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

Volume I

Joanna Lumsden
National Research Council of Canada
Institute for Information Technology – e-Business, Canada

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Chapter IX
Learning-Disabled Children: A Disregarded User Group

Susanne Bay
RWTH Aachen University, Germany

Martina Ziefle
RWTH Aachen University, Germany

ABSTRACT

In usability research it is a common practice to take young and healthy university students as participants for usability evaluations. This chapter focuses on the "weaker" mobile phone users, which have been mostly disregarded in this field: Learning-disabled children. Their interaction with mobile phones is compared to that of average children and students. Results show that the consideration of the "ergonomic worst case," which means a user group with cognitive deficiencies, leads to qualitatively and quantitatively different insights into the impact of specific design decisions. In contrast, when only students are involved as participants in the evaluation of technical devices, the impact of characteristics of the user interface on the ease of use is dramatically underestimated. One factor hampering the ability of learning-disabled children to interact meaningfully with a technical device may be their big difficulty building a correct mental representation of it. Therefore, this process should be especially supported.

INTRODUCTION

In most research projects, focusing on the usability of technical devices students serve as participants for the experimental evaluations. As students are bright and technically skilled, highly performance-motivated, have high cognitive and verbal abilities and no fear of being tested, the examination of this user group can be regarded as benchmark. Of course, this may give an insight into the effects of a specific design on users' performance interacting with the device because results can be interpreted as mainly caused by the design of the technical device, and no shortcomings have to be considered from the users' side. Furthermore, there are practical reasons for this procedure, as students can be recruited very easily by research institutions. On the other hand, the fact that some devices such as the mobile phone can be found in all age groups and levels of society give reason to seriously doubt whether students as participants in usability tests will be able to identify the real impact of specific user interface alternatives on the ease of use of the device. Taking only students' performance as basis for design decisions seems to be risky.

The purpose of the present study was to learn if and to which extent the performance achieved by students in usability studies may be generalized to a broader (or weaker) population. The motivation was to assess with a common technical device and typical tasks whether not only the quantitative performance level but also specific difficulties of the special user group could be identified. If the same difficulties may be found this means that the user interface design should be aligned with the "weakest" user's needs. If specific problems are encountered, a "design for all" approach would not be feasible but special design recommendations for different user groups would be needed.

BACKGROUND

Considering the variance in all factors characterizing the users it is highly debatable if the benchmark procedure for usability evaluations meets the demands of easily usable devices for all target users. There are differences, for example in expertise, experience with technology in general, domain knowledge, cultural factors and upbringing, but also developmental aspects with respect to the huge field of cognitive abilities, ascending in children and descending in older adults. As shown in earlier studies (e.g., Bay & Ziefle, 2003a; Liben, Patterson & Newcombe, 1981; Vicente, Hayes & Williges, 1987; Westermann, 1997; Ziefle & Bay, 2005a, Ziefle & Bay, 2006) a number of cognitive abilities, for example spatial cognition or verbal memory, show a considerable change over the lifespan.

Given that diversity, it may be problematic to focus only on best case conditions and to neglect weaker users. Rather, it might be more advisable to pursue an inverse proceeding in usability research in order to reach what usable designs promise.

Everyday, products as the mobile phone should be conceptualized bearing in mind the "weaker" user, that is, for example, a user with cognitive abilities below average. These users are the ones who need to be supported much more than those who are well trained with technical devices and office software because otherwise they may not be able to handle a device even after a substantial time of exposure. Also, more and more children possess mobile phones, which have not been specifically designed for this user group. Probably children would not even want to use a "kid's phone" because of "image" issues. In the recent past a number of studies have been concerned with enlightening children as a special user group of technical devices or technology in general (Berg, Taylor & Harper, 2003; Carusi & Mont'Alvao, 2006; Hanna et al., 1998; Jones & Liu, 1997; Ketola & Kohonen, 2001; Lieberman, 1998). While some knowledge was collected on children's attitudes (e.g., Vincent, 2004) and general usage criteria (e.g., Crenzel & Nojima, 2006), only few studies have investigated *how* children actually interact with different mobile phones in terms of efficiency and effectiveness (e.g., Bay & Ziefle, 2003b; Bay & Ziefle, 2005; Ziefle, Bay & Schwade, 2006). And in even fewer studies a direct comparison of the children with the performance of other user groups (i.e., young and older adults) was undertaken (Ziefle & Bay, 2004; 2005b).

Similar to the small HCI research output regarding children there is even less knowledge about mentally impaired users' interaction with technology (e.g., Oliver et al., 2001; Petrie et al., 2006; Mátrai, Kosztyán & Sik-Lányi, in press). Especially for these people the importance of usable mobile devices is high. Given the fact that mere calling is not longer the most frequent interaction but impaired users could be supported by memory functionality (e.g., medical monitoring) or navigation aids of mobiles, the mobile device could be a supportive aid enabling more independency and higher mobility of this special group.

Learning-disabled children are said to show the same developmental process as "normal" children, their developmental speed is only slower (on average about 1 to 2 years behind average children). Usually, they do not reach the highest stadium of cognitive development, which is characterized by abstract reasoning about problems (Schröder, 2000). Learning-disabled show a permanently constricted learning field, which means they are only susceptive to concrete and needs-related material. They have a reduced ability for abstractions, limited capacity to structure tasks and are generally slow, shallow and time-limited in their learning process.

