Mobile Application Usability Heuristics: Decoupling Context-of-Use

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Abstract. Context-of-use is a vital consideration when evaluating the usability of mobile applications. Thus, when defining sets of heuristics for the usability evaluation of mobile applications, a common practice has been to include one or more heuristics that consider context-of-use. Yet, most evaluations are conducted within usability labs. Consequently, the aim of this research is to question the utility of attempting to include inherently complex areas of context-of-use within limited sets of mobile application usability heuristics. To address this, a mapping study uncovered six sets of heuristics that can be applied to mobile application usability evaluations. A within-subjects empirical test with six Human-Computer Interaction practitioners evaluated a well-known travel mobile application using three sets of the mapped heuristics. The study found that the common practice of including context-of-use within mobile application usability heuristics is an ineffective approach.

Keywords: Mobile usability, Context-of-use, Heuristic Evaluation.

1 Introduction

Usability heuristics allow Human-Computer Interaction (HCI) practitioners and researchers to focus on the primary areas of software which may cause problems for users. One of the most popular sets of heuristics was originally defined by Nielsen and Molich [1], and is widely known for being fast and inexpensive [2]. Given the prevalence of mobile devices in the past decade, sets of heuristics for mobile technologies started to be defined as traditional heuristics did not consider applications built for small screens nor usage within environments far less constant than desktop applications [3]. Yet, Nielsen's heuristics [4], modified from the original set by Nielsen and Molich [1], remain popular when evaluating mobile applications [5]. In an interview with Jenny Preece [6], Nielsen supported this approach, suggesting that "You can identify a lot of issues with a phone or other mobile user experience by using exactly the same heuristics as you would for any other platform".

One of the items evident across many of these sets of heuristics is the inclusion of context-of-use. Context-of-use is anything that impacts the interaction between a user and an application [7], whereby elements of context, including surrounding light, ambient noise, and interruptions, can change rapidly, potentially impacting the usability of a mobile application [8,9]. Consequently, Savio & Braiterman [10, p.284] argue "For mobile computing, context is everything". To that end, it is no surprise that one or more heuristics are often included within sets of heuristics specifically aimed at considering the impact of context-of-use when evaluating the usability of mobile applications, even though most evaluations of mobile applications are conducted in usability labs [11].

The main aim of this research is to investigate the utility of including inherently complex areas of context-of-use within limited sets of mobile application usability heuristics, by asking the following research questions:

1. Based on the literature, which sets of heuristics are used to evaluate the usability of mobile applications?
2. Which of the mapped sets of heuristics include one or more heuristics that consider context-of-use?
3. To what extent can one or more of the mapped sets of heuristics measure the impact of context-of-use on mobile application usability within lab-based conditions?

2 Background

2.1 Usability Principles

One of the first sets of usability principles is the cornerstone of design today. Gould & Lewis [12] wrote the following principles, stating that system designers should:

- Focus early on users and tasks
- Empirically measure usability
- Design iteratively based on learnings from empirical tests

Nowadays, user experience designers commonly apply each of these principles in their daily work. Yet, Gould & Lewis [12] found that system designers often ignored these principles, believing for instance in the 'power of reason', whereby the prevailing feeling was that task completion was logic, thus there was little need to apply principles nor involve representative users.

As the benefits of usable and useful systems were acknowledged, Human-Computer Interactions experts defined further usability principles, including cognitive principles [13] and heuristic evaluation [1]—the latter becoming a common method among HCI practitioners and researchers [14]. Since its inception, heuristic evaluation has since been modified to cater for a wide range of domains, including Educational Media [15]; Groupware Based on the Mechanics of Collaboration [16]; Ambient Displays [17]; Adaptive Learning Environments [18]; Playability of Games [19]; Inten-

sive Care Unit Infusion Pumps [20]; Intrusion Detection Systems [21]; Virtual Reality Applications [22]; Electronic Shopping [23]; and Child E-learning Applications [24].

Heuristic evaluation is not without detractors. Researchers have argued that results from heuristic evaluation are too subjective [25]. This claim has been counter-argued, whereby other researchers have suggested that this difference in perspective enables the discovery of more diverse usability issues [26]. Additionally, despite the suggestion that heuristic evaluation may not be as effective as it claims [27], the method remains popular.

As mobile devices become more ubiquitous, heuristic evaluation started to be used to evaluate the usability of mobile applications. While the traditional set of heuristics from Nielsen appears to be in common use [5], researchers have argued that traditional heuristics needed to be modified before they can be used for mobile [28, 29]. To that end, several sets of usability heuristics designed specifically for mobile have been defined. While most of these sets of usability heuristics are general in nature, some are specific to a feature and/or a population [30].

