Handbook of Research on User Interface Design and Evaluation for Mobile Technology

Volume I

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Chapter VIII
Transgenerational Designs in Mobile Technology

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ABSTRACT

Mobile devices have proliferated into most working and private areas and broad user groups have access to mobile technology. This has considerable impact on demands for usable designs. As users differ widely regarding age, upbringing, experience and abilities, it is a basic question whether there are user interface designs feasible that meet the demands of user diversity and trans-generational designs. The aim of the present research was to uncover effects of user diversity on menu navigation. Users of a wide age range were examined when interacting with mobile phones. In a detailed way, individual navigation routes were analyzed and effectiveness and efficiency of menu navigation was determined. In addition, effects of individual variables were considered. The results show that the usage of small-screen devices imposes considerable difficulties for all users, but in particular for children and middle-aged adults, who were very sensitive for cognitive demands imposed by current mobile phone designs.

INTRODUCTION

The distribution of mobile devices represents one of the fastest growing technological fields ever. Especially, small interface devices are omnipresent and can be characterized as important technical devices in today's societies. Mobile devices promise to be ubiquitously applicable and cover basic communication as well as office functionalities and allow Internet access. Moreover, the devices are used for route and traffic information, but provide also fun and entertainment applications.

The ubiquity and penetration of mobile devices raise new usability concerns. Many users show considerable problems with respect to the handling, learning, and understanding of these devices, which in turn reduce the ease of use and the perceived usefulness (e.g., Arning & Ziefle, 2006, 2007; Jakobs, 2005; Tuomainen & Haapanen; 2003; Ziefle & Bay, 2004; 2005). Yet, commonly agreed rules, which complexity of functions and which interface design is appropriate, have not been defined, and perhaps due to this fact, usability is not an issue that manufacturers are primarily investing in.

Several factors can be referred to that contribute to these difficulties. While formerly the usage of information technology was mainly restricted to technology-prone users, today, all user groups are addressed by technology. The diversity of the target groups, however, requires a basic understanding of the human factor and should be adequately addressed by device design. Users differ considerably with regard to their needs, motivation, competencies, and aptitudes, which is reflected in users' age, gender, and experience with technical devices.

In addition, more and more transactions include the utilization of technical devices and demand the acceptance and the competence of using technical devices. Thus, technical device usage is increasingly less optional, but represents more and more an indispensable qualification for many working settings. Furthermore, the nature and number of the devices' functionalities is elementarily changing. The traditional functionality of mobile phones, making calls, is only one among many other functions and the devices have an increasing complexity. Aggravating, numerous different device types within and across brands can be found on the market. While the applications and functions are increasingly merging across device types, though, devices differ considerably with respect to their basic structure and interface design. Within cross-platform-designs, it is thus difficult to understand, which operation modes and "device logic" is specific for a certain device and which is valid across devices (e.g., Ziefle, Arning & Bay, 2006). Finally, the miniaturization of the devices also contributes to cognitive difficulty when using technology. The tiny devices have small keys and miniature displays, thus the key handling and the visibility of the displayed information is considerably complicated. Furthermore, due to the restricted display, only few functions can be seen at a time. This increases memory load, as users have to remember function names and their menu location. Also, spatial orientation in the menu is problematical. Users do not experience how the menu is structured and how many functions are in the menu. As a consequence, users often lose their way in the menu.

BACKGROUND

The development of mobile technology and the device interface design still seems mainly to concentrate on what young and experienced users want (Maguire & Osman, 2003). However, children (mobileyouth.org, 2005) and older adults (Arning & Ziefle, 2007; Ziefle & Bay, 2006) are now also major user groups and, though, have not been considered adequately so far. This may be due to the fact that there is only little knowledge whether these groups have specific difficulties when using small-screen devices, and also regarding the factors, which might hamper or benefit a purposeful interaction with these devices (e.g., Arning & Ziefle, 2006, Tuomainen & Haapanen; 2003). Instead, a lot of preconceptions are prevailing. According to casual comments of many participants in our lab, we experienced that there is a "common knowledge" about aptitudes and abilities of age groups interacting with technical devices. Older adults are assumed to be the taillight regarding technical competence (and interestingly, they characterize themselves the same way), and quite low interest in technical developments is ascribed to them. As they have a different upbringing and were educated in times when technical devices were far less complex, they are thought to be considerably penalized. Conversely, children are supposed to easily master the interaction with technical devices. They are believed to understand the mode of operation of those devices much faster by virtue of their contact with interactive technology (e.g., computers, video games) from early on.

Additionally, children's fascination for explorative and inquisitive activities is well known, therefore they are assumed to be especially qualified for the interacting with technical devices.

Contrary to these statements, it was found that adults and children show a similar performance when using technical devices. Both were very sensitive to the demands imposed by the devices and showed considerable performance losses in sub-optimally designed interfaces (e.g., Bay & Ziefle, 2005; Ziefle & Bay, 2004; 2005; 2006; Ziefle, Bay & Schwade, 2006). But the exclusive focusing on users' age for technical performance is not sufficient. Rather, age must be characterized as the carrier of individual characteristics that are known to affect technical performance: cognitive abilities, attitudes, gender, or computer experience. Therefore, we need to understand the interrelation of these factors. If we want to learn if there are designs feasible, that are suited for all user groups or if we want to identify shortcomings, we also need to understand the specific impacts of individual variables, and their interaction with age and gender. The knowledge of the factors, which might underlie the aging and gender impact, though, is mostly limited to the examination of adults. Moreover, the interplay of different factors and performance has not been investigated satisfactorily so far.

Among the individual variables, which are known to play a role for adults' menu navigation performance, spatial ability is very prominent. Persons with high spatial abilities outperformed those with lower levels of spatial ability (e.g., Arning & Ziefle, 2007; Egan, 1988; Goodman et al., 2004; Kim & Hirtle, 1995; Vicente, Hayes & Williges, 1987; Westerman, 1997; Ziefle & Bay, 2006). Also, (verbal) memory is essential for the performance in technical menus. Users with high memory abilities had a better orientation in the menu, because they better memorized the functions and menu locations (e.g., Arning & Ziefle, 2007; Bay & Ziefle, 2003; Hasher & Zack, 1988; Ziefle & Bay, 2006). Moreover, the gender factor is crucial, especially in combination with computer self-efficacy. Female users often show lower self-efficacy and higher computer anxiety (e.g., Busch, 1995 Davies, 1994; Downing, Moore & Brown,2005). Rodger and Pendharkar (2004) referred performance differences between women and men to differences in computer experience levels, which are often lower in women. The interrelation of gender effects and computer experience is corroborated by studies showing that playful and active exploring of technical menus are forming an incidental knowledge of the system, which in turn contributes to computer experience (e.g., Bay & Ziefle, in press; Beckwith et al., 2006). Interestingly, playful interacting with computer systems is a behavior that is more often observed in male than female users (e.g., Van den Heuvel-Panheizen, 1999).

