Usability Heuristics for Mobile Applications
A Systematic Review

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Abstract: Usability is one of the factors that most affects a software quality. The increasing adoption of mobile devices brings new usability challenges, as well as a need for specific standards for this type of product. This paper aims to conduct a systematic review of the literature, complemented by a manual and snowballing search to obtain usability heuristics and heuristic evaluations for mobile applications. The result of the study was a set of thirteen usability heuristics, specific to smartphones, related to the ten Nielsen's heuristics. In addition, five possible ways of evaluating the usability of mobile applications are described. The specification of the heuristics found shows that they can be used both for the evaluation of already developed applications and for the prototyping of new applications, which helps developers achieve their goals regarding product quality. The main contributions of this work is the compilation of desktop usability heuristics in a new, more specific set of heuristics adapted to the mobile paradigm.

1 INTRODUCTION

The use of smartphones has been growing substantially in the market, together with the development and use of applications for these devices (Biel et al., 2010). With the progress in the use of mobile devices and their applications, new challenges appear and some peculiarities need to be studied and developed, such as usability (de Lima Salgado and Freire, 2014).

Usability is defined as the "capacity to be used", that is, the capacity that the device has to be used (Quiñones and Rusu, 2017). In practice, usability depends on what the user wants to do and their goals in the context in which the user is acting (Inostroza et al., 2016).

Usability can be developed in the product and evaluated by usability inspections or usability testing. The form that is constantly used to evaluate this requirement is the heuristic evaluation (Quiñones and Rusu, 2017).

Some researchers have been developing different usability heuristics for specific contexts. The purpose of this study is to verify the usability heuristics specific to mobile applications, and also to verify how to evaluate the usability of these applications.

In this paper we used a systematic literature review, suggested by Kitchenham (Kitchenham, 2004), to specify usability heuristics and heuristic evaluations focused on mobile applications. In addition, a manual search and snowballing practice, proposed by (Wohlin and Prikladniki, 2013), were implemented in this work. The goal was to list approaches that help develop applications with a usability that meets the needs of the end user.

This paper is organized in 7 Sections. The Section 2 shows the theoretical basis of this work. Section 3 presents the systematic review planning. Section 4 describes the conduct of the procedures for selecting a study. The results of the research are described in Section 5, answering the research questions. A case study is described in the Section 6. Finally, Section 7 concludes the results obtained by this work.

2 CONTEXTUALIZATION

This Section presents the concepts of usability, heuristic evaluation, and usability heuristics.

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2.1 Usability

The usability principals have been applied to variety of contexts, such as mobile device, computer devices, mobile apps, website on mobile device, website on computer device, interface, software, PDA, tablets, and so forth.

In the mobile context, the correlation between usability perception and information is greater when the correlations between usability perception and other factors potentially affecting it. In the mobile context, the correlation between usability perception and application design is greater when the correlations between usability perception and other factors potentially affecting it, except information.

In the computer website context, the correlation between usability perception and information is greater when the correlations between usability perception and other factors potentially affecting it. In the computer website context, the correlation between usability perception and application design is greater when the correlations between usability perception and other factors potentially affecting it, except information.

Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process. Usability is defined by 5 quality components (Nielsen, 2003):

- **Learnability.** How easy it is to learn the main system functionality and gain proficiency to complete the job. We usually assess this by measuring the time a user spends working with the system before that user can complete certain tasks in the time it would take an expert to complete the same tasks. This attribute is very important for novice users
- **Efficiency.** The number of tasks per unit of time that the user can perform using the system. We look for the maximum speed of user task performance. The higher system usability is, the faster the user can perform the task and complete the job.
- **Memorability.** When users return to the design after a period of not using it, how easily can they reestablish proficiency? It is critical for intermittent users to be able to use the system without having to climb the learning curve again. This attribute reflects how well the user remembers how the system works after a period of non-usage.
- **Errors.** This attribute contributes negatively to usability. It does not refer to system errors. On the contrary, it addresses the number of errors the user makes while performing a task. Good usability implies a low error rate. Errors reduce efficiency and user satisfaction, and they can be seen as a failure to communicate to the user the right way of doing things.
- **Satisfaction.** How pleasant is it to use the design?

