Ubiquitous Usability: Exploring Mobile Interfaces within the Context of a Theoretical Model

Khaled Hassanein & Milena Head

DeGroote School of Business, McMaster University
1280 Main Street West, Hamilton, Ontario, Canada, L8S 4M4
{hassank, headm}@mcmaster.ca

Abstract. Mobile commerce (m-Commerce), which allows for anytime/anywhere access to information and services, shows great potential. Ubiquitous access to information systems is critical to enable such activities. However, as with most systems, usability is critical to the success of mobile applications. This paper presents a new theoretical usability model that takes into account the unique characteristics of ubiquitous mobile systems. By presenting the various types and limitations of the mobile user, environment, task and interface, this model helps further our understanding of the unique usability aspects of this emerging field. Various mobile interface options are then evaluated within the context of the proposed model. Conclusions are drawn and areas for potential future research are provided.

1 Introduction

Wireless data communication is the independence of time and location, which results in increased flexibility, convenience and ubiquity for users. Mobile commerce (m-Commerce) utilizes wireless networks to enable users to access information, perform transactions and communicate via mobile devices, such as cellular phones, personal digital assistants, pagers, notebooks, etc. Mobile applications provide companies more opportunities to execute business transactions, interact with trading partners, improve customer service levels, extend brand presence, and enhance collaboration between an increasingly mobile workforce. Ubiquitous access to information systems is critical to enable such activities.

m-Commerce can be viewed as a new channel for engaging in e-Commerce. However, some fundamental differences exist which differentiate the two environments, such as their platforms, communication modes, internet access devices, communication protocols, development languages, enabling technologies, and increased security and privacy threats [9],[14]. Another key difference between these environments is the range of unique usability challenges facing the m-Commerce environment. Although progress has been made in terms of wireless technological innovations, many mobile applications remain difficult to use, lack flexibility and robustness [5]. Generally, not enough effort has been directed towards considering the human factors of ubiquitous systems [5].

In this paper, a model for ubiquitous usability is presented in Section 2. This model takes a holistic view of usability, examining user, environment, task and interface elements. Since to the end-user, the human-computer interface is often considered the most important component of the entire system, the remaining sections of this paper focus on the interface element of ubiquitous usability. Section 3 evaluates the ubiquitous usability of various mobile interfaces, within the context of the proposed model. Finally, section 4 provides some conclusions and areas for future research.

2 A Model for Ubiquitous Usability

A usable system will facilitate interaction with its users by making the interface "transparent" to those users, focussing their attention on the mission and not the means [17]. Researchers agree that usability involves many aspects or dimensions, which are often mutually dependent [36],[18],[15],[28],[22]. Nielsen's [28] work, which is often cited, defines usability along the dimensions of learnability, efficiency, memorability, error prevention, and satisfaction.

Within the context of the Web, several models have been proposed to explore the concept of usability [13],[12],[42]. Such models have been designed for systems that are typically used within a static environment (e.g. office or home). The dimensions and aspects of these models are still applicable within a mobile environment to a certain extent. However, they fail to provide a complete picture of all the factors impacting usability for mobile users who are typically engaged in tasks within dynamic environments. As such, the usability of a mobile interface may be heavily influenced by the environment or context in which it is being used [19],[21].

In order to fully understand the factors influencing usability within a mobile setting the elements of user, task, interface and environment need to be considered. The interactions of these various elements result in distinct settings with different usability requirements and consequently different suitable interfaces. We propose a new ubiquitous usability model that incorporates these elements, as shown in Figure 1. User, task, interface and environment elements, which can each be classified into various types and exhibit a variety of limitations, influence each other and impact the overall usability of a mobile experience or setting. The types and the limitations of each of the elements are discussed below in more detail.

2.1 The User

The user is central to this model, as he/she typically determines the mobile task to be completed via a particular interface within an environmental context.

User Types. Users may broadly be classified according to several characteristics and schemes. Below are two common classifications found in the literature.

