The Effect of Mental Models Guiding Users' Action in Mobile Phone Answering Situations

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ABSTRACT

This study was interested in the answering keys of a mobile phone, especially the SEND key. The goal of this study was to find out how the mental model of a certain kind of mobile phone keypad affects behaviour in a situation where a user has to answer calls with previously unknown mobile phones. In this study the participant's task was to answer calls while performing an attention consuming secondary task. Three different kind of phones were used and the location and the amount of perceptual information provided by the answering keys varied in each phone. It was predicted that errors would occur if the layout of the answering keys was not consistent with the participants mental model. The results of the two main user groups supported this hypothesis. It can be concluded that users' pre-existing mental models concerning keypad can be quite strong and should be taken into account when designing the function keys of a mobile phone.

Keywords

Mobile phone, SEND and END keys, keypad layout, mental model

1. INTRODUCTION

Mobile phones are becoming more common in everyday life. There are more than half a milliard mobile phone users in the world and the number is growing. Last year the mobile phone market growth exceeded 60% globally (Nokia's Financial Statements 1999). There are many different mobile phone models on the market and new models replace old ones at a growing rate. The number and layout of the keypad keys as well as their size, shape, colour and symbols vary in different models. This study concentrated on the answering keys of a mobile phone. A mobile phone keypad layout where the SEND key is located on the left and the END key on the right has become the de facto standard (DFS) in Finland. There are also other kind of answering key layouts, for example models that have these keys located in the reverse order and models where both SEND and END operations are made using a single key located in the middle of the upper part of the mobile phone.

This study focuses on a situation where the user's task is to successfully answer a call by pressing the correct key (the SEND key). The purpose of the study was to find out how the user's previous experiences with mobile phones and different answering key layouts effect the user's performance in the answering situation. This kind of information needs to be taken into account when

designing a keypad. Situations where the user might press a wrong key, when trying to answer the phone, are undesirable. The worst possible consequence of this is that the call is accidentally terminated. In order to avoid these situations, it is important to gather knowledge about the factors effecting the usability of mobile phone keys.

Mobile phones are answered in various situations. Answering should take as little attention as possible so that the user can focus simultaneously on whatever s/he is doing, e.g. driving a car. The concept of divided attention means that we share our attentional resources between more than one task at the same time. It is difficult or even impossible to determine universal attentional capacities because they depend on the situation and the abilities of the actor. It is possible to extend one's cognitive capacity with practice in a certain task (Spelke et al. 1976). Which modalities are used in certain tasks also effects the performance. If two tasks are performed using the same modality, action usually becomes more difficult. On the other hand, if the tasks are performed using different modalities (e.g. visual and auditory), the demands they pose on us can be coped with more easily (Eysenck & Keane 1990).

In addition to attentional limitations, the user's action is influenced by knowledge provided by the world and internal representations of the world constructed via experiences (Norman 1988). Understanding the behaviour of a physical system and making predictions about it's behaviour is based on mental knowledge structures which represent information about systems. The concept "mental model" is used in multiple meanings in human-computer interaction literature (Ehrlich 1996). In this paper, the term "mental model" refers to the user's knowledge structure of a system. Procedural knowledge concerning the use of a system can be viewed as a functional model of that system (Preece et al. 1994). When a user is not very familiar with the system or the task, attention and moment-to-moment control of action may be necessary. On the other hand, relatively simple, frequently performed tasks, such as answering the phone, can be done rather automatically. It has been suggested that well learned, automatic actions differ qualitatively from controlled processing and do not consume the attentional resources (Schneider & Shiffrin 1977). Even though automatic processing is economic from one point of view it also has some disadvantages. Action slips occur sometimes during automatic, over-learned activities. An action slip means performance of an action that was not intended and is due to an attentional failure (Styles 1997). Attention is needed when we switch from one action to another and errors might occur if this process is somehow interrupted. This is especially true with motor performance since most action sequences consist of distinct motor programs (Eysenck & Keane 1990). Some motor programs are considered to be stronger than others in the sense that they are more easily activated and can overtake weaker programs. Answering a mobile phone by pressing the SEND key can be thought as being a motor program. When using an unfamiliar mobile phone, the previous mental model underlying the motor program might not work and it has to be modified or changed so that it suits the demands of the new situation. The goal of this study is to investigate, on the one hand, to what degree the previous mental model guides the user when answering a mobile phone, and on the other hand, how perceptual information effects the interpretation of the new situation. In other words, this study focuses on the interaction of "top-down" (interpreter based) and "bottom-up" (stimulus based) information in mobile phone answering situations.