One problem concerning usability is that these attributes sometimes conflict. For example, learnability and efficiency usually influence each other negatively. A system must be carefully designed if it requires both high learnability and high efficiency for example, using accelerators (a combination of keys to perform a frequent task) usually solves this conflict. The point is that a systems usability is not merely the sum of these attributes values; it is defined as reaching a certain level for each attribute (Ferré et al., 2001).

There are many other important quality attributes. A key one is utility, which refers to the design's functionality: Does it do what users need?

Usability and utility are equally important and together determine whether something is useful: It matters little that something is easy if it's not what you want. It's also no good if the system can hypothetically do what you want, but you can't make it happen because the user interface is too difficult. To study a design's utility, you can use the same user research methods that improve usability (Nielsen, 2003).

ISO / IEC 9126-1 (for Standardization and Commission, 2001), related to Software Engineering and product quality, describes usability as the ability of the software product to be understood, its operation learned, to be operated and to be attractive to the user. In addition, it describes six categories related to application quality that are relevant to being implemented during application development.

ISO / IEC 25000 (Suryn et al., 2003) has been developed to replace and extend ISO / IEC 9126 and ISO / IEC 14598. This ISO / IEC 25000 standard, also known as SQUARE (Software Product Quality Requirements and Evaluation), aims to organize, Concepts related to two main processes: software quality requirements specification and software quality assessment, supported by software quality measurement process.

It is observed that there is a lack of a clear and generally accepted definition that defines usability (Inostroza et al., 2016). The measure of usability is complex because usability is not a specific property of a person or product. One can not measure usability with a simple usability thermometer (Lewis, 2014). In view of the human and product factors that interfere with usability the difficulty in measuring it is remarkable. There are several papers that address this difficulty (Quiñones and Rusu, 2017).

2.2 Heuristic Evaluation

The heuristic evaluation, proposed by Nielsen and Molich (Nielsen, 1990), which aims to evaluate the product based on the principles, or heuristics of usability, imposes that between three or five specialists should inspect the application, pointing out what is correct or incorrect (Scholtz, 2004).

In order to evaluate the usability of touchscreen devices, specific aspects of these devices should be taken into account (Inostroza et al., 2012a). The design of smartphones are influenced, mainly, by three aspects (Inostroza et al., 2013):

1. Smartphones are mainly used in the hands of the user.
2. They are operated wirelessly.
3. Support the addition of new applications and Internet connection.

Elements such as light, sound and shape of iteration are not as well defined as in traditional applications. Another challenge is the context of using touchscreen mobile devices. In traditional applications the context of use is well defined in terms of light, sound and form of interaction (mouse and keyboard) (Suryn et al., 2003). However, the ability to use the device in various places, such as queues, hospitals, banks, among others, make smartphone portability an advantage.

There are several other methods to evaluate the usability of an application (Quiñones and Rusu, 2017). As one can observe the evaluation heuristics for mobile devices is not something simple. This study aims to obtain more specific and efficient heuristics for smartphones.

2.3 Usability Heuristics

Usability heuristics have this name, since they are usability guidelines (Quiñones and Rusu, 2017). In 1982, Malone (Malone and W., 1982) proposed the first heuristics to design a user-friendly application. It is revised, that these heuristics were limited, and only applicable for high-level issues in games.

Widely known heuristics are the ten Nielsen heuristics (Jackob Nielsen, 1995). These principles were written by the same authors who idealized the evaluation heuristics to inspect the product aiming the quality of this one. The application building guide contains ten principles (Jackob Nielsen, 1995):

1. **Visibility of System Status** – The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. **Correspondence between the System and the Real World** – The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
3. **User Control and Freedom** – Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
4. **Consistency and Standards** – Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5. **Prevention of Errors** – 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.
6. **Recognition and not Remembering** – 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.
7. **Flexibility and Efficiency of Use** – Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
8. **Aesthetic and Minimalist Design** – Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
9. **Help Users Recognize, Diagnose, and Recover Errors** – Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
10. **Help and Documentation** – Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Although these heuristics are widely used, it is necessary to use specific heuristics for each type of application (Quiñones and Rusu, 2017). With this in view, new heuristics have been created so that inspections and results can be more efficient (Inostroza et al., 2016).

