Instruction Formats and Navigation Aids in Mobile Devices

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Abstract. Three different instruction formats were examined respecting their usefulness for the navigation through hierarchical menus in mobile phones. 56 middle-aged adults had to solve four mobile phone tasks twice consecutively. Before completing the first trial, they were supported by instruction formats which contained different spatial knowledge types [28]. The first form was a procedural step-by-step instruction delivering landmark and route knowledge. The second instruction consisted of a visualized menu tree, in which the menu path to be taken was marked. By this, mainly survey knowledge but also route information was provided. The third instruction format also used the visualized menu tree. However, in addition to the menu path which had to be taken, also functions' labels were given, conveying landmark, route and survey knowledge. Further, a condition was examined in which no help was given. Dependent variables were navigation effectiveness and efficiency. Overall, the step-by-step condition, the instruction type most often used in technical leaflets, had the smallest effect, especially for users with low spatial visualization abilities. With instruction forms which use diagrammatic visualizations and provide survey knowledge, navigation performance considerably improved.

Keywords: Instruction format, navigation aid, navigation effectiveness, efficiency, landmark knowledge, route knowledge, survey knowledge.

1 Introduction

Information and communication technologies have interpenetrated all professional and private fields in the last decades. A prominent role in this context play mobile small screen technologies, e.g. mobile and smart phones, communicators, navigation devices and electronic organizers, which show continuously increasing rates of growth each year [26]. Beyond their ubiquity, these technologies have fundamentally changed the nature of social, economic and communicative pathways in modern societies. Communication and information are present everywhere and at any time and seem to overcome physical as well as mental borders. Though, the effective and successful integration of mobile technologies and broad acceptance of these technologies in all fields of daily life impose considerable challenges on modern societies.

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1.1 The Problem

If critically looking at current developing trends, a number of crucial factors come into fore that may severely impede the barrier free integration of future communication technologies into private and professional societal structures.

(1) *User diversity*: Contrary to former times, when the utilization of information and communication technologies (ICT) was restricted to technology-experienced expert groups, nowadays broader user groups have access to ICT. Thus, the organization of professional and private activities, events and transactions heavily depends on the ease of using these devices by a diverse user population. However, recent studies showed that the usage of small mobile technologies imposes considerable difficulties and that these difficulties are not equally strong for all users. Menu navigation performance was found to be strongly influenced by a number of individual factors, which differentially benefit or hamper navigation [e.g. 21, 12]. Among the individual factors, age, gender, spatial orientation and computer-experience were identified to play a prominent role. Users with high spatial visualization abilities were distinctly advantaged compared to users with low spatial abilities in completing computer tasks [e.g.31], using hypertext [e.g.19] or mobile devices [e.g.2,4,5,8,37,38]. Also, prior computer experience is a crucial factor for navigation efficiency [e.g.1,12,32]. Moreover, gender is increasingly discussed to play an important role in the explanation of technical performance. Women usually report lower levels of computer-related self-efficacy [e.g.4] and a higher computer anxiety [e.g.10], which, in turn, may reduce the probability of active computer interaction and lead to a generally lower computer-expertise level. Likewise, noticeable differences in computer experience between males and females were reported [e.g.3,23], which then mediate gender differences in technical performance. As the usage of (mobile) technologies is increasingly less voluntary, more and more technically inexperienced and/or aged users are urged to use these devices. Usability issues of interface and communication designs are thus of prominent interest.

(2) *Function complexity and device miniaturization*: Mobile devices are typically small-sized with a small communication display but a huge functionality, providing on-the-go lookup and entry of information, quick communication and instant messaging anytime and everywhere. The mobile character of these devices in combination with the small communication window represents a still higher usability demand compared to large display technologies. The limited screen space is extremely problematic for providing optimized information access and the question of how to "best" present the information on the small display. Only few items can be seen at a time and users navigate through a menu whose complexity, extension and spatial structure is not transparent to them as it is most of the time hidden from sight. As a consequence, users are urged to memorize the functions' names, their relative location within the menu and keep up orientation. Disorientation in handheld devices' menus is a frequent problem [e.g. 21,30,31,35,36,37,39], especially for aged users [e.g. 2,21,22,35,36,37] or those with little computer-related knowledge and experience [e.g. 3,4,5,29].

(3) *New application fields*: Aggravating the situation, the application fields and the contexts, in which mobile technologies are used, changed considerably over the last

decade, and, still, they will tremendously change. The traditional functionality of cell phones, effectuating simple calls, plays merely an inferior role. Rather, the devices are used as controllers for technical processes at home (e.g., programming TV), as mobile alternatives to traditional computers, as basic communication devices (e.g., Internet access), and as intelligent robots that administrate personal concerns (e.g., managing accounts). Mobile technologies are assumed to especially support seniors in their daily lives and keep up independent living. As such, the devices are used as e.g. for medical monitoring, as navigation and memory aids. But mobile technologies are also increasingly used in smart homes and ambient intelligent environments, in which devices are communicating with remote computers, sometimes integrated in clothing [e.g.18], furniture or walls [e.g.23]. Taken together, given these developments, usability demands are more important than they ever were. As long as information designs of technical devices are not easy to use and learn technical innovations can not have sustained success.

1.2 The Duties for a Human-Centered Design

Design approaches must therefore take the user-perspective seriously. This claim includes that also instruction leaflets and technical manuals are ergonomically designed and can be widely understood by users. This is the focus of the present experimental study.

