The Impact of Context on the Usability of Wireless Devices

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Abstract

Wireless devices are becoming increasingly popular, having already reached over 1 billion mobile subscribers. As consumers' technology fears and adoption costs are reduced, wireless devices are approaching "mainstream" status around the developed world. Wireless devices propose increasing value to consumers found in "anytime / anywhere" connectivity, communication, and data services. Although progress has been made in terms of technological innovations, many mobile applications remain difficult to use, lack flexibility and robustness. Some key usability challenges facing m-Commerce applications include limited screen size and quality, limited input methods and navigation difficulties. Additionally, the mobile user has to share his or her attention between the application and the surrounding environment. This context of use may have a significant impact on the usability of such devices. The main objective of the proposed research is the evaluation of the impact of context on the usability of wireless devices. This paper begins with an overview of m-Commerce and usability, followed by the proposed research questions and the topic's importance. Literature review findings are then discussed. The intended research approach is described next including operationalization of variables, experimental design and procedure. Finally, contribution to research and limitations for the proposed study are presented.

Keywords: m-Commerce, usability, wireless devices, context of use, task, user, environment, interface, applications, lab experiment.

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1. Summary

M-Commerce makes use of mobile and wireless networks in enabling consumers with a plethora of tools available anytime and anywhere. Growth in this arena is expected to continue and it is expected that over 40% of all business-to-consumer (B2C) e-commerce will be initiated from the next generation of mobile devices, called smart phones that are supported by Wireless Application Protocol (WAP) (Varshney & Vettter 2002a). However, a number of issues surround the area of m-commerce, with usability leading the rest of the pack in the eyes of the consumer, impeding the adoption of newly released wireless devices and the corresponding applications (Coursaris and Hassanein 2002). In the end, a number of factors will come into play in determining the rate of m-commerce adoption, and these factors will be addressed by those active in the m-commerce market.

Usability studies fall under the domain of Human Computer Interaction (HCI). HCI has its roots as early as the 1970's with the work of "software psychology". "Software psychology dealt with the utility of a behavioural approach to understanding software design, programming, and the use of interactive systems, and to motivate and guide system developers to consider the characteristics of human beings (Carroll 1997)." Evolving into the analysis of user requirements and the conception of Graphical User Interfaces (GUI), "usability engineering" had arrived (Hermann & Heidmann 2002; Carroll 1997). A later stage that would form a subset of usability engineering concentrated on interfaces and came to be known as "information visualization" (Hornback 2003). The most recent exploration in the field of HCI was coined "new usability" (Thomas & Macredie 2002) or "ubiquitous usability" (Hassanein and Head 2003). "Ubiquitous usability" is concerned with the context in which new products and services are being used. Varied situational contexts will result in emerging usability factors, making traditional approaches to usability evaluation inappropriate. This evolution of HCI is summarized in Table 1. The corresponding research has produced extensive resources in the form of usability guidelines and standards for various domains. Still, in many areas there has been limited, if any, empirical usability investigation. Furthermore, while there has been some usability research that pertains to m-Commerce, there has been even less that was actually carried out in a contextual setting.

Table 1: Evolution of Human-Computer Interaction (HCI)

Domain	Year	Distinctive Characteristics	References
Software engineering	1970's	Goal: To establish the utility of a behavioural approach to understanding software design, programming, and the use of interactive systems, and to motivate and guide system developers to consider the characteristics of human beings. Two methodological axioms: 1) Assume the validity of the "waterfall" model (i.e. top-down decomposition and discretely sequenced stages with well-specified hand-offs) 2) Assume two central roles for psychology within this context: a) to produce a general description of human beings interacting with systems and software, a description which could be synthesized as a guideline for developers, and b) to verify directly the usability of systems and software as they were developed	Carroll 1997; Schneiderman 1980; Royce 1970
Usability Engineering	1980's	Analysis of user requirements and the conception of Graphical User Interfaces (GUI) Three key notions: 1) Propose iterative development is managed according to explicit and measurable objectives (i.e. "usability specifications") 2) Broaden the empirical scope of design through various techniques for user participation (e.g. *participatory*, *contextual*, *ethnographically informed*) 3) Cost effectiveness of prototyping tools (e.g. *by demonstration*), usability evaluation (*GOMS*, *impact analysis)*, user testing (e.g. *inspections*, *checklist*, *script-oriented*), analytical techniques (e.g. *GOMS* extended, *claims analysis*, *cognitive walkthrough*)	Hermann & Heidmann 2002; Carroll 1997; Kieras 1988; John 1990; Carroll & Rosson 1991; Polson, et al 1992; Nielsen & Mack 1994; Good et al 1986; Bentley et al 1992
Information Visualization	1990's	Subset of usability engineering concentrated on interfaces	Hornback 2003
Ubiquitous / New usability	1990's	Concerned with the context in which new products and services are being used. Varied contexts (i.e. user, environment, interface, and task) will result in emerging usability factors, making traditional approaches to usability evaluation inappropriate.	Thomas & Macredie 2002; Hassanein & Head 2003

The objective of this research is to study consumer behaviour under various environmental conditions (contextual analysis by varying environmental and user characteristics) while using wireless applications (i.e. text messaging, organizer, wireless Web) on a single device type (i.e. Personal Digital Assistant or PDA) by means of a stylus-based gesture-recognition method (i.e. Jot). This behaviour will be analysed by means of quantitative empirical data, but it will also be coupled with qualitative data obtained through a survey that the test subjects will be asked to complete during the experiment. Findings will include conditions impacting user preferences for undertaking the various tasks, environmental impact on the effectiveness and efficiency of the selected interface for the given application in the various environmental settings, and the overall satisfaction of the consumer for the application, the interface, and the overall wireless medium. These findings will facilitate in formulating various usability conclusions that will be beneficial for key m-Commerce participants, e.g. consumers, software/hardware designers, and wireless device manufacturer, as well as fellow researchers.