MAIN FOCUS OF THE CHAPTER

Comprising, the usability of small-screen devices, is an important but sophisticated demand, especially when taking user diversity into account. The interplay of user characteristics for the performance in technical menus is complex and needs a detailed examination. This is what the present paper wants to contribute to. The main focus was directed to a detailed analysis of users' navigation performance when using mobile phones. To understand the impact of user diversity, children, younger, and middle-aged adults were examined. Furthermore, gender effects were explored. Also, the influence of previous experience with technology and cognitive factors, as well as motivational factors, were taken into account. On the basis of a detailed analysis of individual interaction patterns, some implications for the design of mobile phones are discussed.

Method

Independent and Dependent Variables

Two independent variables were examined. The first independent variable was users' age, comparing the navigation performance of children (9-10 years), younger (20-30 years) and middle-aged adults (40-61 years). The second independent variable was gender, comparing female and male participants. Furthermore, participants' experience with technical devices, their spatial ability and short-term memory capacity were determined and treated as between subject variables, possibly affecting performance when using mobile phones.

As dependent variables, the effectiveness and efficiency of navigation were determined. In order to get a detailed insight in navigation behavior and to identify individual navigation patterns, six different measures were surveyed.

For the task *effectiveness*, the percentage of successfully solved tasks (within the time limit of five minutes per task) was measured. A maximum of eight tasks (four tasks solved twice) were to be completed.

Efficiency: (1) The *time* needed to process the tasks was surveyed. However, the time is a rather unspecific measure (as it does not tell us what users actually do in the menu). Therefore, more specific measures were determined in addition. (2) The number of *detour steps* (steps executed in the menu that were not necessary when solving the task on the shortest way possible (3) The number of *hierarchical returns* to higher levels in menu hierarchy, indicating that users in the belief of having taken the wrong path go back to a known menu position, consequently re-orientating themselves. (4) The number of *returns to the top*. This measure was assumed to reflect utter disorientation, as users had to re-orientate by returning to the top menu level, beginning from scratch.

Experimental Tasks

Four typical and frequently used mobile phone tasks were selected. In total, a minimum of 47 steps was necessary to solve the four tasks. Participants had to:

1. Call a number (11 steps)
2. Hide one's own number when calling someone (14 steps)
3. Send a text message (11 steps)
4. Make a call divert to the mailbox (11 steps)

In order to determine learnability effects, the tasks had to be solved twice consecutively. The order of tasks in the two trials was held constant over participants.

Apparatus and Materials

For the mobile phone, a well-known mass model, the Siemens S45, was chosen. In order to experimentally examine the quality of users' menu navigation performance, it was of methodological importance to analyze individual navigation routes in detail, and controlling for confounding factors at the same time. Therefore, the phone was simulated as software solution, run on a PC and displayed on a touch screen (Iiyama TXA3841, with a touch logic by ELO RS232C). Figure 2 shows a snapshot of the emulated phone. The display size corresponded to the original size, but the chassis of the phone and the keys were enlarged in order to enable easy operation of them with the finger on the touch screen. Moreover, a logging software tool was developed, which enabled us to log any user interaction with the system. By this, the number and type of keys used, the functions selected, and the individual navigation routes taken through the menu could be reconstructed in detail.

Figure 1. Snapshot of the emulated mobile phone (Siemens S45)

Participants

In total, 108 participants (58 females, 50 males) volunteered for the study. They were divided into three age groups: In the children group, 22 girls and 14 boys participated (M = 9.4; SD = 0.7). From the 36 young adults, 18 were females and 18 males (M = 24.1; SD = 2.8). Finally, 36 middle-aged adults (18 females, 18 males) took part (M = 47.1; SD = 7.6). The children were in their fourth school year. In the younger group, students of different academic fields volunteered. Participants of the middle-aged group were reached by an advertisement in a local newspaper and had a wide educational range. It was instructed that the study aimed at an evaluation of the usability of mobile phones. The motivation to join the study was high.

Assessing Users' Characteristics Interacting with Navigation Performance

As it was a major aim of the study to learn how the three age groups were interacting with the mobile phone and, moreover, which user characteristics might be crucial for navigation performance, the participants were surveyed regarding their spatial ability, verbal memory and the experience using technical devices. Here, the frequency and the reported ease of using these devices were assessed. Moreover, participants' interest in technology was determined.

Assessing Spatial Abilities and Verbal Memory

Assessing spatial and memory abilities in the children group, two subtests of the HAWIK-R were carried out. In the test on spatial ability ("Mosaic Test") the experimenter showed the child a picture (Figure 2) and the child's task was to reproduce the picture using cubes having different patterns on each of the sides. A maximum of 26 points could be attained in this test.

The test on short-term memory required the children to verbally repeat a row of numbers read aloud by the experimenter. The test consisted of seven rows of between three and nine numbers, which had to be reproduced directly after. The children were given two trials to correctly reproduce each row. A maximum score of 14 points could be reached.

For the adult group, spatial abilities were assessed with the paper-folding test (Ekstrom et al., 1976) in an online version (http://www.lap.umd.edu/vz2). Each of the 20 items includes successive drawings of two or three folds made in a square sheet of paper. The final drawing shows a hole punched in the folded paper. Participants had to mentally rotate the paper from the folded into the fully opened form and to indicate which of a number of possibilities shows the correct drawing. The 20 items had to be solved within 180 seconds. In Figure 3, an example item of the paper-folding test is given.

To assess memory ability in the adult groups, the verbal memory test adapted (Bay & Ziefle, 2003) from the learning and memory test (Bäumler, 1974) was used. Fifteen Turkish words (unknown to German participants) were presented in succession for three seconds each. Directly after the presentation, participants had to recognize the target items among three distractors, each being phonologically or visually similar. The maximum score to be reached was 15. An example from this test is given in Figure 4.

Figure 2. Mosaic test (Hawik-R): The upper row represents the single cube sides. The lower row represents one of the spatial tasks. The spatial demand for the children was to mentally deconstruct the figure into single cubes and to mentally rotate and arrange the cubes according to the figure.