Though, the creation of usable and understandable manuals is a challenging issue. On the one hand, manuals must meet demands of user diversity, thus even users with a different upbringing and education level as well as users with a limited domain-knowledge should be supported adequately. Moreover, the manuals should give users a proper understanding of the device structure and to prevent them from getting lost in the menu, which is especially important for users with low spatial visualization abilities. On the other hand, adults do not want to spend much time reading manuals [e.g.11], presumably because the study of text heavy instructions may be conceived as time-consuming and bothersome. Furthermore, many users report that instructions and manuals usually do not tell them what they need to know, but provide them with a huge amount of "unnecessary" and "useless" information. Accordingly, research confirmed the ineffectiveness of detailed textual instructions, and proposed diagrammatic instructions instead [e.g. 25]. However, diagrammatic instructions also have fallacies: the most severe failure is the lack of unambiguously picturing the initial step of a subtask including the location and object of a required action (e.g.11,14,15,33]. Transferring this concept to the cognitive ergonomic design of instructions for menu-driven small screen devices, as the mobile phone, it is decisive to tell the user where within the menu a certain task has to be accomplished [e.g.6,8,37], thus providing spatial clues. Thus, it may be assumed that processes of spatial orientation take place when users interact with hypertext and navigate through the different nodes and links [e.g.12,17,20] as well as with hierarchical menu structures [e.g.7,9,30].

According to spatial visualization theories [28], three forms of spatial knowledge are proposed to be crucial for proper spatial orientation in natural environments: Landmarks (outstanding points in the environment), routes (the ways connecting different landmarks) and survey knowledge (a graphical and structural outline of a specific terrain). If when navigating through the hierarchical menu structure of a mobile phone comparable processes to the ones involved in spatial orientation in the natural environment take place, then instructions should support users with the different kinds of spatial knowledge. To build up survey knowledge a map of the menu structure could be provided. For large displays the efficiency of such a map has already been demonstrated [e.g.9] and also for small screen devices such as the mobile phone [6,8]. A very recent study [8] examined the usefulness of instruction types for the navigation efficiency in mobile phones, using children as participants. Children are generally assumed to be especially technology prone and experienced, and to easily master the usage of technological devices. Though, in contrast, it was found that children are very sensitive to the cognitive demands imposed by the devices and showed considerable performance losses in suboptimal interface designs [e.g.8,32,34,35,36,37,38]. In order to learn if children benefit from spatial maps, an instruction type delivering survey knowledge was contrasted to a conventional step-by-step instruction, containing route knowledge. Both instructions were compared to a free exploration of the menu which should provide all kinds of spatial information. The findings revealed that the benefit of instruction formats depended on the children's age and the ability to process spatial information (which is carried by age). The younger the children (8 - 9 years), the lower were the benefit by spatial maps *and* by the free exploration. With increasing age, children were able to fully exploit the spatial clues of the map and also to integrate the spatial knowledge they gained from exploring the menu. For the younger children, a sequential aid in form of a step-by-step instruction was more helpful for them.

1.3 Questions Addressed

Summing up, it is of considerable impact that instruction formats and manuals of technical devices are well designed and that they compensate the specific knowledge gaps users experience when navigating through menus of small screen devices. As disorientation is a rather frequent phenomenon in small screen devices, resulting in a lot of detouring within the menu, especially spatial orientation clues should be provided preventing users from loosing their bearings within the menu.

So far, comparably little is known regarding the question how appropriate diagrammatic instructions have to be designed for the "average user", i.e. middle-aged adults, which cannot rely on a mature technical understanding, and which do not have much experience with the handling of small screen devices. As exactly this user group will be the typical end users of modern mobile technologies in novel application contexts, it was of interest to find out if this user group is able to benefit of spatial information about the menu structure delivered by diagrammatic instructions. On the one hand, the survey knowledge should help them to built up a mental representation of the system's structure [e.g.17,27,28,34,37], which in turn enables users to increase navigation efficiency. On the other hand, diagrammatic instructions could also impose considerable cognitive load, as participants have to understand abstract information and to transfer the spatial clues into a proper mental representation of the menu. The present study therefore examines the usefulness of different instruction formats on navigation efficiency. Another point at issue was the sustainability of the different instructions, assessing learnability effects. Three different forms of instructions with varying spatial knowledge clues were examined and compared to each other. In order to learn if any instruction type is superior for navigation efficiency than no help, a control condition was also examined, in which no navigation aid was given. Understanding in how far individual user characteristic may interact with the benefit by different instruction formats, spatial ability was psychometrically assessed and related to performance outcomes.

2 Method

2.1 Experimental Variables

As *independent variable* the type of instruction format was examined.

1. The first type of instruction was a step-by-step instruction containing the different menu functions that had to be selected one after another in order to solve a task. The knowledge provided by this instruction is landmark knowledge as well as route knowledge (names of the functions to be visited one after another), without revealing the menu structure. Fig. 1 shows one example of such an instruction. Participants were instructed that the functions shown in the step-by-step diagram are the key terms they had to memorize, as they are the cardinal points in the menu they should follow. This instruction was presented for a period of 20 s prior to each task in the first trial.

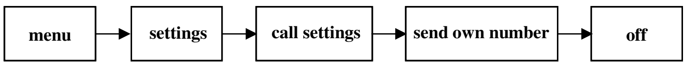

Fig. 1. Step-by-step instruction type

2. The second form of instruction was a menu structure visualized in a graphical tree where the name and location of the functions that have to be selected to solve a task are given. This instruction type provides primarily survey knowledge, but contains also information on landmarks (the functions' names) and route knowledge (interconnections between functions). Figure 2 (left side) shows an extract of a menu tree containing the path and the menu functions. In the experiment, this information was plotted on a sheet of paper, separately for each task, and pinned on the wall. Participants were instructed that this structural map informs them about all the different paths and branches of the phones' menu as well as their interconnections. They were also told that the functions shown in the map were the key terms they had to memorize, as they are the cardinal points in the menu they should follow.
3. The third instruction type was again the graphical tree map (as in the second instruction type), however without any function labels. Thus, an "empty tree" was presented. By this, primarily structural information (survey knowledge and route knowledge) were delivered. Participants were instructed that this structural map informs them about all the different paths and branches of the phones' menu as well as their interconnections (Figure 2 right side).