2. Research Questions

An investigation of usability in the domain of m-Commerce can assume one of many strategies and approaches. In addition, the investigation's focus may facilitate an enhanced understanding in several areas that pertain to usability. Some of these areas are reflected by the questions below:

- What is a consumer's perception of usability?
- What are the specific factors impacting the usability of wireless applications and/or wireless devices?
- What are the various consumer approaches for evaluating the usability of wireless applications and/or wireless devices?
- How can the usability of current wireless applications and/or wireless devices be enhanced?
- What are the benefits for all m-Commerce market players associated with improved usability of wireless applications and/or devices?
- Does availability of multiple interfaces enhance the satisfaction of mobile users (or m-Consumers)?
- Do consumers intend to use wireless devices?
- Will consumers require prior training and/or guidance during use of wireless devices?
- How do consumers feel about the cost structure of wireless data services?
- How does the cost of wireless devices compare to the cost of alternate means of communication for consumers?
- What is the value that wireless devices offer consumers?

While all of the above questions are worth investigating, constraints for a practical and concise investigation require that the research questions be more focused. Hence, the proposed study will explore the following research questions

1) How does context of use impact the usability of wireless devices?
2) What are the implications of context on the design of wireless devices?
3) How does usability affect a consumer's intention to use a wireless device?

Based on these research questions, an in-depth analysis performed through the combination of both quantitative and qualitative data will address the following questions:

- How does a user's mobility impact the usability of wireless devices?
- How does the visual environment impact the usability of wireless devices?

As will be shown later, usability is contingent on the efficiency and effectiveness of, as well as user satisfaction with, the technology. Also, usability impacts a consumer's behavioural intention to use the technology. Therefore, the following hypotheses are formulated and will be investigated through the proposed study:

Efficiency

H1. Lower level of mobility will result in higher efficiency.
H2. Higher level of visibility will result in higher efficiency.
H3. Higher efficiency will result in higher assessment of usability.

Effectiveness

H4. Lower level of mobility will result in higher effectiveness.
H5. Improved level of visibility will result in higher effectiveness.
H6. Higher effectiveness will result in higher assessment of usability.

Satisfaction

H7. Lower level of mobility will result in greater satisfaction.
H8. Improved level of visibility will result in greater satisfaction.
H9. Greater satisfaction will result in higher assessment of usability.

Usability and Intention to use wireless devices

H10. Higher assessment of usability will result in higher intention to use wireless devices.

3. Importance of Topic

Wireless devices are becoming increasingly popular, having reached over 1 billion mobile phone subscribers already (CWTA)[1]. As technology fears and adoption costs are reduced, consumers will perceive wireless devices as "mainstream" and they will no longer be considered as luxurious toys for those financially well-off. Coupled with the increased mobility of individuals due to several factors (e.g. low cost of transportation, large distances traveled for work, being away from home or office, etc.) devices are proposing increasing value to consumers found in connectivity and communication (Coursaris and Hassanein 2002).

Furthermore, as a result of increased competition, network carriers have seen their Average Revenue Per User (ARPU) decrease in the last few years; one example that is representative of carriers around the world can be found here in Canada where the ARPU dropped by 30% in five years (CWTA 2003)[2]. To combat this trend, carriers are promoting wireless data services that will help boost the ARPU and will contribute in alleviating some of the burden of deploying new infrastructure and the cost of third generation (3G) license fees. One such wireless data service is found in text messaging. As can be seen by the Canadian Wireless Telecommunications Association (CWTA), text messaging reached a demand level of over 900,000 per day in March 2003, a growth of 100% since last year. This demand suggests that text messaging is a widely used application for either of the following two purposes (Coursaris and Hassanein 2002):

- Consumers use it for either personal or professional communication with others (text messaging offers an additional communication channel)
- Businesses use it for either:
    - professional communication among employees (text messaging offers an additional marketing channel), or
    - commercial use with their clients (text messaging offers an additional marketing channel)

Text messaging is just one application made available by wireless devices. Organizers, e-mail, and the wireless Web are two additional capabilities available on several devices that could stimulate needed revenue growth for network carriers.

[1] http://www.cwta.ca/industry_guide/facts.php3
[2] http://www.cwta.ca/industry_guide/facts.php3

Therefore, investigating the use of wireless data services is of significance to many parties. In particular, a study that can facilitate enhanced understanding of the usability of text messaging, organizers, and wireless Web browsing can translate in improved communication among consumers, businesses, and between the two, as well as in additional revenue for wireless service providers, network carriers, and indirectly revenue for other m-Commerce market players (e.g. software developers).

Furthermore, usability studies have their roots in the 1970's. Since then the field has evolved and there have been many areas of exploration, but given the emerging state of the m-Commerce industry, usability studies have been limited in this domain and have been performed almost exclusively from a technological perspective.

Overall, the expected contribution of the proposed research to the various interested parties is described in detail in a subsequent section (see: Contributions of this Research).

4. Prior Research

What is Usability?