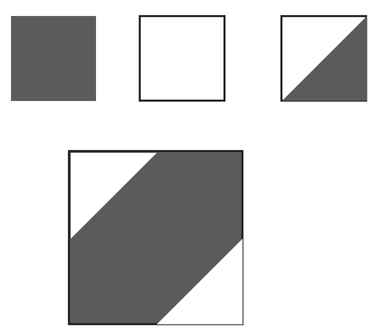
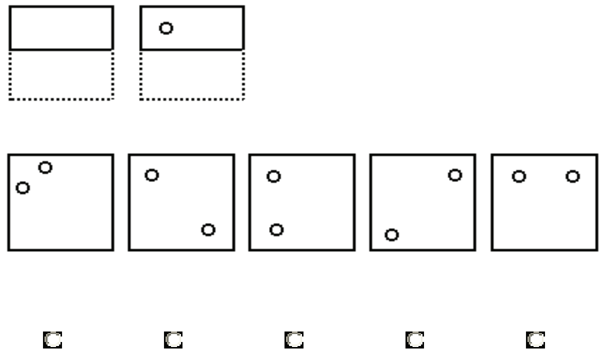


Figure 3. Item example of the paperfolding test (Ekstrom et al., 1976)



Assessing Previous Experience with Technical Devices

A detailed pre-screening of participants' experience with mobile phones and other technical devices as well as the reported ease of using them was carried out. Participants reported if and how often they use technical products (mobile phone, PC, video cassette recorder (VCR) and DVD), using a 5-point scale (1 = several times per day, 2 = once per day, 3 = once or twice a week, 4 = once or twice per month and 5 = less than once or twice a month). Furthermore, the estimated ease of using different technical devices had to be stated on a scale with four answering modes (1= the usage is easy, 2 = the usage is rather easy, 3 = the usage is rather difficult and 4 = the usage is difficult). Finally, participants indicated their interest in technology, using a 4-point scale (1 = low interest; 2 = rather low interest, 3 = rather high interest, 4 = high interest).

Results

The results were analyzed by multivariate analyses of variance assessing effects of age and gender on navigation performance in terms of effectiveness (number of tasks solved) and efficiency measures (time, detour steps, hierarchical returns, and returns to the top. Furthermore, the relationship between the users' age, gender and user characteristics was determined by correlation analyses. The level of significance was set at $p < 0.1$.

The result section is organized as follows. First the outcomes regarding user characteristics in the three age groups are described and how characteristics interrelate. Second, navigation performance is looked at, differentiating performance outcomes regarding age groups and also regarding gender effects. Then, learnability effects are focused upon, comparing the first contrasted to the second trial, determining if and to what extent performance improved for the three ages and for gender groups. A final analysis is concerned with the impact of user characteristics for performance outcomes.

Figure 4. Item example from the verbal memory test (Bay & Ziefle, 2003)

TATIL

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User Characteristics of Participants

In this section, the experience with technical devices, and the reported ease of using them are focused on. Also, the rated interest in technology is illustrated. Furthermore, the users' verbal memory and spatial abilities are described. It is of interest, if these variables are modulated by age or the gender of participants.

Previous Experience with Technical Devices

First, all participants reported to have a high experience using mobile phones. While younger and middle-aged adults possessed an own mobile phone, only 14 of the 36 kids did so. The children, who did not own a phone, though, reported to have frequent access to mobile phones (friends, siblings, or parents). Even though devices offer an increasing number of functionalities, astoundingly, only a very small fraction of these functionalities were used, across all age groups. However, there were age differences in the type of functionalities, which were commonly used. In the children group, the phones were mainly used for games (first choice) followed by calling and sending text messages. The young adult group indicated to use the phones mainly for text messaging and calling, but they also reported to play games and to use the phone as an alarm clock. Contrary, the middle-aged adult group reported to use the phones mainly for calling purposes, and emphasized that the majority of functions are "quite unnecessary." In Table 1, key results (means, standard deviations) are given for the experience measures and the interest in technology.

The frequency of mobile phone usage was significantly different for the three age groups (χ^2= 28.6; p = .000). The children and the middle-aged adult group used it 1-2 times a week (not differing from each other), while younger adults reported to use it once daily. With respect to PC usage, another significant age difference was found (χ^2 = 31.2; p = .000). The PC was used least in the child group (1-2 times a week), while both adult groups indicated to use it at least once a day. Finally, the frequency of using VCR/DVD is low, with the middle-aged adults using it about 1-2 times per month, while children and young adults use VCR/DVD about 1-2 times a week (χ^2 = 17.1; p = .000). When focusing on the ease of using these devices, all participants reported the usage as easy or at least rather easy. Age differences were

Table 1. Means (standard deviations) in user characteristics in all age groups

	Children	**Young adults**	**Middle-aged adults**
Gender	22 girls, 14 boys	18 women, 18 men	18 women, 18 men
Age	9.4 (0.7)	24.1 (2.8)	47.1 (7.6)
Frequency using a…	1= several times a day; 2 = Once daily; 3 = 1-2 times a week; 4 = 1-2 times a month; 5 = less than once a month		
Mobile phone	3 (1)	1.5 (0.8)	2.8 (1.8)
PC	3.2 (1.3)	1.5 (0.8)	1.9 (1.2)
VCR/DVD	2.9 (1.4)	3.2 (1)	4.2 (1.2)
Ease of using is…	1= easy; 2 = rather easy; 3 = rather difficult; 4 = difficult		
Mobile phone	1.4 (0.6)	1.2 (0.5)	2 (1.4)
PC	1.6 (0.7)	1.5 (0.6)	1.8 (1)
VCR/DVD	1.3 (0.5)	1.5 (0.7)	2.1 (1.4)
Interest in technology	1= low; 2 = rather low; 3 = rather high; 4 = high		
	3.4 (0.8)	2.8 (1.1)	2.4 (1.1)

found only with respect to VCR/DVD usage (χ^2= 8.8; p = .000). Finally, the interest in technology revealed another significant age difference (χ^2= 15.9; p = .000). The highest interest was present in the children group (M = 3.4). The lowest interest in technology was reported by the middle-aged adult group (M = 2.8), however, the young adults' interest was also comparably low (M = 2.4).

Across all age groups, female and male users did not differ regarding to the frequency of using mobile phones, VCR/DVD and PC, but introduced themselves as frequent users of common technical products. Also, no correlation of gender and the ease of using mobile phones and VCR/DVD devices were revealed. However, the interest in technology (r = -.26; p = 0.008) and the ease of using the computer (r= -.38; p = 0.000) showed significant correlations to gender: Female users reported the PC to be more difficult to use than the males and their interest in technology was lower compared to male users' interest in technology. Though interrelations were present in all age groups, interestingly, they were most pronounced for children.

