Investigation of Adaptation Dimensions for Age-Differentiated Human-Computer Interfaces

Nicole Schneider, Sabine Schreiber, Janet Wilkes, Morten Grandt, and Christopher M. Schlick

Institute of Industrial Engineering and Ergonomics, RWTH Aachen University
Bergdriesch 27, 52062 Aachen
{n.schneider,s.schreiber,j.wilkes,m.grandt, c.schlick}@iaw.rwth-aachen.de

Abstract. An important issue of the demographic change in the German population is the maintenance and promotion of the employability of aging workforces. However, there are hardly any suitable concepts or usable tools available to realize this goal. Possible approaches should push the individual strengths of the aging workers to the foreground and intercept the possible physical and cognitive losses in ability that occur with an increase in age. A model of age-differentiated adaptation of the human-computer interface, in which automatic adaptations are conducted based on individual user characteristics, is presented in this article. First connections between user characteristics and adaptation dimensions were analyzed in a study with 90 subjects ranging from 20 to 73 years of age. Results indicate a significant influence of graphical layout on memorization as well as interpretation performance.

Keywords: demographic change, adaptive human-computer interfaces, individualization of software.

1 Introduction

The demographic change of the population and the accompanying changes in gainful employment in Germany and other European countries will make it increasingly important to maintain and promote employability of the aging workforces. In terms of meeting these demands, however, there are hardly any suitable concepts and applicable tools currently available that support the individual strengths and weaknesses of the aging employed.

It is likely that a loss of physical abilities occurs with an increase in age. However, communicative, coordinative and creative activities that call upon the existing know-how possessed by older employees may play an ever more important role. The use of computers often poses a notable barrier for older workers since they lack experience and have a generally more reserved attitude towards information technology.

Work and work tools should be designed for individual abilities including the variability of abilities among older workers especially, thus securing employability.

C. Stephanidis (Ed.): Universal Access in HCI, Part I, HCII 2007, LNCS 4554, pp. 1010–1019, 2007.
© Springer-Verlag Berlin Heidelberg 2007

Current interfaces are not flexible though, and they are unable to compensate for the various operation methods or to specifically qualify the aging user. For example, older users do not receive adequate support, so individual adaptation to the characteristics, preferences and abilities of each individual user would be worthwhile.

In the adaptation of software to the individual user-initiated changes and independently computer-executed adjustments can be distinguished. Most of today's software systems possess a configurable user interface in which the appearance, menu structure, etc. can be customized according to individual preferences. However, the user usually does not have sufficient knowledge about the application and his/her own needs, meaning this type of individualization is rarely used [6].

A continuing approach is given by so-called adaptive user interfaces in which the system makes adjustments to itself based on user behavior. These "intelligent" interfaces attempt to anticipate the user's goals and needs through use of "artificial intelligence" and adjust accordingly [8].

Aging workers in particular benefit from the utilization of such computer workplaces because their specific abilities are consistently used and their weaknesses specifically supported. Such a targeted combination of different adaptation dimensions in relation to the physiological and cognitive abilities of aging people is not known, yet it is to be achieved with the approach of age-differentiated and individual adaptation described here.

2 The Approach of Age-Differentiated Adaptation

The approach of age-differentiated adaptation of the human-computer interface aims at the support of elderly people working with the computer. The individual age-based customization is exemplarily conducted in a project management software application. This software is particularly suitable, as it requires complex cognitive skills as well as coordinative-communicative abilities.

Based on the methodology of Jameson [5] three different phases are distinguished: the afference, inference and efference phases. The characteristic user attributes are registered in the first phase and analyzed in the second phase, followed by the drawing of conclusions regarding individualization. In the third phase, the individualized adaptation of the user interface is performed. The three phases are adapted accordingly for the approach of age-differentiated adaptation and then expanded through an evaluation phase. This evaluation phase involves the user in evaluating the adaptive software, which is then updated accordingly within an iterative design process.

Along with these adaptation dimensions, specific user data plays a particularly important role for the individualization of project management software. User-specific adaptation will be conducted based on the abilities of the individual user. The first step in doing so requires the identification of significant correlations between the user-specific data and those related to the adaptation dimensions.

