User Assistance for Multitasking with Interruptions on a Mobile Device

Gebruikers Assistentie voor Multitasking met Onderbrekingen op een Mobiel Apparaat

(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van
doctor aan de Universiteit Utrecht
op gezag van de rector magnificus, prof. dr. W.H. Gispen,
ingevolge het besluit van het college voor promoties
in het openbaar te verdedigen
op donderdag 12 oktober 2006 des ochtends te 10.30 uur

door

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Siks Dissertation Series No. 2006-17. The research reported in this thesis has been carried out under the auspices of SIKS, the Dutch Research School for Information and Knowledge Systems.

The research reported in this thesis was carried out in the project Personal Assistance for onLine Services (PALS) Anywhere. This project was supported by grant MMI0122NC from the Dutch Ministry of Economic Affairs, as part of the Dutch Innovative Research Program IOP-MMI.

ISBN: 90-39343497

Acknowledgments

Over the last five years I have had the opportunity to give birth twice; once to my son Brandon and once to this dissertation. I am not sure which was more painful, but the pregnancy and labor of my son was definitely shorter. The birth of this dissertation was a process involving many people. I would like to acknowledge the following people for contributing their thoughts, comments, discussion, related work and moral support.

First, thank you to my promoter Jörgen van den Berg for the opportunity to do research at UU and on the PALS project. I appreciated his vision, enthusiasm and genuine interest in his students.

Second, to my supervisors Herre van Oostendorp and Mark Neerincx, I thank you for the discussion and criticisms that helped me to shape many aspects of my research. I greatly appreciate the time and effort they took to supervise my work, and to read my dissertation in great detail.

Thank you to the members of the reading committee: Anton Nijholt, Arno Siebes, Gerrit van der Veer, Mary Czerwinski and Huub de Ridder. I feel privileged and thankful for their careful reading and useful comments.

Utrecht University and the TNO Research Institute were excellent places to work. I had very pleasant colleagues that I would like to thank for their positive attitude and moral support, at Utrecht University: Ion Juvina, Joske Houtkamp, Monique Dixon, Henriëtte van Vught, Joris Graumanns, and at the TNO Research Institute: Myra van Esch-Bussemakers, Kim Kranenborg and Jan-Willem Streefkerk. Very special thanks to Bert Bierman for his technical expertise for the experimental set-ups and ever present smiling face.

I would also like to give special thanks to Pat Kesslak, Steve Fadden, Patty Gerretsen, Leo Blomert and Jan Fransoo for sharing their experiences in going through the dissertation process and giving their encouragement. My favorite quote, “just get the damn thing finished.”

Thank you to Tricolore Pizzeria for the delicious Italian sandwiches that helped me through these last five years. I wouldn’t have been able to do it without my daily lunchtime “Italiaanse bolletje zonder kaas”.

I would like to thank my in-laws, the Kap family, for making my transition to living in The Netherlands easier. They taught me a valuable lesson, the importance of a balance between work and family.

I would not have been able to achieve this without the support and love of my parents Alice and Willard. Thank you for working very hard to provide me with the best possible opportunities for education and willingly supporting my addiction to learning. You can finally enjoy your retirement and tell the family that I am not a professional student anymore: I'm done!!

Although I am very proud of this dissertation, related to other things in life it does not mean much at all without the most special people in my life, my wife Judith and my beautiful son Brandon. Thank you and much love for your warm support, care and providing a soft place to land.

Summary

The focus of this research is on assistance for user interaction when multitasking due to interruptions on a mobile device. A major challenge we address is improving the user experience of handling interruptions while using the mobile Web. Current Web interface designs do not consider problems that users have with the mobile interface. These problems are related to a compounding of issues (e.g., small screen size, difficult data input, inappropriate Web design), and interruptions experienced in a mobile context. As a part of our mobile assistance framework, we propose an Attentive Interface for Mobile Multitasking (AIMM). The attentive interface is proposed to dynamically adapt forms of support to facilitate attention and memory when managing interruptions. This research contributes to building a conceptual, theoretical, and empirical foundation for designing mobile assistance.

There has been a lack of adoption by the general public on use of the Internet when mobile computing. When using the Web on a handheld, usability studies have identified issues such as intensive scrolling and paging, increased search activities, user disorientation, slowed reading, and difficulty with data entry. As covered in Chapter 2, we identified that user performance on the mobile Web can be better understood by comparing the use of a handheld device and a desktop PC for tasks that can be represented on both platforms. Furthermore, we proposed assessing user performance with the mobile Web as a complete package (i.e. small screen, input interaction, Web design), and not just one aspect in isolation. In this research, user performance is defined as the time it takes for a user to complete the (primary) task. The problems encountered during use of a mobile device (e.g., the intensive navigation, interruptions) have a direct negative impact on user performance. The performance issues are attributed to cognitive overhead, revealed as problems with attention and memory. There is a lack of research in addressing attention and memory problems in relation to user performance when using a mobile device. Also lacking is interface support for users when doing more than one task, when switching between tasks, and when different modalities are used with interruptions in the mobile context.

In Chapter 3, a multitasking and interruption framework was developed to identify aspects of the user, tasks, context, mobile device, and user performance that are relevant to user handling of interruptions. This multitasking framework has been used as a basis to develop assistance for supporting users when handling interruption tasks on a mobile device. Our research has shown that people often need assistance when combining use of the mobile Web and other computing tasks. From the PALS research discussed in Chapter 3, we conclude that information search and communication needs for using the Internet on a handheld can be similar to that on a desktop PC. Interruptions from people, phone calls, and the environment are frequently described as problematic when using the mobile Internet. In the future, interruptions (e.g., notifications, reminders, messaging) generated on the device itself will further negatively impact the user experience with the Internet on a mobile device. Mobile assistance that is personal, convenient, inexpensive, and that is representative of a model of customer service can be a useful concept to aid in use of the

Web on a mobile device. This assistance is especially supportive when a mobile device is used in a context of changing events and situations that tax the users' ability to handle multiple tasks. Specific types of assistance (e.g., visual indicators) were found to be acceptable to users when handling interruptions during mobile computing. However, there is a lack of knowledge on the handling and presentation of interruptions while using a handheld. A need exists for empirical user research in order to understand what specific mobile display presentations will be effective and beneficial to users when interrupted. These issues were addressed empirically in this research by examining how people handle an interruption task when using the mobile Web, resulting in multitasking.

In Chapter 4, three experiments focus on understanding the influence of an interruption task on user Web task performance when mobile computing. In the first experiment, it was concluded that Web tasks on a handheld take longer to perform due to constraints of the mobile device (e.g., difficult data entry and inadequate Web design for a small screen, requiring intensive scrolling) compared to a desktop platform. Instant message interruptions were shown to be disruptive to Web task performance in comparison to Web tasks without interruptions on both platforms. The second experiment showed that an interruption task, in particular when it is generated from the same device (same origin), leads to high switch costs and therefore to decreased user performance with a single-screen display. Anticipating or expecting an interruption as compared to experiencing an unexpected interruption can be beneficial to primary task performance on a handheld and desktop PC platform. Maintaining the same keyboard modality on an interruption task is less disruptive than switching to a voice modality on a handheld and desktop PC platform. When completing a primary Web task on a handheld and desktop PC, a 'simple' interruption task requiring repetitive interaction is more disruptive than a 'complex' interruption with a less repetitive interaction. Experiment 3, demonstrated that switching to an interruption has a negative impact on remembering a place in a task which is critical to resuming a primary Web task. It seems that the memory for a place in a task has a weaker representation and is more easily forgotten than the content of a task. Furthermore, user Web task performance, when handling interruptions on a handheld, is significantly predicted by cognitive switching ability and general Internet experience. These variables are possible candidate factors to be included in a user model that controls how assistance for interruption management can be personalized to the user.

A fourth experiment is presented in Chapter 5, involving the use of visual markers such as an automated point of return indicator (PRI) and a user controlled interactive suspension point (ISP) to support a user resuming a primary task after an interruption. The experiment was done in a sitting context and in a walking context. We conclude that assistance such as the PRI and ISP can have added value for user performance by supporting resumption of an interrupted primary task on a handheld. The automated PRI can be beneficial to user performance by reducing the amount of time on an interrupted primary task in a sitting and walking context. The user controlled ISP marker is beneficial to user performance, probably because there are high demands on the user in the walking context. In the sitting context the ISP is less beneficial relative to the walking context.

Our conclusions are covered in Chapter 6. Based on our research we conclude the following: mobile assistance that is personal, convenient, inexpensive, and that is representative of a model of customer service, is a useful concept to aid in the use of a mobile device. An interruption task generated from the same device (same origin) having similar interactions to the primary task (e.g., pointing with a stylus or mouse cursor and entering information on screens) with a single-screen display leads to serial switching between tasks that negatively influences user performance. We have attributed delays of interrupted primary task performance to disruption in memory for recognizing where to resume the task. The interference of working memory is mainly attributed to serial switching between tasks, leading to confusion and difficulty in reconfiguring a task for resumption. Our interaction design recommendations include assistance for use of the mobile Web when multitasking with interruptions. As part of the Attentive Interface for Mobile Multitasking framework, we suggest that assistance is needed for supporting the user's attention and memory (e.g., PRI and ISP) on the primary task. User handling of the interruption task can be improved by assistance with user anticipation of an interruption (e.g., interruption transparency). Interceding of an interruption task is also recommended in the form of content summarization of a message. Furthermore, the assistance of interruption management itself needs to be understood and appropriately adapted to the user. Mobile assistance for interruption management should be considered as a means toward improving usability of the Internet from a mobile device.

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Chapter 1 Introduction

At the end of 2001 there were over 850 million cell phone users worldwide; other devices such as pocket personal computers, Personal Digital Assistants (PDA's), and pagers add to the increasing number of consumers using these mobile devices (Sadeh, 2002). Wireless access to the Internet introduced the use of the World Wide Web (WWW) from a mobile device.

For those seeking anytime and anywhere computing, the appeal of lightweight electronic technology is the portability of the mobile or wireless device[1]. In order to satisfy consumer demands for wireless technology there is an increasing awareness concerning the ease of use of mobile devices for "on the go" computing. The use of a mobile device for activities such as Internet shopping, emailing, calendaring, messaging, and other applications (e.g., Microsoft Word) is known as **mobile computing**. Numerous electronic services (e.g., retail services, customer support, gaming, information searches, etc.) exist on the Web primarily for use on a personal computer (PC) (Anderson, Domingos & Weld, 2001; Freire, Kumar & Lieuwen, 2001). The use of electronic services for the purchase and sale of goods over the Internet is known as **electronic commerce**, or e-commerce (Sadeh, 2001). When Internet-enabled mobile devices were used for the monetary transaction of goods and services this became known as **m-commerce** (Sadeh, 2002).

The portability of a mobile device allows combining computing with moving (such as walking, driving, sitting in a coffee shop, or standing at a wireless access point in an airport). A person with a mobile device has the freedom and mobility to use the device in various situations and contexts. The **mobile context** refers to the use of a mobile device that is associated with a constant change in context or a fluid environment (Vaananen-Vainio-Mattila & Ruuska, 2000). The use of a wireless device in different environments and situations adds to the difficulty of a mobile computing task.

The popularity of the Web for easy access to information and services from a desktop computer has driven consumers to use mobile devices to connect to the Web. However, connecting to and surfing the Internet on a mobile device is quite different (e.g., viewing a Web site on a small screen, navigating with the use of a stylus or scroll wheel) from using the Internet from a desktop PC. As a way to differentiate use of the Web on a mobile device from use of the Web on a desktop PC, we refer to the specific attributes for use of Web sites and services from a mobile device such as the **mobile Web**.

There has been much consumer reluctance to fully adopt use of the Web on these small devices. From a consumer perspective, using the mobile Web from a handheld device has not met expected levels of performance. Issues currently exist with the mobile technical infrastructure, hardware, security, interaction with the handheld device, and ease of use of Web sites. Users of mobile devices are compelled to execute Web and other types of tasks that are time critical in relationship to physical location and the amount of time available for completing a task. For example, one might use a handheld to purchase train tickets over the

[1] The term mobile device is used to refer to wireless devices (e.g., laptops, PDA's, pocket PC)

Internet at the train station to avoid standing in line and handling a cash payment. This means that popular handheld computing activities done in transit can be described as “goal oriented” to quickly execute a short task such as purchasing tickets, finding location-based information, checking an account balance, etc. (Sadeh, 2002). Within the context of this work, of special interest are the solutions to address the usability challenges of the mobile Web interface that are encountered when using the Web with wireless technology in various environments. A challenge for successful use of the mobile Web is to provide a highly efficient mobile user interface. Improving the mobile interface for usage and interaction can aid to meet the time critical computing needs of people on the move.

This dissertation is on mobile assistance for supporting user interaction for multitasking stimulated by interruptions. **Mobile assistance** is broadly defined as a form of assistance dedicated to aiding the user of a mobile device. A major challenge that is addressed in this dissertation is improving the user experience for the handling of interruptions and multitasking when using the mobile Web. To meet the challenge, we describe how mobile assistance can improve use of the Web on a mobile device, and more specifically on a **handheld** personal computer (e.g., pocket PC). As a part of the mobile assistance framework we propose an Attentive Interface for Mobile Multitasking (AIMM). The attentive interface is proposed to dynamically adapt forms of interruption management to facilitate a user’s attention and memory for handling an interrupted Web task. Interaction design guidelines for the mobile interface are presented in this dissertation as developed in the AIMM framework.

This work is a part of the Personal Assistant for Online Services Anywhere (PALS) project. In brief, the PALS project aims to substantially improve the user experience of mobile Internet services for a personalized, adaptive, context based, intelligent mobile computing interface concept (Neerincx et al., submitted). A generic solution for a personal assistant is proposed to attune the interaction to the momentary user needs and use context (e.g., adjusting the information presentation and navigation support to the current context, device, and interests of the user) (Lindenberg, Nagata, & Neerincx, 2003). However, we focus on interruption management and propose forms of support for interruption handling that can be adapted (personalized) to the user. Mobile assistance and the AIMM framework address a part of the generic solution for the PALS mobile interface. The AIMM framework and the proposed design guidelines for human and mobile interaction have been iteratively incorporated into the overall research framework of the PALS project.

1.1 Motivation

A mobile device is the only flexible way to gain anytime and anywhere access to the Internet and the Web. Currently, there are no other widely available or as flexible means to use the Web. Users have unsatisfactory experiences with the mobile Web due to influences of handheld technology, Internet, personal situation, and environment. For example, Tom is riding in a taxi and using a handheld to transfer money between bank accounts to purchase a new watch. While conducting the transaction he realizes that the taxi driver has passed his final destination. Tom informs the driver to drop him off at the next corner. Standing on the street he returns to complete the transaction, but has lost his place in the task and has to cancel and start the transaction over. Tom has had an unsuccessful interaction with a transaction on the mobile Web. He does not know whether his transaction was completed and now has to either contact the bank to determine the status of his transaction or redo the task. These actions will cost him more time and diminish his confidence and trust of the mobile financial service.

Today's Web interfaces do not consider the many factors that negatively influence use of the mobile Web. We address issues that users have with the mobile interface related to the handheld device (e.g., small screen, difficult input interaction), display design (e.g., difficulty navigating), and disruption experienced within a mobile context. These issues are addressed empirically by examining how people use the mobile Web and handle interruptions that result in conducting more than one task. In the following sections key usability issues related to the use of the mobile Web are highlighted to support the motivation for this research.

1.2 Usability Issues of Mobile Computing

Contributing factors to the usability of the mobile Web are issues with the mobile network, the nature of mobile computing, and handset technology. The mobile network has slow data transmission speeds and poor network coverage resulting in dead zones, loss of transmission, frequent disconnections, and data loss (Sadeh, 2001). The nature of mobile computing for using the wireless network in an environment with obstacles such as tall buildings, tunnels, mountains, etc. will also result in blocked transmissions, disconnections, and data loss. There are also hardware constraints of the mobile device such as slow processing power (Anderson et al., 2001; Vaananen-Vainio-Mattila & Ruuska, 2000) and low memory (Sadeh, 2002; Freire et al., 2001). Some of the technical issues are being resolved with improvements in the wireless network and handsets. Third generation technology provides more bandwidth and reliability for cost effective and safe data transfer over the wireless Internet, improving a user's experience with the mobile Web. However, people must still cope with the constraints of using a small screen (Anderson et al., 2001; Freire et al., 2001; Sadeh, 2002; Vaananen-Vainio-Mattila & Ruuska, 2000), limited data input capabilities (Vaananen-Vainio-Mattila & Ruuska 2000; Freire et al., 2001), issues with the mobile context (e.g., disruption, noisy location, and awkward position of use) (Lee & Benbasat, 2003; Tarasewich, 2003; Vaananen-Vainio-Mattila & Ruuska, 2000) and poorly designed Web sites (Anderson et al., 2001).

1.2.1 Small Screen Display

A major constraint for using the Web on a mobile device is the small screen. A very minimal amount of information can be shown on a mobile device screen. For example, the screen of a mobile Internet phone has 15 lines vertically and less than 12 characters per line. Users have to repeatedly scroll through menus and submenus, making numerous key presses to select options in order to find the information they need, often committing numerous navigation errors (Albers & Kim, 2000). The small size of the screen can influence how users perform on different activities and tasks.

During the 1980s and 1990s studies showed that reading or browsing through text on a small screen did not adversely affect performance for reading comprehension when compared to a larger screen (Dillon, Richardson & McKnight, 1990). However, studies investigating the effects of screen size on user behavior during Web tasks have reported usability issues concerning task performance and navigation for searching and browsing (De Bruin, de Mul & van Oostendorp, 1992). When users execute Web tasks on a mobile screen, a significant amount of scrolling is needed to complete the tasks (Nielsen & Ramsay, 2000). On a small screen, users typically orient themselves by doing more navigating when looking for information on the Web and are less effective in completing tasks than users on a large screen (Jones, Marsden, Mohd-Nasir & Boone, 1999).

1.2.2 Handheld Data Input

Handheld devices lack a dominant efficient technology or technique for text and touch screen input. Current methods of input negatively influence performance of Web tasks on a handheld device. Unlike the desktop system with the QWERTY keyboard and mouse as a primary text entry device, data entry with a stylus and soft keyboard has been problematic for users of handhelds (Mackenzie & Soukoroff, 2002). Mackenzie and Soukoroff (2002) describe this general method of pointing and selecting or writing with a stylus on a touch sensitive screen as slow and awkward, and recognize the additional impact of the mobile context on entering text. The difficulty with this form of input is the speed and accuracy of selections. Text entry and handwriting speeds on a handheld are much slower and accuracy is problematic. When a user is on the move, how the device is operated, whether standing, sitting, walking, or with one hand or two hands can significantly impact the input process. Users often have high expectations of achieving an adequate text entry speed on a handheld because comparisons are often made to norms of touch-typing and handwriting speeds.

1.2.3 Mobile Web Design

When mobile devices were first available, designing a Web site and content for a mobile device meant using a desktop version of a Web site and presenting it as a miniature version with original content on a mobile device (Anderson et al., 2001). Reiterated throughout the literature on designing for mobile devices is the inappropriate use of desktop PC design guidelines and usability methods that are applied to mobile devices (Lee & Benbasat, 2003; Sadeh, 2001; Tarasewich, 2003; Vaananen-Vainio-Mattila & Ruuska, 2000). Designing a Web site for use in a stable and predictable home or office environment compared to the use of a desktop PC is very different from designing for the mobile context. Often the same design guidelines for the desktop PC were applied to designing Web sites for mobile devices, contributing to a negative user experience with the mobile device (Ramsey & Nielsen, 2000). Inappropriate design of the mobile Web sites compounds the usability problems associated with the constraints of the mobile device due to small screen size, difficult data entry, and a changing mobile context.

Early studies on Wireless Access Protocol (WAP) highlighted critical issues of Web design for mobile interfaces. A usability study by Ramsey and Nielsen (2000) showed that common tasks on a WAP device, such as retrieving news headlines, checking the local weather forecast, and accessing TV listings were taking significantly longer than expected by users. Users encountered slow connections and poorly designed Web sites. Issues concerning WAP usability were generally related to poor navigation design, unclear label and menu choices, incomprehensible Web site structure which did not complement user's tasks (Buchanan et al., 2001; Ramsey & Nielsen, 2000; Sadeh, 2002), lack of differentiation between services (Ramsey & Nielsen, 2000), dead ends, poor content quality, and out of date content (Sadeh, 2002). Usability of the mobile Web has acquired a reputation from studies on the usage of WAP devices (Buchanan et al., 2001).

The design lessons learned from these earlier studies on use of the mobile Web suggest that the constraints of the mobile device interface for small screen size, difficult data entry, and the context of a disruptive environment need to be considered to reduce the problems users experience while mobile computing. The small screen of the mobile device shows a limited amount of information and negatively impacts user interaction for navigation. To deal with the limits of the small screen and reduce navigation in searching for information, innovative ways to present relevant information to the user are needed. One way to handle this problem is to show only information that is personalized to the user. Personalization of the mobile user interface can also address the individual needs of users. Consideration for users with different skills and knowledge can accommodate a broader spectrum of usage situations, leading to a wider range of design solutions and innovations (Shneiderman, 2000). For example, in a disruptive environment, assistance can be helpful by providing reorienting information when a user returns to an activity that was interrupted (Cypher, 1986). Forms of interruption management and enhancement for personalizing the user interface for handling interruptions on a mobile device may be beneficial for the user. As a general solution to capture many of these different situations that are possible in the mobile context, the Personal Assistance for Online Services (PALS) project suggests the use of a knowledge based interface manager that accounts for aspects of user needs and qualities, device characteristics, context, and environment to automatically generate a mobile user interface and provide user assistance (Kranenborg, 2005). With mobile interface assistance and support it is expected that people will spend less time on tasks, increasing efficiency and lowering user frustration, and possibly expanding and increasing usage of the mobile Web.

1.2.4 Disruption in the Mobile Context

A major emphasis in our research is on the effects of interruptions experienced by users in a mobile context. A primary usability issue is the difficulty people have with using the mobile Web in environments that are unpredictable and unstable from one moment to the next (Oulasvirta, Tamminen, Roto & Kuorelahti, 2005). A common problematic aspect of the mobile context is the difficulty that people experience with handling interruptions when using a mobile device. Within the mobile context disruptions are paramount to a user's experience on a handheld. However, there is very little research addressing the issues with interruptions that users experience during mobile activities.

Interruptions have been described as events that redirect attention away from a primary task to process other information (Oulasvirta & Saariluoma, 2004). Previous research on interruptions and human behavior, found that interruptions are disruptive to human performance, resulting in a high number or errors and require longer amounts of time to complete a task (Gillie & Broadbent, 1989; McFarlane, 1999; Bailey, Konstan & Carlis, 2000). Alternating between tasks such as a Web site and an instant messaging (IM) application on a handheld can result in usability issues such as additional time needed to complete a task, incomplete tasks, disorientation, or the need for recovery or resumption of a task while mobile computing (Nagata, 2003; Nagata & van Oostendorp, 2003; Tarasewich, 2003).

Theories from psychology form a basis from which to draw relationships between multitasking, interruptions, attention, memory, and user performance. Our focus is on divided attention which is attending to more than one task when multitasking in the real world (Johnson & Proctor, 2004; Sanders & McCormick, 1993; Wickens et al., 1997). There have been useful theory-based classifications describing a person's current state of actions for multitasking stimulated by interruptions that connect psychological theories to everyday tasks (e.g., Miyata and Norman, 1986). These psychological theories describe the cognitive implications related to attention and memory that are reflected in a user's performance. The use of divided attention suggests dual or multiple processing roles of attention by splitting attention on two or more sources of information when multitasking (Baddley & Hitch, 1994; Sanders & McCormick, 1993). When a person conducts more than one task by sequentially alternating between tasks within a period of time, this is known as multitasking (Preece et al., 1994). Multitasking can be more specifically described as task switching that results in a decline in performance due to a human limitation in information processing. We specifically focus on task switching, where a person switches between a primary and interruption task that results in costs to a user's performance (Pashler, 2000; Preece et al., 1994).

1.2.5 Summary of Usability Issues

In summary, using the Web on a mobile device is more problematic than on a desktop PC. There are a number of identified usability issues that contribute to the dissatisfaction for using a mobile device. Besides issues with mobile technology, there are problematic aspects of the mobile user interface concerning the small screen, input capabilities, Web design. The small screen contributes to intensive scrolling and navigation, a decrease in task effieciency and performance, when compared to use of a larger screen. Data entry on a mobile device can negatively influence Web tasks performed on a handheld device when using a stylus and touch sensitive screen with slow and awkward input. When a user is moving and entering data, there is lower accuracy of selections, negatively influencing data entry and impacting the input process. Poor Web site design and the application of design strategies that were inappropriate for the mobile situation have compounded the usability problems on a mobile device. Issues concerning mobile Web site design include poor navigation, unclear labels and menu choices, confusing Web site structure not matching user tasks, poorly defined services, and poor content quality.

Interruptions are common and disruptive when using a handheld in the mobile context. A focus of our research is on examining the effects of interruptions on user Web performance on a mobile device. Currently, the mobile Web is not equipped for use in unpredictable and disruptive environments. In redesigning the mobile Web interface, our aim is to support a user with handling interruptions and multitasking on a mobile device. Based on this research, we present guidelines for designing mobile assistance to improve management of interruptions. The assistance is intended to support the time critical computing needs of people on the move.

1.3 Research Approach and Thesis Overview

Our research approach used a cognitive engineering method as defined by the PALS general research framework (Lindenberg, Nagata, Neerincx, 2003; Neerincx et al., submitted). Cognitive engineering combines research of cognitive factors on human performance with techniques of usability engineering aimed to enhance human computer interaction (HCI) (Norman, 1986). Our research aim was to develop a mobile assistance concept and provide an empirical foundation on user interruption handling and support of interruptions and multitasking

There were three research segments consisting of concept development, experiments on interruptions, and an integrated framework for user assistance (figure 1.1). The concept development segment was done in the PALS project using Scenario Based

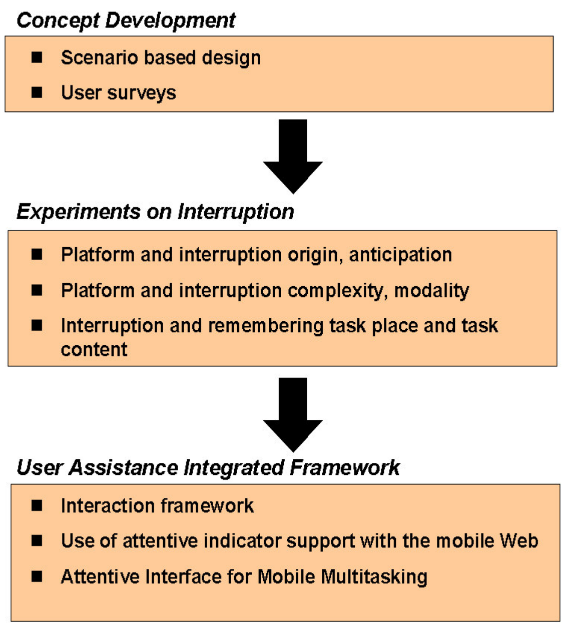

Figure 1.1. Overview on research approach

Design and survey research. Scenario Based Design was used for developing high-level concepts of assistance. The initial ideas of assistance were prototyped and validated with users of mobile devices. A survey was administered to users of mobile devices to characterize users' experiences with mobile devices, Web use, and assistance. The work presented in this dissertation consists of the second and third research segments. The second segment consisted of experiments investigating the effects of interruptions on user performance on a mobile device. The first two experiments identified characteristics of an interruption task such as origin, anticipation, modality, and complexity that influenced user performance on a primary task. The third experiment identified the effects of an interruption on memory for a primary task. The study results were used to develop concepts of support for user mobile assistance. The third segment consisted of development for user assistance where results from the concept development and experiments were integrated to derive a user multitasking and interruption framework, usage model, and adaptation of the support concepts utilizing predictors of user performance. A study was conducted to investigate the usefulness of the proposed assistance support. This last segment contributed to the defining of the Attentive Interface for Mobile Multitasking framework, which consists of focal topics relevant to the user such as multitasking, interruptions, attention and memory, and assistance with mobile devices (Nagata, 2003; Nagata, van Oostendorp & Neerincx, 2005).

1.3.1 Research Questions

The following research questions related to mobile assistance were posed:

Concept Development

What concepts for human computer-interaction need to be considered in designing mobile assistance?

What characterizes a user's experience with mobile devices, Web use, and assistance?

Experiments on Interruption

What effect do characteristics (e.g., origin, anticipation, complexity, and modality) of an interruption task have on a user's Web task performance on a handheld device?

What effect does an interruption have on memory for resuming a primary Web task?

User Assistance Integrated Framework

What types of support for interruption handling are beneficial to Web task performance?

How can a user of a mobile device be supported with assistance for use of the mobile Web when experiencing interruptions that stimulate multitasking?

1.3.2 Thesis Overview

The focus of this dissertation is on mobile assistance for user handling of interruptions while using the Web on a mobile device. In Chapter 2, a literature review provides background information on small screen size, handheld data entry, and multitasking and interruptions in the mobile context. In Chapter 3, the need for mobile assistance is established based on interruption management research and research on assistance from attentive user interfaces. Development of PALS concepts of mobile assistance is described using Scenario Based Design and user surveys, and is validated through user research and storyboarding. The user research further establishes the need for investigating user assistance for multitasking and interruptions. Our attentive interface for a mobile multitasking framework is then formalized focusing on the specific aspect of handling interruptions while using the Web on a handheld device in a mobile context.

