Usability Challenges in Smartphone Web Access: A Systematic Literature Review

Mazen Al-Ismail, A. Sajeev

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Mazen Al-Ismail[1] and A. S. M. Sajeev[1]

[1]School of Science & Technology, University of New England, Australia
malismai@myune.edu.au, sajeev@une.edu.au

Abstract. Systematic literature reviews facilitate methodical understanding of current advances in a field. With the increasing popularity of smartphones, they have become an important means to access the web. Although the literature on this topic is growing in recent times, there has been no effort yet to systematically review it. This paper reports on a systematic literature review of primary studies from 2007 to 2012 that concern mobile web usability. We identify the usability dimensions tested and the testing procedures adopted in the literature. We anticipate that our work will not only help researchers understand the current state of usability testing of mobile web but also identify the areas where further research is needed in addressing the challenges identified.

Keywords: Mobile web, Systematic literature review, Web usability, User experience.

1 Introduction

Web access through wireless devices has exploded in recent times with the increased popularity of smartphones and tablets that run on mobile operating systems such as Android [1] and IOS [2]. According to International Telecommunication Union (ITU), mobile phone subscribers have grown from around two billion in 2005 to close to seven billion by 2013. Mobile broadband access has grown from 268 million in 2007 to 2.1 billion in 2013 [3]. While these developments put unprecedented pressure on designers to make web sites easy to access from mobile devices, growth in mobile-friendly websites has been slow. Google, in a survey of its largest advertisers in 2011, found that only 21% of them have mobile friendly websites [4].

In the mean time, the capabilities of mobile phones have increased from just being able to make phone calls and text messages, to become a sophisticated computing and communication device which can handle internet surfing, send and receive emails, play multimedia and run advanced apps in varying fields from social networking to health to commerce and education. As the number of users of these devices increase and the capabilities of the devices improve, there is a need to understand the challenges that both web developers and web users face in achieving high quality browsing experience on a mobile device. This paper provides a systematic review of the literature on mobile web usability.

Systematic literature reviews (SLR) facilitate methodical understanding of current advances in a field. They help both in recording the achievements in well established fields such as medicine, and at the same time, offering in-depth understanding of developments in emerging fields such as in Information Technology. An example of the former is the SLR of effective methods of giving information to cancer patients by McPherson, et al. [5], and an example of the latter is the SLR of empirical work in global software engineering by Šmite, et al. [6].

Holzinger [7] identifies five characteristics of usability, namely, learnability, efficiency, memorability, low error rate and satisfaction. The International Standards Organisation, on the other hand, gives a more general definition of 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" [8].

Therefore, it is safe to say that usability determines the relationship between a product and its user [9]. From an engineering point of view, usability is reducing the complexity of the interface as much as possible so users can focus on their tasks rather than concentrating on the product. We explore how these dimensions are tested. Our research questions are:

RQ1: What dimensions of usability are examined in mobile web testing?

RQ2: What are the different purposes for which mobile web usability testing is conducted?

The main contributions of the paper are:

- It explores the dimensions of usability that are identified in the literature and explain how these dimensions have been assessed with respect to mobile web usability.
- It explains the current usability testing practices in mobile web and their limitations.
- It applies the systematic review approach illustrated by Kitchenham, et al. [10], thus ensuring that papers reviewed are those meeting pre-specified search and quality criteria within the search period.

The rest of the paper is organised as follows. In the next section, we explain the research method. In Section 3, we explore the different dimensions of usability testing and review how researchers conduct usability tests. In Section 4 we identify some of the limitations of this research, and finally, in Section 5 we give the conclusions.

2 Research Method

In order to conduct a systematic literature review, we used the research method explained by Kitchenham and Chatters [11]. Accordingly, a protocol for literature search was formulated around our research questions. The protocol decided our search terms, choice of search engines, and inclusion and exclusion criteria for the selection of papers. This selection process is explained further in Section 2.1. The papers selected were then assessed based on a set of quality criteria as explained in Section 2.1.1; a score was given to each paper with a view of excluding those that scored less than a threshold value. Finally, the contents of the short-listed papers were compiled and analysed to formulate the answers to our research questions.