A recently conducted experiment that examines different adaptation dimensions and their relation to age-specific user characteristics is presented in the following.

3 Empirical Investigation of Potential Adaptation Dimensions

In an empirical study, font size as well as memorization and interpretation performance were investigated with regard to the optimal age-differentiated and individualized adaptation of network plans for project management.

In the first experiment, Microsoft's standard font size and the recommended font size according to the standard (DIN EN ISO 9241-303) were examined to determine whether it is also suitable for older persons, or if there is an optimal font size according to age. It was hypothesized that an increase in font size has a positive effect of visual acuity on recognition ability as well as an improvement of performance, particularly for older users.

In the second experiment, the influence of layout design of a network plan on the memorization performance of the user was examined. A differentiation between vertical and horizontal orientation of task networks and different spatial spreads between activities of a network plan are highlighted. Based on investigations conducted by Winkelholz & Schlick [12], it was assumed that an improvement of memorization performance will occur for horizontal rather than vertical orientation, as well as for an increase in spread.

Analogous to experiment 2, experiment 3 tested the influence of layout design on contextual task processing. Based on the Proximity Compatibility Principle [10], it is assumed in experiment 3 that a small spatial spread between activities leads to better performance. Wickens postulates that the spatial proximity of data sources brings with it an advantage during integrative task processing, in which a compatibility of cognitive processes is ensured. A positive effect due to horizontal orientation is also expected in this case [11].

At the beginning of the experiments, user-specific abilities and characteristics of the test subjects were determined. Aside from experiments regarding visual acuity, the cognitive ability - in particular spatial sense, memory and fluid intelligence - were examined primarily by means of standardized questionnaires ([9], [7]). Moreover, the attitude and experience of the test subjects regarding technical devices and a project management software application was tested by a questionnaire [1].

The subsequent computer-based tests, which highlight two different adaptation dimensions, font size and layout design of a network plan in terms of age-specific aspects, was divided into three parts.

Each of the three experiments was conducted at a standard workplace PC. A 19” (48cm) LCD screen with a resolution of 1280 x 1024 pixels was used as a display.

In the experiments 90 subjects (45 male, 45 female) between 20 and 73 years of age were tested. For the evaluation of the experiment, subjects were divided into three age groups (20-39, 40-59, 60-75). The first age group consisted of 34 subjects, the second age group of 35 subjects, and the third age group of 21 subjects. The test subjects participated voluntarily in the experiment for a 20 Euro compensation. The majority of participants recruited were employees of the institute and the administration as well as senior citizen students at the university. Related to academic education level, 48.3 percent of participants claimed to have completed post-secondary studies. The second largest group of subjects (27.6 percent) had not completed vocational training.

Daily computer use is approximately 70 percent. Only four subjects indicated that they did not have a PC in their home. E-mail programs and the internet were also used by more than half of all test subjects on a daily basis. Even though 48.9 percent of test subjects dealt with project planning or project management in their jobs, either currently or in the past, only nine out of the 90 participants worked with the market leading MS Project software.

3.1 Experiment 1 – Investigation of Font Size

The goal of the experiment is to determine the connection between visual acuity of test subjects and the optimal font size for these subjects. The influence of various font sizes on recognition ability is highlighted in terms of age-specific factors.

In the first experiment the subjects had to perform a choice-reaction test. After the presentation of a control stimulus, the subjects had to differentiate between this stimulus and additional stimuli that were presented in various font sizes. The error rate and the reaction time are regarded as dependent variables and then evaluated according to the given font size.

Method

The symbol “4” served as a control stimulus that had to be differentiated from capital letters “A”, ”B”, “C”, etc. serving as alternative stimuli. A sequence of 165 symbols, which contained 15 control stimuli, was presented to the subjects. Each of the stimuli was presented for 1.5 seconds in duration. The sequence was randomly created under the condition that the number “4” appears once within a block of 10 symbols. The subjects were instructed to press the space bar when they believed they saw a “4”. All subjects were presented with an identical sequence of symbols. The resulting variance model consists of the factors font size (5 grades) and age-group (3 grades).