As dependent variables four different performance measures were analyzed. As effectiveness measure, (1) the number of tasks successfully solved was determined. Furthermore, measuring efficiency of menu navigation, (2) the time needed to process the tasks, (3) detour steps (number of keystrokes carried out that were not necessary

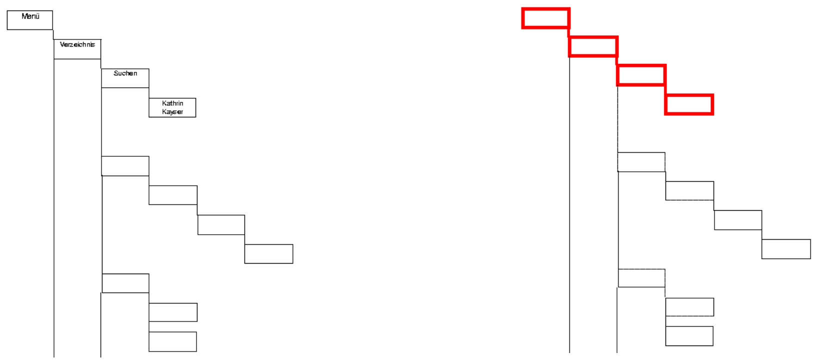

Fig. 2. Instruction types: Tree with functions (left side) and empty tree (right side)

when solving the task the shortest way possible) and finally, (4) hierarchical returns to higher levels within the menu indicating that participants felt to have taken the wrong path in the menu hierarchy and needed to go back to a known position.

2.2 Apparatus and Procedure

A mobile phone corresponding to the Nokia 3210 model regarding menu and keys was simulated as software solution, run on a PC and displayed on a touch screen (TFT-LCD Iiyama TXA3841, TN, 15' with touch logic by ELO RS232C). It was a general question which phone model was appropriate for experimental purposes. The software prototype mirrored exactly the menu structure and the navigation keys given in the real phone. However, the keys and the display of the mobile phone were enlarged compared to the original model in order to exclude motor and visual difficulties. Avoiding biases and concealing the real brand the simulated phone had a neutral design. Three menu functions were presented on the screen at a time. In order to measure effectiveness and efficiency in detail, user actions were recorded online on the keystroke level. Thus, frequency and type of keys used, time spent on tasks and the navigational route could be reconstructed in detail. In order to assure a comfortable and relaxed body posture while completing the tasks, participants sat on a table and worked on the touch screen, which was fixed to the edge of the table.

Each participant was allocated to one of the four experimental conditions. In the three instruction conditions, the specific type of instruction participants would thereafter use was presented and explained referring to a sample instruction. It was carefully ensured that all participants understood exactly what they had to do in each task. Instructions were shown for a period of 20 seconds after being explained what they had to do in the respective tasks and before starting to process each single task.

2.3 Participants

56 participants from a wide professional range volunteered in the experiment, in an age range between 32 and 65 years of age (M=49.6 years, SD=8.7). Half of them (N = 28) were females (M=46.8 years; SD=9.4), the other half (N = 28) were males

(M=47.0 years; SD=8.3). As we aimed at a "normal" group, both academic and non-academic education levels were present. All of them were quite frequent phone and computer users, however, it was taking care of that participants d did not reveal to be technical experts or professionals for small-screen-devices. It was a specific interest in this study if the "average" user would benefit from diagrammatic instructions (compared to no instructional aid) and if specific spatial knowledge demands can be met by the instructions. In all four conditions, gender and age was balanced. In a pre-experimental questionnaire, the previous experience with technology (mobile phone, PC, DVD) was assessed. Statistical testing revealed no differences within technical experience across groups. Also the four groups had a comparable spatial ability.

2.4 Assessing Spatial Visualization Ability

After participants had completed the phone tasks twice consecutively, they were requested to complete a spatial test of mental rotation [3DW,16]. The test contained seven mental rotation tasks and was presented In Figure 3, a test item is shown. Participants had to decide which of the cubes (A-F) has the same sides and the same spatial orientation than the target cube (x). To do so, they had to mentally rotate the different alternatives (A-F) and to compare it with the target cube. A maximum of seven points could be reached.

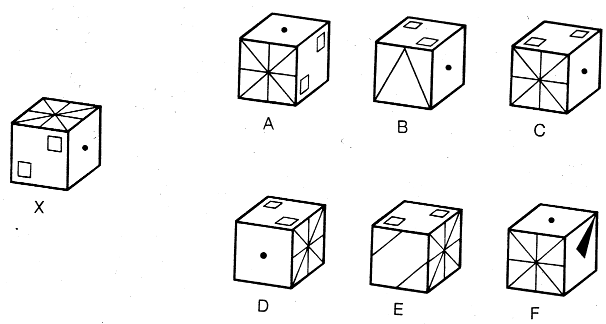

Fig. 3. Exemplary test item from the mental rotation ability test [16]

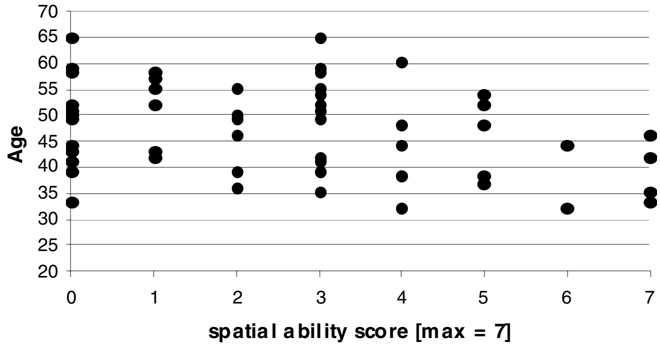

Fig. 4. Spatial ability scores as a function of age of participants

Participants did not have a time limit to complete this test (no speed test). Though, the perceived ease of processing these items considerably varied among participants as did the time they needed to complete the task.