2.2 Addressing Context-of-use

One of the key areas within the field of mobile usability is the impact of context-of-use. Context-of-use, which is anything that might impact the interaction between a user and an application [31], is a vital component of building mobile experiences [32]. This is due to the ever-changing contexts-of-use that mobile users find themselves in.

From a heuristic evaluation perspective, the consideration of context-of-use has been approached in two ways. Firstly, while heuristic evaluations are most often conducted in the lab, a study conducted by Po et al. [33] considered context-of-use using three conditions: heuristic evaluation within the lab for two conditions, one of which simulated context-of-use, one of which did not, and heuristic evaluation in the field. The authors of that work argue against conducting heuristic evaluations in the field as one of their conditions of their study, namely simulated context-of-use within the lab, uncovered the highest number of issues across three conditions. Yet, there are several threats to the validity and reliability of this study. For instance, during the heuristic evaluation, the authors used Nielsen's traditional heuristics, and did not attempt to define a set of heuristics for mobile technologies.

The internal validity of the study suffers from the threat of selection bias, whereby the authors did not randomize participants across conditions, and all conditions had fewer than the recommended five evaluators [40].

It seems that none of the evaluators had practical HCI experience, several evaluators only had one semester in HCI and had little familiarity with heuristic evaluation. This could be a threat to external validity, specifically population validity, in that the evaluators within this study cannot be generalized with HCI experts that have practical commercial experience and commonly undertake heuristic evaluations.

While it is quite difficult to achieve ceteris paribus in an experimental study, or in this case a quasi-experimental study, it should still be expected that all conditions would be as equal as possible. Yet, in this study the authors assigned user interface-related tasks to participants in just two of the three conditions.

The authors state that a by-product of this omission of task assignment in the first scenario was that participants focused on the product, more so than the operation of the product. As high construct validity is achieved only when intended constructs are measured accurately, it might be argued that the authors were measuring two operationalized variables defined from the construct 'usability issues'. Additionally, within the two conditions where evaluators completed six tasks, there is no indication that the tasks were counterbalanced. This could indicate an order bias.

The benefit of in-situ evaluation is an increase in ecological validity. Yet, participants had to think aloud while they were being recorded. Consequently, the reality of the in-situ condition was not realistic.

Participants were all aware which condition they were in within the study. This transparency could result in an interval validity threat known as demand characteristics. This threat can occur when participants know they are in the experimental group, and they change their behavior due to their expectations of the study. The authors of the paper could have minimized this threat by contriving a cover story, only giving the real reason for the study when participants were debriefed. There is no indication that this attempt was made for this study.

Reliability is compromised as it would be impossible to replicate the study. The authors of the work are not fully transparent around the environments and activities of the participants for any condition. For instance, within the in-situ condition, the authors simply state locations, such as cafeteria or bar, and some details, such as dark with changing light. To replicate the study, other researchers would need to know about all conditions, including environmental conditions, if participants were walking, sitting, were interrupted by friends and colleagues, and so forth. Any of these environmental and social factors may impact the findings, yet were not published by the authors.

Finally, the results of the study could be interpreted differently. Within the in-situ condition, fewer evaluators uncovered substantially more issues than the lab-based heuristic evaluation. While the second condition, the lab-based condition with scenarios of use, uncovered more issues, this condition had a great number of evaluators, yet uncovered only 0.4% higher usability issues on average. Additionally, the in-situ study uncovered more critical usability issues, as well as issues where context had an impact. These latter issues were not surfaced within the lab-based studies. Consequently, based on the threats to validity and reliability, it could be argued that the conclusion from Po et al., [33 p.55] that "there appears to be no additional benefit to immersing the evaluator in the context of use" appears to be premature. The authors of this paper argue that further research is needed around heuristic evaluations within and outside the lab, before coming to specific conclusions.

The second approach used to consider context-of-use during heuristic evaluations has been to include one or more heuristics specifically addressing context-of-use. As can be seen within the mapping study conducted in the next section, this has been a more widely-conducted approach. While the face validity of this approach seems to be high given that evaluators can consider all the major areas of mobile usability, including context-of-use, the aim of this paper is to empirically test the approach.

3 Approach

Human-Computer Interaction (HCI) researchers and practitioners have several sets of heuristics from which to choose as they evaluate the usability of mobile applications. These include a traditional set of heuristics from Nielsen [4], as well as several sets of heuristics defined specifically for mobile. A common approach has been to include one or more heuristics that consider context-of-use, which is important from a mobile application usability perspective. However, as heuristic evaluations tend to be conducted within a lab, how effective is this approach?

