The Effect of Context and Application Type on Mobile Usability: An Empirical Study

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Abstract

This paper discusses the effect of context on mobile usability, proposes an expanded model of mobile application context, and conducts an empirical study to test a number of hypotheses concerning the use of software implementation technology and location context in mobile applications. Four different application types (PC web based, PC device based, mobile web based and mobile device based) were tested using a within-subjects repeated-measures design. The results demonstrate that by utilising client side processing and location context, the mobile device based application is able to achieve objective performance and subjective usability measures comparable to those of the PC based versions, despite the limited input and display capabilities of the mobile device. Conversely, the mobile web based application, which was unable to take advantage of location context or client-side application code, showed the lowest quantitative performance.

Keywords: mobile usability, context, smart clients, empirical study.

1 Usability of Mobile Applications

An investigation into the impact of mobile interfaces on the usability of mobile commerce (m-commerce) applications by Buranatrived et al. (Buranatrived and Vickers, 2002) noted that usability has been identified, second only to security, as a barrier to user acceptance. Venkatesh (Venkatesh, 2003) also looks to user experience, identifying it as an important prerequisite for the success of m-commerce applications. Furthermore, Venkatesh urges that the usability of web commerce sites should not necessarily be equated directly with that of m-commerce sites. Nielsen (Nielsen, 2003) echoes this sentiment, arguing for PC-integrated applications and specialised mobile services instead of re-purposed website content. Kiili (Kiili, 2002) found that poor usability of mobile applications in a learning environment tends to disturb the learning process, again supporting the importance of usability in the success of mobile applications.

While it appears possible to use existing usability techniques for the development of mobile applications, some unique characteristics are needed to create usable mobile applications. In her paper on mobile internet usability for mobile learning (Uther, 2002), Uther argues that some traditional usability guidelines relating to navigation, structure and error prevention can be applied to mobile applications. On the other hand, Uther believes that attributes such as limiting user input, displaying only minimal and relevant information on the screen, and the use of context, should be considered specifically from the perspective of mobile applications. Lee and Benbasat (Lee and Benbasat, 2003) identify the usability attributes of context, content, community, customisation, communication, connection, and commerce in both e-commerce and m-commerce applications. However, the process of addressing these attributes can be quite different for varying classes of application. For example, *customisation* for a web user may involve the ability of a site to self-configure based on predetermined requirements, whereas customisation for a mobile user may be based upon geographical location or the physical environment.

Having identified the importance of usability in the success of mobile applications, a number of challenges exist in their development, which may impact upon the usability of the final product. In particular, there is a significant trend towards heterogeneity in terms of both mobile devices and the communication infrastructure upon which they operate. Device variations include form factor (e.g. laptop, tablet PC, smartphone or personal digital assistant (PDA)), input mode (e.g. pen/stylus versus keypad), processing power, battery life, and screen size/resolution/colour depth. In the case of different networking technologies, variations include Bluetooth, Wi-Fi, GPRS and 3G, which can have a significant effect on the reliability of, and bandwidth available for, communications.

In addition to the diversity of hardware upon which applications can run, there are also a number of software development and delivery technologies used to implement mobile application clients. Of most interest to this paper and the empirical study presented in sections 3 and 4 is the distinction between web based clients and device based smart clients with the type of client having an impact on usability reaching

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beyond the basic effect of technology choice on the developer of the application.

In related work, Buranatrived et al. (Buranatrived and Vickers, 2002) have empirically studied the effect of device type by comparing the performance of the same J2ME application running on a PDA and smartphone. However, in that study there is no comparison of application type as it is described below and empirically tested in this paper.

Mobile web applications are similar to conventional PC based web applications, being based on the delivery of static or dynamic web content (usually a mark-up based user interface specification such as XHTML, WML or XML) from a web server to a client based browser. Mobile applications usually deconstruct tasks into a sequential process and like web pages may have a hierarchical tree-like structure, although limited input functionality may restrict navigation across the site tree. Advantages of using web-based mobile applications include easier development and simple integration with existing web applications, centralised deployment and maintenance, and lower user device requirements. Disadvantages include the requirement for constant connection to the internet, security loopholes if WAP is used as the transport protocol (Durham-Vichr and Getgen, 2001), cumbersome navigation, and limited client side functionality.