In Germany, around 2.2 percent of all pupils are characterized as learning-disabled and need therefore special education. They are a marginal group but they deserve some attention from ergonomists and designers, because they are currently totally disregarded in usability research. Furthermore, a detailed look at their difficulties interacting with a mobile phone can give interesting insights into problems an average user will also very likely experience, for example when his attention is not entirely focused on the phone because he is on the move. When pursuing a "design for all" approach, learning-disabled are certainly a prototypical user group that should be considered for participation in usability studies.

MAIN FOCUS OF THE CHAPTER

In the present study the performance of different user groups interacting with mobile phones is compared: A student group and two groups of children—one being average school kids between 9 and 12 years of age, the second consisting of learning-disabled children and teenagers between 11 and 15 years of age. Their performance when solving typical tasks on a widespread phone model, the Siemens C35i, is evaluated. To assess the impact of specific user interfaces of a mobile phone in different user groups, only one aspect of the phone is experimentally varied: the keys that are used to interact with the mobile phone's menu. For reasons of ecological validity the navigation keys of a second widespread mobile phone model, the Nokia 3210, were chosen. Only few adaptations of the menu (such as changing the position of the soft key labels on the display) were necessary to operate the menu of the Siemens C35i with the Nokia 3210 keys.

Method

Participants

In the experiment, three different user groups with a total of 80 participants took part. Thirty students, 20 children with normal intelligence and 30 learning-disabled children and teenagers. The 20 children with normal intelligence were between 9 and 12 years of age, the 30 learning-disabled between 11 and 15 years. (The differences between those two groups regarding number of participants and age were due to difficulties recruiting these special users, yet the age difference is of minor importance since the "cognitive" age of learning-disabled is reduced compared to their "real" age. Half of the participants in each user group processed tasks using the phone with menu and keys both stemming from the Siemens C35i, the other half using the phone consisting of the Siemens C35i menu and the Nokia 3210 navigation keys.

Apparatus

The two mobile phones were simulated on a touch screen connected to a PC where user actions were logged on the keystroke level. To ensure good visibility and avoid difficulties hitting the keys because if the missing tactile feedback the display and the keys of the mobile phones were enlarged compared to the original devices. The appearance of the simulated phones was also modified to exclude effects of preferences for specific brands. The touch screen was fixated on a table in an angle of 35° which enabled an interaction in approximately the same posture as when using a real mobile phone.

Key Description

The two variants of navigation keys differed with regard to the number of keys (more specifically, the number of different options to be pressed) and the number of different functions each of these keys can exert. Moreover, among those keys which exert different functions at different points within the menu, there are such that have a similar meaning (e.g., confirm and save) and such that are quite dissimilar (e.g., end calls and return to a higher menu level).

The two original navigation key solutions which were simulated in the present experiment are shown in Figure 1 and 2.

The C35i keys consist in total of seven key options. Each of the two rocker switches contains two options (marked by a dot on each side of the rocker switch) were the key may be pressed, thus resulting in two “stroke options” per key. Sometimes (depending on the menu level) however, there are not two different options to be selected, but the same function is exerted, independently which side of the rocker switch that was pressed. The label displayed on the display above the key indicates which functions can be exerted. The left rocker switch has six different functions. The functions are scrolling (left: up, right: down), selecting the mailbox, changing, saving entries, and sometimes it has no function at all, depending on the point of the menu. All those actions are semantically very different from the scrolling function. The right rocker switch serves to enter the menu, to select, to correct (left part) and confirm (right part), or to correct (left) and save (right), and to send a message (eight functions/combinations of functions, where six are semantically dissimilar from selecting/confirming). Additionally, there is an extra key with an icon (open book) to open the phone directory. This function is most of the time not active at all. Furthermore, there is a big, centrally positioned key with a green receiver icon on it is used to make calls, which also exerts a function in specific cases (e.g., when a number is displayed), otherwise having no function. Finally, there is a smaller key with a red receiver sign to end calls as well as for hierarchical steps back in the menu.

Figure 1. Navigation keys of the Siemens C35i

Figure 2. Navigation keys of the Nokia 3210

The Nokia 3210 navigation keys exhibit four key options. Two of them have several functions: The c-key is used for corrections of letters and digits as well as for returns to higher menu levels. These two functions can be regarded as similar, as they both mean “undo.” The centrally positioned key is a softkey used to enter the menu, to select highlighted menu entries, to confirm and to effect calls (four functions, three of them semantically similar representing confirmation actions, but entering the menu is not a confirmation action and can therefore be regarded as semantically dissimilar). The scrolling-key is used for movements up and down within any level of the menu.

Overall, the Nokia keys can be judged as simple with respect to both the number of keys and the number of keys with different functions compared to the Siemens keys.

Procedure

To assess the participants` previous experience using different kinds of technical devices, including the mobile phone, they were asked to complete a questionnaire before processing tasks on the mobile phone. The questionnaire was shown on the touch screen and required participants to activate fields by touching the screen. Thus, they were able to get used to the reaction of the touch logic. On a five-point scale the frequency of using different devices had to be answered (1= ”several times a day," 2 = "once a day," 3 = "once a week," 4 = "once a month" and 5 = "less than once a month"). The estimated ease of use of those devices was to be judged on a four-point scale (1 = "very easy," 2 = "rather easy," 3 = "rather difficult," and 4 = "very difficult"). Also, the general interest in technology had to be rated on a four-point scale (1 = "low," 2 = "rather low," 3 = "rather strong," 4 = "strong").