Chapter 4 presents psychological theory for drawing relationships between attention, memory, and multitasking stimulated by interruptions. We relate these theories to real world situations of information workers who are multitasking in a disruptive work environment that result in consequences on attention and memory. The first experiment investigates the influence of interruptions for origin and anticipation of user performance on a handheld and desktop PC. The second experiment validates the first experiment for anticipation of interruptions. In addition, the second experiment examines influence of complexity and modality of interruptions on user performance on a handheld and desktop PC. The results suggest an initial model for predicting user performance on handling interruptions. The third experiment examines the effects of interruptions on remembering the primary task to investigate why interruptions are so disruptive to user performance. In Chapter 5, we cover the user testing done on our support concepts of the Point of Return Indicator and Interactive Suspension Point. These support concepts were to aid a user's attention and memory for a primary task that was interrupted. Finally, in Chapter 6 we present our general conclusions, a refined framework of mobile assistance, recommendations for interaction design of mobile assistance, and limitations of research and future research directions.

Chapter 2 Background and Related Work

Abstract

There has been a lack of adoption by the general public for use of the mobile Internet for mobile computing. There are compounding issues with the use of a small screen, data input and inappropriate Web design that impede use of a mobile device. User interaction that detracts from use of the Web on a handheld have been identified in usability studies, and include intensive scrolling and paging, increased search activities, disorientation, reports of slowed reading and difficulty with data entry. To improve usability of a mobile device an understanding is needed on how user performance is influenced by a combination of interrelated factors (e.g., small screen size, input interaction, Web design) and interruptions in the mobile context. We propose to assess user Web performance on a mobile device as a complete package (i.e. small screen, input interaction, Web design), observing all aspects together and not just one aspect in isolation. User performance can be better understood by comparing use of a handheld device and desktop PC, for tasks that can be represented on both platforms. Furthermore, the issues with use of a mobile device (e.g., intensive navigation, interruptions) have a direct negative impact on user performance. Deficits in task performance on a mobile device are associated with cognitive overhead due to problems with attention and memory. There is a dearth of research addressing attention and memory problems in relationship to user performance on a mobile device. Problems with user performance on a mobile device often arise due to interruptions in the mobile context. There is a lack of interface support for users doing more than one task, switching between tasks and using different modalities. To deal with these issues a multitasking framework is used to conceptualize interface adaptations, leading to a successful mobile interface.

2.1 Introduction

This chapter introduces a brief history on wireless devices and the technical challenges of the wireless network. The everyday uses of the mobile Internet are presented to focus on aspects of design for practical use of a mobile device. Related work is covered on user interaction and the mobile Web focusing on usability issues with screen display and navigation, handheld input and multimodality as related to multitasking and interruptions. The chapter concludes with research implications extracted from the literature that have shaped the experiments presented in chapter 4.

2.1.1 Evolution of the Wireless Handheld

Originally mobile phones were heavy bulky black boxes, used by the military as a primary communication device (Vaananen-Vainio-Mattila & Ruuska, 2000). The use of mobile technology has evolved over the years. In the early 1980's mobile phones were redesigned for use as a consumer product. In the 1990's, mobile technology for the public consumer consisted of sleek pocket sized phones, electronic agendas and personal pocket computers. The numbers of mobile consumers worldwide have increased eight fold within five years. In 1997 there were 100 million mobile phones sold worldwide and ending 2001 there were over 850 million mobile phone consumers (Vaananen-Vainio-Mattila & Ruuska, 2000). In 2000 over 6 million PDA's were purchased with figures exceeding 20 million in 2002 (Sadeh, 2002).

The use of these devices has evolved in complexity from a beeper or cell phone to technology with numerous features. For example, a Blackberry 8700g Phone is a combined mobile phone and PDA (e.g., email, organizer, Web browser, text messaging, multimedia messaging). The Nokia 6682 smart phone has voice recognition dialing and in addition to being a PDA, plays MP3 files, has a built in video capable camera with flash, and a voice memory recorder. Samsung and other manufacturers have developed phones, pagers and a micro browser as wearable devices that can be embedded in jewelry such as a wristwatch. MP3 players and more features for communication and functionality are being added to portable devices. In 2005 Apple released a combined mobile phone and iPod.

The number of features added to the mobile device has grown along with consumer needs for mobile technology. Over 14% of the world populations are mobile phone users, with annual sales of 400 million handsets worldwide (Sadeh, 2002). The current work trend is a movement towards wireless connectivity for enhancing work productivity and efficiency. For example, medical staffs are using handhelds for tracking patient data with the Electronic Patient Dossier developed by Getronics-Pink Roccade, a Dutch IT consulting firm. In 1995, there were less than 10 percent of the total workforce with mobile devices, compared to 30 percent in 2001 and climbing (Broidy, 2001).

2.1.2 The Technical Constraints of Wireless Networks

Wireless communication introduces technical constraints requiring special attention to the mobile network infrastructure and protocols, specifically for the mobile context. The nature of mobile communication transmission introduces many issues with the wireless network, experienced by users of mobile devices.

The first technical constraint is susceptibility to interference when transmitting radio signals through the air resulting in high rates of data loss. For example, transmission signals from a mobile device are often blocked when traveling through a tunnel or by buildings and surrounding high terrain. Reconnection times can range from 15 to 30 seconds (Sadeh, 2002). This lack of reliability and reduced responsiveness of the network erodes users trust and interest in wireless technology (Sarker & Wells, 2003).

The second constraint is lack of network coverage where certain locations have no base stations for transmission resulting in dead zones. The lack of coverage and low data transmission rates in certain areas reduces the users sense of freedom (Nielsen, 2003; Sarker & Wells, 2003). Low data transfer rates are associated with high costs and are a major frustration of mobile device users (Sadeh, 2002). For example, Jakob Nielsen (2003) stresses that page downloads from the Internet on a mobile device are often too slow for extensive interaction and exploring a Web site.

The third constraint is compromised security with wireless communications. Encryption, authentication and other security mechanisms provide possibilities to resolve data security issues. Mobile handsets are prone to theft, along with the personal information stored on the device.

A fourth constraint is maintaining a connection while accessing the Internet with second-generation circuit switched technology (Sadeh, 2002). A live connection has to be maintained when downloading or reading information on the mobile Internet resulting in costs to the user. When mobile Internet services are inadequately designed coupled with slow and expensive data rates, this can lead to a very frustrating and unsatisfactory user experience along with loss of a customer base (Sadeh, 2002).

In meeting these technical constraints, the motivation is to move towards third generation (3G) technology. It takes approximately 10 years to develop and deploy a new generation of mobile communication standards (Sadeh, 2002). As progress in mobile technology is realized for enhancing the mobile infrastructure and securing wireless communication, the end user will also benefit from better reliability for cost effective data transfer and wider use of the mobile Internet. The move to third generation mobile technology (supporting at least 144 kbps) will utilize packet switched cellular technology that chunks small packets of data that do not require a permanent connection, effectively utilizing network capacity. A user can remain connected to the mobile Internet and only pay for the number of packets sent and received by the device.

As 3G technologies are deployed, these technical issues are expected to diminish. The focus of concern will remain on usability of the mobile interface and Internet applications for appropriate presentation of content and services to accommodate the unpredictable nature of mobile computing.

2.2 Use of the Mobile Internet

Mobility and portability are distinctive features of the mobile Internet. A user with a handheld device can have a different context of use throughout the day. There are static and dynamic uses of a mobile device, such as using a PDA sitting at a desk or when walking or driving (Pascoe, Ryan & Morse, 2000). Mobile Internet usage can also vary dependent on Internet connection and location. Accessing the Internet from a “hotspot” in a Starbucks coffee shop or on the street will stimulate different usage than from a wireless LAN located at the office. Changes in location and context contribute to unique aspects of mobile Internet use.

Use of Mobile Web Services

People’s use of the mobile Internet is described as quick goal-oriented activities such as reserving movie tickets and looking for traveling directions (Sadeh, 2002). General use of the mobile Internet is broadly characterized in terms of m-commerce tasks for purchasing items, access to information, and types of communication (e.g., email, messaging etc.). There are many common traits for use of the mobile Internet and desktop Internet for purchasing items and communicating. A survey study by Chae and Kim (2003) on mobile phone Internet use in Korea examined user preferences for m-commerce. Users had a preference for purchasing products over the mobile Internet perceived to be lower in risk, such as for cheaper items like CD's and melody downloads. There is a preference for the desktop Internet, when purchasing or downloading items that have a higher perceived risk. Items that are considered high risk are expensive items such as clothes, furniture and cosmetics.

Use of Communication Services

As for communication services, SMS is the preferred service on a mobile device in Europe and Asia. In contrast, in the U.S.A., mobile Internet communication using email, instant Messaging and chatting is prevalent, similar to use on a desktop PC (Sarker and Wells, 2003). Use of SMS in the U.S.A. has not been as phenomenal as in Europe and Asia, where SMS accounts for a substantial percentage of revenue for some mobile operators (Sadeh, 2002). Messaging with a mobile device is often constrained due to difficulty with the keyboard, affecting the length of the messages and making high volume text exchange infeasible. When communicating via the mobile Internet, the mobile situation evokes the need for an immediate message response. For example, working individuals with large social networks often have a fast paced lifestyle and a need for use of mobile communication (e.g., voice, instant messaging, email, SMS) and the Web. There are important aspects of “staying in the loop” or connected with peers that stimulates use of a mobile device (Sarker & Wells, 2003). Efficiency is also valued by eliminating short periods of wasted time through use of the mobile Web for processing work related tasks, staying up to date on current events or entertainment.

To enhance efficiency and use of Web and communication services on the mobile Internet, a main issue that needs to be addressed is problems with the mobile interface. The user Interface was considered as one of the main barriers for use of the mobile Internet (Sarker & Wells, 2003). Users are more forgiving of the physical limitations of the device due to technological constraints, but were dismayed at the flaws of the interface for use of the Web. There is a need for support of various on-line tasks (e.g., on-line shopping, appointments, financial transactions, messaging) in the mobile context. Support of mobile computing tasks can be beneficial when a user is in a disruptive situation, whether the user is actively moving or during periods of “killing time”, such as when standing in line or waiting at the airport.

2.3 Handheld Interaction Design Philosophies

The look and feel of the mobile device has been streamlined for a wider audience. The pervasive use of mobile devices, focus the design of the user interface towards needs of users versus a business or technical model perspective. The core design of the mobile user interface drives user interaction of a device. The pervasive design philosophies of mobile Microsoft Windows (e.g., Windows CE) and the Palm operating system influence how handheld devices are used. These design philosophies historically have different fundamental aims in design of the mobile user interface.

The Microsoft Windows CE philosophy focuses on drawing similarities between a handheld device and a desktop PC to capitalize on familiarity, suggesting that it would take less time to learn how to use a handheld (Zuberec, 2000). This design implementation drives a form of PC miniaturization of a handheld where use of applications (e.g., Microsoft Word, Outlook etc.) and use of the Internet via a Pocket Internet Explorer for navigating the Web and searching through menus are very similar to the desktop PC (O'Hara, 1997). The Mobile Windows philosophy maintains carrying over a standard graphical user interface from the PC along with a broad scope of activities and tasks to the mobile device. The user still has freedom of choice and is not restricted in conducting familiar PC activities on a handheld.

Furthermore, the Mobile Windows philosophy does not typically suite the mobile context where users frequently access data in short bursts on a handheld. Use of a mobile device is the diametric opposite compared to use of a desktop or laptop, where infrequent booting and longer periods of use are common (Bergman & Haitani, 2000).

In contrast to the mobile Windows philosophy the Palm philosophy promoted design of the Palm Pilot, as an electronic agenda for keeping a calendar, address book, and task list, similar to an agenda that people carry with them (Bergman & Haitani, 2000). For example, four hot buttons are on a PalmVx for selecting direct viewing of a daily calendar, address book, to do list and memo, complementing the most common tasks done with an agenda. Use of the Internet for viewing a Web site is tailored for a small screen. Palm's Web clipping system exports a miniaturized view of a Web page or service to a Palm device. A live connection is needed via a cradle to update and download information from the Web site. The Palm philosophy limits the user interaction and tasks based on specific user goals in consideration of the mobile context. Therefore the Palm interface is less complicated, easy to learn, use, maintain and requires little expert knowledge (Mohageg & Wagner, 2000). On the other hand, the Palm PDA is an example of a device that is dedicated to only a specific cluster of tasks, has a limited purpose and is not necessarily upgradeable (Mohageg & Wagner, 2000).

Through our research we would like to support users with a broad scope of activities similar to the Microsoft Mobile Windows philosophy and tailoring these activities and interaction to use of a handheld device as done by Palm. When designing for use of a mobile interface, the design philosophies highlight the following: 1) a common mental model of interaction is needed for users, such as the PC Windows model or the personal agenda model. 2) an appropriate scope of user interaction that supports completing tasks in a mobile context, such as designing for one handed use with a task oriented focus 3) the user interface needs adaptability dependent on the needs of the user, constraints of the device and restrictions of the environment. We apply this approach in our research for developing concepts of mobile assistance and user interaction.

Summary of Background on Mobile Devices

In section 2.1 a brief review on the history of mobile devices identified that adaptations producing hybrid devices is necessary to fulfill consumer needs. The technical constraints of mobile communication were loss of transmission signals and data, lack of network coverage, low data transmission rates, and lack of security for data and device. Moving to 3G mobile technology will resolve many of these technical issues. However, the success of a mobile device still depends on usability of the mobile interface and Web applications, particularly concerning the presentation of content and services.

There are many similarities of use of the Internet for purchasing and communication on a mobile device and desktop PC. Section 2.2 highlights that there is a broad context of use of the Internet on a mobile device. Problems exist with the mobile user interface influencing use of a mobile device. Use of the mobile Internet with m-commerce tasks and communication can benefit from assistance to enhance the mobile interface for efficient user interaction.

Assistance for use of a mobile device needs to support users with a broad range of activities and by tailoring interaction to the user. As discussed in section 2.3, the interaction design philosophies for use of a handheld device cover several common aspects for designing a mobile interface. The design philosophies highlight the importance of a common mental model, scope of user interaction, and versatility in the user interface. In this research we propose an approach to adapting the user interface for mobile assistance. We investigate user performance with the mobile Web and handling of interruptions (e.g., communication tasks). The outcome of this research will define design guidelines for mobile user interface assistance.

The following sections review related work on use and adoption of the mobile Internet, design philosophies of handheld devices, user interaction related to the small screen display, navigation on the mobile Web, multimodality and multitasking with a handheld device.

2.4 Related Work on User Interaction and the Mobile Web

Usability issues with the mobile interface were described in chapter 1 as the motivation for this research. In this section we review research related to the usability issues described in chapter 1. First, a usability study is reviewed on use of the mobile Internet from a WAP mobile phone. Second, we review studies comparing small and large screen displays. Third, research related to mobile Web screen display and navigation is presented. Finally, the research implications on use of the mobile Web are presented.

2.4.1 Usability of Wireless Access Protocol

Knowledge on user interaction with a wireless device have come from usability studies on WAP phones. A usability study by Ramsay and Nielsen (2000) evaluated 20 users on accessing of WAP services. The participants were asked to record their impressions in a diary for one week. Traditional usability tests were also performed at the beginning and end of the field study. It was found that simple everyday tasks such as retrieving news headlines, checking the local weather forecast, took approximately 2 minutes in total, to complete a task. The tasks took significantly longer than the users' had expected. The tasks were informally estimated to be only 30 seconds long by a group of Internet experts. After one week of using WAP there were no significant improvements in the amount of time needed to complete the tasks. Overall, 70% of the participants did not see themselves using WAP within the next year.

Amidst much controversy and debate, the WAP forum organization has disputed the Ramsay and Nielsen study for using a flawed survey methodology and a small sample size, producing erroneous and biased results (wapforum, 2001a). Nonetheless, there were a few sticking points concerning the user experience with poor Web site design and inadequate content contributing to the problems with use of the mobile Internet (Kaplan-Evans, 2001). First, there was inefficient use of the limited screen display where the content of the information was not appropriately structured to fit on such a small screen. Second, there was a mismatch between the structure of the information and the user's tasks, for example, users had to go to several different parts of a site to find information on TV programs beginning at 8pm. Third, intuitive navigation support was lacking due to menu labels that were vague or unclear in meaning and there were no on-screen indications that a user needed to scroll down to view more information at the bottom of the screen.

A guiding interaction metaphor for the WAP interface is based on a "deck-of-cards". In the mobile realm the viewable content on a small screen is condensed into a limited amount of space, therefore the metaphor of a card is representative of cell phone or PDA that fits into the palm of your hand (Read & Maurer, 2003). Each screen is considered a "card" and a number of related screens are considered a "deck" that a user would navigate through on a WAP device. When a command is entered, a "deck" is sent from the network to a user's handset allowing the user to navigate through the complete deck (Erlandson & Ocklind, 1998).

User interaction for WAP is designed to fit the "deck of cards" metaphor often using a line-based interface and accommodating specific device limitation of mobile phones. Navigating through the screens (cards) with content, involves using a set of buttons or a scroll wheel. Whereas on the pocket PC, the interface is a graphical user interface with direct point and click interaction or jumping immediately from one page to the next by use of a back button or hyperlinks. Navigating through cards or links using buttons is more tedious on a mobile phone than pointing and clicking with a stylus on a handheld (Chae & Kim, 2004). Nielsen (2003) also supports this view that navigating on today's newer mobile devices is much more pleasant than on a WAP phone. When comparing a mobile phone and a pocket PC there are differences in the Web interface and input interaction that will influence the amount of content, information structure, navigation and tasks presented on a device. The use of mobile devices (i.e. mobile phone and handheld device) and the effects of screen size and navigation on user interaction are discussed in the following sections.

2.4.2 Related Work on Small Screen displays

Research on small screen displays done in the 80's and 90's, have influenced our view on use of a mobile device. Previous studies have shown the negative impact on reading, navigating and searching for information on a small screen. A study by Duchnicky and Kolers (1983) investigated the readability and comprehension of scrolled text. The on-screen text was shown at a certain width (i.e.one-third, two-third, full screen), and height of a window (1, 2, 3, 4, or 20 lines). Screens showing a full screen width of text were read 25% faster than screens with one-third the screen width. There was no effect of window height on reading rate. When increasing window height from 1 to 20 lines of text the reading rate increased only 9%. Four lines of text were found to be more efficient than one or two lines. No effect on reading comprehension was found.

Dillon, Richardson and McKnight (1990) examined reading comprehension of a journal article on a screen display for 20 or 60 lines. The participants were asked to summarize the main points of the journal. It must be noted that the 20 line display, although considered in the article as a small screen, was mentioned to be similar to the screen size of a PC, and the 60 line screen was similar to an A4 size paper. There was no significant effect on reading comprehension. However, this study also showed that screen size negatively impacted navigation and indirectly reading speed. Participants reading from a smaller screen jump about and alter the direction of reading text more often than on the larger screen. Participants paged backwards and forwards, manipulating text much more on a smaller screen than on larger screens (see also De Bruijn, de Mul & van Oostendorp, 1992). This intensive navigation was seen as a way to gain orientation on the smaller screen.

2.4.3 Mobile Device Screen Display and Navigation

The amount of Web content displayed on a mobile device is limited to the screen size. In general, viewing a Web site on a small screen can have a cluttered appearance of text, graphics, menus, icons and an inappropriate structure of formatted text (Kim & Albers, 2001). There is often a limited amount of Web content on a small screen. A small screen size leads to less information shown to the user and increases the amount of navigation for scrolling, paging and search activities, to obtain the desired information (Kamba, Elson, Harpold, Stamper & Sukaviriya, 1996). Besides the constraint of the limited screen space, the text size cannot be reduced below a certain threshold of legibility, due to the inability of the human eye to distinguish small type sizes (Chae & Kim, 2004; Kamba et al., 1996).

Comparison of Navigation on a Mobile Phone and Handheld

Navigating the mobile Web consists of movement through a complex information structure on a small display space. General navigation through a Web site on a mobile device typically consists of horizontal and vertical movements. A user's movement when navigating has been defined as either horizontal depth or vertical depth. Horizontal depth exists between pages within a single level of a menu hierarchy and vertical depth as movement between levels of the hierarchy.

Users often experience being lost or disoriented on a mobile device when viewing Web content that was originally designed for a desktop PC monitor (Jones et al., 1999). When comparing navigation on a mobile phone to a handheld device, navigating the Web from a mobile phone has a different interaction paradigm than navigating on a handheld. The difference between a mobile phone and handheld is the interface presentation where most mobile phones (e.g., WAP phone) have a text or line-based interface and handheld devices have a graphical user interface (table 1). For example, the horizontal movement through a Web site on a mobile phone is different from paging on a handheld (Chae and Kim, 2004). On a mobile phone a user must scroll through a menu, then select an entry. To move through pages on a Web site a user must often scroll to the last entry of the current page to move on to the first entry of the next page. Whereas, paging through a Web site interface on a handheld typically involves pointing and tapping with a stylus on hyperlinks or using back and forward buttons. Although, this has rapidly changed with the current hybrid devices where mobile phones have larger screen sizes accommodating a graphical user interface.

Table 1.1: General differences between a handheld and mobile phone interface

	Handheld	Mobile Phone
Screen Display	Graphical User Interface	Text Based Interface
Navigation	Hyperlink Selection	Menu Based Selection
Input Interaction	Point/Tap	Scroll/Enter

Comparison of Navigation on a Handheld and a Desktop PC

As mentioned, navigating on a handheld is similar to use of a desktop PC than a mobile phone. Basic Web site navigation on a handheld consists of within page, between page and between application navigation (e.g., between Web and email). Within page navigation consists of horizontal and vertical scrolling via a stylus to manipulate the scroll bar or arrows at the end of the bars, similar to scrolling in a desktop window. On a handheld device users have to scroll within a page to access the same amount of information as displayed on a single view on a desktop or laptop (Bjork, Redstrom, Ljungstrand & Holmquist, 2000). Between page navigation, consists of forward and backward paging maneuvers through horizontal or vertical layers of a Web site, using a forward or back button or selecting from menus and hyperlinks. It has been suggested that during search tasks, users do not want to use conventional paging on a handheld due to the intensive navigation interaction and large amount of time needed (Jones et al., 1999). Navigating through separate views or paging maneuvers have been assumed to contribute to cognitive overhead that results in lowering user performance (Bjork et al, 2000; Jones et al., 1999, 2002)

An evaluation study by Waycott and Kukulska-Hume (2003) examined students reading course material on a Personal Digital Assistant (PDA). The students reported many common usability issues when using a mobile device. There were difficulties with scanning through text, having poor content overview and reading text on a small screen was slower than on paper. Navigation through the document was difficult with having to page back and forth. Students felt lost in the document with only a few contextual clues such as page numbers and entering text on the soft keyboard was slow and error-prone.

A study by Jones et al. (1999) observed participants using the Web from a simulated handheld screen with a standard mouse and keyboard. Users on a screen display size similar to a PDA were less than 50% effective in completing Web search tasks when compared to using a larger screen. Users scroll much more during tasks, follow links less frequently and use search facilities twice as often than their large screen counterparts. On a handheld, users must scroll through the Web page in order to consider half the results viewed on a desktop computer with no scrolling involved.

In another study by Jones, Buchanan and Thimbleby (2002) performance on information retrieval tasks were examined on three different simulated screen sizes (i.e. wireless access protocol (WAP) phone, personal digital assistant, desktop PC). Use of the WAP interface had the poorest performance, taking twice as long to complete tasks and was 60% less successful than on the conventional desktop screen. User performance on the PDA interface was only 14% less successful than the desktop screen. The smaller screen sizes required more navigation in order to view the same number of search results as on the desktop interface

These studies suggest that intensive navigation (e.g., paging, scrolling) on a mobile device leads to poor task performance (e.g., longer period of time spent on a task, errors). Especially, navigating from page to page negatively influenced user performance.

Therefore, users preferred to use other means such as a search facility rather than moving through pages to view information (Jones et al., 1999, 2002).

We attribute the usability issues associated with navigation on a mobile device to viewing a single-screen of information at a time. Viewing more than one screen full of information is not possible on a mobile device. We call this mode of viewing a "single-screen display". Small screen devices with a Windows based operating system require users to perform a few steps to move between applications such as the Web and email. For example, if the Internet Explorer browser is on screen, in order to view email, requires selecting the email application icon from the main menu. If both the Internet Explorer browser and email are active, then the screen of the application being viewed needs to be minimized (hidden) by selecting the cross at the top right corner of the screen to bring forward the other application on-screen. There are buttons on handheld devices such as a Palm PDA that allow one-handed use for scrolling or direct access to programs, but these buttons are not always found on a handheld.

2.4.4 Characteristics on User Interaction and the Mobile Web

From our literature review, we highlight characteristics on user interaction with the mobile Web.

1) The small single-screen display on a mobile device is an important factor that negatively impacts reading speed (Duchnicky & Kolers, 1983), paging and scrolling by increasing the amount of time on Web activities (Dillon et al., 1990, Jones et al. 1999, Jones et al., 2004; Kamba et al. 1996).

2) More commonalities exist for use of the Web on a desktop PC and handheld than for a handheld and mobile phone. The more common or general experience that users possess is use of the Web from a desktop PC. As suggested in section 2.4, commonalities exist between a desktop PC and a mobile device for use of the Web for e-commerce (e.g., purchasing items, information search) and communication (e.g., instant messaging) (Chae & Kim 2003, Sarker & Wells 2003). In section 2.5, it was shown that navigation on a handheld could be very similar to that on the desktop. Due to the commonalities in use of the Web, it is expected that there is a transfer of knowledge from use of a desktop PC to use of a handheld. This transfer of knowledge is made possible by a common mental model of usage (e.g., graphical user interface) and a similar interaction paradigm for use of the Internet with e-commerce and communication tasks between the two platforms. In chapter 4 experiments 1, 2, and 3, we examine Web task performance using a desktop computing platform as a baseline comparison to a handheld computing platform. These experiments investigate differences in user interaction on a desktop PC versus a mobile device.

3) A user's performance on a mobile device is highly influenced by a compounding of usability issues with the small screen, input interaction, and Web design. Mobile screen simulations as used by Jones et al. (1999, 2002) do not capture the full interaction of users

on a mobile device. It is interesting to examine a user interacting with a handheld as a complete package (e.g.,. small screen, input interaction, Web design). Observing a complete package is realistic of a user's experience with the mobile Web by producing an overall picture of user performance on Web tasks.

4) Problems users have with task performance on a mobile device have been related to cognitive overhead. We associate cognitive overhead to a lack of attention to a task and forgetting aspects of the task. Bjork et al, (2000), Jones et al (1999, 2002) and others have mentioned a form of cognitive overhead that results from users moving between screens resulting in a negative impact on task performance. There is a link between a single-screen display interaction common to a mobile device and user performance in relationship to cognitive overhead. Costs to performance are expected when a user switches between tasks on a mobile interface using a single-screen display. The experiments described in chapter 4 and 5 examine switching between tasks on a mobile interface that result in issues with attention and memory, measured as an impact on task performance. It is also expected that a user's cognitive abilities related to attention and memory can be used to predict a users Web task performance involving task switching. There is a lack of theoretical foundation on the issue of cognitive overhead associated with use of a mobile device. In chapter 4, theory is presented on how attention and memory is influenced during use of mobile Web tasks on a handheld device.

Based on our current knowledge on user interaction with a mobile device, our research examines user performance with the mobile Web, as a complete package (e.g., small screen, input interaction, Web design) that is influenced by interruptions related to the mobile context.

In the following section we review current research addressing navigation and information presentation for mobile interfaces.

2.5 Mobile Interfaces for Optimizing Navigation and Information Presentation

In this section, examples are given of mobile interface designs and techniques that have captured the essence of practical use of a mobile device. These examples are related to improving navigation and information structure for browsing and searching on the WWW. These mobile user interfaces have been demonstrated in various applications developed in research and commercial projects.

Example 1 – Power Browser for Navigating a Web Site

Revisions in how information is structured in terms of hyperlinks and content presentation can enhance how users navigate to find information on the Web. The Power

Browser supports a hierarchical display of information for supporting effective navigation for browsing the Web on a PDA (Buyukkokten, Garcia-Molina, Paepcke, 2000). The content of a Web site are transformed using a proxy server into a format appropriate for the small screen of the PDA. The user display consists of a hierarchical list of links representing horizontal and vertical levels of page structure; each level is indented and marked by a vertical line, using minimal screen space (figure 2.2). The links are displayed as one of the following; an alphabetical listing, in the original sequence as in the Web document, or is page ranked according to estimates on the

Figure 2.2: Power Browser. From “Power Browser: Efficient Web browsing for PDAs,” by O. Buyukkokten, H. Garcia-Molina, A. Paepcke & T. Winograd, 2000, In *Proceedings Computer Human Interaction*, p.432. Copyright: 2000 by ACM Press.

quality or importance of the Web pages. In addition, Power Browser supports browsing and effective searching, respectively, using a local Web site search and keyword entry with word completion. A pilot test revealed that the Power Browser improved user interaction performance by reducing browsing times for directed tasks and improved focused search activities.

Example 2 – Power View for Navigating an Agenda and Email

PowerView is a PDA application supporting situational information and facilitation of navigation for retrieval of information (Bjork et al, 2000). An integrated interface was designed based on common applications such as email, tasks, contacts and meetings.

Information links were used to indicate a connection between two pieces of information in defining the context for a piece of information as set by the user. Based on a tile structure, there are three different views to help a user with tasks. An OverView shows a summary of information available from all information types (e.g., email, tasks, contacts etc.) (figure 2.3). The Navigational view aids a user to navigate within a specific information domain, such as within email. The Context view provides specific information that is relevant to a selected email. The user can manipulate navigation with one hand using buttons on the PDA by selecting a specific tile containing the information domain. Each time a tile was

Figure 2.3: PowerView. From "Power View: Using information links and information views to navigate and visualize information on small displays," by S. Björk, J. Redström, P. Ljungstrand, & L.E. Holmquist, 2000, *Handheld and Ubiquitous Computing 2000*, p. 51. Copyright 2000 by Springer-Verlag.

selected the appropriate view would be displayed. An evaluation compared use of the PowerView and the Windows CE bundle. Users completed 100% of all tasks on PowerView and perceived that the information was arranged more appropriately, compared to 70% of tasks completed on Windows CE.