2.1 Search Process

The search engines we used were:

- Google Scholar: http://scholar.google.com.au
- ACM Digital Library: http://dl.acm.org
- IEEE Digital Library: http://ieeexplore.ieee.org

All search processes were conducted online using the above mentioned libraries. We used the search terms: ((Mobile AND Usability) AND (Web OR Website OR Site) in the title of the article, and year of publication between 2007 and 2012. Even though, we tried to search for literature using the keyword "smartphone", the term has not been widely used in the literature with respect to usability for our period of interest; hence our use of the word "mobile" instead.

We chose to include papers published from 2007 in our review for the following reason. The era of smartphones started largely with the release of iPhones in June 2007. Even though, there were mobile devices such as personal digital assistants (PDA) and WAP (Wireless Access Protocol) capable phones before then, they were not suitable for widespread mobile web access. Thus web usability has become a serious research issue with the advent of smartphones in 2007. The search resulted in 35 papers as shown in Table 1.

Table 1. Number of papers from initial search

Digital Library Name	Number of Papers identified
Google Scholar	27
ACM Digital Library	4
IEEE Digital Library	4

The results were pruned to remove duplicate entries from different search engines. The following inclusion criteria for the SLR were then applied:

- The paper is on the topic of mobile web usability
- The paper reports a primary study
- The paper is peer-reviewed and is written in English
- The paper was not published before 2007
- If the paper is a book chapter, then the book includes at least one other paper on mobile web usability

In the search results, there were eight duplicate entries, three non-English papers, two papers that were not peer-reviewed, and three papers unrelated to the topic; these were discarded. After this step, we ended up with 19 papers which are listed in Table 2.

2.2 Quality Assessment

Each paper's quality for inclusion was evaluated using the following criteria:

- [Q1] Does the paper provide a clear method on usability testing or suggest an approach for designing a mobile web page to enhance the usability?
- [Q2] Does the paper test any usability dimensions?

Each paper was given a score based on a subjective assessment of how well it answered each of the questions (1 means very well, 0.5 means partly and 0 means not at all) and the net quality rating was the sum of the three scores. The minimum required quality rating was set at 1; all the 19 papers met this rating as shown in Table 2.

Table 2. Papers selected for the study and their quality rating.

Authors, year and citation	Title	Total Q1	Q2	Total
Rosario et al (2012) [12]	A Study in Usability: Redesigning a Health Sciences Library's Mobile Site	3	2	7
Yeh & Fontenelle (2012) [13]	Usability Study of a Mobile Website: the Health Sciences Library, University of Colorado Anschutz Medical Campus, Experience	3	2	7
Hong and Kim (2011) [14]	Mobile Web Usability: Developing Guidelines for Mobile Web via Smart Phones	3	2	7
Tsiaousis & Giaglis (2010) [15]	An Empirical Assessment of Environmental Factors that Influence the Usability of a Mobile Website	0	2	4
Shrestha (2007) [16]	Mobile Web Browsing: Usability Study	3	2	7
Schmiedl et al (2009) [17]	Mobile Phone Web Browsing: A Study on Usage and Usability of the Mobile Web	0	2	4
Jeong & Han (2011) [18]	Usability Study on Mobile Web Newspaper Sites	3	0	4
Wessels et al (2011) [19]	Usability of Web Interfaces on Mobile Devices	3	0	5
Carta et al (2011) [20]	Support for Remote Usability Evaluation of Web Mobile Applications.	3	0	4
Diaz et al (2008) [21]	Evaluating the Usability of the Mobile Interface of an Educational Website	3	2	7
Frederick & Lal (2009) [22]	Mobile Web Usability	3	0	5
Brown et al (2010) [23]	Blind Leading the Blind: Web Accessibility Research Leading Mobile Web Usability	3	0	5
Pendell & Bowman (2012) [24]	Usability Study of a Library's Mobile Website: An Example from Portland State University	3	2	7
Kristjansdottir et al (2011) [25]	Written Online Situational Feedback via Mobile Phone to Support	1.5	2	5.5
Amelung et al (2009) [9]	Mobile Usability	3	2	7
Kaasalainen (2009) [26]	Designing for Mobility	1.5	0	3.5
Vartiainen (2009) [27]	Designing Mobile User Interfaces for Internet Services	3	2	5
Tsiaousis & Giaglis (2008) [28]	Evaluating the Effects of the Environmental Context-of-Use on Mobile Website Usability	3	1	6
Ivanc et al (2012) [29]	Usability Evaluation of a LMS Mobile Web Interface	3	0	5

3 Usability Design and Testing Practices

3.1 Summative Versus Formative Evaluation

Usability tests can be formative or summative [9]. Formative evaluation occurs during the development process, whereas summative evaluation occurs after the mobile site is designed and constructed. For formative evaluation, since the system development is not complete, testing is conducted using a software emulator. Another common method of formative evaluation is to use *website wireframes* which are skeletal page-layouts drawn on paper. When a participant "clicks" on a button, the sheet showing the page resulting from the click replaces the current sheet.
While summative tests can use field tests or laboratory tests, formative testing needs a laboratory setup because prototype testing is difficult to perform in the field.

