

Usability Heuristics for Touchscreen-based Mobile Devices

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Abstract—Usability is a main quality attribute for any interactive product. Usability in touchscreen-based mobile devices is something essential and should be considered when launching a new product; it could be a distinguishing feature in a rushing market, as it is the one of the mobile devices nowadays. Traditional methods for usability measuring do not really fit the nature of these devices. There is a need for new usability evaluation methods or at least for the use of traditional evaluations in novel ways. A set of specific usability heuristics for touchscreen-based mobile devices is proposed and (preliminary) validated.

Keywords—touchscreen-based mobile devices; usability evaluation; usability heuristics.

I. INTRODUCTION

A smartphone is a mobile device which offers functionalities beyond just a phone call. There are different kinds of smartphones, where touchscreen-based devices stand out among others, being the most popular nowadays.

The ISO/IEC 9241 standard defines the usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction, in a specified context of use [1]. Usability evaluation of a product is one of the most important stages in the user centered design approach. It allows obtaining the usability characteristics of a product, in this case touchscreen-based mobile devices, and the extent to which the usability attributes, usability paradigms and usability principles are being accomplished.

Usability evaluation methods are commonly divided into inspection and testing methods. Inspection methods find usability problems based on the expertise of usability professionals. Testing methods find usability problems through the observation of the users while they use (and comment on) a system interface [2].

Heuristic evaluation is a widely used inspection method [3] [4]. They are easy to perform, cheap and able to find many usability problems (both major and minor problems). However,

it may miss domain specific problems. That is why the use of appropriate heuristics is highly significant.

Usability evaluation for applications based on emerging information technology brings new challenges. Is it the classical concept of usability still valid? Which are the dimensions of the (new) usability? How can it be measured? How should we develop for (better) usability? There is a need for new evaluation methods or at least for the use of traditional evaluations in novel ways [5].

Traditional usability evaluation methods do not consider the particularities of the touchscreen-based mobile devices and the physical user interface. This leads to a need of new techniques for an accurate usability evaluation for touchscreen-based mobile devices.

The present work focuses on usability evaluation of touchscreen-based mobile devices, by heuristic evaluations. A set of 11 specific usability heuristics is proposed and (preliminary) validated. Section II highlights the main characteristics of touchscreen-based mobile devices, such as taxonomy, physical user interface components and challenges of usability evaluation in these devices. Section III presents the methodology that has been used in heuristics' development and a description of the iterations that have been done up to date. The touchscreen-based mobile devices usability heuristics proposal is presented in Section IV. Section V shows the proposal's preliminary validation. Section VI presents the preliminary conclusions and future works.

II. CHALLENGES OF USABILITY EVALUATION IN TOUCHSCREEN-BASED MOBILE DEVICES

A mobile device can be defined as a small gadget with some basic processing capabilities, with permanent or intermittent wireless network connection and limited memory capacity. A mobile device has usually been designed for a specific function, but it can also perform additional general tasks.

Mobile devices are portable communication and information systems, characterized by three key aspects which

affect their user interface design: (1) they are mainly used in the user's hands, (2) they are used wirelessly and (3) they support the addition of new applications and internet connection [6]. Other important aspects to consider when evaluating the usability of mobile devices are: (1) they have small screen size even if they have to display large amounts of information, (2) the buttons of the device generally have more than one function, and (3) the devices have limited processing and memory capabilities [7].

Schiefer and Decker (2008) classify the mobile devices by size and weight, data input/output modes, performance, kind of usage, communication capabilities, type of operating system and expandability [8]. The mobile devices may be classified as follows: (1) mobile standard PC, (2) mobile internet devices, (3) handhelds or PDAs, (4) smartphones, (5) feature phones, (6) simple phones and (7) special terminals.

Touchscreen-based mobile devices belong to categories (1), (2), (3) and (4). This research focuses mainly on touch phones [9]. However, the results can be adapted to other touchscreen-based mobile devices.