2. RESEARCH QUESTIONS

Even though it is impossible to directly examine the existence and nature of mental models postulated in the user's head, we can try to explore them implicitly by observing the user's behaviour in different situations. Errors and general patterns of behaviour that occur among users during a certain task can tell us something about the users' internal representations that guide their actions in these kinds of situations. The goal of this study is to find out how the mental model generated by the use of a certain mobile phone keypad layout affects behaviour in situation where the user has to answer a call with an unknown mobile phone. How additional perceptual information influences behaviour is also being studied.

2.1 Hypothesis

1. User's previous mental model concerning the answering to a mobile phone guides the user in the situation where only limited amount of perceptual cues are present. Errors occur if the layout of the answering keys is not consistent with the user's mental model.
2. When more perceptual information is provided, errors are less likely to occur. Still the recently active mental model guides the user's action strongly in situations where the user encounters a new phone.

3. METHOD

3.1 Design of the Study

Answering a mobile phone is usually performed in the middle of some other activities. In this experiment a secondary task, playing a PlayStation game, was used in order to create a situation at least partly analogical to real life situations. The goal was to direct the user's attention to another task in which the same modalities (visual, motor) were used as in the actual answering task. It was predicted that with the user's attention focused elsewhere, automatic answering performance and action slips would appear with higher probability than in a task consisting solely of answering the phone. Since this kind of automatic responses can be thought as reflecting rather unconscious, well-learned processes including procedural knowledge, we assume that they will reflect activated mental models in the user's memory.

3.2 Participants

Twenty students (8 male, 12 female) participated in the study. Their age ranged from 19 to 31 years, with an average of 23.6 years. All the participants were right-handed except one who was ambidextrous. Everyone answered the phone with their right hand. All except two of the participants had a mobile phone of their own and their average mobile phone experience was 15.5 months. The data concerning the model of their current and previous mobile phones was also gathered. Ten out of the 18 participants who had a mobile phone had a DFS phone (SEND key located on the left and END key on the right). One participant had a phone where keys were located in the reverse order (SEND on the right and END on the left) and the rest (N=7) had a phone with only a single key for answering operations located in the middle (the Navi™). None of the participants was familiar with the mobile phone model used in the study.

In beforehand, the participants were told that the purpose of the study was to find out information about the usability of certain technical devices. Each one of the participants received a small fee for his or her participation.

3.3 Apparatus

Three kinds of phones were used in the study (figure 1). Each one of the phones was a Benefon Twin GSM 900 and the phones differed from each other regarding to the coding and the location of their answering keys. One of the phones had no symbols on any keys (referred as BLANK). This phone functioned in the reverse order as the DFS: the SEND operation was to be made using key 1 on the right and the END operation using key 5 on the left (figure 2). The two other phones had white SEND and END symbols representing handsets on their answering keys and a regular number keypad. The difference between these two otherwise identical phones was the location of the answering keys. One phone had the SEND symbol on the left and the END symbol on the right (DFS). The keys of the other phone were placed in the reverse order (non-DFS). Pressing some key other than the SEND or END key did not have any effect except that key number two caused the phone to become silent. A Sony PlayStation with an analog controller (dual shock) was used in the study. The game played by the participants was Driver (1998) and it was viewed on a 21" Sony Trinitron colour TV.

Figure 1: *Phones used in the study from left to right: the BLANK phone, the symbol coded DFS phone and the non-DFS phone.*

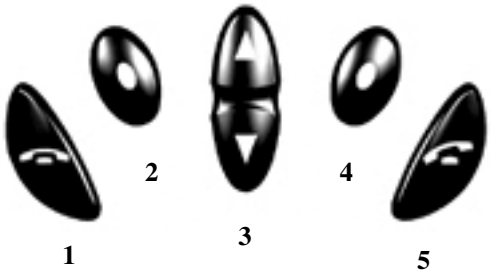

Figure 2: *A closer look of the critical function keys of the test phone keypad (symbol coding) and the number codes for each key.*

3.4 Task

The participant's task was to play a PlayStation game called Driver and answer a mobile phone while driving. The participant was to receive driving instructions through a mobile phone (table 1). The participant received one out of six simple driving instruction per one call and s/he was to obey these instructions and wait for new ones while continuing the game.