Afterwards, participants had to complete four tasks on the simulated mobile phone:

1. Enter a telephone number and make a call
2. Send a text message (SMS) to a specific phone number (to compensate differences in the speed of typing the text, the message was provided and only had to be sent)
3. Hide your own phone number when calling
4. Redirect all phone calls to the mailbox

The participants were given a period of five minutes to solve each of the tasks. When a task was solved correctly, a "congratulations" message was shown on the screen. When a participant did not succeed in solving a task within the period of five minutes the experimenter told the participant that the specific tasks was very hard to solve (in order to prevent user's frustration) and that he should go on with the next.

Independent and Dependent Variables

The first independent variable was the key solution (3210 vs. C35i). The second independent variable was the user group (students vs. average children vs. learning-disabled children).

As dependent variable the participants' performance was assessed by counting the number of ineffective keystrokes carried out. That is, each key stroke that did not lead to any task related effect on the display. This includes:

- Hash (#) and asterisk (*) at any point within the menu
- Numbers when not task related
- Soft keys, function keys and scroll-buttons when not exerting a function

Additionally, the number of steps executed, the time needed to process tasks as well as the number of tasks solved were measured.

Results

The Participants' Experience with Technology

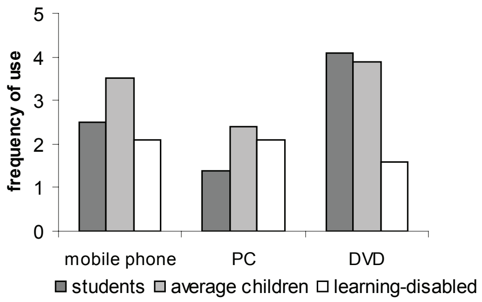
In a pre-experimental questionnaire the participants' experience with different technological devices was surveyed.

The students reported to use a mobile phone between daily and once a week (M = 2.5; SD = 1.6), the wireless phone once a week (M = 3.0; SD = 1.8), the PC between several times and once a day (M = 1.4; SD = 0, 7) and a DVD or VCR once a month (M = 4.1; SD = 0.9). The perceived ease of use of all devices was between "very easy" and "rather easy" (mobile phone: M = 1.7, SD = 0.9; wireless phone: M = 1.4, SD = 0.7; PC: M = 1.8, SD = 0.8; DVD: M = 1.7, SD = 0.7). On average, the students' interest in technology was rated between "rather strong" and "rather low" (M = 2.4, SD = 0.9).

The learning-disabled children had quite some experience using technical devices: The mobile phone (M = 2.1; SD = 1.6) and a PC (M = 2.2; SD = 0, 9) were used daily, the wireless phone (M = 3, 0; SD = 1.6) and DVD player (M = 2.9; SD = 1.3) once a week. The estimated ease of use of all devices was between "very easy" and "rather easy" (mobile phone: M = 1.5; SD = 0.8; PC: M = 1.7, SD = 0.9; wireless phone: M = 1.3, SD = 0.8; DVD: M = 1.6, SD = 1.1). The general interest of the learning-disabled in technology was rated as "rather high" (M = 3.3; SD = 1.1).

Looking at the average children's answers in the questionnaire it may be said that they were somewhat less experienced than the learning-disabled. They reported to use a mobile phone between once a week and once a month (M = 3.5; SD = 1.4), the PC between once a day and once a month (M = 2.4; SD = 1.1), the wireless phone

Figure 3. Frequency of using a mobile phone, a PC and a DVD player in the three user groups (1 = "several times a day," 2 = "once a day," 3 = "once a week," 4 = "once a month," 5 = "less often")



once a day (M = 2.0; SD = 0.9) and the DVD once a month (M = 3.9; SD = 1.0). The reported ease of use was between "very easy" and "rather easy" as in the two other user groups (mobile phone: M = 1.8, SD = 0.9; wireless phone: M = 1.1, SD = 0.3; PC: M = 1.8, SD = 0.8; DVD: M = 1.8, SD = 0.9). Children's general interest in technology was rather low (M = 2.1; SD = 1.0).

As visualized in Figure 3, it has to be stated that the learning-disabled are not less experienced with technology. Quite the contrary, their reported frequency with which they use a mobile phone and a DVD-player is even higher than that reported by the other two groups. Therefore, from this perspective no big performance differences should be expected.

In order to draw back performance differences between the participants using the different key solutions to the experimental manipulation, we had to make sure that the groups did not differ regarding their experience with technology. Therefore non-parametric Mann-Whitney tests were carried out for the variables surveyed in the questionnaire. No significant differences could be detected.

Performance Using the Two Phones

For each of the three groups of participants the number of ineffective keystrokes carried out with the two navigation key solutions is assessed.

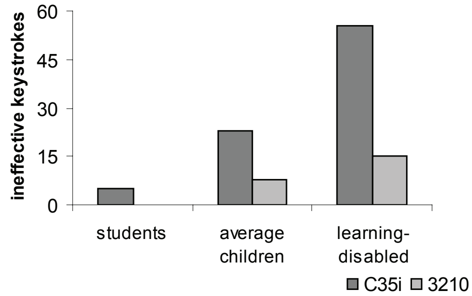
First the total number of ineffective keystrokes carried out by the students, the average children and the learning-disabled using the two phones is analyzed. Figure 4 shows the outcomes.