To that end, the aim of the study was to consider the effectiveness of including one or more sets of heuristics that consider context-of-use from a mobile usability perspective. The approach taken was two-fold:

1. A mapping study identified sets of heuristics used for mobile application usability evaluations
2. An empirical evaluation measured the effectiveness of including one or more sets of heuristics that consider context-of-use from a mobile usability perspective

3.1 Phase I: Mapping Study

The mapping study followed the same protocol as defined within Salgado & Freire, [5], whereby the objective, research question, and inclusion criteria were defined:

Objective: The main goal of the mapping study was to discover which heuristics are used to evaluate usability of mobile devices, and secondly, which elements of those sets of heuristics considered context-of-use.

Research question(s):

1. Based on the literature, which sets of heuristics are used to evaluate the usability of mobile applications?
2. Which of the mapped sets of heuristics include one or more heuristics that consider context-of-use?

Source search method: Sources will be discovered via Google using a search string using the keywords: usability, heuristics, heuristic evaluation, mobile, smartphone.

Inclusion criteria: Publications written in English, indexed by academic journals and databases, discovered by use of one or more of the chosen keywords, focusing on sets of heuristics used to evaluate the usability of mobile technologies.

The resulting sets of heuristics, as well as the associated heuristics related to context-of-use, identified during the mapping study are displayed in Table 1:

Table 1. Mobile application usability heuristics, including references to context-of-use

Author(s)	Usability heuristic(s) related to context-of-use
Nielsen (1994) [4]	(No contextual heuristics, and no approach defined as to how to consider the impact of context-of-use)
Weiss (2002) [34]	Design for Users on the Go
Ji et al. (2006) [35]	Flexibility: The user interface must be flexible so that adapts to various environments and users
Bertini et al. (2006) [36]	Ease of input, screen readability and glancability Aesthetic, privacy and social conventions
Joyce et al. (2014) [37]	Cater for diverse mobile environments
Inostroza et al. (2016) [38]	(No contextual heuristics, and no approach defined as to how to consider the impact of context-of-use)

3.2 Phase II: Empirical Evaluation

Having addressed the first two research questions by mapping six sets of heuristics, the final research question to address was:

3. To what extent can one or more of the mapped sets of heuristics measure the impact of context-of-use on mobile application usability within lab-based conditions?

Addressing this research question by evaluating all six sets of heuristics may have proven to be too time-consuming. Consequently, three sets of heuristics were selected for an empirical evaluation. To avoid recognition bias, each set of the chosen heuristics was labelled with a letter:

- Set A: Nielsen (1994) [4] - Nielsen's traditional heuristics appear to be commonly applied to mobile applications [5].
- Set B: Bertini et al. (2006) [36] - The heuristics from Bertini et al. were one of the first sets defined for mobile technologies.
- Set C: Joyce et al. (2014) [37] - The heuristics from Joyce et al. were defined for mobile technologies and considered areas lacking in previously defined sets, such as the utilization of sensors to reduce the burden on the user.

With the three sets of heuristics selected, a heuristic evaluation was conducted of a well-known travel mobile application. To conduct the evaluation, six evaluators were recruited for a within-subjects study using purposive sampling (4 Female, 2 Male). The experience level of the evaluators is shown in Table 2.

Table 2. Experience level of evaluators

Experience	HCI (Years)	Mobile HCI (Years)
Range	1-20	0-6
Mean	7.5	6.9
SD	2.91	2.2

To avoid learning bias, the sets of heuristic were counterbalanced for every two evaluators (Table 3).

Table 3. Order of heuristics

Participant	Order of heuristics
P1, P6	Set B, Set C, Set A
P2, P5	Set A, Set B, Set C
P3, P4	Set C, Set A, Set B

The study was conducted from February 26th, 2015 to March 16th, 2015. Many aspects of the study were controlled, whereby all participants used the same mobile device, the same version of the mobile application, and the environmental conditions within which the study was conducted were consistent. Participants attempted three tasks each on an LG G2 mobile device running Android 4.4.2 under good lighting and low ambient noise conditions, as would be expected in a usability testing lab. The tasks attempted were:

1. Find a hotel near your current location using GPS for one adult that is available within the next two weeks.
2. Find a return flight for one adult in economy class from London Heathrow to Paris.
3. Read a review of a restaurant in the UK, marking the review as helpful.

