Investigation of Memory-Supporting Design Approaches to the Age-Differentiated Adaptation of Human-Computer Interfaces

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ABSTRACT

Demographic change promotes new concepts for the support of ageing employees during work with computer monitors. An approach to age-differentiated adaptation of the human-computer interface should allow for the specific capabilities and needs of elderly users during primarily cognitive activities. To determine the factors of consideration during the implementation of the adaptation model, experimental investigation took place. It was explored how various adaptation dimensions affect the performance of users and to what extent related age-specific effects occur. The results justify further investigations of design variants.

Keywords

Demographic change, adaptive human-computer interfaces

1. Introduction

Against the background of demographic change in particular, the changing boundary conditions of the work world - such as the increasingly dynamic nature of business and work organization, the increasing information flow and the rise in work with computers - lead to a significant increase in the demands made on employees' cognitive performance. To effectively and productively counter this aspect, strategies of employee retention, in the sense of measures for the retention of productivity and motivation among elderly employees, will be of even greater significance in the future. Work tasks and tools must be adapted to the needs of ageing employees if the described activities are to be executed by an increasingly elderly proportion of employees in the future. The age-differentiated adaptation of the human-computer interface model described in the following creates an approach to the ergonomic support of interindividual experience and performance profiles. The focus is on design concepts that achieve the support of memory performance through user-centered information provision.

2. Age-specific Changes of Cognition and Performance

Models and approaches that deal with changes in performance of ageing persons range from the deficit model, whose assumptions no longer hold today (cp. Naegele 2004, p. 353), to the disuse model, compensation model or competence model, among others (see Astor et al. 2006, p. 17 et sqq.). Instead of the hypotheses of the deficit model, it is often assumed that a "differential age" exists according to varying developments in the performance and personality areas with an increase in age. However, these differences can vary in strength and can move in different directions (cp. Maintz 2003, p. 50). Consequently, a general decrease in performance with an increase in age cannot be assumed. Instead, a change in performance on cognitive and physical levels can be assumed, meaning that a general decrease in operational performance cannot be assumed either. In fact, investigations show that with an increase in age come interindividually greatly dispersed abilities. However, these can be positively influenced through the targeted promotion and ergonomic design of work tools (cp. Munnichs 1989). A precise allocation of employees to tasks according to performance profiles can thus be a significant factor for the employment of elderly workers. This goal can be achieved through the promotion of learning and measures of organizational design. In the following, an overview of each factor that affects an age-typical change in performance is presented. These factors are particularly important for the ergonomic human-computer interface and an adaptation, and must therefore be taken into careful consideration:

- *Increasing Performances:* Higher stability of vigilance for increasing duration and complexity; crystalline intelligence; abstractive ability
- *Constant Performances:* Motor reaction time; signal detection; long-term memory
- *Decreasing Performances:* Visual acuity; premotoric processing time; speed of information processing; performance during multi-tasking; working memory; fluid intelligence; flexibility; spatial sense

The mentioned performance elements and their temporal allocation indicate that several rise with an increase in age, while others either remain constant or decrease. It must be observed that as many of these performance change elements as possible are taken into consideration during the design of work and learning processes. This is necessary to ensure that areas with decreasing performance are compensated, and increasing performances can continue to be developed (cp. Astor et al. 2006, p. 18). In today's world, great meaning is associated with the use and handling of computer programs. The respective tasks, which are unfamiliar to many elderly persons and which lead to massive amounts of information that must be processed daily, justify an emphasis on the cognitive aspects of age-related performance deficits.

Supporting Human Memory with Interactve Systems, workshop at the HCI 2007 (British HCI conference 2007), September 4th, 2007, Lancaster, UK

The changes of basic cognitive functions, such as psychomotorics, intelligence and attentiveness, as well as learning and memory all change with age and then have an impact on the performance of elderly persons. Park (1992) showed that age-related performance decreases occur in the majority of these cognitive processes; these will be briefly introduced here.