Device-based mobile applications or smart client applications are based on the installation of executable code on end-user devices. The configuration of such applications can be client only, client/server or adaptive smart client in which the division of client/server application functionality changes dynamically depending upon networking conditions or device capabilities (Ryan and Perry, 2003). Device-based mobile applications are developed using technologies such as Java 2 Platform Micro Edition (J2ME) (Sun Microsystems, 2004) or the .NET Compact Framework (Microsoft Corporation, 2004), which support a range of PDAs, smartphones and other mobile devices.

In terms of advantages, device-based mobile applications provide sophisticated interaction styles beyond the simple navigation model of web based applications. They also offer a more immediate experience since they are not so heavily bound by request/response cycles inherent in web based design. Furthermore, such applications can be used offline, with information synchronized with the server upon connection and disconnection. Disadvantages include the need for more sophisticated devices, more costly development and deployment (since existing web based applications cannot be readily ported to device based ones), additional user configuration, and problems with client-side incompatibilities.

Note that device-based mobile applications can be used in conjunction with web-based mobile applications. For example, the user can visit a WAP site to download and install a device-based application which would automatically connect to the web server for retrieval and synchronisation when required.

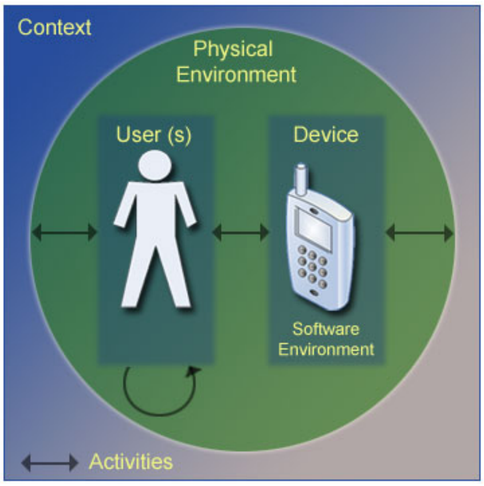

Figure 1: Model of Mobile Application Context

Given the ongoing issues facing the designers and users of mobile applications, the rest of this paper is organised as follows: Section 2 examines existing work on context as it relates to mobile applications and proposes an enhanced context model incorporating the physical environment, application users and the hardware and software characteristics of applications as they execute within the runtime environment of a particular mobile device. Section 3 describes the rationale and methodology behind an empirical study examining the effect of application type and the use of location context in a number of application scenarios. Furthermore, section 3 states a number of hypotheses to be tested and discussed in section 4. Section 5 ends by drawing conclusions and identifying opportunities for further work.

2 The Effect of Context on Mobile Usability

The effect of context on mobile applications is a topic of substantial interest to researchers and practitioners alike. Tarasewich (Tarasewich, 2003) provides a recent model that defines context as extending beyond simple geographical location to encompass the physical environment, users or participants, the activities in which they are involved, and the interaction between the three. Figure 1 further expands the concept of context to include the device itself since not only is user performance explicitly affected by the form factor of the device, but also indirectly by application performance as dependent upon the software or runtime context available during execution. Therefore whilst Tarasewich alludes to the diversity of devices and the resulting difficulties with compatibility, we believe that contextual parameters of the device and its software environment are first class entities in any model of mobile application context.

A more subtle distinction is that rather than considering activity as an entity in itself, Figure 1 defines activity as the interaction between the application users[1], the application (via the device), and the physical environment.

This model is further supported by the notion of *distributed usability* (Vrazalic, 2004) which expands the concept of traditional usability to include contextual factors, with the interaction of user, environment and application forming a distributed system. Earlier, in a case study of a traffic accident analysis system, Spinuzzi (Spinuzzi, 1999) concluded that usability is distributed across an entire activity network including the physical environment, the user and his or her goals, rather than being localized to a single application or computer system.

2.1 Interaction between User and Physical Environment

In terms of concrete examples, interactions between the user and the physical environment can be readily cited. An example of positive or purposeful interaction would be a landmark used as data input into a location aware application, or the identification of a wireless hotspot or other mobile service. Conversely, environmental factors likely to have a negative impact include noise, poor lighting, obstacles causing communication black spots, physical confinement, and impairment of dexterity due to excessive movement or other potentially hazardous operating conditions.