Having attempted each task, each participant conducted a heuristic evaluation using each set of the chosen heuristics:

Set A: Nielsen (1994) [4]
Heuristic 1: Visibility of system status. The system should always keep users informed about what is going on, through appropriate feedback within reasonable time

Heuristic 2: Match between 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.

Heuristic 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.

Heuristic 4: Consistency and standards. Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

Heuristic 5: Error prevention. 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.

Heuristic 6: Recognition rather than recall. 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.

Heuristic 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.

Heuristic 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.

Heuristic 9: Help users recognize, diagnose, and recover from errors. Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Heuristic 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.

Set B: Bertini et al. (2006) [36]
Heuristic 1: Visibility of system status and losability/findability of the mobile device.

Heuristic 2: Match between system and the real world.

Heuristic 3: Consistency and mapping.

Heuristic 4: Good ergonomics and minimalist design.

Heuristic 5: Ease of input, screen readability and glancability.

Heuristic 6: Flexibility, efficiency of use and personalization.

Heuristic 7: Aesthetic, privacy and social conventions.

Heuristic 8: Realistic error management.

Set C: Joyce et al. (2014) [37]
SMART1: Provide immediate notification of application status. Ensure the mobile application user is informed of the application status immediately and as long as is necessary. Where appropriate do this non-intrusively, such as displaying notifications within the status bar.

SMART2: Use a theme and consistent terms, as well as conventions and standards familiar to the user. Use a theme for the mobile application to ensure different screens are consistent. Also create a style guide from which words, phrases and concepts familiar to the user will be applied consistently throughout the interface, using a natural and logical order. Use platform conventions and standards that users have come to expect in a mobile application such as the same effects when gestures are used.

SMART3: Prevent problems where possible; Assist users should a problem occur. Ensure the mobile application is error-proofed as much as is possible. Should a problem occur, let the user know what the problem is in a way they will understand, and offer advice in how they might fix the issue or otherwise proceed. This includes problems with the mobile network connection, whereby the application might work offline until the network connection has been re-established.

SMART4: Display an overlay pointing out the main features when appropriate or requested. An overlay pointing out the main features and how to interact with the application allows first-time users to get up-and-running quickly, after which they can explore the mobile application at their leisure. This overlay or a form of help system should also be displayed when requested.

SMART5: Each interface should focus on one task. Being focusing on one task ensures that mobile interfaces are less cluttered and simple to the point of only having the absolute necessary elements onscreen to complete that task. This also allows the interface to be glanceable to users that are interrupted frequently.

SMART6: Design a visually pleasing interface. Mobile interfaces that are attractive are far more memorable and are therefore used more often. Users are also more forgiving of attractive interfaces.

SMART7: Intuitive interfaces make for easier user journeys. Mobile interfaces should be easy-to-learn whereby next steps are obvious. This allows users to more easily complete their tasks.

SMART8: Design a clear navigable path to task completion. Users should be able to see right away how they can interact with the application and navigate their way to task completion.

SMART9: Allow configuration options and shortcuts. Depending on the target user, the mobile application might allow configuration options and shortcuts to the most important information and frequent tasks, including the ability to configure according to contextual needs.

SMART10: Cater for diverse mobile environments. Diverse environments consist of different types of context of use, such as poor lighting conditions and high ambient noise are common issues mobile users have to face every day. While the operating system should allow the user to change the interface brightness and sound settings, developers can assist users even more for example by allowing them to display larger buttons and allowing multimodal input and output options.

SMART11: Facilitate easier input. Mobile devices are difficult to use from a content input perspective. Ensure users can input content more easily and accurately by, for instance displaying keyboard buttons that are as large as possible, as well as allowing multimodal input and by keeping form fields to a minimum.

SMART12: Use the camera, microphone and sensors when appropriate to lessen the user's workload. Consider the use of the camera, microphone and sensors to lessen the users' workload. For instance, by using GPS so the user knows where they are and how to get there they need to go, or by using OCR and the camera to digitally capture the information the user needs to input, or by allowing use of the microphone to input content.

Prior to re-evaluating the mobile application with a different set of heuristics, participants conducted each task once more. Any issues surfaced during the evaluation were allocated with a severity rating by each participant. The severity ratings were adapted from Sauro [39]:

- *Minor:* Causes some hesitation or irritation
- *Moderate:* Causes occasional task failure for some users or causes delays and moderate irritation
- *Critical:* Leads to task failure or causes extreme irritation

4 Results and Discussion

Using the three sets of heuristics, the six evaluators found a total of 145 usability issues (Mean=48, SD=9) during the evaluation (Figure 1).