The cognitive processes of psychomotorics affect the processing and integration of received signals in existing structures when incoming signals must be recognized during discrimination tasks. Premotoric processing time increases with age as reactions to different stimulus factors require more time. Motoric reaction time, i.e., the time needed for a movement after a signal is first deciphered, still remains nearly constant (Lehr 2003, p. 109 et sqq.). The cause behind such results is attributed to the delayed information processing of older persons, i.e., these persons require more time to register preceding information of a reaction and then to form an overview of the immediate situation. However, once this has occurred there is no longer a difference in reaction speed compared to that of younger persons.

Often the ability to remain attentive in the long term (vigilance) is more important than reaction speed. Investigations that examined the ability to work under pressure and the precision of psychomotoric reactions during long lasting information offers came to two important conclusions: 1. With an increase in age comes an increase in the stability of performance during longer periods and increased complexity of processes. 2. There are no measurable age-specific performance differences for signal detection (cp. Lehr 2003, p. 110 et sqq.). However, other authors postulate a reduction in attentiveness. Particularly, the ability to divide attention between various elements decreases. This can be attributed to decelerated information processing and reduced working memory capacity (cp. Kullmann / Seidel 2005, p. 42).

The meanwhile rejected assumption of a general performance decrease with an increase in age, as postulated in the deficit model, can be inferred from intelligence research. This research points out that significant interindividual differences exist in intelligence performance. This variability stems from the various social backgrounds of the persons involved, yet occurs more frequently for certain components of intelligence (cp. Lehr 2003, p. 77). Intelligence can be divided into "fluid" and "crystalline" intelligence based on the distinction made by Cattell (1963). Fluid intelligence encompasses basic processes of information processing and problem solving. "Fluid" refers to speed, adaptability and agility of cognitive processes as well as swift orientation in new situations (cp. Kullmann / Seidel 2005, p. 41). This form of intelligence decreases after middle age. Crystalline intelligence, however, involves experience-based knowledge that is acquired throughout the course of one's life, therefore also continuously increasing into old age (cp. Stöckl et al. 2001, p. 97). For tasks that have an emphasis on speed a decrease in intelligence performance with an increase in age must be noted. Performance for language and knowledge related tasks either remains constant or increases (cp. Benda 1997, p. 290).

It is assumed that performance is greatly dependent on learning ability since the humans of today are constantly faced with the challenge of adapting to changing demands and situations. Thus, learning ability, especially in the occupational context, becomes one of the most important competencies. If elderly persons appear to be slower in their learning behavior it does not necessarily mean that the ageing process alone is to blame. Instead, multicausal explanations may exist. Experimental studies of learning ability in elderly persons produced several results (Astor et al. 2006, p. 24) that are also significant for the ergonomic design of the human-computer interface.

From these results the assumption that elderly persons are generally poorer learners than younger ones cannot be supported. Rather, elderly persons learn in a different manner. Often, external circumstances can cause the poorer learning results of elderly persons. For example, in most organizations a variation in learning behavior different to that of the younger employees is not catered to. There is no doubt, however, regarding the assumption that the speed of information processing decreases with an increase in age (cp. Bruggmann 2000, p. 28). This can be traced back to a changing level of memorization performance. An increase in age results in a reduction in short-term memory capacity of 4% to 28%, especially for visually acquired information (cp. Lehr 2003, p. 96). Short-term memory becomes more sensitive to disturbances during impact procedures of learning material (cp. Thomae / Lehr 1973, p. 27) and is overstrained more quickly by complex learning material. Information transfer to long-term memory also becomes more difficult (cp. Bruggmann 2000, p. 28). Additionally, reproduction of learned material without sufficient prior knowledge of the topic is increasingly challenging for elderly persons. If prior knowledge exists, however, memory performance remains constant even into old age.

Since computers and systems that primarily address cognitive demands are dealt with, the deceleration of information processing and decrease in working memory capacity also have an effect on their usage. The described performance deficits create significant challenges for ergonomic software design intended for various, including elderly, users. Current user interfaces are still not flexible enough to consider and compensate the various cognitive performance prerequisites of different users. The individualization of the human-computer interface presents a promising approach to achieving cognitive performance, and, with the following approaches, will significantly contribute to the support and improvement of memory performance.