The display was placed in front of subjects at a viewing distance of 70 cm according to standards (BGI 650). The test subjects maintained this distance through the use of chin rests. In addition, the optimal height of the monitor was determined individually for each participant (BGI 650, DIN EN ISO 9241-303).

All symbols were presented in five different font sizes. If necessary, the subjects were allowed to wear glasses. Besides the stimuli in prescribed minimum font size as well as recommended font size (BGI 650, DIN EN ISO 9241-303), the test subjects were also presented with Microsoft's standard font size and a particularly large font size. The five fonts sizes used are 9, 12, 16, 22 and 27 minutes of arc (MOA).

3.2 Experiment 2 – Investigation of Effects on Memorization

The goal of the experiment was to determine the effect of age, as well as the cognitive abilities related to it, on memorization performance. Different layouts of network plans were thereby investigated as additional influencing variables.

The task of the second experiment was to memorize a randomly created sequence of highlighted activities from different layouts of network plans. The number of correct repeated sequences as well as the reaction time was used as a measure of performance.

Method

Figure 1 shows the six layouts that were used in the second experiment. Each layout consists of 25 activities. The six layouts differ depending on their orientation, horizontal (H) versus vertical (V), and their spatial spread, i.e., the distances between the activities (1 - no spread, 2 - clustered, 3 - uniformly spread). The motivation for the choice of these structures is based on experiments and analyses of Winkelholz & Schlick [12].

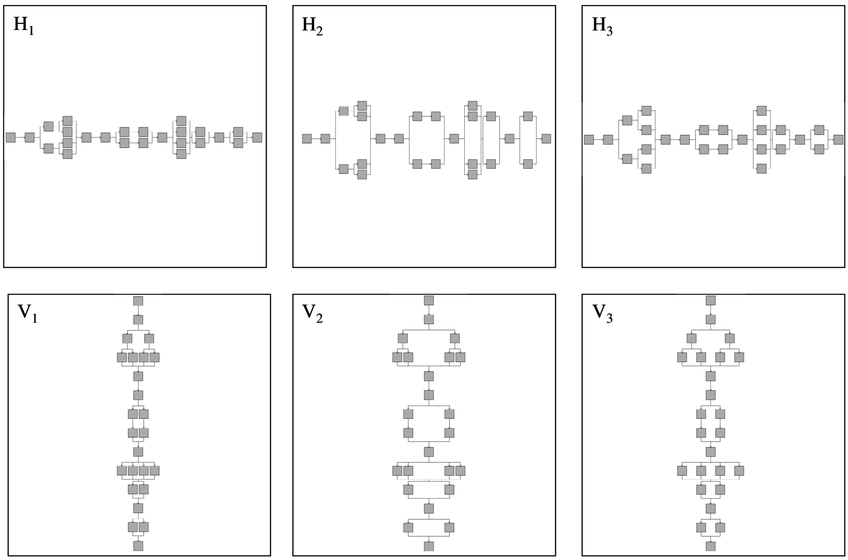

Fig. 1. Screenshots of the six layouts of task network plans

After an acoustical signal, the computer started to highlight activities of one randomly created sequence. Only singular activities of the sequence were highlighted for two seconds. The sequences were five items long. There was no break between the highlighting of two activities. The highlighted activities differed from the unhighlighted activities by color (blue instead of grey). The end of a sequence was indicated by a second acoustical signal. The test subjects were instructed to repeat the highlighted activities in correct order, by clicking them on screen with a mouse. After five activities had been clicked, another acoustical signal rang out. After a short break the next sequence was presented. There were six randomly created sequences for each layout. The same six sequences corresponding to one layout were presented to each subject. The order in which the various layouts were presented differed between groups of test subjects. The resulting variance model consists of the three factors age-group (three grades), orientation (two grades) and spread (two grades).

3.3 Experiment 3 – Investigation of Layout Effects on Interpretation Performance

The goal of the third experiment was to determine the influence of layout design on the interpretation performance (error rate and reaction time), as well as age-specific influencing variables and their relationship to layout design.

