Holzinger, A., Höller, M., Schedlbauer, M. & Urlesberger, B. (2008). An Investigation of Finger versus Stylus Input in Medical Scenarios. ITI 2008: 30th International Conference on Information Technology Interfaces, June, 23-26, 2008, Cavtat, Dubrovnik, IEEE, in print.

An Investigation of Finger versus Stylus Input in Medical Scenarios

Andreas Holzinger, Martin Höller
Research Unit HCI4MED, Institute of Medical Informatics, Statistics and Documentation
Auenbruggerplatz 2/V, A-8036 Graz
andreas.holzinger@meduni-graz.at

Martin Schedlbauer
University of Massachusetts
Lowell, MA 01854
mschedlb@ cs.uml.edu

Berndt Urlesberger
Department of Neonatalogy
Graz University Hospital
Auenbruggerplatz 2/V, A-8036
berndt.urlesberger@ meduni-graz.at

Abstract. *An in-situ study on the routine work of clinicians at Graz University Hospital was carried out in order to evaluate the input method preferences. We conducted several experiments consisting of selection tasks on two different types of tablet PCs, with the end users in three experimental conditions: sitting, standing and walking. The results show that the medical staff performed better when using stylus operated device. In almost all tests, subjects performed the selection tasks significantly faster and more accurately ($p < 0.001$) with the stylus operated device, even though it had a smaller screen and therefore the targets were smaller. The only exception was the selection performance when seated, where no significant difference was found ($p = 0.06$). However, the error rate was significantly lower for stylus input for all experiment conditions. This result is also supported by the analysis of the questionnaires, where it was found that almost all subjects preferred stylus input.*

Keywords. *Human performance, input device evaluation, medical workflows, touch selection, tablet PC*

1. Introduction

The importance of Information Technology (IT) in health care is growing rapidly. However, the daily interaction with computers in health care is not widely *accepted* yet by medical professionals. Most computers in hospitals are stationary PCs or laptops carried on ward round trolleys and are operated with mouse and keyboard. Current software for use in health care (*e.g.*, patient documentation systems) is designed to be used with indirect pointing devices, such as a trackball or mouse.

Recent technical improvements in the field of touch sensitive screens, miniaturization, lower power consumption and longer battery life have made it possible to design and produce better mobile computers and tablet PCs.

The usage of such portable and lightweight devices will become more and more common in the medical domain in the future and, consequently, aspects of Human–Computer Interaction and Usability Engineering (HCI&UE) are of growing relevance in the process of user interface design for medical software [4]. Few clinicians are expert computer users, consequently, the operation of a mobile device must be as easy and as intuitive as possible, so that the medical professionals are able to focus on their patients. User interfaces intended for use during standing and walking requires additional consideration with regard to design [10], [11].

2. Background

There are several interaction models that allow user interface designers to determine task completion time and accuracy based on the layout and geometry of controls. Models have been proposed by, among others, MacKenzie *et al.* [9] and Schedlbauer [11]. The effect of posture on the user's performance has been addressed by Schedlbauer *et al.* in [10]. The results described in [11] by Schedlbauer and in [8] by Lin *et al.* show that using a stylus as the input method while walking is acceptable. The aspect of screen coverage by the hand in conjunction with the user's handedness (dextrality) is another important factor to consider when designing user interfaces. These issues have been addressed, *e.g.*, by [1], [2]. Issues of designing touch screen interfaces in medical contexts have been researched by Holzinger *et al.* [3], [6], [7].

3. Material and Methods

3.1 Test Devices

The devices used within the tests were tablet PCs with a resolution of 1024x768, running Microsoft Windows XP Tablet PC Edition.

The first one was a Motion C5 (see Fig. 1), which is a stylus operated (only) tablet PC specially designed for applications in professional healthcare environments such as hospitals. The C5 has a 10.4" LCD screen (211x158 mm), a 1.2 GHz Intel Centrino processor, 512 MB of system memory and a weight of 1.5 kg. For our experiments we used the first C5 available in Europe.

Figure 1. Motion C5 tablet PC

The second device was a Motion LE1600 (see Fig. 2), which can be operated with a stylus or finger. In our experiments it was used for finger touch tests only. The LE1600 has a 12.1" screen (246x184 mm), a 1 GHz Intel Centrino processor, 512 MB of system memory and a weight of 1.4 kg. A possible confounding variable is obviously that both devices are not exactly the same size and weight, however, this was not perceived negatively by the test subjects.

Figure 2. Motion LE1600 tablet PC

3.2 Participants

Test subjects included N = 7 medical doctors and M = 5 nurses, all female and between the ages of 22 and 53 years. Two of the subjects were left-handed (see table 1).