3.2 Testing Different Dimension of Usability

From the ISO definition [8] given in Section 1, we can deduce three dimensions of usability, namely, effectiveness, efficiency and user satisfaction. These three are the most common dimensions for which usability testing is conducted. Generally, as part of the test, participants are asked to use their mobile phones to perform a number of tasks (e.g., a task in [20] is to check the United Airlines departure flights to Chicago). Effectiveness of a mobile web page was measured by the successful number of completed tasks and efficiency as the time taken for task completion. A high completion rate and a short period of time required to complete the tasks indicate that the examined system is effective and efficient, respectively. Satisfaction is the degree of accessibility and comfort perceived by the user of the measured system. It is measured by interviewing or surveying the participants to explore their user experience with the system. The normal practice is to use a post-test questionnaire of various satisfaction items with responses measured on a Likert-type scale. As exceptions, Kristjánsdóttir, et al. [25] used semi-structured interviews in addition to a questionnaire, and Yeh and Fontenelle [13] used product reaction cards [32] which are explained later in this section.

In exploring the above three dimensions of usability, authors have used various usability terms which include error rates [14, 15, 20, 24, 28], ease of use [24], user experience [16, 17, 24, 25], usefulness [13, 24, 25], appearance [24], feasibility [25], accessibility [16, 24], effort [16], understandability [13, 25], clarity [16, 24] and relevance [13]. These terms are not all independent (for example, a low error rate is discussed in the context of effectiveness, and ease of use in the context of satisfaction), which leads to a classification of usability dimensions as shown in Fig. 1. Next, we provide the dimensions and the contexts of usability tests in the literature. The tests include investigating usability of websites on mobile phones vis-à-vis desktops, and mobile optimized sites vis-à-vis non-optimised sites; they also include studying the effect of environmental factors such as background noise on mobile web usability, and studying specific web applications related to library access and health intervention.

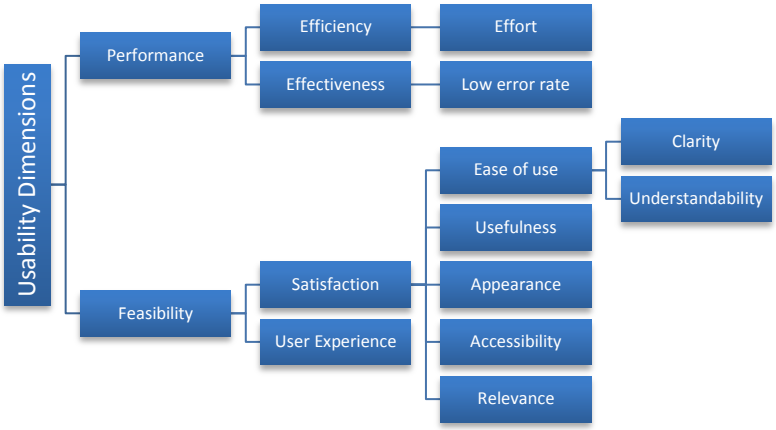

Fig. 1. Classifying usability dimensions.

Rosario et al. [12] tested the effectiveness of redesigning a health science library's mobile site. Firstly they implemented open-ended questions where participants (library users) identified the most needed services, namely the need to search journal databases, access full-text articles, access databases, access e-books, search library catalogue, and find the library hours. After that, participants were invited to perform tasks using a prototype design on paper, simulating the intended mobile library web. While all participants could complete tasks such as finding the library hours, only 10% could complete the task of viewing full-text of an article on line; they found the search interface confusing and the screen size inadequate. Finally, the mobile library web was designed with basic HTML incorporating the results of the usability testing of the prototype.