In this experiment, the subjects had to answer questions regarding the schedule as well as the duration of activities in differently laid out network plans. The amount of correct answers and the reaction time were measured as independent variables.

Method

For the third experiment the same six layouts as those used in experiment 2 (see Fig. 1) were used in simplified form. Additionally, the start and end times for each activity were added to each activity in the graphic. The subjects were asked four different questions per layout. Representatively, a layout with one of the four questions is depicted in Figure 2.

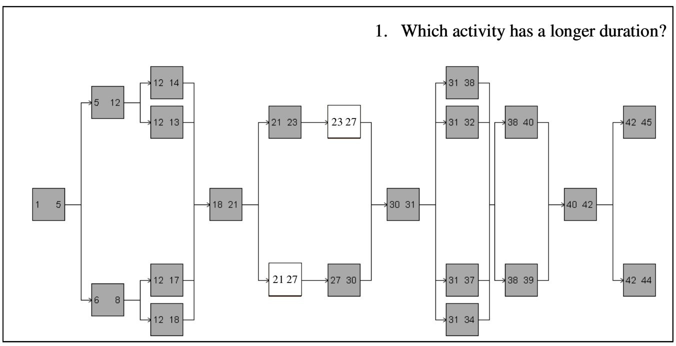

Fig. 2. Screenshot of one layout with one of the according task for this layout

After an acoustical signal, the computer started to highlight, depending on the question, one or two randomly created activities of the network plan. Here, a highlighted activity differs from an unhighlighted activity by color - orange instead of grey. Then, after two seconds, one question concerning the highlighted activities appeared. Afterward, the subject had to answer the question by marking the correct activity, respectively, the correct number, by mouse click. There was no time limit for this task. Following this, the next question was presented. There were four questions for each layout:

1. Which activity has a longer duration?
2. Which activity ends first?
3. How many direct predecessors does this activity have?
4. How many direct successors does this activity have?

These can be assigned to two question types according to their content: type 1, consisting of questions 1 and 2, demands a numerical analysis of the activities and type 2, consisting of questions 3 and 4, requires a visual-spatial analysis.

The sequence of questions within a layout was randomly selected. Each test subject was presented with identical questions in the same sequence per layout. The order in which the various layouts were presented differed between groups of test subjects. The resulting empirical design contains the four factors orientation (two grades), spread (two grades), type of question (two grades) and age-group (three grades).

4 Data Analysis

In order to compute the results, correlation analysis (Spearman coefficient) was used to determine connections between results of the preliminary interviews and psychometric tests and the computer-based tests. The data of the main investigation was evaluated using the general linear mode by analysis of variance with repeated measures according to the experimental designs mentioned above. Additionally, o^2 [4] was calculated for significant effects in order to be able to draw a conclusion about the strength of an effect by the extent of the involvement of the corresponding factors in the explanation of variance. The level of significance is $p<0.01$ if another level is not mentioned.

5 Results and Discussion

5.1 Experiment 1 - Investigation of Font Size

The results of the first experiment are outlined in the following according to accuracy, i.e., amount of correct and incorrect responses and reaction time.

Accuracy

At a font size of 9 MOA there are significant correlations with the quantity of correct answers. The older the subject, the lower the number of correct answers. However, there is no significant relationship between age and performance with a font size bigger than 9 MOA.

A main effect exists for age group, with $F=11.38$, $p<.01$ and $o^2=.032$, corresponding to an explained variance of 3.2 percent between subjects. An additional strong effect exists related to font size ($F=38.98$, $p<.01$, $o^2=.256$ within subjects). The interaction between font size and age group must also be pointed out: it indicates an explained variance of 13.7 percent ($F=11.14$, $p<.01$). However, a ceiling effect occurs above a font size of 12 MOA.

Reaction Time

A significant correlation of $r=.23$ ($p<.05$) for both 9 MOA and 12 MOA exists between age and the required time for problem solving at various font sizes. This means that, for smaller font sizes, older people require more time to give a correct answer. The font size factor is able to explain 42.8 percent of variance within the test subjects ($F=67.38$, $p<.01$). A ceiling effect occurs for font sizes greater than 16 MOA.

