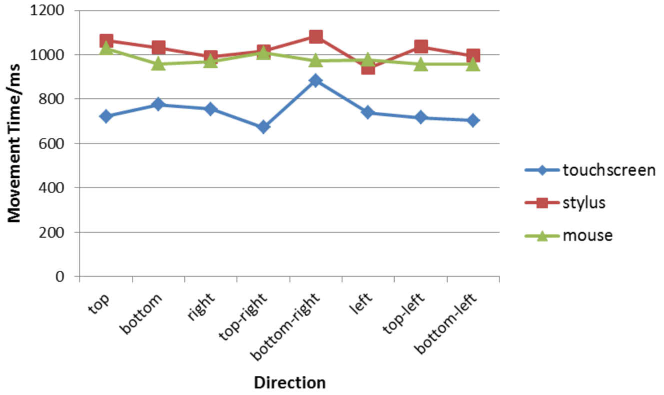
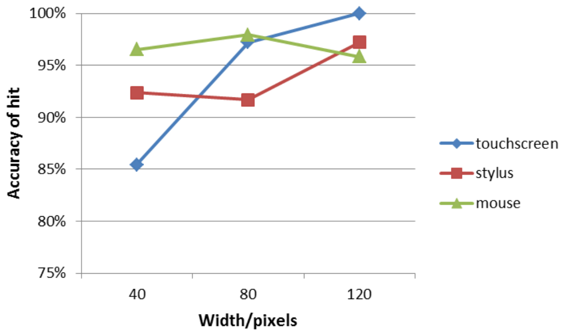


Figure 4. The Interactive Effect of Direction and Input Devices on Movement Time for Younger People

4.2 Analysis of Accuracy of Hit

ANOVA analysis shows that the accuracy is significantly affected by *W* ($F_{2,10}$=11.962,p=0.002) and the interaction of input device and *W* ($F_{4,20}$=4.921,p=0.006). There is no significant effect of input device (p=0.213), Direction (p=0.667) and *A* (p=0.293) on accuracy of hit.

There is no statistical difference in accuracy when younger people use touchscreen, stylus and mouse. The accuracy of hit is 91.4%, 95.6% and 97.7% respectively with 40, 80 and 120 pixels target width. Pairwise comparison analysis indicate that there is no significant difference in accuracy rate when *W* is 80 and 120 pixel. Since input device and *W* have significantly interactive effect on accuracy rate, we further analyze the impact of *W* on accuracy rate when using different input devices, as shown in Figure 5. When *W* is 40 pixels, the click accuracy rate of touchscreen is only 85.4%, it has no significant difference from the accuracy rate of stylus (which is 92.4%), but they are significantly lower than the accuracy rate of mouse (96.5%). When *W* is increased to 80 pixels or above, there is no significant difference between the accuracy rate of touchscreen and the accuracy rate of mouse, and their accuracy rates are higher than 96%.



Fugure 5. The Effect of Target Width on Accuracy of Hit with Three Input Devices for Younger People

5. Data Analysis of Elderly People Experiment

5. 1 Analysis of Movement Time (*MT*)

ANOVA analysis shows that *MT* is significantly affected by input device ($F_{2,10}$=20.189,p<0.001), *ID* ($F_{8,40}$=26.115,p<0.001), Direction ($F_{7,35}$=2.425,p=0.039); the interaction of input device and *ID* ($F_{16,80}$ =2.555,p=0.003)and the interaction of input device and Direction ($F_{14,70}$ =4.092,p<0.001). There is no significant interaction effect of *ID*, D and input device (p=0.910) on *MT*.

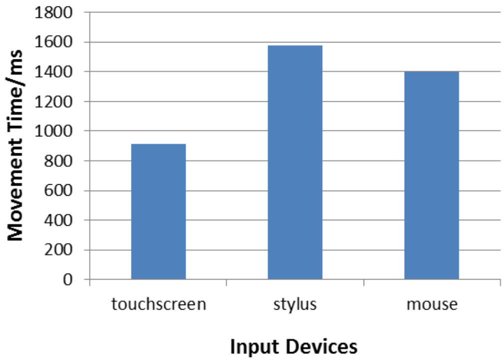


Figure 6. Movement Time with Three Input Devices for Elderly People

The average movement time for touchscreen, stylus and mouse are 912.7ms, 1576.0ms and 1397.0ms respectively, as shown in Figure 6. Analysis of pairwise comparison shows that the elderly people spend significantly less time with touchscreen than mouse and stylus (p<0.003), but there is no significantly difference of *MT* induced by mouse and stylus (p=0.215).The movement time with touchscreen is 42.1% and 34.7% faster than that with stylus and mouse respectively. In terms of *MT*, touchscreen is the optimum choice for elderly people.