3 SYSTEMATIC REVIEW PLANNING

The systematic review uses the approach suggested by Kitchenham (Kitchenham, 2004). A systematic literature review is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest. Individual studies contributing to a systematic review are called primary studies; a systematic review is a form a secondary study.

The systematic review involves three steps:

1. **Review Planning:** define the need for a systematic review; Raise research questions; And define a review protocol: data sources, strategy and search terms, study selection criteria, study quality, data extraction, and data synthesis.
2. **Realization of the Review:** select and analyze the studies; Answering research questions; And present the results, discussions and conclusions.
3. **Reporting the Review:** to write the review results and format the final document.

Inclusion and exclusion criteria were defined for the selection of papers, which should deal with heuristics, or guides, of usability only for mobile applications, therefore, papers that were specific to applications or desktop sites were excluded. After the search, ambiguous and / or irrelevant papers for the study were also excluded. Each of these steps will be described in detail the following.

In addition to the systematic purist review proposed by Kitchenham (Kitchenham, 2004), other research techniques were also performed: the manual search and snowballing. As can be seen in Section 3.6. The manual search, described in Section 3.6.1, and snowballing, described in Section 3.6.2.

3.1 Research Questions

The systematic review will seek to answer through the selected primary studies the research questions shown in the Table 1.

Table 1: Research Questions.

ID	Research Question
RQ1	What heuristics are used to evaluate product quality in mobile applications?
RQ2	What metrics are used to evaluate usability heuristics for mobile applications?

3.2 Databases

In the systematic review (Quiñones and Rusu, 2017), it is pointed out as later works the use of the IEEE and ACM bases, besides the ScienceDirect that was used by the researchers. Therefore, the 3 bases will be used in this systematic review.

3.3 Search String

The search string that has been used expects at least one of the terms ”usability heuristic” or ”usability heuristics” to refer to at least one of the terms ”mobile” or ”smartphone”, so that only mobile-related usability heuristics are selected. The terms ”evaluation” and ”Human-Computer Interaction” were also inserted with the intention of refining the research.

After planning what terms should be inserted, the result was:

((”usability heuristic” OR ”usability heuristics”) AND (mobile OR smartphone)) AND (evaluation) AND (”Human-Computer Interaction”) AND (”user experience”)

3.4 Study Selection Criteria

A number of different criteria were used to select studies that fit the needs of this research. For this, criteria for inclusion and exclusion of studies were developed. To be selected the studies should follow the following criteria:

1. Research papers that contain propositions for usability heuristics for mobile applications;
2. Studies that propose an approach, process or methodology to establish usability heuristics;
3. Studies published between 2007 and 2017 and written in English or Portuguese.
4. papers written in English or Portuguese.

The following types of papers were excluded:

1. Studies that contain proposed heuristics for other aspects (eg aesthetics, automation, hyper-heuristics);
2. Studies that do not explain how usability heuristics were developed;
3. Theses (eg master's theses) or monographs;
4. papers not focused primarily on the definition of usability heuristics, such as reports on usability case studies or usability tests;

5. Studies related to the infrastructure of mobile communication, mobile hardware or robotics;
6. papers focused on desktop, web or game applications;
7. Studies outside the field of computer or software engineering;
8. Incomplete studies, such as only abstracts and expanded abstracts;
9. Studies with less than four pages, published as ShortPaper;
10. Studies that present only opinions without any empirical evidence of support.

After using the search string in the previously selected databases, an initial **set of 43 papers** were obtained. From these studies the qualitative analysis was performed, in which, if an paper did not have relevant information to extract, could be excluded from the analysis. Taking into account the purpose of the review of this study, a set of four criteria was established:

1. The paper contains specific heuristics for mobile devices;
2. The paper describes in detail the proposed usability heuristics, with sufficient information to understand them;
3. The set of usability heuristics is an original proposal or the adaptation of another set of heuristics;
4. The paper presents, in detail, a way to evaluate the usability of the application.

3.5 Data Extraction

The data extraction strategy was mainly defined by the design of the data extraction forms that would precisely register the information obtained from the selected studies.