Verbal Memory and Spatial Ability

First, outcomes in verbal memory in all age groups are addressed. On the left side of Figure 5, the scores of the children are illustrated. From the 14 points, the children reached, on average, "only" 5.4 points (SD = 1.5), and none of the children was able to reach the maximum score. Young adults (Figure 5, center) reached, on average, 12.4 points (out of 15). The middle-aged adult group (Figure 5, right) showed also a solid memory performance (M = 10.3; SD = 2.6), even though their memory score differed significantly from the younger adults' score (F (1,71) = 15.3; p=0.000).

In Figure 6, the outcomes in spatial abilities are pictured. The children (Figure 6, left) differed considerably with respect to spatial abilities. The inter-individual variance among children was high (range 4-26 points; M = 15.6; SD = 5.5), showing big developmental differences among 9-10 years old kids. For the younger group (Figure 6, center), the spectrum of correct answers ranged between 8 and 19 points (out of 20), reaching a mean performance of 13.2 (SD = 3.1). Finally, the middle-aged group reached an average score of 12.9 out of 20 points (SD= 3.7). The range of answers (4 points minimum and 20 points maximum) also represents a high variance, showing that spatial abilities do not follow a systematic decrease with increasing age. Statistical testing revealed no significant differences between spatial abilities of younger and middle-aged adults. Also, no gender differences were present neither with respect to verbal memory, nor spatial ability. However, for the children, there was a significant correlation of gender and the level of spatial ability (r = 0.6; p=0.03), with boys having higher spatial abilities (M = 18/26 points) than girls (M = 14/26 points).

Figure 5. Outcomes in verbal memory (left: children; center: young adults; right: middle-aged adults)

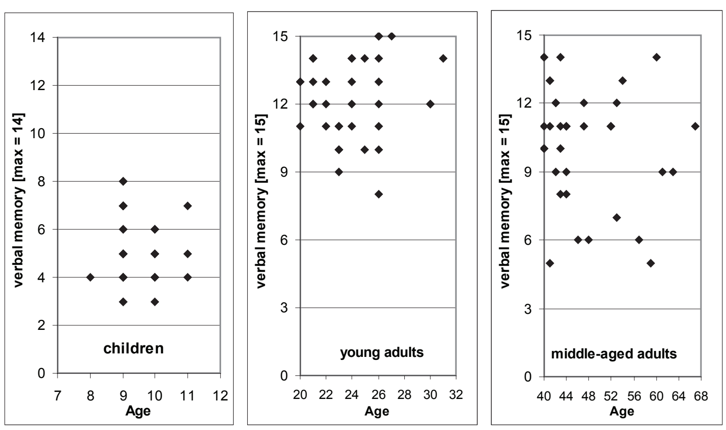
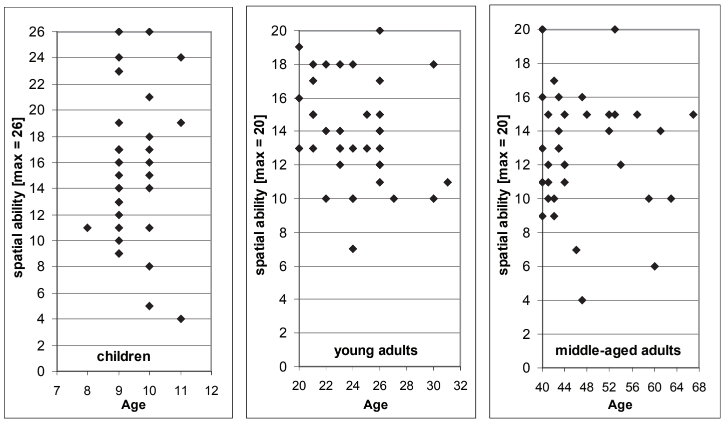


Figure 6. Outcomes in spatial abilities (left: children; center: young adults; right: middle-aged adults)



Menu Navigation Performance

When comprising the navigation performance in the eight tasks, a significant omnibus effect of age was found (F (2,102) = 18,1; p=0.00). Moreover, a significant omnibus effect of gender was revealed (F (1,102) = 3.1; p=0.01) as well as a significant interaction effect of age and gender (F (2,102) = 2.9; p=0.002). The age effect (single F-test; F (2,102) = 59.9; p<0.000) was based on significant differences between all age groups.

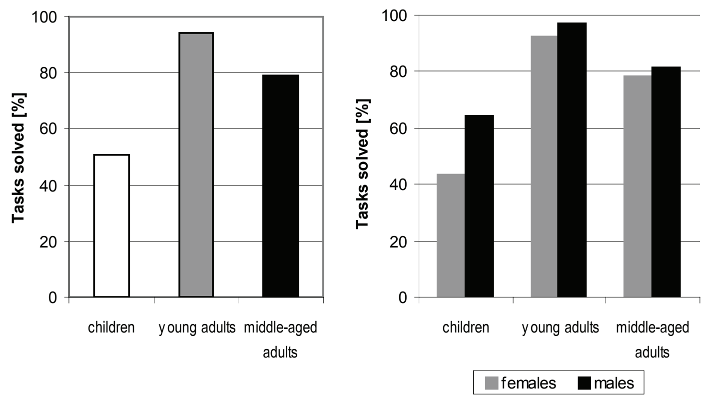
In Figure 7, the outcomes in task effectiveness are illustrated (left side: effectiveness for all age groups; right side; effectiveness for age and gender groups).

As can be seen there, the children showed the lowest effectiveness, reaching a mean task effectiveness of 51 percent. The best performance was present in the younger adult group, yielding a task effectiveness of 94 percent, while the middle-aged adults' effectiveness ranked in between (79 percent). Even though adult participants showed a considerably better performance than the children, it is quite astounding that not even the students were able to solve the eight tasks completely successfully. Also the effects of gender (F (1,102) = 11.3; p=0.001) as well as the interaction of age and gender (F (2,102) = 3.1; p=0.05) become obvious. The significant gender effect was originated by the girls' lower task success compared to the boys (girls: 43 percent; boys: 64 percent), while gender differences in the adults groups were not found to yield significant effects.

Furthermore, task efficiency is considered. Effects of age were significant for each of the single measures (time: F (2,102) = 50.5; p=0.000; detour steps: F (2,102) = 41; p<0.000); hierarchical returns: (F (2,102) = 22.6; p<0.000; returns to the top: (F (2,102) = 12.3; p=0.000). Independently of the measure, the children showed the lowest task efficiency, followed by the middle-aged adult group. The best task efficiency was present for young adults.

