User Specific Design of Interfaces and Interaction Techniques: What Do Older Computer Users Need?

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Abstract. The increase of a "graying" society is apparent in recent decades and as such, the attention of marketing and product design is more and more focused on older users of technical devices. The study addresses the relevance of hardware and software design in human-computer interaction of older users. It was found that performance significantly increased (up to 3 times) with easier sensumotor transformation and easier task type. However, this was more prominent in middle-aged users than in younger users. Task difficulty revealed a rather unspecific impact on performance (43%), and was equally apparent in both age groups. Recommendations derived from this review show that older users will profit most from touch based or mouse operated interfaces. Additionally, easy icon and menu designs are often missed and will become more and more important for older users.

Keywords: Age, User Characteristics, Task Type, Task Difficulty, Input Device.

1 Introduction

Several input devices accomplish for an effective human-computer interaction (e.g. mouse, pen, touchpad, trackpoint). Yet, the user is still confronted with the question, which device serves the best for ones' purpose. The usage of input devices is also affected by the undergoing changes with aging, for example in motor and cognitive performance. The age-related decline in motor performance is well documented [e.g. 1,2,3,4]: Reaction and movement time slow down up to 200% [1]. When handling an input device, findings also showed an age-related decrease in motor performance of middle-aged and older adults compared with young users [e.g. 5-12]. The slowing-down was found to be quite independent from the type of input device (e.g. touchpad and trackpoint [5,6,7], pen [8]), though mostly reported for the mouse [8,9,10,11,12]. Smith et al. [9] reported that motor performance of middle-aged and older mouse users was 2.5 times and 3 times, respectively, inferior to that observed in young users. Also Chaparro et al. [10] numeralized the age-related decline of older mouse and trackball users by the factor 1.6.

In the present paper we will address several critical aspects in the design of human-computer interaction and its relation to age, i.e. the effect of input-device type on performance of older users, of task type and of task difficulty. The aim is to retrieve

C. Stephanidis (Ed.): Universal Access in HCI, Part I, HCII 2007, LNCS 4554, pp. 1020–1029, 2007.

the specific impact of these factors in the human-computer interaction in order to establish recommendations for a user-guided design of interfaces and interaction techniques for users of older age.

Several experiments of our lab will be reviewed against the background of a framework of user-computer interaction (Figure 1 [5]). The framework assumes that technical features of the hardware and the transformation of hand movement into cursor movement (= sensumotor transformation [13,14]) determine the basis of interaction efficiency. Either user characteristics (e.g. age [11], expertise [15]) and / or task type and task difficulty [e.g. 16] further influence the outcome as well as both aspects may also interact with each other. The performance outcome will come under an evaluation process and feedback is provided to optimize soft- and hardware design.

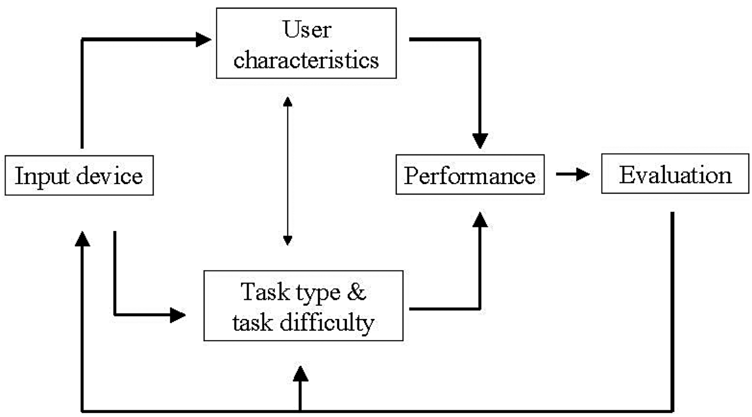

Fig. 1. A framework of user-computer interaction [5]