Table 1. Overview of subjects

Subject	Age	Profession	Handedness
1	22	Doctor	right
2	33	Doctor	right
3	42	Nurse	right
4	30	Nurse	right
5	53	Nurse	right
6	50	Nurse	right
7	34	Doctor	right
8	26	Doctor	right
9	49	Doctor	left
10	41	Doctor	right
11	51	Nurse	right
12	49	Doctor	left
Average	**40**		

3.3 Experiments

Each test subject was asked to complete a questionnaire before and after the experiments, designed to gather general demographic data including age, gender, profession, handedness. Additionally, the subjects were asked about their currently preferred input method for computers (mouse, stylus, or finger) and whether, in their opinion, the use of a mobile computer would be practical in daily clinical work. An approximate translation of the original German questions is:

1) How good are you with computers? (Basic computer literacy)
2) Have you ever used a finger operated touch screen? (Touch experience)
3) Have you ever used a stylus operated touch screen? And if yes, then:
4) Which input method do you prefer?
5) In your opinion, does it make sense to use a mobile computer in daily clinical work? (Opinion, Acceptance, Expectations)

Question 1 had to be rated from 1 to 5 (equivalent to A to E), according to the Austrian grading system, with 1 being the best. Questions 2, 3 and 5 had to be answered with yes or no. In question 4, users selected mouse, stylus or finger. Question 5 allowed free text.

Figure 3. Subjects carrying out experiments

Procedure

Three experiments similar to the experiments described in [14], were conducted on both test devices; the C5 device was operated with stylus input, while the LE device was operated with finger input. Each experiment consisted of four blocks with different circular target sizes, ranging from 15 pixels to 60 pixels in diameter. In each block, subjects had to do 20 trials, which consisted of hitting a home area in the center of the screen and then hitting a target appearing at a random position on the screen. The subjects were instructed to hit the targets as fast and as accurately as possible. Times were logged between hitting the home area and the target. All tests took place in the hospital environment.

Each subject went through all three experiments with both modes of input: finger and stylus. Photos of the subjects carrying out the experiments can be seen in Fig. 3. The software package *MTE* developed by Schedlbauer [14] was used to design and carry out the experiments and to analyze the data.

Before each experiment, the subjects received a short introduction by the test facilitator. The subjects were given a warm-up block with 30 trials to accustom them to the application. The results of the warm-up trials were not recorded. After the warm-up, the subjects had to carry out the four different test blocks with increasing target sizes in each block. Between test blocks, subjects were allowed to rest for a short time to avoid fatigue.

Experiment 1: Sitting

This experiment was a simple, standard aiming task, similar to selecting a user interface control such as a command button or menu choice. While *seated*, the subject had to hit differently sized targets appearing at random positions on the screen, as fast as possible.

Experiment 2: Standing

In this experiment, the application was repeated while the subject were required to remain in a standing position. The intention of experiments 1 and 2 was to gather baseline data for basic evaluation of the devices and input methods and also for further comparison with the results of more complex tasks.

Experiment 3: Walking

Finally, the subjects had to walk slowly while carrying out the aiming tasks described in experiment 1. With this experiment, we wanted to test how big user interface elements on the screen have to be so that the user is able to walk around and focus on the environment and simultaneously operate the computer. This is a very common scenario in a healthcare environment (e.g., ward rounds).

After going through all three experiments on both devices, the subjects were asked to fill out another questionnaire in order to ascertain changes in their opinions. Additionally, the subjects could provide positive and/or negative comments for both devices. The following post-experiment questions were asked:

1) Which input method do you prefer *now*?
2) Does it *now* make sense to use a mobile computer in your daily clinical work?
3) Which device is more suitable for your clinical work?
4) How good were you with the stylus?

5) How good were you with the finger?

In question 1, subjects could select from mouse, stylus and finger. Question 2 had to be answered with yes or no. In question 3 the C5 or the LE1600 device had to be selected. Questions 4 and 5 had to be rated from 1 to 5, with 1 being the best. Additional comments were requested.

4. Results

Statistical significance was assessed using two-tailed *t*-tests with an *alpha* (*p*) of 0.05. All collected data samples were used; no outliers were removed.

4.1 Experimental Results

In almost all tests, subjects performed the selection tasks significantly faster and more accurately ($p < 0.001$) with the stylus operated device, even though it had a smaller screen and therefore the targets were smaller. The only exception was the selection performance when the user was sitting down, where no significant difference was found ($p = 0.06$). However, the error rate was significantly lower for stylus input under all experimental conditions.