Novice/Expert: Expertise can be considered along several aspects: experience with the task domain, system, and with computers/devices in general [28]. There is ample evidence to support the intuitive notion that domain experts behave differently from novices [34]. Experts do not just know more, they know differently. Experts are better able to organize data into meaningful chunks [7], and they have a rich set of structures within which to characterize new problems. Experts also tend to take top-down approaches to problem solving, whereas novices tend to use bottom-up approaches that lack comprehensive planning [2].

When using an interface, system expert users can quickly form goals and sequences of actions to achieve those goals. They prefer the interaction to be efficient in terms of time and required actions. Novice users, on the other hand, prefer an interface that is easy to use and "guessable", which helps them to guess the next most appropriate action.

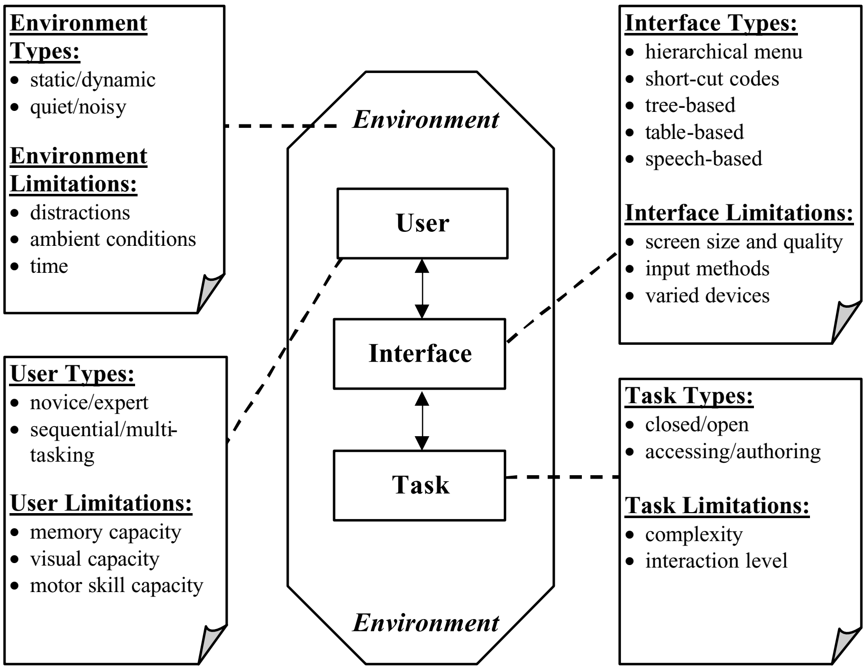


Figure 1: Ubiquitous Usability Model

Sequential/Multi-tasking: The work of psychologists such as Sperry [40] led to the concept of left brain and right brain orientation. The left brain is generally associated with sequential processing, whereas the right brain is generally associated with spatial ability and multi-tasking. Users that are oriented towards multi-tasking may more easily interact with a mobile device while also interacting within their environment (such as talking with others, watching TV, walking, etc.)

User Limitations. In performing mobile tasks, as with any other tasks, humans are limited by their memory, visual and motor skill capacities, among others. These constraints are explored below.

Memory Capacity: Miller's work [25] in chunking and the "magic number seven" emphasized that humans are extremely limited in how much information they can recall from memory. We have a much greater capacity for recognition (selecting a relevant item from a larger list) than for recall (remembering an item without any cues) [1]. A mobile interface that forces the user to recall specific commands that are used infrequently may be very difficult or cognitively taxing due to human memory limitations.

Visual Capacity: Visual capacities and perceptions vary across individuals, visual stimuli and environments. For example, we are less sensitive to the colour blue (especially as we age); peripheral vision is more dominant in dim lighting; and red objects appear closer than blue objects [10]. Visual processing may also be highly dependent on user expectations. For example, if a user expects a particular image and is presented with something that is similar (but different), the expectation may override the visual input, leading the user to incorrectly process the image. As with any system, mobile interfaces must be carefully designed to account for the visual capacities and perceptions of mobile device users.