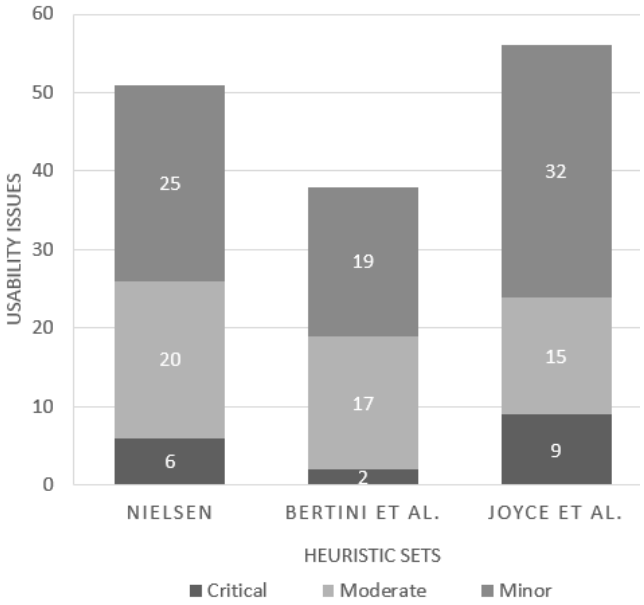

Fig. 1. Issues found during the heuristic evaluation.

Yet, only five minor issues (3.45%) were raised by two (P1 & P6) of the six evaluators relating to context-of-use. All issues related to context-of-use were raised by the heuristics from Joyce et al. [37], with no context-of-use issues raised during the evaluations using the heuristics from Nielsen [4] and Bertini et al. [36]. The comments associated with the issues related to context-of-use stated only that there was no indication that the app changed to adapt to various scenarios. Thus, even though issues had been raised, accurately measuring the impact of context-of-use on mobile application usability would prove challenging. Consequently, HCI designers would be unable to make changes that might reduce the impact of context-of-use on the usability of the mobile application.

Other researchers may argue that a relatively small number of evaluators participated in the study. However, the study represents a real-world scenario, given that the recommended number of evaluators for a heuristic evaluation is five [40].

5 Conclusion

Heuristic evaluation has been recognized as a fast, effective, and inexpensive approach to evaluating the usability of software applications. When applied to mobile applications, context-of-use should be an important consideration of heuristic evaluations. A common practice, therefore, has been to include one or more heuristics dedicated to the consideration of context-of-use within sets of heuristics defined for mobile applications.

This work investigates this practice by mapping sets of heuristics used to evaluate the usability of mobile applications, listing specific heuristics that consider context-of-use, then empirically testing the extent to which these sets of heuristics can measure the impact of context-of-use on mobile application usability within lab-like conditions. It is important to note that this work is not an argument for nor against lab or field studies. The authors agree with Tan et al. [41] that both are needed at various points in the mobile application development life cycle. As stated by Kjeldskov and Skov [42], "The important question is not if or why one should do lab or field studies, but rather when we should do what". Rather, the authors question the utility of attempting to include inherently complex areas of context-of-use *within* limited sets of mobile application usability heuristics. Based on an empirical test of three sets of heuristics, the authors conclude that the commonly applied approach of including context-of-use as part of mobile application usability heuristics is not effective.

To address this issue, initial work has started on an alternative framework [43]. The proposed framework will allow HCI practitioners and researchers to measure the impact of changing contexts-of-use on the major elements of mobile application usability. While the framework based on context-of-use analysis defined by Maguire [7], it differs in several ways from that authors work and from the common practice of including context-of-use with heuristics, whereby the proposed framework:

- Decouples the complexity of context-of-use from the equally complex field of usability, addressing one of the concerns from a respondent in a related survey [37], who stated that "[there are] so many contexts for mobile use"
- Is aimed at dynamic and fast-paced development environments
- Is defined specifically for evaluating the usability of mobile applications

Subsequently, the proposed framework addresses several limitations of context-of-use analysis, namely "The reader may feel that the method is too heavyweight and will require the generation of lots of paperwork by several people" [7, p.480] and "Another question is how the Context of Use should be addressed in a more dynamic development environment…where the requirements, expectations and perceived opportunities are evolving all the time" [7, p. 481]. To that end, by decoupling context-of-use from usability, the proposed framework can be used as a lightweight approach to measure the impact of context-of-use on mobile applications that may be used in varying contexts, by fast-paced agile and continuous delivery teams.

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