MT is linearly related to *ID* with higher fitness (R^2=0.952), as shown in Figure 7. This phenomenon indicates that Fitts' Law is still suitable for elderly users in two-dimensional pointing tasks.

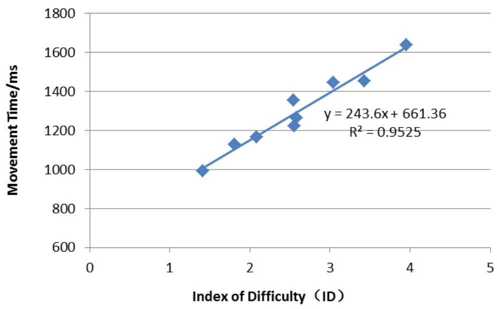


Figure 7. The Linear Regression between Movement Time and ID for Elderly People

The order of *MT* values from low to high for all directions is: right (1227.4ms), bottom, bottom-left, left, bottom-right, top-right, top-left and top (1400.0ms). . Further analysis of pairwise comparison shows that there is no significant difference of *MT* values in top-right, right, bottom-right, bottom, bottom-left and left direction (p> 0.067), and no significant difference of *MT* in top-left and top direction (p=0.274). That is, when the target is located in the first, second or third quadrant of the screen, it will take less time to click the target, but when the target object is located in the fourth quadrant of the screen, it will take a long time to click the target. In terms of *MT*, some important target can be put on the bottom-left or the right part of the interface when designing the interface, so that the operation can be done faster.

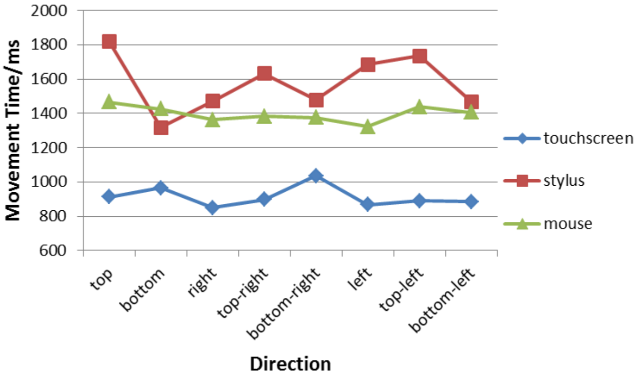


Figure 8. The Interactive Effect of Direction and Input Devices on Movement Time for Elderly People

The effect of directions on *MT* for different input devices is indicated in Figure 8. *MT* induced by touchscreen is smaller than that by stylus and mouse for all directions. *MT* induced by stylus is smaller than that by mouse only in the bottom direction. Data analysis also found that moving direction has no significant effect on *MT* when using mouse as input device ($p=0.258$), that is, older people will not be affected by the location of targets when using mouse to perform pointing tasks; and when using touchscreen, the *MT* of bottom-right is significant longer than other directions, this is because all the subjects are right-handed users, the targets appeared on the bottom right direction may be blocked by user's right hand to some degree, thereby increasing the time to find target object.

5.2 Analysis of Accuracy of Hit

ANOVA analysis shows that the accuracy is significantly affected by input device ($F_{2,10}=14.013, p=0.001$), *ID* ($F_{8,40}=13.981$, $p<0.001$) and the interaction of input device and *ID* ($F_{16,80}=10.199, p<0.001$). There is no significant effect of Direction on the accuracy ($p=0.292$). The interaction of input device and Direction ($p=0.280$), *ID* and Direction ($p=0.086$), input device, *ID* and Direction ($p=0.941$) didn't significantly affect the accuracy of hit.

The accuracy of hit for using touchscreen, stylus and mouse is 80.6%, 84.0% and 96.9% respectively. There is no significant difference of accuracy between touchscreen and stylus ($p=0.115$), which is much lower than the accuracy induced by mouse ($p<0.026$).

Since the effect of *ID* on accuracy is irregular, we further analyze the individual effect of *W* and *A* on accuracy. ANOVA analysis shows that both *W* ($F_{2,10}=20.461, p<0.001$) and *A* ($F_{2,10}=7.699, p<0.001$) significantly affect the accuracy . More interesting finding is that when the size of target is 40 pixels, *A* has no significant effect on the accuracy rate ($p=0.548$). That is, when the target object is smaller, the length of *A* will not affect the accuracy rate. When the target object is increased to 80 or 120 pixels, *A* will affect the accuracy rate to a certain degree ($p<0.001$), but *A* still has no significant effect on the accuracy rate ($p=0.102$) between 200 and 390 pixels. A longer distance of 580 pixels makes the accuracy rate have a significantly lower, but still can be maintained at 91%. In sum, the accuracy of hit increases with increasing target width and decreases with increasingly hitting distance, but the accuracy of hit is more affected by *W* than by *A*, as shown in Figure 9.