If input devices are categorized by their ease of sensumotor transformation, then they will be ranked according to their mapping between hand movement and cursor movement. Direct input devices, like finger or pen, represent the easiest way of transformation since the pointing gesture with either finger or pen directly activates the action on the display. The sensumotor transformation within the mouse is still easy. Hand and cursor movement are analogous, but appear in different locations and the output location is rotated by 90°. The hand movement is executed on a horizontal surface and is proximal to the user, and the cursor movement appears on a vertical display and is distal to the user. Similar to the mouse is the movement transformation of the touchpad: with the touchpad also finger movements on the pad are mirrored as a cursor movement on the display. However, it is assumed that the sensumotor transformation of the touchpad is less easy compared to the mouse since the touchpad is more sensitive towards velocity and acceleration changes due to less friction of the system [12,14]. The sensumotor transformation of the trackpoint is most difficult compared to the other input devices [14, 15]. The trackpoint senses finger force, which results in cursor velocity. Thus, the compatibility between finger action and cursor action is low. In a recent study we could show that the better performance of input devices with rather easy sensumotor transformations comes from an optimized movement execution in terms of fewer submovements and a good balance between movements' velocity and covered distance [14].

With this background results of the reviewed studies are analyzed according to two age-related hypotheses: (1) In literature age-related declines by the factor 1.6 and higher were reported for input device usage of older compared to younger adults [9, 10]. It is hypothesized that the usage of pen, mouse, touchpad and trackpoint is by the factor 1.6 less efficient for middle-aged users compared to young users. Furthermore, the sensumotor transformation will interact with age insofar that age differences are more prominent in input devices with a difficult sensumotor transformation. (2) The impact of software design on the efficient input of younger and middle-aged users is surveyed. It is assumed that motor performance becomes less efficient with an increase of complexity of task type and with an increase of task difficulty [16]. Furthermore, the age relevance of these software design factors will be analyzed.

2 Method

Table 1 shows methodological aspects of the studies [5,6,7,11,17,18], which were included to the data review.

Table 1. Input device and sample size per study

	Input device	Young age group	Middle-aged group
Sutter, Ziefle [17]; Oehl, Sutter, Ziefle [18]	Pen	N = 18	N = 18
Sutter, Ziefle [11]	Mouse	N = 14	N = 14
Armbrüster, Sutter, Ziefle [6,7]; Sutter [5]	Touchpad	N = 20	N = 14
Armbrüster, Sutter, Ziefle [6,7]; Sutter [5]	Trackpoint	N = 20	N = 14

2.1 Participants

In all experiments participants of the young-age group were aged between 20 and 30 years (M = 24 years). The middle-aged group consisted of participants aged above 30 years and age ranged from 30 to 66 years (M = 51 years). Sample size was between 14 and 20 participants (Table 1).

2.2 Sensumotor Transformation (Input Device)

The sensumotor transformation of input devices was varied from very easy (pen) to easy (mouse, touchpad) and to difficult (trackpoint). In the experiments a professional stylus for industrial touch applications (WES®) and the "Premium optical wheel mouse" (Logitech) were used. Data of pen and mouse were collected with a standard desktop computer, 266 MHz Intel Pentium II CPU. The touchpad was integrated into a Dell Inspiron 7500-notebook. The touch-sensitive panel (2" by 1.5") was located in the wrist rest beneath the keyboard with two mouse buttons underneath. For the trackpoint a Toshiba Satellite 1700-300-notebook with an integrated trackpoint was used. The small force-sensitive joystick was placed between the "G", "H" and "B" keys on the qwerty-keyboard, the mouse buttons are located in the wrist rest. In all experiments data output was provided to an external TFT flat screen (Philips 150x; 1024x768 pixel) to control the visual quality of display presentation. Cursor velocity of mouse, touchpad and trackpoint was set at "medium" speed (1500 - 4500 pixel per second), the cursor acceleration was deactivated.

2.3 Task Design (Type and Difficulty)

Task type was varied between simple (point-click task) and complex (point-drag-drop task). Task difficulty varied from 2.6 to 4.4 bits (see below). For the point-click task (Figure 2, subtask 1 only) a square target and a cross-hair cursor appeared on the screen. Users were instructed to move the cursor from the start position to the target and adjust the cursor inside the target. The correct cursor positioning was indicated by a change of the square target's color from black into green to provide visual feedback. A trial was completed by pressing the left-mouse button. Thereafter, a new trial was started with a self-paced press of the space bar.