1. Speedup forward.
2. Drive slowly forward.
3. Turn right.
4. Turn left.
5. Drive backwards.
6. Turn around.

Table 1: *Driving instruction given to the participant through the phone.*

The experiment consisted of three situations and different phones were used in each situation (BLANK, DFS or non-DFS). All the participants answered first the BLANK phone. In the two following situations half of the subjects (group 1) answered first the DFS phone and then the non-DFS phone. The second half of the participants (group 2) had the phones given to them in the reverse order (non-DFS, DFS). Ten phone calls were answered with each phone and the time between the calls varied randomly between seven and 22 seconds. The order in which the driving instructions were given was also random. Each participant also took part in a short interview concerning the experiment after the task.

3.5 Procedure

The procedure was similar in all three situations. The participant was seated in front of the TV and the PlayStation game console and s/he was given a short guidance concerning the game and the use of the game controller. The playing of the game consisted of driving around the streets of American cities. The participants were told that their task was to drive the car, answer incoming calls while driving, listen to the instructions and follow them. They were told that the answering should be done as fast as possible and that the calls were made by the second experimenter located in the adjacent room. The participants were instructed that after receiving the driving instruction they should hand the phone to the third experimenter who then terminated the call and placed the phone back on the table. They were also instructed that if they would accidentally press a wrong phone key while answering or otherwise failed to get the driving instruction they should hand the phone to the experimenter and wait for the next call.

When the actual experiment began, a mobile phone (BLANK) was placed on the table right to the participant. Within a few seconds the phone began to ring and the participant answered the phone. After receiving the driving instruction the participant handed the phone to the experimenter. After ten calls the phone was replaced by another test phone (either DFS or non-DFS symbol coded phone). Ten additional calls were made and the phone was switched once again (either non-DFS or DFS symbol coded phone) for the last ten calls to be made. Every time the phones were switched the participant was informed that s/he is entering to a new situation. The participant was not informed that the phones were different. The keypresses and errors were recorded on a separate sheet of paper by the first experimenter who observed the participant and also by the second experimenter who made the calls from another room. After the last call was over, the participant was interviewed orally. Interview consisted of five semi-structured questions that are presented in table 2. The interview was recorded and analysed afterwards.

1. Did you notice any differences between the phones you answered?
2. Was it more difficult to answer the phone in some situations than others ?
3. How did you choose the SEND key in the first situation (BLANK phone)?
4. Which test phone would you choose, if you could have one?
5. Do you have any improvement suggestions concerning the layout (symbols, size, colour etc.) of the answering keys?

Table 2: *Post-test interview questions.*

4. RESULTS

4.1 The BLANK Phone

In the first situation where the BLANK phone was used, no errors were made after the fourth call. The participants made usually more than one keypress per call, especially during the first four calls. The

participants were divided to two main user groups according to their mobile phone model. The number of keypresses required for errorless performance was 3.5 on the average for the participants who owned a DFS mobile phone (N=10). The DFS user's first four keypresses are presented in more detail in figure 3. Each bar represents a keypress and different colours represent different keys (see figure 2 for the number codes of the keys). Figure 3 shows that 70% of the DFS users first pressed key 1. Notice that this key causes the call to be terminated since the answering functions of the BLANK phone are the opposite of DFS. Key 5 is the correct SEND key.