Example 3-SmartView for Navigating and Searching Web Site Information

SmartView is an application that uses a similar approach as PowerView, for viewing a Web site. SmartView provides a thumbnail overview of a Web page by outlining the page into regions that can also be clicked-on for a zoomed-in detailed view (Rodden, Milic-Frayling, Sommerer & Blackwell, 2003). The selected region is reformatted to fit the display and reduces scrolling. To enhance searching of Web pages SearchMobil is included as a part of SmartView. SearchMobil provides a search booklet of top ten results and an annotated view of a document that indicates the relevant parts of the document related to the query and directs users to an appropriate detailed view (figure 2.4). The annotations consist of color-coded outlined regions, highlighting of query terms and small squares to indicate the number of query term hits in a specific region.

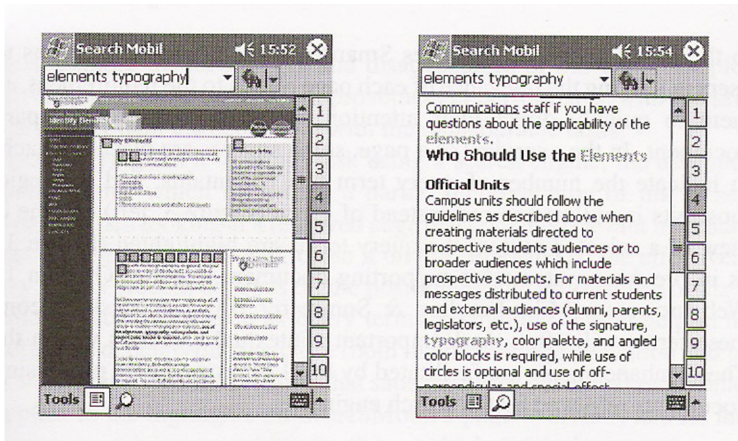

Figure 2.4: SearchMobil, showing an overview with annotations (left) and a detailed view with highlighted query terms (right). From “Effective web searching on mobile devices” by K. Rodden, N. Milic-Frayling, R. Sommerer & A. Blackwell, 2003, Proceedings Human Computer Interaction 2003: People and Computers XVII – Designing for Society, p. 285. Copyright 2003 by Springer-Verlag.

Other Examples for Improving the Mobile Web Interface

There are also other interface concepts that are of interest for improving usability of a handheld device. These include: The use of semi-transparent icons that are laid over text that is presented on a small screen (Kamba et al., 1996). Adaptive Rapid Serial Visual Presentation (Adaptive RSVP) (Oquist & Goldstein, 2003), which adapts the successive presentation speed of text to the characteristics of the text to be viewed at a single visual location to improve reading speed. Single-dependent automatic zooming which combines zooming and panning of information on a small screen for document and map navigating tasks (Jones, Jones, Marsden, Patel & Cockburn, 2005). The Power Browser project has also included forms of text summarization for the Web (Buyukkokten, et al., 2001) and Web form entry via a form-filling component (Kalijuvee, Buyukkokten, Garcia-Molina, Paepcke, 2001).

These examples have shown a number of design concepts to improve the handheld interface for presentation of information content using hierarchical or tile displays, information categorization, summarization and ranking and rating for aiding search or browse types of tasks on a handheld interface. Currently lacking for mobile interface design is supporting users of mobile Web interfaces when switching between tasks and improving browsing for less well defined tasks. When using a mobile device to multitask, switching can occur between the task on the mobile device (e.g., online shopping) and a task in the environment (e.g., speaking to a friend) or with another task on the device itself (e.g., messaging). In chapter 4 we examine use of a mobile device for task switching with tasks generated as interruptions from the environment and from the device. In Chapter 5 an experiment is presented that aims to validate concepts that support task navigation when browsing or completing a transaction type of task while multitasking and switching between tasks. In the following sections we cover research on multimodality, as an alternative to stylus and soft keyboard data entry on a handheld and research on multitasking and interruptions in the mobile context.

2.6 Related Work on Handheld Input and Multimodality

In section 1.1.3 the inefficiencies with data input methods on a mobile device were described as problematic for users. In this section the background on handheld input technology is briefly described, followed by usability issues with handheld data entry and a brief overview of new techniques to improve handheld data entry.

2.6.1 Data Input on a Handheld Device

The primary mode of communication with a handheld is via the soft screen. The screen allows touching on screen icons with a stylus, also known as a pen, and is used as a pointing and tapping device. The stylus is used to select a menu item or icon for viewing applications, selecting alpha or numeric characters on a soft keyboard or for handwriting (Bergman & Haitani, 2000). For text input there is keyboard input and pen (handwriting) input. For keyboard input, text is most commonly entered using a soft keyboard that produces machine-readable text.

Other techniques include handwriting a special script on the screen that is converted into typed text using character recognition. Handwriting can also be done with digital ink that transfers the actual handwriting on to the screen. For example, signing on a digital pad when receiving a package from the United Postal Service. Digital ink requires more system memory and the text is difficult to index and search and is not managed well by today's computing technology (MacKenzie & Soukoreff, 2002). An example of a pen based technique, is the Graffiti handwriting system on a Palm. This system utilizes a special Graffiti alphabet that is converted by the computer to typed text (MacKenzie & Soukoreff, 2002; Waycott & Kukulska-Hume, 2003).

Keyboard or handwriting techniques require the use of two hands and is often more cumbersome than using a PC keyboard. Data input interaction with a handheld can be problematic, especially when the hand holding the stylus covers part of the screen and precision with selecting targets is less accurate with a stylus (Bjork et al., 2000). Works around techniques are often developed by users to enhance efficiency with text entry. For example, students who found text entry on a PDA to be slow, awkward and error prone, devised methods such as abbreviating text during note taking and ignoring errors (Waycott & Kukulska-Hume, 2003). The limitations and drawbacks that people experience on a PDA, support the idea that improved methods for data entry are needed on a handheld device.

Research on improving data entry for a handheld device has focused on techniques of improving handwriting with new keyboard methods (for a review of text entry techniques see MacKenzie & Soukoreff, 2002). Some of the new handwriting methods include: Unigesture, a tilt to write method, where the user tilts the device sideways to specify a letter and a word is inferred by the system (Sazawal, Want & Borriello, 2002), directional stroke recognition technique (Kostakos & O'Neill, 2003) and SHARK, shorthand aided rapid keyboarding (Zhai & Kristensson, 2003).

Other techniques go beyond current data entry methods with a keyboard or pen. Different forms of communication with the mobile device incorporated with the advancements in context and location aware computing. Multimodal interfaces are a means to integrate speech, gesture, tactile, and other body movements to communicate with a mobile system.

There are other methods being devised to improve on the current handheld data entry techniques along with advancements in multimodal interfaces as a means to improve communication with the handheld via the user interface. In the next section we discuss the usefulness of multimodal mobile interfaces.

2.6.2 Multimodality for Mobile Devices

Alternative interaction techniques have been addressed in the use of multimodal interfaces for enhancing data entry and communication for a user in motion with a mobile device. Multimodal interfaces process two or more combined user input modes such as speech, pen, touch, manual gestures, gaze, and head and body movement (Oviatt, 2003).

The use of different modality combinations with a handheld interface is a relatively new area of multimodality research. In early studies, the use of modality and mobility was investigated with larger mobile platforms such as a laptop. Oviatt (2000) examined speech and pen input adaptations during naturalistic noisy conditions and communication exchange on a Quickset multimodal system in a mobile environment. The participants used the Quickset interface on a portable Fujitsu Stylistic 1200 PC. The Quickset interface simulated fire and flood control activities as part of an emergency management exercise. Commands were issued with pen and speech input. The users were continuously walking through a noisy cafeteria and experienced variable lighting and interruptions by other people. The results were analyzed for speech recognition, pen recognition and a multimodal (combined speech/pen) recognition. The results showed that in noisy environments speech recognition with Quickset failed during mobile use, compared to a quiet stationary position. There were no differences in pen recognition for mobile or stationary use. Compared to speech recognition as a standalone, the combined multimodal processing lowered the speech error rate by 19-35% in the stationary and mobile condition. This study supports the use of a multimodal combination for speech and pen input in mobile environments. However, speech recognition technologies are still very error-prone.

IBM Research was one of the first companies to implement a multimodal mobile assistance phone system in Australia. A pilot study by Lai (2004) examined in a laboratory setting use of mobile email on a multimodal system for a combination of speech, and telephone keypad input on a mobile phone. The multimodal interface called the Mobile Assistant was compared to a current unimodal (telephone keypad) WAP browser system for access to mobile email messages. A questionnaire administered to participants was analyzed. Overall, the use of the Mobile Assistant for use of the speech and telephone keypad input was of significantly more value for quality of use and easier to use than the unimodal WAP phone.

The utility of a mobile multimodal interface is highly dependent on acceptance for use in an outdoor or public environment. Jost, Haussler, Merdes and Malaka (2005) investigated how pen and speech combined, facilitated user interaction on mobile information tasks in an outdoor context. An evaluation study was conducted on a PDA with the SmartKom system. SmartKom is a prototype system that facilitates multimodal interaction for use of tourist information in outdoor environments. The participants completed tourist type tasks (e.g., map interaction, tour planning, retrieving sightseeing information) using a combined pen and speech input in an outdoor and indoor setting. After completing a task with SmartKom the users were asked to rate the task interaction on the following aspects (i.e. convenience, speed, intuitive usability, efficiency, and overall system acceptance). This method was than compared to a method that the user was familiar with (e.g., map interaction on SmartKom was compared to a digital Web-based mapping solution or using a paper map) for performing the same task. The results for use of SmartKom in the outdoor environment showed that users fundamentally accept multimodal interaction as an appropriate paradigm for mobile systems. The usability rating suggested that the outdoor condition for multimodal input with SmartKom was equal to or better than the method familiar to the user. Using SmartKom in an outdoor environment was rated by users to be more convenient, faster, intuitive, efficient and well accepted compared to the users best-known method. Use of SmartKom for the touring tasks was more relevant in the outdoor situation than when compared to use of SmartKom for the same touring tasks in the indoor laboratory environment.

2.6.3 Research Implications for Handheld Input and Multimodality

There are two research implications that have been extracted from the current literature.

1) There is no research to our knowledge examining the impact of using different modalities on user performance of a mobile Web task. Although users have rated speech and pen interaction on a mobile device as highly usable, there may be a negative impact on user task performance. There is a need for research on the utility of multimodal interfaces and how it influences a users performance on a handheld device. As presented in chapter 4 experiment 2, it is expected that use of a multimodal interface combining pen and speech on a handheld can positively influence a user's Web task performance.

2) A further examination is needed on how modality can influence a user's Web task performance when switching between two different tasks. Studies have mainly examined the use of a combination of speech and pen modalities for accomplishing tasks (e.g., sending and receiving email) in a specific application or domain (e.g., mobile email) (Jost et al., 2005; Lai, 2004). Using different modalities associated with different applications or domains may enhance switching between tasks. For example, using pen input for a Web task and speech input for an instant message communication task may facilitate user performance when switching between tasks. In experiment 2, it is expected that switching between pen and speech modalities for different tasks can positively influence Web task performance.

2.7 The Mobile Context as Related to Multitasking and Interruptions

This section characterizes the mobile context, first from research on context-aware computing, then from the user experience in common everyday situations, commuting, running errands, and social interaction. A framework on the user experience in a mobile context incorporates a context of multitasking and interruptions.

2.7.1 The Mobile Context

A context of use characterizes a situation relevant to the interaction between humans, applications and the surrounding environment (Dey, Abowd, & Salber, 2001). The mobile context is no longer associated purely in regards to a users location. The challenge of appropriately representing the mobile context is due to the continuous changes that a user experiences within the urban environment (Kaasinen, 2003; Kim, Kim & Lee, 2005; Tamminen, et al. 2004).

A system is considered context-aware if information on context is used to provide relevant information and services for the user's task (Dey, 2001). Research on context-aware computing defined the mobile context primarily by the current physical location of a device. In the 1990's research on the context of use for a mobile device has been restricted to a fixed indoor context (e.g., offices, classrooms, museums, hospitals etc.) for use of a specific system application. For example, Cyberguide (Abowd, et al., 1997) was designed to assist visitors with a tour of a lab. A shopping assistant (Asthana et al., 1995) assisted store shoppers with details on products, price analysis etc.. Other applications such as the Egyptian Museum Digital Guide (Martin, 2003) and Marble Museum Guide (Ciavarella & Paterno, 2004) provided a visitor with a tour of the museum. For these projects context-awareness simply meant processing information on a current physical location.

Characterizing the Mobile Context

Research on use of a mobile device in urban or outdoor environments is still in its infancy. The outdoor context has been examined primarily for specific groups of users (e.g., tourists, researchers and business people) with a specific system application, such as GUIDE, a context aware electronic tourist guide (Cheverst, Davies, Mitchell, Friday & Efstatiou, 2000) and the minimal attention user interface for fieldworkers (Pascoe et al. 2000). Recently, the focus has shifted to general user populations such as street pedestrians in an urban environment. Interfaces designed for general user groups within a mobile context pose a great challenge. Several authors (e.g., Kaasinen, 2003; Kim, et al., 2005; Tamminen et al., 2004) have examined use of mobile devices within the context of everyday urban travel situations (e.g., work commutes, running errands, visiting).

The ethnographic study by Tamminen et al. (2004) investigated the dynamic changes in context when a user is on the move in public places. The study focused on analyzing the everyday activities and journeys (e.g., commuting, errands, shopping) of people (e.g., the elderly, single mothers, youngsters) taking place in an urban environment. The travel episodes were identified based on the following criteria: the episodes were specific to the mobile context (rare in fixed contexts), the travel episodes were recurring and specific enough to be considered as activities of context-aware computing.

The findings resulted in four characteristics specific for the mobile context.

Sidestepping. When a user moves from point A to point B there are unplanned (ad hoc) situations that occur, a few examples are: bumping into acquaintances, stopping to buy a snack or popping in to a store on the way to a primary destination. These unplanned actions are seen as sidestepping and are often social in nature.

Social solutions for handling problems with navigation. When a user has difficulty finding a location or misses public transport, social channels are used either by asking someone on the street for directions or calling someone on the cell phone.

Temporal considerations. Time and place are over emphasized in the mobile context; a person is either hurrying or waiting. Hurrying compresses activities into a tighter timeframe and requires the full attention of the person for management of activities and anticipation of adhering to a timeframe. Waiting stretches the relationship between time and action and can be used for various time killing activities.

Multitasking. Doing more than one task involves paying attention to surroundings, repositioning, monitoring of performance and reasoning on whether a goal is getting closer. People tend to engage in multitasking only when it does not hinder them from noticing signals in the environments for completing their primary task (e.g., waiting for a bus a user may make a cell phone call. During multitasking, available cognitive resources for interacting with a device are limited.

The characteristics of the mobile context are based on events or travel episodes that require multitasking as stimulated by interruptions that consist of expected or unexpected events. Each characteristic pinpoints multitasking that takes the user away from a primary task in order to handle some form of interruption. The user experience in the mobile context naturally leads to multitasking and handling of interruptions. Based on the characterization of the mobile context a user-centered focus on multitasking and interruptions has been derived: The **mobile context** *consists of a series of changing events and situations, taxing the users ability to handle multiple tasks.*

As described in the next section, the research on use of a mobile device suggests that multitasking may be problematic for users. In the next section we focus on issues of multitasking with a mobile device. In chapter 3 we propose a user interaction framework that specifically addresses aspects of multitasking and interruptions during use of the mobile Internet in a mobile context.

2.7.2 Multitasking with a Mobile Device

Multitasking has been described as conducting more than one task in an alternating fashion (Preece et al., 1994). In characterizing multitasking with a mobile device, this section begins with traits of mobile tasks, followed by a review of research examining multitasking with a mobile device. Lastly, key issues related to multitasking with a mobile device are summarized.

Tasks conducted on a mobile device have been characterized as ad hoc or unplanned, spontaneous, time critical, triggered by other people or events, relatively short in number of steps, a limited amount of time to spend on a task, low in amount of attention dedicated to a task, highly personal in terms of information content, high rate of interruption during a task and the need for completing a task can change (Vaanaen-Vainio-Matilla, K. & Ruuska, S. 2000). These general characteristics describe multitasking as a common trait for use of a mobile device.

As mentioned in section 2.5, when using a mobile device to multitask, switching occurs between the task on the mobile device (e.g., online shopping) and a task in the environment (e.g., phone call) or on the device itself (e.g., messaging). To our knowledge there is a dearth of research on multiple tasks conducted on the device itself. Current research has focused on use of the mobile device combined with activities in the environment.

Research on multitasking with a handheld device has addressed different facets of user, mobility and tasks. Jameson and Klöckner (2004) assessed dual tasks or concurrent activities during use of a cell phone (e.g., dialing a cell phone while viewing the screen and walking). Users typically apply a general strategy of suspending execution of one task while dealing with demanding parts of another task. Users that were walking and dialing a cell phone would either slow down or stop walking, suggesting difficulties when doing more than one task on a cell phone.

An ethnographic study by McClard and Somers (2000) examined how families integrated use of a wireless tablet in the home. The study found that participants valued a wireless tablet (a handheld computing platform that is smaller and lighter than a laptop but larger than a pocket PC) due to enabling a high degree of multitasking between the tablet and a household activity, such as simultaneously watching TV, and tablet Internet surfing or instant messaging.

Pascoe, Ryan and Morse (2000) addressed specific multitasking activities of mobile field workers during collecting data while animal tracking. A minimal attention user interface (MAUI) was developed so that the field worker expends "minimal attention" during interaction with a mobile device. The MAUI consisted of different interaction combinations that required the least amount of attention from the user so as to not interfere with the primary activity of the user. Specific characteristics of the users primary task were defined according to the user, environment task and tools to which a particular mode of interaction had the best fit. For example, a researcher (user) conducted the fieldwork activity in the African bush (environment) for observing animals, which had to be done quietly (task) using a PDA (tool). Therefore, the MAUI interaction mode was a push button mode that allowed the researcher to enter data while keeping an eye on the animals. Early trials with the MAUI were successful suggesting that the interaction modes minimized the distraction from the users fieldwork activities.

2.7.3 Research Implications on Multitasking with a Mobile Device

Two research implications have been extracted for multitasking with a mobile device.

1) Users have difficulty with conducting more than one task when using a mobile device. Multitasking and interruption handling is a core characteristic of using a handheld in a mobile context. Specifically there is a lack of research examining multitasking on a mobile device with interruption tasks generated from the same device. Research has shown that users have difficulty with multitasking activities with mobile devices for combining physical

movement such as walking and dialing a mobile phone or using the Internet (Jameson & Klöckener, 2004). The use of larger mobile devices such as a wireless tablet has been less problematic for multitasking (McClard & Somers, 2000). Earlier work on mobile devices primarily focused on the consequences resulting from constraints of limited screen size, capacity and bandwidth, rather than the suitability for conducting multiple tasks. The main theme of the experiments presented in chapter 4 is focused on investigating user Web task performance on a handheld when multitasking with interruptions from the environment or the device.

2) An interaction framework capturing characteristics of the user, mobile device and task is needed to conceptualize mobile interface assistance. Multitasking is dependent on the combination of characteristics of device, environment and task in relationship to the modality needed to complete the tasks, suggesting a need for a user interaction framework. For example, the MAUI utilized an interaction framework that made multitasking in the field easier by allowing the researcher to focus on the primary task of watching the animals and using a minimal amount of attention resources to collect data on the PDA. In Chapter 3 we present a user interaction framework for multitasking with interruptions on a mobile device.

2.8 Conclusions

In conclusion, a main barrier to use and acceptance of the mobile Web is due to problems with the mobile user interface. A compounding of existing issues related to the small screen, data input and poor Web design contribute to poor usability of a mobile device. Usability studies with WAP, PDA and other handheld devices have confirmed issues experienced by users such as high amounts of scrolling and paging, increased search activities, disorientation, reports of slowed reading and scanning, and difficulty with data entry.

We focus on understanding user performance by comparing use of a handheld device and desktop PC. User performance on the Web with a desktop PC can provide a general baseline comparison to Web performance on a handheld device. It has been assumed that there are many similarities between use of the Web on the desktop and a mobile device. Therefore, a user's knowledge of the Web should transfer to use of the mobile Web on a handheld. Furthermore, we propose to assess performance on a mobile device as a complete package (i.e. small screen, input interaction, Web design) observing all aspects together and not just one aspect in isolation. Since previous research has shown that user performance on a mobile device is influenced by a combination of factors (e.g., screen size and task complexity), an externally valid picture of user performance is gained by observing user performance with a mobile device as a complete package.

Difficulty with navigating and other usability issues have a direct negative impact on user performance and what researchers have described as cognitive overhead associated with attention and memory problems. The research focused on wireless platforms do not address how user interactions on a mobile device result in cognitive overhead. There is also a lack of research on cognitive theory that may explain cognitive overhead due to problems with attention and memory during use of a mobile device.

There have been many new design concepts to improve the mobile interface for screen display and navigation (e.g., hierarchical displays, tile displays,) and improving data entry with new handwriting and keyboard methods. Currently lacking for mobile interface design is supporting users when doing more than one task, and switching between tasks in consideration of interruptions experienced in the mobile context. Multimodality can be used to support user handling of multiple tasks and switching between tasks.

Central to improving usability of a mobile device is an understanding of the mobile context. In our literature review we have found that the mobile context is a disruptive environment where multitasking and interruptions are common (e.g., sidestepping). Users have difficulty with conducting more than one task on a mobile device at the same time. There is a lack of research focusing on user interaction with mobile devices specific to disruption in a mobile context related to multitasking and interruption handling. A multitasking framework should be used as a basis for developing a mobile interface that supports the user's primary task and a user's attention (Nagata et al., 2005). This issue of multitasking with interruptions is the focus of the empirical research presented in Chapter 4.

Chapter 3 Mobile Assistance[2]

Abstract

Our research has shown that people often need assistance when combining use of the mobile Web and other computing tasks. In this body of work, the specific focus of mobile assistance is to support a user with multitasking and interruption handling on a mobile device. When presenting to users support via an attentive interface for mobile multitasking it was shown that users are accepting of different types of assistance (e.g., visual indicators that are manual or automated). However, there is lack of knowledge on presentation of assistance for managing interruptions during use of a handheld. A need exists for empirical user research in order to understand what specific mobile display presentations will be effective and beneficial to users when interrupted. A multitasking and interruption framework was used to identify aspects of the user, tasks, context, mobile device and user performance that are relevant to user handling of interruptions.

3.1 Introduction

Today, user assistance for Web information systems consists of customer service via email, chat, and help desks. Shneiderman (2000) points out that on-line assistance can meet the challenges of supporting a wide range of users with the Web. We propose to extend the concept of customer service to include mobile assistance as computing support to improve usability of the mobile Web. This type of assistance will aid a user with completing tasks on a handheld device in a mobile context.

In Chapter 2 our literature research has shown that it is common for a user "on the move" to do more than one task. In section 2.7.1 we described the mobile context as a series of changing events and situations that tax the users ability to handle multiple tasks. Within this body of work we define **mobile assistance** as *aiding in use of the mobile Web during interruptive situations that lead to multitasking*. Our approach to mobile assistance includes presentation of an **attentive interface**, that adapts support for managing

[2] Parts of the research reported in this chapter have appeared in separate publications as:

Nagata, S.F., van Oostendorp, H. & Neerincx, M. A. (2004) Interaction Design Concepts for a Mobile Personal Assistant, In *Proceedings of the SIG CHI.NL*. The Netherlands: SIGCHI.NL.

Nagata, S.F., Neerincx, M. & van Oostendorp, H. (2003) Scenario Based Design: Concepts for a Mobile Personal Service Environment, In C. Stephanidis (ed.). *HCI International 2003 Adjunct Proceedings* (pp. 11–12). Mahwah, NJ: Erlbaum.

Lindenberg, J., Nagata, S.F. & Neerincx, M.A. (2003). Personal assistant for online services: addressing human factors. In D. Harris, V. Duffy, M. Smith, C. Stephanidis (Ed.), *Human Centered Computing : Cognitive Social and Ergonomic Aspects* (pp.497-501). Mahwah, NJ: Erlbaum.

interruptions and improving user performance. The attentive interface is derived from our mobile multitasking and interruption framework.

Our research is focused on supporting users with Web services, such as when Internet shopping. When online shopping people often encounter problems with the check out process, browsing for items, and have difficulty with remembering a location of an item in an on-line store (Bellman, Lohse & Johnson, 1999). These points in an on-line shopping task can be extremely vulnerable to influences of interruptions experienced in a mobile context. User interface support can improve the success of completing the shopping activity during vulnerable points in the task.

In this chapter, the following topics are presented:

- Research related to computing assistance for attentive user interfaces and interruption management.
- PALS concepts are introduced pertaining to assistance for mobile support.
- Results from our user survey on use of mobile devices, the Internet, and assistance.
- Personalization within the PALS project
- The Attentive Interface for Mobile Multitasking concept describing our framework for multitasking with interruptions in a mobile context.
- General conclusions

3.2 Related Work on Computing Assistance

Research efforts on human and computer interaction have introduced new mobile interfaces that focus on optimizing specific aspects of the user interface. Several examples (e.g., Power Browser, Smart View, GUIDE, MAUI) of mobile interfaces were given in chapter 2 (sections 2.5 - 2.6) for improving navigation, information presentation, handheld input, multitasking and context awareness.

Assistance to the user often results in adaptations to the user interface. For example, arranging interface layout, combinations of input/output modality, consulting activities for collaborative engagement, directing a user with recommendations and providing location based services. We distinguish three general forms of systems that provide computing support to users, with a focus on assisting users with the Web. Assistance often represents user information that is collected and reflected within the system to support the needs of the user. A focus is on how does the system interpret and meet the needs of the user.

First, there is support provided as part of a general system or program via software components for auto-correction, wizards, critiquing systems and help systems. These software components assist the user through a limited understanding of context, by making assumptions of the users “actions” and “intent”. For example, a user can be automatically assisted with writing (e.g., auto correction of text, text suggestion), stepping through a process (e.g., Power Point Auto Content Wizard), critiqued (e.g., spelling and grammar checks) or by use of automated help systems such as Microsoft's "Clippy".

Second, there are knowledge-based systems that extract information from databases and information resources that need to be interpreted and realized to provide computing assistance within a specific domain. The user is often heavily involved in entering relevant data, maintaining the information that is used by the system and in tailoring the assistance received from the system. An example of a knowledge based assistance system is a shopping assistant that aids in comparative price analysis, navigating through a store, providing details on products, finding a current price by scanning a barcode and playing the shoppers favorite music (Asthana et al., 1995).

A third form of assistance is known as adaptive or personalized systems. These systems utilize user models or an agent infrastructure, or both to interpret information about the user and present system generated adaptations of the user interface. User models have been defined as models that systems have of users that reside inside a computational environment (Fischer, 2001). Explicit models are based on user data collected specifically from the user, whereas implicit models infer user information based on user behavior (Jameson, 2003). The models encompass user characteristics of specific preferences, users interest, computing behavior and performance and are used to predict an individual's behavior, needs and future computing actions. The assistance provided to the user is based on the users current task and is an automated dynamic adaptation made by the system (Fischer, 2001).

For example, Stock Tracker is an adaptive recommendation system providing personalized stock trading advice (Yoo, Gervasio & Langley, 2003). The Stock Tracker gives personalized buy and sell stock recommendations, utilizing an implicit user model constructed from a user profile. The user profile is acquired automatically based on user responses to recommendations made by the system. The stock recommendations are generated from a stock trading analysis combined with information that is filtered from the users previous stock trading behavior with Stock Tracker.

An example of a complex assistant is the Patient Advocate as described by Miksch, Cheng, Hayes-Roth (1997). This form of assistance utilizes an adaptive agent infrastructure for monitoring and consulting about a patient's health condition. This is also a knowledge-based system used to interpret raw data, derive explanations and provide recommendations for the medical domain. The assistance provided by the Patient Advocate is aimed to adapt outpatient care delivery to patients needs by monitoring and consulting on specific health conditions. The assistant helps patients to manage basic activities associated with certain medical conditions (e.g., gestational diabetes). The assistant also provides access to personal medical records, and tools for coordinating and scheduling medical appointments.

3.2.1 Attentive User Interfaces

The attentive user interface (AUI) which is assistance for supporting a user's attention was introduced in 2003 (Vertegaal, 2003). An AUI is expected to support the user by establishing priority for how a user interacts with a system. The priority of interaction, urgency and relevance of information can be established by mediating communication and signalling a request for attention, (Horvitz, Kadie, Paek & Hovel, 2003; Vertegaal, 2003). By signalling a request for a users attention this sets a certain priority for the user as to what needs to be done first.

An attentive user interface is often a part of an attention aware system that observes user activity and anticipates a user's needs (Horvitz, Jacobs & Hovel, 1999). An attention aware system collects a user's physiological measures (e.g., eye gaze, heart rate, motor activity) (Vertegaal, 2003; Chen & Vertegaal, 2004) and other sources of information for events (e.g., calendar information), user interaction with software and information on the user (e.g., user interests). This information is used to develop implicit models on the focus and priorities of a users attention to infer knowledge on the person, tasks and use of a device (Horvitz et al., 2003).

Streefkerk, van Esch-Bussemakers and Neerincx (2006), have described the application of an AUI for use by police officers. The police force is in need of attentive user interfaces that provide the right information in the right place and time. In order to adapt the attentive user interface to police officers, performance measures are needed for situation awareness (knowledge of a person's surroundings at a certain point in time), emotion (a user's emotional state), trust (does the user trust the system) and physiological measures such as heart rates. By monitoring these measures, attentive services can be adapted to the police officer in various situations.