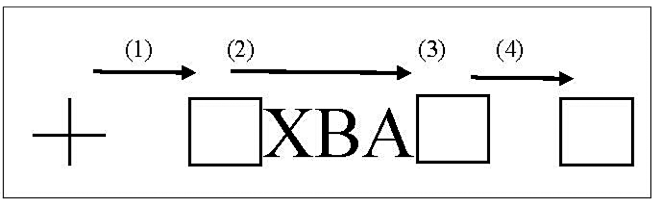

Fig. 2. Task types: Point-click task (subtask 1) and point-drag-drop task (subtasks 1-4)

The point-drag-drop task consisted of several single actions that were executed one after another. The task, as visualized in Figure 2, appeared on the screen. In a point-drag action the centrally placed strings are highlighted (subtask 1&2). Then the object is picked up and moved inside the square target (drag-drop action: subtask 3 & 4). For the drag actions participants are instructed to drag the cursor by pressing the left mouse button. For every successful subtask a visual feedback is given. Releasing the left mouse button at the end of subtask 4 completed the trial. Task difficulty varied in movement distance (2.5, 5 cm) and target size (0.25, 0.5 cm). This resulted in three IDs (ID = index of difficulty, [16]): 2.6, 3.5 and 4.4 bits.

To balance movement direction, targets were presented 45°, 90°, 135°, 180°, 225°, 270°, 315° and 360° to the centrally arranged cursor. This required horizontal, diagonal and vertical cursor movements to hit the target.

3 Results

Data were summarized according to the hypotheses with the independent variables age, sensumotor transformation, task type and task difficulty. For analysis t-tests and ANOVAS were carried out. The level of significance was set at 5 %.

3.1 Effects of Age and Sensumotor Transformation

The mean movement time (ms) for young and middle-aged adults is displayed in Figure 3 for mouse (square), touchpad (triangle) and trackpoint (circle). Effects of sensumotor transformation are obvious. In both age groups performance was best for the mouse, followed by the touchpad and was worse for the trackpoint. For touchpad and trackpoint significant main effects for sensumotor transformation and age were observed (sensumotor transformation: $p < 0.05$ and age: $p < 0.05$ [7]). The interaction of both factors was also significant ($p < 0.05$ [7]). Also for mouse performance significant age effects were found for the point-click task ($F(1,12) = 5.02$, $p < 0.05$). Younger mouse users were by 316 ms faster compared to middle-aged users (970 vs. 1287 ms [11]). The comparison of sensumotor transformation showed that mouse performance of younger users was 1.5 times better compared to the touchpad (970 vs. 1426 ms, $t(6) = -7.55$, $p < 0.01$) and 1.8 times better compared to the trackpoint (970 vs. 1719 ms, $t(6) = -12.41$, $p < 0.01$). This was found to be more prominent for middle-aged users. Mouse performance was 1.5 times better compared to the touchpad (1287 vs. 1993 ms, $t(6) = -5.53$, $p < 0.01$) and 2.5 times better compared to the trackpoint (1287 vs. 3195 ms, $t(6) = -14.94$, $p < 0.01$). This means that in both age groups performance significantly decreased when sensumotor transformation became more difficult. However, the interaction between age and sensumotor transformation seems to be exponentially. Whereas in the difficult sensumotor transformation the age effect is biggest (age factor for trackpoint 1.9), it drops when sensumotor transformation gets easier (age factor for mouse and touchpad 1.3-1.4) and is reported to distinguish completely for very easy sensumotor transformations (age factor for pen 0 [17,18]).