The unique features and characteristics of touchscreen-based mobile devices that make the usability evaluation a challenging process may be defined as follows [10]:

- *Mobile context of use:* All aspects related to the interaction between the user, the system and the environment occur concurrently. Auditive distraction (e.g.: noise) or visual distraction (e.g.: excess or lack of lighting), can disturb the user. A proper evaluation method should consider most of the context of use characteristics.
- *Small screen size:* To make information fit in a small display can be not aesthetically pleasing, or even worst, completely illegible. Different tests should be performed, considering distinct screen sizes.
- *Screen resolution:* Low screen resolution can degrade the perceived quality of the multimedia data displayed in the device screen. Different screen resolutions may lead to significantly different usability issues.
- *Limited processing, memory and energy capabilities:* Some applications require large amounts of memory and/or processing power for graphical support and data processing, which can exceed the device capabilities. The system performance may vary according to available memory, energy and processing power. These issues should be considered in usability evaluations.
- *Data entry methods:* Small buttons and labels can reduce the efficiency and effectivity in data entry, reducing the data entry speed and raising the error rate. Evaluations that minimize the impact of data entry methods should be performed (as long as they are not the research focus).

III. DEFINING TOUCHSCREEN-BASED MOBILE DEVICES USABILITY HEURISTICS

Usability inspections, including heuristic evaluation, are well documented and many publications describe the usage of these methods. Literature usually focuses on describing the advantages and disadvantages of usability evaluation methods but not on how to develop new methods and/or usability heuristics.

In order to develop specific usability heuristics for touchscreen-based mobile devices, 6 steps methodology was followed [11]:

- *STEP 1:* An exploratory stage, to collect bibliography related to touchscreen-based mobile devices, their characteristics, general and/or related (if there are some) usability heuristics.
- *STEP 2:* A descriptive stage, to highlight the most important characteristics of the previously collected information, in order to formalize the main concepts associated with the research.
- *STEP 3:* A correlational stage, to identify the characteristics that usability heuristics for touchscreen-based mobile devices should have, based on traditional heuristics and case studies analysis.
- *STEP 4:* An explicative stage, to formally specify the set of touchscreen-based mobile devices heuristics, using a standard template.
- *STEP 5:* A validation (experimental) stage, to check touchscreen-based mobile devices heuristics against traditional (Nielsen's) heuristics by experiments, through heuristic evaluations performed on selected case studies, complemented by user tests.
- *STEP 6:* A refinement stage, based on the feedback from the validation stage.

STEP 1 explored specific touchscreen-based mobile devices characteristics, taxonomy and usability-related aspects.

STEP 2 re-examined the meaning of usability and its characteristics, in the context of touchscreen-based mobile devices.

As no specific and/or related touchscreen-based mobile devices usability heuristics were found, Nielsen's 10 well known and extensively used heuristics were used at *STEP 3* [4].

The standard template used at *STEP 4* was the following one:

- *ID, Name and Definition:* Heuristic's identifier, name and definition.
- *Explanation:* Heuristic's detailed explanation, including references to usability principles, typical usability problems, and related usability heuristics proposed by other authors.
- *Examples:* Examples of heuristic's violation and compliance.

- *Benefits:* Expected usability benefits, when the heuristic is accomplished.
- *Problems:* Anticipated problems of heuristic misunderstanding, when performing heuristic evaluations.

A. First Iteration

In a first iteration, *STEPS 1, 2* and *3* of the above described methodology were followed. At *STEP 1*, a critical review of related literature was performed.

At *STEP 2*, main concepts regarding touchscreen-based mobile devices were formalized, such as taxonomy, physical user interface characteristics and ergonomics, among others.

At *STEP 3*, a guided inspection was carried out using Nielsen's heuristics, in order to identify usability issues and positive characteristics of the analyzed devices. A first set of usability heuristics for touchscreen-based mobile devices was developed, without using a formal specification template. The initial proposal consisted of 11 usability heuristics:

- 10 heuristics were inspired by Nielsen's heuristics and complimented by the formalized concepts regarding touchscreen-based mobile devices (defined at *STEP 2*).
- Heuristic no. 11 was obtained through the analysis of mobile concepts, positive aspects and usability issues.

The usability heuristics set was complimented by a basic checklist proposal.

B. Second Iteration

The set of usability heuristics obtained after performing the first iteration was refined through the execution of a second iteration. *STEPS 5, 6*, and *4* were carried out, in this order.

At *STEP 5*, as an adapted validation stage, the usability heuristics set was critically reviewed by a usability expert.