Regarding a specific focus on attention and interruption handling, Horvitz et al. (2003) has addressed handling of messages that may pose a disruption or interference with ongoing computing tasks. Horvitz, Jacobs and Hovel (1999) and Horvitz et al. (2003) described research for automatically assessing incoming messages and making inferences on a user's focus of attention by monitoring multiple sources of information. This research resulted in development of a "Notification Platform for controlling the flow of messages to multiple devices, by balancing the value of the information with the attention-sensitive costs of disruption." The platform has a Notification Manager that uses an attention model to make decisions on the costs and benefits of alerting a user about incoming messages. The Notification Manager receives information on user attention and location from a "Context Server". The Context Server collects information tracked by sensors for various aspects of the user (e.g., head position, task completion time) and device (e.g., location, calendar events). The Notification Manager makes decisions weighing the cost benefit analysis of alerting a user about incoming messages. The end result for the user is an optimal alerting and display modality for presentation of an interruption on each device.

3.2.2 Interruption Management

A review of interruption taxonomies (Gievska, 2004; Ho, 2004; McFarlane and Latorella, 2002; Obermayer & Nugent, 2000), interruption frameworks and models for managing interruptions (Gievska, 2004; Gupta et al., 2005; Ho, 2004; Horvitz et al. 2003; McCrickard & Chewar, 2003, Speier, Vessey & Valacich, 2003) describe factors of user characteristics, tasks and the mobile context. These factors contribute to determining the

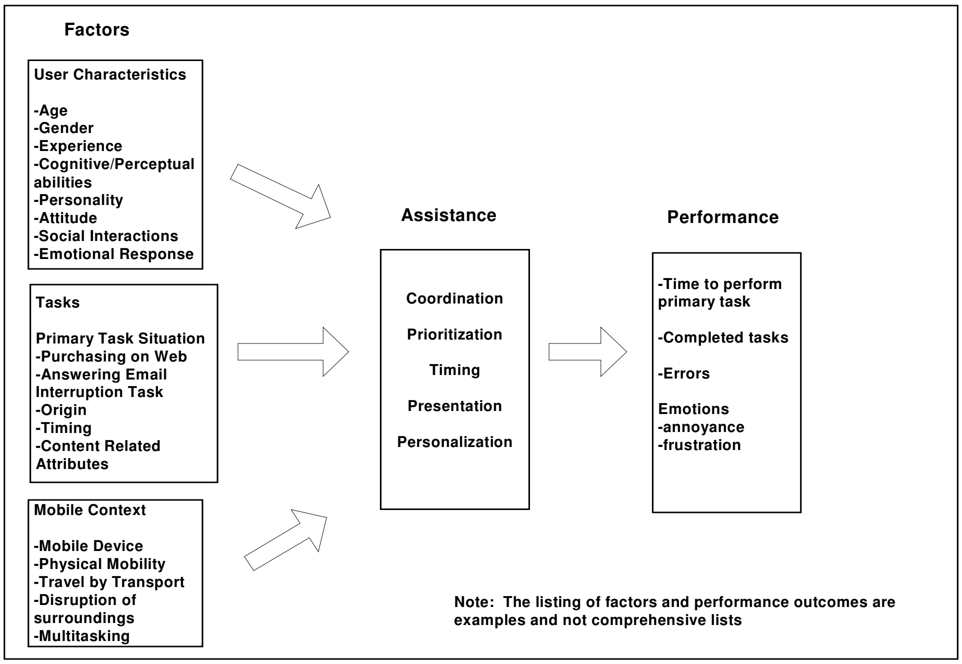

Figure 3.1: A categorization of factors that influence user assistance and performance outcomes.

type of assistance for users for managing interruptions that influence performance. We have categorized five common interruption management techniques (Figure 3.1).

These five common interruption management techniques are:

- Coordinating the presentation of the interruption via notification (e.g., negotiated, scheduled, immediate, mediated and triage involving handling of more than one interruption task).
- Determining prioritization for urgency of the interruption task.
- Timing for presentation of the notification and interruption task.

- Attention oriented display presentation of notification and interruption task (e.g., modality, visual display)
- Adaptations of the user interface for receiving personalized forms of interruption handling.

We consider interruption management as a way to formulate assistance for aiding interrupted task performance. Techniques of interruption management inform how assistance can be applied to situations that are disruptive to users. Techniques of interruption management have been addressed in research on command and control systems that produce a high number of alerts or warnings in complex and event driven domains that require multitasking. Research on interruption management has been focused on a naval Multi-Modal Watchstation (Obermayer & Nugent, 2000), commercial flight deck (Latorella, 1998), naval ship control center (Neerincx, Grootjen & Veltman, 2004), automobiles (Monk, Boehm-Davis & Trafton, 2004), instant messaging (Cutrell, Czerwinski & Horvitz, 2001) decision making (Speier et al., 1997) and office work environment for use of email (Gupta et al. 2005).

Approaches to Managing Interruptions

There have been various approaches to managing interruptions including the use of assistance. McFarlane (1999, 2002) examined user assistance for handling interruptions and studied the effects on user task performance. The interruptions were presented in the following manner: (a) immediately by an assistant interrupting the user at any time, (b) negotiated, where the assistant announces need to interrupt the user then supports user negotiation for receiving interruption, (c) mediated solution, the assistant withholds an interruption and contacts the user via a different platform (e.g., by phone call) and requests to give the interruption, and a (d) scheduled solution, a pre-arranged schedule is used to interrupt the user. User performance was measured when multitasking between a continuous video gaming task of catching jumpers and the interruption task consisting of a computerized shape and color matching task.

The results showed that there was no best choice for coordinating interruptions to improve user performance. Instead there are tradeoffs between the type of assistance and user performance. When comparing all solutions, the negotiated solution, emphasizing support for human control over coordinating the onset of interruptions was the best for supporting performance on the continuous gaming task of catching jumpers. The immediate solution produced the best performance on the computerized shape and color matching interruption task, with large costs evident in performance on the gaming task. The mediated solution produced average performance levels on both the gaming and interruption task, but was neither the best nor the worst solution compared to the other solutions. The scheduled solution resulted in the best performance on task switching, with large costs to performance on playing the game and the interruption task.

According to McFarlane, a negotiated assistance solution seems to be the most appropriate when needing to support the primary task while receiving interruptions.

However, when considering use of a negotiated solution in the mobile context it is expected that users of a mobile device do not have the time, propensity or the cognitive wherewithal to negotiate with the assistant on receiving an interruption. This is primarily due to the user already being in a highly dynamic environment and having to handle interruptions. Adding an additional interaction for having to negotiate with an assistant has the potential of increasing the disruptiveness of the interruption task.

The manipulation of an interruption task was also examined by presenting information automatically or requested by the user on a pending interruption task. Ho, Nikolic, Waters and Sarter (2004) investigated how air traffic operators handled their immediate tasks when receiving information on a pending interruption task. It was found that when the operators received information on the modality (i.e. visual, tactile or auditory) they would be receiving the interruption task and the estimated amount of time it would take to complete the pending interruption task, this information was beneficial for scheduling and managing of air traffic control (ATC) tasks. When the operator received information that an interruption task was a visual task with low priority, the operator delayed the visual interruption task and first completed the air traffic control tasks, to avoid concurrent performance of the two tasks. By requesting information on the interruption task, the operator could better manage the interruption task. However, requesting the information from the system did lead to a distraction away from the primary ATC task lowering task performance. Overall, automated information presentation on the interruption task was the most beneficial to the primary ATC task when compared to the user having to request information on the interruption task.

Automated forms of interruption management may be more appropriate for handling interruptions in a dynamic environment such as the mobile context. As shown by Ho et al., (2004) in a highly dynamic air traffic control environment, automated presentations of information on the interruption task was beneficial to user performance. In this situation, an automated presentation of information on the interruption task was very useful to the ATC controllers. This information helped them to anticipate how to handle the interruption task in coordination with the primary task. We expect that for interruption management to be beneficial in the mobile context, a mediated form of interruption could be beneficial to users in supporting their primary task.

Other studies examining automated forms of interruption management, by mediating the timing of interruptions have found the following: by first determining the task situation requiring mediation and introducing the interruption at an appropriate moment, this leads to benefits for resumption of the primary task (Gievska, 2004), users perceived less annoyance, frustration and reduced mental demands (Gieveska, Lindeman & Sibert, 2005; Adamczyk & Bailey, 2004), less distraction (Gieveska, Lindeman & Sibert, 2005) and less time pressure (Adamczyk & Bailey, 2004). These studies show that mediation of interruptions can help to improve user performance. However, automated handling of the interruption itself is only one side of the coin. There is also the aspect that support of the primary task is also beneficial to task performance.

Another approach to interruption management is to manipulate aspects of the primary task to influence user response and performance. To manage the effects of an interruption the visual display presentation of the primary task is changed. There has been a recent focus on managing instant message interruptions that are disruptive to computing tasks. Cutrell, Czerwinski and Horvitz (2001) examined the effects of a marker that was used as a reminder for resuming a book title search task (primary task) after an instant message interruption on a desktop PC. The study showed that the marker had no positive effect for aiding users to resume the primary task after an interruption compared to having no marker after an interruption.

Although no effect of the visual markers was found on the desktop PC, we expect that supporting the primary task with markers on a mobile device may be beneficial to user performance. We expect the use of markers on a mobile device may be beneficial when viewing information on a "single-screen display". A single-screen display allows only one screen at a time to be viewed by the user and requires more intensive interaction on a mobile device, which is not required on a desktop PC. In chapter 4 and 5 these issues will be discussed in detail. In the next section we review designing for interruption management

Design for Interruption Management

Research on interruptions has generated various design recommendations for implementing interruption management into computing systems. These design recommendations are often vague and require validation through user testing. However, these recommendations provide some guidance for improving user handling of interruptions.

Formal design standards rarely include advice for management of interruptions or explicit directions for user support when multitasking (McFarlane & Latorella, 2002). Recently, design recommendations have been proposed for mitigating the impact of interruptions on user performance. Obermayer and Nugent (2000) have reported on the design of an alerting and attention management system for a naval Multi-Modal Watchstation. These recommendations suggest ways to design the complex interaction between a human and system with a visual/auditory/manual interface presentation. The interruption management recommendations include: 1) Provide interrupt resistant HCI. Presentation of an alert or alarm is an interruption and interruptions may cause errors. Presentation of interruptions need to match the level of urgency, 2) Manage attention. Use multiple levels of "attention getting" in guiding the operator to the next step, 3) Operator control. Permit the operator a degree of control in delaying, deferring or canceling messages, 4) Manage messaging. Manage simultaneous and competing messages, and 5) Archive messages. Provide ways to search and view messages.

Another aspect of assistance for interruption handling as was mentioned above, is the coordination of user interaction with interruptions. McFarlane (1999) and McFarlane and Latorella (2002) proposed four design solutions to coordinate user interruption: a) immediate solution, an assistant interrupts the user at any time and insists that the user immediately interacts with it, b) negotiated solution, the assistant announces need to interrupt the user then supports user negotiation for receiving interruption, c) mediated solution, the assistant does not directly interrupt the user but contacts the user by a phone and request interaction, d) scheduled solution, a pre-arranged schedule is used to interrupt the user.

In general, the above design recommendations contribute to an understanding of the core aspects of assistance for coordination, prioritization and timing with large screen platforms. Designing human computer interaction for interruptions experienced by a user on a handheld has been addressed primarily in a generic fashion. For example, a design recommendation suggests the task flow be designed in a flexible enough way so that task switches and interruptions are allowed (Vaananen Vainio – Matilla & Ruuska 2000). This recommendation lacks specificity for determining the following: How flexible should the task be? What is the impact of task switching on a users performance? Should all interruptions be allowed? What is the impact of an interruption on a users performance? An understanding is needed on how users deal with constraints of a mobile device while handling interruptions. The portability of a handheld suggests that use of the device can occur in different surroundings; therefore a user is susceptible to different kinds of disruptions. The source of an interruption can be from the handheld itself such as from email or Instant Messaging notification, calendaring reminders or of external origin such as a phone call, overhead page, beeper etc. There is a strong need for explicit and empirically founded guidelines for designing interruption management for use in a mobile context.

3.2.3 Research Implications on Mobile Assistance

There are two implications from the research literature that have influenced our investigation on mobile assistance

1) There is a lack of user studies examining interruptions during real world computing tasks. We need an understanding of what specific display presentations will be effective and beneficial to users (Horvitz et al. 2003). The work by Horvitz et al. (2003) lays a foundation for managing interruptions via attentive user interfaces. in highly disruptive and complex situations. We focus on the mobile context as an interruption-laden environment and especially lacking is knowledge on handling and presentation of interruptions during use of a handheld. In Chapter 5, we examine the influence of mobile assistance on user performance, when handling an interrupted Web task.

2) There is a need to integrate the management of interruptions on a handheld device to enable efficiency with multitasking in a mobile context. Overall, there has been very little research addressing interruption management in mobile computing. The management of interruptions can be beneficial by reducing disruption, managing multiple tasks and facilitating optimal performance on a task when experiencing distractions while mobile computing. We first need to understand how people experience interruptions in a mobile context. The research by Cutrell et al. (2001) indicates that computing interruptions are disruptive to task performance on a desktop PC. Our experiments investigate the implications of instant messaging interruptions for Web task performance on a handheld compared to a desktop PC.

The experiments described in chapter 4, empirically investigate the following:

- Factors important to understanding a specific context of interruptions affecting user Web task performance.
- A user's recognition memory for resuming an interrupted Web task.
- Attentive user support for Web tasks as a basic form of assistance.

In the following sections, a high-level conceptualization of mobile assistance is presented as part of the PALS initiative. The aim of the PALS project has been to attune mobile assistance to needs of the user, by tailoring assistance to specific user characteristics, location, interaction history and usage context (Neerincx et al., (manuscript submitted). The PALS concepts are used as a foundation to develop a user interaction framework for mobile interface support.

3.3 PALS Concept Development

An aim in the PALS project was to improve the user experience for financial and travel services offered via the Web. The PALS project focused on developing assistance for the user interface, specifically to improve the user experience of mobile Web services for the financial and travel domains (Lindenberg et al. 2003). To improve the user experience, a critical requirement for the success of electronic commerce, is the appropriate user interface for e-commerce systems (Lee, Kim & Moon, 2000, Lohse & Spiller, 1998).

People have a common mental picture of shopping at a mall or grocery store. When in this shopping environment, people typically experience a personal form of customer service (Aberg & Shahmehri, 2001). Today's electronic store lacks the customer service that people are used to receiving in a brick and mortar store. In an electronic store the help button on the home page replaces a sales clerk's friendly advice and help. The layout of the Web store is a maze of pull down menus, product indices and search features (Lohse & Spiller, 1998). The ease of using a Web store drives customer loyalty for repeat visits to a store (Lee et al., 2000). Lohse and Spiller (1998) found that Web store shoppers demand and require more services than local retail shoppers. Poorly designed Web stores, often have shoppers demanding services for finding and selecting merchandise. They also require prompt and clear answers on frequently asked questions (FAQs). Since Web stores never close, shoppers expect that assistance is available 24 hours a day 365 days a year.

A brick and mortar retail-shopping environment was chosen as a basic customer service metaphor for personal assistance in the m-commerce domain. Metaphors can help the user to create a mental model for appropriate behavior in certain situations (Norman, p.70 1988). A mental model refers to a representation of a system that reflects the individuals understanding of it (van der Veer & Puerta Meleguizo, 2002). Norman (1988) describes three aspects of mental models, the *user model* that is developed by the user to understand how the system operates. The user model must match the *design model* that is conceptualized by the designer. The *system image* is than critical to conveying the appropriate message and interactions to the user. People typically have a common mental model of customer service when receiving assistance for completing certain shopping activities. For example, a customer receives assistance (forms of help or aid) from a store representative (e.g., sales clerk, counter clerk, stock boy) to find a pair of shoes or locate an item that is on sale. In the context of retail shopping, a **service** is defined as work done by an assistant for a customer or end user. The customer service metaphor is used to develop types of assistance. It is expected that a user can transfer his/her previous experience with retail customer service to the experience of receiving mobile assistance.

In the following sections we report on research contributing to development of the PALS concept.

3.3.1 PALS Scenario Based Design

Scenario Based Design (SBD) is a cohesive method for extracting design ideas and obtaining data in the form of scenarios (Carroll, 2000). SBD was used as an organized brainstorming session to create an early “top down” vision of PALS. A workshop was held with five project members from the Dutch business sectors of banking and finance (Rabobank), telecommunication (KPN), software (CMG) and members from the TNO Human Factors Research Institute and Technical University Twente. The workshop was used to collect scenarios that described how each participant envisioned usage of the PALS system in a mobile context. The scenarios were analyzed qualitatively.

> Here is an example of a scenario excerpt from a participant.
>
> “Nancy is a 30 year old and works as a lawyer in a law firm in the city of Amsterdam. She travels back and to work from home every day. The trip takes about half an hour from a suburb and she does it mostly by car and sometimes by train.
>
> Nancy and Peter her law partner goes to the office by car or train, while monitoring traffic information/ train information. They have meetings with colleagues and customers where agents make the appointment and take care of email, sms, voicemail, videomeetings, facetoface meetings, phone calls. The agent picks out the preferred mode dependent on the person/time of day. They research and read information on the cases she’s working on. Agent scans the texts and provides a summary to be saved in the profile…..

The outcomes of the scenario analysis described types of PALS services, a PALS usage model and two generic scenarios.

PALS Assistance

The concept of assistance was revealed in the scenarios. The interaction between the user and PALS were formalized into the following types of assistance.

> **Directed (D) service**, "Do what I say". The user submits a command for assistance (e.g., similar to a search engine request). For example, "find XYZ travel route not impeded by traffic".
>
> **Solicited (S) service**, "Can you help me?" The user requests assistance. For example, "help me find real estate prices on the Web".
>
> **Non-solicited (NS) service**, "Smart interaction". The assistance automatically, personalizes interface presentation and interaction services on the device. For example, "the user is reminded of his current transaction history to help him with completing a mobile task".
>
> **Independent (I) services**, "The assistance is provided via relevant" intelligent actions based on user profile information and other sources (e.g., calendaring, email etc.). Assistance that is independent, arranges tasks external to the device, whereas with non-solicited services assistance is provided on the device itself. For example, on the basis of a person's schedule and predicted travel time a wake up call is generated.

These services integrate a familiar concept of "retail customer service" between PALS and the user. To further explain PALS services we give examples of real life experiences. For example, a customer walks into a store and makes a *Direct* request to find an item. The sales person sends the customer to a specific aisle. If the customer is unable to find a product, he/she can then *Solicit* the representative for help in finding an item. *A Non-solicited* service can also be presented to the customer where a sales clerk will ask "May I help you find something today" or an announcement on the store intercom informing shoppers on the sale item of the evening. Receiving flyers at a residence or bagging of groceries are services based on *Independent services* by the store representatives.

PALS Usage Model

The PALS usage model (figure 3.2) represents the user, task and environment.with the PALS system providing assistance on a mobile device. In order to enhance user Web task performance, the attentive interface generates solutions in the form of support concepts to aid users in conducting tasks during use of the Web. The support concepts of interruption mediation, task attention indicators, adaptation of the Web interface, are elaborated on in section 3.6.

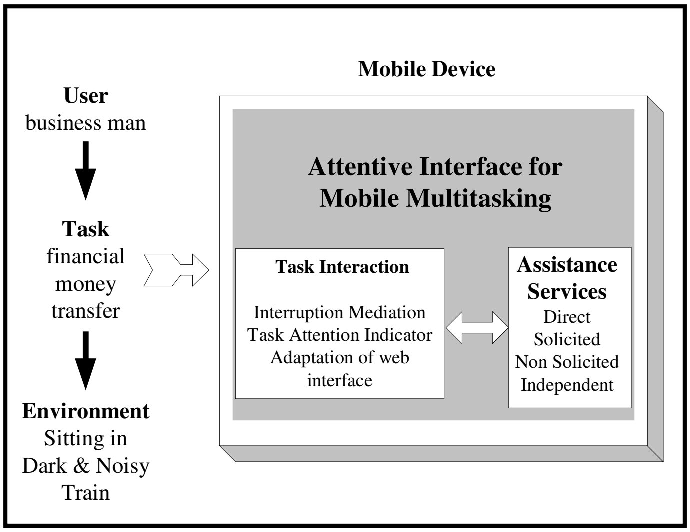

Figure 3.2. PALS Usage Model

A summary of user, task and context characteristics was captured from the workshop scenarios. User characteristics were described as: user demographics (e.g., age 16-65 years, occupation), cognition (e.g., memory, attention), intent of use (e.g., finance, household, domestic), and user interests (e.g., music, travel). Task characteristics consisted of Web transactions, information search, scheduling and appointments. Context characteristics consisted of location (i.e. train, office, home), and physical mode (i.e. sitting, walking). In addition, general lists of interaction qualities were also identified from the scenario data. The general PALS "look and feel" are summarized as the following: non-intrusive assistance with minimal interaction giving direct or explicit advice or suggestions, pro-active with self initiated activities, immediate meeting the needs of the user, and enabling smart and informative interaction and support for the mobile context.

PALS Generic Scenarios

These are excerpts from two generic scenarios, demonstrating the four types of PALS assistance services.

PALS Financial Scenario

"Hank is a busy professional ….by train he travels to a business meeting. He visits his Internet bank account with a handheld device to transfer money between accounts. The train is a little dark, noisy…PALS provide a screen display with attention cues and efficient navigation path to conduct tasks quickly and accurately (NS). While in the financial Web site PALS intercepts all non-emergency instant messages informing the messenger to hold or try back later (NS). Account information is automatically saved and updated to the Internet account by PALS if there are lapses in service while the train is moving (NS)."

PALS Travel Scenario

"Barbara is an active senior citizen…. Using a desktop computer she organizes a weekend trip. PALS presents the travel Web site with a screen view accommodating her vision (NS). She asks PALS to direct her within the site for destination specific hotel information (S) and decides on a hotel. Late for an appointment, she provides PALS with dates and accommodation information requesting PALS to book hotel reservations (D). At her lunch appointment, she uses her handheld to show the accommodations to her friends, presented in a consistent fashion from the original desktop view (NS). PALS confirms the hotel reservation then provides her with a list of suggestions for further travel arrangements (I)."

To conclude, key ideas generated from the Scenario Based Design method were used to develop PALS concepts. The main idea focused on assistance that is presented as adaptive changes in the user interface. To support this idea the usage model of the PALS system linked the mobile context, user, tasks and the assistance services (i.e. Direct, Solicited, Non-solicited and Independent). The generic PALS scenarios represented examples of situations where mobile assistance is used to support the user.

In the PALS project, the outcomes of the Scenario Based Design have influenced research on mobile assistance. The initial PALS user requirements were defined based on the generic scenarios and have been instantiated into a PALS interface demonstrator (see Lindenberg, Nagata & Neerincx, 2003). Furthermore, PALS survey and storyboard research gave insight on users of mobile devices and user acceptance of PALS features. In the next section, PALS survey research is presented to gain an understanding on user experiences pertaining to assistance and use of the mobile Internet.

3.4 PALS User Survey

Within the PALS project a survey study was conducted to characterize use of a mobile device with the Internet. A total of 112 people participated in the survey. We highlight the survey results that are relavent to our research on mobile assistance and multitasking with interruptions in a mobile context.

User Characteristics

The participants were an average of 23 years old, 53% male and 47% female. Ninety-three percent were students and the others had various careers (e.g., veterinarian, postman, sports instructor). Sixty–four percent of participants were university educated and 36% had equivalent to a vocational degree or high school degree. Experience related to computer use, 38% considered themselves as expert users, 61% of participants had experience with computers but did not consider themselves as expert users and a very small percentage, 1% had little use and experience with computers. In the last 6 months, 61% had purchased 1-4 items on the Internet, 20% had purchased 5 –11+ or more items, and the rest of the participants had not purchased items on the Internet. As for transactions related to banking and finances the majority of users 51% had from 5-11+ transactions, 18% 1-4 transactions, and 30% had no transactions.

Internet Use on the Desktop PC and Mobile Device

All participants used the Internet from a desktop PC on a regular basis with 43% using the Internet for 6 years or longer, and 57% less than 5 years. Only nineteen percent of the mobile phone users accessed the Internet from a mobile device, less than once a week from home or while on public transportation. The highest ranked activities were communication and searching for general information on the desktop PC and mobile device. Based on this sample of users, general use of the Internet on a mobile device reflects the same use as on the desktop PC, regarding information search and communication activities. Web activities on the desktop PC were highly popular for banking transactions and travel and leisure services (e.g., route planning, checking arrival and departure times for public or commercial transport, and purchasing tickets for travel or concerts).

Regarding use of Web services on a mobile device, there was limited use of the Web for travel and leisure services and limited to no use of financial services. Over half of all users were interested in future use of financial (e.g., banking) and travel services (e.g., checking arrival and departure times) on a mobile device. The participants indicated a high use of these services on the desktop Web. There is a strong possibility that in the future thses services will also be in demand on a mobile. Although there are many financial and travel services on the mobile Web, these participants have not shown interest in these services. When users were asked informally as to why they did not use the Internet from their mobile device, the primary reason was the high cost of Internet access and the device was unhandy or impractical. Users mentioned the constraints of small screen size and difficult data entry as problematic. This finding supports previous research by Sarker and Wells (2003) concerning the lack of use of the mobile Internet due to high costs and device constraints.

Interruptions and the Mobile Context

The mobile Internet is commonly used in safe and stable locations such as at home, sitting in a train or bus and not always in fully mobile situations such as while walking. Whether using a mobile device at home or in public transport there were interruptions (e.g., by people, telephone calls) when computing (Table 3.1). People are disrupted when using a mobile device. We believe, people have the same expectations for use of the mobile device as the desktop PC. The mobile device is expected to fulfill the same needs for use of messaging and communication. However, on a mobile device there will be many more interruptions generated from both the mobile context and the device itself in regards to notifications, reminders and messaging tasks. In an outdoor situation, there are probably many disruptions that influence the usability of Web services on a mobile device. One example is the lack of use of financial services on the mobile Internet. The costs may be too large if an error is made during a transaction, so financial services are not used on the mobile Internet. Another factor could be a lack of security in a changing environment.

Table 3.1: Interruptions when using the Internet

	Desktop (%)	Mobile Device (%)
People	79	50
Telephone	77	40
Instant Messaging	73	0
Loss of Internet Connection	32	27

Use of Assistance

Most participants have used a form of customer assistance by phoning a call center, use of an automated teller or kiosk and Internet customer service. People have less experience with visiting a customer service desk or using mail to request assistance (Table 3.2). There was a general preference for use of a call center or the Internet (e.g., frequently asked questions (FAQ), chat, email), rather than visiting a customer service desk, automated telephone service or use of an automated help point. A CHI square analysis showed that there was a significant difference ($p < .05$) related to gender and use of assistance. The majority of women (67%) preferred use of telephone services over the Internet and men were evenly split between use of call centers and the Internet.

Overall this user group preferred assistance that required a customer service person. However, the assistance did not have to be directly with a person (e.g., chat communication). Services that required a delay in communication such as email were also acceptable. The participants preferred either the use of a call center or Internet assistance such as email or chat assistance. On further analysis women preferred use of telephone assistance over the Internet. Assistance from a call center is preferred due to the following: “personal interaction and no travel involved”, “there are typically no long procedures to solve a problem and you can use a telephone anywhere”, “ you receive clear answers and can ask questions to clarify”, “ you receive direct contact and receive relevant answers to your situation”. Participants who preferred assistance via the Internet stated the following reasons “ fast, simple and easy access”, “no human contact needed to gain an answer via email” “specific problems in your own time can be solved”, “…..telephone services have high costs.” Personal interaction and convenience was a common theme for user preference of telephone assistance. Convenience, less human contact and lower cost were the overriding themes for use of Internet assistance. Since 50% of men and 67% of women preferred telephone assistance, we conclude that personal interaction and convenience are qualities that are valued by customers. Participants were questioned on the type of help they preferred when using a desktop application or a Web service. More than 50% of users when using a computer prefer to interact or have contact with a customer service agent (e.g., call center, e-mail, chat etc.). As discussed above, participants did not have a preference for direct or delayed communication. However, they did have a preference to communicate and

Table 3.2: Consumer assistance

	Experience with (%)	Preference (%)
Call Center	93	39
Kiosk	87	5
Internet Customer Service	84	32
Automated Telephone Service	86	5
Visit customer service desk	60	14
Service via postal mail	44	0
Other	0	5

Table 3.3 Desktop PC application and Web service assistance

	Deskto PC Application Preference (%)	Web Service Preference (%)
Customer Service Agent	57	56
Help Function	12	5
Computing Assistant	5	4
Internet FAQ	8	17
Automated Telephone Service	1	3
Paper Manual	5	3
Other	12	12

deal with a real person. We conclude that people have similar expectations of assistance when shopping in a retail environment or when needing help with computing or Web tasks. We expect that use of mobile assistance is one way to alleviate issues that people may have with use of Web services on a mobile device. The assistance can reduce the need for customer service contact. One way to enhance mobile assistance is to use personalization to support the user. For example, an interruption during a Web task could leave a person disoriented by not knowing the status of the task or where to resume the task. In our research we integrate the assistance services (e.g., Solicited, Unsolicited etc.) in a personalized fashion to provide intelligent support for resuming a task. This support could be in the form of generating an automated visual marker (which is an immediate relevant answer to the users problem of disorientation) for the user to resume the task and providing the tools for the user to deal with the issue. With this type of support the user does not need to seek additional help to deal with an interruption. In the PALS project personalization is further addressed on several aspects for personalization suitability, user modeling and user profiles as described in the next section.

3.5 PALS Personalization and User Study

Personalization has been described as incorporating user information to deliver appropriate services and content for meeting a user's needs (Cremers & Neerincx, 2004). Neerincx et al. (manuscript submitted) describes user modeling in the PALS project as incorporating three personalization concepts, personalization suitability, user models and user profiles. Personalization suitability addresses whether the personalized changes are needed and effective for the user. User models as described in section 3.2 contain either explicit (information collected from the user) or implicit (infer information based on user behavior) information about the user for generating a personalized or adaptive user interface. In the following sections we briefly discuss the integration of adaptive support to the concept of mobile assistance.