The students carried out 5.1 (SD = 6.3) ineffective keystrokes when using the C35i keys and 0.2 (SD = 0.6) with the 3210 key solution. Children in the C35i group made 22.8 (SD = 31.5) ineffective keystrokes, those of the 3210 group only 7.7 (SD = 7.7). Learning-disabled made 10 times as many ineffective keystrokes than the students and more than twice as many as average children when using the C35i (M = 55.3, SD = 71.2). Learning-disabled using the 3210 key solution made 14.9 (SD = 16.1) ineffective keystrokes, which also represents a considerably higher number compared to students and children. However, the performance difference between the two groups using different key solutions becomes more obvious in learning-disabled children (55.3 vs. 14.9 ineffective keystrokes) than in other user groups. Thus, the huge impact of different key solutions on user's performance becomes only apparent when participants other than students are taken into consideration. For a deeper insight into the performance of the different groups, the number of keystrokes carried out in each of the tasks is looked at in detail.

Effects of Key Solutions on Students

Figure 5 shows the performance outcomes for the first user group, the students, where the number of ineffective key strokes in each of the four tasks

Figure 4. Ineffective keystrokes carried out in the four tasks by the three user groups when using the Siemens C35i keys and the Nokia 3210 keys



is visualized. Students using the mobile phone with the Nokia 3210 keys carried out almost no ineffective keystroke (on average only 0.1 in tasks 2 (SD = 0.5) and 3 (SD = 0.3)) and also using the Siemens C35i keys the number of ineffective keystrokes may be regarded as negligible: When effecting a call no ineffective keystroke was carried out. When sending an SMS 2.9 (SD = 5.6), when hiding their own number 1.9 (SD = 3.8) and when making a call divert to the mailbox only 0.3 (SD = 0.7) times keys were stroked ineffectively. For the tasks of sending a short message ($t(28) = 1.87$; $p < .1$) and of hiding their own number ($t(28) = 1.91$; $p < .1$) marginally significant differences, depending on the key solution used, could be detected. Nevertheless, due to the small total number of ineffective keystrokes affected, it could be concluded, that the different key solutions do not significantly affect the performance interacting with the mobile phone.

But, before drawing this conclusion, a closer look should be taken at the performance of the other user groups.

Effects of Key Solutions on Average Children

Figure 6 visualizes performance outcomes for the average children carrying out the four tasks with different phones. It becomes evident that this user group undertakes considerably more keystrokes and also the difference between the two key solutions is somewhat clearer.

When effecting a call, children using the 3210 keys make 0.3 (SD = 0.9) ineffective keystrokes. With the C35i keys 0.6 (SD =2.0) ineffective keystrokes are undertaken. Thus, this task seems not to impose high demands on the children. In task two, where a text message was to be sent, with the 3210 keys 3.7 (SD = 6.8) and with the C35i 8.9 (SD = 10.0) ineffective keystrokes are undertaken. In the task of hiding their own number, participants press 2.8 (SD = 4.6) keys ineffectively when using the 3210, and 5.8 (SD =8.7) keys with the C35i solution. The last task, in which a call divert had to be carried out, led to the greatest performance difference between the two key solutions. Using the 3210, keys were stroked without exerting an effect only 0.7 (SD = 1.1) times, whereas in case of the C35i keys this happened on average 7.8 (SD = 15.2) times. In spite of the big numerical differences in performance between the users of the two phones, t-tests did not reveal any significant effect for any task, which may be due to the big variance in the data.

From these results obtained with children possessing average intelligence, it may be assumed that the navigation key solution exerts some effect on the users' performance interacting with a mobile phone, but the impact does not seem to be dramatic. After all, when solving tasks using the Siemens C35i on average only 9 times a key is stroked without exerting any effect. This should not unsettle a user. However, the results give a

Figure 5. Number of ineffective key strokes carried out by students using the two navigation key solutions

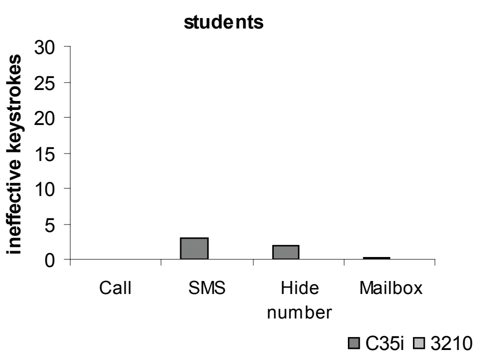
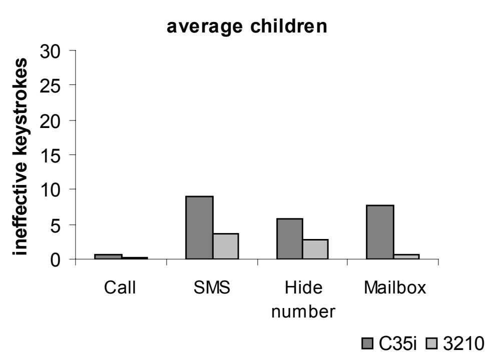


Figure 6. Number of ineffective keystrokes carried out by average children using the two navigation key solutions



first hint that different navigation key solutions used to control the same menu can lead to some interesting differences in performance.

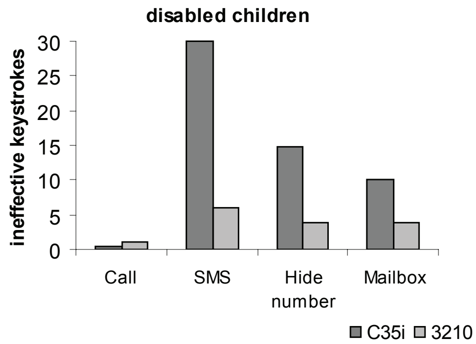
For a deeper insight into the effects, a user group, which should be more sensitive towards complex rules of interaction, is surveyed.

