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EDITORIAL PREFACE

This is *Third* Issue of Volume *Six* of International Journal of Human Computer Interaction (IJHCI). IJHCI is an International refereed journal for publication of current research in Human Computer Interaction. Publications of IJHCI are beneficial for researchers, academics, scholars, advanced students, practitioners, and those seeking an update on current experience, state of the art research theories and future prospects in relation to applied science. Some important topics covers by IJHCI are affective computing, agent models co-ordination and communication, computer mediated communication, innovative interaction techniques and user interface prototyping for interactive systems etc.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Started with Volume 6, 2015, IJHCI appears with more focused issues related to human computer interaction studies. Besides normal publications, IJHCI intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

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IJHCI editors understand that how much it is important for authors and researchers to have their work published with a minimum delay after submission of their papers. They also strongly believe that the direct communication between the editors and authors are important for the welfare, quality and wellbeing of the Journal and its readers. Therefore, all activities from paper submission to paper publication are controlled through electronic systems that include electronic submission, editorial panel and review system that ensures rapid decision with least delays in the publication processes.

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When to Ask Participants to Think Aloud: A Comparative Study of Concurrent and Retrospective Think-Aloud Methods

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Abstract

This paper presents the results of a study that compared two think-aloud usability testing methods: the concurrent think-aloud and the retrospective think-aloud methods. Data from task performance, testing experience, and usability problems were collected from 30 participants equally distributed between the two think-aloud conditions. The results suggest that while the thinking aloud method had no impact on task performance and testing experience, participants using the concurrent think-aloud method reported a larger number of problems with the test interface than participants using the retrospective think-aloud method. These findings suggest a reason for preferring the concurrent think-aloud method to the retrospective one.

Keywords: Usability Testing, Think-aloud Studies, Verbal Protocols.

1. INTRODUCTION

Usability is increasingly recognized as a key factor in the success of interactive software systems. Several studies have reported the benefits of more usable software interfaces, including greater user satisfaction, productivity and security [1]. As a result, a number of usability evaluation methods have been developed over the last four decades in attempts to improve the usability of software products. One of these evaluation methods is concurrent think-aloud (CTA) protocol, which has been used as the primary tool for understanding users' task-solving behaviours during usability testing [2]. This method involves test participants working on a set of predesigned tasks and talking aloud about their thoughts and task performance. This enables evaluators to identify the areas of a system that cause problems for the user and thus require further development. However, since the introduction of CTA into the usability field in 1982 cited in [3], questions have been raised regarding the validity of CTA data. Some scholars argue that thinking aloud while performing tasks may feel unnatural and thus may threaten test validity by altering what participants say and do [4]. Others contend that CTA protocol produces data mainly relating to descriptions of actions and procedures and does not yield more detailed explanatory data which usability evaluators often need to collect [5].

To counteract these issues, an alternative approach has been developed to gather verbal data which seeks to increase the utility and validity of the resulting verbal protocols. This method, retrospective think-aloud (RTA), addresses the above issues by allowing test participants to perform tasks silently and comment on their performance afterwards [4]. The retrospective method, therefore, does not interfere with participants' thought processes, and is deemed more capable to mirror real-world use. However, RTA also has its own limitations, chief amongst, which are its reliance on memory and the subsequent possibility of post-task rationalisations [4].

This paper presents the results of a study comparing the CTA and RTA methods. It is structured as follows: the next section discusses the existing literature focusing on the development of think-aloud methods and recent studies related to the evaluation of TA methods, and concludes by stating the aims and hypothesis of the current study. Further sections discuss the research method, the data analysis, and the results found. The papers concludes with a brief discussion and conclusion.

2. RELATED WORK

The development of think-aloud protocols is usually attributed to Ericsson and Simon [6]. These protocols were originally developed for the purpose of gaining insight into people's mental processes in cognitive psychology research. Later, they began to serve as a basis for understanding how people perform certain activities such as reading, writing and decision-making in different domains [7]. They are currently used in the context of usability testing to study human-computer interactions, and have become the methods of choice for many practitioners [8]. The primary benefit of think-aloud methods – unlike other forms of observation, which rely on many assumptions – is that think-aloud encourages the person being studied to verbalise their thoughts, thereby shedding light on the reasons for the behaviour being observed [4]. Nevertheless, the validity of think-aloud reports, particularly those generated from CTA, has been the subject of much heated debate within usability evaluation [9; 10]. For example, a study by [11] questioned the effect of concurrent verbalization on task behaviour and noted that participants who were encouraged to think aloud when performing tasks took longer than those who were not encouraged to think aloud to complete the same tasks. This change is often referred to as reactivity. This finding runs counter to Ericsson and Simon's [6] claim that thinking aloud does not affect task processing. For usability testing, reactivity can be problematic as it may lead to identifying and fixing false problems or failing to detect real issues. Other evidence suggests that verbal reports produced by the CTA protocol contain information largely related to the step taken to achieve a certain goal (such as reading or describing actions) which are less relevant to usability evaluators' interest [7]. By contrast, the less popular protocol method, RTA, appears to yields more elaborate and explanatory data as the RTA participant is not under strain and instead is free to think aloud naturally during the retrospective phase [7]. Moreover, since the participant is free to perform the tasks without the need to think aloud, the risk of reactivity is eliminated. As mentioned earlier, however, RTA reports are open to information loss and post-hoc fabrication.

There have been a small number of attempts to compare CTA with retrospective protocols [e.g. 12; 9; 23]. So far, most studies of CTA have compared its effectiveness to that of usability evaluation methods such as heuristics or walkthrough evaluation methods [13; 14]. The few studies that do evaluate CTA and RTA methods reveal little evidence of a difference between the two, describing them as comparable methods. However, these studies are limited, as is shown in a review by [15], by their failure to consider the nature of the problems detected; poor experimental design; and the omission of representative participants and realistic tasks.

2.1 The Present Study

The purpose of the present study was to investigate the utility and validity of two think-aloud usability testing protocols – CTA and RTA methods – taking into account the limitations of the above-mentioned studies. Based on previous research, the following hypotheses were proposed:

H1: RTA will outperform CTA in revealing more usability problems.

H2: There will be no difference in terms of task performance between the two conditions.

H3: Participants will be more satisfied with RTA.

3. METHODOLOGY

3.1 Study Design

This study involved a between-group design to prevent irreversible carry-over effects between the compared conditions. Participants were divided into two groups. The independent variable was the think-aloud method: one group of participants was allocated to CTA, and the other to RTA. The dependent variables were the usability problems that were discovered, task performance data, and participants' testing experiences. The effectiveness of the TA methods under study was evaluated based on the number and severity of problems discovered through each method. Task performance was measured by the time needed to complete a task and task success. Participants' testing experiences were evaluated via a post-test questionnaire which participants were asked to fill in; the questionnaire was developed based on previous research [7; 16] and consisted of rating scale questions. Participants were asked to rate on a five-point scale the level of ease they felt when participating in the testing session, their comfort, their convenience, the degree to which they felt at ease when concentrating on the tasks, the degree to which they felt at ease when remembering to think aloud, and their willingness to participate in a similar test in the future.

3.2 Selection of Test Object

The University of East Anglia (UEA) Ticket Bookings website was chosen to be the targeted object for the experiment in this study (www.ueaticketbookings.co.uk) (Figure 1). The UEA Ticket Bookings (UEA-TB) website is a commercial website overseen by the UEA Box Office. Its commercial services, which mainly target students but can also be accessed by the general public, include booking tickets and buying items such as UEA hoodies. The UEA-TB website was chosen for this study due to its interactive interface with multiple functions, processes, and features. The representative users of this website are easily accessible (as they are university students), which will assist in recruiting representative participants who actively use the targeted website. In addition, since the UEA-TB website is a significant element of UEA student life during the academic year, improving its usability may lead to increased student satisfaction.

FIGURE 1: Test Object.