3. Model of Age-differentiated Adaptation

The approach to age-differentiated adaptation of the human-computer interface followed here is focused on compensating fluctuations in performance, thereby especially helping elderly persons in their work with computers. This individual adaptation is therefore exemplarily carried out with project management software since work with network plans places coordinative-communicative demands on the user while also requiring complex cognitive processes. The automatic adaptation is based on the methods of Jameson (2001). A distinction is made between three different phases in this approach - afference, inference and efference. In the first phase the typical user characteristics are registered. These are then analyzed in the second phase and conclusions are drawn regarding individualization. In the third phase the individual adaptation to the user interface is performed. For the age-differentiated adaptation model the three phases are adapted accordingly and an evaluation phase is added in which the adaptive software is evaluated by the user and then updated correspondingly. Based on the mentioned specific performance abilities and characteristics of elderly persons, and on the application area of project management, certain individualization dimensions in regard to adaptation of the human-computer interface are of particular interest. These dimensions include font size and presentation form or menu structure, yet particular significance results from the dimension of memory aids. If the previously mentioned cognitive developments and their influence on computer use are implemented as a basis, then cognitive fluctuations in performance could be recognized and caught. These could then be used as memory aids to assist users in the processing of complex tasks in the network plan. Therefore, possible function commands or current status indicators for the task being processed could be shown. The importance of possible memory aids was formed from the results of initial experiments that will be briefly mentioned here.

3.1 First Experiments and Results

In an experiment with 90 subjects (20 to 73 years of age) the influences of font size on recognition and of the layout design of network plans on memorization and interpretation performance were investigated. First, user-specific abilities, experiences and attitudes were determined through various tests. Aside from visual acuity data, cognitive performance, spatial sense, fluid intelligence and memorization ability of the subjects were acquired via standardized questionnaires and tests. The main experiment divided itself into the following three sub-experiments: 1. Microsoft's standard font size and the recommended font size according to DIN was examined regarding suitability for elderly persons, and whether an increase in font size would lead to an improvement in performance. The goal was to determine the optimal individualized adaptation of the font size based on the user's visual acuity. 2. Various network plan layouts (for details see Schneider et al. 2007) were examined to determine whether a vertical or a horizontal orientation would have different effects on the memorization performance of users. Additionally, different spatial spreads, i.e., between activities of a network plan, were analyzed. The goal was to determine a possible age influence, and thereby related cognitive abilities, on memorization performance. 3. Analogous to 2., the influence of layout design on interpretation performance was also examined here. The goal was to determine the influence of layout design on interpretation performance through evaluation of network plans and age-specific influence factors, along with their relation.

An evaluation of the test procedures shows that spatial sense and memorization ability both decrease with an increase in age. The results of the font size experiment for age-differentiated software design show that the commonly preset standard font size (12') is sufficient for all age groups. Whether or not this size is sufficient in occupational practice during long-term visually demanding project management tasks will be examined in follow-up experiments. The results of layout design of network plan show that a distinction between different task types, memorization and interpretation must be made for the adaptation of software. A larger gap between activities is necessary for good memorization performance. Furthermore, a horizontal network plan orientation is more favorable than a vertical one. This outcome supports the visual-spatial memory theory of Winkelholz / Schlick (2006). However, a smaller gap between activities has a more positive effect on the performance of subjects in the interpretation of network plans. This conforms to the proximity compatibility principle (PCP) (Wickens / Carswell, 1995). This theory postulates that the spatial proximity of displays is useful for mental information integration in which a compatibility of cognitive processes is provided, thereby decreasing "information access costs". Regarding layout, the expected positive effects of horizontal orientation could also be confirmed here (cp. Winkelholz / Schlick 2006). The varying task-dependent effect of spatial spread on subjects' performance expresses an interesting trade-off in the layout design of network plans. The layout variant, i.e., which spatial spread between activities is better suited for the processing of project management tasks, will be examined in follow-up investigations.

4. Future Work

Due to the age-related cognitive performance deficits, especially the working memory and spatial sense, the graphical design of network plans presents a particularly promising adaptation dimensions. Based on previously acquired insights, follow-up experiments will involve the investigation of solutions to the described trade-off. In addition, innovative interaction procedures will be examined regarding whether or not they can contribute to the compensation of determined sensorimotor deficits among elderly users. For this purpose, different design variants of network plans and age-specific viewpoints are conceived and empirically analyzed. Three design variants (see below) derived from previous results, which may contribute to the support of spatial sense and compensation of working memory capacity loss, will be empirically tested.