Usability studies have their roots as early as the 1970's with the work of "software psychology". "Software psychology dealt with the utility of a behavioural approach to understanding software design, programming, and the use of interactive systems, and to motivate and guide system developers to consider the characteristics of human beings (Carroll 1997)." Evolving into the analysis of user requirements and the conception of Graphical User Interfaces (GUI), "usability engineering" had arrived (Hermann & Heidmann 2002). A later stage that would form a subset of usability engineering concentrated on interfaces and came to be known as "information visualization" (Hornback 2003). The most recent exploration in the field of usability was coined "new usability" (Thomas & Macredie 2002) or "ubiquitous usability" (Hassanein and Head 2003). "Ubiquitous usability" is concerned with the context in which new products and services are being used. Varied situational contexts will result in emerging usability factors, making traditional approaches to usability evaluation inappropriate. The above research has produced extensive resources in the form of usability guidelines and standards for various domains. Still, in many areas there has been limited, if any, empirical usability investigation. Furthermore, while there has been some usability research that pertains to m-Commerce, there has been even less that was actually carried out in a contextual setting.

In evaluating the usability of an item (e.g. device or application interface), the context of use and the specifics of the user need to be identified so as to yield a reasonable analysis (Thimbleby et al 2001; Maguire 2001). For example, if attempting to assess the usability of a mobile phone involves studying simulated tasks that involve a novice user (e.g. inexperienced with electronic devices) in a non-mobile state (e.g. seated at desk) who is subjected to environmental constraints (e.g. inside a building with poor network signal) and challenging tasks (e.g. information search and retrieval from a wireless web site) where additional factors impact the effectiveness and efficiency of the device/interface tested, then the results obtained could be argued as invalid. Instead, the experiment needs to consider the product and the user and be designed subject to those considerations in addition to the environmental and task-related constraints (Smith et al 1997).

There are many approaches to evaluating usability, some of which are better suited for certain types of evaluations (e.g. single product feature vs. entire product) (Blandford and Rugg 2002). These approaches include focus groups, task analysis, usability testing, storyboarding, rapid prototyping, pilot studies, early prototype evaluations, surveys / questionnaires, participatory design, ethnographic studies, cognitive walkthroughs, competitive analysis, and comparative studies (Savage 1995).

Usability evaluation models explored

There have been a few definitions of usability put forth by scholars. One of these definitions was proposed by Nielsen (1993), where usability was defined as the process of testing with a handful of techniques to gain learnability, efficiency, memorability, less errors, and satisfaction. Rubins (1994) proposes similar usability attributes, including learnability, effectiveness, usefulness, and attitude. A third definition is put forth by the International Organization for Standardization (ISO). According to usability definition (ISO 9241), usability is defined as efficiency, effectiveness, and satisfaction (Bevan 2001).

Comparing these three definitions strong similarities become apparent. First, learnability and memorability can impact user satisfaction. For example, if it is not easy for a user to learn a new system (learnability), or if a user needs to re-learn between times (memorability), then the user could get frustrated (low satisfaction). Second, less errors imply higher effectiveness (greater correctness of answer). Third, attitude (proposed by Rubins) can be expressed in terms of satisfaction. Therefore, the three theories presented coexist using the ISO's definition of usability:

- *Efficiency*: the level of resource consumed in performing tasks,
- *Effectiveness*: the ability of users to complete tasks using the system, and the quality of output of those tasks,
- *Satisfaction*: users' subjective satisfaction to using the system

Further to this definition, Frokjaer et al (2000) tested the three constructs for correlation. The results show that the three constructs should be considered independent, unless domain specific studies suggest otherwise, and that all three should be included in usability testing. Therefore, an

initial research model is shown in Figure 1. The figure includes a dashed outline encompassing efficiency and effectiveness under the umbrella of performance (Watters et al 2003) along with an arrow showing potential impact on user satisfaction. As Frokjaer suggested, the impact of these variables on usability will be tested focusing on wireless devices.

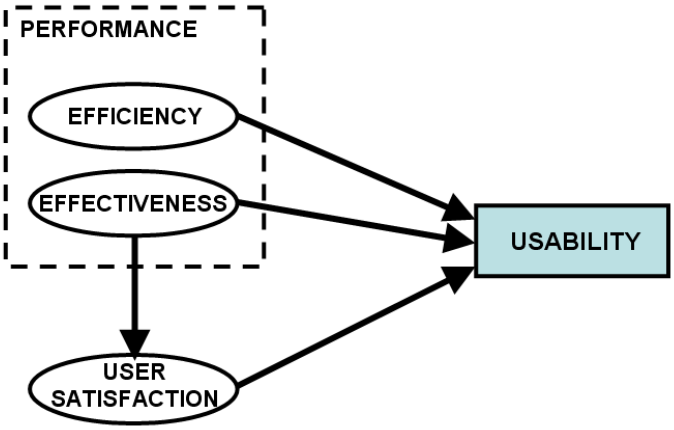

Figure 1. Proposed research model for the usability of wireless devices.

Since usability was argued to impact the growth of m-Commerce (i.e. slower adoption), the research model should be modified to include and also test for the adoption of wireless devices. The initial research model for the usability of wireless devices (see Figure 1) should be adapted to the models of the Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1975) and Technology Acceptance Model (TAM) (Davis et al 1989). According to TRA, a consumer's "behavior is determined by his/her behavioral intention, and behavioral intention is determined by both the person's attitude and subjective norm concerning the behavior in question", in this case being the use of wireless devices. Furthermore, attitude is determined by the consumer's beliefs about consequences of performing the behavior multiplied by the evaluation of those consequences. Usability is one such belief that impacts a user's attitude towards using wireless devices. Therefore it can be argued that usability impacts attitude, which in turn determines behavioral intention. Similar to TRA, TAM also argues that actual use of a computer system (i.e. wireless device) is impacted by the user's behavioral intention to use the system. As subsequent studies have shown (Agarwal et al. 2000, Venkatesh 1999, Venkatesh 2000), there is a strong positive relationship between attitude towards use, behavioral intentions towards use, and actual

use of a system. Therefore, by measuring only the consumer's behavioral intention towards using wireless devices should satisfy the proposed hypotheses. This extended research model is shown in Figure 2.

