The Effect of Vibrotactile Feedback on Novice Older Adults in Target Selection Tasks

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Abstract. In this study, older adults are examined as computer users, their characteristics and problems they are facing with computer systems are described; utilization of vibrotactile feedback mouse in graphical user interfaces is proposed to enhance their computer usability experience. An original Fitts experiment variation with 9 participants (mean age 69.67), who are novice computer users without any health related issues which may interfere with performance, has been done and the results of 2880 trials were analyzed. Results indicated that in vibrotactile mode, subjects completed the tasks faster (60%) and increased their target selection performances measured by Fitts' index of performance (43%, $p<0.05$).

Keywords: Human computer interaction, older adults, Fitts' Law, vibrotactile feedback.

1 Introduction

As relative population of elderly citizens is steadily rising particularly in developed countries [1, 2], governments indicate a strong tendency to transfer public services to the electronic platforms, to be accessed through computers, as much as possible to reduce operational public service costs and to increase accessibility to services offered [3]. Since the segment of older computer users are broadening fast [4] and most of the computer systems are not suitable for the older computer users [5], we directed our focus towards senior adults as computer users and identified their barriers in computer usability. To enhance their usability experience, we have revisited and implemented a vibrotactile feedback solution.

1.1 Older People

Examining older people in a scientific way has been a tough issue since population is highly heterogeneous. Besides, it is not always possible to find significant correlation between age, mental condition and physical condition [6]. On the other hand, older people are very likely to have at least one chronic disease such as hypertension, arthritis, diabetes, various cancer types and all kinds of heart problems [7]. Health problems developed as years past can cause elderly to run into various problems, impairing or blocking their daily life activities such as accessing communication tools, going for shopping etc.

M.M. Robertson (Ed.): Ergonomics and Health Aspects, HCII 2011, LNCS 6779, pp. 171–179, 2011.

Specified characteristics of older users can be listed as follows: They are less experienced compared to younger ones [8]. They are not quick learners [9]. They have weak working memory and motor skills [10]. They experience vision loss [11]. They feel hesitation when it comes using technology [12]. On the other hand, if the technological tool they are to use is not expensive and is highly usable, they can overcome this hesitation in time [13]. Senior users are members of the fastest growing computer user segment [4].

1.2 Computer Usability Problems of Older Adults

The loss of flexibility, limited motor skills, vision problems, weak memory and cognition compose a grup of barriers against older people when they are considered as computer users. Mead et al. [14] compared the performances of young and older users with different experience levels on a university library on-line search application and stated that young ones had better performance than olders. Mead et al. also reported that computer experience is a significant factor affecting the task completion success of olders in a positive way. Fisk et al. [15] reported that older users spend more time than younger ones do during the visual display processing. The cause of this relatively slow processing may be attributed to age related defects on sight and cognition. Due to impaired manual dexterity through normal aging process, older users usually have difficulties with standart input devices such as keyboard and mouse [16]. Being away from common computer concepts is a primary obstacle for the senior adults. They face problems in comprehension of user interface conventions due to their lack of contextual knowledge [15]. Janicki concluded that older users have difficulties when it comes to understanding technical terminology [17].

Understanding task model and, even it is understood, translating the model into the sequential activities is usually problematic for older users [18], since information processing ability declines through the years [19]. Hanson [20] examined older subjects regarding to their accessibility levels to Internet and reported obstacles that are possible to be overcomed by re-designing browsers and web applications for elderly. Several design principles are strongly recommended by government agencies for making computer applications more usable by seniors [21]. Those principles are clearly addressing age related deficiencies on vision, perception, cognition and motor functions. Some studies made it clear that special design for older users is absolutely beneficial. Worden et al. [22] conducted a study with experienced and novice group of older and young subjects, and mesured their performance on pointing tasks by using specially designed mouse area-cursor and sticky icons and reported that olders are slower than youngers but older people got 50% faster in completing the tasks by using area-cursor and sticky icons compared to their timings with standard cursor and icons. In Cybrarian project [6], *user sensitive inclusive design* principles are used for developing a special web browser and an e-mail client for older people and it is reported that seniors performed better with specially designed tools.

Using the mouse is a major barrier for older people. The users with motor skill problems produced 10% more error rates in pointing tasks [23]. Keates and Trewin [24] measured the effect of age and Parkinson disease on pointing and clicking tasks with 24 subjects and reported that olders and subjects with Parkinson disease recorded much longer task completion times than younger ones. Furthermore, it was revealed that older ones were moving the mouse in a very special way as they were drawing the cursor near target haltingly and they wait significantly longer for target validation before clicking. Those strategies developed are showing that seniors are likely to make effort for being able to use the mouse successfully. After a three years long broad study, Sayago and Blat [25] stated that older people experience difficulties while using the mouse and they use keyboard for assisting the mouse on pointing and selection tasks. As using the mouse requires sensitive muscle coordination and agile actions like clicking, which require strong motor abilites and clear vision, olders are likely to have difficulties in pointing and selection tasks by using that tool.