In Figure 8, the key results in task efficiency are illustrated for age groups and gender. As can be seen there, the children needed 20 minutes and 36 seconds and made 672.7 detour steps, when processing the phone tasks. The detouring of the children is considerable when taking into account that, overall, a minimum of 94 steps were needed to solve the tasks (47 steps per trial). Furthermore, the children made about 81.1 returns in menu hierarchy, and left the menu 8.1 times, to begin from scratch. Compared to the children, both adult groups were much more efficient even when the young adults significantly outperformed the middle-aged adult group. For the student group, it took 6 minutes 39 seconds to complete

Figure 7. Task effectiveness (%) in the three age groups (left) and both gender groups (right)



the tasks; compared to 14 minutes 19 seconds in the middle-aged group- this equals a benefit of 57 percent. Also, the students carried out only—but still—213.7 detour steps, returned 15.5 times to higher levels in menu hierarchy and began 0.9 times from the very beginning. In contrast, the middle-aged group made 414 detour steps, and returned, on average, 52.5 times to higher levels in menu hierarchy. Also, they made 5.4 complete returns to the top menu level.

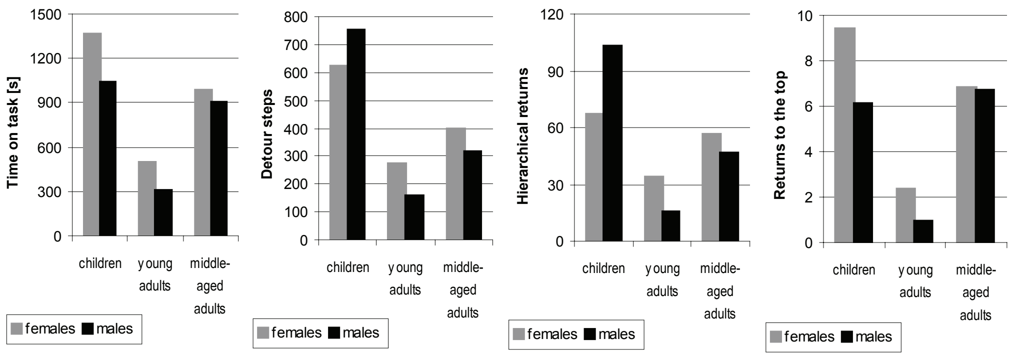
Looking on gender effects, male participants showed a generally more effective, and also a more efficient navigation style. However, gender effects were not symmetrical across ages and measures, respectively. The most pronounced gender differences were present in the children group, while gender effects decrease with increasing age. A quite interesting effect was revealed for the navigation strategy, which was different for girls and boys. The boys were more successful solving the tasks compared to the girls. Also, they needed less time and showed overall a smaller amount of returns to the top. So far, their navigation style is similar to adult male participants when compared to female participants. Yet, the boys' higher effectiveness was reached by a higher amount of exploration behavior in the menu. This can be taken from the high number of detour steps and hierarchical returns. Actually, their detouring was larger than that of all participants. Apparently, the boys capitalize the additional detouring on an overall better navigation performance, in contrast to the girls but also in contrast to both adult groups. Interestingly, the boys returned to a lesser amount to the top menu level compared to the girls, which shows from another side that the boys' detouring is more probably reflecting an active menu exploration rather than disorientation—otherwise they should have started from scratch more often.

Learnability Effects: Comparison of Navigation Performance in the First vs. Second Trial

Learnability effects, especially their interaction with age and gender effects might give additional insights in the difficulties users experience when interacting with small screen devices.

Again, first the task effectiveness is looked at. A significant learnability effect ($F(1,102) = 17$; $p=0.000$) was revealed, showing that in the second trial more tasks were solved successfully compared to the first trial (children: first trial: 47 percent, second trial 55 percent; young adults: first trial: 93 percent, second trial 95 percent; middle-aged adults: first trial: 75 percent, second trial 84 percent). No interaction effects of learnability and gender and learnability and age were revealed. Thus the higher task success in the second run was equally large for all participants.

Figure 8. Task efficiency (time on task, number of detour steps, hierarchical returns and returns to the top)



Next, efficiency is taken into account. In Figure 9 efficiency measures (time on task, detour steps, hierarchical returns and returns to the top) are depicted, differentiating the three age groups. Independently of the measure, there is a clear age pattern. Young adults showed the best performance and children the lowest performance.

According to the learnability effects regarding effectiveness, one would expect hat efficiency should also be higher in the second trial, therefore participants should spent less time on tasks, accompanied by fewer detour steps. In addition, also the number of returns in menu hierarchy and returns to the top should considerably decrease in the second run. Even though significant learnability effects for efficiency measures were present (time: F (1,102) = 9.8; p=0.002; detour steps: F (1,102)=6,4; p = 0.01), it becomes obvious that within navigation efficiency learnability effects are not equally high for all groups, but interact with the age of participants (time: F (1,102) = 22.3;p=0.000) as well as with gender (time: F (1,102) = 7.8; p=0.006; hierarchical returns: F (1,102) = 5.5; p=0.002; returns to the top: F (1,102) = 2,5; p<0,1). Moreover, there were also three-fold interactions between learnability, age and gender (time: F (1,102) = 2, 3; p<0.1; hierarchical returns: F (1,102) = 2, 5; p<0.1; returns to the top: F (1,102) = 2, 4; p<0.1). In order to disentangle the complex interrelation, first the nature of the interacting effect between learnability and age is addressed (Figure 9).

From Figure 9, it can be seen that actually only the young adult group profit from executing the tasks a second time. They were faster, executed less detour steps, and carried out fewer returns in menu hierarchy and also fewer returns to the top in the second trial compared to the first. The children and the older group, however, showed a different pattern. As the young adults, they were also faster in the second trial, however, in contrast to students, their detouring behavior did not improve in the second trial, as taken from the number of detours steps, the hierarchical returns and the returns to the top level. In short, one could characterize children's and older adults' navigation style as less cautious in the second compared to the first run (as they were faster), but still inefficient.

However, it is a basic question, whether learnability effects are similar across female and male users. This is analyzed in Figure 10. Here, tasks' efficiency is pictured for all participants, males (gray lines) and females (black lines) as well as for all age groups. The upper row of Figure 10 represents task efficiency of the children, the middle row navigation efficiency of the older group and the lower row shows efficiency measures of the young adults.