Next, a review of independent variables that may impact usability leads to the work by Hassanein and Head (2003), who propose a ubiquitous usability model (see Figure 3), where usability is dependent on four elements, namely the user, the environment, the task, and the interface. Since the interface will be a fair representative of PDAs available with Jot as the input mode (see section: Task and Procedure), and the task will consist of authoring and retrieving text messages, authoring and retrieving contact information, and accessing a wireless Website, the two factors (interface and task) are not investigated and are therefore irrelevant to the proposed research model.

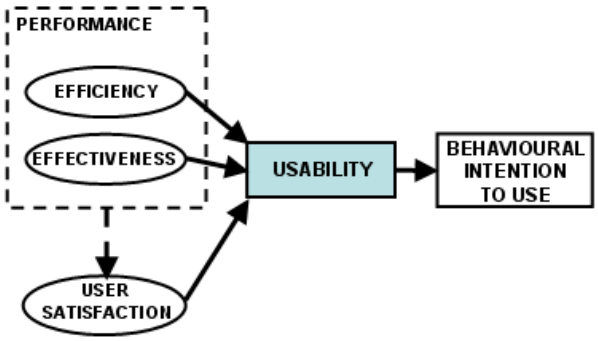

Figure 2. Extended research model for the usability of wireless devices.

Finally, the two variables examined are the environment (for this study, visual environment) and the user (for this study, user mobility). Revising the extended research model one last time, Figure 4 shows the proposed research model for a contextual usability evaluation of wireless devices. The next section will focus on empirical usability studies that relate to m-Commerce.

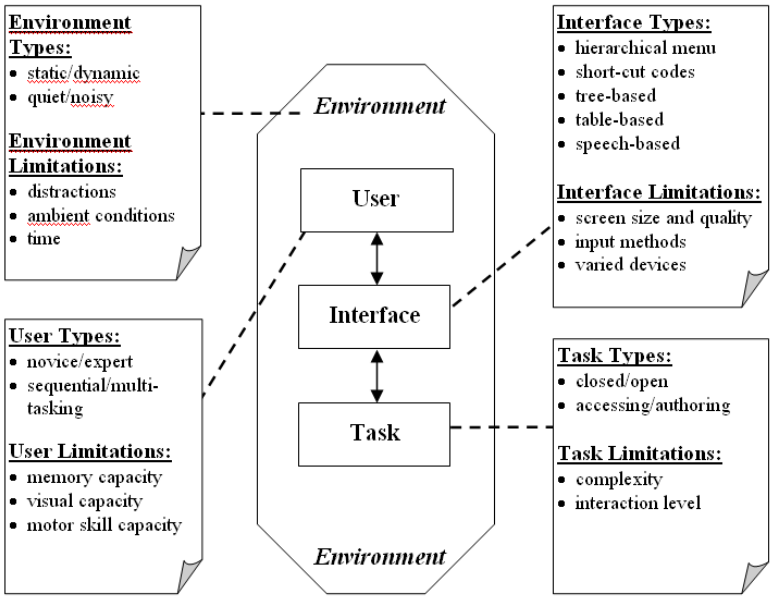

Figure 3. Ubiquitous Usability Model (Source: Hassanein and Head 2003)

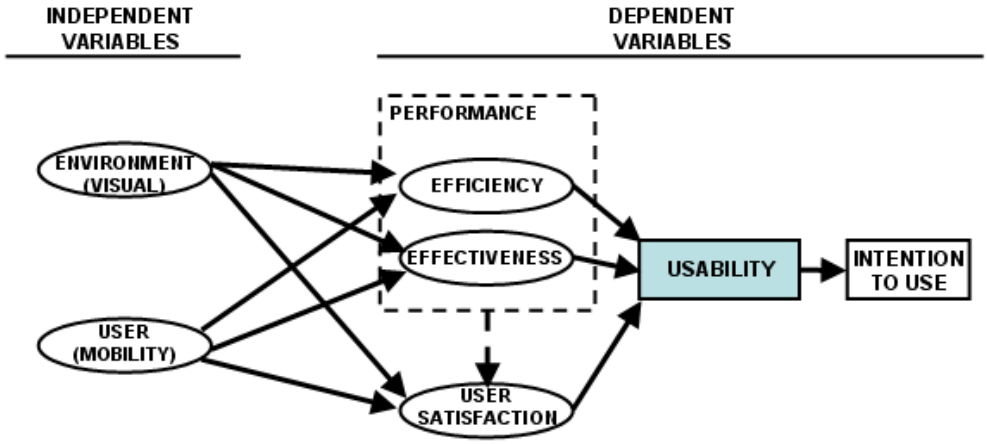

Figure 4. Proposed research model for a contextual usability evaluation of wireless devices

Usability Studies Explored

While there has been extensive research in the area of human-computer interaction (HCI) over several domains, only the results of researchers concentrating on usability-related themes focusing on wireless applications and/or devices will be presented here. The remaining HCI research reviewed is provided as additional references and some of the areas they cover are:

- Prototyping / User-centric design for usability of new technology
    - (Bruseberg and McDonagh-Philp 2001; Hawk 1993; Fang and Salvendy 2000; Hall 2001; Newell and Gregor 2002; Dray et al 2002; Lacohee and Anderson; Nielsen 1996; Lamberts 2002; DeGroot and VanWelie 2002; Hermann and Heidmann; Jaaksi 2002; Sears and Lund 1997)
- Menu design
    - (Wright and Lickorish 1994; Liu et al 2002; Marcus and Chen; Thimbleby 2001; Kaikonnen and Roto 2002)
- User-adapted interfaces
    - (Oppermann 1994; DeRosis 1998; Seffah and Forbrig 2002; DeArriba and Brugos 2002; Paradis et al 2003; Lee and Jang 2002; DeCarolis et al 1995)
- Search and retrieval
    - (Smith et al 1997; Padovani and Lansdale 2002; Sutcliffe et al 2000; Finkelstein et al 2002; Leporini and Paterno 2003; Cockburn and Jones 1996; Cockburn and McKenzie 2001)
- Cognitive models and HCI
    - (Davis 1993; Anderson et al 1993; Potosnak 1989; Staggers and Norcio 1993; Kao and Archer 1997)
- Standards & Guidelines for HCI
    - (Bevan 2001; Ross and Burnett 2001; Newell and Gregor 2002; Potosnak 1989; Powlik and Karshmer 2002; Leporini and Paterno 2003; Kohno and Rekimoto 2002; Noirhomme-Fraiture and Vanderdonckt 1993)
- Training & GUI
    - (Agarwal et al 1996)

Next, the ubiquitous usability framework (Figure 3) discussed earlier will be used for the presentation of any previous research that relates to usability of wireless applications and/or wireless devices. The benefit of using this framework for the literature review is found in both the structure it provides for the discussion to follow, as well as it will help highlight any areas that are lacking investigation. Thus, the proposed direction for this dissertation may be supported.

Table 2 classifies all studies reviewed here according to their author(s) and the four usability elements (i.e. user, environment, task, and interface). This table assists readers in scanning previous research according to a particular factor impacting usability.

Table 2. Previous empirical usability studies related to m-Commerce

	USER (subjects)	ENV'T	TASK	INTERFACE
Karambelas et al. (2003)	Expert (8)	Static, lab	Closed, various tasks	PDA – overall
Sears and Arora (2002)	Novice (31)	Static, lab	Closed, 6 tasks, various	Input (Jot vs. Graffiti)
Benbasat and Todd (1993)	Novice (48)	Static, lab	Closed, 1 task (sending a memo)	Display: emulator, & mouse: Direct manipulation vs. menus & Icons vs. text
Piolat et al (1997)	Novice (54)	Static, lab	Closed, 2 tasks - reading	Display: emulator, page reading Scrolling vs. Page-by-page
Suhm et al. (2001)	Novice (15)	Static, lab	Closed, 4 tests, speech recognition and error correction	Input: keyboard & mouse, speech, gesture, handwriting; Output: computer screen
Dyson and Haselgrove (2001)	Novice (36)	Static, lab	Closed, articles read, 6 types of questions	Display: computer screen, line length & reading speed
Trumbly et al (1993)	Novice (16), Expert (16)	Static, lab	Game simulation	Interface: dialogue style (menu/command), colour (yes/no), values (default/no), error messages (short/lengthy), help (automatic/upon request)
Buyukkokten et al (2002)	Expert (N/A)	Static	Closed, find information a page	Display: Emulator, various info presentation formats
Oquist and Goldstein (2002)	Novice (16)	Static, lab	Closed, subjects read a long & a short text	Display: PDA (Compaq iPAQ 3630 Pocket PC)
Watters et al (2002)	Novice (84)	Static, lab	Closed, 2 table lookup tasks	Display: emulator
Hornbaek et al (2003)	Novice (32)	Static, lab	Closed, 2 maps, locate objects	Display: computer screen
Waterson et al (2002)	Novice (10)	Static 5 lab, 5 remote	Closed, find info on website; clickstream data vs. observation	PDA (Handspring Visor Edge)
Lindroth et al (2000)	Range (12)	Static, lab/office	Closed, 3 tasks, enter data	PDA (Palm V)
Pascoe et al (2000)	Novice (1)	Remote	Open, several tasks	3Com PalmPilot
Kim et al (2002)	Advanced (37)	Remote	Open, mobile Internet tasks	Mobile Internet Phone

Findings from Usability Studies and Proposed Research Direction

The studies cited above present the following characteristics. First, most studies so far have been static and almost all of them have been conducted in a controlled setting (i.e. laboratory), even though most of them investigated wireless applications and/or devices. Although naturalistic studies are very difficult to perform successfully, it is surprising to find that few scholars (Watterson et al 2002; Lindroth et al 2001; Pascoe et al 2000; Kim et al 2002) have investigated a setting where the user is mobile. Hence, it is intended that the research involve both mobile and fixed (i.e. seated) participants. Given the high degree of complexity associated with naturalistic (or field) studies, this experiment will also be conducted in a controlled laboratory setting.

Second, user types have been predominantly novices. This is an appropriate choice especially in the context of usability studies. Therefore, it is intended that the proposed research will be carried out with novice participants, as this will enhance the quality of the results especially for the construct of intention to use wireless devices.

Third, interface types have been predominantly emulators. This approach introduces uncertainty in the results, since the outcome is derived from inappropriate settings, such as form factor, processor power and overall system performance, as well as misleading user-system interaction and consequently misleading user experience. For these reasons, it is intended that the experiment be carried out on an actual wireless device that is representative of the current availability in the market. The choice to use a PDA allows for testing of varied interface types, such as external keyboards, buttons, voice, and/or stylus-based data entry methods, which are not available on all PDAs. Therefore, the interface type to be tested will be a gesture-recognition system, namely Jot, since it demonstrates improved performance over another stylus-based entry method (namely Graffiti) as found by Sears and Arora (2002), and it is reasonable to assume that this method will be used in the years to come due to its advantages over other forms of input modes (e.g. carrying and attaching an external keyboard every time the user needs to enter data, user is able to enter data while moving, etc.).