Motor Skill Capacity: Measures of human motor skills include speed and accuracy, which are important in the design of interactive systems [10]. Fitts' law [11] states that the time taken to hit a target (such as a menu item, button or icon) is a function of the size of the target and the distance that has to be moved. Since users find it difficult to manipulate small objects, targets should be as large as possible and the distance to be moved as small as possible. Mobile devices, which are characterized by small screen displays, are challenged when trying to make targets as large as possible. Large targets on a small screen would greatly limit the number of objects that could be displayed.

2.2 The Environment

Ubiquitous mobile systems are likely to be used within varying environments. Therefore, the usability of such systems is impacted by the context in which it is being used.

Environment Types. Environments may be broadly classified according to several characteristics. Below are two environmental classifications applicable to ubiquitous usability.

Static/Dynamic: In a static mobile environment, the user is engaged in applications while being stationary (e.g. sitting at an airport). In a dynamic mobile environment, on the other hand, the user is engaged in mobile applications while moving around (e.g. walking through a mall). A dynamic environment imposes more challenges for the user and the user interface.

Quiet/Noisy: A quiet mobile environment is characterized by minimal audio/visual interferences. A noisy mobile environment, on the other hand, suffers from a high level of such interferences. Since mobile tasks are typically performed outside the settings of an office or a home, the user has less control over the level of noise in his/her environment. For example, a mobile user will experience a higher level of interference with their mobile tasks while walking on a noisy street bustling with traffic compared to working in the privacy of their quiet office. A noisy or interactive environment, where the mobile user is distracted by noise or communication with other individuals while engaging in a mobile task will obviously impose some additional constraints on the ability of the user to focus solely on the mobile task at hand.

Environment Limitations. The environment may pose several limitations that influence task performance for a ubiquitous mobile system. Some of these limitations are explored below.

Distractions: These limitations arise due to the dynamic nature of a typical mobile environment. A mobile user operating in such an environment will potentially be subjected to many distractions due to various stimuli that will compete for her/his attention while interacting with mobile applications [30]. Such stimuli include the presence of others and noise levels.

Ambient Conditions: Mobile applications might have to be performed under suboptimal environmental conditions such as poor/high luminance, and extreme temperatures. Mobile users are very limited in what they can do to control such conditions. These conditions may also change suddenly without warning. For example, users surfing the Web on a PDA under well lit conditions, might suddenly find themselves in total darkness as their train passes through a dark tunnel.

Time: Substantial research suggests that when faced with time pressure, users process information more selectively [41],[43] and use less complex decision strategies [8],[31]. Miller et al. [26] proposed that there are three major ways of coping with time pressed situations:

- *Acceleration:* Users process the same information at a faster rate. Errors may occur due to the temporary overload of memory or processing capacity.
- *Avoidance:* Users process information at the same rate and simply stop when time has run out. This may result in incomplete tasks or poor decisions due to incomplete information.
- *Filtration:* Users chose to examine only the subjectively important data for consideration. The cognitive process is altered as a result of the time pressure.

Therefore, in a mobile environment where users often have only short periods of time to complete wireless activities, their tasks and decision making capabilities may be altered or limited. This limitation gains added importance when we consider that the mobile user is typically paying for accessing mobile applications by the minute.

2.3 The Task

In addition to user and environmental considerations, usability within a mobile environment is influenced by the characteristics of the task.

Task Types. Tasks may be broadly classified according to several characteristics, two of which are outlined below.

Closed/Open: A closed task has a specific objective that is often decomposed into sub-goals. An open task has a general objective and is considered more exploratory, vague, and non-specific compared to closed tasks [6]. Searching for a specific stock price on a mobile device would be considered a closed task, whereas browsing a news site for stories that may be of interest would be considered an open task.

Accessing/Authoring: In an access task, the mobile user is engaged in programmed processing (sequence of known steps) to retrieve available information. In an authoring task, the mobile user is engaged in emergent processing (steps that unfold according to intermediate results) in order to generate new information. For example, retrieving the latest news would be considered an access task, whereas sending a e-mail message is an authoring task [39].

Task Limitations. The task itself may pose several limitations that influence the usability of ubiquitous mobile systems. Some of these limitations are outlined below.