At *STEP 6*, some of the usability heuristics were redefined according to the feedback received at *STEP 5*.

STEP 4 led to a formally specified set of usability heuristics for touchscreen-based mobile devices, using the standard template defined above.

C. Third Iteration

After the second iteration, a new validation and refinement process was carried out. *STEPS 5, 6* were followed, in this order.

At *STEP 5*, a guided inspection was performed. The evaluation was carried out on a *Blackberry Storm* device, by 4 evaluators, grouped by the level of expertise. The two most experienced evaluators used Nielsen's heuristics; the two less experienced evaluators used the touchscreen-based mobile devices heuristics proposal.

Data obtained at *STEP 5* was analyzed at *STEP 6*, in order to build a list of observations and possible improvements to the proposal. A mapping between the touchscreen-based mobile

devices heuristics proposal and Nielsen's heuristics was built, in order to highlight similarities and differences.

IV. A SET OF USABILITY HEURISTICS FOR TOUCHSCREEN-BASED MOBILE DEVICES

The usability heuristics proposal for touchscreen-based mobile devices is presented below.

(TMD1) *Visibility of system status:* The device should keep the user informed about all the processes and state changes through the use of a specific kind of feedback, in a reasonable time.

(TMD2) *Match between system and the real world:* The device should speak the users' language with words, phrases and concepts familiar to the user, instead of system-oriented concepts and/or technicalities. The device should follow the real world conventions and physical laws, displaying the information in a logical and natural order.

(TMD3) *User control and freedom:* The device should allow the user to undo and redo his actions, and it should provide "emergency exits" to leave the unwanted state. These options should be clearly pointed, preferably through a physical button or similar; the user shouldn't be forced to pass through an extended dialogue.

(TMD4) *Consistency and standards:* The device should follow the established conventions, on condition that the user should be able to do things in a familiar, standard and consistent way.

(TMD5) *Error prevention:* The device should have a careful graphic user interface and physical user interface design, in order to prevent errors. The non-available functionalities should be hidden or disabled and the user should be able to get additional information about all available functionality. Users should be warned when errors are likely to occur.

(TMD6) *Minimize the user's memory load:* The device should minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

(TMD7) *Customization and shortcuts:* The device should provide basic configuration options and should give expert users access to advanced configuration options. The device should provide shortcuts to the most frequent tasks and should allow their customization and/or definition.

(TMD8) *Aesthetic and minimalist design:* The device should avoid displaying irrelevant or rarely needed information. Each extra information unit reduces the system performance.

(TMD9) *Help users recognize, diagnose, and recover from errors:* Error messages in the device should be expressed in plain language (no codes), precisely indicating the problem, and constructively suggesting a solution.

(TMD10) *Help and documentation:* The device should provide easy-to-find documentation and help, centered on the

user's current task. A list of concrete (and not too large) steps to carry out should be provided.

(TMD11) *Physical interaction and ergonomics*: The device should provide physical buttons or similar user interface elements for main functionalities. Elements should be placed in a recognizable position. The device dimensions, shape, and user interface elements in general, should fit the natural posture of the hand.

The full specification of heuristic TMD1 is shown below.

- *ID: TMD1*
- *Name: Visibility of system status*
- *Description*: The device should keep the user informed about all the processes and state changes through the use of a specific kind of feedback, in a reasonable time.
- *Explanation*: Through the interaction with the device, the user can perform many tasks. These actions can lead to changes in the system status, which should be informed to the user, one way or another. Changes that occur without the intervention of the user, but require the user interaction (e.g.: incoming phone calls, video calls, email messages, timer alert, low battery alert) should also be informed.

The specific feedback methods may use:

- *Sound* (e.g.: ringtone, message tone, email tone, low battery tone, camera shutter sound). These sounds should be distinctive (by default) and customizable.
- *Lights* (e.g.: notification light, under button light, camera flash).
- *Graphic information* (e.g.: static icon, animated icon, text notification, pop-up alert message, pop-up error message).
- *Vibration*.
- *Examples*:

Fig. 1 shows some examples of specific feedback on a Nokia X6 touch phone. Graphic information feedback can be seen on the left side of the image: (a) pop-up alert message, indicating the existence of a new instant messaging message; (b) static icon, indicating the same information. An example of notification light is displayed on the right side of the image.