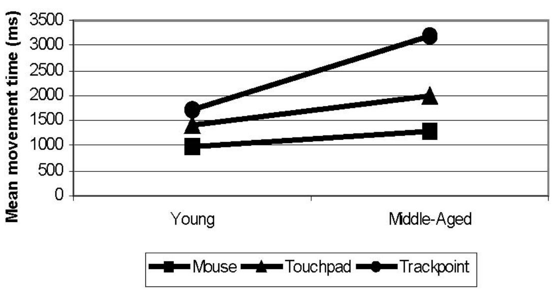

Fig. 3. Mean movement time (ms) in the point-click task as a function of age and input device

3.2 Effects of Age and Task Type

The mean movement time (ms) of middle-aged adults is displayed in Figure 4 for the point-click and point-drag-drop task (mouse = square, touchpad = triangle, trackpoint = circle).

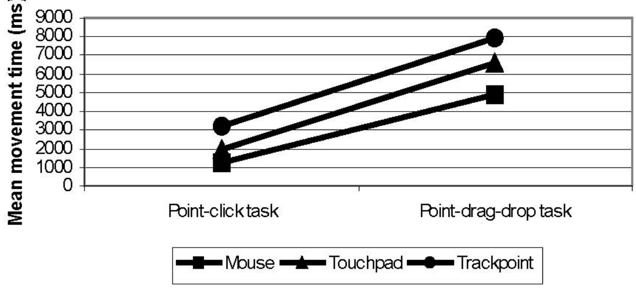

Fig. 4. Mean movement time (ms) of middle-aged users as a function task type and input device

The effect of task type is obviously apparent in all input devices (touchpad and trackpoint: $p < 0.05$ [6,7]; mouse: $F(1,12) = 30.24$, $p < 0.01$). As can be seen in Figure 4 middle-aged users solved point-click tasks 3.0 times faster compared to point-drag-drop tasks. This task-relevant increase of movement time was not affected by sensumotor transformation (interaction n.s.). As displayed in Figure 5, however, the increase was rather stronger for middle-aged users compared to young users as indicated by the significant interaction of age by task ($F\ (1,92) = 4.32$, $p < 0.05$). From point-click to point-drag-drop tasks movement time increased by 4284 ms and 3331 ms, respectively, for middle-aged (solid line, Figure 5) and young users (dashed line).

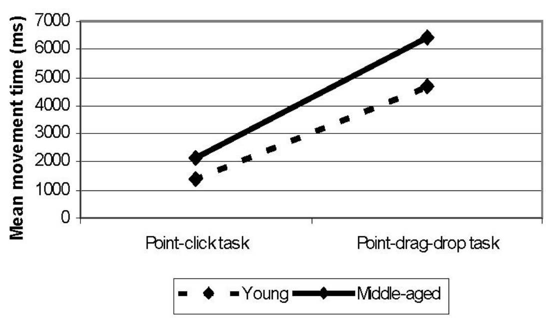

Fig. 5. Mean movement time (ms) as a function of age and task type

Findings show that middle-aged users are very sensitive towards task type and execute complex tasks far less efficient as younger users.

3.3 Effects of Age and Task Difficulty

In all studies significant effects of task difficulty were found. The effect of task difficulty is apparent in all input devices and was found for middle-aged users of touchpad, trackpoint ($p < 0.01$ [6]) and mouse ($F(1,18) = 3.31$, $p < 0.1$) as well as for young users (touchpad and trackpoint: $p < 0.05$ [5]; mouse: $F(1,18) = 11.02$, $p < 0.01$). The regression analyses accounted for up to 97% of variance in movement time by task difficulty. From the easiest (2.6 bits) to the most difficult task (4.4 bits), movement time increased between 31% for the mouse and 43% for the trackpoint. Movement time of young and middle-aged trackpoint users increased by 40% and 43%, respectively. For the touchpad a raise of 37% for young users and 40% for middle-aged users was observed. And for the mouse, movement time rose by 35% and 31% for young and middle-aged users. A similar increase was reported for young and middle-aged pen users [17,18]. Apart from the age effect, no interaction between age and task difficulty was found in these studies (interaction n.s.). It can be concluded that the decrease of performance due to the task difficulty is equal in both age groups, young and middle-aged users.