Effects of Key Solutions on Learning-Disabled Children

Figure 7 shows the number of ineffective keystrokes carried out by the group of learning-disabled children when using the Nokia 3210 keys and when using the original keys of the Siemens C35i.

Huge performance differences become evident. When using the 3210 keys between one and six ineffective keystrokes were carried out by the learning-disabled in the four tasks (call: M = 1.1, SD = 1.7; SMS: M = 6.1, SD = 7.4; hide own number: M = 3.8, SD = 5.7 and call divert to mailbox: M = 3.9, SD = 5.0). In contrast, when the learning-disabled children used the original keys of the C35i phone, averages of up to 30 ineffective keystrokes—when sending a text message, SD = 48.5—were reached. And also when hiding their own number and diverting calls to the mailbox with 14.8 (SD = 16.4) and 10.1 (SD = 15.3) a substantial number of ineffective keystrokes was undertaken. In the task of calling a number only 0.4 (SD = 1.1) ineffective keystrokes were made (Figure 7). T-test show significant differences between the two key solutions in the task of hiding their own number ($t(28) = 2.46$; $p < 0.05$) and a marginally significant difference in sending a text message ($t(28) = 1.89$; $p < 0.1$). This impressive performance differences between the two key solutions when they are used by learning-disabled should not be ignored. Interestingly, it is not the original key solution that leads to the best performance, but the solutions originating from an alternative phone, the Nokia 3210.

Figure 7. Number of ineffective keystrokes carried out by learning-disabled children using the two navigation key solutions



Which Keys Lead to the Difficulties?

The question, why the Siemens C35i keys led to many more ineffective keystrokes, may be answered by looking at the specific keys, which were stroked very often without exerting a function. The key that led to the biggest number of ineffective strokes was the receiver key, which is used to effect calls in the C35i solution. This key was used on average 28.7 times by the learning-disabled, 4.9 times by average children and on average 0.6 times by the students without exerting any effect. The key is comparably large, green and centrally positioned on the mobile phone, and was therefore presumably mistaken as a confirmation key.

The second type of keys, which were often used without exerting a function at the current point within the menu, were the soft keys of the Siemens C35i. Learning-disabled pressed these keys 17.7 times ineffectively, average children 9.2 times and students 4.1 times. The two soft keys of the C35i model exert many different functions at different points within the menu, and can sometimes exert different functions when stroked left or right. Sometimes, they have only one or even no functionality at all. This changing assignment of modes-of-operation has probably confused the users and especially the learning-disabled children, which led to many ineffective keystrokes.

Performance Differences between the User Groups in other Variables

For an insight into the performance differences between the three user groups of the present study two other variables, processing time and detour steps, are looked at. These variables are not directly related to the usability of the key solution, but are caused mainly by the difficulty imposed by the menu of the mobile phone. Therefore no differentiation between the two navigation key solutions used is made.

When effecting a call, both groups of children needed more than double the time (average children M = 44.2s; learning-disabled: M = 41.3s) than the students (M = 19.1s). In the task of sending a text message the differences between the groups increased: Students needed 83.1s, children 161.8 and learning-disabled 212.3s. Similar patterns of results were found for the tasks of hiding their own number and making a call divert to the mailbox. To hide their own number students needed 116.8 s, average children 221.4s and learning-disabled 242.7s. To make a call divert to the mailbox students needed 109.1s, average children 204.3s and learning-disabled 225.7s (Figure 8).

Thus, when considering only student participants, the difficulty imposed by the phone with a maximum of two minutes for completing the task of hiding their own number is not irrelevant, but still limited. However, when considering the performance of learning-disabled, who needed on average four minutes for this task, many were not able to actually solve it. The need for an improvement of the mobile phone's user interface becomes obvious.

A look at the number of steps executed while trying to solve the tasks confirms the argument. In the first task, where a number had to be entered and a call effected, performance between the groups does not differ meaningfully. Students need 12.9 steps, average children 16.9 and learning-disabled 17.4 steps. In the other tasks, learning-disabled children need mostly more than twice as many steps as the students. To send an SMS students need 51.2 steps, average children 68.6 and learning-disabled 120 steps. In the task of hiding their own number students execute 86.7 steps, average children 129.9 and learning-disabled 163.4 steps. In the last task students made 76.9 steps during their attempts to solve the task, average children made 141.4 and learning-disabled made 155.7 steps.

It becomes evident that the difficulty to perform different tasks on a widespread mobile phone is underestimated when only students are selected as participants for usability tests.

Figure 8. Time needed to process the four tasks by the three user groups

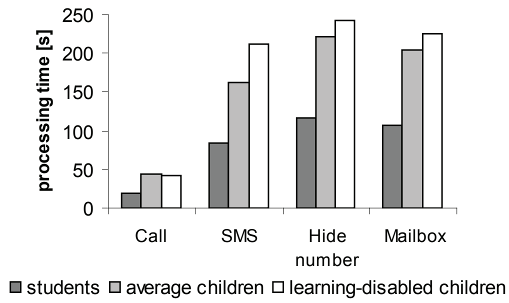
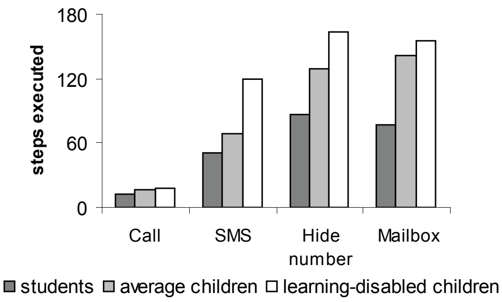


Figure 9. Steps executed while processing the four tasks by the three user groups



What is so Special About Learning-Disabled?