3.3 Designing Tasks

It is vitally important that tasks in usability studies represent the activities that end users would complete when using the test website to accomplish specific goals [17]. To this end, the first author interviewed two UEA students who had previously used the UEA-TB website to gain insight into how users use the website in order to create representative tasks. The interviewer employed a semi-structured interview technique by directing the interview to a general discussion about users' activity on the UEA-TB website, thus allowing the interviewees some freedom to express their opinions and giving the interviewer a deeper understanding of their responses. The interviews took place in a meeting room at the UEA and lasted for about 15 minutes each. The interviewees allowed the interviewer to take notes and record the conversation, which helped the interviewer to summarise the interviews. Based on the information acquired, six tasks were created: logging in, updating an address, adding items to the basket, editing basket, simple searching for events, and advanced searching (see Appendix B). All tasks were designed to be carried out independently from one another, meaning that even if a task was not completed successfully, participants could still carry out the other tasks. The tasks were also subjected to four pilot tests prior to final testing to ensure that they were free from bias and ambiguity. During the experiment, the six tasks were presented in ascending order of difficulty. The researchers were aware that participants might initially have felt nervous, and therefore ensured that the first task was the easiest in an attempt to help participants to overcome the pressure and cope with the tasks.

3.4 Participants
The number and backgrounds of the participants who used the TA methods under study to evaluate the UEA-TB website were carefully considered in order not to influence the results obtained. The ideal number of participants in usability testing has been the subject of much debate. Some researchers state that three participants are sufficient to identify about 50% of the most important usability issues [18], while others suggest that five participants can find 80% of all usability issues [19]. However, it is arguable that these numbers are not applicable to the current study, as its aim is to compare the effectiveness of two usability testing methods rather than to detect usability issues using a single method. Therefore, with consideration to time constraints and to enhance validity, 30 participants were engaged in this study, with 15 participants assigned to each method. The researchers ensured that the participants were a representative sample of university students and were interested in the test website via an online pre-test questionnaire (Appendix A) which gathered information about their background and web usage. Participants were divided as evenly as possible in terms of gender and online usage experience, and received a £5 shopping voucher as a reward for their participation.

3.5 Resources and Equipment
All testing sessions were conducted in the same laboratory at the University of East Anglia. Participants used the same lab computer which had a high-speed connection to the Google Chrome browser, an external microphone, and a large screen to ensure that even sight-restricted participants could see the website content. ScreenPresso software was used to record the participants' screen footage and their verbal comments. Other resources included a consent form, tasks sheet, an observation sheet (Appendix C) on which the test facilitator (first author) took notes, and a timer.

3.6 Experimental Procedure
This study was approved by the UEA Ethics committee. Each testing session began with the test facilitator welcoming the participant to the lab and then asking him/her to read and sign the consent form before starting the test (Figure 2). The consent form explained the aim of the study and informed the participant that s/he would be observed and his/her voice and screen actions would be recorded during the session. Next, the participant was asked to fill in a background questionnaire. The participant was then given two minutes to familiarise himself or herself with the lab computer. On completion of this step, the participant was given a task list and was asked to perform each task in sequence on the test website. CTA participants were asked to think aloud while performing the tasks, whereas RTA participants were required to perform all tasks silently and, once they finished, were invited to verbalise their thoughts on a video recording their performance. During the test, the facilitator strictly followed Ericsson and Simon's [6] guidance, and only issued a think-aloud reminder if the participants fell silent for 15 seconds; there were no other interactions. The observation sheet was used to record the following information: time spent

on tasks (in seconds), task completion rate (successful or unsuccessful), usability problems discovered, type of test, participant's identification number. At the end of the session, participants in both conditions were requested to fill in the post-test questionnaire and were then thanked and permitted to leave.

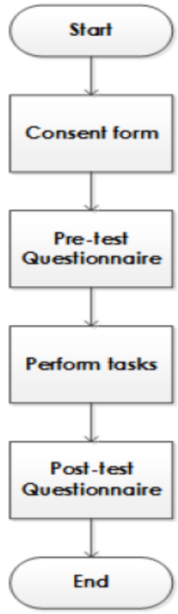

FIGURE 2: Experimental Procedure.

3.7 Piloting and Correction

Prior to the actual experiments, a pilot study was crucial for testing and refining the study procedure and its instruments. As suggested by [20], four participants were recruited to conduct the pilot test. These participants had similar characteristics to the participants in the main experiment, but did not participate in the main study. The pilot test revealed that some tasks were ambiguous and were not clear enough for the piloting subjects. As a result, these tasks were reworded and clarifying information was added. The pilot study also helped the researchers to enhance the content of the consent form. All other aspects of the pilot test went smoothly and remained part of the actual experimental procedure.

4. RESULTS

4.1 Usability Problems

Overall, 53 problems were extracted from the test sessions files of both think-aloud (TA) conditions (Figure 3). The CTA condition generated 45 problems, 33 of which were unique to that condition, while the RTA condition yielded 20 problems, 8 of which were unique to that condition. Thus, both groups commonly identified 12 of the total number of problems (see Appendix D).

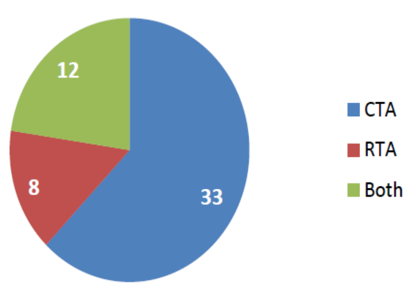

FIGURE 3: Unique and Shared Usability Problems.

As shown in Table 1, t-test suggests that the difference between the two methods' performance in terms of finding usability problems is significant, CTA appeared to be more effective than RTA in detecting problems.

CTA		RTA		Value
Mean	SD	Mean	SD	
16.8	6	9	3.3	(p= 0.01)

TABLE 1: Number of problems detected per task in both testing methods.

According to [21], usability issues can fall into one of the following categories of severity: minor, major, and critical. To ensure an objective assessment of the problems discovered in this study, the researchers asked a usability expert with a PhD degree in usability evaluation to rate the final set of usability problems discovered by the two groups. The expert was asked to rate severity of the problems based on their frequency, impact and persistence, as suggested by [22]. The 45 usability problems discovered by the CTA group were classified by the usability expert into 17 minor problems, 20 major problems and eight critical problems. The 20 problems discovered by the RTA group were classified into five minor problems, eight major problems and seven critical problems. Interestingly, there were no significant statistical differences found between the groups' performance in terms of the types of problems found.

A number of researchers claim that a group of five participants is able to find 80% of usability issues [19]. To further examine this controversial issue, a detailed analysis was undertaken to find out the relationship between the number of issues found and the number of participants in each TA group. It was found that the first five participants in the CTA indeed found just under 80% of the total number of usability problems identified by their group, and that the first five participants in the RTA found 85% of the total number of usability problems identified by their group (Figure 4). The researchers also found that the last three CTA participants and the last four RTA participants could not identify any new usability problems whatsoever, as they only discovered what had already been identified by their predecessors. In total, 12 CTA and 11 RTA participants were able to discover all reported problems.

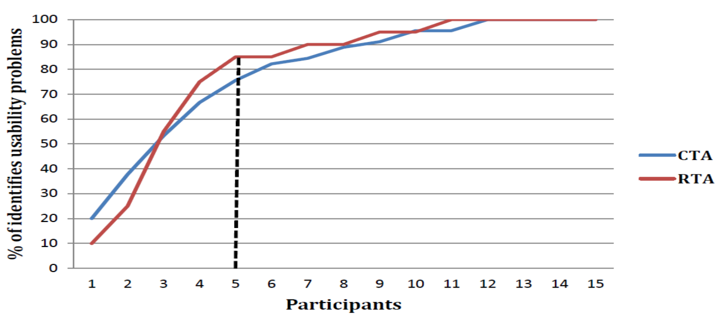

FIGURE 4: Relationship between usability problems found and number of participants.

4.2 Task Performance

Each participant was asked to perform six tasks on the UEA-TB website, meaning that a total of 90 tasks were performed by each group. Participants in the RTA group successfully completed 86 out of 90 tasks, whereas participants in the CTA group were able to successfully complete 83 tasks (Table 2). On average, 93% of the tasks were completed successfully. Participants in the CTA condition completed 5.53 out of the six tasks, in contrast to 5.73 by participants in the RTA condition. The RTA group spent a total of 6206 seconds on the tasks, while the CTA group spent a total of 7175 seconds on the tasks (Table 3). Nevertheless, an independent t-test found no significance differences between the two TA groups on any of the performance measures (Table 4).