PALS Adaptive Support

An adaptive system applies a user model to adapt specific aspects (user interface) to the user (Brusilovsky, 2001). Jameson (2004) specifically describes an adaptive system as interface adaptations or personalization that is for an individual user. Fischer (2001) makes a distinction between adaptive and adaptable approaches to user modeling. As shown in figure 3.4 an adaptive system involves a dynamic adaptation that is actively changed by the system with no special effort by the user. Adaptable interfaces according to Fischer are focused on presentation of appropriate content information with the user having to tailor and enter information for the system.

As a way to enhance the mobile interface, PALS assistance considers ways to adapt the mobile interface to the user (Neerincx et al., manuscript submitted). The PALS

	Adaptive	Adaptable
Definition	dynamic adaptation by the system itself to current task and current user	user changes (with substantial system support) the functionality of the system
Knowledge	contained in the system; projected in different ways	knowledge is extended
Strengths	little (or no) effort by the user; no special knowledge of the user is required	user is in control; user knows her/his task best; system knowledge will fit better; success model exists
Weaknesses	user has difficulty developing a coherent model of the system; loss of control; few (if any) success models exist (except humans)	systems become incompatible; user must do substantial work; complexity is increased (user needs to learn the adaptation component)
Mechanisms Required	models of users, tasks, and dialogs; knowledge base of goals and plans; powerful matching capabilities; incremental update of models	layered architecture; domain models and domain-orientation; "back-talk" from the system; design rationale
Application Domains	active help systems, critiquing systems, differential descriptions, user interface customization, information retrieval	information retrieval, end-user modifiability, tailorability, filtering, design in use

Figure 3.3: Fischer's comparison of Adaptive and Adaptable systems. From Fischer, G. (2001). User modeling in human-computer interaction. *User Modeling and User-Adapted Interaction*, 11, 65-86.

concepts incorporate an adaptive approach to mobile assistance. Other PALS features include aiding navigation by predicting the user's navigation decisions using information foraging and Web usage mining (Herder, 2006) and adapting content and dialogue to the user via a proactive scheduler (Lindenberg et al., 2003).

PALS User Study

In determining user requirements for PALS, Brölman (2004) conducted an exploratory study with 24 participants, on user acceptance of specific PALS features that were presented on storyboards viewed on a pocket PC. Each participant viewed a total of 22 PALS features and rated each feature on a 5 point scale for usefulness, attractiveness and necessity of the feature. Each feature was presented on a Web page image with a short scenario. The first image showed the Web page and the second image showed the same Web page with the PALS feature. Examples of various features include the Point of Return Indicator, a visual marker that highlights the users specific location on a Web page (Nagata, 2003), presentation of an interruption in a specific modality and presentation by timing of interruptions based on the users situation (Nagata et al., 2004). We further analyzed the data by Brölman, focusing on features related to our research. There were technical difficulties with two of the PALS features regarding interruption modality, therefore; the data was not analyzed for these features. A descriptive analysis showed the following: the Point of Return Indicator was rated as useful by 61% of users, 52% of users rated the indicator as attractive and 75% of users rated the indicator as a “need to have” to a “good to have”. As for interceding of instant messages, 29% of users rated this service as useful, 34% found it attractive and 78% of participants rated the service as a “not necessary” to a can have”. The participants were less enthusiastic about assistance on timing of receiving interruptions where information was withheld till an appropriate moment. Brölman (2004) found that users distrusted assistance that withheld information, fearing information that was needed would be withheld.

We focus on a mobile user interface that presents dynamic adaptive support to a user. A framework for an attentive interface is proposed, to adapt user assistance for enabling multitasking and interruption management.

3.6 A Framework for an Attentive Interface for Mobile Multitasking (AIMM)

Mobile devices are in need of a new user interface to assist with conducting more than one task on a mobile device. As described by Lindenberg et al., PALS is proposed to mediate between the user and service by adapting the user interface to the user’s interest, usage history, device and use context. This information is based on profiles that are kept by the PALS system (figure 3.4). In order to adapt the mobile interface to the user, the profiles need to reflect aspects of user interaction related to the mobile context. Therefore, information on a user’s experiences and abilities related to aspects of multitasking and interruption handling is a unique aspect that can be included in user profiles.

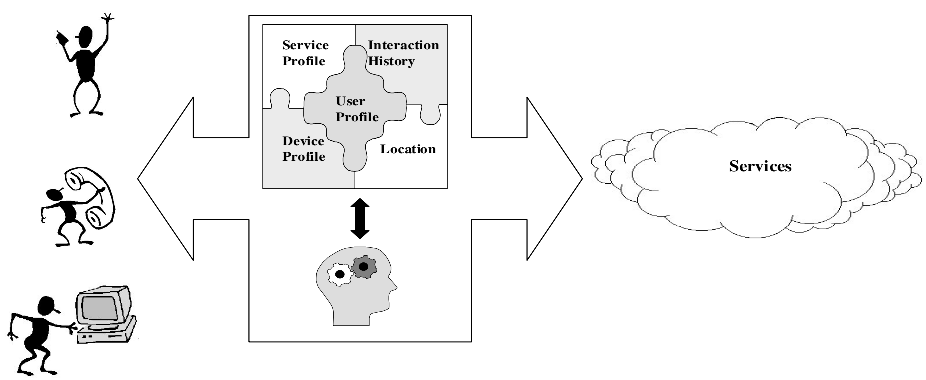

Figure 3.4: PALS Original Concepts. From Lindenberg, J., Nagata, S.F. & Neerincx, M.A. (2003). Personal assistant for online services: addressing human factors. In D. Harris, V. Duffy, M. Smith, C. Stephanidis (Ed.), *Human Centered Computing : Cognitive Social and Ergonomic Aspects* (pp.497-501). Mahwah, NJ: Lawrence Erlbaum Associates.

The Attentive Interface for Mobile Multitasking (AIMM) (figure 3.5) will support a user on a primary Web task when handling interruptions. AIMM assists with managing interruptions by supporting a user's attention and memory, enhancing performance on a mobile Web task. The support is provided via assistance services as defined in section 3.3.1. The PALS environment keeps user, context and system profile information and an agent infrastructure for basic functioning of the attentive interface on a mobile device.
We have drawn from research on the minimal attention user interfaces (Pascoe et al. 2000), mobile context (Tamminen et al., 2004), notification systems (Horvitz et al. 2003; McCrickard & Chewar, 2003) and interruptions (Speier, Vessey & Valacich, 2003) for our user interaction framework on multitasking and interruptions in a mobile context as described in the following sections.

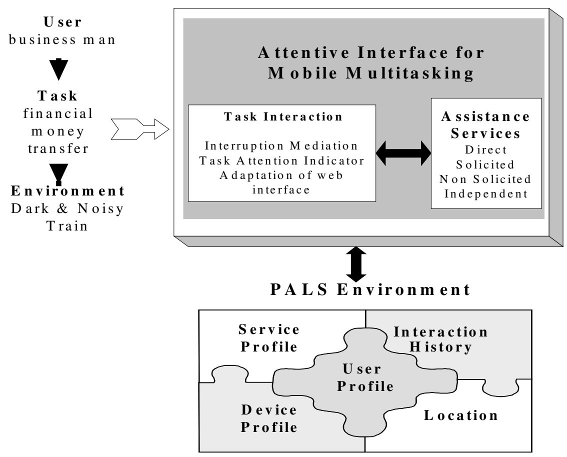

Figure 3.5. AIMM incorporated with the PALS environment

3.6.1 Mobile Multitasking and Interruption Framework

The MAUI (minimal attention user interface) by Pascoe et al. (2000) used a simple and effective framework as a foundation for describing the user interaction for mobile fieldwork. The framework consisted of the environment (African bush), user (ecologist researcher), task (giraffe observation) and tools (Palm Pilot and data collection software). All the essential characteristics of the ecology fieldwork activities described in the framework influenced the design of the assisting interface. The interaction modes for the MAUI were described based on the fieldwork environment framework and the restrictions or limitations posed by each characteristic in the environment. For example, the task of observing giraffes in the bush has a limitation where the researcher needs to keep eyes on the giraffe under observation for data collection. Therefore, the visual mode on the handheld is prohibited for

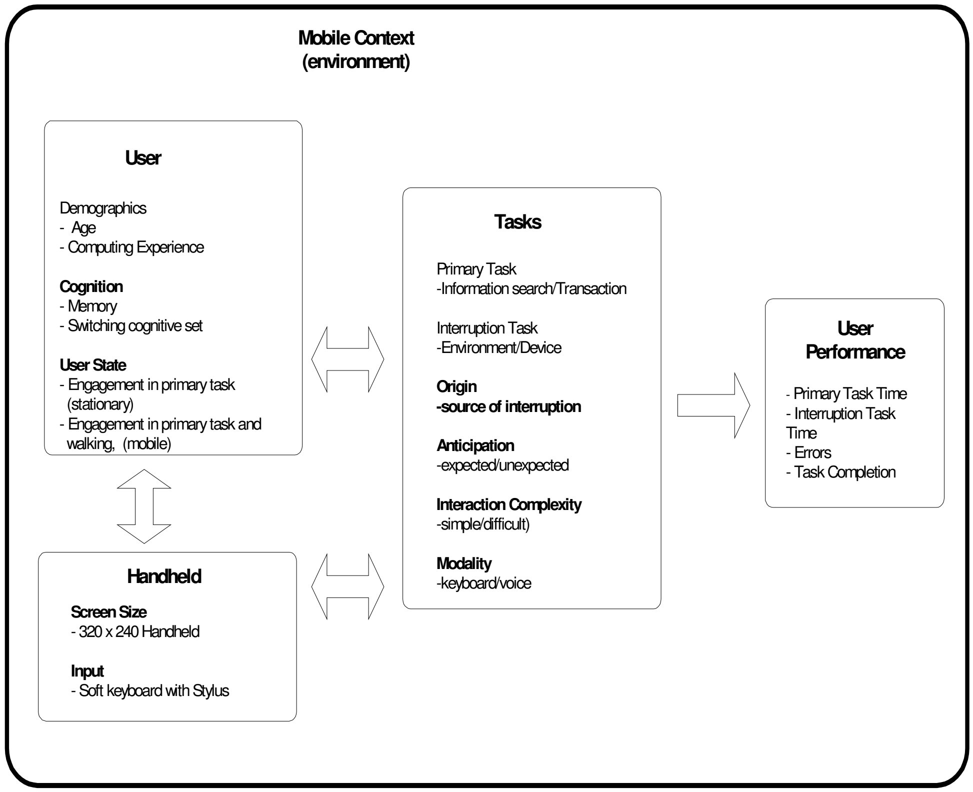

Figure 3.6: Multitasking and interruption framework

data collection during this task and the interface is adapted to a tactile data collection mode. We apply the same basic framework related to the characteristics of mobile activities for environment, user, task, platform (tools) and expand the framework by adding user performance (figure 3.6). In the next section we describe aspects of the environment, handheld, user and task characteristics that influence user performance.

3.6.2 Environment

We have characterized the mobile context as a series of changing events and situations, taxing the users ability to handle multiple tasks. As described by Tamminen et al. (2004) and in the PALS survey research there are many opportunities for users to be disrupted in a mobile context. Interruptions in the environment such as bumping into a friend, cell phone calls, stopping for a snack, missing a bus etc. When mobile computing, in addition to the disruptiveness of the outside environment, there are interruption generated on the device (e.g., electronic reminders, email and instant messaging). Our examination of the mobile context is within a framework of interruption and multitasking

3.6.3 Handheld, Tasks and User Performance

Handheld

We focus on the use of a handheld device as a complete package. Examining the use of specific characteristics of a device is beyond the scope of this work. As we covered in the previous chapters there are many device constraints (e.g., small screen, data input) and resulting usability issues for use of a handheld and the Internet in various locations (see sections 1.2, 2.6 – 2.8).

Primary Task

We focus on m-commerce Web tasks as a primary task and activities for notification and communication as a secondary (interruption) task. The interaction between a primary and secondary task represents a simplification of task switching activity for how people multitask in a context of disruption. Previous research has shown that interruptions are disruptive to a primary task (Gillie & Broadbent, 1989) and that interruptions influence how the information for the primary task is processed (Speier et al., 2004) (e.g., time, errors, decision making). Understanding the influence of an interruption task on Web task performance in a mobile context, lays an empirical foundation for developing user assistance support. We will discuss more on the theory of interruptions in chapter 4.

We investigate primary tasks that are Web transaction (e.g., purchasing an item) and Web information search tasks. In general these tasks involve form fill in and stepping through a certain well-defined and structured business process. For a Web store, the checkout process is the most critical part of purchasing an item and has been identified as being more complicated than necessary (Lohse & Spiller, 1998). A user can spend a significant amount of time on a complicated checkout process making the task vulnerable to interruptions, abandonment, leading to loss of a customer. Aiding a user to quickly resume a transaction task can be beneficial to completing a task and saving time.

An information search task involves navigating or browsing for information or products. The act of browsing is similar to “window shopping” and is less well defined than a transaction task that follows certain steps. When a task such as browsing does not follow specific steps it is difficult for a computing system to track the users progress. Browsing through a Web site is a task defined by the user, where steps of the task and goals can change. This type of browsing often occurs during activities of “killing time” in the mobile context. When browsing, consumers may find it difficult to remember where something was located in an online store, whereas in a real store there are many physical cues for guidance (Lohse & Spiller 1998). If a user is browsing on the mobile Internet and happens to find an interesting item, but suddenly needs to attend to something else. With assistance a user can later return to the specific item for inspection or purchase.

Interruption Task

While using a mobile device, interruptions come from the environment (e.g., phone calls, people, paging) or from the device itself that are computing generated interruptions (e.g., error messages, instant messaging, email) which can be disruptive to a user. As mentioned in section 2.5, when using a mobile device to multitask, switching can occur between the task on the mobile device (e.g., online shopping) and a task in the environment (e.g., speaking to a friend) or with another task on the device itself (e.g., messaging). Research on how interruptions from the environment influence a person's activities has been examined primarily in work environments (e.g., Czerwinski, Horvitz & Wilhite, 2004; Gonzalez & Mark, 2004; O'Conaill & Frohlich, 1995). The current research on mobile computing interruptions has focused on computing generated interruption such as notifications from instant messages received on the device itself.

Instant messaging (IM) is a real time communication medium used via the Internet. When a message is received on a computing platform the user is notified by an auditory beep, flashing icon or both. IM is expected to surpass email as a primary online communication tool by 2005. People are choosing IM over phone and email preferring the immediacy and streamlined efficiency for real-time transfer of information (Enbysk, 2002). IM is also gaining in popularity with businesses by facilitating informal communication in a context of mobility in the corporate environment. For example, when a user is away from the desktop computer, IM received on a mobile device can be used to schedule meetings, negotiations can continue and awareness of the presence of coworkers can be maintained (Huang, Russell & Sue, 2004). In an outdoor mobile context instant messaging can be used to resolve certain issues (e.g., missing a bus and using IM asking for someone to pick you up) in an urban environment. Previous research has also shown that instant messaging is disruptive to primary task performance on a desktop (Cutrell et al, 2001). Therefore, our framework specifically addresses user interaction between a primary Web task and instant messaging as an interruption task. In order to examine the effects of switching to an interruptions task, user performance is measured as the time it takes to complete an interrupted primary task.

3.6.4 User Characteristics

Individual users have different needs when it comes to use of a mobile device. Sarker and Wells (2003) found that user demographics and technology related skills are important determinants to influencing the acceptance of wireless devices. A person's age and experience with computing devices are important predictors in determining use of a mobile device. Experienced and frequent users have different needs, compared to new or beginning users of the mobile Internet. In general, computing experience can vary greatly between users. Therefore, a mobile interface that adapts to a person has to consider specific user characteristics. A person's cognitive ability for multitasking, attention and memory can influence how tasks are performed. We draw relationships between a person's cognitive abilities and task performance. Attending to one task after another in a sequence cued by the environment incurs switch costs (Altmann & Gray, 2000; Rogers & Monsell, 1995). Switching between tasks such as a primary task and interruption task have been related to costs in lowered performance, lowered efficiency and increased errors (Gillie & Broadbent, 1989; Cutrell, Czerwinski & Horvitz, 2000). As described in our framework we examine specific cognitive abilities as potential indicators relevant to predicting user performance on interrupted Web tasks.

User State

Tamminen et al. (2004) equates the mobile context with multitasking. If a user is mobile there is constant repositioning to avoid obstacles in the environment, a person walking through the city is already involved in two tasks (e.g., walking and avoiding obstacles). When a user is stationary, multitasking will occur so it does not hinder noticing signals in the environment (e.g., making a cell phone call while looking for a bus). This suggests that a user is more likely to conduct mobile computing activities in a stationary mode in an urban environment (e.g., standing in one place or sitting in a train). We examine both a stationary and mobile state of the user in a laboratory environment. In chapter 5 we further discuss user state and present a study on the effects of user state and use of support while mobile computing.

3.7 General Conclusion

In conclusion, we have identified that users have difficulties with particular aspects of on-line shopping (e.g., checkout process). Assistance for the mobile Web interface is needed to support a user's attention and memory for handling interruption. We propose that mobile assistance can improve usability of the mobile Web for a wide range of users. Mobile assistance presented as an adaptive personalized interface can aid in use of the mobile Web during interruptive situations that lead to multitasking. However, there is a lack of empirical user research on specific adaptive display presentations for managing interruption. Effective types of attentive interface assistance need to be identified. The influence of the assistance on interrupted task performance needs to then be examined. As described in Chapters 4 and 5, we use the framework of multitasking and interruption (user, tasks, context, mobile device and user performance) for investigating user performance when handling interruption. We identify forms of assistance and test whether this form of support benefits user performance on a Web task in a disruptive situation. This dissertation contributes to the general foundation of deriving mobile assistance for multitasking and interruption handling on a mobile device.

Chapter 4 Multitasking and Interruptions[3]

Abstract

An area of interest in the field of Human Computer Interaction, examines the impact of interruptions and multitasking on human performance in the domain of mobile computing. Of particular interest related to mobile device use and the dynamics of the mobile context, the impact of interruptions and multitasking has been attributed to cognitive overhead associated with attention and memory of the user. Three experiments are presented with a focus on understanding the influence of an interruption task on user Web task performance. Experiment 1 examines platform, origin and anticipation of an interruption task on user Web task performance. Experiment 2 is used to validate the first experiment and examines complexity and modality of an interruption task. Experiment 3 examines the influence of platform and interruptions on memory and resumption of a primary Web task. Results indicate that Web tasks with instant message interruptions were more disruptive to user performance than phone interruptions on the handheld or desktop PC. Switching to a different modality (e.g., keyboard to voice) for an interruption task, is disruptive to performance. Anticipation of an interruption was less disruptive of task performance compared to an unexpected interruption. A repetitive interruption, compared to low repetition, negatively impacted user performance. An interruption negatively influenced recognizing a specific place to resume a task, but has less of an impact on recognition of the task information content.

4.1 Introduction to Multitasking and Interruption

Interruptions have been generally defined as events that draw attention away from a primary task (Miyata & Norman, 1986). For example, interruptions are seen as a notification event that prompts transitions of attention from a primary task to an interruption task (McCrickard, Catrambone, Chewar & Stasko, 2003). Interruptions lower user performance by reducing efficiency, increasing errors (Cellier & Eyrolle, 1992; Gillie & Broadbent, 1989; Kreifeldt & McCarthy 1981) and increasing time to complete a primary task, (Bailey, Konstan & Carlis, 2001; Bailey, Konstan & Carlis, 2000; Cellier & Eyrolle, 1992; Cutrell et al., 2000; Czerwinski et al., 2000a; Gillie & Broadbent, 1989; Kreifeldt & McCarthy 1981).

Recent research on human computer interaction examined the effects of computing interruptions on desktop computing tasks for use of applications (e.g., use of Microsoft Excel, Microsoft Word) and the Web (Bailey et al., 2001; Bailey et al., 2000; Cutrell et al.,

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[3] Parts of the research reported in this chapter have appeared in separate publications as:

Nagata, S.F. (2003). Multitasking and Interruptions During Mobile Web Tasks. In *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting* (pp. 1341 – 1345). St. Louis: Mira Digital Publishing.

Nagata, S.F. & van Oostendorp, H. (2003) Multitasking in a Mobile Context. In P. Gray, H. Johnson, & E. O'Neill (Eds.), *Proceedings Human Computer Interaction 2003 Designing for Society* (pp. 145–146). Bristol: Research Press International.

Nagata, S.F. van Oostendorp, H. & Neerincx, M. A. (2005). A User Based Framework to Support Multitasking on a Mobile Device, *In Proceedings HCI International 2005*, St. Louis, Missouri: Mira Digital Publishing.

2000; Cutrell et al., 2001; Czerwinski, Cutrell & Horvitz, 2000a; Czerwinski et al., 2000b). Since there are many similarities of the graphical user interface on the desktop PC and a handheld device, these studies may provide a general indication on how computing interruptions can influence user performance when handheld computing.

Interruptions experienced in a personal computing environment (Gillie & Broadbent, 1989; McFarland, 1999; Cutrell et al., 2000; Czerwinski et al., 2000a) and when multitasking while mobile computing (Jameson & Klockner, 2004; Oulasvirta, 2005) can have a negative impact on user performance. Furthermore, declines are evident in memory performance of a user when multitasking (Preece 1994). Memory can be impaired by interruptions making it difficult to effectively return to an interrupted task.

Concerning the use of the mobile Web we make the following observations:

A theoretical foundation has not been well established to address the cognitive overhead that users experience while mobile computing. In this chapter theory is presented on how attention and memory is influenced during use of mobile Web tasks on a handheld device. The influence of interruption on attention and memory are reviewed in research articles regarding mobile interface usability (e.g.,; Lee & Benbasat, 2003**,** Oulasvirta et al. 2005, Tarasewich, 2003).

There is a dearth of research on use of handheld devices in relationship to multitasking and user performance. A form of cognitive overhead that involves attention and memory has not been examined in relation to performance when multitasking on a handheld device. A primary focus of previous research has been on use of desktop computing applications in an office environment. The issues of multitasking and handling interruption are reviewed with respect to the influence of interruptions on human behavior in applied experimental studies in the field of Human-Computer Interaction. Applied studies on the effects of interruptions on human behavior have investigated the use of desktop computers and Instant Messaging (IM). IM or "on-line chatting" is a popular form of Internet communication enabling instantaneous notification and communication of text information between people using the same messaging application (e.g., America Onlines Instant Messenger, Yahoo!'s Messenger). These studies report that IM interruptions on a desktop computer are disruptive to a user's performance on a primary task compared to tasks that are not interrupted (Cutrell et al., 2000).

Our first two experiments, examine how specific chacteristics of an interruption that include origin, anticipation, complexity and modality influence performance on a primary Web task. For example, a primary task of using a handheld device to search for movie tickets can be switched to an interruption task to send an email, then resuming the movie ticket search primary task. Use of a desktop computer for Web tasks provides a baseline standard to compare performance to Web tasks done on a handheld device. A third experiment investigates the effects of an interruption task on memory for a primary Web task.

The following questions are addressed in these three experiments:

1) What effect does an interruption have on user Web task performance during use of a handheld device or desktop PC?
   -How do characteristics of origin, anticipation, modality and complexity of an interruption influence Web task performance?

2) What effect does an interruption have on memory for resuming a primary Web task?

3) What factors predict how users handle interruptions on a computing platform?

4.2 Multitasking, Interruptions and Attention in the Real World

A growing body of work that characterizes how information workers manage multiple tasks in everyday work activities, has identified interruptions as a common trigger for a worker to switch between tasks (Czerwinski et al., 2004; Gonzalez & Mark, 2004; O'Conaill & Frohlich, 1995). There are some similarities between the office environment of information workers and what users experience in the mobile context. Similar to the mobile context, office environments are characterized as being highly disruptive with many interruptions. An interruption usually stimulates a worker to move to a different task producing multitasking behaviour.

Multitasking in an Office Environment

Observational studies of information workers have reported averages of 25 to 32 interruptions occurring in an 8-hour workday (Gonzalez & Mark, 2004; O'Conaill & Frohlich, 1995). A diary study relying on self reporting showed an average of .7 interruptions per task, indicating almost a 1:1 interruption to task ratio (Czerwinski et al. 2004). Tasks done in an information work environment span a period of time anywhere from an observed average of 3 minutes (Gonzalez & Mark, 2004) to a self reported average of 53 minutes (Czerwinski et al. (2004) and are highly dependent on the type of work and culture of the office environment. Of those persons interrupted during a task, 41% of the time people did not return to continue the task that was interrupted (O'Conaill and Frohlich, 1995).

A recent study by Gonzalez and Mark (2004) examined how information workers (e.g., administrators, managers, consultants, accountants) manage multiple tasks with different goals, deadlines and resource constraints using various technologies (e.g., PDA, cell phone, e-mail and instant messaging). Ethnographic techniques for "shadowing" and long interviews were used to collect observation data. The results characterized the office work as having a high amount of interruption with constant switching among physical and digital artifacts and strategies used to maintain work continuity in the midst of disruption. Due to frequent interruptions, strategies such as reminders written on sticky notes or planners and agendas were used to prioritize and maintain attention for returning to a task. Also, printing of emails kept in piles on the desk or a special email inbox folder containing messages to be attended to, were frequently observed.

In general, this research shows the following: 1) Interruptions lead people to switch to a different task. 2) There is a negative impact on attention when a person is interrupted. Consequently the person's attention often does not return to the initial task. 3) People devise various strategies to manage interruptions and minimize the disruptive effects on attention and memory for a task. This suggests that providing assistance with interruption handling when computing can be useful for indoor situations.

Multitasking and Attention During Use of a Mobile Device

Specifically related to use of a mobile device, Oulasvirta, Tamminen, Roto and Kuorelahti (2005) examined use of a mobile phone in relationship to attention in a mobile context. In an outdoor situation a user commits approximately 4-8 seconds of attention to the mobile task with attention being drawn more to the environment, when compared to a laboratory situation. During concurrent task situations a slowing of a secondary task was described as a depletion of cognitive resources. Many situations in the mobile context describe concurrent task situations where the primary task occurs in the context of movement (e.g., walking, talking, etc) and use of the device is secondary or supplementary. This provides tentative evidence that attention is taxed during tasks of mobility or tasks that have a higher immediate priority such as talking to a friend. There is also an important safety issue involved when users multitask concurrently (e.g., walking and searching the Web) using both visual and gross motor capacities. Users are intuitively aware of the consequences for conducting two tasks simultaneously and are able to exert control over this type of dual tasking situations in a mobile context. When in a dual task situation cognitive resources are drawn from one task (e.g., slowing walking) to another task (e.g., attending to mobile display). There are evident dangers (e.g., tripping on the sidewalk, falling down a manhole) when proceeding to walk without a minimum level of attention that is needed for safety.

We adopt the view of Oulasvirta et al. (2005) that there is competition for cognitive resources between tasks requiring mobility in the environment and interacting with a mobile device. The most important task is typically related to a user's movement and is given a higher priority and the attention resources are re-distributed to lesser priority tasks such as a mobile Web task. When the priority of the task on the mobile device supersedes other activities, switching between tasks often occurs instead of handling two tasks simultaneously. During these situations interruptions can stimulate a user to multitask, having a detrimental impact on the primary task. These sources of interruptions can be from the external environment, or from the handheld device itself.

4.3 Theoretical concepts on working memory and attention

Human working memory is like glue that holds together a person's ability to do more than one thing at a time. When executing multiple tasks everyone has experienced failures in memory that seem trivial. For example, while getting into the elevator, you begin speaking to a colleague and forget to press the button for your exiting floor. During these situations the forgetfulness that people experience occurs in working memory (also called short term memory). **Working memory** has been described as a temporary storage and working area for information to be transformed and acted on before it is stored in long term memory (Wickens, Gordon & Liu, 1997). For information to enter working memory, a limited amount of information needs to be first attended to, then accepted into working memory where it is transformed through rehearsal and manipulation (Baddeley, 1993; Johnson & Proctor, 2004). A person's attention is required, to transfer information from sensory receptors (e.g., vision, hearing) into working memory and then into long-term memory.

Aspects of Working Memory

A model of working memory (Baddeley, 1993) depicts a "central executive" that acts as an "attention controller", coordinating information from the two lower level systems. These two lower level systems consist of the "phonological loop" for verbal information and the "visuo-spatial sketchpad", which is responsible for visual images (figure 4.1). These two lower level systems act as processing and storage areas for verbal and spatial information. The phonological loop has a "phonological store" that captures external speech information, and an "articulatory control process" for inner vocalizations or speech. Since memory traces of verbal speech decay in a matter of seconds, the articulatory control process uses a sub-vocalized rehearsal of words (i.e. mentally repeating words) to refresh and update the phonological store. The visuo-spatial sketchpad is involved with visual imagery for processing of patterns, determining "what" something is, and processing of spatial information (e.g., location in space), determining "where" something is located. This

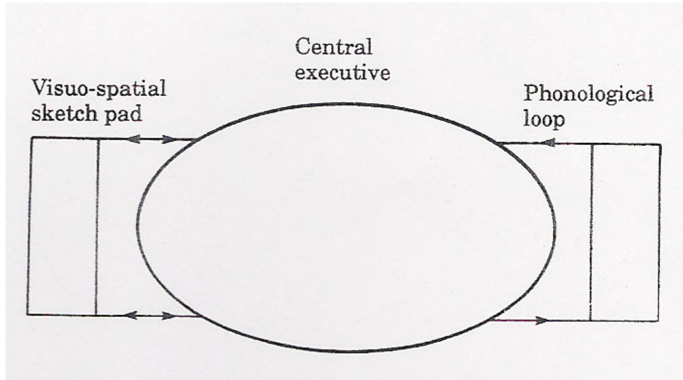

Figure 4.1: Baddeley's central executive. From "*Human Memory Theory and Practice,"* by A. Baddley, A.,1990, p. 71. Copyright 1990 by Lawrence Erlbaum Associates.

working memory model, describes how attention is involved in extracting, retaining and maintaining visual or verbal information.