The mean Error Rate (ER) and mean Movement Time (MT) across all three experiments can be seen in figures 4 and 5. There is a marked increase in both movement time (selection performance) and error rate (accuracy) in experiment 3 – selection while walking. Subjects found it difficult to perform the tasks while walking; the motion of the tablet PC and the increased attention that has to be paid to avoiding obstacles caused a substantial decrease in selection accuracy. Table 2 shows the mean error rates by target size and input method averaged across all three experiment conditions. Clearly, stylus input is more accurate for all conditions: sitting, standing, and walking.

Interestingly, selection performance as measured by mean movement time was only significantly different for the smaller target sizes. For target size 60*px*, no significant difference was observed, which implies that once the target size reaches about 12*mm*, it can be easily touched under all conditions. The same is true for accuracy.

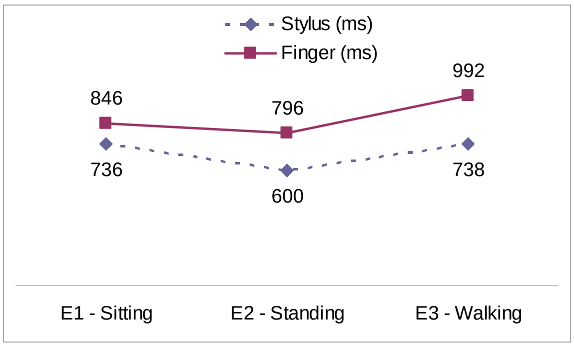

Figure 4. Mean movement time across all experiments for each mode of input

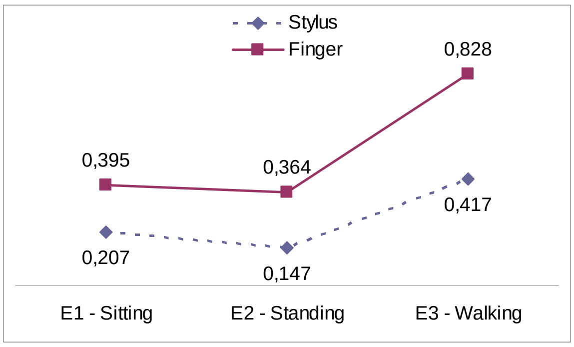

Figure 5. Mean error rate across all experiments for each mode of input

Table 2. Mean error rates by target size across all experiment conditions

Target size	Finger	Stylus
15 *px*	1.47	0.80
30 *px*	0.36	0.11
45 *px*	0.16	0.04
60 *px*	0.12	0.08
all	**0.53**	**0.26**

Detailed analysis of selection accuracy revealed that for the smallest target size of 15*px* (about 3*mm*), the error rate ranged from 88.6% for finger and 39.5% for stylus when standing to 230% for finger and 131% for stylus when walking, making such tiny targets essentially unhittable. Selection accuracy did not reach an acceptable value with a target size of less than 45*px* (9*mm*), where is ranged from 19.1% for finger and 2.3% for stylus when standing and 22.3% for finger and 5.5% for stylus when walking.

4.2 Differences between Nurses and Doctors

During the experiments, we discovered a difference between the behavior of medical doctors and nurses. The doctors seemed to be genuinely interested and very enthusiastic about the experiment, the devices and the influences of using such devices in their daily work. Most of the nurses on the other hand expressed resentment and displeasure and seemed to be disinterested before the experiment.

4.3 Usage of Tablet PCs

After the first questionnaire the doctors were skeptical about the daily use of mobile computers. Only two doctors said it would make sense to use tablet PCs. After the experiments the opinions about the use of tablet PCs had changed among the doctors so that only two of them retained their negative opinion and the rest thought that it would make sense to use mobile computers on a daily basis in a hospital.

4.3 Preferred Input Method

Before the experiments, all but two subjects preferred the mouse for controlling a computer. This changed significantly after they worked with our test devices, when nine out of twelve subjects preferred the stylus. All nurses preferred the stylus. Two doctors still preferred the mouse and one doctor switched from mouse to finger.

4.3 Device Preference

In the second questionnaire, ten out of twelve subjects preferred the stylus operated C5 over the LE1600 for usage in a clinical environment, although almost all subjects complained about its weight. The general opinion was that carrying a tablet PC for two hours during ward rounds would be unacceptable. Some subjects were already fatigued and felt pain in the arm after the rather short experiments, which lasted for about 40 minutes per subject.

The C5’s stylus is attached to a string on the right side of the device. This caused handling problems for the two left handed subjects who had to fiddle with the string.