Finally, the task types have been typically closed, a setting that allows for controlled behaviour in the experiment and objective data. Closed tasks will be used in this experiment as well for the same reasons. The tasks will be identical for the four test groups. The tasks will involve authoring and retrieving text messages, authoring and retrieving contact information, and accessing a wireless Website.

Having described the various settings for this experiment, Table 3 illustrates the study proposed by showing the treatment conditions (i.e. independent variables). Figure 4 shows the research model that will be tested in this study. The constructs of efficiency, effectiveness, and satisfaction as determinants of usability have also been studied by numerous scholars, as shown by the meta-analysis study performed by Mahmood et al (2000).

Table 3: Treatment conditions (i.e. independent variables) for proposed study.

Experiment independent variables	**Static (User)**	**Mobile (User)**
Low Visibility (Environment)	***Group I***	***Group II***
High Visibility (Environment)	***Group III***	***Group IV***

In summary, four groups of 25 persons will complete each treatment. The independent variables are the mobility of the user (seated vs. walking) and the visual environment (low vs. high, as in glare vs. clear). The dependent variables are satisfaction, effectiveness, efficiency, usability, and intention to use.

5. Research Approach

Operationalization of independent variables

The independent variables studied are user mobility (seated vs. walking), and visibility of wireless device screen content (i.e. visual environment: clear vs. glare). The importance of these three variables has been articulated by Maguire (2001). The proposed experiment is one of a 2 x 2 factorial design (treatments include variations in user mobility and visual environment), giving four experimental conditions. This design will allow for any differences found among the four groups to be attributed to the increased levels of mobility and visibility and the specific interface type. This approach was also used by Watters et al (2003).

The two levels for each of the first two variables (mobility and visibility) were set based on the work by Maguire (2001). Aside from his work, there has been no other comparable study, to the best of this author's knowledge. Each of the two levels for these variables is expected to have an impact on the task effectiveness, task efficiency, and user satisfaction.

Operationalization of dependent variables

The dependent variables studied are five perceptual variables including user satisfaction, effectiveness, and efficiency, usability, and intention to use wireless devices. Effectiveness was assessed qualitatively based on questions by Cross and Smith (1996). Quantitative assessment of effectiveness was based on the task completion (i.e. how many users completed the task) and how accurate was the completed task (e.g. how many errors did the users make in entering the text message). Efficiency was evaluated qualitatively by questions by Teo et al (2003), and quantitatively by the following (all quantitative criteria adapted from Chittaro & Dal Cin 2002):

- Time to complete task (e.g. how long did it take users to write the text message?)
- The number of actions (e.g. how many actions did the users make in sending the text message?)
- The time spent on specific sub-tasks, e.g.:
    - How much time did users spend on navigating to the text message entry screen?
    - How much time did users spend on correcting errors in the text message?

The satisfaction instrument was based on the System Usability Scale (SUS), developed by Brooke (1996). The SUS was modified by replacing the words "the system" with "the wireless device". By doing so the questions remained the same preserving the internal validity of the

questions, while at the same time making the questions more specific to the wireless device in use, an expected benefit for participants who are completing the survey and would not be misled. The SUS was also modified for this research by removing questions 5 and 6. The questions read "I found the various functions of the system were well integrated" and "I thought there was too much inconsistency in the system" respectively. The reason these questions were removed is that they do not fit well with wireless devices and the tasks at hand, given their low complexity. Also, question 2, "I found the system unnecessarily complex", and question 8, "I found the system cumbersome to use", were removed as they were redundant with question 3. Question 4, "I think that I would need the support of a technical person to be able to use the system" was replaced with "I will be able to use these applications again in about 1 month without having to be reminded of how to use it" by Woodroof and Burg (2003), because it adds the memorability element, while removing a question about complexity, an element addressed in question 3. Woodroof and Burg (2003) also contributed the new question 2, "It is easy to recover from the errors I make when using wireless devices" which deals with errors. Finally, the new questions 5 and 6 were taken from (Teo et al 2003).

Finally, usability and intention to use (adopt) wireless devices were determined by questions from Ducoffe (1996) and Teo et al (2003). All questions were rated on a seven-point Likert scale.

The author will ensure content validity for the above items in three phases. First, the author will consult two experts in the field of information systems usability and measurement theory. Second, the survey questions will be tested with post-graduate students who have extensive experience with wireless devices. Upon analysis of feedback, corrections / amendments will be made to refine the survey instructions and wordings. Third, the revised survey will be administered to a pilot group consisting of three subjects for each experimental cell (total of 12 subjects). Upon completion of the survey, if the pilot group feedback suggests that no substantial changes are required, the final version of the survey will be produced.

Experimental design and procedure

Task and procedure

The PDA model will be chosen for its ability to receive user input by means of Jot (a stylus-based data entry). Furthermore, this model will be a fair representative of the typical PDA currently available in the market.