The literature on the computer usability problems of older people emphasize that mouse is a very problematic device for them. Interpreting and processing the standard visual positional feedback from the mouse is a challenging issue for older people due to usual aging problems on motor skills, sight and perception. According to the multiple resource theory by Wickens [26], producing feedback to be processed by different cognitive resources may result in enhanced performance due to the parallelism. Using the mouse with multi modal feedback is examined well by several parties. Akamatsu and MacKenzie [27] measured the effect of tactile, force feedback and combination of tactile and force feedbacks with 12 subjects. It is stated that using tactile feedback and the combination of tactile and force feedbacks are beneficial for subjects compared to normal feedback mode. Jacko et al. [28] showed that having multi modal feedback results in performance gain on drag and drop tasks assigned to older adults. Emery et al. [29] examined the multi modal feedback effects on drag and drop tasks designed for the older adults and they noted that haptic feedback must be combined with other feedback modes since “the age dependent degeneration of the peripheral nervous system common in individuals 40 years and older, older adults may be less sensitive to haptic feedback”. The subjects of this experiment were grouped into three levels of computer experience so that the interrelations between the feedback modes and experience could be isolated. Results revealed that experienced group performed well with double and triple feedback modes but less experienced groups could not take the advantage of triple feedback mode. The automation of motor skills [30] may result in the higher cognitive resources left for processing new and extra ordinary feedback signals coming from the mouse as experienced users are completing most of the actions taken for task completion without making any effort but novices are not. Fraser and Gutwin [31] indicated that “redundant targeting feedback can improve the usability of graphical interfaces, both for low-vision users and also for normally sighted users in visually stressed environments”. Cockburn and Brewster studied the effect of different combinations of multi modal feedback modes [32] and they stated that “all feedback modes reduce targeting times” after examining non-speech audio; tactile; and pseudo-haptic sticky feedback on small target acquisition tasks.

2 Hypothesis

In the same direction with previous research, suggesting a positive effect of multi modal feedback on pointing tasks, it is proposed that the novice older computer users would show better performance in completing the target selection tasks while they are using the pointing device in vibrotactile feedback mode.

3 Method

3.1 Subjects

The experiment took place with the participation of 9 right handed male volunteers who were living in the nursing home belonging to the Social Services Department of Istanbul. Volunteers' ages were ranging from 63 to 81 (Mean Age=69.67, σ=5.12). Only 2 out of 9 subjects were familiar with computers: First was using his laptop for 2 years and the latter was experiencing computer usage for 18 months on his personal computer. This experiment was the first contact with computers for the rest of the participants. None of the participants was having any chronic mental or physical diseases that may affect their computer usage in a negative way; they all were considered as normal, healthy older persons by the responsible specialists of the nursing house.

3.2 Design

Participants were asked to complete a simple target selection task by using the mouse in normal and vibrotactile feedback modes after a warming up session of 5 minutes. 4 different blocks of clicking tasks in 2 different axes (horizontal & vertical) were prepared. Each block was having 20 repeating clicks. It was a within subject repeated measures design. The levels of the design were given in Table 1:

Table 1. Design levels of the experiment

Block	Index of Difficulty (bits)	Axis	Feedback
1	3.87	Horizontal	Normal
2	2.81	Horizontal	Normal
3	1.81	Horizontal	Normal
4	2.67	Horizontal	Normal
5	3.87	Vertical	Normal
6	3.48	Vertical	Normal
7	2.48	Vertical	Normal
8	2.87	Vertical	Normal
9	3.87	Horizontal	Vibrotactile
10	2.81	Horizontal	Vibrotactile
11	1.81	Horizontal	Vibrotactile
12	2.67	Horizontal	Vibrotactile
13	3.87	Vertical	Vibrotactile
14	3.48	Vertical	Vibrotactile
15	2.48	Vertical	Vibrotactile
16	2.87	Vertical	Vibrotactile

The number of trials to be collected from 9 participants, in 2 axes, 2 feedback modes, 4 blocks in each axis, 20 clicks in each block was 2880 (9×2×2×4×20).

Each subject was given a red target bar on the screen which was appearing in the right and left or top and bottom of the screen in a sequential order regarding to the task block's direction. Once the bar was clicked, it was disappearing from its latest location and appearing in the opposite side of the screen. In each block, the width of the bar and/or the distance between 2 opposite bar locations was changing so that each block was yielding a different task difficulty.

In the vibrotactile mode the feedback rules were as follows:

1. The mouse vibrates for 500 milliseconds when the cursor located on the target bar.
2. If the cursor leaves the target before 500 milliseconds past, the mouse stops vibration.
3. If the cursor re-enters in the target area, the mouse vibrates for 500 milliseconds again.