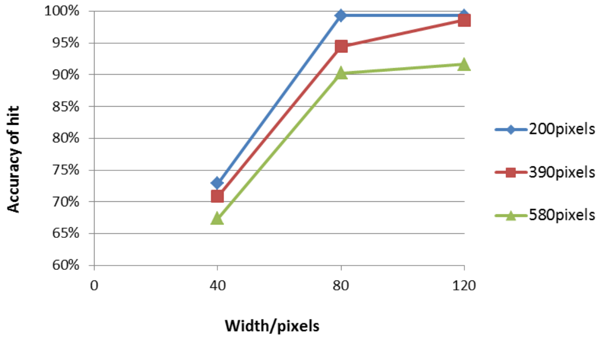


Figure 9. The Interactive Effect of Target Width and Distance on Accuracy of Hit for Elderly People

The effect of target width on accuracy of hit for the three input devices is shown in Figure 10. We can see that the accuracy of hit induced by mouse is the highest for all the target width conditions. Pairwise comparison analysis indicates that when W is 40 pixels, the accuracy of hit induced by the three input devices is significantly different ($p<0.001$) with the order of accuracy from low to high is mouse, stylus and touchscreen. When *W* becomes larger (80 or 120 pixels), the accuracy of hit induced by touchscreen is not significantly different from that by mouse ($p=0.474$), but they are significantly higher than that by stylus ($p<0.045$).

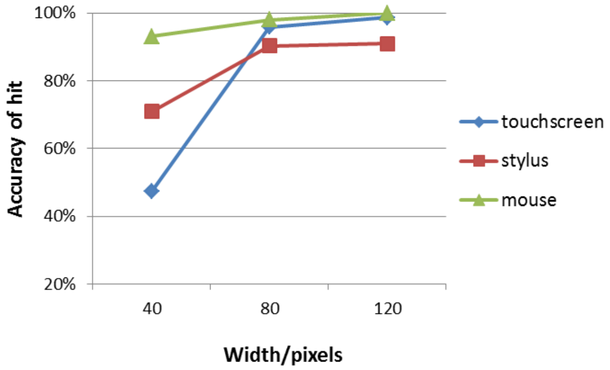


Figure 10. The Effect of Target Width on Accuracy of Hit with Three Input Devices for Elderly People

After the test, a questionnaire survey is asked to complete about which is your favorite device in the pointing tasks. All the elderly people regard the touchscreen as the easiest, fastest and comfortable device, which is consistent with the objective data analysis results.

5. Comprehensive Discussion

Combined with the experimental data of 6 elderly people and 6 younger people, the paper further makes ANOVA analysis and finds that different user groups ($F_{1,10}=26.158, p<0.001$) have significant effect on *MT*, input device and user group ($F_{2,20}=5.978, p=0.009$) have significant interactive effect on *MT*. As shown in Figure 11, no matter using what kind of input device, the *MT* of elderly people is significantly higher than that of younger people.

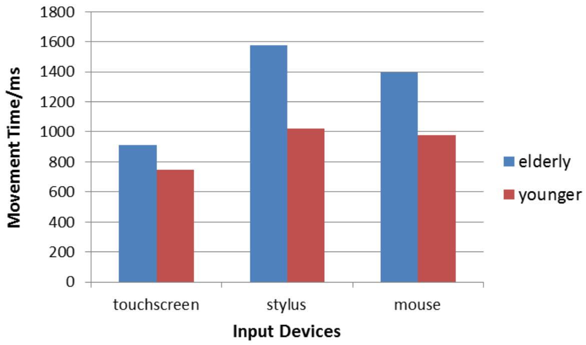


Figure 11. Movement Time between Elderly vs. Younger People with Three Input Devices

As for the two kinds of user groups, touchscreen provides the optimal operating time among the three input devices, we further compare the superiority of touchscreen to the other two input devices used by elderly people and younger people in terms of operating time, as shown in Table 1. For older people, using touchscreen is 42.1% and 34.7% faster than using stylus and mouse respectively; and for younger people, using touchscreen is only 26.9% and 23.8% faster than using stylus and mouse. Thus, elderly people can benefit more from the touchscreen than younger people.

Table 1. How Faster is the Touchscreen than the Other Two Input Devices (Elderly vs. Younger People)

Comparison between touchscreen and stylus/mouse in *MT*	stylus	mouse
Elderly	42.1%	34.7%
Younger	26.9%	23.8%

When the size of target is 40 pixels, elderly people achieve low accuracy rate when using touchscreen and stylus, and younger people can only achieve accuracy rate of 85.4% when using touchscreen, as shown in Table 2. In order to eliminate the interference of this kind of data, we further analyze users' performance when the size of target is 80 pixels and 120 pixels respectively.