Spatial ability scores are given in Figure 4. As can be seen there, only few participants succeeded to solve all tasks correctly. Conversely, there were a considerable number of participants who did not even solve one of the tasks correctly. Also, there was a significant correlation between spatial ability scores and the age of participants ($r = 0.456$; $p<0.01$) showing that with increasing age spatial ability significantly decreases. Though male participants had, on average a higher spatial score (M= 2.9 out of seven; SD=2) than female participants (M=2.5; SD=2.3), differences did not reach statistical significance.

2.5 Experimental Tasks

Four basic and very common mobile phone tasks (calling a number stored in the phone book, sending a text message, hiding one's own number in the display, making a call divert) had to be solved by the participants. In total, 36 steps were necessary to solve the four tasks on the shortest way possible. In order to measure learnability, all four tasks were presented twice. In the second run, participants were not given any instructional help. This was of specific significance as it was a central interest to analyze the sustainability of the respective instruction type. After a short break, participants completed the tasks a second time, in the same order than in the first trial. For each task, a time limit of 5 minutes per task was set.

3 Results

Data were analyzed by MANOVA procedures and by ANOVA analyses with repeated measurements, assessing learnability effects. The significance level was set at 5%. Spatial ability and gender were treated as between-subject variables in order to learn if the usefulness of instruction formats interacts with these individual factors. Regarding spatial ability, by median split two groups across the participants groups were formed. By this, participants with "high" spatial ability score were contrasted to participants with "low" ability score.

First, the main effect of instruction format are reported, followed by effects of spatial abilities and gender. After that, learnability effects on navigation efficiency are addressed as well as interacting effects between the extent of learnability and the type of instruction format. This will answer the question if there are namable differences between the different instruction formats and, still more important, about the sustainability of the instruction formats over time.

3.1 Effects of Instruction Formats on Navigation Performance

First, effects if the different instruction formats are reported. Descriptive outcomes can be found in Figure 6. There, the effectiveness (upper left diagram) the mean effectiveness, the time participants needed to process the task (upper right diagram), the number of detour steps (lower left diagram) and the number of returns to higher levels in the menu (lower right diagram) is pictured.

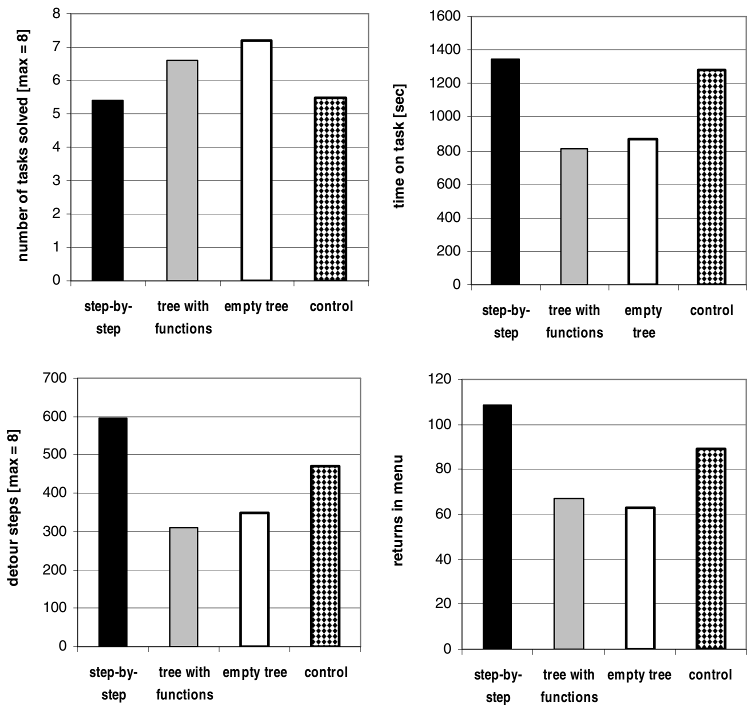

Fig. 5. Navigation effectiveness and efficiency in the four experimental conditions

Statistical testing revealed a significant main effect of instruction format on all dependent measures: task effectiveness ($F(3,41)=3.2$; $p<0.05$), time on task ($F(3,41)=2.7$; $p=0.05$), number of detour steps ($F(3,41)=5.8$; $p<0.05$) as well as on the number of returns to higher levels in the menu ($F(3,41)=11.2$; $p<0.05$). Among the instruction formats, the step-by-step condition was the instruction format which performed worst. Taking both trials together, participants solved, on average, about 6 tasks out of eight successfully and needed about 19 minutes to process the tasks. In addition, 477 detour steps and 90 returns to higher levels in menu hierarchy were carried out, hinting at a considerable difficulty to find the targeted function. Both map conditions performed significantly better. Supported by the empty tree, the most abstract instruction format, participants solved on average, 7.2 tasks (out of eight), 14 minutes processing times, only 320 detour steps and executed 69 returns in the menu. The tree which was providing landmark knowledge in addition (function names), also yielded a benefiting effect: It took, on average, 14.9 minutes to solve 6.5 of the eight tasks successfully. Participants executed 371 detour steps and about 67 hierarchical returns to find the targeted function. The question if any instruction format is better than having no help has to be answered in the negative. There was no significant performance difference between the control condition and the step-by-step condition.