2.2 Interaction between User and Device

Regarding the interaction between the user and the device, again there are tangible physical features that can have either a positive or negative effect. The most obvious are the type of input modes and size/sensitivity of input devices, but of equal importance is the actual runtime environment consisting of physical factors including memory and CPU capability, and software factors such as virtual machine support (e.g. Java (Sun Microsystems, 2004) and .NET (Microsoft Corporation, 2004), operating systems capabilities (e.g. handwriting recognition) and the number and type of applications installed.

2.3 Interaction between Device and Physical Environment

An area that appears to have been less explored is the interaction between the physical environment and the device, which may or may not have follow-on effects for the user. For example in the case of a network handover, as a user roams from one cell or hotspot to another, the transition may involve a seamless interaction between device and environment in which case the user remains completely unaware of this interaction. However, if the handover causes a delay, or in the worst case a connection dropout causing application error or data loss, the user is affected and thus the usability of the application is reduced as a result of the physical environment. Like the previous interactions, device-environment interaction can also be positive, for example a noise cancelling capability in which the device is able to filter environmental noise from the main sound source of the user's voice. Furthermore, with the increasing interest in sensor networks (Mark Gaynor et al., 2004) there exists the opportunity for sensors to bridge the gap between environment, device and user in a number of interesting new ways. Another active area is that of location based services (Rao and Minakakis, 2003) which utilise geographical location context via global positioning services such as GPS in order to provide customised mobile application services. The potential of location context, in terms of improved user performance in information retrieval tasks, has been demonstrated in studies by Bristow et al. (Bristow et al., 2002, Bristow et al., 2004) in the specific case of wearable computing. However, in addition to such beneficial uses as service location and physical navigation, there is the concern of privacy violation or of surreptitiously tracking one's whereabouts with the intent of spying or causing harm.

Whilst the previous list of examples of interaction is in no way exhaustive, it aims to support the model of context presented in Figure 1 and to show that the effect of context is complex and diverse and thus for mobile applications to reach their true potential, further research should be conducted regarding the effect of context on application usability. In order to demonstrate how the utilisation of even a single context parameter, in this case geographical location context (Rao and Minakakis, 2003), can provide measurable usability gains, the following section describes an empirical study of a number of mobile application variants running on a real device over a GPRS network.

3 Methodology

The empirical study presented in this section concerns the usability testing of two application scenarios deployed in four different configurations in order to measure the effect of location context and application type on the objective usability attributes of performance and error rate, and subjective attributes of

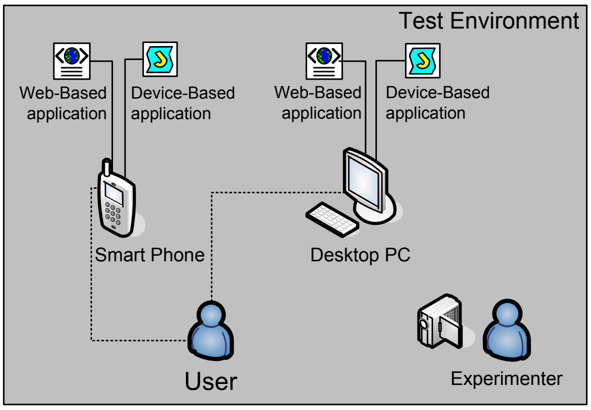

Figure 2: Test Environment

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[1] 'Users' include not only the single physical user of the device but also any non-user who for any reason participates in, or influences the outcome of, the application use-case

user satisfaction, learnability, efficiency, ease of use, and context awareness (see Table 1). For simplicity, the physical environment and provision of location context via GPS were simulated; although the study was conducted on a real Motorola A925 smartphone using a GPRS connection to the internet. This phone features stylus or virtual keyboard based input and is representative of the current generation of smartphones, with a smartphone being defined as having a personal organiser, internet and email capabilities, sophisticated input/output mechanisms and the ability to install and execute third-part applications (Narayanaswamy, 1999). The test was conducted one participant at a time in an enclosed environment, with minimum background noise in order to evaluate the effect of application type and location context. Note that a study of other environmental effects would require either field testing or more sophisticated simulation as discussed in section 5 on future work. The test environment including the user, devices, applications and experimenter are shown in Figure 2.