Method	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Total
CTA	15	15	15	14	13	11	83
RTA	15	15	15	14	15	12	86

TABLE 2: Number of tasks completed successfully.

Method	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Total
CTA	1106	1231	764	742	1897	1435	7175
RTA	720	967	696	540	1671	1612	6206

TABLE 3: Time spent on tasks in seconds.

	CTA		RTA		P Value
	Mean	SD	Mean	SD	
Completion rate	5.53	0.74	5.73	0.59	ns
Time on tasks	478	87	414	159	ns

TABLE 4: Task performance measures.

4.3 Participants' Experiences
Figure 5 shows participants' ratings of their experiences. A Mann-Whitney test found no differences in testing experience between the two conditions. The CTA and RTA groups gave similar ratings for the ease of the experiment, the ease of concentrating on the tasks, the ease of thinking aloud, the level of distractions caused by the evaluator, and their willingness to participate in similar experiments in the future.

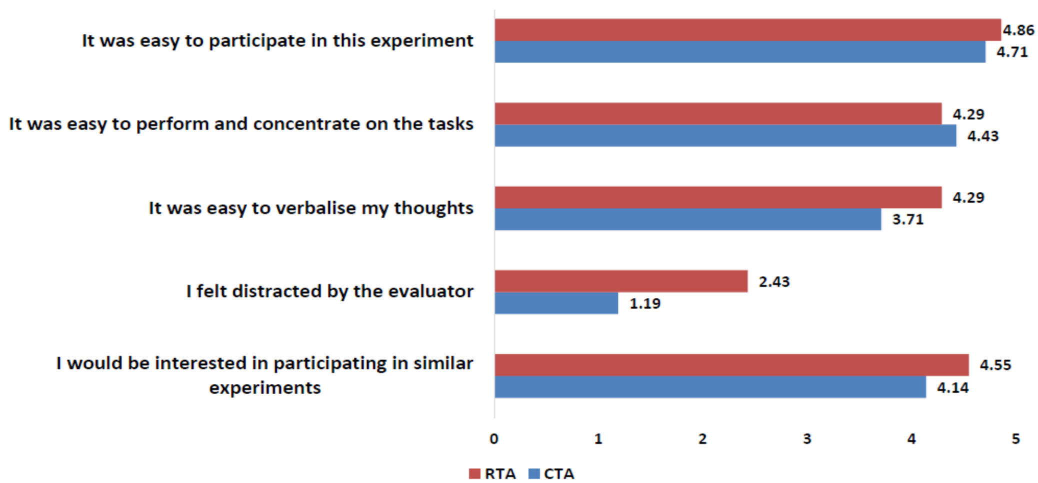

FIGURE 5: Average subjective ratings given by participants.

5. DISCUSSION AND COMPARATIVE EVALUATION
For maximum reliability, this study followed a systematic approach recommended for use in usability studies. The number and characteristics of test participants, number of tasks, targeted object and evaluation measures all were taken into consideration in order to eliminate any factors that might have affected the results. The following provides a discussion of the study results and a comparative evaluation of the findings with other empirical studies in the field.

The first hypothesis of this study was rejected, as the CTA method was found to be more effective than the RTA method at detecting usability problems. A possible explanation for this finding may be that asking the CTA participants to think aloud while performing the test tasks afforded them the opportunity to report usability problems as soon as they arose, whereas the

RTA participants were more likely to forget usability problems during the retrospective phase even though they may have noticed them during the performance of the tasks. This result is in line with the findings of [23], who concluded that CTA testing outperformed RTA testing in identifying usability problems. This finding lends support to Ericsson and Simon's [6] argument that vital information may be lost in the case of retrospective research. This would cast doubt on using the outcome of a RTA evaluation as an overall indication of the usability of the test object that is being assessed.

The second hypothesis of this study was accepted, as an independent t-test found no differences between the CTA and RTA conditions, neither in terms of successfully completed tasks nor in terms of the time it took the participants to complete the tasks. This suggests that the task performance of the participants in the CTA condition was not affected by the double workload of having to think aloud and carrying out the tasks at the same time. This finding supports Ericsson and Simon's argument that thinking aloud does not have an effect on task performance [6], and in agreement with [12]. Task performance outcome in CTA testing can, therefore, be regarded as a valid representation of the behaviour of real-life users. With regard to the third hypothesis, the hypothesis was rejected, as CTA participants appeared to have the same experience as those in the RTA condition. For the CTA condition, this means that participants were not affected by the dual-task. Nevertheless, this result should be accepted with some caution, as it is primarily based on participants' subjective rating and may be biased due to factors like social desirability [7]. This finding echoes that of [12] but conflicts with [9] who found that RTA participants reported more satisfaction than CTA participants. One possible justification for this difference may be the latter study did not take steps to control the participants' individual differences by matching them as closely as possible between conditions as in the case of this study.

5.1 Limitations and Future Work

As with any research, this study has its inevitable limitations. However, these limitations may represent opportunities for further work. First, this study used a between-group design which did not allow for a rigorous control for individual differences and their possible effects on think-aloud performance. Second, this study only focused on CTA and RTA methods. For future expansion, the researchers are currently working on a study combining both methods into a single method and comparing that combined method with both CTA and RTA.

6. CONCLUSION

The aim of this study was to provide usability evaluators with a better understanding of the utility and validity of the CTA and RTA testing methods in collecting usability data, with a view to contributing to existing knowledge on TA approaches and helping evaluators to make more informed decisions about which TA method to use in particular contexts. The results of this study indicate that thinking aloud did not lead to reactivity under CTA conditions; however, CTA significantly outperformed RTA in terms of the number of usability problems discovered, although no statistically significant differences were found in the types of problems detected. The participants in the two groups were equally satisfied with the methods under study. The CTA method would, therefore, seem an appropriate method for usability testers who are interested in detecting as many usability problems as possible, regardless of the types of the problems found. If usability testers are interested in portraying user performance as it might occur in the real context of use, they have the choice between using the CTA method or the RTA method. Overall, taking the results obtained and practical considerations into account such as time taken to complete study, a case can be made for preferring the CTA protocol to the RTA protocol in usability evaluation studies.

7. ACKNOWLEDGMENTS

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APPENDIX A: Background Questionnaire

ID ……..

Please circle/underline your answer of following questions:

1. Age:

18-21 22-25 26-29 30+

2. Gender:

Male Female

3. What is your first language?

…………………………………………………………………………………

4. What is your nationality?

…………………………………………………………………………………

5. What is your current education level?

Undergraduate student

Master student

PhD student

Other (please specify)

…………………………………………………………………………………

6. How long have you been using the Internet?

Less than a year 1-2 years

3-5 years More than 5 years

7. On average, how many hours a day do you use your WWW browser?

Less than an hour 1-2 hours 3-4 hours 5+ hours

8. Have you ever visited UEA Ticket Booking website?

Yes No

9. Have you ever participated in a usability testing experiment?

Yes No

APPENDIX B: List of Tasks

1. Login in UEA ticket booking website by using email address: thmmr@hotmail.com and password: a2014a.

2. Update your address to House Number: 37 City: Norwich, Street: Caddow Road County: Norfolk, Postcode: NR5 9PQ Country: United Kingdom.

3. Find the artist "Motorhead" and add it to your favourite.

4. Find the venue "The Talk" and view its contact details.

5. Find "Unisex Grey T-Shirt", add 3 size medium (include postage and packaging inside UK) and 2 size XL (include postage and packaging inside UK) to your basket.

6. Find all events that will take place in venue: the Aquarium/The Zoo, Lowestoft, during: August.

APPENDIX C: Usability Observation Sheet

Usability Test Observation Sheet

Participant's ID No.: …… TA Method Type: ……… Date: …………

Session Starts at: ………. Session Ends at: ………

Task #: …1….

Time on tasks: …….. No. of clicks: …..