Table 2. Accuracy of Hit with 40pixels Target Width

	Touchscreen	Stylus	Mouse
Elderly	47.2%	70.8%	93.1%
Younger	85.4%	92.4%	96.5%

ANOVA analysis indicates that different user groups ($F_{1,10}$=27.799,$p<0.001$) and input device($F_{2,20}$=28.040,$p<0.001$) exert significant effect on *MT*, input device and user group($F_{2,20}$=5.569,$p=0.012$) also exert significant interactive effect on *MT*. The *MT* of elderly people and younger people was 1217.2 and 842.3 ms, the *MT* of using different input devices is shown in Figure 12 and Table 3. When the interference of small target is excluded, and the size of target is adjusted to suitable size for elderly people, regardless of input device, the average *MT* of elderly people is still longer than younger people. It can be seen that elderly people cannot escape the reduced operational efficiency caused by aging even when using simple pointing operation for interaction. However, it can be seen from Table 4 that elderly people's operation efficiency increases much faster than younger people after using touchscreen, this means that elderly people can benefit more from touchscreen, they need touchscreen devices more than younger people do.

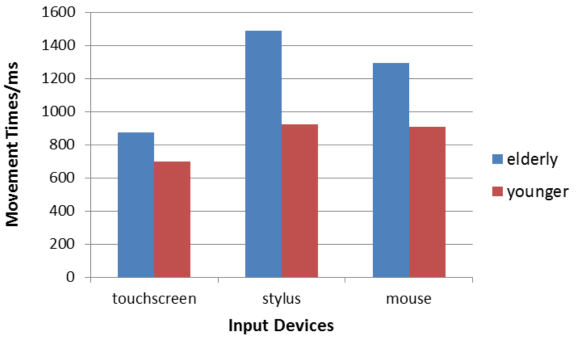


Figure 12. Movement Time between Elderly vs. Younger People with Three Input Devices without 40pixles Data

Table 3. Movement Time between Elderly vs. Younger People with Three Input Devices without 40pixles Data

Movement time/ms	touchscreen	stylus	mouse
elderly	871.9	1488.7	1291.2
younger	695.7	921.6	909.7

Table 4. How Faster is the Touchscreen than the other Two Input Devices between Elderly and Younger Groups (without 40 Pixels Data)

Comparison between touchscreen and stylus/mouse in *MT*	stylus	mouse
Elderly	41.4%	32.5%
Younger	24.5%	23.5%

Table 5. Accuracy of Hit with Three Input Devices (Elderly vs. Younger People)

	touchscreen	stylus	mouse
elderly	97.2%	90.6%	98.9%
younger	98.6%	94.4%	96.9%

When the size of target is 80 pixels or above, the average accuracy rates of elderly people and younger people are shown in Table 5, the accuracy rate of elderly and younger people in using touchscreen reaches the same level of using mouse, and exceeds the effect of using stylus.

6. Conclusion

The paper makes a comparative study on operating performance of elderly users and younger people in using three kinds of input device to perform two-dimensional-pointing operation and their subjective user experience. The analysis results of experimental data indicate that the interactive behaviors of younger people and elderly people are in line with Fitts' law. Generally speaking, elderly people take a longer time to complete such simple pointing operation task than younger people do, no matter what kind of input device they use, even if the size of target is 80 pixels or above. Thus, elderly people cannot escape the reduced operational efficiency caused by aging. Compared with indirect input devices such as stylus and mouse, touchscreen is a better choice for both younger people and elderly people, and touchscreen can greatly reduce the operating time of elderly people than that of younger people, elderly people can benefit more from touchscreen, they are in much urgent need of touchscreen devices than the younger people.

The size of target object has significant impact on accuracy rate, under the minimum width of target set by the experiment (40 pixels), the click accuracy rate of elderly people in using mouse has slightly high rate of 93.1%, the click accuracy rate of using stylus and touchscreen is very low, and is 70.8% and 47.2% respectively; however, when the size of target object is increased to 80 pixels or above, the click accuracy rate of touchscreen is quickly upgraded to a level comparable with mouse, even higher than using stylus, and there is no significant difference between younger people and elderly people. In the designing of user interface, therefore, the target size should not be less than 80 pixels (approximately 11.2mm). The use touchscreen can achieve good performance, but designer should take into account the fact that users' dominant palm will block some areas when using finger to touch the computer interface. Further research will involve wide investigation on more elderly users, more types of touch devices, as well as the availability and ergonomics of various gestures for elderly users.

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