Different design variants of a network plan (Fig.1) are introduced that can compensate the individual age-specific physiological and cognitive performance deficits and can make an "optimal" ergonomic individualization of project management software possible.

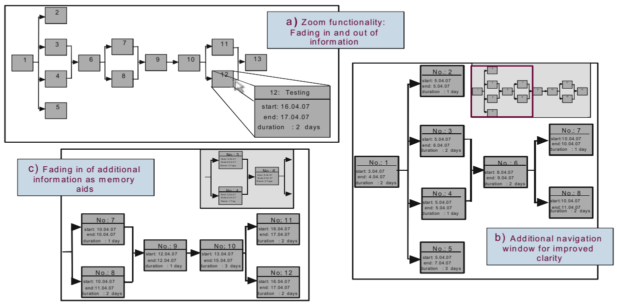

Figure 1: Design Variants for Visualization

The complete and clear presentation of a network plan on a computer screen is often only possible through a reduction of information, i.e., leaving out information within activities. Such a reduced network plan offers a good overview of the entire structure, yet it is not suitable for a precise analysis. This dilemma can perhaps be solved by the zoom function. The dispersed information elements on the screen can be focused on, enlarged, and thus explored in detail through interactive zooming. A variable information density results for which the level of detail can be increased via zooming in and decreased via zooming out. Simultaneously, the display in the lowest zoom level provides an overview of the entire process. Navigation within the information space during zooming can be simplified if a small additional window is faded in beside the desktop. The complete desktop is depicted in smaller form in this case, and the zoomed-in area is graphically highlighted. Investigations of zoom function effectiveness, particularly for various age groups, are not known. The first design variant (Fig.1a) attempts to counteract the trade-off between clarity and the necessary detailed information through the zoom function. A network plan with reduced information, i.e., less required space, is designed in favor of greater clarity. For example, in this network plan only the names of the activities are contained in the network plan nodes. Additional information necessary for the analysis of the network plan can be requested by the user through marking of the activity. The information is then displayed through a zoom function or a layering of display elements (so-called ToolTip function).

If all activities within a network plan are to be displayed with the greatest amount of information possible, a splitting of different screens is required due to the resulting size. This can be realized through a scrolling or paging function. Information is displayed on a long continuous page during scrolling. During paging, however, the information is displayed in smaller units on several pages. Most of the previous investigations against this background were carried out with respect to the internet. According to studies by Schwarz et al. (1983) investigating the effect of paging and scrolling on different task types, a task-dependent effect can be assumed. Paging was generally preferred, and led to improved performance in sorting tasks. No difference in performance was determined between scrolling and paging in the search for connections between elements or for reading tasks. Studies investigating age effects during paging or scrolling do not exist. However, for elderly persons with decreasing spatial sense and memory in particular, difficulties in the navigation of activity graphs can be expected. The second design variant (Fig.1b) is based on a fully labeled network plan. The loss of clarity is to be counteracted and the age-specific performance changes regarding working memory and spatial sense (orientation) are to be compensated by an additional window in which the entire process is scaled down. In this scaled down window the currently displayed section on the screen is also marked.

Due to previous results, it is assumed that both initially mentioned design variants can each only compensate specific age-related performance deficits. However, the goal is to achieve extensive support of all relevant performance areas. A possible solution will be examined in the third design variant which focuses on the use of memory aids for the support of the working memory. So-called ToolTips offer assistance in the sense of memory aids. Temporary faded-in textual information about a focused on object are referred to here. These tips appear when the cursor pauses on an object for a specific amount of time, yet they cannot be explicitly invoked. Bookmarks of websites can also be used as memory aids. No investigations about age-differentiated design of these software support functions are known. The design variant (Fig.1c) includes the following display and usage concept: the user can select a section of a network plan, such as individual nodes, whose information is crucial for further processing. The selected network plan section is then displayed in a separate screen region so that the user can quickly and easily access the information, even if the foundational network plan section is no long visible on the screen (e.g., due to scrolling).

5. ACKNOWLEDGMENTS

Our thanks to the German Research Foundation for supporting this work within SPP 1884 “age-differentiated work systems“.

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