Task Completion Rate:

❑ Successful ❑ Unsuccessful

No.	Usability Problems Discovered
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Notes: ……………………………………………………………………………………
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APPENDIX D: Usability Problems List

Method: C=CTA; R=RTA; B=Both
Severity: 1=Minor, 2=Major; 3=Critical

#	Description	Method	Severity
1	Too many links on home page.	C	1
2	Log in link is not on the top.	B	2
3	Log in link is not clear (small).	C	1
4	No welcome message nor user's name shown as a proof of a successful logging in.	C	2
5	Too many and too small pictures on home page.	C	2
6	Too much content on home page (difficult to scan).	C	2
7	Some of the text on the address page looks like clickable links.	C	1
8	Confusing labels/names for address fields	C	1
9	On the address page there is a "View" current address link and an "Add new address" link, but there are no direct links for updating or deleting a current address.	B	2
10	The link "View" next to the user address is confusing. Users think clicking this link will open a map.	C	1
11	Font size is too small on the address page.	B	1
12	County field should be optional (not required). House no., street name, city and country fields are enough.	C	1
13	Should allow searching for address through postcode and house number.	R	1
14	Main menu font is too small.	R	2
15	Search option on home page is not comprehensive.	B	3
16	No comprehensive search tool.	C	3

17	There is no "Add to basket" button on the item pages.	B	1
18	The button "Buy now" does not comply with what it says (it only adds items to basket).	C	2
19	When items are added to basket, an ambiguous message appears "5 minutes left before your reserved tickets ...etc."	C	2
20	On the basket page, there is a "Back to Events" button. The basket page should include a "Back to Shop" button.	C	1
21	Confusing instructions on product pages: "Choose delivery and then at next stage choose (collection) - to avoid a double delivery charge".	C	3
22	Quantity field on item page should be changed to a drop-down list.	B	1
23	There is not enough of a breakdown list for the total cost on the basket page (should present delivery cost).	C	1
24	Too many options on item page (a list of 16 options to choose from).	R	3
25	Too much text on artist page.	C	1
26	Small font size on artist page.	C	1
27	Favourite tab on customer zone menu is too close to "Add to favourites" button on artist page, which causes some confusion.	R	2
28	Adding the artist's logo as well as the artist's name would simplify finding an artist from the artist list.	C	1
29	No contact details on Venue Contact Details page.	B	3
30	Low contrast between main menu font and background colour (sidebar links stand out more than main menu).	C	3

31	On the Venues page, a disturbing message appears every time users hover over the venue links.	C	2
32	No search tool to search for venues by name.	B	2
33	Events page is not well organised.	C	2
34	Too many pictures on the Events page (difficult to access via slow internet connection).	C	2
35	Too much scrolling on the Events page.	C	2
36	No "back to top" button after scrolling down a long way.	C	2
37	Too many options on advanced search options.	C	2
38	Inconsistency on options layout (difficult to scan).	B	2
39	No enough spaces between search options.	C	1
40	Some tick-box labels are partially overlapping.	C	3
41	Venue names on advanced search are not sorted in alphabetical order.	C	1
42	No validation on data entry on advanced search ("from" and "to" date fields).	R	3
43	Confusing to have two buttons next to each other: "View all" and "A-Z"; they both have the same functionality.	C	2
44	On the Venue Address page, the text is duplicated.	B	2
45	Some pages are broken and a message is shown: "the code, which causes an error".	B	3
46	Once advanced search is opened, there is no button to close it.	C	2
47	Duplicate map on one page (one is too small).	B	3

48	No confirmation messages after completing certain tasks (e.g. updating address).	C	2
49	In main menu "Customer Service" is not properly worded. It should be changed to "Contact us".	C	2
50	No "FAQ" link in the main menu (nor in footer).	R	2
51	Low contrast between the colours of the website elements (header, body, and footer).	R	1
52	Some icons such as "Add to favourites" are static. The "Add to favourites" icon does not change even if the artist is added to favourites.	C	1
53	Even though the website contains too much content, about 40% of the screen width is wasted on the margin	R	3

User Interface Context of Use Guidelines for Mobile Apps

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Abstract

Due to the intensive use of mobile devices and the variable context of use, mobile apps user interface guidelines that take into account users' context of use is in urgent need to provide users with a good user experience while on the go. The objective of this paper is to propose context of use mobile user interface design guidelines and test their applicability on the design of a mobile version of an environmental e-government website. We collected a group of user interface design guidelines from different sources in the literature and linked them to the appropriate context of use, while some guidelines were linked to more than one context of use. An expert user, with no design experience used the proposed guidelines to design the mobile app. We conducted usability tests of the mobile app using two methods of testing: performance measurements and subjective measurements. To perform the performance measurement, we gave nine tasks to each of the 15 users and gave two questionnaires to each user to perform the subjective measurement. The results showed the following: the mobile app that was designed using the proposed guidelines—which the users tested while moving between different simulated environmental conditions—performed tasks in a similar time to the expert. This finding supports the applicability of the proposed guidelines in terms of designing mobile apps that will provide users with a good user experience. Thus, the proposed guidelines for designing a context-aware mobile app user interface were useful for producing a good user experience using the mobile app.

Keywords: User Interface Design, Contextual Design, Human Computer Interaction (HCI), Context Aware, Context of Use, Mobile User Interface Guidelines, Mobile Apps.

1. INTRODUCTION

The past couple of years have witnessed an exponential growth in the use of smart phones and their applications for different purposes. The always-on nature of mobile phones, the ability to communicate anytime and from anywhere, and the continuously increasing support features that are available mean that these devices are able to provide the critical information users need in emergencies. Mobile devices have expanded in functionality from being merely a device that dials numbers to being a personal digital assistant. In comparison to laptop computers, they are smaller, cheaper, and continuously improving. Furthermore, their features allow users to use take advantage of them during many of their transactional daily activities in many areas such as learning, services, security, and banking [1]. The mobility of telecommunications and the support of many communication services are two distinct advantages of mobile communication devices [2].

Although one of the biggest challenges in designing a mobile version of a website is the context in which it will be used, developers sometimes ignore the fact that users will want to interact with such devices while on the move [3]. As mobile devices are designed to enable users to use them while mobile, the ability to use a website while mobile is a critical factor in its success or failure, especially for websites that have important information and must be used accurately [3]. Some of the issues that need to be considered when designing for small, portable devices are small screen sizes, limited connectivity, high power consumption rates and limited input modalities [3].

Web use on a mobile device is different than Web use on a desktop computer because the goal for designing mobile versions is to downscale the full version of a website to fit the mobile screen and decide which content, services, and functions to keep from the desktop website [4]. The effectiveness and benefits of mobile phone technologies has exceeded expectations, and the need for designing mobile versions is increasing due to the fact that the different contexts of use that occur while using them are affecting their usability [4]. Although the mobile devices and wireless technology are being upgraded, providing a variety of functionalities, Web browsers try to solve interaction problems that occur when small-screen devices are used to access Web pages designed for large screens. Browsing large Web pages is not adapted for small-screen viewing and is still very inconvenient [5]. The small display size of mobile devices limits their ability to transmit information effectively in comparison with desktop computers regardless of the increasing quality of displays [5]. The user interface is one of the most important parts of any program because it determines how easily you can make the program do what you want [6]. A well-designed and usable mobile-versions interface is critical since mobile-device interface design is more restrictive than desktop interface design. The most challenging problems facing mobile interface designers include [7]:

- constantly changing context of usage;
- limited user attention given to the device and application;
- mobile device user's hands are typically occupied with other physical tasks;
- high mobility during tasks as well as the need to adopt a variety of positions and postures; and
- interacting with devices while in motion (at high speed), driven by the external environment.

2. CONTEXT AWARENESS

Dey and Abowd (2000) defined context as: "Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."

There are many types of context such as location, identity, activity (or environment), and time [8]. Context includes lighting, noise level, network connectivity, communication costs, communication bandwidth, and even the social situation [9].