The results outlined above give reason to argue that designers of interfaces for mobile phones (and presumably of other electronic devices, too) should focus on weaker mobile phone users, such as learning-disabled, if they want to make sure that their device is really usable for a broad range of users. However, to understand what makes the learning-disabled a special group, it is worthwhile to examine their specific characteristics that may be of importance for the interaction with mobile devices.

Memory

The first important aspect, which differentiates learning-disabled from other users, is their memory capacity. The high correlation between memory capacity and the performance using a mobile phone was shown in a study by Bay and Ziefle (2003a). Participants of this study who were between 27 and 61 years of age had reached 12.6 points (SD = 2.2) in a test of figural memory. The learning-disabled of the present study were asked to solve the same memory test (LGT-3, Bäumler, 1974) and it revealed that the memory ability of the learning-disabled was somewhat lower with a mean of 9.8 (SD = 2.2) out of 20 points. This may be one reason for the big difficulties experienced by the learning-disabled. They may have had troubles remembering the functions, each of the different keys exerted, and which of the menu functions they had already selected. However, correlations between the scores in the memory test and performance measures, when using the mobile phone, did not reach the significance level in the present study.

Locus of Control

In earlier studies (Bay & Ziefle, 2003a; Ziefle, Bay & Schwade, 2006) it was found, that users' "experienced competency" with respect to the use of technical devices in general can also affect performance outcomes when using mobile phones. The locus of control regarding the use of technology (LOC) as measured through a standardized test (Beier, 1999) showed significant correlations with the number of tasks successfully solved on a mobile phone in a group of younger and older adults. Thus, users having high values in LOC showed a better performance than those with lower values. Even if it is not clear, whether the LOC is the antecedent of a good performance or if the successful interaction with technology is the antecedent of the high LOC value, the correlation shows that the felt competency and the real competency of using technical devices go in parallel in adults.

It is a basic question whether the learning-disabled have equally high self-assessment. On the one hand, it may be assumed that learning-disabled are intimidated by technical devices. This may be due to their negative experience interacting with them. Such an attitude could have negative impact on the way they approach technical problems and is therefore worth looking at. On the other hand, it is also equally plausible that the learning-disabled have no valid or realistic self-estimation with respect to their own competencies when using technical devices.

The learning-disabled children's locus of control interacting with technology was therefore surveyed with a standardized instrument by Beier (1999). It consists of eight statements, such as "I like cracking technical problems" or "Whenever I solve a technical problem this happens mostly by chance." These statements have to be affirmed or denied by the participants on a six point scale.

The learning-disabled reached an average score of 73.4 (SD = 15.7) of a maximum of 100 points. The participants in an earlier study (Bay & Ziefle, 2003a) had reached 66.1 points. The average children, in comparison, revealed a similar level with, on average, 67.4 points (SD = 14.1). The students showed a somewhat higher LOC level with 76.6 points (SD = 10.5), however, surprisingly, they did not reach values close to the upper end of the scale, as one could have expected.

Does the LOC really affect performance and can this be found in all user groups?

To assess interrelations between performance using the mobile phone and locus of control regarding technical devices, Spearman rank correlations were carried out. To begin with the benchmark, students showed a weak, but marginally significant correlation between the number of tasks solved and LOC values (r = -0.3; $p < 0.1$). Also, for the average children group LOC values were found to considerably affect performance (number of keys used ineffectively: r = -0.47; $p < 0.05$; tasks solved: r = -0.50; $p < 0.05$; time on task: r = -0.36; $p < 0.05$). Thus, for younger and older adults as well as for average children the LOC was interrelated with performance, even though to a different extent.

It characterizes the specificity of the disabled children that a significant correlation between LOC values and performance using the mobile phone could not be found in this group, for none of the dependent variables. This shows that this user group was not able to self-assess themselves realistically with respect to their technical competency. On the one hand, their absolute level in LOC was not very different from the other user groups, however, their performance level was distinctly lower: Their efficiency was 10 times lower with respect to the number of ineffectively used keys and the children needed double the time and twice as many detour steps when compared to the benchmark, the students' performance.

Mental Models

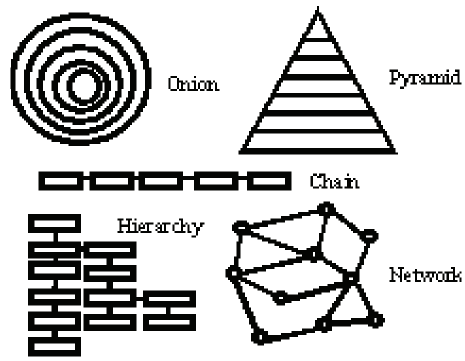
The importance of mental models for a purposeful interaction with technical devices has been emphasized by a number of studies (e.g., Norman, 1983), also more specifically for the interaction with mobile phones (Bay & Ziefle, 2003b; Ziefle & Bay, 2005). It was found that the better the mental representation of the spatial structure of the device (that is, the hierarchical nature in the case of mobile phones), the better was the performance of a user.