Complexity: The complexity of any task is determined by its nature and scope as well as by the level of user involvement required. Additionally, the availability, volume, accuracy and structure of data can greatly impact the complexity of the task. Generally, mobile users have access to a very limited amount of information compared to regular Internet users. Limited information would bind the types of tasks that could be successfully completed via mobile devices. However, some types of information may be abundantly available. When the quantity of information leads to information overload, the mobile user may no longer comprehend the information due to its sheer volume [20] combined with mobile device limitations. Additionally, as with the wired Web, information in a mobile setting may be opinion-based rather than fact-based and data maintenance may not be considered a priority. Unstructured information may also impose additional cognitive burdens on the user during task completion. In a mobile setting, where additional complexity may exist within the environment, reducing task complexity gains increased importance.

Interaction Level: Some tasks may require a higher level of interaction (such as online games) compared to others (such as weather forecast requests). In a mobile setting where environmental distractions and limited input mechanisms hinder interaction, highly-interactive tasks may be more difficult to accomplish.

2.4 The Interface

Much like any system, in the eyes of the user, the interface of a mobile application is the system. Several mobile interface types and limitations are explored below.

Interface Types. Several alternative mobile interfaces have been deployed or proposed in current literature. These designs present different approaches to address some of the usability challenges faced in mobile environments. Here we focus on cell-phone interface options for mobile applications, and distinguish between five interface types, which are illustrated in Figure 2. Although Figure 2 illustrates the interface types within a cell-phone device, such interfaces are also used across various other mobile devices.

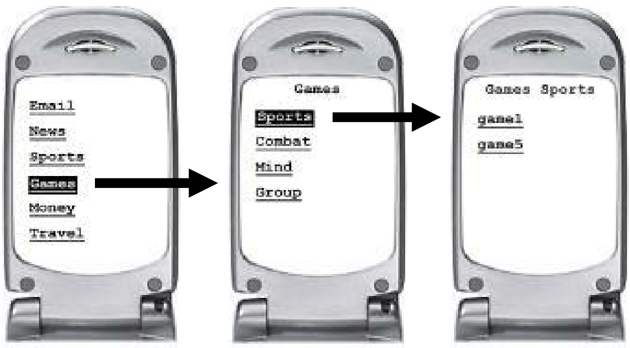
Hierarchical Menu: Users are presented with a series of options that, when selected, present a series of sub-options. This navigation continues until the user finds the desired function or information. This is the most commonly used interface approach for mobile applications [5]. Figure 2a shows a possible sequence of menus to obtain a list of available games that have a sports theme.

Short-Cut Codes: Users spell out the application, function or information they wish to access by pressing the appropriate numeric keys, which have associated alphabetic letters [24]. For example, if a mobile user wishes to access "Game Sport", as shown in Figure 2b, he/she would begin by pressing "4" (for "G", since the key 4 has letters GHI) followed by "2" (for "A", since the key 2 has letters ABC), and so forth.

Tree-based: Upon selecting a top-level node within a tree-structure, the tree is expanded to show sub-topics available within this option [5]. Users can jump to sibling and parent content with a single action, rather than backtracking and moving forward again, as is the case with the menu interface. Figure 2c illustrates a sample menu structure to find a list of available sports-related games, where indentation level is marked by vertical lines rather than folder icons in order to conserve screen space.

Table-based: Tables can allow for more information to be displayed within a small screen, where icons or symbols can be used to represent some information [33]. An example of a table-based interface is shown in Figure 2d. In the top row of the table, symbols represent desired sorting functions or key characteristics for online games (sports, combat, mind, and group). On the right side of the table, the available games are listed. The results are represented using standard QFD (Quality Function Deployment) symbols, where triangles indicate a weak relationship, empty circles indicate a medium relationship and filled circles indicate a strong relationship.

Speech-based: When interacting with mobile devices, users' eyes may be needed on the environment rather than on the interface. Speech recognition and synthesis may help alleviate some user burdens during mobile device interactions. Speech recognition and synthesis may be applied to any of the mobile interface modes discussed above, but are best suited for interactions with hierarchical menu or short-cut codes interfaces. Mobile users can verbally select items from a presented menu or can verbally input a command to directly activate the desired function or retrieve the desired information (as shown in Figure 2e).