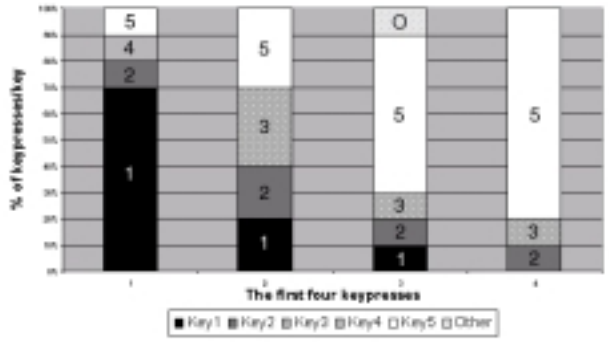

Figure 3: *The first four keypresses of the DFS users (N=10).*

The other main user group, single key users, consisted of participants who owned a mobile phone where the SEND and END operations were made using a single key located in the middle of the upper part of the phone (N=7). Their number of keypresses required for errorless performance was 4.4 on the average. Figure 4 presents the results concerning the first four keypresses for the single key users. As can be seen, 70% of the single key users first pressed key 3 (middle key).

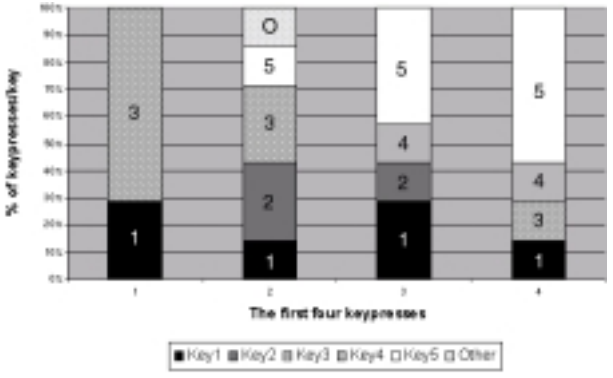

Figure 4: *The first four keypresses of the single key users (N=7).*

The first keypress is the most interesting one when considering the participants' previous mental models. As can be seen from figures 3 and 4, the two main user groups' pressed different keys when trying to answer the first call. The keypresses of the only participant who had a non-DFS mobile phone and the two participants with no previous mobile phone experience are not discussed here because of the low number of participants in these groups.

4.2 The DFS and Non-DFS Phones

In the second and third situations following the BLANK phone the participants answered calls with symbol coded phones. The participants were divided in two groups where half of the participants first answered the DFS phone and after that the non-DFS phone (group 1, N=10). The other half received the phones in the reverse order (group 2, N=10). Group 1 and 2 contained participants from different user groups. The results of the second and third situation (symbol coded phones) are not divided to user groups as in the BLANK phone results because there were no obvious differences between the groups. Errors made by group 1 are presented in figures 5 (DFS phone) and 6 (non-DFS phone). The errors were divided in two classes: errors that terminated the call and other errors (incorrect keypress that did not terminate the call). With the DFS phone (figure 5) seven calls were terminated during the first call. The number of errors declined gradually after the first call, still after the seventh call some errors were made. Only during two calls no errors were made. The total amount of errors was 21 in 100 calls.

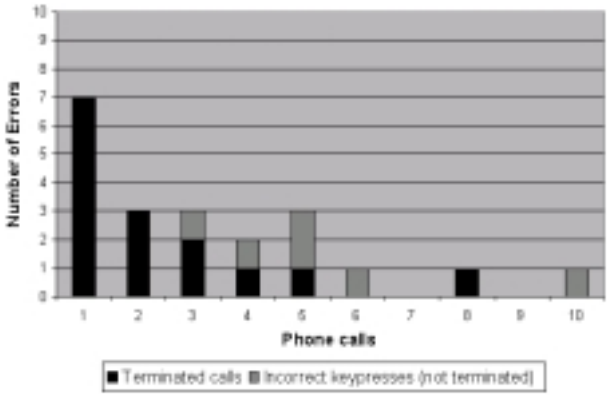

Figure 5: *The errors made by group 1(N=10) in the second situation (DFS phone).*

Group 1 made four errors during the first call and one error during the second call with the non-DFS phone (figure 6). After that only one error was made so a total of six errors were made during 100 calls.