3.1 Experimental Design

Potential users were selected from the population of current and former university students in Melbourne, Australia. Each candidate filled out a user profile questionnaire, which is available upon request from the authors. To reduce the confounding factor of experience, the final sample of 12 comprised only those with minimal experience using a smartphone and/or mobile applications.

The independent variable in the study was application type with four different implementations of two application use cases developed specifically for this purpose. The four levels of the variable were PC web based, PC device based, mobile web based and mobile device based, as described below.

Web-based PC application: XHTML application deployed on a web server using server-side scripting to dynamically generate pages from a database. The user interface was formatted to take advantage of the space available on a desktop web browser.

Web-based mobile application: Same XHTML application as above but with the markup based user interface formatted for the limited display area available on the smartphone.

Device-based PC application: Java application using AWT (Sun Microsystems, 2001) user interface. Communication with the web server via the transmission of XML content via HTTP.

Device-based mobile application: Same AWT application as above deployed on Personal Java on the Symbian SDK (Symbian, 2004), with the user interface formatted for the limited display area available on the smartphone. Additionally, the mobile version featured additional functionality based on the simulation of location context which was not included in the desktop version since it was not considered useful or realistic in a static desktop environment.

Note that one of the principal goals of the four application types was to make the mobile and PC variants as similar as possible so that any effect on the dependent variables (Table 1) could be attributed to the effect of the device itself rather than differences with the individual implementations. In addition, the naming and layout of user interface elements was as consistent as possible between web and device based applications (see Table 5 and Table 6) although the device based applications had fewer data entry screens as a result of the ability to cache data and perform local processing without the need for server request/reply cycles. All of the application variants were internally instrumented to collect quantitative information related to performance and communication latency (time in seconds) and number of user errors.

The experimenter had the responsibility of conducting the test as follows with complete orientation scripts and task scenarios available from the authors upon request. Briefly, participants were instructed on the objectives of the study and informed that their participation was to be recorded on video to assist later analysis. Users completed a pre-training exercise on the smartphone involving use of the input stylus and virtual keyboard[2], launching the mobile browser, opening a web site from a bookmark, and launching a device-based application. This provided a baseline of experience with data entry and helped minimise practice effects. A task list was then administered to each participant, with the tasks carried out on each of the four application variants using a random rotation based ordering strategy to further minimise the effect of stage-of-practice, as necessary for within-subject designs (Shaughnessy et al., 2002). Participants were asked to *think-aloud* during the test, and if unable to progress on a given task were instructed to move on to the next one. After completing the tests, the users filled out a post-experience questionnaire to collect qualitative data based on their experience using the four application variants.

Complete transcripts of the application scenarios and specific instructions given to participants are available from the author. However, the two use-case scenarios are briefly summarised below.

> Scenario 1: Select a restaurant based on parameters such as cuisine type, price, rating and location. In the case of the mobile device based application, the simulated location context allowed a list of restaurants, within a given kilometre radius of the user's current location, to be automatically displayed (i.e. location context was utilised within the user interface).
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> Scenario 2: Following restaurant selection above, the user was to book a table based on a schematic layout

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[2] Users were not trained to use the handwriting recognition on the device as pilot testing showed this to require additional learning and system calibration.

Usability Attribute Measured	Description	Data Collection Technique
Objective Measures		
Performance	Time taken to complete tasks measured in seconds at the sub-task level Descriptive statistics and ANOVA test performed to test statistical significance	Data from logs and code instrumentation Collected automatically during test
Number of Errors	Errors committed by the user Descriptive statistics provided	
Subjective Measures		
Learnability	How the user interacted with the application based on training received Ranked by the user on a scale of 5	Post experience questionnaires completed by the participants
Efficiency	How effective the application was in achieving the task Ranked by the user on a scale of 5	
Ease of Use	How intuitive or usable the application was. Ranked by the user on a scale of 5	
User Satisfaction	How pleasant the user's experience was Ranked by the user on a scale of 5	
Context Awareness	Ability of the application to utilize the location of the user Ranked by the user on a scale of 5	

Table 1: Dependent Variables

and a smoking or non-smoking preference. Following table selection, finalising the reservation involved the entry of date, time and contact number.

As mentioned previously, the objective dependent variables of performance and error rate were measured via instrumentation in the application. The subjective measures of learnability, efficiency, ease of use, user satisfaction and context awareness were derived from a 1-5 scale in the post-experience questionnaires. The dependent variables are summarised in Table 1.