- *Benefits*:
 - Improved experience of use*: Specific feedback helps user to properly react to events, improving her/his experience.
 - Better system status control*: Specific feedback helps user to be aware if there are changes in the system status.
- *Problems*: It could be difficult to distinguish between the lack of feedback and the delayed feedback, due to performance issues. When using the device, the available memory, battery charge level and running

applications affect the device performance, which can delay or even disable some types of feedback.



Figure 1. Examples of specific feedback on Nokia X6 device.

Table 1 presents the mapping between the 11 usability heuristics for touchscreen-based mobile devices and Nielsen's 10 heuristics.

TABLE I. MAPPING BETWEEN TOUCHSCREEN-BASED MOBILE DEVICES HEURISTICS AND NIELSEN'S HEURISTICS

Touchscreen-based mobile devices heuristics		Nielsen's heuristics	
<i>Id</i>	<i>Name</i>	<i>Id</i>	<i>Name</i>
TMD1	Visibility of system status	H1	Visibility of system status
TMD2	Match between system and the real world	H2	Match between system and the real world
TMD3	User control and freedom	H3	User control and freedom
TMD4	Consistency and standards	H4	Consistency and standards
TMD5	Error prevention	H5	Error prevention
TMD6	Minimize the user's memory load	H6	Minimize the user's memory load
TMD7	Customization and shortcuts	H7	Flexibility and efficiency of use
TMD8	Aesthetic and minimalist design	H8	Aesthetic and minimalist design
TMD9	Help users recognize, diagnose, and recover from errors	H9	Help users recognize, diagnose, and recover from errors
TMD10	Help and documentation	H10	Help and documentation
TMD11	Physical interaction and ergonomics		

Touchscreen-based mobile devices usability heuristics TMD1 to TMD10 particularize Nielsen's heuristics H1 to H10, based on the touchscreen-based mobile devices characteristics. Although heuristics names are quite similar, their definitions are substantially different. For instance, the touchscreen-based mobile devices heuristic (TMD5) and the related Nielsen's heuristic (H5) have the same name ("Error prevention"), but the heuristics' meanings are radically different, as table 2 shows.

TABLE II. COMPARISON BETWEEN HEURISTICS TMD5 AND H5, “ERROR PREVENTION”.

TMD5 – Error prevention	H1 – Error prevention
The device should have a careful graphic user interface and physical user interface design, in order to prevent errors. The non-available functionalities should be hidden or disabled and the user should be able to get additional information about all available functionality. Users should be warned when errors are likely to occur.	Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

V. USABILITY HEURISTICS FOR TOUCHSCREEN-BASED MOBILE DEVICES IN PRACTICE: EARLY VALIDATION

As described in Section III.C, a guided inspection was performed as an early validation experiment. The set of 11 touchscreen-based mobile devices heuristics were evaluated against Nielsen’s heuristics, in one case study. The evaluation was performed on a *Blackberry Storm 2* (9550) device/*Blackberry Operating System* (v. 5.0.0.1015). The following applications were analyzed: (1) menu, (2) name and address book, (3) calendar, (4) messaging and (5) camera.

The inspection was carried out by two separate groups of evaluators, in equal conditions. Each group was composed by two evaluators, of similar level of expertise. One group used only the set of touchscreen-based mobile devices heuristics, while the other group used only Nielsen’s heuristics. Usability problems found by the two groups were then compared.

A total of 53 usability problems were identified by the four evaluators. More usability problems were captured using the touchscreen-based mobile devices heuristics, than using Nielsen’s heuristics:

- (P1) 18 usability problems (34%) were identified by both groups of evaluators,
- (P2) 21 usability problems (40%) were identified only by the group that used the touchscreen-based mobile devices heuristics,
- (P3) 14 usability problems (26%) were identified only by the group that used Nielsen’s heuristics.

Table III shows the number of usability problems identified by each group of evaluators, grouped by heuristics. It also shows the average severity of the usability problems (on a 0 to 4 severity scale).

Evaluators that used touchscreen-based mobile devices heuristics were able to identify more usability problems than the evaluators that used Nielsen’s heuristics, even if their level of expertise was slightly lower. Moreover, the usability problems identified by the first group of evaluators were qualified as more sever (an average severity of 3.19, while the second group scored an average severity of 2.33). In a rough evaluation, it seems that the set of 11 touchscreen-based mobile devices heuristics works better than Nielsen’s heuristics.