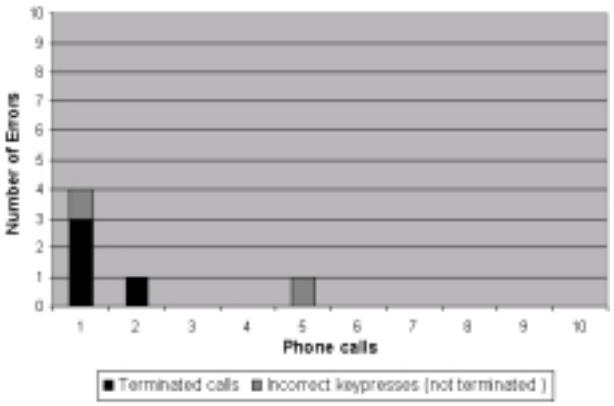

Figure 6: *The errors made by group 1(N=10) in the third situation (non-DFS phone).*

The errors made by participants in group 2 are presented in figures 7 (non-DFS phone) and 8 (DFS phone). With the non-DFS phone (figure 7) two errors were made during the first call and after that only one error was made. Total amount of errors was three in 100 calls.

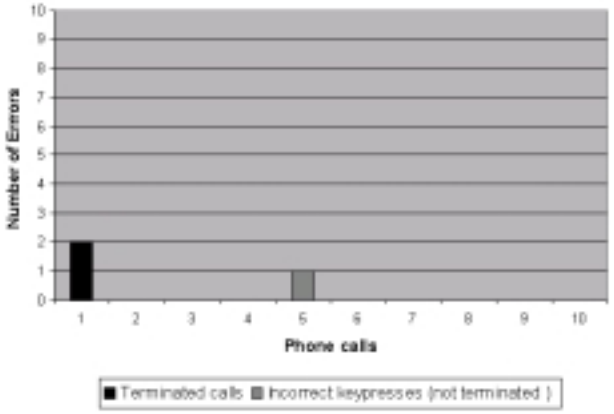

Figure 7: *The errors made by group 2 (N=10) in the second situation (non-DFS phone).*

Group 2 made eight errors during the first call with the DFS phone (figure 8). The number of errors declined after that, but four participants terminated every call. All the errors made with this phone terminated the call. A total of 47 errors in 100 calls were made.

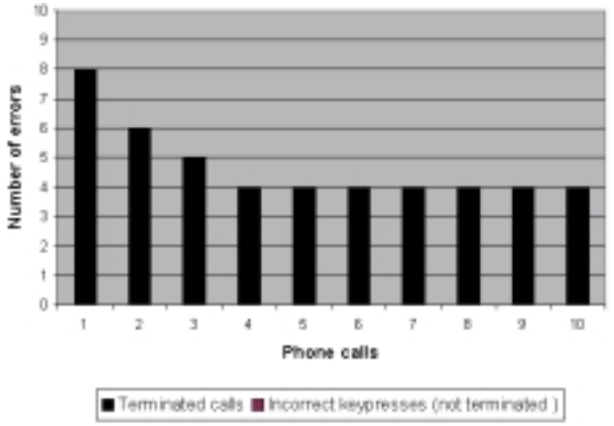

Figure 8: *The errors made by group 2 (N=10) in the third situation (DFS phone).*

4.3 Post-test Interview Results

Only the main propositions of the post-test interview results are presented here. Fifteen participants (N=20) noticed that the answering key layouts varied between the test phones. Five participants did not notice any difference between the phones. When asked if it was more difficult to answer in some situations than others, six participants reported that it was easier to answer when the SEND key was located on the left (symbol coded DFS phone). When answering the first call (BLANK phone), nine participants reported that when choosing which key to press first, they chose the first key on the left (key 1). Seven participants reported that they first pressed the biggest key in the middle (key 3) and after that the leftmost key (key 1). The reports of the participants did not necessarily correspond to their actual action in the answering situation.

Fourteen participants reported that if they could choose one of the phones used in the study, they would choose the symbol coded DFS phone. When asked for improvement suggestions concerning the answering keys different kinds of suggestions were given concerning colour coding, clearer symbols and bigger size of the keys. Two participants also suggested that the SEND key would be located on the left. Three

participants suggested that both answering functions would be placed on the middle key (key 3).