After including the study in the systematic review, the following information was identified and extracted:

1. The authors and the year of a study;
2. The usability heuristics used;
3. The heuristic evaluation used to validate the usability of the application.

3.6 Procedures for Selecting a Study

With the technique of Systematic Review it is possible, from the research questions and the defined string, besides the inclusion and exclusion criteria, to identify papers in the selected databases. However, in this work, with the reading of the papers it was possible to implement the Manual Search in periodicals previously known as of the area, and the use of the technique snowballing (Wohlin and Prikladniki, 2013), that allows the search of papers from the references of the papers selected by the Systematic Review.

The research procedures of this work in which the Systematic Review is used in Automatic Search, followed by Manual Search and Snowballing. This way of researching is similar to the one used in (Selleri Silva et al., 2015). The steps of this research are described on the Figure 1. All the steps are also better described bellow:

- ***Step 1:*** Perform automatic search, manual and snowballing in order to identify a preliminary list of studies. Duplicate studies were discarded.
- ***Step 2:*** Identification of potentially relevant studies, based on title and abstract analysis, discarding studies that are clearly irrelevant to the research. If there was any doubt about a study regarding its inclusion or exclusion, the next step was to check whether the study was relevant or not.
- ***Step 3:*** Selected studies in previous steps were reviewed by reading the introduction, methodology section and conclusion and applying the inclusion and exclusion criteria. If reading the above items was not enough to make a firm decision, the study was read in its entirety.
- ***Step 4:*** thus, a list of primary studies was obtained and subsequently subjected to critical examination using the criteria established.

3.6.1 Manual Search

The manual search was performed by analyzing the titles and abstracts (if necessary) of studies published in Journals that deal with Human-Computer Iteration. In addition, the Search String, has been applied in Google Scholar. Those considered potentially relevant were added to the set of papers selected.

3.6.2 Snowballing

Database searches are challenging for a variety of reasons, including selecting databases to use, different interfaces to databases, different ways of constructing search strings, different search limitations in databases, and identifying databases and synonyms of terms used[6]. This reasoning leads to two conclusions:

1. Choosing the first step in the search strategy often becomes the only step, that is, search databases;

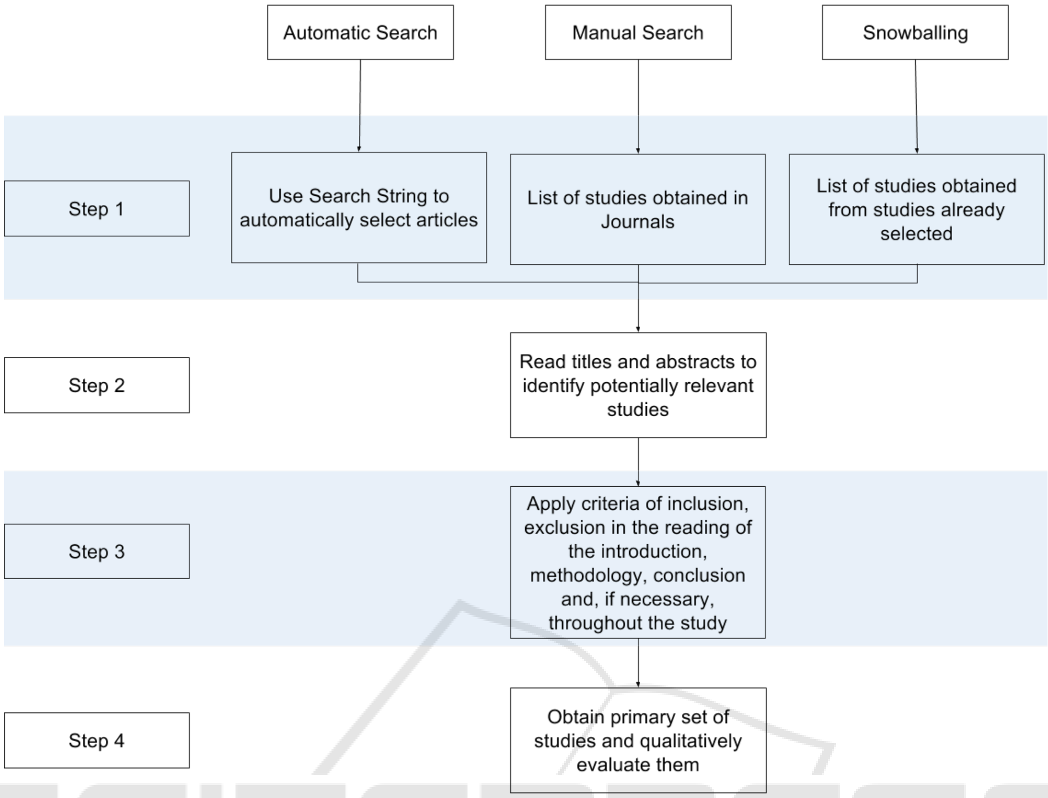

Figure 1: Procedure for Selecting a Study.

2. Given the challenges with the databases, important studies can be lost.

Based on the snowballing instructions proposed by Wohlin and Prikladniki (Wohlin and Prikladniki, 2013), in this study the steps used to perform this technique were:

1. Use the papers selected in automatic and manual searches as the initial set of selected studies;
2. Based on the selected studies, check references by looking at works of authors already included, since they obviously carry out relevant research in relation to their objectives;
3. Based on the set of documents found, check studies that cite the selected studies (forward snowballing). It is recommended to use Google Scholar as it captures more than individual databases.

4 CONDUCTING THE PROCEDURES FOR SELECTING A STUDY

This Section presents how the studies were selected doing the procedures described on the Section 3.6.

4.1 Conduct of Systematic Review

Using the search string in the previously chosen databases, a total of **38 papers were pre-selected**, finishing Step 1 of the job search procedure. described in Section 3.6.

By performing Step 2, the titles and abstracts of the selected studies were read and, if necessary, the reading of the introduction, methodology and conclusion was carried out, thus performing Step 3. At the end of these procedures a total of 5 papers were chosen.

4.2 Conduct of Manual Search

The Manual Search was carried out in parallel with the Systematic Review. The bases chosen to search for new studies were:

- Google Scholar - https://scholar.google.com.br/;
- Springer - http://www.springer.com/;
- MobileHCI - https://mobilehci.acm.org/.

A total of **4 papers** were pre-selected, submitted to the steps described in 3.6. At the end of the Manual Search search, 2 papers were inserted into the primary set of studies.

4.3 Conduct of Snowballing

After obtaining the **7 papers** selected via Manual Search and Systematic Review, Snowballing was performed. Where 10 papers were pre-selected and submitted to the same selection criteria of the other papers. One of these papers was selected, since the others had already been selected by the other search methods, or were useful only for specific fields, such as games or maps.

5 RESULTS

This section summarizes the results obtained after the systematic review. The results analysis focuses on the presentation of Table 2 which shows the studies found using Manual Search, Systematic Review and Snowballing. In addition, **Research Question (RQ) 1 and 2** presented in the Table 1 are also answered in this Section.

A **total of 50 papers** were analyzed during the conduction of the searches specified in sections 4, 5 and 6. From this total of studies **8 were selected** for Data Extraction, as Section 3.5 presents.

Table 2 shows the selected studies. Based on the results obtained, the following subsections summarize the analysis of each research question.

Table 3 shows the amount of studies selected related to their database.

5.1 RQ1 What Heuristics are Used to Evaluate Product Quality in Mobile Applications?

Since its appearance, Nielsen's set of usability heuristics (Jackob Nielsen, 1995) has been widely used in many research papers. However, nowadays there is more effort to develop and provide new sets of heuristics (Jimenez et al., 2016). Currently, Nielsen heuristics are used as a basis for developing or adapting new sets of usability heuristics.