2a: Hierarchical Menu Interface

2b: Short-Cut Codes *2c: Tree-Based Interface*

2d: Table-Based Interface *2e: Speech-based for Short-Cut Codes*

Figure 2: Various Mobile Interface Options for an Online Games Example

Interface Limitations. The various mobile interfaces are impacted by one or more of the following limitations.

Screen size and quality: Mobile devices are conveniently sized to fit in small areas, such as a pocket, consequently constraining their display area. Therefore, mobile devices are not well suited for displaying text-intensive content the same way a desktop computer is. Additionally, screen resolutions, color depths and contrasts are still limited in most current mobile devices.

Navigation structure is also difficult to convey in the limited screen space of mobile devices. Mobile applications that provide extensive navigation through information and transaction options will require many key presses.

Input methods: Traditional keyboards and mice are not available on most mobile devices. Hence, more effort is required by users to enter data/requests and errors are more likely. Errors are especially inconvenient in a mobile environment since they can be expensive and time consuming if a user has to repeat an action.

Varied devices: There is a vast variety of mobile devices, which differ in their screen size and quality, input and output methods, and battery, memory and storage capacity. Applications optimized for one type of device may not work well on other devices. Mobile users may even switch between platforms while carrying out a single task. For example, a shopper may search for a particular gift on a laptop, download the search results onto a PDA for evaluation while traveling to work, and purchase the desired gift through a cellular phone.

3 Ubiquitous Usability of Mobile Interfaces

Several types of mobile interfaces were discussed in Section 2. Each of these interfaces possess advantages and disadvantages that may make it better suited for use within certain mobile settings. Table 1 presents the advantages and disadvantages of these interface types within the context of our ubiquitous usability model. As an illustration, the hierarchical menu interface supports novice users by presenting a series of menus from which to choose appropriate options. While hierarchical menus increase the average number of key presses, this is acceptable to the novice user who requires guidance through an unfamiliar navigation system. However, an expert user who frequently uses the system to complete a familiar task would wish to reduce the average number of key presses and task time. This is particularly important in a mobile setting since the user is typically paying for accessing mobile applications by the minute and the uncontrollable nature of the environment may necessitate tasks to be completed quickly to avoid interruptions. Therefore, short-cut codes which bypass a navigation structure and allow direct access to a desired task are better suited for expert users. Short-cut codes do not support novice users since no necessary guidance is provided for the unfamiliar system. A table-based interface, on the other hand, may support both novice and expert users. The novice user is presented with multiple options from which they can choose, and the expert user can quickly select the desired option without being forced through a successive navigation structure. However, such an interface may not be suited for all types of tasks, applications or information. A speech interface could be applied to any of the other interface modes. As such, it would tend to inherit some of the advantages and disadvantages of these interfaces. However, a speech-based interface imparts an advantage that it is hands-free, supporting multi-tasking for both novice and expert users.

Table 1: Advantages and Disadvantages of Mobile Interface Types

Mobile Interface	Advantages	Disadvantages
Hierarchical Menu	***User*** • supports novice users [23],[37] • relies on recognition rather than recall (addressing the memory capacity limitation) [32] • focuses the user on a few choices (addressing the visual capacity limitation)	***User*** • cumbersome for expert users [37] • increases the average number of key presses (contributing to the motor skill limitation) • menu choices are based on designer, not user, intuition [29] • force the user to consider the system/information in a top-down manner [38]
	Task • alerts users to the existence of task options they may be unaware of • reduces screen clutter (addressing the complexity limitation)	***Task*** • lacks visual cues for overall navigation structure (contributing to higher complexity for accessing tasks) [29] • may require numerous backtracking actions (contributing to higher complexity for accessing tasks)
	Environment • appropriate for both quiet and noisy environments	***Environment*** • time consuming • awkward within certain dynamic settings • awkward within certain ambient conditions (in particular, dim lighting)
Short-Cut Codes	***User*** • supports expert users [23],[37] • highly reduces the average number of key presses (addressing the motor skill limitation) • limited screen clutter (addressing the visual capacity limitation)	***User*** • does not support novice users [37] • relies on recall rather than recognition (contributing to the memory capacity limitation) [32] • codes are pre-determined by designer, rather than user intuition
	Task • supports closed tasks	***Task*** • does not support open tasks • overall information structure not conveyed (contributing to higher complexity for accessing tasks) • users may be unaware of all task options