The difficulties of the learning-disabled children interacting with the mobile phones may therefore be due to a deficiency in building an appropriate mental representation of the menu structure. Therefore the users' mental model of the menu was assessed by showing the children a number of drawings that are supposed to visualize different kinds of mental models. The children had to process the phone tasks first, and were then asked to choose the one of the shown alternatives that was most appropriate, according to them. The different drawings of the mental models are shown in Figure 10.

The menu of a mobile phone has a hierarchical structure. However, only seven of the 30 learning-disabled children chose this drawing.

It is of interest, whether users who chose the correct drawing also performed better than those without a correct mental representation of the mobile phone menu. And indeed the analyses revealed a somewhat superior performance of the learning-disabled who were aware of the hierarchical nature of the menu. They executed 394.3 steps (SD = 148.2) in contrast to 569.6 steps (SD = 255.6) needed by the rest (Figure 11). This difference was marginally significant ($t(28) = 1.73$; $p < .1$). Users with a hierarchical mental map also solved somewhat more tasks (M = 2.9; SD = 1.1) and executed less ineffective keystrokes (M = 21.6; SD = 18.1) compared to the majority without a correct mental map who solved only 2.5 tasks (SD = 1.1) and made nearly twice as many ineffective keystrokes (M = 39.2; SD = 61.5). With regard to the processing time, differences were much smaller, but still showing a benefit of the correct mental representation (M = 829.4, SD = 251 versus M = 853.1, SD = 251.5 of the majority without a correct mental map).

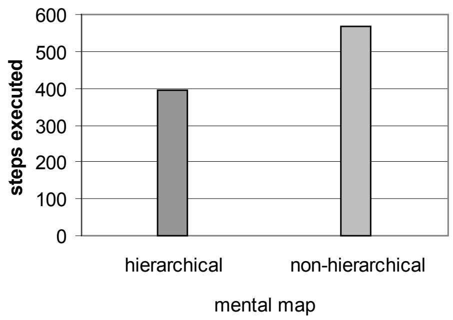
Figure 10. Drawings used to assess the users' mental representation of the menu structure



Thus, the impact of a correct mental representation of the mobile phone menu on learning-disabled children's performance could be shown.

In a study by Bay and Ziefle (2003b), the benefit of having a correct model on the performance interacting with mobile phones was also found for average children. It was shown that nearly all (80 percent) of the examined children aged nine to 16 had a correct mental representation of the hierarchical nature of the menu. The results of the present study confirm the importance of a hierarchical mental representation of the menu and suggest that this is a crucial factor, which may explain the huge inferiority of the learning-disabled compared to other user groups including other children.

Figure 11. Performance difference between users with a hierarchical and a non-hierarchical mental representation of the menu



CONCLUSION

A study was conducted with the aim to explore the differences in performance between learning-disabled children, average children and students when interacting with a mobile phone. This study was undertaken out of two reasons: Firstly, learning-disabled have been completely disregarded as users of everyday technical products as the mobile phone. Secondly, the consideration of participants in usability research who do not possess high cognitive abilities can provide meaningful insights into the real implications of specific user interface design decisions. As one important example for a design decision the navigation key solution was varied. Participants processed four typical phone applications on two mobile phones simulated on a touch screen. One phone corresponded to the Siemens C35i regarding menu and navigation keys, the second phone had the same menu, which was to be operated with navigation keys stemming from the Nokia 3210 model.

Thirty students, 20 average children aged between 9 and 12 years of age and 30 learning-disabled children and teenagers between 11 and 15 years took part in the study. As expected, results revealed similarities between the three user groups as well as differences. The similarity between groups is the basic pattern of performance outcomes when using the C35i keys in contrast to the 3210 keys: All user groups showed a considerably better performance when using the simple and easy to understand 3210 keys compared to the rather complex C35i key solution. This means, that there are design solutions that benefit every user independent of age and cognitive abilities. This result makes the idea of the “design for all” approach feasible.

The difference that showed up between the user groups is the huge inferiority of the learning-disabled compared to the student group as well as to the average children. Learning-disabled students needed more than double the time and steps to process the tasks than the students and about one third more time and steps than average children for example when sending a text message. Also, the effect of the different key solutions becomes more evident in the learning-disabled compared to the other groups, which can be taken from the total amount of ineffectively used keys. In total, using the C35i keys the learning-disabled made on average 55 ineffective keystrokes while solving the four tasks, and this is actually ten times more than students and more than twice as many as the average children carried out when using the C35i keys. However, learning-disabled children made only 15 ineffective keystrokes with the 3210 keys, which shows how much this user group benefits from good design. With student users, this difference between the two key solutions did not become as obvious, since with the more complex phone only five ineffective keystrokes were carried out on average—an number that apparently may be neglected. Thus, the real difficulties that can be caused by a navigation key solution and the importance of creating less complex solutions only becomes evident when a user group like the learning-disabled is considered. If only students are taken as participants in usability tests—as it is very often the case—important aspects are completely ignored. For example, the present study could show how dramatic the impact of inconsistent assignment of functions to keys can be, which only reached a meaningful effect on performance in the group of learning-disabled users. Average children and students experienced the same difficulties but were able to overcome them after some practice.

It may be concluded that whenever a "design for all" approach is pursued, the ergonomic "worst case" has to be taken into consideration. Even if the recruitment of those users requires more time, it is worth the effort and represents a very insightful experience. But what is so special about the learning–disabled as user group?