4 Discussion and Recommendations

The design of human-computer interaction is more and more considered towards its usability for older computer users [8,9,10,11,12]. Beyond efficiency operating an input device itself also specific factors of the software design were addressed in this paper and analysed in its relation to performance decrements often observed in older computer users. In literature age-related performance declines by the factor 1.6 and higher were reported for older compared to younger users of mouse and trackball [9,10]. The studies reviewed in this paper [5,6,7,11,17,18] focused on middle-aged adults and therefore maybe underestimate age effects that will become more and more apparent in the older adulthood [1].

The findings of the present study demonstrate that efficiency of input-device usage distinctly drops from early to middle adulthood by now. Performance differences between young and middle-aged users were not constant, but were affected by sensumotor transformation. As hypothesized age differences were biggest for the trackpoint (factor 1.9), which had the most difficult sensumotor transformation. It dropped for mouse and touchpad, where sensumotor transformation is easier (factor 1.3-1.4). And, in contrast to Charness et al. [8], there were no performance differences at all between older and younger users for the pen (factor 0). In further studies this rather exponential impact of sensumotor transformation on age should be addressed more systematically. The question arises if older users react less flexible towards changes in sensumotor transformation. Assumed that older users possess more specific stimulus-response associations, consolidated by lifelong experience, then they react very efficient to already known sensumotor transformations (e.g. pen: pointing gesture). However, their performance will drop distinctly and more prominent compared to younger users when sensumotor transformation gets difficult and unfamiliar (e.g. trackpoint: force-velocity transformation). This assumption could also be true for task complexity where a similar pattern of age-related performance was found. Middle-aged users reacted very sensitive towards changes in task type and executed the more complex task far less efficient than younger users. The performance decrement from the point-click- to the point-drag-drop task was by 1s higher for middle-aged users compared to young users. For task difficulty no relation with age has been surveyed. From the easiest (2.6 bits) to the most difficult task (4.4 bits) movement time increased by 31 to 43%, independently from age and input device. So far, the results for task difficulty clearly underestimate the situation given in software applications. The range of IDs will be much wider and therefore (up to 6 bits [19], the performance will be much more affected than surveyed here (65% [5]). As can be derived from these studies, sensumotor transformation and task type have a specific age-related impact on performance. That means, transferred to the framework of user-computer interaction [5], hard- and software features should be harmonized with the age of its user in order to achieve an optimized interaction.

So there is still the question about what older computer users need? What recommendations can be derived from this review for an optimized design of interfaces and interaction techniques for users of older age. The choice of interaction technique is often restricted by space, pollution and other environmental factors (e.g. vibration, heat), and mobility. Whenever possible easy input techniques should be chosen, i.e. a touch based interface that is operated with either finger or pen. This is realized in a huge amount of publicly used interfaces (e.g. ATM machine, information terminal). However, it lacks in many consumer products (e.g. desktop computer, television) that are still operated by mouse or remote control although touch screens are very widespread. Besides the pen, with all other input devices interaction becomes more or less inefficient (dependent on their sensumotor transformation) and even worse for older users. This can be faced twofold: either to level the effect of sensumotor transformation with a simple pointing task instead of complex drag actions and / or with easy designed object in term of task difficulty (e.g. big and nearly located icons). The simple task type in combination with an input device with easy sensumotor transformation will be operated by 6.2 times faster than the contrary. This was shown in the present review for middle-aged users executing with a mouse point-click tasks in contrast to executing point-drag-drop tasks with a trackpoint (Δt = 6.6 s). At least, all interfaces and interaction techniques have in common that, if task difficulty is reduced (e.g. enlargement of icon and menu size, reduction of distance) then users will profit up to 43%. However, task difficulty in common software applications was found to be higher (up to 6 bits [19]) than surveyed in our studies (max. 4.4 bits). Thus, the advantage of easy tasks will be even more distinct than 43%. That means also, that the design of easy tasks is a crucial and neglected factor in interface design up to now. It is still an important way to optimize the interaction not even for older users.

All in all, recommendations derived from this review show that older users will profit most from touch based or mouse operated interfaces. Additionally, easy icon and menu designs are often missed and will become more and more important for older users.

Acknowledgements. We wish to thank Jamal Sobeh and Christine Seibert for supporting this research.

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