Two things should be noted in this context: One is that the step-by-step-condition is the most frequently used instruction format in conventional leaflets of technical devices, thus corroborating the information designs of menu-driven small screen devices to be suboptimally designed. The second point refers to the overall navigation performance. It should be kept in mind that the phone used here was a mass model with a medium complexity and that overall not more than 72 steps had to be carried out in order to solve the four tasks twice on the most direct path. The fact that average users carried out between 320 and 480 detour steps and , for reorientation, went back about 70 times to higher levels in menu hierarchy, shows the enormous cognitive difficulty of users to orientate within the menu of small screen devices.

3.2 Effects of Spatial Ability on Navigation Performance

The spatial ability revealed to be a prominent factor for navigation performance, confirming outcomes of previous studies. Participants with high spatial abilities (scores above the median) showed a significant higher navigation performance than participants with a lower spatial ability score.. The main effect of spatial ability was found across all dependent variables (task effectiveness: $F(3,41)=24.7$; $p<0.05$; time on task: $F(3,41)=26.2$; $p<0.05$; number of detour steps: $F(3,41)=5.8$; $p<0.05$ and number of returns in menu hierarchy: $F(3,41)=11.2$; $p<0.05$). Descriptive outcomes for all dependent variables are visualized in Figure 6.

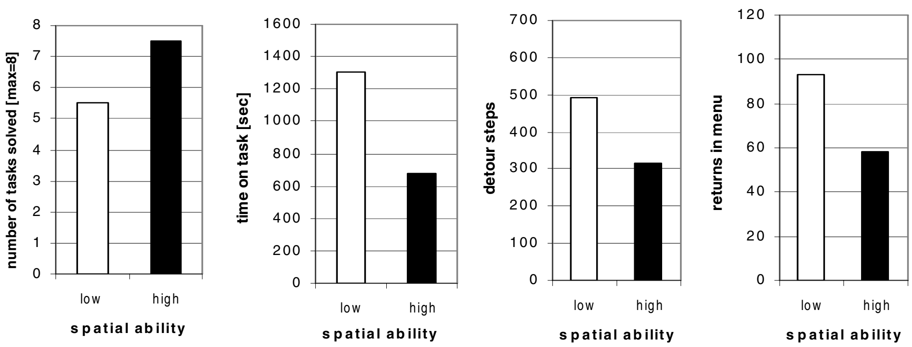

Fig. 6. Effects of spatial ability on navigation performance. White bars indicate performance of users with spatial ability scores below, black bars above the median.

3.3 Effects of Gender on Navigation Performance

Another analysis was run to learn if gender differences can be identified regarding navigation performance. In the literature, there are a number of studies according to which female users show a lower technical performance compared to men, but there are also studies, which could not identify performance differences. Performance differences between males and females are assumed to be mediated by the lower technical experience of female users, a lower technical self-competency and lower spatial abilities. In our study, female users did not differ within the extent of technical experiences and spatial abilities. Therefore, one could expect that gender differences in navigation performance would not be there.

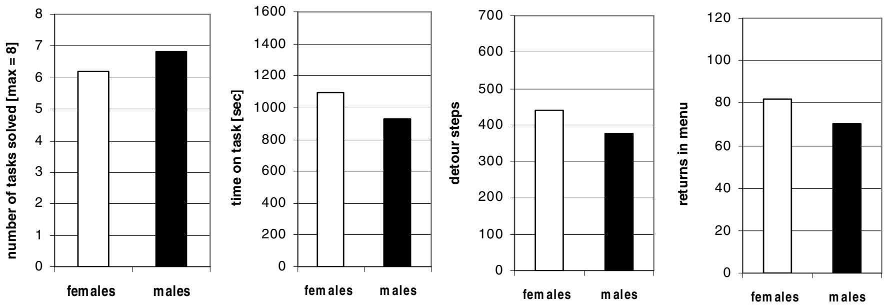

Fig. 7. Gender effects on navigation performance

Accordingly, statistical testing did not reveal a significant omnibus effect, but a marginally significant effects were found for task effectiveness $F(3,41)=3.9$; $p<0.1$) and time on task $F(3,41)=3.1$; $p<0.1$). In Figure 7, descriptive outcomes for all dependent measures are visualized.

Taken together, the gender effect was not clear (at least compared to the clear effects of instruction format and spatial ability), but though cannot be fully ruled out.

3.4 Learnability Effects on Navigation Efficiency

A special focus of the present study was laid on learnability effects, the question if the navigation performance improves from the first to the second trial (Figure 8). In all dependent variables a profound and significant learning effect was revealed (Task effectiveness: $F(1,41)=3.3$; $p<0.1$; time on task: $F(1,41)=55,9$; $p<0.05$; detour steps: $F(1,41)=24.8$; $p<0.05$; returns in menu hierarchy: $F(1,41)=9.5$; $p<0.05$).

Interestingly, the nature of learnability effects seemed to mainly concentrate on an increase within the efficiency with which participants navigated through the menu. They navigated considerably faster in the second run and also, with lesser detouring within the menu. In contrast, participants could not increase their task effectiveness in the same scale.