Context-awareness is often defined in relation to an application or a computational service, which includes the ability to detect and sense or to interpret and respond to the characteristics of a user's local environment [10]. It is also defined as a state where the device is aware of the situation in which it is being used [11]. Context-aware applications look at the who's, where's, when's, and what's of the entities and then use the information to determine why the situation is occurring [8]. This technology has gained an increasing amount of attention in recent years; it may offer solutions to more efficient use of mobile applications and services while the increasing complexity and growing number of features set challenges to intuitive and easy-to-use devices [11]. It has appeared as an important and eligible feature in distributed mobile applications, which deal with the ability of applications to exploit information about the user's environment (context) in order to dynamically select and execute relevant services that better match the user's needs [12].

A context-aware device can infer the use condition, and adapt its behavior according to the circumstances [11]. Mobile handheld devices constitute an interesting platform for context-awareness because they have been highly adopted by large user groups especially in the form of mobile phones [11]. They are used in different kinds of situations, different users' preferences, and different prioritized features [11].

Context awareness can facilitate the device's use in demanding situations by dynamically adapting the devices' behavior by appropriate means [11]. In short, context-awareness aims to provide users with better services and adapt the behavior of the device by using and handling the contextual information.

Exploiting the changing environment with a new class of applications that are aware of the context in which they are running is one challenge of mobile distributed computing [9].

The context of use of the mobile devices has deep effects on interaction when considering users on the move, instead of users using devices (mobile or not) while sitting at a desk in their office or home. These effects show at different levels [13]:

- Perceptual: there are physical parameters of the mobile user's environment, such as illumination, noise, temperature and humidity, vibration and motion, etc., which are extremely variable, limiting, and can exclude one or more modalities.
- Motor: mobile conditions can harm a user's ability to control her/his controlled movements or take specific attitudes (e.g., standing) that interfere with motor operation of the device (e.g., time and errors in selecting options and the effectiveness of using writing recognition or gesture recognition software).
- Social: even when using specific forms would be perfectly possible from a perceptual and motor point of view, social norms related to different environments may make it impossible or unadvisable. For example, keeping sound on at a conference is not accepted, while looking at the device screen is accepted.
- Cognitive: unlike the office and home environments, people in mobility conditions can apply only very limited attention to interact with applications on the device because they have to focus on a constant flow of events and stimuli that come from the environment. Some of these events can affect personal safety (e.g., noticing potential dangers while users are in a street).

According to Al-Nuaim (2014), the challenges of the context-aware issues that designers face can be categorized into three groups:

- the mobile device and user behavior while using it;
- the usability of the mobile website design; and
- the user interaction with the mobile website.

Therefore, the general needs of a context aware system are [14]:

- context acquisition: how to obtain the contextual information;
- context representation: how to organize and store the context information; and
- context use: how to use the context information in an appropriate manner.

Content adaptation is a key part in the process of designing applications because we have to adapt the content presentation to meet the user preferences and the different capabilities and limitations of mobile devices and wireless technologies that are used by different users [15].

A user interface designed for a mobile device is the main concern in designing applications [16]. While there has been success in developing rules to guide the design and implementation of interfaces for desktop machines and their applications, the design of mobile device interfaces is still relatively unexplored and unsupported [17]. Many public and private entities design mobile apps of their websites without basing their design decisions on powerful design approaches because there is a lack of research concerned with finding guidelines, practices, and recommendations for designing usable mobile apps [4].

There are many user interface design guidelines available within the literature for designing mobile apps but they do not address or are not linked well to context of use. We need clear and easy to apply design guidelines for mobile apps to maintain a good user experience for users when they use their devices while on the move and in different environment conditions; especially if they use the app in urgent situations or need critical information for their safety.

Due to the intensive use of mobile devices and the variable context of use, mobile apps user interface guidelines that take into account users' context of use is in urgent need to provide users with a good user experience while on the go. The objective of this paper is to propose context of use mobile user interface design guidelines and test their applicability on the design of a mobile version of an e-government website (Presidency of Meteorology and Environment) in the Kingdom of Saudi Arabia.

Due to the mobile devices properties, which differ from the desktop counterpart, such as being small, desktop websites are altered to fit a mobile's small screen. If they are left unaltered, this will lead to scrolling up and down or right to left. Therefore, there is urgent need for mobile apps design guidelines to adapt the websites within displayed mobile devices. The lack of the research in mobile web design guidelines made it necessary to collect guidelines from the literature that can address the context of use and design mobile apps that provide users with a good user experience while mobile.

According to [18], there are some attributes of usability that should be considered:

1. **Learnability:** It refers to how easy is the website for users to accomplish basic tasks the first time they encounter the design so that the user can rapidly start getting work quickly with it.
2. **Efficiency of use:** Ease of the website means how much time and effort is required for users to achieve their objectives when using the website.
3. **Memorability:** It means is it easier for the users to navigate the website next time if they have visited the website before because of their previous experience**.**
4. **Low Error Rate:** It refers to how many errors do users make, how severe are these errors, and how easily can they recover from the errors.
5. **Subjective Satisfaction:** It means how do users feel about their interaction with the website, how much do they like using the it and will they return to the website or not.

3. CONTEXT OF USE

Mobile apps have different menu hierarchies, smaller sizes, and fewer images than their desktop counterparts [18]. Such design choices are necessitated by the characteristics of the client device, such as small screen size, limited input capabilities, and limited Internet connection speed, thus potentially leading to increasing usability problems [18] [19].

The characteristics of locations where the mobile phone use may take place, such as home, work, on the move, alone or with others may include several types of distractions like background noise, ongoing conversations, cars and people that pass by, and so on [20]. These distractions require the user's visual, auditory, and/or cognitive resources, which are also necessary for the mobile web-browsing task [20]. The competition between the task that the user will do and the distractions may reach a point where the user's awareness, memory, and attention resources are overloaded, thus decreasing user performance and, hence, the usability of the Web-browsing tasks [20].

Context of use must contain the characteristics of the intended users, the tasks users will perform, and the environment in which website visitors will use the system [21].

Juha et al [22] have developed the project "Kontti – Context-aware services for mobile users". The project was part of the "NETS Networks of the Future" research program run by the National Technology Agency of Finland (Tekes). Kekes and VTT Information Technology financed the project with three companies: Nokia, Radiolinja and Teamwave [22]. The results of the Kontti project indicated that the most promising applications for context-aware services are event guides and professional use [22]. Further, contexts can be used for opening new communication channels for messaging and as a mediator where any recipient can pick up a public message [22].

Jesper and Jeni [23] have outlined an ongoing research activity into the challenges of interaction design for context-aware mobile computer systems. They have proposed the concept of indexicality as an interesting new approach to the interaction design for this emerging class of mobile systems, and have outlined three examples of context-aware prototype systems where this concept has been deployed in practice and evaluated through user studies [23].

The key requirement to develop and deploy a Context Aware Mobile Government Application is presented by Ariza Avila [14]. The Context Management application was developed using open standards to communicate with other applications. A real scenario in Vila Nova de Cerveira was also modeled and represented [14]. Vila Nova de Cerveira is a municipality in the district of Viana do Castelo in Portugal. In this scenario two hundred and twenty objects were modeled including public equipment, relationships and services [14]. They faced some challenges in the development process such as how the context aware application must interact with the Context Manager application [14]. One of the advantages of the researcher's general approach is the freedom to use the Context Manager in several ways, by modifying or creating new interaction models and by adding different selection algorithms for object querying [14]. The researcher faced another challenge in the deployment of the solution which was the provision of context information which is obtained the location context dimension of mobile phones by the cell identification from the mobile phone 56 operators [14]. The solution for the location information was to create a service that feeds the location to the model using as a source GPS embedded in the mobile device [14].

Jonna H. [11] had studied the user interaction issues related to context-aware mobile devices by conducting several case studies, which relate to location-awareness, information sharing and collaboration, privacy, and end-user programming with context aware mobile applications. These studies were used as the basis for developing design guidelines, which were then evaluated and iterated. The revised guidelines seek to offer some tangible help to designers, who are not necessarily specialized either in context awareness or interaction design [11]. The design guidelines include factors related to the uncertain character of context awareness [11]. The user maintains control over the device in any situation because an appropriate level of automation for executing actions needs to be selected, and user control secured [11]. In relation to the uncertainties in context recognition, user control and user's interruptability must be balanced and appropriate visibility to system status provided [11]. As context-awareness may generate or offer access to large amounts of data or services, it is important also to avoid information overflow [11]. Moreover, the application design should respond to the user's needs on personalization and privacy, and to take into account the restrictions of the social context of the use situation [11].