A similar study done by Yeh and Fontenelle [13] measured the effectiveness, efficiency and satisfaction of a health sciences library by comparing optimized and non-optimized mobile websites. Effectiveness and efficiency were measured by asking participants to perform 10 information retrieval tasks. Yeh and Fontenelle used Microsoft's desirability toolkit with product reaction cards [32] to measure satisfaction; each card has a word that could describe a usability facet (examples are words like accessible, confusing, efficient, frustrating etc.) and participants are asked to select cards that reflect their user experience. As a further measure of satisfaction, participants are later interviewed to find reasons for their choice of reaction cards. Unlike a Likert-type questionnaire that tends to have mostly positive statements, which might result in participants unintentionally selecting positive answers, the product reaction cards are designed with 40% negative words and the remaining positive words. The authors found that optimized websites significantly improved the effectiveness (19% improvement) and efficiency (9% improvement) of information retrieval on smartphones. With respect to user satisfaction, there were less number of negative words (slow and unrefined) chosen by the participants in the case of the optimised site than in the case of non-optimised site (confusing, difficult, hard to use, ineffective, not valuable, slow, time consuming, and unrefined).

In another usability experiment, Pendell and Bowman [24] tested an existing mobile-optimized library website by asking participants to perform five tasks to measure effectiveness, efficiency and satisfaction. Effectiveness was measured in terms of errors which they classified into three categories: fatal (for example, not being able to complete a task), major (for example, being able to complete a task but with delays) and minor (completing a task with errors easily corrected by the participant). Satisfaction was measured by asking participants to take notes of their experience and further through a post-test survey on the site's appearance and ease of use. As in the case of [12], all participants completed the task of finding the library hours successfully. However, many users took a long time to search for a book; one of the reasons was that the developers included in the mobile site pull down menus and options to search different types of collections simply because they were available in the full site; this is an example of a challenge in mobile optimization where judicious decisions need to be made on what to exclude from the full site in order to improve usability.

Tsiaousis & Giaglis [15] reported a very different kind of study where they tested the impact of environmental contexts on effectiveness, efficiency, and satisfaction of general mobile web access. The study was conducted in a laboratory to control and simulate environmental contexts. For example, they studied the impact of meaningful sound (e.g. someone talking) versus background noise (e.g printer or fax sound) on participants who were browsing a mobile website; they found that sounds with 'semantics' significantly decreased effectiveness and efficiency compared to meaningless noise. This test was conducted in a laboratory since it is hard to control background sound in a field test; field factors can be easily controlled in a laboratory, for example, by turning on printers to create noise and asking volunteers to start dialogues with participants to create sound with semantics.

In another study, Schmiedl et al. [17] measured efficiency by comparing the access on a mobile phone of a full website versus the corresponding mobile optimized site. They used five mobile optimised sites such as ebay and amazon and asked the participants to perform three to four tasks first on the full website and then on the mobile optimised site, and the time of accomplishing tasks were measured. They found 30 to 40% increase in efficiency in accessing mobile-optimized sites compared to the non-optimized versions. User satisfaction was also measured by seeking post-test comments from the participants, and interestingly, feature limitations were reported as annoying by the participants. This illustrates the dilemma between increasing efficiency by reducing features to make access faster, and achieving user satisfaction by providing a feature rich site. Schmiedl et al. also found that touch screen phones were preferred for surfing, with an additional keyboard found as an advantage whereas use of a pen for navigation was disliked.

Although many studies measured effectiveness by the number of successful tasks completed, Hong and Kim [14] measured it by the number of errors that were made by participants. They conducted three studies. In the first study, participants were observed to find out when and where they made errors during web browsing on mobile. They used the think-aloud technique were participants are asked to speak their mind while performing the tasks and the session was video recorded. The common errors were related to (a) interaction where novice users had trouble with finding the right icons and hyperlinks on the screen and (b) navigation from one page

to another. In the second study the participants were interviewed to collect qualitative data on their browsing experience. The most frequent complaint was the complexity of the websites accessed. Finally, 33 mobile sites were analysed for their efficiency of design layout which resulted in recommendations on good layout.

Shrestha [16] measured effectiveness, efficiency, and satisfaction by asking participants to complete four tasks on a desktop browser and then on a mobile browser. The tasks on both the desktop and mobile browsers were similar in scope, and the websites were not optimized for mobile devices. The number of completed tasks on the mobile phone was compared with the number of completed tasks on the desktop, which reflected effectiveness. In order to measure efficiency, the tasks were timed to compare the completion time on mobile versus desktop. Finally, participants were asked to rate their level of satisfaction with each task performed. This is one of the earliest papers in our study literature when there was hardly any mobile optimized sites. Understandably, too much scrolling and getting visibly lost in the website were the highest reported usability problems. Of the total time spend on tasks 80% was on mobile device and only 20% on desktop thus indicating the difficulty of web tasks on mobile phones when the experiment was conducted.