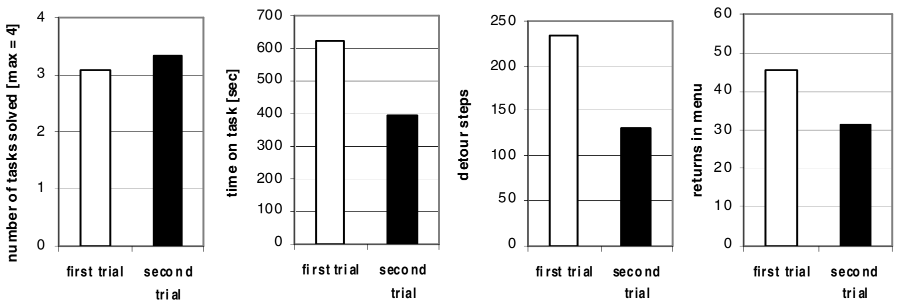

Fig. 8. Learnability effects on navigation effectiveness and efficiency from the first (white bars) to the second run (black bars)

3.5 Interaction of Learnability and Instruction Formats on Navigation Efficiency

Do instruction formats differ within learnability effects? To answer this question navigation performance in the first trial compared to the second trial was analyzed for each of the instruction formats, separately. Figure 9 illustrates the outcomes.

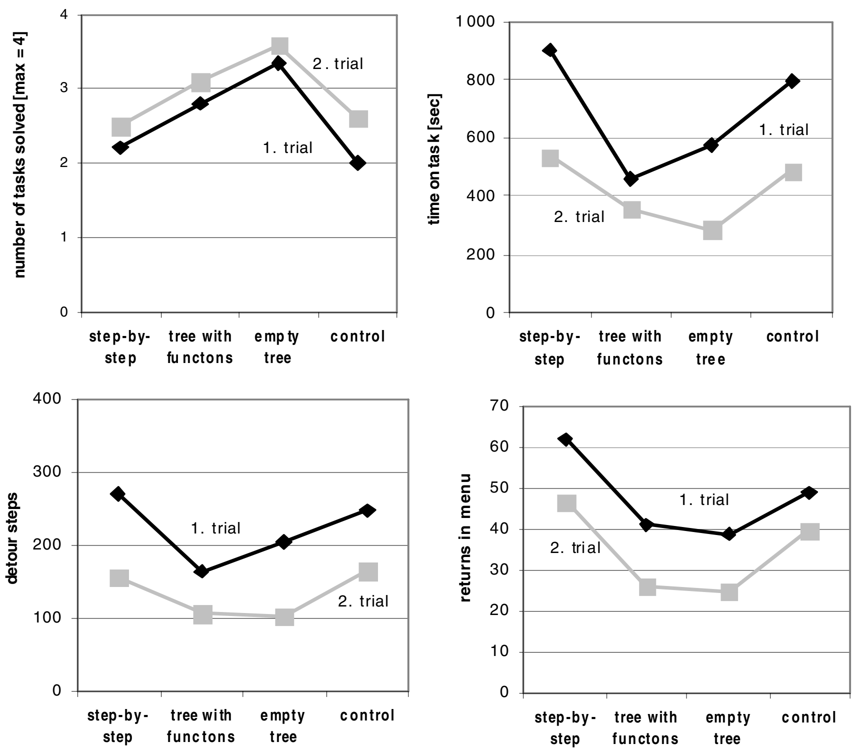

Fig. 9. Learnability effects on navigation effectiveness and efficiency in the first compared to the second trial depending of different instruction formats

Beyond the distinct main effects for instruction format (tree conditions are superior) and learnability (performance increases from the first to the second run), generally, no significant interacting effect between instruction formats and learnability were identified. Though, for the time on task ($F(1,41)=3.8$; $p<0.05$) and the number of detour steps ($F(1,41)=2.8$; $p=0.05$) interacting effects of learnability and instruction format reached statistical significance. A closer insight revealed that the learnability effect from the first to the second run was stronger in the step-by-step condition compared to other instruction formats. However, it should be noted that performance in the step-by step condition still was considerably low (significant main effect) compared to the performance in the tree conditions.

3.6 Interacting Effects between Users Spatial Ability, Instruction Formats and Learnability Effects

It is a crucial question if we can assume that individual factors, as e.g. users' spatial abilities mediate effects of different instruction formats. If so, then we should carefully select specific formats depending on individual user profiles. As spatial abilities have revealed to be a prominent mediator of performance in menu navigation of small screen devices, it was a crucial question if there are interacting effects between users' ability to process spatial information, the type of instruction format and learnability effects. ANOVA analyses with repeated measurements showed marginally significant effects for this three-way interaction ($p<.1$). In order to understanding the nature of the interaction, in the following the outcomes are visualized in detail for each of the dependent measures, directly contrasting participants with high and low spatial abilities. First, task effectiveness is looked at (Figure 10).

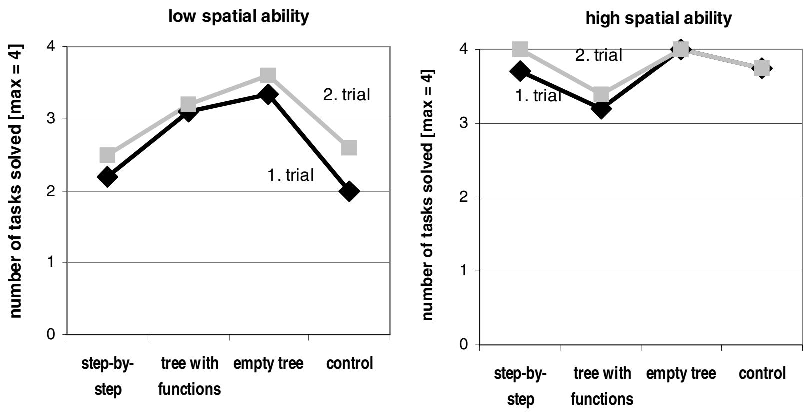

Fig. 10. Task effectiveness in the first and the second run, depending on the type of instruction format and spatial abilities. Left: Low spatial ability group, right side: high spatial ability group.