Oscar L. [25] provided some suggestions on interface design for mobile devices which were results from the design process of a prototype for mobile shopping. Additionally, the evaluation of a number of guidelines and methods for usability would show which could be used most efficiently [25]. The tests and evaluations of the prototype provided suggestions for the improvement of the prototype [25].

4. GUIDELINES FOR DESIGNING MOBILE APPS

According to Al-Harigy (2014), fifty nine guidelines were filtered from different user interface design resources and collected for designing applicable mobile apps that would address ten different contexts of use to insure good user experience while using the mobile apps, especially when the user is not in an ideal situation. These guidelines are as follows (while the details of the sources, justifications for using them, and the descriptions of each are explained in AlHarigy (2014)):

Guidelines (GL) 1: Analysis Guidelines

- GL 1.1: Know your users [24]; [25]; [26].

- GL 1.2: Determine the purpose of the site / service and identify the primary goals of the website before beginning the design process [27]; [28]; [29].
- GL 1.3: Decide whether you need more than 1 mobile site [30]; [28].
- GL 1.4: Quick access to the full site and back [31]; [28]; [32].
- GL 1.5: Ensure the site information is up-to-date [33]; [29].
- GL 1.6: Provide a functional bilingual website [33]; [34]; [35].

GL 2: Page Layout Guidelines

- GL 2.1: Design for portrait layout [36].
- GL 2.2: Divide the screen area into title, content, and navigation from top to bottom [36].
- GL 2.3: The main content of the screen and the most important information should be shown at the top [29]; [36]; [27]; [37].
- GL 2.4: Avoid using wide elements [28]; [36].
- GL 2.5: Minimize white spaces on the page [29]; [36].
- GL 2.6: Elements of mobile interfaces such as names, colour schemes, and dialog appearances should be the same as their desktop counterparts [28].
- GL 2.7: Place a logo or logos in a consistent place on every page to ensure users are fully aware they are on your website [27]; [33]; [28]; [35].

GL 3: Guidelines for Using Colors

- GL 3.1: Limit the number of different colors used on a page [36].
- GL 3.2: Use colors meaningfully [36].

GL 4: Simplicity and Clarity Guidelines

- GL 4.1: Avoid visual noise and clutter [29]; [36].

GL 5: Consistency Guidelines

- GL 5.1: Maintain consistency with the platform of use [29]; [36]; [35].
- GL 5.2: Apply consistent design and layout throughout the site [36]; [35].

GL 6: Content Selection Guidelines

- GL 6.1: Ensure that content is suitable for use in a mobile context [36].
- GL 6.2: Provide content that is engaging, relevant, and appropriate to the audience [29]
- GL 6.3: Only the most relevant and essential information should be shown [36]; [28].
- GL 6.4: Use clear and simple language [36]
- GL 6.5: Provide a short but descriptive page title [36]

GL 7: Visual and Interaction Design Guidelines

- GL 7.1: Select the font and background color that provide sufficient contrast and would not hamper the visibility of text or links [5]; [31]; [35]; [7].
- GL 7.2: Keep fonts large to optimize the reading process [31]; [36]; [29].
- GL 7.3: Organize text using sub-headings and links [36]
- GL 7.4: Minimize margins [36]
- GL 7.5: Avoid having too many text styles and sizes on the same page [36]
- GL 7.6: Organize documents so they are readable without requiring an associated style sheet [29]
- GL 7.7: Ensure that text highlighting techniques are not confusable with static contents and links [36]

GL 8: Guidelines for Using Images and Icons (Graphics)

- GL 8.1: Minimize the use of images [38]; [28]; [27]; [39]; [40]; [41].
- GL 8.2: Avoid using large or high resolution images [36]
- GL 8.3: Handheld mobile device's icon design should be as direct, simple and unique as possible [7]; [38].
- GL 8.4: Icon color design cannot use more than five kinds of colors [7]
- GL 8.5: For touch phones, leave generous amounts of space around widgets such as radio buttons, arrows for dropdown boxes, checkboxes, scrollbars, and links [28]; [42].

GL 9: Guidelines for Using Tables

- GL 9.1: Do not use tables unless the device is known to support them [36]
- GL 9.2: The table width and height should not exceed the display width and height [36]

GL 10: Site Navigation Design Guidelines

- GL 10.1: Provide consistent navigation mechanisms [36]
- GL 10.2: Keep the number of levels in a hierarchical structure few in number (Use a flat hierarchy) [36]; [43].
- GL 10.3: Use links to the main screen and do not repeat the navigation on every page [36]; [32]; [44].
- GL 10.4: Use the “back” command [36]; [37].
- GL 10.5: Balance the choice between scrolling and paging [36].
- GL 10.6: Limit scrolling to one direction [31]; [36]; [44]; [39].
- GL 10.7: Minimize the amount of scrolling [31]; [36]; [29]; [45].
- GL 10.8: Limit navigation options and keep them direct [31]

GL 11: Guidelines for Managing Hyperlinks

- GL 11.1: Use text for links rather than images where possible [5]; [27]; [40]; [29].
- GL 11.2: Clearly identify the target of each link [36].
- GL 11.3: Provide large target size and padding [31]; [36].

GL 12: User Input Guidelines

- GL 12.1: Reduce or completely eliminate the need for data input, especially text input [31]; [36]; [29].
- GL 12.2: Replace text input with a list selection [36]; [28]; [29]; [46]; [47].
- GL 12.3: Automatically place a blinking cursor at the beginning of the first data entry field when a data entry form is displayed on a page [29]

GL 13: Feedback Guidelines

- GL 13.1: Indicate visited and unvisited links [36]; [29].
- GL 13.2: Provide an informative error message [36]; [29].

GL 14: Mobile Context Guidelines

- GL 14.1: Ensure that the user interface elements are clearly visible in low light [42]; [34].
- GL 14.2: Take advantage of inbuilt functionality [30]; [28].
- GL 14.3: Take into account the impact of the social context [11]; [47]; [48].
- GL 14.4: Design for limited and split attention [47]
- GL 14.5: Allow for single or no-handed operation [47]
- GL 14.6: Make sure there is an option for large font [48]

Different contexts of use that occur while using mobile apps that may affect their usability, so the mobile user interface design guidelines must take into account and address each of them. According to Kumar and Sinha (2007), we have to consider four main contexts to adapt the content. Table 1 represents the main categories of context and their related contexts of use:

TABLE 1: Main categories of contexts and their related context of use.

Main contexts	Explanation	Context of use
Personal context	Any information that is used to describe the user’s personal characteristics and information, such as name, gender, date of birth, and his service and content preferences. These contexts are user personal characteristics context, mobility context and critical time context	• User personal characteristics context: Contains the guidelines that relate to users’ characteristics, such as age, gender, educational level, and familiarity for using the mobile device that the developer needs during the analysis phase. • Mobility context: Contains the guidelines relating to using information and organizing the mobile device interface content to be appropriate to use while users are moving and engaging in daily activity. • Critical time context: Contains guidelines that relate to the use of the mobile app to find information in urgent situations that affect the users’ safety

Main contexts	Explanation	Context of use
Device context	Any information that is used to characterize the user's mobile device. It is critical to specify the user device capabilities in M-Government applications because they can have a big impact on what content is appropriate and meaningful to be delivered to the user, such as small screen context and mobile device characteristics context, content context, and interface elements consistency context.	• Small screen context: Contains the guidelines relating to the mobile device screen and its limitations, such as the design layout, margins, space between the elements, and images. • Mobile device characteristics context: Contains the guidelines relating to the mobile device characteristics and the interface design, such as using specific colors and fonts due to the device's capability. • Content context: Contains the guidelines relating to the content organization in the mobile app user interface. • Interface elements consistency context: Contains the guidelines that relate to maintaining the consistency between the interface elements through all website pages so the user feels that he/she is on the same website while navigating, such as by using the logo in a consistent place on all web pages.
Connectivity context	Specifying the type of wireless technology that the user will use because each of them has different data transfer rates such as network connectivity context.	• Network connectivity context: Contains the guidelines that relate to using specific features while taking into account the users' different connection types and ensuring the speed of loading the website pages.
Location context	Includes any information that describes the user location or any information related to location, such as lightning conditions context and social situations context.	• Lighting condition context: Contains the guidelines that relate to use specific features in designing the mobile app according to the different lighting levels while using the mobile app which affect the website usability. • Social situation context: Contains all of the guidelines that take into account the environment around the user while using the mobile device, such as the noise and the split attention.