5. DISCUSSION

5.1 The BLANK Phone

According to the first hypothesis, errors occur in the participants' performance if the layout of the answering keys is not consistent with the participant's mental model. The data concerning the errors made by the 17 participants in two main user groups (DFS and single key users) provide support to this hypothesis. The most interesting result regarding the postulated mental models is the first keypress made by the participants. It is shown in figure 3 that participants who had a DFS mobile phone were generally prone to press first the key 1, which corresponds best to the SEND key of their own phone. Also in the single key user group, most of the participants first pressed key 3 in the middle of the phone (figure 4), which most resembles the SEND key of their own phone. It is also interesting that none of the participants in the DFS user group first pressed the middle key (key 3). The participants in this group that pressed any other key than key 1, pressed either keys 2, 4 or 5 on the right or left sides of the phone. On the other hand, none of the single key users first pressed key 2, 4 or 5. The two single key users who did not press key 3 first pressed the key 1. Both of these participants' previous phones were DFS phones.

Figures 3 and 4 also present the three following key presses after the first keypress. In the DFS user group, three out of the four participants whose second keypress was key 1 or 2 (the keys on the left side of the phone) had previously had a DFS phone. The four other participants, who made errors, pressed key 3 in the middle and none of these participants had had a mobile phone other than their present phone. This data may indicate that the mental models of these participants were of different strength depending on their previous experiences with mobile phones. The participants with the "weaker" model changed their behaviour more easily when their model did not work. Perhaps their action was then guided more by perceptual factors than internal representations.

The Navi™ layout is newer compared to the DFS design and thus most of the single key group participants' previous mobile phones had been DFS phones, that is if they had had any. Still there was no obvious pattern of behaviour noticed within the single key user group regarding the second keypress, although more keypresses were made with the keys on the left and the key in the middle than with other keys. It is therefore questionable to presume that the results of this experiment reflected "stronger" or "weaker" mental models depending on the participants previous mobile phone.

The results might still reflect, in addition to some mobile phone specific mental models, other more general patterns of behaviour. It was more common among the participants to press keys in order from left (keys 1 and 2) to right (keys 4 and 5), than from right to left. If the participant first pressed the middle key (3), the most common pressing order was: middle, left and right. When people are asked to place letters or numbers on a blank keypad, they tend to place them in the same order as they read text: from left to right and from top to bottom (Helander 1998).

The number of keypresses required for errorless performance indicate that the DFS users were slightly faster than the single key users in learning the correct key. One explanation for this is that the DFS users have a mental model that corresponds better with the test phone than the one of the single key users. In the DFS users' model, two keys exist on both sides of the phone, whereas in the single key model, only one key for answering functions is present. Though faster learning was observed within the DFS user group, it should be noted that during the first keypress, seven out of 10 of these participants accidentally terminated the call. It seems that the DFS users' number of terminated calls declined more rapidly because, after terminating a call once, they avoided pressing key number 1 again. It seems that the users were able to learn the correct key quite fast. Still, it needs to be taken into account that the test situation was not completely in accordance with real life situations. We don't usually receive ten calls in such a rapid succession. Each time a call is received there is the risk that strong mental models guide our behaviour automatically and errors might occur when these models conflict with the reality.

5.2 The DFS and Non-DFS Phones

The second hypothesis predicted that when more perceptual information is provided, in this case the white SEND and END symbols, errors are less likely to occur. It was also predicted that the mental model generated in the previous situation is still active and errors do occur if the new situation is not consistent with the model. The results presented in figures 5 and 6 support this hypothesis. The mental model of the previous situation seems to guide action, despite additional perceptual

information. The effect was especially strong among a few participants in group 2, who used a non-DFS phone in the first two situations and a DFS phone in the last situation. Despite the SEND and END symbols on the keys, four participants in this group terminated each of the ten calls in the last situation. Three of these participants were DFS users and one was a single key user. In the post-test interview these participants also reported that they did not notice any differences between the three phones used in the experiment. This is quite striking since it was predicted that white SEND and END symbols on the keys would provide at least some additional information. The concept of fixation used in cognitive psychology means that, sometimes when people try to solve problems, they tend to fixate on one kind of method so strongly that it hinders their performance in the task when another kind of method is required for solving the problem (Eysenck & Keane 1990). Sometimes a memory for a particular sequence of operations can dramatically blind subjects to other possible solutions (Anderson 1995). The pattern of behaviour observed among the four participants can perhaps be interpreted as a fixation to a particular functional model about mobile phone answering keys.