Whereas all of the studies above measured effectiveness and/or efficiency, one study that did not use these "standard" dimensions of usability testing is by Kristjánsdóttir, et al. [25]. They tested a mobile-web solution for cognitive behavioural intervention for people with chronic pain; essentially, patients kept an online diary of their feelings and behaviour on the web using a mobile phone and received feedback from a therapist in the same way. The usability test involved testing feasibility and usefulness of the mobile web-based intervention. Feasibility was measured in terms of user experience and satisfaction which were assessed through questionnaires and semi-structured interviews. Usefulness of the feedback received was also measured through a daily two-item questionnaire. Most participants found the mobile web-based solution "supportive, inspiring and meaningful". Two-thirds of the participants reported that the solution has increased their insights into their symptoms and taught them new methods to cope with their symptoms. However, negative issues included frustrations with filling out the diary and receiving a validation error because of poor internet connection, frustration with a patient feeling misunderstood and not being able to explain herself and the therapist sending feedback to the wrong patient by clicking the wrong button; problems that probably would not occur in a face-to-face situation.

4 Limitations

As in any research, this review has several limitations. We have chosen the research period from 2007 to 2012 which means that papers published outside this period are not included. Web access on mobile devices has been of interest in the days of PDAs and feature phones, and therefore, there will be usability studies on them which we have not covered. We did not include them in our research primarily because the issues identified in those days are probably of less interest with the paradigm shift that smartphones have achieved. We note that some of the early tests within our period of

study also used feature phones and therefore their results may not be as relevant as later studies.

Even though, we believe that google-scholar is very comprehensive in its literature search capability, our choice of search engines and keywords may have caused some relevant papers not to be discovered.

Our search term used the word "mobile", however, all the papers resulted from the search used mobile phones for their usability testing; in future, other popular devices such as android tablets and iPads will also become part of usability test literature.

5 Discussion & Conclusion

As the capabilities of mobile devices increase, they are rapidly becoming popular for browsing the web. However, recent surveys have shown that even commercial companies, for which web as a medium for marketing and advertising is critical, are lacking in optimizing their web sites for mobile access [4, 30]. This adds to the usability challenges of browsing the web from a mobile device. A systematic literature review is often used to methodically identify the issues reported in the literature. We employed the same method to answer the research question:

What dimensions of usability are examined in mobile web testing?

We identified the usability factors that are tested by different researchers. The three dimensions most studies used are effectiveness, efficiency and satisfaction. Effectiveness and efficiency are measured quantitatively whereas satisfaction is measured often through post-test surveys or interviews with the users; use of product reaction cards [32] was also found in one study. These dimensions were found to be subsuming a larger number of usability factors, the relationships between which we captured in Fig. 1.

Our final research question was:

What are the purposes for which mobile web usability testing is conducted?

We found that researchers conducted usability tests to:

- Compare user experience between mobile optimized sites and non-optimized sites
- Compare user experience between websites accessed on desktops and accessed on mobile phones
- Study the effect of environmental factors such as background noise on mobile web usability
- Study the effectiveness of mobile web-based applications such as in health
- Test the usability of web sites such as University library sites after optimizing them for mobile devices.

Both formative and summative evaluations are presented in the literature. We observed the following major limitations in the current usability testing practices:

- Most studies use small samples which makes statistical analysis difficult. The absence of discussions on generalizability of the results in most of the studies is a consequence of this limitation.
- The use of software tools to streamline the collection and analysis of data is also found to be lacking. A few researchers have used tools to draw paper

prototypes for formative studies but not for the collection and analysis of data. One of the papers in the period of study described a software tool for collection of usability data [20] which is promising; however, this or other tools are not used in the empirical papers reviewed. Tool support will assist in measuring, particularly, effectiveness and efficiency in web usability.

- Some tests were not controlled for variability in the mobile devices used; this could particularly be a problem since device heterogeneity is one of the challenges in mobile web usage.

In summary, the systematic literature review has identified and categorised the usability dimensions that are tested by mobile web researchers, and the purposes for which usability testing is currently employed. We believe, this study will assist researchers and practitioners in understanding the current challenges and limitations of mobile web usability, and encourage them to work on addressing them.

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