Items of information from working memory are stored in connection with related information in long-term memory. Long-term memory has been described as a composition of semantic networks, representing a categorization of related information based on previous experience (Wickens, Gordon & Liu, 1998). There are two types of knowledge important to long-term memory. Anderson (1995) describes declarative knowledge as what we know about concepts, facts, schemas and mental models that can be verbalized. Procedural knowledge is implicit and difficult to verbalize. An example of procedural knowledge is using a keyboard without looking at the keys, typing the individual letters to form words. These acts are difficult to articulate how they are accomplished. Declarative knowledge is gained more quickly, and faster to decay. Procedural knowledge is slowly acquired and takes longer to decay. How particular information is learned and stored either as procedural or declarative knowledge, influences the use of information when designing displays and for training purposes.

Aspects of Attention

Attention is viewed as essential to focusing on and filtering information that is transferred into working memory. There are three aspects of attention (Baddeley, 1993; Sanders & McCormick, 1993; Wickens et al., 1998): 1) **Selective attention** is an active selection of attending to specifically chosen cues or pieces of information. 2) **Focused attention** is exerting concentration for filtering out extraneous information to attend to something specific (Baddeley, 1993; Sanders & McCormick, 1993; Wickens et al., 1998). 3) **Divided attention** is attending to more than one task (Sanders & McCormick, 1993; Wickens et al., 1997). Aspects of focused and divided attention are involved in multitasking in the real world (Johnson & Proctor, 2004). For example, reading a newspaper at a bus stop and having to monitor for the bus. Attention is divided between reading the newspaper and hearing a bus and looking up to see if the bus has arrived then focusing attention back to reading the newspaper. When doing more than one task, processing of mental resources allows a person to focus and split attention to different tasks. Wickens and Holland (1991) describe the concept of **resource** as the capacity for allocating processing (e.g., mental effort) to perform tasks. **Time-sharing** describes how resources are shared when doing multiple tasks. It is considered "the ability to perform more than one cognitive task by attending to both tasks at once (concurrent or dual task) or rapidly switching attention back and forth between tasks (task switching)" (Wickens et al., 1998). When time-sharing between two tasks there can be a decrease in performance on one or both tasks, in comparison to performance on a single task. When two tasks are performed concurrently, the negative impact on performance is called "dual task decrements" or "dual task interference" (Wickens et al., 1998; Wickens & Holland, 2000). When switching between tasks the negative impact on performance is known as "switch costs" (Rogers & Monsell, 1995). The cost of switching between an interruption and primary task are examined in our experiments. We further address the relationship between attention, interruption and multitasking in section 4.4.2.

4.4 Theoretical Framework for Multitasking and Interruptions

To understand the relationship of attention, memory and people's actions during multitasking, we review theory on multitasking. Miyata and Norman (1986) described a practical framework of multitasking. Specific topics covered in this framework concern working memory and attention, conscious and subconscious processing systems, interruptions, current and suspended activities. We address the theories of automatic and controlled processing, serial attention and task switching.

4.4.1 Relationship of Multitasking, Working Memory, Attention and Cognitive Processing

In this framework by Miyata and Norman (1986), the capacity of working memory is seen as a limiting factor of information processing. Whether processing of information is verbal or spatial as described in Baddeley's working memory model, capacity, time, attention and similarity of information pose restrictions on working memory (Wickens et al., 1998). Capacity refers to how much information can be stored in working memory (e.g., 7 $\pm$ 2 chunks of information, (Miller, 1956). Time refers to the length of time that the information can be maintained in working memory (e.g., 7 seconds for a memory store of three chunks, (Card, Moran & Newell,1986). Attention is considered in terms of resources available for processing. Similarity refers to the features of information that is being processed. When attending to two or more tasks that are processed with similar features, such as doing two verbal tasks, a person can have difficulty remembering information from the verbal tasks. Attending to two tasks requires time-sharing of resources that can result in inadequate processing of resources for one or both tasks leading to decrements in performance. For example, when word processing on a computer and talking on the phone, people often tend to cease or slow down talking and sometimes ask for sentences to be repeated. We specifically focus on theories that describe attention for information processing, that may reside in working memory.

A Model of Attention for Multiple Task Performance

The theoretical framework by Miyata and Norman (1986) presents a limited explanation on the subconscious and conscious systems of control for understanding how resources are processed. They described the subconscious system as having unlimited resources producing automatic behaviors, and the conscious system as being resource limited producing controlled behaviors. To further understand processing and assignment of resources we extract from an attention model of multitasking. Theorists have proposed a model of attention for multiple task performance. Control processes are described that supervise the selection, initiation, execution and termination of tasks. The model of attention by Shiffrin and Schneider (1977) focus on automatic and controlled processing that has different demands on attention.

Automatic processing occurs with extensive practice of a task so a task sequence can proceed automatically and does not "stress the capacity limitations of the system." Automatic processing is fast, demanding few resources and can be done subconsciously, where several well-learned tasks can be done simultaneously (Miyata & Norman, 1986; Shiffrin & Schneider, 1977). When tasks are automatically processed, these tasks can be considered to be well-learned tasks that do not interfere with each other, capitalizing on a user's skill to process the task. Once initiated automatic processing is difficult to modify (Shiffrin & Schneider, 1977). **Controlled** processing is a person's conscious and deliberate control of tasks requiring active attention for a temporary task sequence that is limited by memory capacity and easily modified (Miyata & Norman, 1986; Shiffrin & Schneider, 1977). In complex processing situations, automatic and controlled processing can run in parallel and controlled processing is often used to initiate automatic processing (e.g., reading) (Shiffrin & Schneider, 1977). A general criticism of this theory is the strict differentiation between automated and controlled processing and that attention is unimportant within the automated processing framework (Johnson & Proctor, 2004).

It is also important to consider attention and memory for tasks that are practiced and a skill is gained in completing tasks. A contrary view to Shiffrin and Schneider's view is the instance theory of automaticity proposed by Logan in 1988 (Johnson & Proctor 2004). This theory considers "instances" as episodes where attention is directed to relevant information that was previously encoded in memory (Logan, 1988). Based on the number of practice instances information is retrieved faster and more readily. This type of automatic processing is based on memory retrieval, where attention is needed at encoding and retrieval (Johnson & Proctor, 2004; Logan, 1988). Therefore attention is considered the interface between memory and events in the world (Johnson & Proctor, 2004).

4.4.2 Theories of Interruptions and Multitasking

Miyata and Norman (1986) provide a perspective on processing of interruption tasks. Interruptions occur from events in the environment known as **external interruptions**. In our research we focus on external interruption as opposed to **internal interruptions**, which are from our own thoughts. In the mobile situation, people are assumed to be in a certain state of readiness in dealing with different situations for interruption handling. A person in a mobile situation is assumed to exhibit **interrupt driven processing** by changing activities by responding to events in the environment. A user's state of readiness in dealing with interruptions will have an effect on user performance. The readiness of a user is further addressed (below) on theory of task switching.

Furthermore, theory on task structure describes the intermingling of activities and how users can process an interruption in the midst of focusing on a task. Cypher's (1986) theory on task structure explains the intermingling of how tasks and activities between a user and a system can impact a user's handling of activities and general user performance. **Tasks** are comprised of sub tasks and steps to achieve an end result related to an activity (e.g., search for book). An **activity** (e.g., purchase the book The Da Vinci Code) is comprised of tasks to achieve an end goal. Cypher (1986) describes that people can do 5 or 6 things at once by **interleaving activities**, leading to handling of multiple activities. There are two types of activities that describe how people consciously manipulate tasks. **Current activities** are controlled by actions, typically in the **foreground** requiring conscious attention and **suspended activities** are activities that are on hold to be done at a later time. These suspended activities are held in the background, out of conscious attention. **Resuming** an activity occurs when an activity that was in background is reengaged. When moving between a primary and interruption task people will interleave these activities engaging in multitasking.

Task Switching and Multitasking

When a person switches between tasks this requires time-sharing which is the allocation of resources to the tasks in an optimal fashion (Wickens & Holland, 1997). Task switching can result in switch costs, which are decrements in performance. These switch costs are associated with an increase in reaction time and error rates (Johnson & Proctor, 2004; Wylie & Allport, 2000). Researchers believe that decrements in performance or switch costs are representative of the controlled processing of two or more tasks (Wylie & Allport, 2000). Based on laboratory experiments on task switching there have been several explanations as

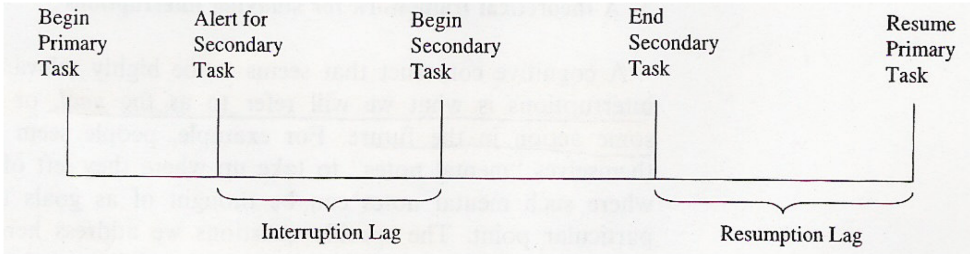

Figure 4.2: Interruption lag and resumption lag. From "Preparing to resume an interrupted task: Effects of prospective goal encoding and retrospective rehearsal," by J.G. Trafton, E.M. Altmann, D.P. Brock & F.E. Mintz, 2003, *International Journal of Human-Computer Studies*, 58, p. 586. Copyright 2003 by Elsevier.

to why switch costs occur. The theories are informative regarding an understanding of the cognitive mechanisms of task switching, even though the testing paradigms used in the laboratory are quite simplistic (e.g., using a key press task where either a switch was required or no switch), compared to a real world situation.

The costs attributed to task switching have also been examined as a problem of memory. Allport, Styles and Hsieh (1994) attributed switch costs to "task set inertia", which is interference of a memory trace from the previous task. Altmann's (2002) theory on functional decay describes cognitive mechanisms of memory that are responsible for the costs to performance when moving between tasks. This theory proposes that interference is a constraint on cognitive control when switching tasks. Memory decay or reducing activation of a memory trace of the current task is necessary for preventing interference with the next task.

A theoretical framework by Trafton, Altmann, Brock and Mintz (2003), considers the role of memory when processing interruptions using a goal activation model, for understanding the activation of items in memory. The model considers activation and frequency of use for a particular memory item, based on history of use and associations to cues in the environment and context. One assumption is retrieval of the most active item in memory. Maintaining items in memory by reducing decay is critical to resuming a primary task. The theories of functional decay and goal activation suggest that when switching between tasks, decay of memory is beneficial and necessary to move on to the next task. However, memory decay can be detrimental when having to maintain a task in memory for later task resumption.

Trafton et al. (2003) described delays in time that form when switching between a primary and interruption task (figure 4.2. An interruption lag is described as the first interval of time between the alert or notification and the interruption task. The resumption lag is the second interval of time between the interruption task and resuming the primary task. The interruption lag and resumption lag can be explained as delays in time that contribute to switch costs, byincreasing response time when moving from one task to the next.

Trafton suggests that when a person receives an interruption warning followed by an interruption lag there is rehearsal and preparation that occurs for resuming a primary task. This preparation during the interruption lag was shown to be beneficial to user performance, compared to a situation without a warning and interruption lag. A question that we interject is whether the positive effect on performance was due more to the warning or more to the actual lag. However, by introducing an artificial interruption lag as done in the study by Trafton et al. there is no real benefit to overall performance time. By artificially introducing an interruption lag the total amount of time to perform a primary task will increase. The additional time for an interruption lag tend to outweigh the benefits. For our purposes introducing an interruption lag is not especially suitable for use as a support concept for handling interruptions in a mobile context, due to increasing overall task time.

An approach such as visual markers is needed to shorten the resumption lag and shorten the primary task time by aiding a person's memory. In chapter 5 we further discuss the use of visual support concepts that are proposed to aid a person's memory and shorten the amount of time needed to complete a task that has been interrupted.

4.5 Introduction to Experiments

A user is often required to immediately handle interruptions during use of a handheld in a mobile context. Disruptions can occur from surrounding sources such as cell phone calls, beeper and overhead paging. A handheld device also generates internal interruptions from chat programs, instant messaging, email, personal agenda notifications, Web advertising and in the future possibly a proliferation of agents that communicate to assist the user with mobile computing activities. The origin of an interruption whether generated from the device (e.g., instant messaging, email) or an environment related interruption (e.g., cell phone, intercom, noisy train) can influence how a user performs a primary task.

Interruptions have been mainly examined in a desktop computing environment. The characteristics of interruptions in these studies provide a foundation to understanding the effects of interruptions on user performance. Based on the previous research examining computing interruptions we focus on specific characteristics of interruptions that are relevant for the mobile context. The interruption characteristics examined in our experiments are related to the presentation of the interruption for origin, timing, content related qualities and modality (table 4.1).

Our first experiment investigates the effects of origin (i.e. phone calls, Instant Messaging (IM)) and anticipation (i.e. expectation or no expectation) of an interruption task on Web task performance, when using a specific platform (desktop, pocket PC). The first study gives a general understanding on the influence of an interruption task on use of a mobile or desktop computing platform.

The second experiment validated the first study, and further investigates the effects of modality (i.e. keyboard, speech) for an IM interruption task on Web performance. In addition, complexity of an interruption is investigated to address implications related to IM tasks that require heavier use of cognitive resources in processing an interruption task.

The third experiment addressed the effects of an IM interruption task on attention and memory for a primary task when using different platforms (desktop PC, handheld). Furthermore, in order to understand the processing of items in memory when switching between a primary Web task and interruption task, a users memory for place in a task and task content was measured for task resumption.

Table 4.1: Studies investigating characteristics of interruptions

Interruption Task Characteristics	Definition	Authors
Origin	Source of interruption	Storch, 1992
Timing	Coarse Breakpoint Task Models	Adamczyk & Bailey, 2004 Bailey & Konstan, 2006
	Phase of task (planning, execution, review and extraction)	Cutrell et al. 2000; Czerwinski et al. 2000a
	Frequency of recurrence	Speier et al. 1997 Gievska , 2004
Content Related Qualities		
Complexity	Cognitive complexity	Gillie & Broadbent, 1989
Similarity	Task type+memory Task type	Gillie & Broadbent, 1989 Czerwinski et al, 1991 Edwards & Gronlund, 1998 Bailey et al. 2000
Length	30 seconds 15-30 seconds	Gillie & Broadbent, 1989 Bailey et al. 2000
Relevance	Relevant content	Cutrell et al. 2000; Czerwinski et al. 2000a
Modality	Auditory & Visual	Latorella, 1998

4.6 Experiment 1: The Influence of Platform, Interruption Origin and Anticipation on Web Task Performance

The first experiment is a pilot study that examined the effect of origin of interruption (i.e. interruption from environment, computer generated interruption) and anticipation (i.e. expected, unexpected) of an interruption on user Web task performance on a mobile device (i.e. Pocket PC) or desktop computer. Instant messaging is a popular communication tool, because of its common and practical use for communication at home and work. The origin of a message from which an interruption is received during a computing task was expected to be problematic for users, negatively influencing Web task performance. Furthermore, anticipation of an interruption would allow a user to prepare for an interruption, facilitating task switching and attention for a task, reducing the amount of time spent on a Web task.

4.6.1 Origin of Interruptions

A user of a handheld in a mobile context can experience interruptions generated from the environment (e.g., cell phone, beepers, someone knocking on door etc.) (Figure 4.3) and interruptions generated on a handheld (e.g., electronic notifications, instant messages and reminders). The latter are also called computer-initiated interruptions (Bailey et al., 2000). We use the term “origin” to indicate whether the source of the interruption is from the environment or a computer initiated interruption.

Interruptions originating from instant messages have been found to negatively impact desktop computing tasks. Studies by Cutrell et al. (2000, 2001) and Czerwinski et al. (2000a, 2000b) examined the effects of interruptions on computing tasks. There was an increase in time needed to complete a computing task interrupted by instant messaging.

Other research has shown that interruptions from the environment such as phone calls can also be disruptive to user task performance. Receiving phone calls were disruptive to a task requiring participants to place letters in alphabetical order from a randomized set of letters, compared to performance on the same tasks without phone calls (Lyda, Osborne, Coleman & Rienzi, 2002). However, when comparing computing interruptions versus external interruptions from the environment, on-screen messages were shown to be more disruptive to performance of data-entry tasks on a computer than interruptions from telephone calls or human visitors (Storch, 1992).

We examine the effects of phone calls and instant messaging, since they are common forms of communication in the mobile context and were shown to be disruptive to an ongoing task. In experiment 1 the origin of an interruption task is investigated to answer the following questions. Are instant messages or phone calls more disruptive to user performance on a mobile device?

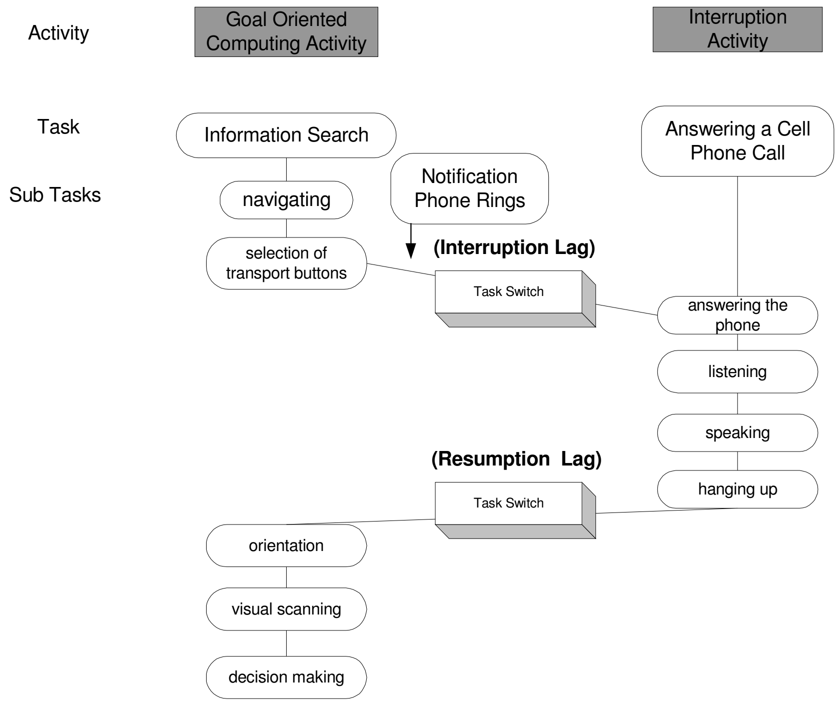

Figure 4.3. Flow of a primary task with an interruption task

4.6.2 Anticipation and Timing of Interruptions

Anticipation of an interruption task can have beneficial effects on performance of a primary task. Studies have demonstrated that anticipation of a forthcoming event can aid a user to prepare for an interruption, having a positive effect on performance of a primary task (Czerwinski, Chrisman & Schumacher, 1991; Ho et al, 2004; Obermayer & Nugent, 2001). User anticipation to receive an interruption can assist with attending to an interruption, making user actions more efficient to perform tasks. For example, research on warnings show that advanced notice of an interruption has a positive effect on primary task performance, due to rehearsal for later resumption of a task (Czerwinski et al., 1991). McCrickard and Chewar (2003), suggests that anticipation of an interruption task is also tied to the goal of the user. For example, a user has a goal of purchasing stock and wants to be interrupted to receive a stock alert. Whereas, another user does not have a specific goal to purchase stock, and receives an unexpected stock alert.

Introducing an interruption at the appropriate moment based on the user's expectation of receiving an interruption also optimizes the timing of the interruption. The users readiness for receiving an interruption is determined by enhancing a user's expectation to receive an interruption creating an optimal moment for handling of an interruption. Most of the previous research has focused on presenting interruptions that are unexpected by the users. Interruptions that are unexpected have been shown to negatively impact user performance on computing tasks (Bailey et al., 2001; Bailey et al., 2000; Cutrell et al., 2000; Cutrell et al., 2001; Czerwinski et al., 2000a; Czerwinski et al., 2000b; Gillie & Broadbent, 1989). Conversely, introducing anticipation or expectation of an interruption can be beneficial to the user. The disruptiveness of an interruption on a user's computing task has also been attributed to the timing of the interruption.

Timing of Interruptions

Previous studies have focused on task-based reasoning and timing approaches of interruption handling. The timing of introducing interruptions has been investigated for general phases of a task for planning, execution and evaluation (Cutrell et al., 2000; Czerwinski et al., 2000a). It has been found that instant messages received during the evaluation phase (reviewing and extracting of information from a Web search) of a task, resulted in longer times to complete the primary computing task, compared to receiving interruptions during planning or executing a Web search task (Cutrell et al., 2000; Czerwinski et al., 2000a).

A task-based approach for improving timing of interruptions mainly focuses on the sequence of steps in a task for introducing interruptions at a certain moment. Specific task models have been developed to determine breakpoints for interruptions in a task sequence (Adamczyk & Bailey, 2004). The timing for receiving interruptions has investigated using task models that represented the opportune moments during a task for introducing an interruption. The task models were defined using breakpoints. Breakpoints were defined as being either "coarse" or "fine". The coarse breakpoint is described as a larger unit of a task, and a fine breakpoint can be considered a subtask. For example, when a user has opened an email message (coarse breakpoint) and finished all the subtasks of reading and answering the email (fine breakpoint), an interruption is introduced at this point before the user opens another email message (coarse breakpoint). This research on improving timing of interruptions has shown promising results for lowering disruption of interruptions to user performance and reducing annoyance and anxiety (Adamczyk & Bailey 2004; Bailey, Konstan & Carlis 2001; Bailey, et al. 2000). However, as mentioned in section 3.5, the idea of timing interruptions (e.g., withholding an instant message until an appropriate moment arrived in the task sequence) is not always acceptable to users. In our research, we have chosen to examine anticipation of an interruption for managing interruptions.

Frequency

Another important consideration that is however, beyond the scope of our work concerns the frequency of interruptions. Speier, Valacich and Vessey (1997) investigated the frequency of interruptions on performance of a computerized decision-making task. The study showed that more frequent interruptions on a decision making task resulted in lower decision accuracy and increasing the amount of time to complete the task. There have been very few studies examining the frequency of interruptions and further investigation is needed on this area.

4.6.3 Hypotheses

H1: Web tasks with interruptions take longer to complete on a mobile device compared to a desktop computer, due to interruption and a compounding of mobile interface issues (e.g., small screen, limited input interaction).

H2: On-screen interruptions are more disruptive to user Web performance, compared to external interruptions. There will be an increase in the amount of time to perform a Web task, due to receiving the IM interruption task on the same platform and same modality of interaction.

H3: Anticipated interruptions are beneficial to user Web performance time compared to interruptions that are unanticipated. There will be a decrease in the amount of time to perform a Web task due anticipation of the interruption, facilitating user attention and promoting efficient Web task interaction for resuming the primary task.

4.6.4 Method

Participants

For this pilot study eight participants (age 25 – 54 years) were recruited and received monetary compensation for 2.5 hours of participation. All participants met the criteria of owning or having experience with a handheld device or desktop computer. Participants were randomly assigned to a pocket PC group (n = 4) and desktop PC group (n= 4). The study procedures were conducted in a laboratory setting.

Design

The experiment consisted of a between group variable for device (pocket PC and desktop PC), two within group variables for anticipation (expected, unexpected) and origin (external (phone, intercom) or internal computing (IM) making a 2 x 2 x 2 mixed repeated measures design. Participants performed 16 tasks, divided into four blocks with four tasks in each block. To balance the presentation of tasks, two forms with tasks were administered, half of the participants began with the Fitch and Mather Web site and the other half began with the Duwamish bookstore Web site (figures 4.5 and 4.6). The four types of interruptions, unexpected external and unexpected internal, expected external and expected internal were counterbalanced using a Latin Square design. The four types of tasks were repeated over

Figure 4.5: Duwamish Bookstore Web site Desktop View (Top), Pocket PC View (Bottom)

Figure 4.6: Fitch and Mather Web site – Desktop View (Top), Pocket PC View (Bottom)

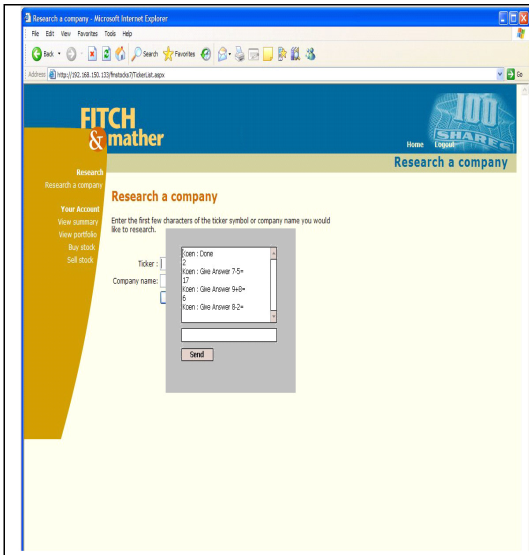

Figure 4.7: Desktop PC with instant message

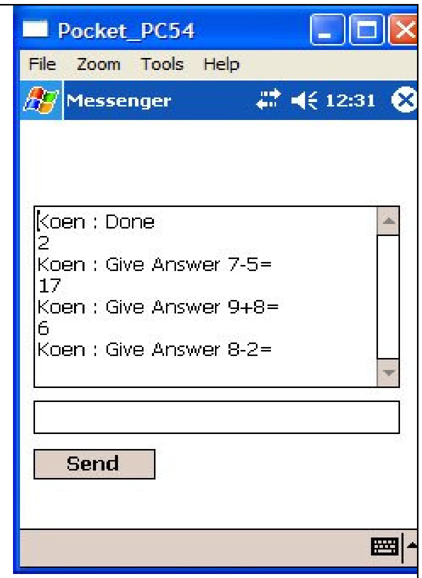

Figure 4.8: Pocket PC with instant message

four trials. Tasks were paired with interruptions and the task instructions either mentioned an interruption (e.g., you will be receiving a phone call during the task) or did not mention an interruption. The interruptions consisted of easy addition and subtraction (e.g., give answer 3 + 5 =) questions (figure 4.7 and 4.8). Control tasks were randomly given without interruptions. The tasks consisted of information search and transaction tasks (e.g., buy shares of stock for companies X, Y, Z, search for a C++ programming book and record the most expensive price).

Material and Equipment

All Web and IM tasks were administered on an HP5550 with a CPU speed of 206 MH, 32MB Flash ROM, 64MB RAM, Pocket PC 2002 operating system, 12 cm (5.3 inches) screen size and stylus input on a soft keyboard for data entry. The desktop PC was a Dell 2.4 giga Hz, Pentium IV, with a 17-inch LCD monitor. The Web sites used for the study were a financial stock related (Fitch and Mather) and bookstore (Duwamish) Web site, an Enterprise Sample of Visual Studio.Net developed by Microsoft. The Web sites were located on onsite servers, for consistency in access and bandwidth.

Procedure

The participant first filled out a consent form and received a general explanation of the testing goals and the lab video recording and intercom set-up. The participant filled out a questionnaire and received a training session on use of the pocket PC or desktop PC with two practice tasks for each Web site, instant messaging or phone message. The testing session consisted of the first scenario with Web task followed by a short break. After the break a second scenario was administered and the testing concluded with a semi-structured interview.

The participant read a short scenario describing the context (e.g., lunch break at work) and goals (e.g., buying birthday presents for family, diversifying stock portfolio) for completing the Web tasks. Participants were instructed to respond to the instant message or phone message similar to being in a chat with the evaluator. The evaluator would send a question to the user by IM or telephone and once the user answered the message the next question was given until the user completed all questions. The sequence of events for the participant began with reading the task aloud, executing the Web task, responding to the notification (i.e. phone call or IM notification), answering the messages (i.e. addition or subtraction questions) then returning to the original Web task. Individual sessions were videotaped for data collection and analysis.

The user performance data was collected from the following: 1) beginning of Web task to the notification, 2) interruption task, 3) primary Web task to end. The data analysis consisted of the mean performance times for completion of the primary Web task. The number of errors was recorded for the following types of errors: input (e.g., typing corrections), conceptual (e.g., errors with purchasing a book or stock), memory (e.g., forgot password).

4.6.5 Results

The results present an analysis for the total performance time in seconds to complete the Web tasks, excluding the interruption task. The mean performance time for each interruption type over four trials per subject was used in the analysis. A repeated measures analysis of variance (ANOVA) (alpha = .05) was performed. The control tasks without interruptions were excluded from the repeated measures analysis. There were data points for the control tasks that were considered outliers and were removed from the dataset. The remaining data was not adequately matched to the tasks with interruptions, so the data was not further analyzed. Estimates of the mean performance times for the control tasks are shown in figures 4.9 and 4.10.

There was a significant difference between the pocket PC and desktop groups $\underline{F}$ (1, 6) = 20.42, $\underline{p} < .001$. Web tasks with interruptions took longer to complete on the pocket PC ($\underline{M}$ =116, $\underline{SEM}$ = 6) than desktop computer ($\underline{M}$ = 74 seconds, $\underline{SEM}$ = 6) and there were few errors for the pocket PC ($\underline{M}$ = 4, $\underline{SEM}$ = 1) and desktop ($\underline{M}$ = 3, $\underline{SEM}$ = 1) groups. Therefore, an ANOVA was not used to further analyze the data on errors. Results also indicated a significant main effect for origin $\underline{F}$ (1, 6) = 6.26, $\underline{p} < .05$ (Figure 4.9). The instant message interruption increased the time to complete a Web task compared to a phone interruption for both the pocket PC and desktop platforms.