Through this study, one can detect the use and development of different sets of usability heuristics specific to mobile applications. These heuristics are listed below:

ID - Name: MHU1 - Visibility of System Status

- **Definition:** The device must keep the user informed about all processes and state changes through comments and within a reasonable time frame.
- **Explanation:** Through interaction with the device, the user must be able to perform different tasks. These actions can lead to a system state change, which must be communicated to the user in some way. In addition, there are other events that are not triggered by user interaction, but require further response, ie: phone calls, video calls, and more.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Chuan et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU2 - Correspondence between the Application and the Real World

- **Definition:** The device must speak the language of the users and not technical terms of the system. The device must follow the conventions of the real world and display the information in a logical and natural order.
- **Explanation:** Today, touch-screen-based mobile devices have particular features that allow the user to interact with them in innovative ways, such as: touchscreen, proximity sensor, and GPS. Through these new modes of interaction, the user can perform tasks more intuitively, imitating real-world interaction rules. As an example, by scrolling down a long list, if the user "slides" with a certain speed, the list will continue to move, mimicking the effect of inertia. Each interaction is expected to show a response similar to that expected in the real world. In addition, the language (text or icons) must be related to real world and recognizable concepts.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Chuan et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU3 - User Control and Freedom

- **Definition:** The device must allow the user to undo and redo their actions and provide "emergency exits" clearly pointed out of leaving unwanted states. These options should preferably be available through a physical button or equivalent.
- **Explanation:** When the user makes a mistake when entering text, modifying configuration options or just reaching an unwanted state, the system must provide appropriate "emergency exits". These outputs should easily allow the user to move from an unwanted state to a desired one. In addition, the user should be able to undo and redo their actions in a simple and intuitive way. On the other hand, the user must also be able to easily manage the applications that are running on

Table 2: Selected Studies for Data Extraction.

Search Type	Research
Systematic review	1. (Motlagh Tehrani et al., 2014); 2. (Chuan et al., 2014); 3. (Inostroza et al., 2013); 4. (Inostroza et al., 2016); 5. (Quiñones and Rusu, 2017).
Manual Search	1. (Yáñez Gómez et al., 2014); 2. (Al-nuiam, 2015).
Snowballing	1. (Inostroza et al., 2012b).

Table 3: Selected Studies Related to their Database.

Database	Amount
ACM	1
IEEE	4
ScienceDirect	2
International Journal of Human Computer Interaction	1

Table 4: Selected Studies for Data Extraction.

MHU	S 1	S 2	S 3	Average Number	Standard Deviation
MH1	1.00	0.00	0.50	0.50	0.50
MH2	1.00	2.00	0.00	1.00	1.00
MH3	2.00	0.00	2.50	1.50	1.32
MH4	3.00	1.00	0.00	1.00	1.00
MH5	4.00	1.00	1.00	2.00	1.73
MH6	1.00	0.00	0.00	0.33	0.58
MH7	1.00	1.00	0.00	0.67	0.58
MH8	3.00	0.00	0.50	1.17	1.61
MH9	2.00	0.00	0.00	0.67	1.15
MH10	4.00	2.00	0.00	2.00	2.00
MH11	1.50	3.00	3.00	2.50	0.87
MH12	1.00	2.00	0.00	1.00	1.00
MH13	3.00	3.00	0.00	2.00	1.73

the device and the features in use. When using the data network, the user must be able to control the amount of data being transmitted and the associated time.

- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU4 - Consistency and Standards

- **Definition:** The device must follow the established conventions, allowing the user to do things in a familiar, standardized and consistent way.

- **Explanation:** Often, different parts of the system that are related and must be similar have different design or logic. In general, all concepts presented in contrast to the conception of the user concept produce confusion to some degree. This confusion can lead to decreased use efficiency or poor satisfaction, among other side effects. All in all, it is expected that the system will follow standards and conventions to achieve an intuitive and easy to use interface.

- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Chuan et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU5 - Error Prevention

- **Definition:** Your device must hide or disable unavailable feature.
- Warn users about critical actions, and provide access to additional information.
- **Explanation:** The device should attempt to be explicit with respect to each option and feature. Considering a small screen size, this can be a big challenge. In this way, the icons play a very important role. Unfortunately, sometimes a small image is not enough to describe in detail a function or similar, and to correct this, the system must provide additional information on the user's demand. The information should be clearly displayed, trying to avoid long dialogue sequences. In addition, the user should be warned, especially when some actions may have unwanted effects. Potentially dangerous options should be placed at deeper menu levels (so it is not recommended to assign a physical button to one of these options).
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU6 - Minimize User Memory Load