3.2 Hypotheses

Two pairs of hypotheses, relating to the objective and subjective dependent variables respectively, were formulated as stated below and tested in section 4.

The device-based mobile application is expected to exceed the performance and usability of the web-based mobile application due to the utilisation of location context, fewer screens and reduced bandwidth requirements, according to the following hypotheses:

H1a. The device-based mobile application will perform better (according to the two objective measures of Table 1) than the web-based mobile application.

H1b. The device-based mobile application will be more usable (according to the five subjective usability attributes from Table 1) than the web-based mobile application.

The utilisation of location context by the device-based mobile application is expected to help counteract the negative impact of its limited input/output capabilities. This is because the location and the list of restaurants will be selected automatically, thereby reducing the amount of user input, resulting in H2a and H2b as follows:

H2a. The performance of the device-based mobile application will be comparable to both the web and device based PC applications.

H2b. The usability of the device-based mobile application will be comparable to both the web and device based PC applications.

4 Results of Empirical Study

The raw scores for the empirical study are tabulated for each of the twelve users in Table 2. Note that potential outliers, for example user 5 on device based PC and user 11 on device based mobile, were not removed in order to maintain a complete data set and thus the independent variable rotation necessary to counteract stage-of-practice effects.

4.1 Performance and Usability

The first test performed was a repeated-measures ANOVA to determine if application type had a significant effect on total *time taken* to complete the tasks. The pair-wise comparisons in Table 3 show the effect of web based mobile application to be significant at the 0.019, 0.006 and 0.03 against device based pc, web based pc and device based mobile applications respectively. This provides partial support (i.e. time taken is one of two objective quantitative measures) for *H1a*, which stated that the device-based mobile application would perform better than the web-based mobile application.

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	User 11	User 12	Mean	Median	SD
Device-based PC Application															
Use Case 1 - Time taken	85	66	39	72	117	75	37	42	61	50	48	57	62.4	59	22.9
Use Case 2 - Time taken	37	18	13	32	39	20	16	30	31	21	26	34	26.4	28	8.6
Total - Time taken	122	84	52	104	156	95	53	72	92	71	74	91	88.8	87.5	29.2
Errors	1	0	1	1	0	0	0	2	0	0	1	0	0.5	0	0.7
Learnability	5	5	4	3	5	5	5	2	5	4	4	4	4.3	4.5	1
Efficiency	5	3	4	4	5	4	5	2	5	4	4	3	4	4	1
Ease of Use	5	3	5	3	5	4	4	2	5	4	5	4	4.1	4	1
Joy of Use	2	5	4	2	5	4	3	2	5	4	4	4	3.7	4	1.2
Context Awareness	5	5	3	4	5	5	2	2	4	4	5	3	3.9	4	1.2
Total	4.4	4.2	4	3.2	5	4.4	3.8	2	4.8	4	4.4	3.6	4	4.1	0.8
Web-based PC Application															
Use Case 1 - Time taken	49	69	53	45	48	83	38	33	40	61	48	49	51.3	48.5	13.9
Use Case 2 - Time taken	29	36	26	16	20	57	18	19	24	51	27	21	28.7	25	13.1
Total - Time taken	78	105	79	61	68	140	56	52	64	112	75	70	80	72.5	26.1
Errors	1	0	0	0	0	1	0	0	1	0	0	1	0.3	0	0.5
Learnability	4	5	4	4	5	4	5	5	5	5	5	4	4.6	5	0.5
Efficiency	4	5	4	5	5	5	4	4	5	5	4	3	4.4	4.5	0.7
Ease of Use	4	5	4	4	5	5	4	5	5	4	5	4	4.5	4.5	0.5
Joy of Use	3	5	3	4	5	3	3	4	5	5	4	4	4	4	0.9
Context Awareness	5	5	5	5	5	5	2	4	4	5	5	3	4.4	5	1
Total	4	5	4	4.4	5	4.4	3.6	4.4	4.8	4.8	4.6	3.6	4.4	4.4	0.5
Device-based Mobile Application															
Use Case 1 - Time taken	61	46	70	52	41	72	62	36	45	45	99	39	55.7	49	18.2
Use Case 2 - Time taken	38	35	45	32	30	47	39	18	31	44	73	26	38.2	36.5	13.8
Total - Time taken	99	81	115	84	71	119	101	54	76	89	172	65	93.8	86.5	31.4
Errors	1	0	0	1	1	0	0	0	0	1	0	0	0.3	0	0.5
Learnability	3	5	4	4	5	5	5	5	5	5	4	2	4.3	5	1
Efficiency	4	5	4	3	5	5	5	5	5	5	4	3	4.4	5	0.8
Ease of Use	4	5	4	3	4	5	4	5	5	5	5	3	4.3	4.5	0.8
Joy of Use	4	5	4	3	5	5	3	5	5	5	5	3	4.3	5	0.9
Context Awareness	5	5	5	2	5	5	4	5	5	5	5	3	4.5	5	1
Total	4	5	4.2	3	4.8	5	4.2	5	5	5	4.6	2.8	4.4	4.7	0.8
Web-based Mobile Application															
Use Case 1 - Time taken	61	96	78	82	96	88	74	85	41	60	121	107	82.4	83.5	21.9
Use Case 2 - Time taken	35	32	35	54	35	32	30	42	28	28	49	57	38.1	35	10.1
Total - Time taken	96	128	113	136	131	120	104	127	69	88	170	164	120.5	123.5	29.3
Errors	1	0	1	0	1	1	0	1	0	0	0	0	0.4	0	0.5
Learnability	3	4	4	5	5	5	5	3	5	5	4	2	4.2	4.5	1
Efficiency	5	3	4	5	5	5	4	3	5	5	4	3	4.3	4.5	0.9
Ease of Use	4	5	3	5	4	5	4	4	5	5	5	2	4.3	4.5	1
Joy of Use	4	5	3	5	5	5	3	4	5	5	5	2	4.3	5	1.1
Context Awareness	5	5	5	5	5	5	2	4	4	5	5	4	4.5	5	0.9
Total	4.2	4.4	3.8	5	4.8	5	3.6	3.6	4.8	5	4.6	2.6	4.3	4.5	0.8
Training Useful?	3	5	4	5	5	5	4	4	5	5	5	3	4.4	5	0.8