5.2 Experiment 2 - Investigation of Effects on Memorization

The following results are grouped according to accuracy and reaction time. The accuracy is measured through the number of correctly repeated sequences.

Accuracy

The age group of 20-39 year olds shows significantly better accuracy when memorizing the items in the network plans than the other two age groups. A significant main effect occurs for age group with $F=15.12$ at a level of significance of $p<.01$ and an explained variance of 12.7 percent between subjects.

A horizontal layout scores significantly higher than the vertical layout ($F=64.51$, $p<.01$, $o^2=.080$). No difference between cluster and uniformly distributed spread exists. A layout without spread, however, scores significantly lower ($F=64.63$, $p<.01$, $o^2=.19$). The interaction effect with a three percent explanation of variance between direction and spread is significantly more distinct for a horizontal layout direction than for a vertical layout. Significant correlations of $r=.28$ up to $r=.42$ exist between the memorization performance of this experiment and the results of the psychometric tests in the pretest for the determination of memory, spatial sense and fluid intelligence.

Reaction Time

A significant age effect between subjects can also be determined regarding reaction time ($F=7.93$, $p<.01$, $o^2=.054$). A significant orientation effect also exists ($F=6.2$), but at a level of significance of $p<.05$ and an explanation of variance of 1.2 percent it is not very distinct. The horizontal layout once again scores better than the vertical layout. The spatial spread effect is significant ($F=7.5$, $p<.01$) and lies at $o^2=.030$. Significant correlations exist between all layouts and age groups. Layouts H_2, H_3 and V_2 indicate highly significant negative correlations ($r=-.25$ to $r=-.44$) with the results of the dice test and the number-symbol test. Therefore, the better the test result, the lower the time needed for reaching the correct solution in these layouts.

5.3 Experiment 3 - Investigation of Layout Effects on Interpretation Performance

The results of experiment 3 are described only in terms of the required reaction time. No statements can be made regarding accuracy since nearly no mistakes have been made by subjects performing this task.

Reaction Time

In particular, the question type and the age group have effects on the time required to correctly answer questions in this experiment. The age effect explains 18 percent of the variance ($F=21.08$, $p<.01$), while the question type explains 17 percent within the test subjects ($F=77.58$, $p<.01$). Question type 1 leads to significantly better performance than question type 2. The spread effect is equally significant with

F=10.85 at p<.01 and an explanation of variance of 2.2 percent. Equally distributed spread thus leads to significantly better performance in terms of less time required than for cluster spread and layout without spread. A significant interaction effect exists related to question type and age group, and explains 7.5 percent of variance within test subjects (F=17.32, p<.01). Question type 2 scores significantly lower in age group 60-75 years than in the other two age groups. A significant negative correlation between both question types and all layouts is shown by test results regarding required time and spatial sense (r=-.449, p<.01), fluid intelligence (r=-.425, p<.01) and memory (r=-.465; p<.01).

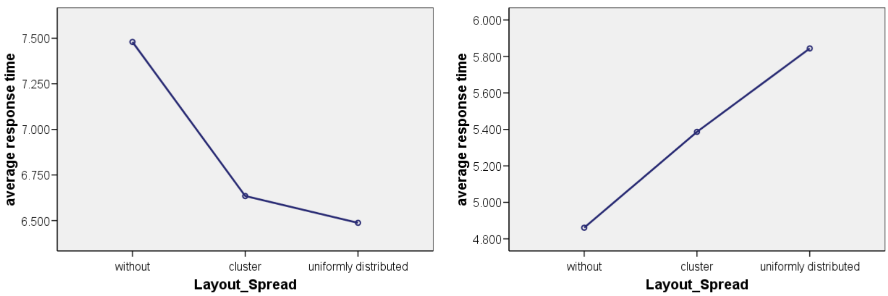

Fig. 3. Average response time concerning different layouts for memorization in exp.2 (left) and interpretation performance in exp.3 (right)