5.3 Designing the Answering Keys

It seems that a new kind of layout of the answering keys can be learned quite fast in a situation where several calls are answered rapidly in succession, the situation might be different in a real life context. As noted earlier, action slips can occur during over-learned activities and this is especially true in the case of motor performance. A strong motor program, for example pressing the key on the left side of the phone when answering a mobile phone, can possibly overtake weaker programmes. It has been suggested that location planning in motor performance might be isolated from cognitive processes (Gazzaniga et al. 1998). This provides further support for the possibility that motor programs can proceed independently of conscious control.

The results indicate that top-down representations such as mental models, guide action quite strongly when operating with a keypad. It might be that perceptual information is not even paid attention to as long as the model being active seems to work. If action according to the active mental model leads to results that conflict with goals, perceptual, bottom-up, information is used for finding new solutions. On the other hand, if perceptual information provided by the situation is not sufficient, the users' action might become considerably more difficult. In the worst case, the user keeps on fixating on the old solution.

Perceptual factors involving the selection of the key to be pressed should be evaluated carefully since it would be very undesirable that attention would be drawn to an incorrect key. Expectancy can improve performance since the detection of a target in visual display can be speeded up if a cue indicating the location of the target is presented before the actual target (Posner et al. 1980). Still, at least in visual search tasks, the voluntary, top-down control of attention is slower than automatic, bottom-up control of attention (Kröse & Julesz 1990). The critical factor effecting the search of a target is assumed to be the number of target features which are required to classify each stimulus in the display as a target or distractor (Fisher & Young 1987). If the target can be classified on the basis of a single feature the search process is parallel but when feature conjunctions are searched for, focused attention is required (Treisman & Gelade 1980). If the SEND key could be distinguished from the other keys with the help of one feature, for example colour or size, it would be effortless to locate it. The most common improvement suggestion in the post-test interview concerning the answering keys was colour coding. This suggestion probably reflects the fact that generally SEND operation is coded with green and END operation with red in the mobile phone models where two separate keys exist for these operations. The effectiveness of colour coded symbology in the answering keys is studied using the same paradigm in our other study (Hyyppä et al. 2000) and will not be discussed here in more detail. The point made here is that the information about the automatic processes of the visual system could be applied to the design of the keypad keys since these mechanisms seem to be general human information processing capabilities. Support for this notion is provided by evidence indicating that performance in intelligence tests does not correlate with the ability to identify single targets or targets defined by a single non-confusable feature while some intelligence effects have been observed in more attention demanding situations (Laux & Lane 1988).

The post-test interview results indicate that the participants preferred the DFS keypad layout over the non-DFS layout. When asked to pick one of the test phones, most of the participants chose the symbol coded phone where the SEND key was located on the left. Users might have some prejudices towards new kinds of mobile phone user interface styles (Ruuska & Väänänen-Vainio-Mattila 1999). It would be interesting to know which phone would have been chosen, if also a single

key phone and other answering key layouts would have been among the choices. The participants also reported that the DFS phone was the most easiest to answer. In addition to habits this might reflect the most easiest way to perform the keypress. Perhaps the most ideal way to answer, at least for the users who answer the phone with their right hand, would be to press keys on the left side of the phone. The participants in this experiment used mostly their thumb when answering the phone. Fitts (1954) found that subjects were more accurate in terminating flexor than extensor movements in a reciprocal tapping task.

6. CONCLUSIONS

Because errors do occur in answering situations that differ or contradict with the user's mental model, one way to avoid errors would be to design mobile phone keypads where the possibility of making errors is eliminated. This has already been made in models where there is a single key for both SEND and END functions. When the phone rings, only the SEND operation can be performed with the key and only after it has been performed, END operation is available. This kind of model forces the user to answer and terminate a call only in a correct manner since there doesn't even exist a possibility that a call would be accidentally terminated. Still it should be noted that a user might want occasionally to terminate a call instead of answering it, maybe just to quiet down the phone. This function should also be easily achieved. Another solution would be to support the top-down representations already existing in the users' memory with some form of standardisation. If nothing else, keypad layout ambiguity could be reduced with appropriate perceptual information.

7. ACKNOWLEDGMENTS

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