According to the Fitts' law [33], movement time (*MT*) to a target of width (*W*), at a distance (*A*) is as follows:

$$MT = a + b \log_2(\frac{2A}{W}) \quad (1)$$

Where a and b are experimental constants of linear regression. Shannon formulation [34] was used in this experiment:

$$MT = a + b \log_2(\frac{A}{W} + 1) \quad (2)$$

Shannon variation has been chosen because it is known that [35] it mimics the information theorem underlying Fitts' law, it produces always positive results and it provides better fits with observations. The *log* term in the equation 2 is defined as index of difficulty (*ID*). Index of difficulty is measured in terms of "bits", which comes from the analogy with Shannon's information theorem. In addition to the index of difficulty, Fitts also defined a measure for the performance, named index of performance (*IP*) which is as follows:

$$IP = 1/b \quad (3)$$

IP is measured in bits/seconds which is analogous to throughput indices of electronic communication devices such as modems. In this experiment, the performance difference between normal and vibrotactile feedback modes of the pointing device was measured by using *IP* derived from the collected data from the task designed. Movement time, target width, target distance and clicking offset data were collected for each clicking action.

3.3 Apparatus

Vibrotactile Feedback Mouse. An electronic circuit that activates an eccentric micro electric motor with the digital control signal, is designed and produced. The control signal is designed to be received from the serial port of the computer. After having the physical circuit produced, a standard A4 Tech™ PS/2 optical mouse is modified to encapsulate the circuit and became a vibrotactile mouse.

Software and the Computer. A computer program with a graphical user interface that is implementing a variation of the original Fitts' experiment, explained in the design section, was developed by using Microsoft Visual Basic 6™. The standard

Microsoft ™ serial port controller component (Mscomm32.ocx) is used to send control signal to the mouse for activating the vibrator when the cursor moves in the target area and for deactivating the vibrator when the cursor is out of the current target. A standard desktop computer with a 2.8 GHz CPU, 2 GB of main memory and 1024×768 pixels of LCD display was used to run the software.

4 Results

After the experiment, the data collected was analyzed and refined from the outliers. The data belonging to the subject 2 was discarded due to the measurement defects so that it was not fitting into the Fitts' model. The obtained facts from 8 subjects are as follows:

Whole experiment took 3.5 hours. The average movement time (MT) to target was decreased at a proportion of 60% in vibrotactile feedback mode.

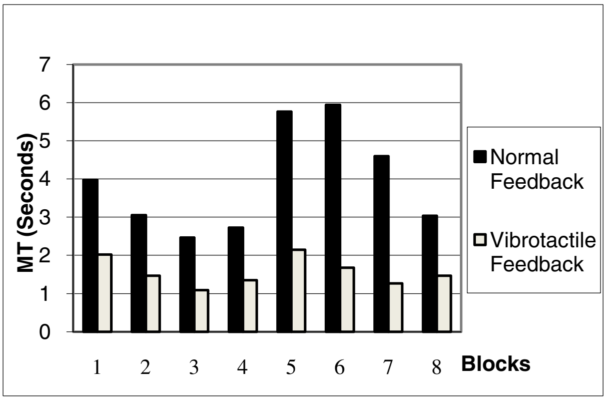

Fig. 1. Average task block timings compared

Especially subject 8, who has got no visual or motor function impairments, has acquired the target 85% faster in vibrotactile feedback mode compared to the normal feedback mode. The result on movement times showed that subject became faster in completing the task in vibrotactile feedback mode.

Table 2. *IP* scores compared in normal and vibrotactile modes

Subject#	IP Normal	IP Vibrotactile
1	9.21659	14.30615
3	12.48439	9.442871
4	2.893519	11.29944
5	10.83424	13.73626
6	5.78369	5.24109
7	3.067485	5.813953
8	0.628417	2.554931
9	5.260389	9.21659
T-Test	0.032	(p<0.05)
Average	6.27	8.95
σ	4.19	4.17

The average index of performance increased 43% in vibrotactile feedback mode and the resulting array of IP values between two modes are moderately significant statistically ($p=0.032$; $\sigma_{normal}=4.19$, $\sigma_{vibrotactile}=4.17$, see Table 2).

The results suggested that non impaired older computer users were performing better at completing the target selection tasks while they were using mouse in vibrotactile feedback mode.

As stated in the method section, this experiment was the first contact with a computer for 7 out of 9 subjects. In the warm up sessions, the mouse as “the pointing device” and the terms like “pointing” and “clicking” were introduced to the participants. During the experiment, most of them intuitively succeeded to use the mouse in both modes. On the other hand, in some cases, the subjects were forgetting to click the target although the pointer was located on the right place. In those cases, the benefit of vibrotactile feedback to the users was sharper: They immediately clicked the target after the mouse had vibrated.

Most of the subjects considered the experiment as a joyful and competitive game so that, they were trying to be faster than their predecessors to win the “game”.

5 Conclusion

As the target selection and pointing tasks are the majority of activities when users are dealing with the graphical interfaces [36], any enhancements on these tasks may result in better computer usability experiences.

In this study, we examined the effect of using vibrotactile feedback mouse on selecting targets at different difficulty levels of tasks. The results show that older adults performed better significantly in the case of using vibrotactile mouse. Since there is an elevated threshold, for a novice adult to start using a computer than an experienced one. We can conclude that, barriers that prevent older novice users from effectively using computers can be significantly reduced through introduction to multimodal feedback input devices such as vibrotactile mouse.

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