Again, we see the better overall performance of male compared to female users as well as the clear performance superiority of younger adults. Furthermore, it becomes obvious that the children group is considerably different compared to

Figure 9. Task efficiency (time on task, number of detour steps, hierarchical returns and returns to the top) in the first compared to the second trial for all age groups

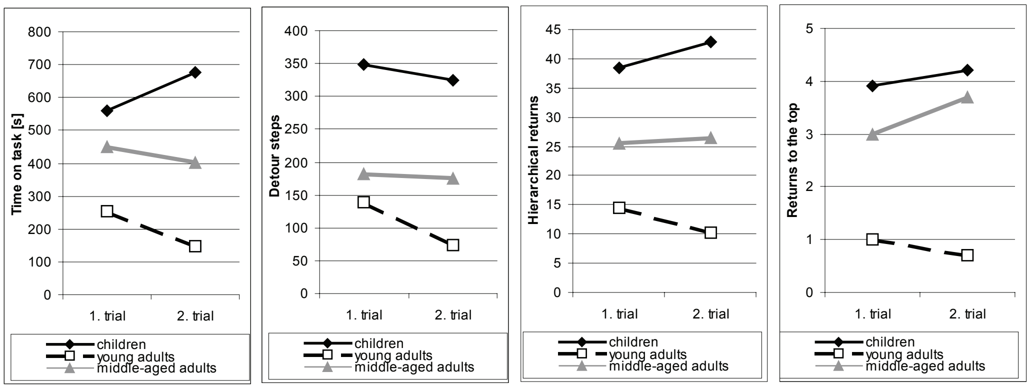
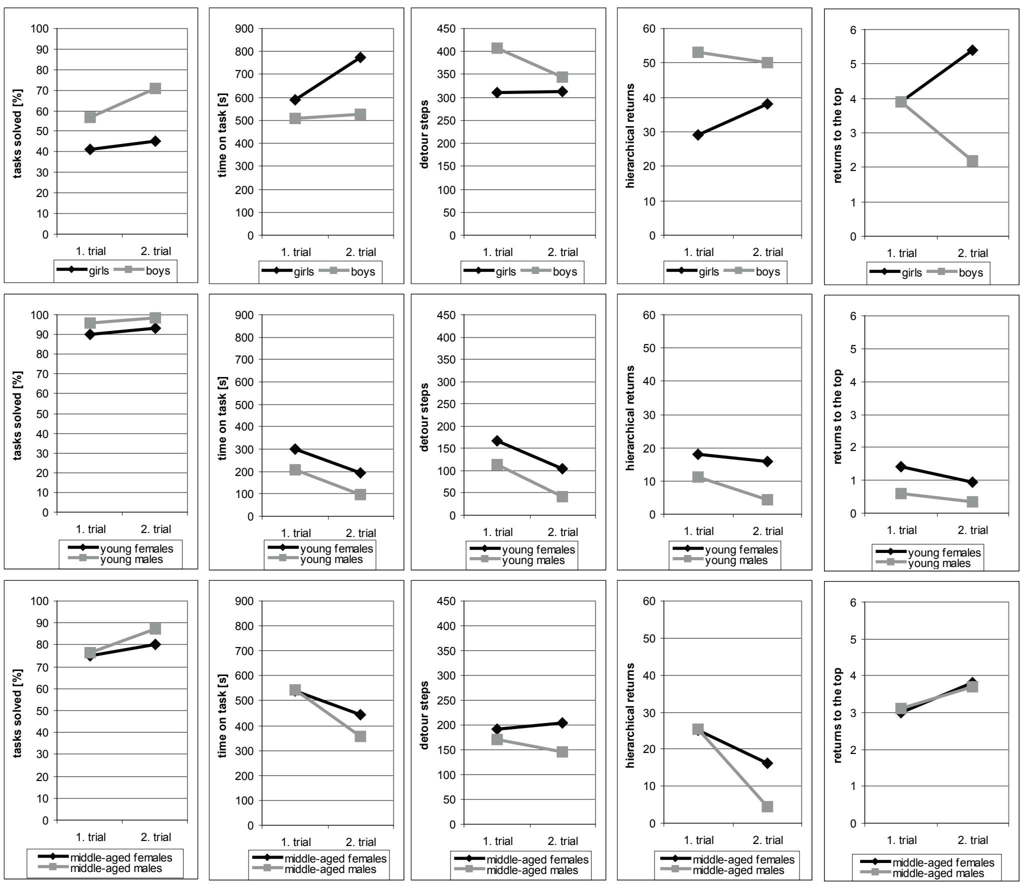


Figure 10. Task efficiency (time on task, number of detour steps, hierarchical returns and returns to the top) in the first compared to the second trial for all age groups (upper: children, middle: younger adults and lower row: middle-aged adults) as well as for female (black lines) and male (gray lines) participants



both adult groups: First, children had overall the lowest efficiency. Second, children did not profit from learnability, at least not the whole children group. Third, gender effects are most pronounced at this age, with boys having not only an overall better performance, but also revealing a different navigation style than the girls. The boys showed learnability effects, and profit from executing the tasks a second time, while, quite contrary, the girls did not show learnability effects and even had a lower performance in the second compared to the first run. Fourth, again, the boys' different navigation strategy becomes evident, which is characterized by a higher tasks success, a faster navigation with lower returns to the top. This effective strategy is reached by a more active and explorative menu navigation pattern—the boys carried out even more detour steps and hierarchical returns in the second trial than the girls in the first. With respect to the returns to the top, the measure for menu disorientation, the boys left the menu only twice in the second trial, compared to four times in the first.

User Characteristics and their Effects on Menu Navigation Performance

So far, we found performance differences between age and gender respecting effectiveness and efficiency when using a mobile phone. In this section it is analyzed, which of the user characteristics may account for these differences. Is users' experience with technical devices a substantial source of performance or is their interest in technology the source of the differences? Which role are the differences in spatial ability and verbal memory playing for menu navigation performance? First, the interrelations of the experience with technical device and the interest in technology are focused (Table 2).

Neither the reported interest in technology was interrelated with performance outcomes, nor the reported ease of using the devices showed significant correlations. Thus, motivational factors as the individual interest in technology were not decisive for performance. Also the perceived ease of using the devices did not reflect the actual navigation performance. However, participants' previous experience in terms of the self-reported

*Table 2. Correlations between user characteristics and navigation performance (***p = 0.000; ** p =0.05;* p = 0.1)*

N = 108	Tasks solved	Time on task	Detour steps	Hierarchical returns	Returns to the top
Frequency using a…					
Mobile phone	**r = -0.46*****	**r = 0.5*****	**r = 0.44*****	**r = 0.45*****	**r = 0.45*****
PC	**r = -0.48*****	**r = 0.41*****	**r = 0.42*****	**r = 0.36*****	**r = 0.26****
DVD/VCR	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**
Ease of using a…					
Mobile phone	**n.s.**	**r = 0.27****	**n.s.**	**n.s.**	**n.s.**
PC	**n.s.**	**r = 0.23****	**n.s**	**n.s**	**r = 0.26****
DVD/VCR	**n.s.**	**n.s.**	**n.s**	**n.s**	**n.s**

frequency of using technical devices was strongly interrelated with performance outcomes, showing that frequent usage and activities with the devices lead to a elaborated knowledge that is basically benefiting performance for all age groups (even though it should be considered that the experience level was not sufficient to reach an "optimal" performance (100 percent task success) in neither of the groups).