Table 2 points to the guidelines from Al-Harigy (2014) that address the contexts of use presented in Table1. The proposed guidelines from Al-Harigy (2014) are distributed between the different contexts of use where each guideline address more than one context of use. The following relate the guidelines to the context of use issues (Table 2):

TABLE 2: The contexts of use with the related guidelines.

Context of use	Related guidelines
Users' personal characteristics context	GL#1.1; GL#1.2; GL#1.6; GL#6.2; GL#6.4; GL#7.2; GL#14.6.
Small screen context	GL#2.1; GL#2.2; GL#2.4; GL#2.5; GL#3.1; GL#4.1; GL#6.5; GL#7.1; GL#7.4; GL#7.5; GL#8.1; GL#8.3; GL#9.2; GL#10.3; GL#10.5; GL#10.6; GL#10.7; GL#10.8; GL#11.1; GL#12.1.
Mobile device characteristics Context (different screen size, supporting font type, different resolution of the mobile devices, memory size)	GL#3.2; GL#5.1; GL#7.1; GL#8.2; GL#8.3; GL#8.4; GL#9.1; GL#9.2; GL#10.4; GL#11.1.
Content context	GL#7.6; GL#10.2; GL#10.5; GL#10.7; GL#11.2; GL#13.1.
Lighting conditions context	GL#3.2; GL#7.1; GL#7.2; GL#8.4; GL#11.1; GL#14.1; GL#14.6.
Mobility context (context of use for the mobile device, such as using it while walking and moving, waiting in a queue, urgent situations, etc.)	GL#2.3; GL#3.2; GL#6.1; GL#6.2; GL#6.3; GL#6.5; GL#8.3; GL#8.5; GL#10.2; GL#10.3; GL#10.5; GL#10.8; GL#11.3; GL#12.1; GL#12.2; GL#12.3; GL#14.1; GL#14.4; GL#14.5.
Network connectivity context	GL#8.1; GL#8.2; GL#11.1.
Social situations context (such as noise level, limited attention)	GL#2.3; GL#3.2; GL#6.3; GL#10.2; GL#14.3; GL#14.4.
Interface elements consistency context	GL#2.6; GL#2.7; GL#5.1; GL#5.2; GL#8.1; GL#10.1.
Critical time context	GL#10.2; GL#12.1; GL#12.2; GL#12.3.

5. TESTING THE PROPOSED GUIDELINES

The contexts of use guidelines mentioned in Table 2 were given to an expert user with a computer Science background with no design experience to design a mobile version of the PME website. PME is a website example of a citizen-centered e-service website that is used in an emergency to provide information that users may need in critical situations. The PME desktop website was chosen for the following reasons:

- It does not have mobile version.
- It contains current updated information compared to other e-government websites.
- It has an early warning system and weather forecast features that can be used for emergency situations, such as dangerous sand storms or flooding.
- The PME website (Figure 1) contains services that could be used by the citizens on the go and in emergencies such as weather forecasts, early warnings, and emergency calls.

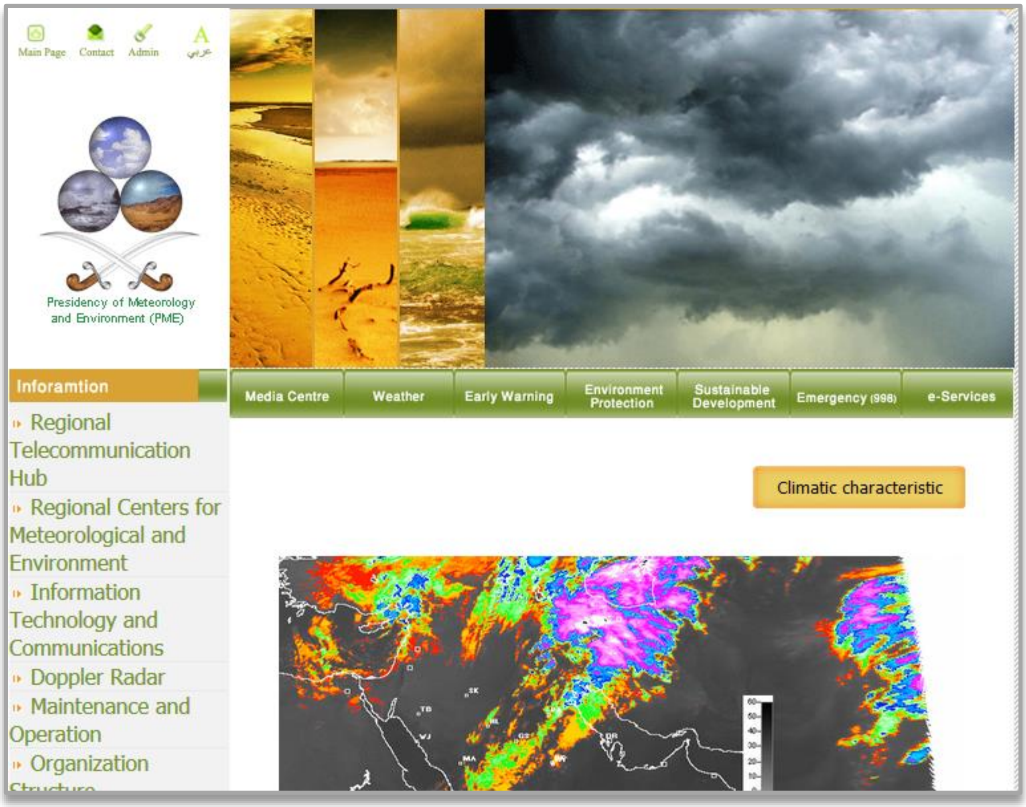

FIGURE 1: PME Desktop Website.

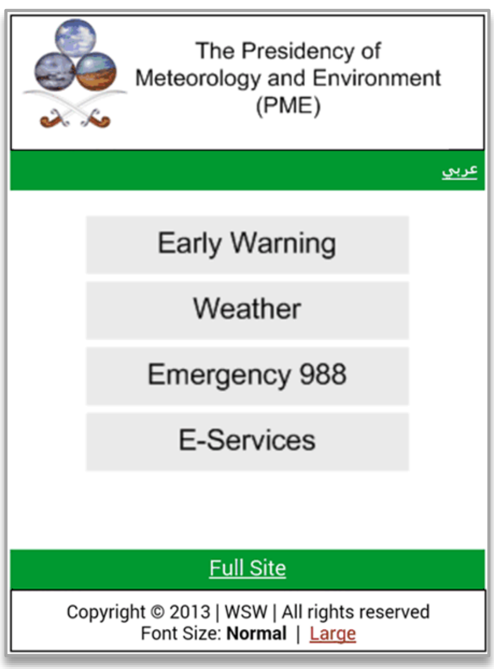

FIGURE 2: Proposed PME Mobile App.

The proposed PME mobile app (Figure 2) was designed by using Adobe Dreamweaver CS6 because it contains an HTML5 editor and it allows the developer to choose the size of the mobile interface.

According to Nielsen (2012) [18], there are five parameters for usability, as mentioned before, which covered in this research:

- Efficiency of use
- Subjective Satisfaction
- Learnability
- Memorability
- Low Errors Rate

The usability test of PME's mobile app was conducted with 15 participants who were local Jeddah citizens whose ages ranged from 20 to 40 years who had different educational backgrounds and mobile devices. An expert user with a background in computer science performed the tasks and the time measured in seconds was calculated for each task by using a stopwatch. This time was used as a base time or as a criteria for comparison. The usability test tasks were typical tasks that simulate information or broadcasts needed by users in urgent situations while they are on the move in real time. The tasks include finding all of the cities that have early warnings and their duration, as well as the description of the early warning situation in a city, emergency calls, notifications sent about incidents, locating the weather forecast for a city, and customization.