Table 2: Raw Data

Pairwise Comparisons

(I) APPTYPE	(J) APPTYPE	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
DEVICE PC	WEB PC	8.833	11.383	.454	-16.221	33.887
	DEVICE MOB	-5.000	14.006	.728	-35.828	25.828
	WEB MOB	-31.667(*)	11.535	.019	-57.054	-6.279
WEB PC	DEVICE PC	-8.833	11.383	.454	-33.887	16.221
	DEVICE MOB	-13.833	9.974	.193	-35.786	8.119
	WEB MOB	-40.500(*)	11.906	.006	-66.705	-14.295
DEVICE MOB	DEVICE PC	5.000	14.006	.728	-25.828	35.828
	WEB PC	13.833	9.974	.193	-8.119	35.786
	WEB MOB	-26.667(*)	10.726	.030	-50.275	-3.059
WEB MOB	DEVICE PC	31.667(*)	11.535	.019	6.279	57.054
	WEB PC	40.500(*)	11.906	.006	14.295	66.705
	DEVICE MOB	26.667(*)	10.726	.030	3.059	50.275

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Least Significant Difference.

Table 3: Repeated measures ANOVA for Application Type and Total Time

Pairwise Comparisons

(I) APPTYPE	(J) APPTYPE	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
DEVICE PC	WEB PC	8.083	3.767	.055	-.207	16.374
	DEVICE MOB	2.333	4.583	.621	-7.754	12.421
	WEB MOB	-7.917	4.915	.136	-18.735	2.901
WEB PC	DEVICE PC	-8.083	3.767	.055	-16.374	.207
	DEVICE MOB	-5.750	2.675	.055	-11.637	.137
	WEB MOB	-16.000(*)	3.453	.001	-23.600	-8.400
DEVICE MOB	DEVICE PC	-2.333	4.583	.621	-12.421	7.754
	WEB PC	5.750	2.675	.055	-.137	11.637
	WEB MOB	-10.250(*)	3.344	.011	-17.611	-2.889
WEB MOB	DEVICE PC	7.917	4.915	.136	-2.901	18.735
	WEB PC	16.000(*)	3.453	.001	8.400	23.600
	DEVICE MOB	10.250(*)	3.344	.011	2.889	17.611

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Least Significant Difference

Table 4: Repeated measures ANOVA for Application Type when Using Context

H1a was not fully supported because there was no significant difference between application types in terms of the second quantitative dependent variable *number of errors*, with no user making more than one error on any given application type.