	Environment • highly time efficient	***Environment*** • awkward in environment with multiple distractions since it requires the user's full attention • awkward within certain ambient conditions (in particular, dim lighting)
Tree-Based	***User*** • supports novice users [37] • relies on recognition rather than recall (addressing the memory capacity limitation) [32] • moderately reduces the average number of key presses (addressing the motor skill limitation)	***User*** • somewhat cumbersome for expert users [37] • tree structure is based on designer, not user, intuition [29] • quickly occupies limited screen space (contributing to the visual capacity limitation)
	Task • reduces backtracking actions (reducing complexity for accessing tasks) • overall information structure is conveyed (reducing complexity for accessing tasks)	***Task*** • increases screen clutter (contributing to the complexity limitation) • difficult to use with a deep and/or broad tree structure [27]
	Environment • appropriate for both quiet and noisy environments • time efficient	***Environment*** • awkward within certain ambient conditions (in particular, dim lighting)
Table-Based	***User*** • could support both novice and expert user • relies on recognition rather than recall (addressing the memory capacity limitation) [32] • reduces the average number of key presses (addressing the motor skill limitation)	***User*** • table structure is based on designer, not user, intuition • quickly occupies limited screen space (contributing to the visual capacity limitation)
	Task • somewhat reduces backtracking actions (reducing complexity for accessing tasks) • information structure is partially conveyed (reducing complexity for accessing tasks) • can present more data in a tight space [27],[33]	***Task*** • increases screen clutter (contributing to the data limitation) • may not be suited for all types of tasks, applications or information
	Environment • appropriate for both quiet and noisy environments • somewhat time efficient	***Environment*** • awkward within certain ambient conditions (in particular, dim lighting)

Speech-Based	***User*** • could support both novice and expert users • minimizes key presses (addressing the motor skill limitation) • hands-free, supporting multi-tasking • natural input [3] • not affected by visual and motor skill limitations	***User*** • inappropriate for users with speech impediments or thick accents • poor quality speech-synthesis may lead to user annoyance [4] • speech output is slow, serial, and provides no short-term memory aids [35],[16]
	Task • appropriate for both accessing and authoring tasks	***Task*** • inappropriate for tasks requiring privacy • inappropriate for tasks containing ambiguous words
	Environment • may be appropriate in various ambient conditions (such as dim lighting)	***Environment*** • may be influenced or degraded by the environment (e.g. noise)

It is important to note that the statements within Table 1 are generic to all mobile devices, however some variations may exist according to the specific characteristics of these devices. For example, screen size is not as much of a limitation for a PDA or wireless laptop device as much as it is for a cell-phone.

Table 1 also illustrates that preferences for the various mobile interface options may vary according to the user, task and environment. Such settings do not remain constant. For example, a user may progress from novice to expert, engage in various types of tasks within a dynamic environment. As such, a highly usable ubiquitous system should allow for multiple interface options to best match the current user, task and environment. Even when the task remains constant, designers of ubiquitous systems must realize that user preferences will vary according to their experience and context of use.

4 Conclusions

Usability plays an important role in the success of any system. Mobile systems are no exception to this rule. Ubiquitous usability is determined by the elements of its user, environment, task and interface. This paper presented a theoretical ubiquitous usability model that incorporates these elements and outlines their interactions. This model helps us to better understand the unique usability aspect of this emerging and promising field. Focus was then directed to usability issues associated with the mobile interface. Various mobile interface options were presented, evaluated and compared within the context of the proposed model. This work suggests that several factors will determine the appropriateness of various mobile interfaces, including: (i) user characteristics and preferences; (ii) environmental attributes and constraints; and (iii) task characteristics and requirements.