Furthermore, the effect of anticipation was significant $\underline{F}$ (1, 6) = 69.11, $\underline{p}$ < .001 and a significant interaction effect was found for anticipation and device $\underline{F}$ (1, 6) = 20.92, $\underline{p}$ < .001 (Figure 4.10). The expectation of receiving an interruption decreased performance time on a Web task compared to no expectation of an interruption for the pocket PC and desktop platforms, particularly on a mobile platform. There was no significant interaction effect of origin and anticipation.

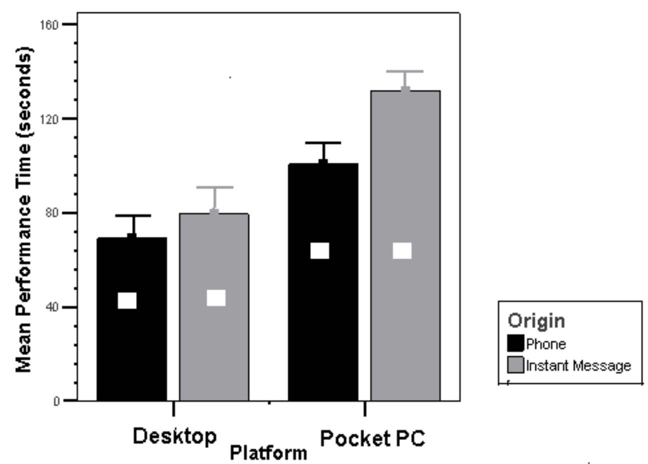

Figure 4.9. Origin of Interruptions Note: The white box within each bar is an estimate of control task performance.

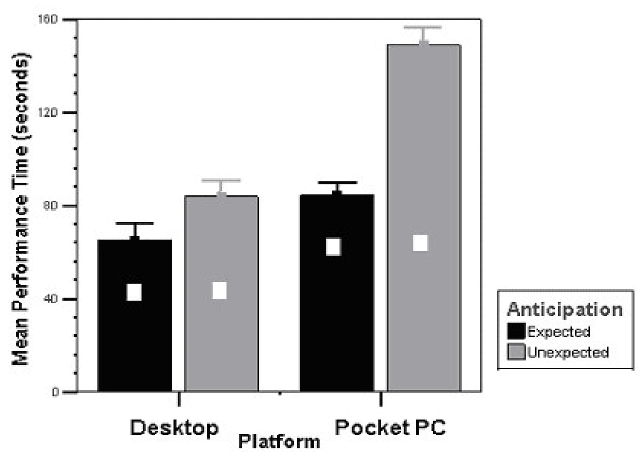

Figure 4.10. Anticipation of Interruptions. Note: The white box within each bar is an estimate of control task performance

4.6.6 Conclusion

The results support the first hypothesis. Web tasks with interruptions take longer to complete on a mobile device than desktop. Mobile Web task performance time with interruptions took 1.5 times longer in comparison to the desktop group. The interruptions and compounding of mobile interface issues (e.g., small screen, limited input interaction, poor Web design) contributed to performance differences between groups. Similar to the observations by Jones et al. (1999, 2002), a high rate of scrolling on the pocket PC was observed for users to complete tasks. Navigating through the task, was not an issue, the tasks constructed for the study were geared towards short tasks with specific end goals.

The results support the second hypothesis. Interruptions from IM are more disruptive to Web task performance time compared to phone interruptions on both mobile and desktop platforms. Cutrell, et al. (2000) also reported slower processing of tasks with IM interruptions during desktop computing. In addition, our study suggests that the similarity of mobile computing medium, between the interruption task (e.g., IM) and primary task (Web task) affects performance on the primary Web task. Gillie and Broadbent (1989) reported similar findings for disruption of a primary task. Wickens and Holland (2000) also describe that the similarity between tasks can result in confusion, therefore lowering performance on tasks.

The results support the third hypothesis. An expectation of an interruption has less of a negative effect on Web performance compared to an unexpected interruption. Czerwinski et al. (1991) also reported a positive effect on performance when an advanced notice or warning of an interruption is given. In general, expectation of an interruption promoted preparation in moving from one task to the other, therefore decreasing the time to perform a Web task. It was found that an expected interruption during a Web task, particularly decreased performance time on a mobile device. A notable reduction in Web performance time was from lack of participant experience in multitasking and interruptions in the mobile context. Users commonly have desktop experience in multitasking and handling interruptions. Therefore, a ceiling effect was evident for desktop Web performance time. Users in both groups had previous desktop Web experience; suggesting this experience does not easily transfer to use of the Web on a mobile device.

4.6.7 Discussion

In general, interruptions negatively influence human performance due to switching between tasks. First, switching between a primary task and an IM interruption task has higher performance costs on a pocket PC than on a desktop PC. Overall, similarity in computing mediums for task (IM, Web task), input interaction and the small screen required demands on attention and memory for multitasking that subsequently prolonged total performance time on the pocket PC. The change in performance time was attributed to the amount of attention and memory required during multitasking. The primary Web task and interruption task were controlled for memory load, the users had to only remember their previous position in the task. Therefore, the limitation may have been attributed to demands on attention and memory for resuming the primary task, resulting in longer amounts of time needed to perform the Web task.

A user that is serially switching between two tasks incurs switch costs (Altmann & Gray, 2000; Rogers & Monsell, 1995). Using the Web on a handheld device and receiving an on-screen interruption, results in a sequential progression between the two tasks. The user's attention is on either the Web task or the interruption task, due to the limited screen size of the handheld. This attribute of a handheld device is less conducive to multitasking than a desktop computer. On a handheld there is more intensive interaction involved when having to switch between screens, intensively scroll and enter data at the same time.

Second, when switching between a Web task and IM interruption on the same platform there is a negative impact on user performance. Processing of a primary Web task and interruption task on a platform can be confusing to a user, leading to a longer amount of time to complete a primary task. Because the two tasks are processed on one computing medium, there are similarities that occur between the two types of tasks (e.g., switching between similar types of screens, same soft keyboard input) that may confuse the user. Wickens and Holland (2000) described responses for the primary task may activate stimuli or cognitive activity belonging to the secondary or interruption task. The activaition of two simiarl tasks often causes confusion for the user. This confusion can slow resumption of the primary task, prolonging Web task performance time. However, phone interruptions allow for better multitasking interaction between the handheld and phone, by switching between a different medium and modality of interruption. Storch (1992) also suggested that similarity in modality between the computing and interruption task explained the disruption of an on-screen interruption. When the user switches from a phone call back to a primary Web task, the switch to and from a different medium produces adequate cues to allow for efficient primary Web task action.

Switching between a primary task and interruption task generated on the same device may benefit from cues to engage attention. These cues can enhance memory recognition directing the user to resume the task. The anticipation of an interruption is speculated to facilitate attention to a task, promoting efficient actions and stimulating memory for completing a task.

Several questions and criticisms arise from this study requiring further investigation. We need to clearly understand whether the interruption task was disruptive due to the modality of interaction with the interruption task and/or because the interruption was received on the same device. Storch (1992) also encountered this same issue in her study as to why on-screen interruptions are more disruptive than phone interruptions. We need to separate the interruption task for origin (phone, IM interruption) and modality (voice, keyboard). The phone interruption was an external interruption and required users to listen to the interruption task and respond with speech. The IM interruption task was from the device platform and required users to visually read the interruption task and respond with the keyboard. This leads to difficulty in distinguishing if the effect of the interruption task is from the origin also referred to as medium (phone vs. IM) or to modality (voice vs. keyboard). The second experiment will address the issue of separating origin and modality of an interruption task addressing the following question. How does modality between a primary Web task and an IM interruption task affect user performance on a primary Web task?

Another criticism is on the small sample size of this study. Besides issues with the control tasks the data analysis from this pilot study was compelling enough to be reported. We acknowledge that there may be a bias in the study due to the small sample size. Therefore, in experiment 2 a much larger group of participants have been recruited which will rectify the issue of sample size. In experiment 2, we further investigate an empirical basis for Web task performance related to the effects of platform, interruption modality, anticipation and complexity. This first study is used as a learning experience, so in experiment 2 we address the issues with the control tasks

There is a current trend for introducing the use of speech for multimodal interfaces for the mobile context (e.g., Sawhney & Schmandt, 2000). This makes the use of a voice interface compared to keyboard interaction appealing for future research as explored in the following study. Introducing the use of a voice interface with an IM interruption task on a handheld or desktop can introduce users to a strangely unfamiliar situation that can impact user performance. There are no common computing voice interfaces in use today by the general population. In experiment 2, the computing medium and the interruption origin for IM is kept consistent and a speech interface is introduced to investigate modality presentation for IM interruptions during mobile Web tasks.

4.7 Experiment 2: The Influence of Platform, Interruption Anticipation, Complexity and Modality on Web Task Performance

Experiment 1 showed that Instant Messaging is more disruptive to Web performance than phone interruptions on a handheld and desktop platform. In this second experiment, we examine the disruptive influences of instant messagin on Web task performance. To understand how a user's Web task performance is influenced when switching between an interruption task and primary task, we examine computing platform, interruption anticipation, modality and complexity of an interruption task.

4.7.1 Modality of Interruption

Multimodal interfaces have incorporated speech interaction (e.g., voice dialing) as a means to aid users of mobile phones (Jameson & Klockner, 2004). Speech and audio has been suggested as a secondary modality for messaging communication to complement functionality on a mobile device (Sawhney & Schmandt 2000). Sawhney and Schmandt (2000) demonstrated a wearable "Nomadic Radio" with auditory cues, synthetic speech, voice and tactile input to navigate and provide notification by scaling message presentation. An early evaluation of the "Nomadic Radio" reported the following: 1) Listening to a message was beneficial when performing tasks concurrently such as reading and typing. However, the message was disruptive when one of the tasks involved the same modality, such as listening to another person and typing. 2) Navigating and browsing a system using only speech commands was less optimal and confusing for the users.

In contrary to the current view for widespread use of multimodal interfaces for computing applications, Wickens and Holland (2000) stress precaution in use of speech interfaces. They highlight that voice technology is benefical in specific situations that involve multitasking with highly spatial tasks such as flying a plane. Therefore, computers with a voice interface that are not highly spatial in nature may result in even worse performance. Examining combinations of multimodal interaction is essential for understanding how switching between modalities influences user performance. This second study investigates the use of specific modality (e.g., speech, keyboard) interaction to complete an IM interruption task.

4.7.2 Content Related Qualities of Interruptions

Qualities of an interruption that are related to the content of an interruption task are generally described in terms of complexity, similarity, length of an interruption task, and relevance of the interruption to the primary task. The studies in this brief literature review have investigated these interruption qualities and the impact on user performance on computing tasks.

Task Complexity

There is no universal definition for distinguishing between different levels of task complexity. (Topi, Valacich & Hoffer, 2005). The complexity of a task is often determined in comparison to another simpler task. Complexity has been described for decision-making tasks. A complex decision making task has a high number of choices to make a decision, while a simpler decision making task has fewer choices (Kerstholt, 1992). For information search tasks, the queries that require joining search terms with "and/or" are considered more complex and queries without joining search terms are considered simpler queries (Topi et al., 2005). The complexity of a task depends on the amount of information cues that have to be processed and the relationships and sequencing of the cues (Wood, 1986). Since there are more information cues processed in a complex task than in a simple task, the complex task can have a strong influence on the processing of other tasks.

Interruptions have been shown to have an affect on user performance of complex tasks. Speier, Vessey and Valacich (2003) investigated the influence of a computer generated interruption task on simple and complex production management decision-making tasks. These tasks involved identifying data trends and extracting values or performing calculations. The interruption task was an information acquisition task. This interruption task was introduced by inserting a screen on the PC monitor announcing that the manager wanted the task to be completed immediately. Users performed with better decision accuracy and faster performance time on the interrupted simple decision making tasks, compared to tasks with no interruptions. On the interrupted complex decision making tasks users performed with less decision accuracy and slower performance time, when compared to tasks with no interruptions. These results suggest that interrupted simple decision making tasks, produce more accurate solutions and faster performance. When processing a complex interrupted task a person's attention may become narrower and more focused, often leaving out information cues which effects task completion resulting in lowered task performance (Speier et al., 2003). A complex task requires more attention for processing than a simpler task. Therefore, when switching between a complex primary task and an interruption task, re-engaging the complex decision-making task is difficult because of the level of attention and memory required to resume the complex task. The study by Speier et al. (2003) shows that when conducting more than one task, a complex task can negatively influence a users performance. An interrupted complex task has also been shown to influence memory, when more reminders are requested after a complex interrupted task, than on a simpler interrupted task (Cutrell et al.,2001). A complex interruption task is expected to have a large negative impact when resuming a primary task.

Complexity of an Interruption Task

The experiments by Gillie and Broadbent (1989) examined the effects of length, similarity and complexity of an addition and subtraction interruption task on participants playing a computerized game. The game consisted of users having to navigate to different locations and collect items from a list. The authors concluded that an interruption task that is highly complex (e.g., digits were coded as letters and letters needed to be decoded to perform mental arithmetic) and having greater similarity to the primary task (e.g., primary and interruption task involves a list of words), is disruptive to the primary task, more so than a simple interruption task (e.g., mental arithmetic for addition or subtraction).

Specifically pertaining to complex interruption tasks, Gillie and Broadbent (1989) showed that complexity of a short arithmetic interruption task involving recall for decoding of letters into digits has a disruptive effect on primary task performance, especially when the two tasks involve similar material. This suggests that a complex interruption task involving extensive processing and is similar to the primary task has a greater negative influence on performance time for a primary task.

Task complexity and interruptions play a role in negatively influencing user performance. We examine the effects of a complex interruption task on user Web task performance. Is a complex interruption task more disruptive to Web task performance than a simple interruption task?

The content related qualities of interruptions mentioned below have been previously investigated in research on interruptions. A detailed investigation of these qualities is not within the scope of the current studies. Specific control of these qualities has been administered to the interruption tasks in our experiments.

Similarity and Length of an Interruption Task

Bailey et al. (2000) examined the effects of similarity of computing initiated interruptions on user performance of different computing tasks. Computing tasks involving addition of digits, word counting, image comprehension, reading comprehension, registration of user information and word selection were interrupted by a reading comprehension task or a stock scenario task. Overall, the computing tasks that were interrupted took longer to complete than the uninterrupted computing tasks. The user spent more time on the interrupted tasks of adding, counting, reading comprehension and word selection tasks, than the image comprehension, and information registration tasks. An increase in the amount of time to complete the interrupted primary tasks was attributed to the memory load of the task and the information that the user needed to recall to resume the task. However, the similarities shared between an interruption task and primary task did not play a role for disruptiveness to the primary task, compared to an interruption task and a primary task that were dissimilar. These findings are contradictory to the findings of Gillie and Broadbent.

The results by Gillie and Broadbent (1989) and Bailey et al. (2000) have been inconsistent on whether the similarity of an interruption task to a primary task is disruptive to performance. The type of similarity compared in these two studies focused on processing similar types of tasks. For example, both tasks involve similar aspects for recalling word lists, reading etc., the memory load of the interruption tasks differed. The interruption task in the Gillie and Broadbent study involved memorization whereas the Bailey et al., (2000) study did not. The disruptive effect of the interruption task may involve combined effects of task similarity and memory load of the interruption task.

The length of an interruption does not seem to play a role in the disruptiveness of the interruption on the primary task (Gillie & Broadbent, 1989; Bailey et al., 2000). Therefore, the amount of time to complete an interruption task does not have an affect on the primary task, within certain limitations. Since these studies were done in a controlled laboratory environment the duration of the interruptions spanned from 15-30 seconds (Bailey et al. 2000; Gillie & Broadbent, 1989). As reviewed in section 4.2 interruptions in the real world can last for a long time prompting that users often do not return to complete a task.

Relevance of Content

The relevance of an interruption to a primary task has been shown to be beneficial to user performance. Receiving instant messages on a desktop, that were relevant to a computing task, were less disruptive to user performance than irrelevant messages (Cutrell et al., 2000; Czerwinski et al., 2000a). Another example is drawn from the Speier et al. (2003) study, where the interruption task was administered as a message from the supervisor to immediately perform the interruption tasks. The interruptions were related to the primary task and may have had positive performance effects on the simple tasks for decision accuracy and faster performance time. However, the participants were reported to have a negative perception of the interruptions.

These studies highlight that the disruptiveness of an interruption is dependent on the presentation of the interruption (e.g., timing, content), state of the user (e.g., information processing, intensive interaction). In order to reduce the performance costs of interruptions the availability of support (e.g., markers, reminders) for attention and memory is needed in resuming computing tasks.

4.7.3 Hypotheses

H1: IM interruptions are more disruptive on the pocket PC, prolonging Web task performance time, when compared to the desktop computer. Limitations of the pocket PC for small screen size, difficult input interaction, inadequate Web design, compounded by the similarity of interaction between the IM and Web task increases the amount of time to perform a Web task.

H2: IM interruptions using speech (different modality from use of keyboard on primary task) is less disruptive to Web task performance time, compared to interruptions using the keyboard (same modality as primary task), due to less confusion in switching between modalities contributing to decreasing the amount of time to perform a Web task.

H3: An expectation of an IM interruption decreases Web task performance time, as opposed to an unexpected interruption. The expectation for receiving an interruption during a task facilitates attention in preparation for resuming a primary task resulting in a decrease in the amount of time to perform a Web task.

H4: A complex IM interruption task increases Web task performance time, compared to a simpler interruption task due to a higher amount of effort in processing the interruption task.

4.7.4 Method

Participants

Forty-six participants were recruited through the TNO institute subject database and received monetary compensation for 3 hours of participation. All participants met the study criteria given in study 1. Forty participants with a mean age of 22 years were included in the study. Six participants were excluded due to technical problems during data collection. Participants were randomly assigned to an HP3555 pocket PC with keyboard interaction group (n = 10), HP3555 pocket PC with voice interaction group (n = 10), desktop PC keyboard interaction group (n = 10), and desktop PC voice interaction group (n = 10).

Design

This experiment consisted of two between group variables, platform (pocket PC and desktop PC) and interruption modality (keyboard, voice) and three within group variables anticipation of an interruption (expected, unexpected), interruption complexity (simple math, difficult math) and interruption (none, instant message). The study design was a 2 x 2 x 2 x 2 x 2 mixed repeated measure design. The types of interruptions, expected simple math, unexpected simple math, expected difficult math, unexpected difficult math were counterbalanced using a Latin square design. The control tasks (tasks without interruptions) were matched to the tasks without interruptions and presented at random.

Participants performed 32 tasks on the same financial and bookstore Web sites described in study 1. The presentation of tasks were balanced using two forms. The task instructions either mentioned an interruption (e.g., you will be receiving an instant message) or did not mention an interruption. The messages consisted of either simple or difficult addition, subtraction, multiplication and division questions. The simple math question were primarily arithmetic and consisted of single digit and a few double digit questions (e.g., give answer 7 + 3 = , give answer 10 – 6 =). The difficult math questions were primarily double or triple digit questions in an algebraic form (e.g., give answer 65 - ____ = 47, give answer 430 - _____ = 75). Each set of IM questions were balanced between simple and difficult messages based on the possible amount of time spent across the simple and difficult questions. For example, if a message consisted of two difficult questions that would take 10 seconds to answer, more simple questions were given filling approximately 10 seconds.

We controlled for the interaction in switching between the Web task and interruption task on the handheld and desktop platforms. The interaction on the desktop PC was made to be a single-screen display in number of steps similar to the handheld, when switching between the Web task and IM. The desktop and handheld participants were trained to move from the Web task to the IM in the same number of steps. The desktop PC, IM screen was presented to the user in the center of the desktop monitor and a grey background covered the rest of the screen. The visual presentation of the instant message interface on the desktop matched the single-screen presentation and interaction for switching between screens as on the handheld (figure 4.11 and 4.12). By controlling for presentation and interaction in this fashion, there is a better understanding of the influence of the interruption and that the effect is attributed to the interruption based on a specific interaction.

The evaluator generated the IM's from sets of predefined math questions for the voice and keyboard conditions. A wizard of Oz method was set up for the voice interface. A microphone and intercom set up, delivered the participant's spoken answer to the evaluator in another room. The evaluator would send the answer to the IM interface then generate another question for the participant.

Material and Equipment

All Web and IM tasks were administered on a HP5550 or Dell desktop PC (see section 4.6.4 for details). Three neuropsychological tests the Digit Span, Trail Making tests and a computerized spatial ability test were administered during the study. The Digit span test is part of the Wechsler battery of tests and is a memory test commonly used for measuring the span of immediate recall (Lezak, 1995). The digit span test requires a person to reproduce as many numbers from a sequence of numbers as possible. The trail-making test is a standard component of the Halstead Reitan Neuropsychological Test Battery to assess motor speed and visual search (Lezak, 1995). Part A of the test requires drawing lines to numbered circles to consecutively connect 25 circles in numeric order. Part B requires drawing lines alternating between number and letters (A-Z) (i.e. 1-A, 2-B, 3-C…). Especially part B of the trail making test detects ability of switching cognitive sets when multitasking, and is heavily dependent on attention resources for adequate processing (Miner & Ferraro, 1998). The computerized spatial ability test, developed at the TNO Human Factors Research Institute is used to measure a person's ability to mentally rotate objects in

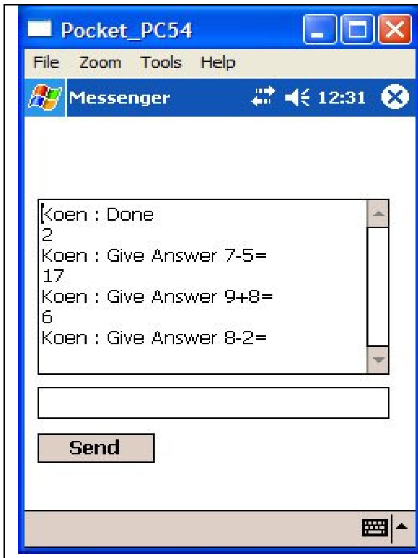

Figure 4.11. Instant message on pocket PC

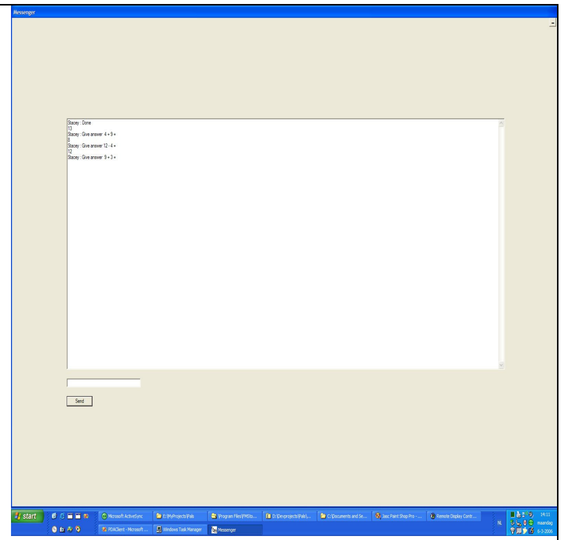

Figure 4.12. Instant message on Desktop PC

space (figure 4.13) (Neerincx, Pemberton and Lindenberg, 1999). The participant viewed a total of forty screens for the spatial ability test. The participant has 15 seconds in total to determine which of the four peripheral images matches the center image, by clicking on the image. Or, if none of the images match the central image, participant selects "geen" meaning none. It is possible to change answers during the 15-second interval. A warning beep is given after 12-seconds to inform the participant that the 15-second time-limit is approaching. These tests are considered baseline indicators of memory ability, multitasking ability and spatial ability as a current indication of cognitive ability in regards to Web task performance.

Procedure

The first procedure described in experiment 1 also applies to experiment 2. With the exception that participants received only instant messages. In addition, the training session included training on use of the voice interface. To complete the IM using speech, the participant used a voice interface and the commands of send, delete and the numerical answers for the IM task. During the primary Web task the participant received an auditory notification for an IM. Using a microphone the participant spoke the answer to the question and gave the command send. The participant then viewed the spoken answer on the IM screen, and could delete the

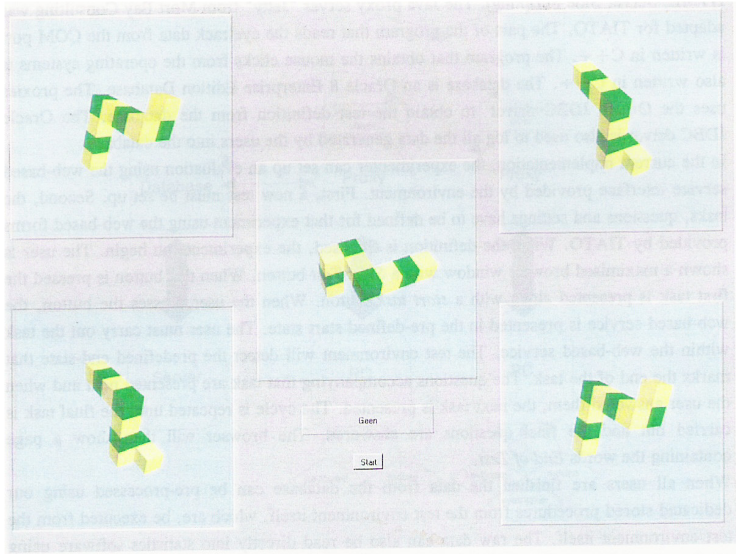

Figure 4.13: Screen from spatial ability test. From "U-WISH Web usability: methods, guidelines and support interfaces" by M.A. Neerincx, S. Pemberton & J. Lindenberg, 1999, TNO Research Institute Internal Report, No. TM-99-D005. Copyright 1999 by the TNO Research Institute.

answer by saying the command "delete" or continue. After answering the messages, a "Done" message was sent to the participant who could then move back to the primary task. The keyboard condition allowed for the same interaction with the message as the voice command interface.

User performance data was collected from the following: 1) beginning of Web task to the notification, 2) interruption task, 3) primary Web task to end. The data analysis consisted of the mean performance times for completion of the primary Web task. The number of errors was recorded for the following types of errors: input (e.g., typing corrections) and conceptual (e.g., errors with purchasing a book or stock),

4.7.5 Results

The performance times for four trials per subject were analyzed using a repeated measures ANOVA (alpha = .05). The mean performance time for the Web task, excluded the time to switch between tasks and the amount of time to complete the interruption task. Assumption tests for repeated measures ANOVA indicated no outliers, homogeneity of variances with Levene's test and a normal distribution of data. All mean values are reported in seconds. A descriptive analysis showed that users had similar mean performance times on the interruption tasks consisting of the following: desktop PC, simple (M = 17, SEM = 1), difficult (M = 18, SEM = 3) and pocket PC simple (M = 18, SEM = 1) and difficult (M = 16, SEM = 2).

The data was first analyzed comparing user performance on Web tasks with and without interruptions on the computing platforms. The number of errors made on a pocket

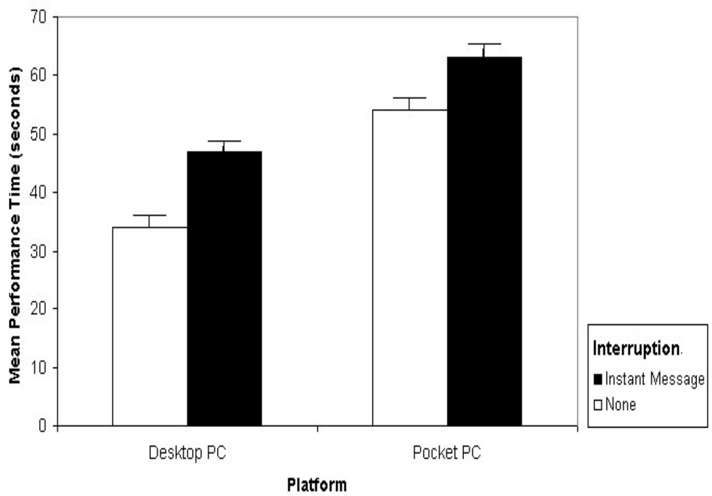

Figure 4.14: Platform and Interruption

PC (M = 5, SEM = .6) and desktop PC (M = 3, SEM = .623) were significantly different F (1, 38) = 4.297, $p < .05$. The most common type of errors on the primary task was input errors. There was no main effect of errors for the tasks with interruptions and without interruptions.

There was a general significant difference between performance time on the pocket PC (M = 59, SEM = 2) and the desktop PC (M = 41, SEM = 2), F (1, 38) = 31.76, $p < .001$, for Web tasks with and without interruptions. There was a main effect of interruptions, which significantly increased Web task performance time on the pocket PC (M = 63, SEM = 3) and desktop PC (M = 48, SEM = 3), when compared to the Web tasks without interruptions PC (M = 54, SEM = 2) and desktop PC (M = 35, SEM 2), F (1, 38) = 45.58, $p < .001$ (figure 4.14). There was no significant interaction effect of platform and interruption.

Another analysis examined user performance on tasks with interruptions done on the computing platforms. Mean performance times are shown in table 4.2 For overall handling of tasks with interruptions (expected and unexpected) there was a significant difference in performance time for the pocket PC (M = 59, SEM = 2) and desktop PC (M = 42, SEM = 2), F (1, 36) = 30.08, $p < .001$. There was a significant effect on performance time for modality, F (1, 36) = 4.70, $p < .05$ (figure 4.15). Completing the instant message using voice on the desktop (M = 46, SEM = 3) or voice on the pocket PC (M = 62, SEM = 3) was slower than using the keyboard on the desktop PC (M = 39, SEM = 2) or the soft keyboard (M = 56, SEM = 2) on the pocket PC.