Because of the small sample size, the *least significant difference* option was used for confidence interval adjustment in the pair wise comparisons, instead of the stricter Bonferroni or Sidak tests. Additionally, given the limited power of the ANOVA test it is possible that small differences existed between the other application types, however testing with a larger sample size would be necessary to explore this further.

In terms of subjective usability data (Table 1), the difference between application type was generally not significant although for *user satisfaction*, the effect of mobile versus PC device based application was almost significant at the .05 level (0.054) in favour of the mobile version (this unexpected result is discussed further in section 4.4). Therefore *H1b*, which stated that the device-based mobile application would be more usable according to the five subjective usability measures, was not supported although there was a slight trend in favour of this hypothesis across all of the usability measures.

4.2 Location Context

To determine the extent to which location context contributed to the mean difference of approximately 27 seconds between the web and device based mobile applications, a second ANOVA was conducted on the times taken for the specific portion of the application in which location context was utilised i.e. the location and restaurant selection process. The results, which are presented in Table 4, show not only that the use of location context contributed to an average time reduction of a little over 10s for the device based mobile application, but also that this difference was significant at the 0.05 level. As with H1a this provided partial support (i.e. one of the two objective performance measures) for *H2a* which stated that the performance of the device-based mobile application would be comparable to both the web and device based PC applications. Note that although the performance of the device based mobile application was slightly less than the web and device based PC variants (although not statistically significantly so), it was closer to them in terms of time taken than the web based mobile application. Again like H1b, *H2b* was not supported since there was a low error rate across all four levels of application type.

4.3 Implementation Issues

In order to identify factors in addition to location context, contributing to the performance of the mobile device based application, it is necessary to look to implementation issues such as page display speed and bandwidth usage. Such factors are a result of the software environment in which applications run as discussed in section 2.2.

Firstly, the device based applications have an advantage in terms of bandwidth usage, especially after the application has first been downloaded and installed. This is because the web pages comprising the web based application are dynamically generated on a per request basis, and thus cannot be cached. Consequently, the total data usage for the two use cases was approximately 76kB for the web based applications versus < 1kB for the device based applications. At an average speed of about 5kB/s for the GPRS connection, this equates to a difference of approximately 15 seconds in terms of data transfer alone, thereby demonstrating the potential advantage of device based applications, and further explaining the difference in terms of mean performance between the mobile web based and device based application types. Conversely, when comparing the web based and device based PC applications, this difference was not evident since these applications ran on a broadband connection, thereby minimising the impact of the added bandwidth.

A final advantage of the device based mobile application, which may have contributed to its superior performance, was its greater use of client side processing. This meant that many of the application screens or responses could be generated locally without a request to the server, an advantage which is closely correlated with the more easily quantified bandwidth advantage described above.