- **Definition:** The device must provide visible objects, actions, and options to prevent users from having to memorize information from one part of the dialog box to another.
- **Explanation:** Short-term human memory is limited, so the user should not be forced to remember information from one part of the system to another. Instructions on how to use the system should be visible or easy to obtain. When talking about mobile devices, the limited display size puts designers in a difficult position as to which interface elements should be hidden or minimized. In this way, it is important that confidential information be placed in a visible position. Users should not write text from one part of the system to another, on these devices it is better to select and copy than to write.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU7 - Customization and Shortcuts

- **Definition:** The device must provide basic and advanced settings for setting and customizing shortcuts for frequent actions.
- **Explanation:** Each user has their own needs and trying to satisfy them all with a standard menu or interface can be challenging. In this way, allow users to create their own shortcuts and customize most parts of the system can help. Through access to advanced configuration options, savvy users can improve their usability and new users can have a deeper sense of ownership.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Chuan et al., 2014) and (Inostroza et al., 2016).

ID - Name: MHU8 - Efficiency of Use and Performance

- **Definition:** The device must be able to load and display information in a reasonable amount of time and minimize the steps required to perform a task. Animations and transitions should be displayed seamlessly.
- **Explanation:** The combination of hardware features and software needs is not always the best. The basic software is expected to be compatible with hardware, especially with processing capabilities, to avoid black screens and long standby times. In addition, animations, effects, and transitions should be displayed seamlessly without interruption. Another critical point is the length of the sequence of steps to perform a task. Complex, potentially dangerous, or infrequent tasks may contain several steps to enhance security. Simple or frequent tasks should be short. If the user wants to set an alarm at 4 A.M, he does not expect a 4-step process.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU9 - Aesthetic and Minimalist Design

- **Definition:** The device should avoid displaying unwanted information by overloading the screen.
- **Explanation:** For devices with an old release date, each unit of information displayed on a

small screen involves less performance. Designers should be careful when displaying information across the screen. In addition, overloaded interfaces can cause stress to the user.

- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU10 - Helping Users Recognize, Diagnose and Recover from Errors.

- **Definition**: The device should display error messages in a familiar language to the user, accurately indicating the problem and suggesting a constructive solution.
- **Explanation**: When an error occurs, the user does not need technical details or cryptographic alert messages. The user needs clear feedback messages in a recognized language with instructions on how to recover from the error.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Chuan et al., 2014), (Inostroza et al., 2013), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU11 - Help and Documentation

- **Definition:** The device should provide documentation that is easy to find and help, focusing on the user's current task and indicating concrete steps to follow.
- **Explanation:** The device must provide access to detailed information about the available features in a clear and simple way, from any part or state of the system where the user is located. It is recommended that this information be included in the device. Otherwise, the documentation must be available on a website or in print.
- **Studies that Justify Its Use:** (Inostroza et al., 2012b), (Yáñez Gómez et al., 2014), (Motlagh Tehrani et al., 2014), (Chuan et al., 2014), (Inostroza et al., 2016) and (Quiñones and Rusu, 2017).

ID - Name: MHU12 - Pleasant and Respectful Interaction with the User

- **Definition:** The device must provide a pleasant iteration with the user so that the user does not feel uncomfortable while using the application.
- **Explanation:** The system must complete partial data entry in specific fields, as well as grant the possibility of saving the data that the user inserted in screens with many fields. The data entry fields must match the expected data type.
- **Studies that Justify Its Use:** (Yáñez Gómez et al., 2014), (Chuan et al., 2014) and (Inostroza et al., 2016).

ID - Name: MHU13 - Privacy

- **Definition:** The device must protect the user's confidential data.
- **Explanation:** The system should request the user's password for the modification of important data, as well as provide information about how the user's personal data is protected and about copyright content.
- **Studies that Justify Its Use:** (Yáñez Gómez et al., 2014).