As can be seen from figure 10 (right side), persons with high spatial abilities show high success rates independently from the type of instruction. Also, learnability effects are quite small, as the performance was already nearly perfect in the first run. The picture changes when looking on the group with lower spatial abilities (left side). Their task effectiveness strongly depends on the type of instruction format. Participants which were supported by diagrammatic structural information containing survey knowledge sow a higher task success compared to the step-by-step-instruction and the control group.

Regarding the time needed to complete the task (Figure 11), also a marginally significant three-way interaction was found (F (1,41)=2.4; p<0.1).

Beginning again with the high-spatial-ability group (Figure 11, right side), we do not see any interacting effect between learnability and instruction format. Independently of the type of instruction, the time needed to process the tasks was higher in the first compared to the second run, showing a solid learnability effect.

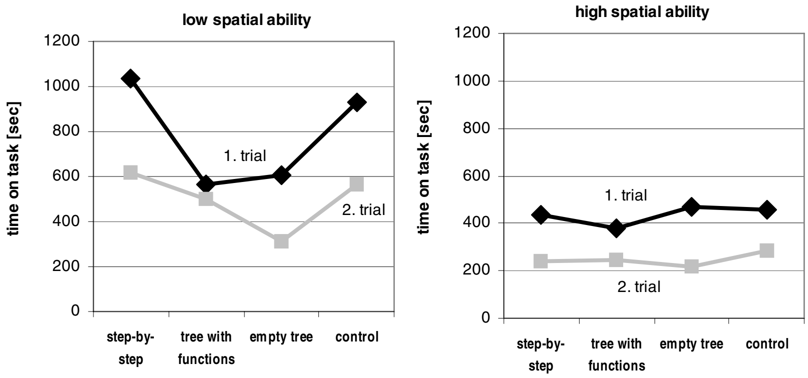

Fig. 11. Time on task in the first and the second run, depending on the type of instruction format and spatial abilities. Left: Low spatial ability group, right: High spatial ability group.

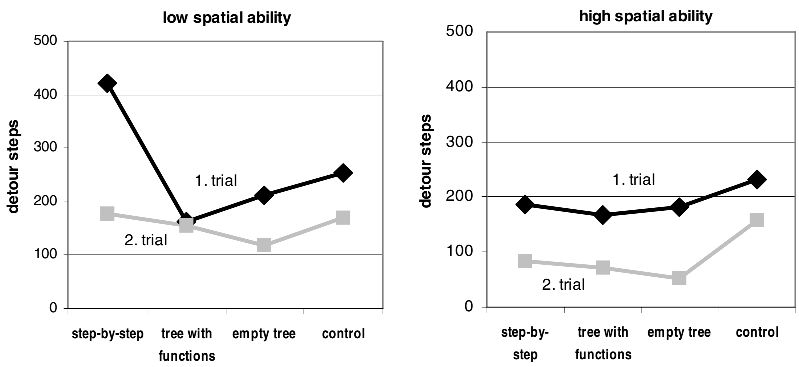

Fig. 12. Number of detour steps carried out in the first and the second run, as a function of the type of instruction format and spatial abilities. Left: Low spatial ability group, right side: High spatial ability group.

However, participants with lower abilities reacted quite differentially depending on the type of instruction (Figure 11, left side). The step-by step-condition and the control condition yielded the lowest performance. However, whenever participants with low spatial abilities are supported by an instruction format containing survey knowledge, navigation performance increases. This shows that the map conditions do compensate the specific knowledge gaps of participants having only low spatial abilities.

For the number of detour steps (Figure 12), a similar pattern was found revealing a marginally significant three-way-interacting effect ($F(1,41)=2.4$; $p<0.1$).

Participants with high spatial abilities (Figure 12, right side) showed a similar detouring behavior, more or less independently from the type of instruction format, but carried out significantly fewer detour steps compared to the first run. Again, it is the low spatial group (Figure 12, left side), which showed differential effects of instruction formats. Performance is low for this group, when they received the step-by-step format or do not get any help. But performance is considerably advantaged whenever instruction formats deliver survey knowledge.

Finally, the number of returns in menu hierarchy is looked at (Figure 13). For this measure, no three-way interacting effect was found. However, for the sake of completeness, the detouring behavior in both groups and experimental conditions are illustrated.

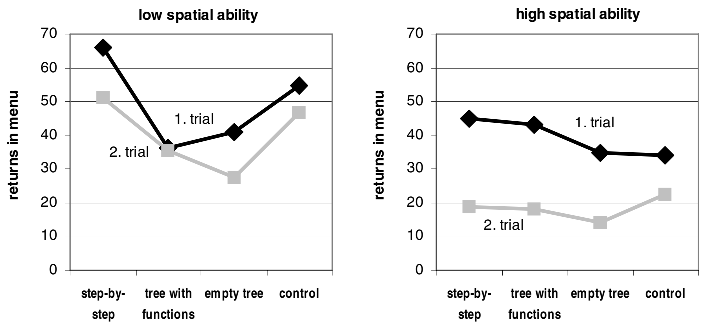

Fig. 13. Number of hierarchical returns in the first and the second run, depending on the type of instruction format and spatial abilities. Left: Low spatial ability group, right side: High spatial ability group.