With respect to the impact of cognitive factors (spatial ability and verbal memory), correlation analyses were run for each age group, separately. The outcomes are summarized in Table 3.

For the children group, neither spatial abilities nor verbal memory had a significant impact for children's navigation performance. Thus, even those kids, who had—relatively to other children of this group—possessed a high verbal memory capacity and spatial ability were not specifically advantaged in menu navigation over those kids, who have only lower cognitive abilities. In other words: navigating through mobile phone menus was a high cognitive demand for all children. In contrast, both adult groups showed interrelations with spatial abilities, even though the relation was much more pronounced in the young adult group compared to the older adult group. Users with a high spatial score solved more tasks, were faster, and also made fewer detour steps and hierarchical returns. Also they did not return to the start level as often than adults with lower spatial abilities.

The impact of verbal memory capacity for navigation performance was comparably low. For the young adults, none of the performance measures showed significant interrelations with verbal memory. In the middle-aged adult group, however, effects of variability in memory capacity were revealed: users with high memory abilities solved significantly more tasks and were faster in comparison to those with a lower memory capacity.

Implications for Design

Even though the central focus of this work was directed to a detailed analysis of user behavior interacting with mobile phones and, also, to the impact of user diversity for performance, the present findings may also give some insights for design concerns to be considered for mobile devices. Also some training and tutoring issues may be derived.

The results reported here uncover both, similarities as well as differences in the navigation behavior of kids, young and older adults. Thus, we learn that there are design implications, which favor "a design for all approach" as well as differential aspects, which should be pursued to support specific user groups.

Across age groups, considerable difficulties were revealed in completing these common and easy phone tasks on a standard mobile phone. Not

*Table 3. Correlations between user characteristics and navigation performance (***p = 0.000; ** p =0.05;* p = 0.1)*

	Tasks solved	Time on task	Detour steps	Hierarchical returns	Returns to the top
Spatial ability					
Children	**r = 0.29***	n.s	n.s	n.s	n.s
Young adults	**r = 0.29***	**r = -0.36****	**r = -0.29***	**r = -0.48*****	**r = -0.29***
Middle-aged adults	**r = 0.37****	**r = -0.40****	**n.s**	**n.s**	**r = -0.45*****
Verbal Memory					
Children	n.s	n.s	n.s	n.s	n.s
Young adults	n.s	n.s	n.s	n.s	n.s
Middle-aged adults	**r = 0.40****	**r = -0.36****	n.s	n.s	n.s

even the students, bright and technology prone were able to solve the four tasks completely successfully. Nevertheless students showed the best performance compared to kids and older adults. All participants carried out a lot of detouring in the menu, as taken form the high number of detour steps, the returns in menu hierarchy and the returns to the top menu level, beginning from scratch. Thus, it must be concluded that current small screen devices are—cognitively—challenging to use. This is valid for kids and older adults, which—due to their developmental status—can be categorized as "weaker" users, but it is also valid for the "best case" student user group. According to statements of participants after the experiment, the difficulties they experienced in the menu had mainly three sources. The first difficulty referred to the complexity of the menu. Even though the task complexity was relatively low, with three menu levels at the most, participants (especially kids and older adults) had considerable problems to orientate, often not knowing were they were in the menu and where they had to go next. A second point refers to keys' complexity. Ambiguous functionality and design of keys lead to difficulties and provoked many unnecessary key actions. This was especially the case for navigation keys, which had a high complexity (keys, with several functions on different menu levels). Third, the naming of menus, sub-menus, and functions is also of crucial importance for good usability of a mobile phone.

However, there were also findings that hint at specificities of user groups, which should be considered. The first refers to different coping styles of children and older adults, when confronted with suboptimal and not very intuitive interfaces. Older users were nearly annoyed and insistently emphasized that they want to have devices that meet their demands of low complexity and all necessary functions within easy reach. Otherwise, they are not willing to use these devices. For the children, mobile phones still represent a high status and attractive gadget. Nevertheless, the children reacted highly sensitive to their failure and tended to attribute the failure to their own incompetence, but they also criticized that the mobile phone was "pretty hard" to use. This is of specific pedagogic impact. The success and the ease with which devices can be used contribute considerably to users' self-efficacy, the perceived competency and usability of technical devices (e.g., Arning & Ziefle, 2007; Ziefle, Bay & Schwade, 2006). Sub-optimally designed interfaces might lead to a lower frequency of using technical devices, in order to avoid negative feelings. However, frequent interaction with technical devices is an essential precondition for the formation of technical expertise, which in turn benefits navigation performance. Gender effects were also identified. Female users reported a significant lower interest in technology, and also, rated the ease of using technical devices as lower. While gender differences in performance did not reach significance level in both adult groups, for the children, they were most pronounced. The boys reached overall a higher performance, which was supported by a specific and successful navigation strategy. The boys were highly explorative and active in the phones' menu, pursuing a trial and error style. In contrast, the girls showed a much lower activity when interacting with the phone. Playful experimentation is assumed to yield educational benefits because the users may incidentally gain knowledge of the system by exploring its structure.

As practical implications from the current research, the following recommendations can be given:

Interface-design:

- Keep menu structures as flat as possible and avoid high complexity, this helps to reduce menu disorientation.
- Keys complexity should be held as low as possible. Avoid the allocation of many functions to single keys (multimode). Whenever keys with more than one function have to be used, those functions should be grouped to one key, which have a (semantically) similar meaning ("correct," and "step back"). Avoid mode keys with semantically dissimilar functions ("step back," "hang up"). Also, the spatial position of the keys is important. Very frequent functions should be allocated

to centrally located keys. Do not change position of frequently used keys.