The proposed experiment is one of a 2 x 2 factorial design. This design will allow for any differences found among the four groups to be attributed to the increased levels of mobility and visibility and particular interface type. This approach was also used by Watters (2003). The task will consist of authoring and retrieving a text message, authoring and retrieving contact information, and accessing a wireless Website. The subject population will primarily (if not exclusively) consist of university students. Selection of the subjects will be made on the condition that the subjects have no prior experience with PDAs. Any experience with PC-based text messaging will be acceptable and documented. Hence, the experiment will be realistic in the experience a new user would have when first buying and using a PDA. The reason for selecting novice users as test subjects is supported by Palen el al (2001). Finally, a one-hour training session will be held to familiarize the subjects with Jot, the stylus-based data entry method to be used for authoring a text message, entering contact information, and accessing a wireless website.

To increase the realism of the task, test subjects will need to make their way through the menu to the appropriate screen (e.g. text message authoring screen) on their own. The duration of each task will be distinctly recorded as navigation time and authoring time, so as to increase the accuracy and validity of the conclusions. Finally, there will be a task validity test to ensure task realism.

The four groups will conduct the experiment in four separate, but consecutive, sessions. The tasks to be completed will be the same in all experimental treatments, with only user mobility and visibility as changing parameters. All participants will be physically separated by allowing for a minimum five-minute margin between sessions. Each participant will begin by completing the pre-experiment survey, continuing with the experimental tasks, and finally ending with the

post-experiment survey. During all phases, participants will not be allowed to interact with others in an attempt to isolate the environmental conditions that are being tested (i.e. not having additional environmental conditions, such as privacy, influence the outcome). The experiment administrator will not offer any assistance throughout the experiment, again in an attempt to approximate the realism of the task.

There will also be a pre-test and post-test survey. Each of the two tests has a different set of goals. The pre-test survey will be used to collect demographic data, including important dimensions such as user skills, user experience and user expectations. These three factors have been shown to impact user satisfaction, along with perceived ease of use and perceived usefulness of a technology (Mahmood et al 2000). The instruments used to test these factors are included in Appendix A. The post-test survey will be used to evaluate user satisfaction, perceived ease of use, and perceived usefulness of wireless devices and the intention to use them. Many scholars have supported these constructs, as presented in a meta-analysis by Legris et al (2002). The instruments used to test these constructs are included in Appendix B.

Subjects

A total of 100 subjects will participate in this experiment. The decision to set the sample size to 100 was determined according to the requirements of the statistical method selected, which for this study was Partial Least Squares (PLS). The reasons for selecting PLS include the advanced analytical tools offered by Structured Equation Modeling, a second-generation statistical method, and because it is well suited for exploratory research such as the one at hand. As such, the subjects required for PLS are 10 times the number of items in the most complex instrument. In this study, the most complex instrument is that of user satisfaction with 9 items. Therefore, PLS requires 90 subjects for the analysis of this model. To compensate for error (i.e. subjects' experimental sessions and/or surveys that cannot be used), another 10 percent of the total subjects required was added, bringing the total to 99. Since there are four groups however, this number was rounded up to 100, resulting in 25 subjects per treatment. This sample size per treatment group appears to be surpass the requirements of an HCI study. First, Nielsen (1994) showed that four to five experimental subjects could find 80% of usability problems. Second, Carroll (1997) suggests that an average of nine subjects in laboratory usability evaluations is

enough for HCI. Therefore, the researcher feels confident in the conclusions to be drawn by such a large sample (i.e. 100).

Subjects will be individuals that are students, staff, or faculty of this institution. Each subject will participate on only one treatment group, and assignment will be fully randomized to control for confounding effects due to differences in subject characteristics. Each subject will receive payment of $20 for participating in this experiment, which is expected to consist of two hours. The first hour will be used to train the subjects on the use of Jot, while the second hour will be needed to run the experiment and have the subjects complete the required tasks. ANOVA testing will ensure that there are no significant differences between groups in terms of gender, age, and user experience with computers.

6. Contributions of this Research

The proposed research is valuable as it offers significant contributions to several parties across several areas.

To begin with, by using consumers as test subjects, the experiment will yield valuable findings on their perception of usability, as well as the impact various conditions (here, mobility and the visual environment) have on a consumer's use of a particular wireless application. In addition, the consumers' intention to use wireless devices will be explored, and given that the subjects will be Canadians, noteworthy comparisons will be drawn for the current and intended levels of using wireless data services among Canadians versus the rest of the world.

Secondly, software designers stand to benefit from this research, seeing how currently they primarily use their expertise when designing the interface of a new application, in the absence of insightful consumer feedback. Consumer feedback will be solicited in this experiment both quantitatively (through the experimental tasks) and qualitatively (through the survey).

Thirdly, network carriers will gain from the intended study, because they are constantly seeking information that will be helpful to them in delivering improved services to consumers. In addition, the study sample will generate data on the consumers' intention to use text messaging, organizers, and the wireless Web, as well as their satisfaction with both the application and the medium, information that is valuable to Canadian network carriers.

Finally, this study will also help broaden the academic body of knowledge on the topic of usability. So far usability has been studied primarily from a technological perspective (see: Previous Research). This research effort will add a novel dimension to usability studies by focusing on the user and the environment with various tasks at hand, in the same experiment. It is one of the few efforts that would fall under the umbrella of "new usability", from which additional studies may emerge. This approach effectively resolves issues that arise when usability studies are carried out on emulators, including those of absence of form factor, unrealistic hardware performance, misleading human-computer interaction and user experience.

7. Limitations

It has been observed that adoption of the various m-Commerce services depend to some extent on the cultural disposition on the user. Consequently, analysts often make reference to three geographical regions (i.e. North America, Europe, Asia / Japan) not only because they lead the pack in m-Commerce adoption, but also because they present cultural differences and consequently distinct consumer behaviours (O'Keefe et al 2000). This research will be carried out exclusively with Canadians as test subjects, so any conclusions may not be accurate if generalized on a global scale for the above reason.