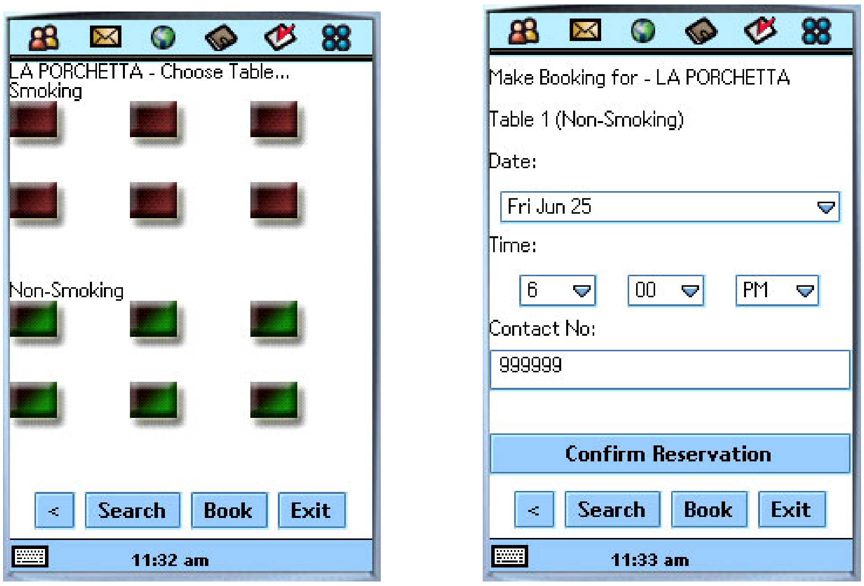
4.4 Other Findings

As first identified in section 4.1, perhaps the most surprising result was that the performance of the web based PC application was better than that of the device based PC version. This was counter to expectations but can be explained by looking to the subjective user feedback in Table 2 which shows the lowest rating given to the device based PC application. Familiarity with the web browser interface could be a possible reason for this result. This was further supported by the qualitative feedback from the post experience questionnaires which reflected both a familiarity and preference for the web based model and a criticism of the layout of the device based PC application, which had been deliberately designed to be as similar as possible to its mobile counterpart.

5 Summary, Conclusions and Future Work

This paper has made two contributions to the emerging field of mobile usability.

Firstly it has introduced a new model of context which considers not only the interaction between user, device and physical environment, but also the impact of the runtime software environment and how this co-interacts with the previous three entities. An empirical study has provided support for the new model by showing that even a single contextual factor, in this case location context, can provide a measurable and statistically significant improvement in terms of objectively measured task performance.



LA PORCHETTA - Choose Table...

Make Booking for - LA PORCHETTA

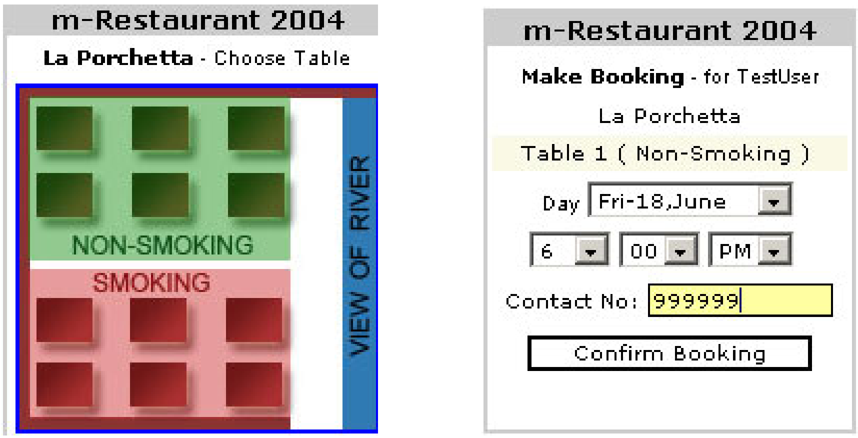
Table 1 (Non-Smoking)

Date: Fri Jun 25

Time: 6 00 PM

Contact No: 999999

Table 5: Screen shots from device based mobile application (J2ME Java MIDlet)



La Porchetta - Choose Table

Make Booking - for TestUser

La Porchetta

Table 1 (Non-Smoking)

Day Fri-18,June

6 00 PM

Contact No: 999999

Table 6: Screen shots from web based mobile application (HTML running in browser)

Secondly, this paper has studied the effect of application type, showing that implementation technologies and type of application client used to deliver mobile applications can again have a measurable quantitative impact. This was most notably evident with the superior performance of the device based mobile application over its web based counterpart.

This paper also provides a number of opportunities for further work, some as a result of limitations of the empirical study itself, others stemming from new findings that have been presented herein. The main limitation of the study concerns the relatively small sample size, which allowed the detection of only moderate to large effects. Consequently, most of the results related to the subjectively measured variables failed to reach statistical significance. Nevertheless, given the improvement in actual task performance, future studies using different interfaces involving more complex problems and a larger sample could further study the usability of different application types.

Another opportunity for further research involves more extensively testing the model of mobile application context presented in this paper. This would serve to determine whether measurable gains to task performance and usability can be obtained using a wider range of contextual factors related to the interaction between the physical environment, user, device and software environment.

Finally, as reflective mobile middleware (Capra et al., 2003) and adaptive mobility systems (Ryan and Westhorpe, 2004) begin to be deployed on a wider scale, the effect of the non-physical application environment is likely to become even more important to the usability of next generation mobile applications.

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