- Respecting the naming of menu functions, basically, very similar terms ("phone setting" vs. "call setting") should be avoided. Also, do not use abstract terms ("incognito"), unfamiliar abbreviations ("GBG," "GSM") or technical terms ("D2 services," "SIM-activity"). For many users, they are not easy to understand and therefore, are not easily to be learned. Furthermore, very generic terms ("options," "settings") are highly misleading terms. Even though these terms are not difficult to understand, it is nevertheless not easy to deduce which functions are summarized under these category labels. Apparently, it is difficult to know which functions are and which are not present within these categories, as the general terms basically allow—semantically spoken—a targeted function to be housed, however, in many cases they actually do not. Categorizing the functions in intuitively understandable menus and sub-menus is also of great importance for a good design.

Training and pedagogic issues:

- It is essential to encourage active and playful interaction with the device quite early in the learning process, especially for children and middle-aged users, in order to enable the development of perceptions of achievement and competence. By playful interacting with technical devices, users get casually to know which features and functions are available, where these functions are located within the menu, and also how to activate the functions. This may especially benefit users, who cannot rely on a high spatial ability, a high verbal memory capacity or a high technical self-competence, to develop a solid expertise respecting using small screen devices. Thus, it is of high importance to motivate and encourage users to actively interact with mobile devices.

CONCLUSION

This study aimed at a critical actual inventory of user characteristics and the competence using a mobile phone. On the user side, effects of age and gender were analyzed, as well as technical experience and perceived ease of device usage. Moreover, interest in technology was taken into account. Further, spatial ability and verbal memory capacity were psychometrically determined and related to menu navigation performance. On the performance side, an elaborate analysis of navigation patterns was undertaken. Beyond the task success and the processing time, the individual extent of detouring behavior was analyzed. In this context we determined the number of detour steps, but also, how often participants returned to higher levels in menu hierarchy. As a measure for utter disorientation, we analyzed how often participants, after they delved into distraction, returned to the first menu level, beginning from scratch. Methodologically, this detailed analyzing procedure can be strongly recommended, as it mirrors exactly what users actually do and enables the determination of the relation between performance and user judgments, which are often biased. Considering that the majority of manufacturers evaluate mobile phones primarily operating with user ratings for evaluation purposes, the validity of user ratings is questionable. Of course, preference ratings can be obtained much more easily, but they possibly do not reflect the actual difficulties of users in the system. If a device is supposed to be accepted in the long run and also acknowledged by a diverse user group, the impact of a detailed analysis of navigation patterns seem essential.

Our participants had a solid experience with different state-of-the-art technical devices. It could be shown that the experience with technical devices considerably advantaged menu navigation performance. Interestingly, and perhaps contrary to expectations, the children had, relatively, the smallest computer experience, but nevertheless a high interest in technology—higher than the interest reported by both adult groups. As shown, the common prejudice of children to easily master the handling of technical devices—due to their early contact with technology—is not true, at least not in the most stringent form. From a pedagogic point of view, it is important to motivate especially kids to frequently use and handle technical devices, in order to support the formation of technical experience.

With respect to cognitive abilities, which underlie the performance in technical systems, spatial abilities turned out to be important for the menu performance. This shows that the navigating in small screen devices imposes considerable demands on users' ability to "spatially" orientate within the menu. Spatial abilities are assumed to provide a specific advantage. Persons with high spatial abilities are able to construct a mental representation of the systems' structure during navigation (Sein, Olfman, Bostrom et al., 1993), and therefore have a better orientation in the system. However, the impact of spatial abilities for performance turned out to be age-related. While younger and middle-aged adults were able to profit from high spatial abilities, this was not the case for the 9-10 year old kids in our experiment. This confirms earlier findings (e.g., Bay & Ziefle, in press; Shemakin, 1962), according to which the ability to cognitively process spatial hints and to mentally represent structural knowledge is fully developed not until children are 12-13 years. It would be insightful to examine if there are specific trainings or software tutors feasible, which can support younger children and help them to achieve a good performance.

A final remark is concerned with some limitations regarding the methodology used. Our results are based on laboratory experiments and on the interaction with a simulated mobile phone. This was accomplished in order to provide experimental control and to rule out confounding effects. However, we acknowledge that the results presented here might represent a solid underestimation of the real situation. In our experiment, the cognitive workload to use mobile devices was much lower than they usually are in the interaction with mobile devices in real environments. In a mobile context users have to manage different and complex demands, simultaneously, and in the laboratory setting a quiet setting was present and users were able to concentrate on the tasks. Also key handling and visibility problems may occur in real contexts, which were controlled for in the experiment. Another limitation refers to the selection of the middle-aged adult group, which is definitively not representative for the whole group of adult users, especially older users (65+). Thus, overall, we have to concede that the performance levels reached in our setting might be higher compared to more realistic settings.

FUTURE TRENDS

Due to the fast cycles of technical innovations and the development of novel and still more complex technical devices, usability demands will still increase. This is of vital interest facing the demographic change and the increasing prominence of mobile devices. Therefore, research activities should address user diversity more strongly than hitherto. Many topics in this context should be pursued in greater detail. One is to examine the nature and benefit of the exploratory behavior of users when interacting with technical devices. It is a central question if there are specific interaction strategies, which should be encouraged or supported by trainings, and if there are differential aspects, which should be applied in specific user groups. Another interesting research question is the question whether the findings reported here are limited to devices with an exclusively hierarchical menu structure (as the mobile phone) or if the navigation patterns found here can be transferred to devices with a network data structure, which might provoke a completely different interaction pattern.

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KEY TERMS

Ease of Use: The ease of use describes the extent to which users believe a technical system to be free from effort and easy to handle.

Effectiveness: The term reflects the degree to which system objectives (e.g., tasks) are being achieved.

Efficiency: The term describes the degree to which a certain performance is achieved in terms of productivity. For example, it can be analyzed how many detouring routes are carried out until users reach their targeted goal in the menu, and how often they return to higher levels in menu hierarchy to re-orientate.

Navigation Performance: The term navigation in this context describes the process of moving through a menu structure in order to retrieve information or choose functions. The individual navigation routes the users take while searching for a specific target function may give valuable insights into shortcomings of menu design.

Trans-Generational Designs: Trans-generational designs are interface designs, which are usable and understandable by a broad user group, thus meeting the needs and demands of user diversity. They aim at coming up with developmental (cognitive, physical and sensory) specificities, which are present in users of different ages.

Usability: The term describes users' effectiveness, efficiency, and satisfaction with which users achieve specified goals in a technical system.

Spatial Ability: It is conceptualized as the ability to mentally manipulate and integrate visual stimuli consisting of more than one part. This includes the ability to imagine of rotations of objects or their parts.

Verbal Memory: Verbal memory is the basic ability to store and retrieve verbal or semantic information without additional processing.