4 Discussion

The present research was guided by two major goals. One goal was concerned with the question which instruction format would be beneficial for navigation performance in a rather typical user group, which does not possess a sophisticated technical understanding and experience, but rather represents the typical "average" user. The other goal was to find out if we can rely on a "design-for all"- approach, or if we need to tailor instruction formats according to specific information needs and user abilities. As disorientation is a rather frequent problem when using mobile small-screen devices with a hierarchical menu [2,4,5,8,19,36,37], the usefulness of instruction formats were under study, which contained different types of spatial knowledge. Based on the theoretical framework of spatial orientation [28], we varied three types of spatial knowledge within the instruction formats. One type represented an sequential aid (step-by-step-instruction), which tells users which step they have to do one after another. This type provides mainly landmark knowledge and resembles the conventional navigation aid in leaflets of technical devices. The second type contained more spatial information. A diagrammatic map of the menu structure was presented to participants, with the function names as additional clues. This type delivered survey knowledge (knowledge about the structure of the menu), landmark knowledge (function names) as well as route knowledge (interconnections within the menu). A third instruction type again used a visualization of the menu tree, however, in this type the function names were not given, but only the path, which had to be taken by participants, was marked. Accordingly, this type contained survey and route knowledge.

The results showed that a procedural step-by-step-instruction had by far the smallest effect. Participants in this condition showed the lowest task effectiveness and needed more time to complete the tasks. Also, the detouring behavior within the menu was much larger than in those conditions, in which the map of the menu was given in a diagrammatic form. Still more critical, the step-by-step condition showed even larger impedimental effects than in the control condition in which users did not receive any instructional aid. In contrast, instruction formats containing structural knowledge, as it was present in both map conditions, enabled the participants to come along much better with the tasks. Task success was much higher and the detouring in the menu was distinctly reduced, taken from the smaller number of detour steps and returns to higher levels in menu hierarchy in these conditions. It is an interesting finding that the map with functions, which contained the richest spatial information (survey, route and landmark knowledge), did not yield a better performance compared to the map, in which only the path to be taken was marked (delivering survey and route knowledge). This shows on the one hand that the function names are less decisive for a proper menu orientation if users receive information about the menu structure. On the other hand it may be concluded that survey knowledge in combination with route knowledge are essential for users in order to properly orientate within the menu.

Based on the strong evidence for the considerable impact of users' characteristics on navigation performance in mobile devices [e.g.13,17,20,21,31,36,37], the impact of users' abilities was related to performance measures. It was of high ergonomic interest whether an interface can be created that enables weaker users to use mobile phones competently, and, further, to reduce disorientation.

Especially, spatial abilities had been identified to play a crucial role for navigation performance [e.g.12,13,17,20]. But what makes spatial abilities so important for menu navigation? It is assumed that spatial abilities specifically advantage navigation performance by supporting users in constructing a proper mental representation of the systems' structure [e.g. 27]. The mental representation on its part helps users to harmonize their relative position in the menu and, at the same time, to keep the menu structure in mind while navigating through the system. Thus, by having an appropriate model and a structural concept of the mental 'room' that has to be navigated through, performance is increased. In the mobile phone, where the overall structure of the menu is not transparent, and the screen size is very limited, spatial abilities may be even more crucial, because users have to develop a mental representation of the structure when navigating through the functions.

It is an important finding of the present study that the specific benefit of survey knowledge was distinctly larger in persons which have lower spatial abilities. Supported by the map, task success was higher, the time on task was reduced and considerably fewer detour steps and returns to higher levels in menu hierarchy were carried out. Thus, we can assume that the map compensates their specific knowledge gap and helps users with low spatial abilities to develop a proper mental representation of the menu structure. By this disorientation in the menu is considerably reduced.

Regarding the question which of the instruction formats shows the largest learnability effect, it was found that participants in all conditions did improve navigation performance from the first to the second trial, showing a solid learnability effect. Even if this finding is promising, it should be kept in mind that, still, the step-by-step condition, the instruction type frequently used in conventional leaflets of technical devices, led to the smallest performance, especially in those users which need to be especially supported.

A final note is concerned with the overall performance of the participants observed here. One might have expected that the mobile phone tasks would have been processed without too much friction losses. Even if this might be true for the task effectiveness in the participant group with high spatial abilities (as most of the participants solved slightly more than seven out of eight tasks), it should be taken into account that in our study participants were given 5 min for each task, plenty of time compared to the time periods users take in real life. Looking at efficiency measures however, it was found that typical end users of mobile small screen devices carried out a lot of detouring routes instead of solving the tasks the shortest way possible. Given the reference of 36 steps that were necessary to solve the four tasks on the most direct path, this seems to be quite substantial. Conceivably, this shows that mobile phones - at least in the way being currently designed – impose a high cognitive load on users.

From the data of this study the usage of diagrammatic instruction formats can be insistently recommended for a wide range of users. It is to be noted that the information about the menu structure and the knowledge about the hierarchical nature and as well as information about interconnections between menu categories are the most important features that should be transported to users.

However, the findings presented here are limited to hierarchically structured menu types of mobile phones. Therefore, future studies should continue in this line of research and examine appropriate instruction formats also for non-hierarchical small-screen device menus. In contrast to the exclusively hierarchically structured data in cell phones, PDAs and smart phones provide both, network structures as well as hierarchical menu parts and it can be assumed that in hypertext structures, which do have a much higher function complexity in addition, disorientation is even more likely to occur.

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