Potential areas for future research may include:

- The proposed ubiquitous usability model and the analysis of various mobile interface types (presented in Table 1) represent the opinions of two usability experts. Further validation is recommended with a wider panel of usability experts.
- Developers of m-Commerce applications tend to utilize Web design principles and guidelines. A similar problem was faced during the early days of Web development, when designers tried to apply guidelines of print media to the new hypermedia Web environment. A new set of usability guidelines that considers the unique demands of ubiquity is required.
- Beyond the ubiquitous usability issues presented in this paper, personalized mobile interfaces may play a key role in the success of future m-Commerce systems. The impact of such interfaces on the user experience should be further explored.

Both consumers and businesses yearn for the flexibility and convenience afforded by ubiquitous systems. The key to the success of such system hinges on their usability.

References

1. Barsalou, L.W. (1992). Cognitive Psychology, Hillsdale, NJ: Erlbaum.
2. Batra, D., Davis, J.G. (1989). A study of conceptual data modelling in database design: similarities and differences between expert and novice designers. in J.I. DeGross, J.C.
3. Beaudouin-Lafon, M. and Conversy, S. (1996). Auditory illusions for audio feedback, In M. Tauber (eds.), ACM CHI'96 Conference Companion, ACM Press, Addison-Wesley, pp.299-300.
4. Berglund, B., Harder, K. and Preis, A. (1994). Annoyance perception of sound and information extraction. Journal of the Acoustical Society of America, 95, 1501-1509.
5. Buchanan, G., Farrant, S., Marsden, G., Pazzani, M. (2001). Improving Mobile Internet Usability. Proceedings of WWW10, Hong Kong, May.
6. Carmel, E., Crawford, S., Chen, H. (1992). Browsing in hypertext : a cognitive study. IEEE Transactions on Systems, Man, and Cybernetics, 22(5), September/October.
7. Chase, W.G. and Simon, H.A. (1973). Perception in chess. Cognitive Psychology, 4, 55-81.
8. Christensen-Szalanski, J.J.J. (1980). A further examination of the selection of problem-solving strategies : The effects of deadlines and analytic aptitudes. Organizational Behavior and Human Performance, 25, 107-122.
9. Coursaris, C. and Hassanein, K. (2002). Understanding m-Commerce: A Consumer-Centric Model. Quarterly Journal of Electronic Commerce, 3(3), 247-271.
10. Dix, A., Finlay, J., Abowd, G., Beale, R. (1998). Human-Computer Interaction: Second Edition. Harlow, UK: Prentice Hall.
11. Fitts, P.M. and Posner, M.I. (1967). Human Performance. Wadsworth, Wokingham.
12. Frokjaer, E., Hertzum, M., Hornback, K. (2000). Measuring usability: Are effectiveness, efficiency and satisfaction really correlated? In: Proceedings of ACM Conference Human Factors in Computing (CHI'00). ACM Press, New York, 345-352.
13. Ghose, S., Dou, W.Y. (1998). Interactive functions and their impacts on the appeal of internet presences sites. Journal of Advertising Reserarch, 38, 29-43.