One nurse had concerns about hygienic issues arising with the use of the finger operated LE1600. The hands are more exposed to germs than other parts of the skin. So every user leaves bacteria on the touch screen. While the C5 is built for clinical use, it is not sure whether the treatment with disinfectant on a regular basis would damage the LE1600.

The subjects' cited better reaction time and better accuracy as the main reasons for preferring the C5 to the LE1600.

5. Discussion

The experimental results clearly show that the stylus is superior to the finger as an input device because it is faster and more accurate. This is an important consideration when designing user interfaces for real-world mobile application, particularly those used in health care environments. Most subjects experienced substantial problems during experiment 3 (walking). As shown, performance and accuracy suffered, particularly for targets less than 9*mm* in diameter.

According to MacKenzie [9], an error rate of about 4% is acceptable. This error rate is only achieved by the stylus at a target size of 45 pixels or larger, which is equivalent to about 9*mm*.

Another interesting insight is the change of the subjects’ opinions about using a tablet PC on a daily basis in clinical work and the change of the preferred input method after conducting the experiments. After the experiments, mobile computers became acceptable and the stylus was the preferred mode of input.

6. Conclusion

After analyzing the tests conducted by the subjects, it became clear that using a stylus is faster and more accurate than using finger touch. This was not anticipated before the investigation and was contrary to previous studies with patients, especially older patients ([3], [5], [7]). The answers given by the subjects in the questionnaires also support this result. With few exceptions, the introduction of mobile applications on tablet PCs would be accepted by the participants of this study.

Taking into account other factors, such as hygienic issues and device specific features, we can conclude that a stylus operated tablet PC is preferable to a finger operated device in a professional medical context.

7. Acknowledgements

We thank the medical professionals of the Department of Neonatology at the Graz University Hospital for taking part in the experiments of this study; since this was during their ordinary shift it was definitely a strain on them. Our thanks to the anonymous reviewers for their valuable comments.

8. References

[1] Bieber, G., Rahman, E. A. A. and Urban, B., *Screen Coverage: A Pen-Interaction Problem for PDAs and Touch Screen Computers*, *Third International Conference on Wireless and Mobile Communications ICWMC 2007*, 2007, 87-92.

[2] Hoffmann, E. R. and Sheikh, I., *Finger width corrections in Fitts' Law: Implications for speed-accuracy research*, Journal of Motor Behavior, 24 (1991), 259-262.

[3] Holzinger, A., *Finger Instead of Mouse: Touch Screens as a means of enhancing Universal Access*, In Carbonell, N. and Stephanidis, C., eds., *Universal Access, Theoretical Perspectives, Practice, and Experience. Lecture Notes in Computer Science Vol. 2615*, Springer, Berlin, Heidelberg, New York, 2003, 387-397.

[4] Holzinger, A., ed., *HCI and Usability for Medicine and Health Care: Third Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, USAB 2007 Lecture Notes in Computer Science (LNCS 4799)*, Springer, Berlin, Heidelberg, New York, 2007.

[5] Holzinger, A., *User-Centered Interface Design for disabled and elderly people: First experiences with designing a patient communication system (PACOSY)*, In Miesenberger, K., Klaus, J. and Zagler, W., eds., *Lecture Notes in Computer Science. Vol 2398*, Springer, Berlin et al., 2002, 34-41.

[6] Holzinger, A. and Errath, M., *Mobile computer Web-application design in medicine: some research based guidelines*, Universal Access in the Information Society International Journal, 6 (2007), 31-41.

[7] Holzinger, A., Sammer, P. and Hofmann-Wellenhof, R., *Mobile Computing in Medicine: Designing Mobile Questionnaires for Elderly and Partially Sighted People, Springer Lecture Notes on Computer Science LNCS 4061*, Springer, Berlin, New York, 2006, 732-739.

[8] Lin, M., Goldman, R., Price, K. J., Sears, A. and Jacko, J., *How do people tap when walking? An empirical investigation of nomadic data entry*, International Journal of Human-Computer Studies, 65 (2007), 759-769.

[9] MacKenzie, S., *Movement time predictions in Human-Computer Interfaces, Readings in Human-Computer Interaction, 2nd Edition*, Morgan Kaufman, Los Altos (CA), 1995, 483-493.

[10] Schedlbauer, M. and Heines, J., *Selecting While Walking: An Investigation of Aiming Performance in a Mobile Work Context AMCIS 2007*, 2007.

[11] Schedlbauer, M. J., Pastel, R. L. and Heines, J. M., *Effect of Posture on Target Acquisition with a Trackball and Touch Screen, 28th International Conference on Information Technology Interfaces (ITI)*, IEEE, Cavtat, Croatia, 2006, 257-262.