5.2 RQ2 What Metrics are Used to Evaluate Usability Heuristics for Mobile Applications?

After developing an application using the usability heuristics listed on the Section 5.1 it should be checked whether the application contains them. The heuristic evaluations used by the studies selected are shown below:

ID: HE1

- **Explanation:** Specialists judge 1 to 4 as the application: 1 for heuristic items, 2 for those that correspond to usability gaps, 3 for heuristic items that were not evaluable in the real life-cycle phase, and 4 for non-usability issues to the interface.
- **Studies that Justify Its Use:** (Yáñez Gómez et al., 2014)

ID: HE2

- **Explanation:** The evaluation process came about in the evaluators' environment. All 6 experts spent about 30 minutes to 45 minutes examining the prototype. The steps in the procedure were to identify the number of specialists, identify suitable evaluators, organize a consultation with the evaluators, distribute the questionnaire to the specialists, complete the questionnaire by the evaluators, obtain comments to improve the design and redesign the application based on expert comments for better interactive interface.
- **Studies that Justify Its Use:** (Motlagh Tehrani et al., 2014)

ID: HE3

- **Explanation:** Given a series of activities for 15 users, it was timed the time each took to complete them. These activities were performed under different environmental conditions (heat, light, etc.).

The average user time was compared to the time a specialist took to complete the activities, if the average user time and expert time were similar, then this means that the application has good usability. In addition, a questionnaire with 47 questions was applied to all those involved, in which one should note between 1 and 5 for the parameters: learning ability, memorability, efficiency and error rate.

- **Studies that Justify Its Use:** (Al-nuiam, 2015)

ID: HE4

- **Explanation:** Two separate groups of evaluators inspected the device. Each group consisted of two or three evaluators. One group used the proposed heuristics while the other group used Nielsen.
- **Studies that Justify Its Use:** (Inostroza et al., 2013)(Inostroza et al., 2012b)

ID: HE5

- **Explanation:** The participants performed a heuristic evaluation of the app. Then, the number of problems by heuristics/experimental groups, the average severity and the associated standard deviation. Severity was estimated on a 0 (low) to 4 (high) scale.
- **Studies that Justify Its Use:** (Inostroza et al., 2016)

6 CASE STUDY

A total of 03 specialists performed the HE5 on an Android app called Carona Phone.

The app consists in a platform which wishes to help people who wants to request a ride to go from a place to another, it is more used by students who want to go from their house the university. The person who will give the ride have to register his or her information in the application, such as: name, car and route. On the other hand, the person who wants to request the ride have to put his or her information on the Carona Phone. Finally, the software will show the user who wants a ride or who can give the ride in the specific route and time.

The specialists separately tested each one of the features, and then, rated it. The problems were estimated on on a 0 (low) to 4 (high) scale. In this way they were not influenced by the other judgments. To do it they used the 13 mobile usability heuristics found in this paper, this elements were the ones who received the grade from 0 to 4. In this way they could say which heuristics were implemented well and which ones needed to be improved.

The Table 4 shows the severity number related to the usability heuristics for mobile by each specialist, the average number and the associated standard deviation.

The heuristic with the best average number, closest to 0, which means few problems, was the MH1(Visibility of system status) showing that this heuristic was well developed by the designers of the application. On the other hand, MH5(Error prevention), MH10 (Helping users recognize, diagnose and recover from errors) and MH13 (Privacy) evaluated 2.00, and finally, MH11 (Help and documentation) got the highest value, 2.50, meaning that those aspects are highly recommended to be redesigned to get a better user experience of the application.

The case study show that the heuristic evaluations and the usability heuristics for mobile that are shown in this paper can help the designers to find the problems on the applications that are being developed and fix them.

7 CONCLUSION

In view of the growth in smartphone production, usability is a key attribute for product quality. Usability is also a fact that facilitates the use of the software by the customer, which can help in the user's loyalty.

In order to reach the final set of usability heuristics and heuristic evaluations, 4 steps were taken to select studies. At the end of the study selection process a set of 13 usability heuristics were found, along with 5 possible ways of evaluating them.

The main contributions of this work is the compilation of desktop usability heuristics in a new, more specific set of heuristics adapted to the new mobile paradigm. In addition, the study shows which heuristics are currently used by researchers of usability heuristics for smartphones. The specification of the collected items shows that it can be used as a reference guide to help design more usable interfaces and not just as a reactive assessment tool for existing prototypes. Future work must consider this to contain this partial result.

Another case study using these heuristics and one of the evaluations listed may be a future work. The proposed 13 heuristics facilitate the detection of usability errors. However, it is always possible to improve usability heuristics, heuristic evaluations, and research methodology.

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