14. Ghosh, A.K. and Swaminatha, T.M. (2001). Software Security and Privacy Risks in Mobile E-Commerce. Communications of the ACM, February, 44(2), 51-57.
15. Gould, J. D. (1992). How to Design Usable Systems. Handbook of Human-Computer Interaction. M. Helander, North-Holland: 757-789.
16. Halstead-Nussloch, R. (1989). The Design of Phone-Based Interfaces for Consumers. In CHI'98 Conference on Human Factors in Computing Systems, Austin, TX, pp.347-352.
17. Head, M. M. (1997). User Interface Features: Facilitating Information Access and Decision Making. Information Systems, School of Business, McMaster University: 228.
18. Holcomb, R. and A. L. Tharp (1991). What Users Say About Software Usability. International Journal of Human-Computer Interaction, 3(1): 49-78.
19. Jameson, A. (2002). Usability Issues and Methods for Mobile Multimodal Systems. In: Proceedings of the ISCA Tutorial and Research Workshop on Multi-Modal Dialogue in Mobile Environment, Germany, June.
20. Keyes, E., Sykes, D., Lewis, E. (1989). Technology + design + research = information design. Text, Context, and Hypertext, Cambridge, MA: The MIT Press, 251-264.
21. Kim, H., Kim, J. Lee, Y., Chae, M., Choi, Y. (2002) An Empirical Study of the Use contexts and Usability Problems in Mobile Internet. Proceedings of HICSS-35, Hawaii, January.
22. Kirakowsky, J. (1996). The Software Usability Measurement Inventory: Background and Usage. Usability Evaluation in Industry. P. W. Jordan, B. Thomas, B. A. Weerdmeester and I. L. McClelland. London, Taylor & Francis: 169-178.
23. Kurtenback, G. and Buxton, W. (1993). The Limits of Expert Performance Using Hierarchic Marking Menus, Proceedings of INTERCHI'93, April.
24. Marsden, G. and Jones, M. (2001). Ubiquitous Computing and Cellular Handsets - are menus the best way forward? in South Africa Annual Conference of the South African Institute of Computer Scientists and Information Technologists (SAICSIT2001) Pretoria, South Africa.
25. Miller, G.A. (1956). The magical number seven, plus or minus two: some limits of our capacity for information processing, Psychological Review, 63, 81-97.
26. Miller, G.A., Galanter, E., Pribram, K.H. (1960). Plans and the Structure of Behavior, Holt, Rinehart and Winston, New York.
27. Molander, M. (2001). Reducing the user interface. IBM developerWorks Paper Series, ftp://www6.software.ibm.com/software/developer/library/us-reduce.pdf, accessed May 2003.
28. Nielsen, J. (1993). Usability Engineering. Boston, MA, Academic Press.
29. Norman, K.L. (1991). The Psychology of Menu Selection: Designing Cognitive Control at the Human/Computer Interface. Ablex Publishing Corporation.
30. Pascoe, J., Ryan, N. and Morse, D. (2000). Using while moving: HCI issues in fieldwork environments. ACM Transactions on Computer-Human Interaction ToCHI, 7(3), September 2000, pp. 417-437.
31. Payne, J.W., Bettman, J.R. (1988). Adaptive strategy selection in decision making. Learning, Memory, and Cognition, 14(3), 534-552.
32. Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., Carey, T. (1999). Human-Computer Interaction. Addison-Wesley:UK.
33. Pulli, P.J. and Antoniac, P.M. (2000). MARISIL – User Interface Framework for Future Mobile Mediaphone. Proceeding of the 2nd Int. Symp. on Mobile Multimedia Sys. and Applications, Delft, 1-5.
34. Rector, A. L., Newton, P. D., and Marsden, P. H. (1985). What kind of system does an expert need? People and Computers: Designing the interface. Cambridge: Cambridge University Press. U.K. pp.239-247.
35. Schmandt, C. (1994). Voice Communication with Computers. Van Nostrand Rheinhold, New York.

36. Shneiderman, B. (1986). Designing the User Interface: Strategies for Effective Human-Computer Interaction. Reading, MA, Addison-Wesley
37. Shneiderman, B. (1998). Designing the User Interface: Strategies for Effective Human-Computer Interaction. Addison-Wesley.
38. Somberg, B. L., Boggs, G. J., & Picardi, M. C. (1982, October). Search and decision processes in human interaction with menu-driven systems. The Human Factors Society 26th Annual Meeting.
39. Sørensen, C. (2002). Digital nomads and mobile services. Receiver Magazine, Vodafone Group, http://www.receiver.vodafone.com.
40. Sperry, R. W. (1968). Hemispheric Deconnection and Unity in Conscious Awareness. Scientific American, 23, 723-733.
41. Svenson, O., Edland, A. (1987). Change of preferences under time pressure: choices and judgments. Scandinavian Journal of Psychology, 28, 322-330.
42. Teo, H., Oh, L., Liu, C., Wei, K. (2003). An empirical study of the effects of interactivity on web user attitude. International Journal of Human-Computer Studies, 58, 281-305
43. Verplanken, B., Weenig, M.W.H. (1993). Graphical energy labels and consumers' decisions about home appliances : A process tracing approach. Journal of Economic Psychology, 14, 739-752.