In addition, to accommodate soliciting the large sample necessary to complete this study, the test subjects will be individuals that are students, staff, and/or faculty. Again, this constraint may not yield accurate results in terms of intention to adopt wireless devices and m-Commerce services, but effort will be made to have the sample cover the entire spectrum in terms of gender, age, education, income, and computer proficiency. This effort may minimize the corresponding error associated with not having a true random sample.

Furthermore, the nature of the tasks will be simulated in a laboratory setting. As such, any sense of urgency (or other contextual emotional response) that a user might experience in a real-setting would not arise here, other than those triggered by mobility and visual environment. While this is a limitation in terms of the realism of the study, it is a means of controlling for additional variables that could not be otherwise measured at this time. Thus, the study is expected to have relatively low external validity, but high internal validity. In addition, the experiment will be carried out at a single point in time and is therefore limited in its ability to evaluate usability over a period of time.

Finally, the results from this study are not generalizable. According to the researcher's definition of usability, context of use is a critical factor. Therefore, if the same input interfaces are to be tested for a different application other than the tasks tested, or if the tasks are to be completed by other input-interface types than the gesture recognition (Jot), then the findings from the study will need to be validated. The same limitation applies for testing the impact of the user's mobility and the visual environment on other input-interfaces and/or applications.

8. Outline of Thesis Chapters

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  1.1.2 Usability
  1.1.3 Why study Usability?
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  2.2.1 Introduction
  2.2.2 m-Commerce Market Participants
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2.3 Usability
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3.2 Survey Design
  3.2.1 Pre-test survey
  3.2.2 Post-test survey
Chapter 4. Results
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References
Appendices

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Appendix A: Pre-Test Survey Draft

What is your gender?
- Male
- Female

What is your age?
- 18 to 24
- 25 to 29
- 30 to 34
- 35 to 39
- 40 to 44
- Over 44

What is your income?
- Less than $25,000
- $25,000 to $50,000
- $50,000 to $75,000
- $75,000 to $100,000
- More than $100,000

What is your highest level of education?
- Did not complete High School
- High school
- Some College / University
- College / University Graduate
- Graduate Degree
- Other

How many hours per week are you online for work or study?
- Less than 5
- Between 6 and 10
- Between 11 and 20
- Between 21 and 30
- More than 30

How many hours per week are you online for recreation?
- Less than 5
- Between 6 and 10
- Between 11 and 20
- Between 21 and 30
- More than 30

Please indicate the number of hours you access the Internet per week from each of the following:

- At Home: _____
- At Work: _____
- At School: _____
- At a Friend's Home: _____
- Via a Wireless Device: _____
- At a Public Library: _____
- At an Internet Café: _____
- Other – Please Specify: _____

If you access the Internet from home, what type of connection do you have?

- Telephone Modem
- Cable Modem
- DSL
- Wireless
- Web TV
- ISDN
- Satellite
- Other – Please Specify: _____

Which of the following wireless devices do you currently own?

- Pager
- Two-way pager
- Cellular phone (analog or digital)
- Personal Digital Assistant (PDA)
- Handheld PC
- Laptop / Notebook
- Smart phone

Have you ever used a stylus to enter data on a PDA before today?

- Yes
- No

How long did you require training on entering data with the stylus?

- Less than 15 minutes
- Between 15-30 minutes
- More than 30 minutes

Do you subscribe to wireless services other than voice?

- Yes
- No

IF YES, please specify:_____

Have you ever bought any products or services wirelessly?

- Yes
- No

IF YES

How many times have you bought products or services wirelessly?

- 1
- 2 to 4
- 5 to 9
- 10 or more

Approximately how much did you spend on each wireless purchase?

- $1-$25
- $26-$50
- $51-75
- $75 – $100
- More than $100

Why have you bought these products / services wirelessly?

_____
_____
_____

IF NO

Why have you not bought products or services wirelessly?

_____
_____
_____

Appendix B: Post-Test Survey Draft

The following dependent variables are measured on a 1-7 Likert scale where 1 represents strongly disagree, 4 represents neutral, and 7 represents strongly agree, unless otherwise stated.

(I) Satisfaction

1. I think that I would like to use a wireless device frequently.
2. It is easy to recover from the errors I make when using the wireless device.
3. I thought the wireless device was easy to use.
4. I will be able to use the wireless device again in about 1 month without having to be reminded of how to use it.
5. I feel satisfied with my use of the wireless device.
6. I feel pleased with my use of the wireless device.
7. I would imagine that most people would learn to use the wireless device very quickly.
8. I felt very confident using the wireless device.
9. I needed to learn a lot of things going before I could get going with the wireless device.

(II) Effectiveness

1. The wireless device increased my ability of communicating with others.
2. The wireless device provided me with an effective alternative for communicating with others.
3. The wireless device helped me to meet my communication needs.

(III) Efficiency

1. I could easily author a text message.
2. I could easily retrieve a text message.
3. I could easily enter contact information.
4. I could easily retrieve contact information.
5. I could easily access a wireless Website.
6. I was able to access the various wireless device applications quickly.
7. I took little effort to use the wireless device.
8. The wireless device allowed me to communicate quickly.

(IV) Usability

Please indicate on the scale the extent to which you agree with the adjective that represents your assessment of the usability of the wireless device

1. not efficient……efficient
2. not effective……effective
3. not satisfactory……..satisfactory
4. not usable…….....usable

(V) Intention to use

1. I intend to use a wireless device in the near future