TABLE III. USABILITY PROBLEMS IDENTIFIED IN BLACKBERRY STORM2.

Group 1: Using touchscreen-based mobile devices heuristics			Group 2: Using Nielsen’s heuristics		
Id	Number of problems	Average Severity	Id	Number of problems	Average Severity
TMD1	3	3.17	H1	2	3.25
TMD2	9	2.83	H2	4	1.80
TMD3	2	2.75	H3	1	4.00
TMD4	2	3.50	H4	4	2.50
TMD5	2	3.50	H5	3	3.00
TMD6	1	2.50	H6	1	2.50
TMD7	5	2.80	H7	5	3.40
TMD8	2	4.00	H8	3	2.83
TMD9	1	4.00	H9	0	0
TMD10	1	3.00	H10	0	0
TMD11	2	3.00			
Total	30		Total	23	
Average Severity		3.19	Average Severity		2.33

The possible correlation between the two series presented in table III was examined. As TMD11 has no equivalent in the Nielsen’s heuristics set, the value associated to TMD11 was eliminated. The correlation coefficient is 0.647; therefore the relationship may be described as moderate.

The average number of usability problems per heuristic was 2.8, when applying touchscreen-based mobile devices heuristics, respectively 2.3, when applying Nielsen’s heuristics. In order to check if the difference is significant, the *T* test was applied. Variances are not significantly different, as the *F* test showed. Consequentially, the *T* test for equal variances was applied.

The *T* value was 1.73, and its associated probability was 0.3 (being the level of significance 0.05). Therefore the 0.5 difference between the average numbers of problems will not be considered as significant.

In other words, both evaluation tools (touchscreen-based mobile devices heuristics and Nielsen’s heuristics) identify usability problems in similar way. Nevertheless, the proposed set of 11 heuristics seems to be more appropriate, as it was able to identify (slightly) more usability problems than the Nielsen’s set of heuristics. This is just a preliminary and quite early conclusion, and more experiments have to be done.

Question arises with problems (P3). Why these problems were not identified when using the touchscreen-based mobile devices heuristics?

The 14 usability problems identified only by the group that used Nielsen’s heuristics were associated to heuristics *H7 – Flexibility and efficiency of use* (5 problems), *H4 – Consistency and standards* (4 problems), *H2 – Match between system and the real world* (4 problems), *H8 – Aesthetic and minimalist design* (3 problems), *H5 – Error prevention* (3 problems), *H1 – Visibility of system status* (2 problems), *H6 – Minimize the*

user's memory load (1 problem) and *H3 – User control and freedom* (1 problem). The set of the touchscreen-based mobile devices heuristics provides similar tools that can potentially identify all these problems (heuristics *TMD7*, *TMD4*, *TMD2*, *TMD8*, *TMD5*, *TMD1*, *TMD6* and *TMD3*, respectively). Therefore, it seems that evaluators that used the touchscreen-based mobile devices heuristics subjectively ignored problems (P3).

Table IV shows the average severity of the problems detected by group using each set of heuristics and the number and severity average of problems detected by both. The average severity of problems (P3) is the lowest one. Again, it seems that the touchscreen-based mobile devices heuristics worked better than Nielsen's heuristics.

TABLE IV. SEVERITY AVERAGE BY GROUP

Id	Problems identified	Number of problems	Average Severity
P1	By both groups of evaluators	18	3,14
P2	Using touchscreen-based mobile devices heuristics	21	3,00
P3	Using Nielsen's heuristics	14	2,68

VI. CONCLUSIONS

Usability in touchscreen-based mobile devices is something essential and should be considered when launching a new product, as it could be a distinguishing feature in a rushing market as the one of mobile devices nowadays. There is a need for new usability evaluation methods or at least usability evaluations should be particularized for touchscreen-based mobile devices.

A set of 11 specific usability heuristics was developed. Early validation proved its usefulness and potential. However, more experiments are necessary.

A right balance between specificity and generality should be followed. If heuristics are too specific, they will probably become hard to understand and hard to apply. General heuristics, complemented by specific usability checklists, will probably work better, most of the time.

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