The results of the first experiments on age-differentiated font sizes in the design of software indicate that the often predefined standard font size of 12 MOA is sufficient for all age groups. This seems to be the case if, as in these experiments, only recognition and short-term strain are dealt with. The missing correlation between visual acuity and font size must still be explained. Even older subjects with significant limitations in visual acuity (age and visual acuity are significantly correlated) are still able to perform well. A possible explanation is the trade-off between limited visual acuity and short-term strain, or perhaps an increase in attentiveness. It is possible to perform well when dealing with a pure recognition task, such as the one in this case, yet it should be investigated if this performance level remains with long-term tasks, such as the execution of project management tasks. As a result, it can be asked which font size is most suitable for older users during long-term tasks that also pose more complex demands than just stimuli discrimination.

It can be noted that in terms of layout design, a large spread between the activities in a network plan is necessary for good memorization performance (high amount of correct answers, low amount of required time; see Fig. 3 left). This conclusion is supported by the theory of Winkelholz & Schlick [12], which assumes an improvement in memorization performance due to horizontal rather than vertical orientation and an increase in spread.

For the extraction of information on a semantic level, however, a small spread between activities has positive effects (see Fig. 3 right, corresponding to the Proximity Compatibility Principle according to Wickens & Carswell [10]). The expected positive effect of a horizontal orientation stated by Winkelholz [11] can also be confirmed by this experiment.

6 Future Work

The discrepancy related to layout design for different task types, memorization and interpretation discovered here should be further analyzed in future work. Additionally, the influence of scrolling on user performance must be taken into consideration in the determination of the optimal layout design for larger network plans. Therefore, it should be investigated whether an optimal layout structure, e.g., with greater spatial spread, leads to poorer performance due to the scrolling necessary because of its larger presentation manner.

Acknowledgement

The research was funded by the German Research Foundation according to the priority program no. 1184, *Altersdifferenzierte Arbeitssysteme*.

References

1. Beier, G.: Kontrollüberzeugung im Umgang mit Technik. In: Dissertation an der Humboldt Universität Berlin (2004)
2. BGI 650: Bildschirm- und Büroarbeitsplätze. In: Leitfaden für die Gestaltung, Germany (2005)
3. DIN EN ISO 9241-303: Ergonomie der Mensch-System-Interaktion - Teil 303: Anforderungen an elektronische optische Anzeigen; Deutsche Fassung prEN ISO 9241-303 (2006)
4. Eimer, E.: Varianzanalyse: Eine Einführung. 1. Aufl. Stuttgart, Berlin, Köln, Mainz: Kohlhammer, S. p. 109ff (1978)
5. Jameson, A.: Systems that Adapt to Their Users: An Integrative Perspective. Saarbrücken: Saarland University (2001)
6. Kobsa, A.: User modeling and user-adapted Interaction. In: Conference companion on Human factors in computing systems, pp. 415–416. ACM Press, New York (1994)
7. Liepmann, D., Beauducel, A., Brocke, B., Amthauer, R.: Intelligenz-Struktut-Test 2000 R, Hogrefe Verlag, Göttingen (1999, 2001)
8. Wahlster, W.: Adaptive Layout of Dynamic Web Pages. In: Akademische Verlagsgesellschaft Aka GmbH (2003)
9. Wechsler, D.: Die Messung der Intelligenz im Erwachsenenalter. In: Textband zum Hamburg-Wechsler-Intelligenztest für Erwachsene (HAWIE). Bern: Huber (1956)
10. Wickens, C.D., Carswell, M.: The Proximity Compatibility Principle: Its Psychological Foundation and Relevance to Display Design. Human Factors 37(3), 473–494 (1995)
11. Winkelholz, C.: Analyse, Modellierung und Simulation der visuelle-räumlichen Kognition bei der Mensch-Maschine-Interaktion, Dissertation, RWTH Aachen (2006)
12. Winkelholz, C., Schlick, C.: Modeling human spatial memory within a symbolic architecture of cognition. In: International Conference Spatial Cognition 2006 , Universität Bremen, Germany (2006)