As a first hypothesis it may be assumed that learning-disabled children and teenagers have lower expertise and experience using different technical devices. Results show, however, that the contrary is the case. The learning-disabled of the present study showed a higher frequency of using a mobile phone, a DVD-player and a PC than average children and even partly outreached the students. Thus, this hypothesis has to be rejected.

When memory ability, which was found to influence the ability to interact with technical devices, was assessed some, but again, no meaningful differences between learning-disabled and other user groups were detected. However, for this user group, correlations between memory ability and performance measures did not lead to significant interrelations.

Furthermore, the locus of control of the learning-disabled children did not show to differ meaningfully from that of other users. In contrast, the learning-disabled children and teenagers surveyed in the present study seemed to be pretty convinced of their ability to handle technology well (nearly as convinced as the average children and the students were). Not only their locus of control was high but also the estimated ease using a mobile phone, a PC or a DVD player was high: They were rated between "very easy" and "rather easy" to use by the participants. Thus, the reported expertise has also to be ruled out as explanatory variable.

A last aspect that may account for the inferior performance of learning-disabled children and teenagers is the lack of an appropriate mental model of the functioning of the mobile phone, more specifically of the menu structure. And indeed only seven out of 30 learning-disabled were able to identify the hierarchy as the correct model of the menu structure. For a comparison, in Bay & Ziefle (2005) it was found that 80 percent of 9 to 16 years old children were aware of the hierarchical nature of the menu. Also, the present study showed that learning-disabled children possessing a correct mental map performed better in solving tasks on the mobile phone than participants whose mental map was incorrect.

It is often assumed that people automatically build-up cognitive representations of the functioning of technical devices while interacting with them (e.g., Norman, 1983). Thus, frequent exploration and active handling of the technical device is believed to support the development of adequate representations with respect to how the mental room, which has to be navigated, is structured. Furthermore, the exploration of the menu structure is assumed to pre-structure the interconnections and relations between functions and sub-categories present in the menu. However, learning-disabled apparently have big difficulties building a correct representation of the menu structure, considering that they reported to use a mobile phone on a daily basis. At least, the mental representation they have built does not correspond to the real information structure of the phone. Therefore, it may be concluded that the process of building a mental representation needs to be actively supported. This may be done through training or better visual cues on the spatial structure to be incorporated on the mobile phone's display (Ziefle & Bay, 2006).

Some final remarks are concerned with potential methodological limitations of the presented research study. One could critically argue that the phones under study were simulations on a touch screen rather than real mobile phones. This criticism can be met with three arguments: First, as only the keys were under study and have been experimentally varied independently of differences with regard to the menu, there were no real phones available that met these requirements. Second, different mobile phones differ in so many attributes and aspects (size, form, color, key shape, labels, haptics, etc.) that any comparison would be misleading for the question at issue, because we actually do not know which of the aspects leads to performance differences. Third, with the special user group under study—learning- disabled children—it was a deliberate aim to design the experimental situation as easy and comfortable as possible and with the simulation visual as well as psychomotor difficulties could be ruled out. It is clear that our results therefore represent an underestimation of the real performance but performance differences can be unequivocally traced back to the experimental variation. The same argument can serve to explain the feedback provided when a task was solved successfully. Whenever the children had solved a task they were presented a "Congratulations!" message—something that is not given in real life situations and definitively makes the experimental situation easier than in reality. However, as average as well as handicapped children use to quickly lose their motivation it was of central importance to sustain children's enthusiasm taking part in the experiment. Even though an underestimation of performance differences between the phones may have taken place, the key result that handicapped children show the very same structural problems with phones but react more sensitive on specific user interface design decisions in not affected by these methodological issues.

FUTURE TRENDS

Future studies should focus on supporting the process of cognitive mapping in participants. Even if the performance outcomes were qualitatively very similar between the different user groups, it may not necessarily be deduced that the development of a proper mental model is also similar. In the contrary, it is very likely that different user groups need different types of support for this purpose. Different types of training, instructions in manuals or information visualization on the display of the mobile phone itself should be evaluated with respect to their helpfulness for different user groups.

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KEY TERMS

Ecological Validity: Degree to which results of experiments are transferable to behavior in real world situations. The higher the ecological validity of an experiment the higher is the probability that results found in the experiment can be found in the same fashion in the field.

Ineffective Keystrokes: Measure for performance evaluation. Counting each key stroke carried out by a user that does not lead to any task related effect on the display enables to measure the difficulty imposed by the navigation keys of a mobile phone independent of the difficulties caused by the menu. Ineffective keystrokes include Hash (#) and asterisk (*) at any point within the menu, number keys when not task related as well as soft keys, function keys and scroll-buttons when not exerting a function.

Learning-Disabled Children: Children with a developmental speed that is slower than that of average children (about 1 to 2 years behind). Usually learning-disabled also do not reach the highest stadium of cognitive development which is characterized by abstract reasoning about problems. Learning-disabled show a permanently constricted learning field, which means they are only susceptive to concrete and needs-related material, they have a reduced ability for abstractions, limited capacity to structure tasks and are generally slow, shallow and time-limited in their learning process.

Mental Models: concepts in the mind of users about the functioning of devices, metaphors, and ideas which lead the user while interacting with the device.

Mobile Phone Menu: Form of displaying mobile phone functions that go beyond effectuation of calls to the user. Mobile phone menus usually have a hierarchical tree structure, which the user needs to navigate through via keys in order to find and select the desired function.

Navigation Keys: Keys used to operate the menu of a mobile phone, usually consisting at least of two keys fro scrolling up and down within one level, one key for selection and one key for returning to higher menu levels.