Two methods were used for evaluating the mobile app's usability: performance measures and subjective measures. Performance measures were calculated by giving a set of nine tasks to each of the 15 users to examine the mobile app calculating time on task for each user. To test the applicability of the proposed guidelines and to simulate the different contexts of use while using the mobile app, users were tested while moving in different environmental conditions (e.g., lighting, heat, indoor, outdoor, etc.). They were asked to use one hand while performing the tasks. All of the tasks were read to the users by the observer of the test because they were walking while performing the tasks.

Table 3 shows the base time and the users' time for each task. Figure 3 presents the comparison between the base time and the average time for all users.

TABLE 3: Times calculated for the expert and the users.

Users	Tasks								
	Task1	Task2	Task3	Task4	Task 5	Task 6	Task 7	Task 8	Task 9
Expert	4.3	8	1.3	1.5	6.8	10	1.3	1.9	3.86
User 1	4.11	8	3.5	1.5	9.98	12.61	3	4	4.92
User 2	4.05	5.45	3.43	1.52	8.36	17.26	1.5	2	2.88
User 3	7.18	8.47	1.61	6.06	13.63	22.14	5.63	1.65	1.95
User 4	10.8	10.55	4.45	5.29	12	18	5.56	5.9	5.5
User 5	5.18	3.71	4.14	7.35	5.19	23.28	1.51	5.13	2.44
User 6	6.65	4.52	1.66	6.72	7.54	16.77	12.18	9.16	18.37
User 7	4.16	4.24	2.39	5.42	7.05	16.85	4.47	6.46	7.56
User 8	4.75	6.18	1.31	8.14	5.8	20.54	1.69	4.83	4.63
User 9	3.24	3.28	1.64	2.5	3.89	14.62	3	1.64	3.5
User 10	3.54	4.28	2.1	4.6	4.19	10.65	2.45	2.3	3.23
User 11	7.52	6.33	1.48	8.45	8.05	23.47	6.16	11.86	2.17
User 12	8	8.36	2.69	5.59	8.45	29.48	7.39	3.81	5.32
User 13	4.14	5	1.83	6.92	6.07	19.17	2.16	7	4.2
User 14	5.34	7.5	1.69	5.4	6.5	11.31	3.23	3.12	4.7
User 15	5.3	5.2	2.1	3.4	5.1	11.54	2.34	7.22	3.2

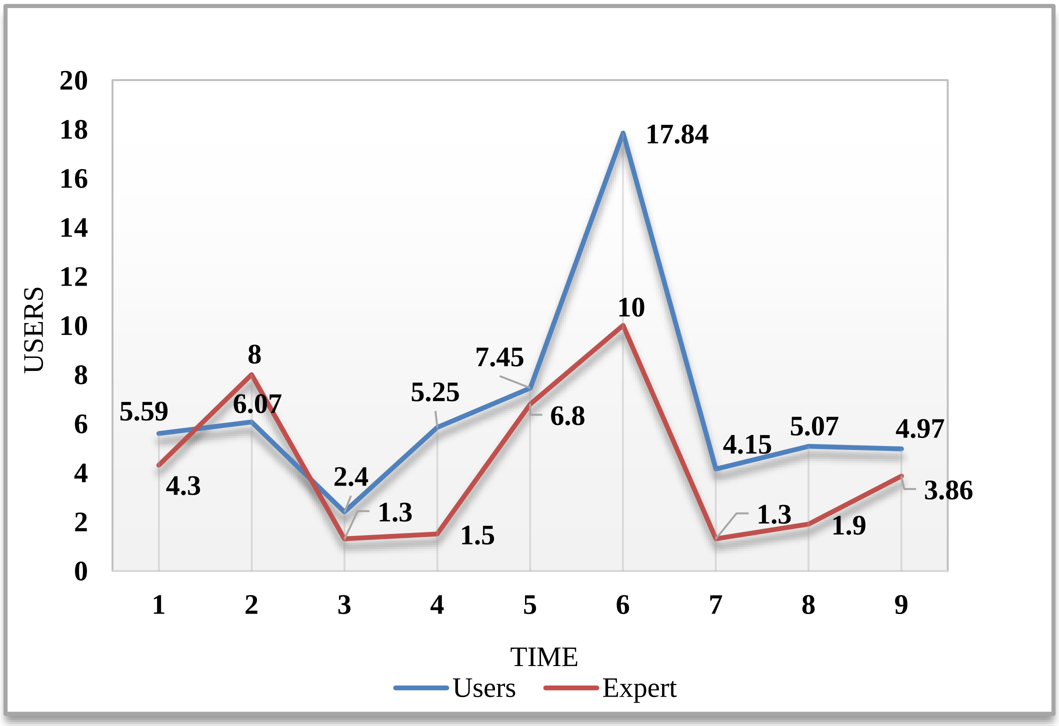

FIGURE 3: Comparison between the expert time and the users' average usage time.

Although some of the older users were not familiar with the use of mobile apps, the average time on task for all users were close to the time on task calculated for the expert. Some of the users even achieved less time on task than the expert time on task. The performance evaluation addressed four parameters of Nielsen's five usability parameters:

- Learnability: means the proposed mobile app is easy to learn for first time users and they could rapidly start working with it.
- Memorability: means that the proposed mobile app is easy to remember for the casual user.
- Efficiency: means that all the users could achieve the goal and complete the tasks accurately in amount of time close to or less than the expert's time.
- Low errors rate: means that the proposed mobile app has no error rate.

Subjective evaluations were conducted after users finished the tasks of the mobile app. The users evaluated the mobile app's user interface by giving each user a post-task questionnaire and a post-test interface evaluation questionnaire after completing all of the tasks. The post-task questionnaire was for rating each task on ease of use from a scale from 1 to 5, 1 being very easy. The post-test interface evaluation questionnaire was given to each user upon completion of all of the tasks. It contains 47 questions that are divided into five sections to rate the proposed mobile app in terms of text legibility, the effect on the content readability, clarity, ease of use, aesthetics, and overall satisfaction. All of the questions were close-ended. Each section has different rating scales according to the type of response appropriate for each item. According to the post-task questionnaire, eight tasks were rated by the users as being 100% very easy; in addition, one task was rated as being 73.3% very easy and another was designated as 26.7% easy. The subjective evaluation addressed the fifth parameter of Nielsen's five usability parameters which is satisfaction and positive attitude of the users towards the proposed mobile app. The results of the performance and subjective measurements show the satisfaction and positive attitude of the users toward the proposed PME mobile app. Thus, the proposed guidelines for designing a context-aware mobile app user interface were useful for producing a good user experience by using the PME mobile app.

6. CONCLUSION

The intensive use of mobile devices and the variable contexts of use that occur while using them deem it necessary to design a mobile app user interface that provides users with a good experience. A website designed for the desktop is not appropriate for use on a mobile device's small screen. Due to the lack of the research in mobile user interface design guidelines, it was necessary to collect user interface guidelines that are applicable to mobile user interface design and relate them to different contexts of use. The mobile user interface design guidelines that take into account the different contexts of use are especially important when users employ the mobile app of a website for their safety where errors and misunderstanding cannot be tolerated.

The guidelines collected from different literature resources and the different contexts of use that were addressed were used to design a mobile app version of the PME desktop website. The usability test was conducted on 15 users by using two methods of measurement. Each user performed nine tasks. Two questionnaires were given to the users. The usability test results show that the mobile app was designed by using the proposed guidelines while users were moving between various simulated environmental conditions in the approximate amount of time that it took an expert to complete the task; such considerations support the applicability of the proposed guidelines in designing the mobile apps. The results of the performance and subjective measurements show the satisfaction and positive attitude of the users toward the proposed mobile app of PME. Thus, the proposed guidelines for designing a context-aware mobile app user interface were useful for producing a good user experience while using the PME mobile app. For future work, we recommend to adapt the user interface according to the context of use. Although there have been several attempts to develop context-aware adaptation of mobile apps, it is not easy to develop systems that are adapted to single context of use, since none have a usable, well integrated and common solution fit for all users across many devices and platforms.

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