There was a main effect for anticipation of an interruption $F\ (1, 36) = 18.73$, $p < .001$ (figure 4.16). Web tasks with expected interruptions (M = 46 SEM = 1) were completed

Table 4.2 Mean performance times for Web tasks with interruptions

Platform	Modality	Anticipation	Complexity	Mean	SEM
Pocket PC	Keyboard	Unexpected	Simple	55	5
			Difficult	67	5
		Expected	Simple	54	3
			Difficult	48	3
	Voice	Unexpected	Simple	73	5
			Difficult	56	5
		Expected	Simple	58	3
			Difficult	60	4
Desktop PC	Keyboard	Unexpected	Simple	48	6
			Difficult	38	5
		Expected	Simple	36	3
			Difficult	34	4
	Voice	Unexpected	Simple	61	6
			Difficult	43	5
		Expected	Simple	47	3
			Difficult	34	4

faster than tasks with unexpected interruption (M = 55, SEM = 2). There was no significant interaction effect for anticipation and platform.

There was a main effect for complexity of an interruption task $F\ (1, 36) = 10.85$, $p <$ 001 (figure 4.17). Web tasks with a simple interruption task (M = 53, SEM = 2) took longer to complete than Web tasks with a difficult interruption task (M = 47, SEM = 2). There were significant two way interaction effects for complexity and platform, $F\ (1, 36) = 4.87$, $p < .05$, (figure 4.18) and complexity and modality, $F\ (1, 36) = 7.53$, $p < .009$, (figure 33) which modifies the main effect for complexity of an interruption task.

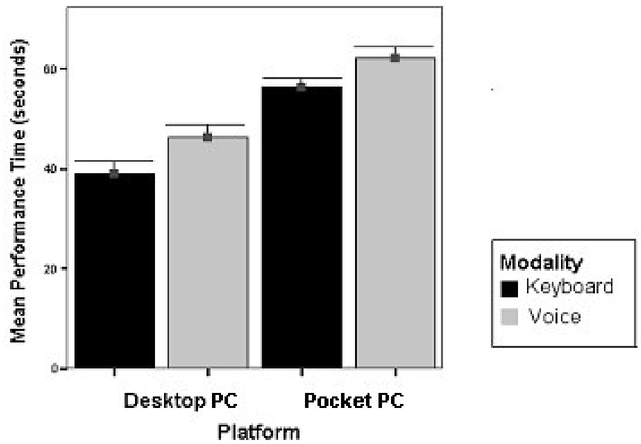

Figure 4.15: Modality and platform of an IM interruption task

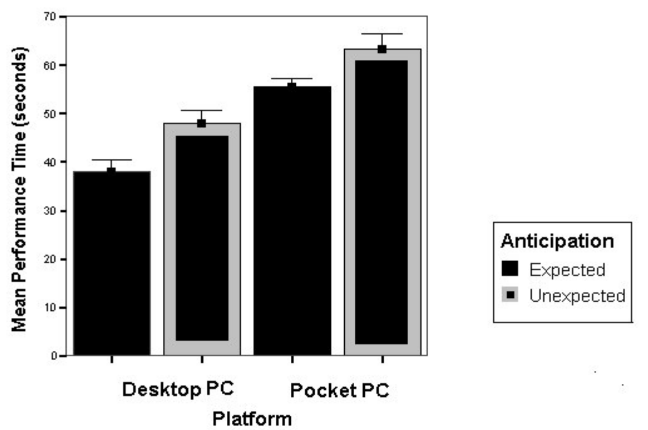

Figure 4.16. Anticipation and platform of an interruption task

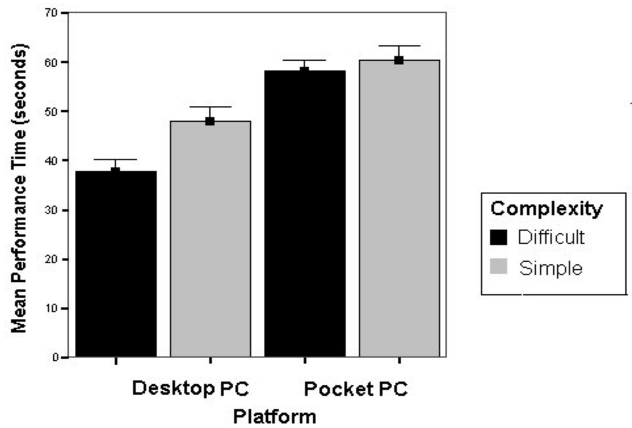

Figure 4.17: Complexity and platform of an interruption task

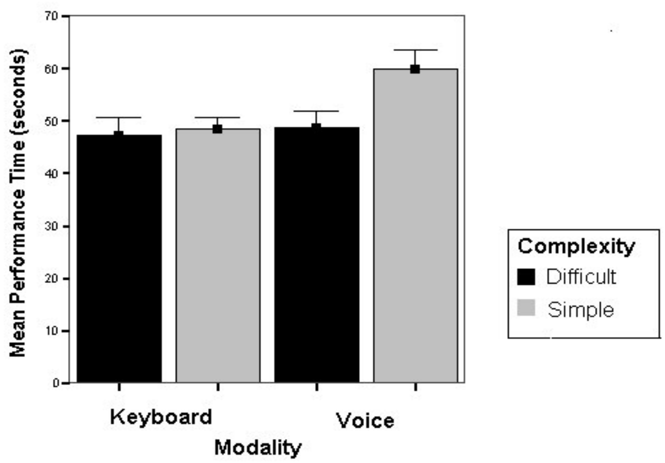

Figure 4.18. Modality and Complexity of an interruption task

Table 4.3: Predictor variables for interrupted Web task performance, significance at $p < .05$. Adj R^2 =Adjusted R^2 is the amount of explained variance. The regression equation consists of the constant and the unstandardized beta coefficients for each predictor variable.

Platform	**Dependent Variable**	**Predictors**	**Adj R^2**	**Regression Equation**
Desktop PC	Primary Task Performance Time (PT)	cognitive switching ability (csa)	52%	PT = .688 + 2.23*wintuse + .781*csa
		weekly desktop Internet use (wintuse)	10%	
Pocket PC		cognitive switching ability (csa)	14%	PT = 55.46 + 4.31*yintuse + .425*csa
		years desktop Internet use (yintuse)	20%	

User Model for Predicting User Performance with Interruption Handling

Regression analysis was used to explore the data for finding variables that predict user Web task performance when handling interruptions on the Desktop PC (n = 20) and Pocket PC (n = 20). A small number of predictor variables were chosen to be included in the analysis based on theories that were presented earlier in the chapter (sections 4.3 and 4.4) related to user cognitive switching ability, interruptions handling and use of the Web. We refer to performance on the Trails B test as cognitive switching ability and use the term multitasking to the users application of cognitive switching ability. The predictor variables included in the analysis were related to self rated level of computing experience, years of desktop Internet use, desktop weekly Internet use, mobile weekly Internet use, cognitive switching ability (i.e. Trails A & Trails B), memory ability (i.e. Digit Span) and spatial ability. Refer to table 4.3 for the prediction equations.

Cognitive switching ability[4] (Beta = .832) and weekly desktop Internet use (Beta = .343) were significant predictors for Web performance with interruptions on a desktop PC ($p < .01$). Cognitive switching ability and weekly desktop Internet use explain 62% of the variance for interrupted Web task performance on the desktop PC. The effect of multitasking ability controlling for weekly Internet use is larger than the effect of weekly Internet use controlling for multitasking ability. Cognitive switching ability was positively correlated with Web task performance on the desktop PC ($r = .743$, $p < .001$), suggesting that the ability to multitask allows a person to better handle interruptions, which is beneficial to Web task performance.

[4] Cognitive switching ability is measured in amount of time needed to complete the task. The lower the amount of time is better.

Web performance with interruptions on the Pocket PC can be predicted by years of desktop Internet use (Beta = .420) and cognitive switching ability (Beta = -.412), ($p < .05$). Cognitive switching ability and years of desktop Internet use explain 34% of the variance for interrupted Web task performance on the pocket PC. The effect of years of Internet desktop use controlling for cognitive switching ability is larger than the effect of cognitive switching ability controlling for years of desktop Internet use. On the pocket PC, interrupted Web task performance is negatively correlated with cognitive switching ability ($r = -.488$, $p < .05$) and positively correlated with Internet use ($r = .495$, $p < .05$). These results are contrary to what was expected. An interpretation of the negative correlation between cognitive switching and Web task performance is that participants who were good at multitasking had less experience with the mobile Internet contributing to poor handling of Web tasks that are interrupted and visa versa. These results also show that there is a relationship between multitasking and direct experience with the mobile Internet. A direct correlation exists between cognitive switching ability and experience with the mobile Internet ($r = .480$, $p < .05$). This shows that the participants in our study who were good at multitasking had little experience with the mobile Internet and visa versa, which contributed to our unexpected results.

The direct correlation of years of Internet use with Web task performance suggests that general experience of the Internet does not translate to performance of handling interruptions during Web tasks on a pocket PC and the experience on use of the desktop Internet can work against performance if a person is a novice user. From the participants in the pocket PC group, 30% used the mobile Internet on a weekly basis and 100% of the participants had general experience with use of the desktop Internet on a weekly basis. People who have a lot of experience with the Internet from a desktop PC may have certain expectations of how the mobile interface should function and this may have ramifications on performance when handling interruptions. Whereas, users with less experience on the desktop Internet may be more quick to adapt to using a pocket PC.

4.7.6 Conclusions

In conclusion, IM interruptions were shown to be disruptive to Web task performance in comparison to Web tasks without interruptions on both platforms. In general (with and without interruptions) there were more errors made on the pocket PC than the desktop PC attributed to difficulty with interaction on the pocket PC. The results support the first hypothesis that Web tasks with IM interruptions were more disruptive on the pocket PC, when compared to the desktop computer. On both platforms, the instant message interruptions were disruptive to Web task performance time when compared to the Web tasks without interruptions. The overall increase in Web task performance time on the pocket PC, compared to the desktop PC is attributed to the interruptions, and compounding constraints (small screen, difficult data entry and poor Web design). When an interruption task and primary task is on a device with a single-screen display this leads to serial switching between the tasks. The switching between screens can negatively influence a user's attention and memory, creating problems for resuming the primary task.

The second hypothesis stated that IM interruptions using speech (different modality from the primary task) is less disruptive to Web task performance time, compared to interruptions using the keyboard (same modality as primary task). The results do not support this hypothesis. Switching from a keyboard Web task to complete an IM interruption task using voice modality increases Web task performance time. This reveals higher costs of switching between modalities for sequential tasks on the same device. This finding suggests that switching between a voice interface, and keyboard interface is even more disruptive than maintaining use of the keyboard for the interruption and primary Web task. One explanation of this result may be the participants' unfamiliarity of using a speech interface on a computing platform, which may increase switch costs.

The third hypothesis for anticipation of an interruption stated that an expectation of an interruption decreased Web task performance time, as opposed to an unexpected interruption. The results support that anticipation of an IM was benefical to performance. The expectation of an interruption aided in facilitating attention and memory, to promote efficient Web task actions, compared to unexpected interruptions.

The fourth hypothesis stated that a complex interruption task increases Web task performance time, due to a higher amount of effort in processing the interruption task. The results did not support this hypothesis. As a result of controlling the length of the simple and difficult interruption tasks a confounding is noted regarding the number of questions. The number of questions presented to the user during the interruption task influenced Web task performance time. The simple repetitive interruption was more disruptive to the primary Web task than the less repetitive complex interruption task.

In determining predictor variables for interrupted Web task performance, our results suggest that handling interruptions while using the mobile Web on a pocket PC, involves more than just cognitive switching ability and general desktop Internet experience. A combination of multitasking skill and experience with the mobile Web contributes to a user's skill in handling interruptions. In order to verify predictors for a user model, participants with mobile Internet experience need to be examined.

4.7.7 Discussion

On both platforms IM interruptions were shown to be disruptive to Web tasks, in comparison to control tasks. The instant message interruptions were disruptive to Web task performance, with an increase in time of 9 seconds (15%) for the pocket PC and 13 seconds (27%) for the desktop PC, compared to control tasks.[5] There was a larger negative impact

[5] Note. The 9 seconds was computed from the pocket PC performance time without interruptions (M = 54) and with interruptions (M = 63). The 13 seconds was computed from the desktop PC performance time without interruptions (M = 35) and performance time with interruption (M = 48).

of interruptions on the desktop PC from generating two tasks on the same device requiring serially switching between screens to move between tasks.

On the pocket PC, more time was spent on the primary task when the interruption task was unexpected, in comparison to the desktop PC. Nine seconds was attributed to the disruptiveness of the interruption on attention and memory. Six seconds was attributed to compounding constraints of the device (e.g small screen, difficult input interaction, poor Web site design).[6]

Expectations for use of the Web on a mobile device

A likely scenario is that a user will compare use of the Web on the desktop PC to use of the Web on a handheld. There is a large amount of additional time that a user spends on a mobile Web task, than a Web task done on a desktop PC. Our results show that compared to a desktop PC, there is a significant 26% increase in amount of time needed to complete a task with interruptions on a handheld. There is a 38% increase to complete a task without interruptions on a handheld when compared to the same situations on a desktop PC. Presentation and interaction of the instant message on the desktop was controlled to be similar to the pocket PC. User performance on the desktop should be faster (as shown in experiment 1), further increasing the difference between the two devices.

People's tolerance for use of a Web site can be very low. Research on mobile devices has shown that an increase in time to complete a task on a pocket PC can result in annoyance, frustration and anxiety for the user (Bailey & Konstan, 2006). Practice and training may be beneficial for lowering the disruptiveness of an interruption task and improving performance for use of the pocket PC (Hess & Detweiler, 1994). However, we experienced much difficulty in finding people who use the mobile Web. Unfortunately, our research suggests that although someone may have considerable experience on the desktop Internet, this ability does not fully transfer to use of the mobile Web. Experience with use of the mobile Internet is very important for good performance on a mobile device. The expectation of many first time users, is that use of the Internet on a mobile device should be as easy as on the desktop PC. If the expectation for ease of use on a mobile device is not met, use of the mobile Internet may be abandoned completely by a user.

An Examination of Issues from the First Study

This study addressed two issues raised in the first study. We further investigated whether the interruption effect on Web task performance was due to origin (phone, IM interruption) or modality (voice, keyboard) of the interruption task. In the first study, it was observed that a change in origin of the interruption task was beneficial to primary task performance. While receiving interruptions on the same device as the primary task is more detrimental to task performance. In our second study we decided to examine modality of the

[6] Note. There is a difference of 15 seconds between interrupted task performance on the desktop PC (M = 63) and pocket PC (M = 48). Nine of the 15 seconds can be attributed to the interruption (as calculated in footnote 5), leaving 6 seconds to be attributed to other constraints.

interruption task instead of origin. Meaning the origin of the interruption task was kept consistent using IM for the desktop and handheld platform. A part of our research goal was to understand if changing the modality of an interruption task would be beneficial to performance. There was poorer performance on Web tasks when using voice rather than using the keyboard to respond to the instant message.

Based on this second study we conclude that interruption origin probably has a larger impact than modality of an interruption, when serially switching between tasks. When delivering an interruption from the same platform, and a user switches to a voice modality versus maintaining use of the keyboard for the interruption task, there was no positive influence on performance of the primary task. This suggests that when interruptions and the primary task are on the same device, this has a larger negative impact than interruptions delivered from an origin different from the primary task. However, since we did not specifically examine different origins of an interruption, while controlling for modality, no conclusions can be made about the influence of interruptions from an external origin.

What modality combination between the Web and interruption task (keyboard or voice) will lead to better user performance on the primary Web task? On the pocket PC continuing the same modality between a Web task and IM was less disruptive. Maintaining the same modality, compared to switching to voice interaction, saved approximately 10 seconds. Switching between voice and the keyboard may have created a learning overload situation for user interaction, which contributed to higher switch costs. Participants in the group using both voice and the keyboard learned two different modalities for the tasks whereas the other participants used only the keyboard modality throughout the tasks. Using voice has a higher memory load, when commands need to be remembered. Using voice during an IM computing task is not a common user interface situation. Adjusting to this new situation of replying in speech to an IM message than switching back to a soft keyboard was new to all participants.

The findings on anticipation are consistent with the first study. The expectation of an interruption decreased Web task performance time especially with a mobile device. This suggests that more than just an auditory or visual notification is needed for informing users of interruptions. A form of interruption transparency for leveraging a user's expectation of an interruption task may be beneficial for user performance.

Examining Complexity of an Interruption Task

The fourth hypothesis stated that a complex interruption task, will increase Web task performance time due to the higher amount of effort in processing the interruption task hindering reconfiguration in returning to the primary task and resulting in switch costs to performance time. The study by Gillie and Broadbent (1989) suggested that length of an interruption between 30 sec to approximately 3 minutes is not critical for disruption of a primary task. However, complexity related to mental processing involved with the interruption task can play a role in the disruptiveness to a primary task. In this study, the simple interruption task was found to be more disruptive to Web performance time. This finding was unexpected based on previous studies on complexity with interruption tasks, which suggest that a simple interruption does not disrupt primary task performance compared to a complex interruption (Gillie & Broadbent, 1989). Pertaining to the interruption task used in this experiment the length of time spent on both the simple and difficult interruptions were controlled. By controlling for the length of time for the simple and difficult questions, a higher number of simple questions had to be administered during the interruptions to match the amount of time spent on the difficult questions. This suggests that an interruption task that does not require a high amount of cognitive processing can still be disruptive when the amount of interaction is high.

Predictors of User Web task Performance

In predicting how users handle interruptions for a specific mobile context a small set of factors were investigated. We propose that the initial regression models can be used as a starting point to predict Web performance during handling of interruptions. However, further validation is needed for the models that include participants with mobile Internet experience. In the future this information can be used to provide appropriate interface support for interruption management. Algorithms based on the regression models can be developed and be used for implicit user models that determine baseline Web task performance for handling of interruptions. When a users Web performance for interruption handling can be predicted this information can be used to provide appropriate support in managing interruptions (e.g., point of return indicators) to aid users in performing tasks more efficiently. For example, a new mobile Web user with poor cognitive switching ability and many years of Internet experience can benefit from interruption management techniques (e.g., a visual point of return indicator presented upon task resumption). Knowing a users baseline performance with interruptions can aid to manage communication between virtual assistance and the user. By knowing this information the user can be supported by managing computing interruptions such as internal communication to be more transparent during Web computing. Presentation of communication can be managed according to a users anticipation or expectation of receiving information from an internal computing source. Overall, this research suggests that platform specific (desktop PC or pocket PC) user models need to be developed for interruption handling and management.

Future Research

There are several implications for future research. To better understand the effects of interruptions on use of the mobile Web regarding the effects of modality on Web task performance and to clarify multitasking ability as a predictor for interruption handling, a minimum criterion is needed for participants that have mobile Web experience. When initially recruiting participants for our study, we were overly optimistic on our criteria for use of a mobile device, which included owning or use of a mobile device and having general desktop PC Internet experience would suffice as criteria for our user sample. Another factor was the difficulty in finding people who actually used the mobile Internet.

The Web sites chosen for this study were not ideally designed for the mobile Web in terms of content presentation. Also, the Web sites were fairly simplistic in number of pages and the tasks designed for the study were also very simplistic types of tasks for use on the mobile Web. The simplicity of tasks may have contributed to a low amount of errors on tasks. We currently regard the higher number of errors for the pocket PC as related to the difficulty of input interaction. The results suggest that no matter how simple the tasks or the Web site the content presentation needs to be redesigned specifically for use on the mobile Web.

Interruption origin and a comparison from different sources were not investigated in our study. We speculate that origin of an interruption plays a large role on influencing performance on the primary task. An on-screen interruption is probably more disruptive to a Web task due to the instant message covering all or a part of the Web display, and cues are less readily visible to resume a task. An external interruption such as a telephone call does not disrupt the user as much as an on-screen interruption, since cues of the on-screen task are readily available for resuming the primary task. Another similar example is that people often forget where to resume an ongoing conversation after being interrupted by call waiting. Therefore, interruptions that are delivered via the same device are more disruptive. Further research is needed on determining the disruptiveness of interruptions based on different origins.

In order to improve user handling of interruptions we now focus on the disruption of attention and memory for Web tasks after an interruption generated from the mobile device. The effects of the interruptions on Web performance time can be due to problems with a user refocusing back to the primary task and remembering where to resume the task. The first two studies have shown that an increase in performance time occurs when a user is interrupted during a Web task. It is unclear whether the increase in performance time is related to problems with remembering the content of the task (e.g., What company stock did I need to purchase?) or to problems in remembering the place of resumption or step in the task (e.g., What was my previous step and what is my next step?). These issues are addressed in the following experiment.

4.8 Experiment 3: The Influence of IM interruptions and Platform on Remembering Task Place and Task Content

The studies presented in this body of work on multitasking and interruptions with the Web, have showed that switching between a primary Web task and on-screen instant message interruption results in poor Web task performance on a pocket PC and desktop PC. Poor task performance indicates that user's have difficulties with continuing a primary task, therefore increasing the amount of time to complete the primary task. When a user resumes an interrupted primary task there may be a weaker memory representation of the primary task. Switching between tasks and intensive scrolling and paging when using a small screen on a mobile device may lead to a weaker memory trace when resuming the primary task. Examining user recognition for an interrupted task can contribute to understanding a user's memory when continuing a Web task. A visual marker to aid attention and memory for a Web task may be effective in enhancing task performance for interrupted Web tasks.

4.8.1 Memory for Interrupted Computing Tasks

Everyday, interruptions stimulate people to multitask. An interruption can influence a user to alternate or switch attention (task switching) between a primary task and an interruption task.. Attention and memory is involved in accurately moving the user from a primary task to an interruption task and back to the primary task. This multitasking can place an increased burden on attention and memory. Task switching describes user performance on multiple tasks conducted in an alternating fashion by engaging one task then the next task. We are interested in how an interruption task influences memory of a task by observing recognition for task content and task place of a Web task. As shown in our previous studies, the influence on memory for a Web task is associated with costs to task performance time.

Previous work has shown that different characteristics of interruption tasks influence memory for a primary task in various ways. The most direct influence of an interruption task on memory is that people need more reminders for resuming a computing task when interrupted. More reminders are needed for resuming a complex task that is interrupted than when a less complicated computing task is interrupted (Cutrell et al., 2001). Other studies have shown that the similarity of tasks also has an influence on memory for the primary task. Oulasvirta and Saariluoma (2004) found that the semantic relatedness of text in an interruption task and primary task, results in forgetting, intrusion and confusion on memory for the primary task when compared to a dissimilar text of an interruption and primary task. There does not have to be complete overlap in similarity of the interruption task to the primary task in order for the interruption task to be disruptive (Edwards & Gronlund, 1998). Trafton et al. (2003) as a part of the goal activation model (discussed in section 4.4.2) suggests two mechanisms, prospective goal encoding and retrospective rehearsal, to explain memory for resumption of a primary task. Prospective goal encoding is a form of "mentally looking ahead" to see what needs to be done. Retrospective rehearsal is described as looking back to see what has been done.

In examining how interruptions influence memory recognition for a primary task, there is a specific user interface interaction that we would like to address when on a desktop PC versus a handheld. On a desktop PC a large screen affords having multiple screens available, such as a search task screen and instant message screen fully or partially visible. Viewing multiple windows, leads concurrent type of interaction where both tasks are easily kept active in working memory. We expect that concurrent interaction between a primary task and interruption task has less of a disruptive effect on performance, than serially switching between tasks when using a single screen diplay. A limitation of a handheld device is the single-screen display. In this experiment, we control for the single screen display to assure that on the desktop PC there would not be use of the active window as a place marker for the primary task or use of the foreground window as an environmental cue. The desktop PC display was set-up to be used in a similar fashion as on the mobile device. .

In this study, we examine the effects of interruptions on the specific aspect of memory for task place and task content when resuming a Web task. Memory for task place is recognizing the users last location or step in a primary task (e.g., filled in text box for stock). Memory for task content is recognizing specifics on the primary task (e.g., name of last company stock that was bought). We speculate that when resuming a primary task after an interruption, recognizing a previous step to resume a Web task is a more difficult than recognizing the content of a task. By investigating aspects of memory in relationship to interruptions, this work builds upon previous research (e.g., Cutrell, 2001; Czerwinski et al., 2000; Trafton et al., 2003) conducted in the field of HCI.

4.8.2 Memory for Task Place and Task Content

There are issues associated with memory for resuming a primary task that contribute to poor Web task performance. By examining memory for task place and memory for task content, we can better understand types of assistance that need to be developed and whether users of mobile devices will benefit from certain forms of assistance. The increase in amount of time needed to complete a Web task interrupted by the computing system, can reflect problems with memory for returning to a specific step in a task, referred to here as memory for task place (e.g., Where was I?) or memory for task content (e.g., What was I doing?) for recognizing specific information on a task.

Memory for task place is the users recognition for the last location or step (e.g., filled in text box, clicked submit button) of an interrupted primary task. Memory for task content is a user's recognition for specific information on the primary task, (e.g., name of company stock). Specific content of the task is remembered in order to inform the user in continuing the primary task.

A user will suspend a task at a specific step, to move to an interruption task. For the user to successfully resume the suspended task, there has to be some recollection on the place or step in the task where the user left off. Web tasks are remembered based on the contents related to goals of the task. For example, the goal of a Web task is to buy a certain cookbook by Jamie Oliver or purchase 100 shares of stock from the company Cisco. In meeting the goals of the Web tasks users then broadly define Web tasks in terms of process that a user has to achieve. For example, find cookbook, pay for cookbook, make sure it is sent to the correct address, and confirm the order.

According to theory on attention, it is possible that the similarity of medium and interaction (i.e. two tasks on one device with similar interactions) creates interference causing confusion between the primary task and interruption task and contributing to difficulty with reconfiguring of attention for resuming the primary task (Altmann, 2000). We argue that contributing to the difficulty for resuming a primary task is the interference of the interruption task and decay of memory for the primary task. Therefore, interruptions are problematic due to the associated switch costs. During this process, it takes longer to recognize steps or content of the primary task in order to continue with the task. In addition, on a handheld device remembering where to resume a primary task can be more difficult due to the navigation and scrolling interaction that weakens memory for the place of resumption.

4.8.3 Hypotheses

H1: Resuming a Web task on a pocket PC is more difficult when compared to the desktop PC. On the pocket PC, difficulties with Web scrolling and paging leads to a weaker memory representation for resuming a primary task, than on a desktop PC.

H2: Resuming an interrupted task is more difficult on the desktop PC and pocket PC, than with no interruptions during a task. Interruptions are disruptive to user performance for resuming a primary task, due to memory decay and interference. This interference leads to confusion between the interruption task and the primary task, which results in poor memory performance.

H3: Remembering a place in a task is more difficult than remembering the content of a task. Tasks are typically viewed as a goal that needs to be accomplished (e.g., I have to find the ticker symbol for Coca Cola, I would like to buy 300 shares of Intel stock etc.), making it easier to remember the content, which is equivalent to a goal of a task. Users are forced into a sequence of steps in order to complete a Web task and do not often think of a Web task as a sequence of steps (e.g., click on buy stock button etc.), which makes it difficult to recollect a step in a task.

H4: Receiving an IM interruption during a Web task results in poor memory for task place when compared to memory for task content. After completing an interruption task, remembering the last step in the primary Web task is even more difficult due to the similarity of the interactions for the IM and Web task that creates confusion and the memory decay of short term memory to move attention from the primary Web task to the interruption task. The disturbance of the interruption task slows the general processing of the resumed Web task, which can lead to poor Web task performance.

4.8.4 Method

Participants

Twenty-four participants were recruited through the TNO Institute subject database. All participants met the same criteria stated in study 1 and received 3 hours of monetary compensation. Participants were randomly assigned to a pocket PC group (n = 12) or desktop group (n = 12).

Design

This experiment consisted of a between group variable for platform (pocket PC, desktop PC), and within group variables for interruption (interruption, none) and type of information (task place, task content) and the dependent variable consisted of memory performance scores for task place versus task content. The study design was a 2 x 2 x 2 repeated measures mixed design. Participants performed twenty-four tasks on the same financial and bookstore Web sites described in study 1 and 2 with two forms to balance the presentation of tasks.

The interruption tasks were counterbalanced using a Latin Square design. The tasks consisted of an instant message with simple addition, subtraction, multiplication and division questions. The simple math question were primarily arithmetic and consisted of single digit and a few double digit questions (e.g., give answer 7 + 3 = , give answer 10 – 6 = . The IM's sent to the participant were generated from a set of predefined math questions.

For the condition with an IM interruption the participant would first complete an instant message task, then received the memory question (Figure 4.19 and 4.20). In the control condition the memory question was presented and immediately answered by the participant. The user interaction with the memory question was limited to reading the question and selecting a radio button to submit an answer.

The evaluator would send the IM notification or memory question at a pre-designated place within a Web task that was matched across conditions for each task.

The interactions in switching between the Web task and IM messenger on the handheld and desktop were similar in number of steps and presentation. The participants in the desktop PC and pocket PC groups were trained to move from the Web task to the IM in the same number of steps. The visual presentation of the desktop IM screen was presented to the user in the center of the desktop monitor, with a gray background. The visual presentation of the instant message on the desktop, matched the presentation for number of answer choices and for switching between screens as on the handheld.

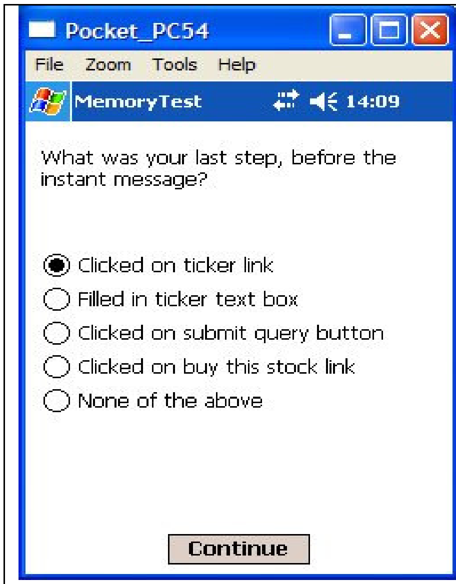

Figure 4.19. Pocket PC memory test

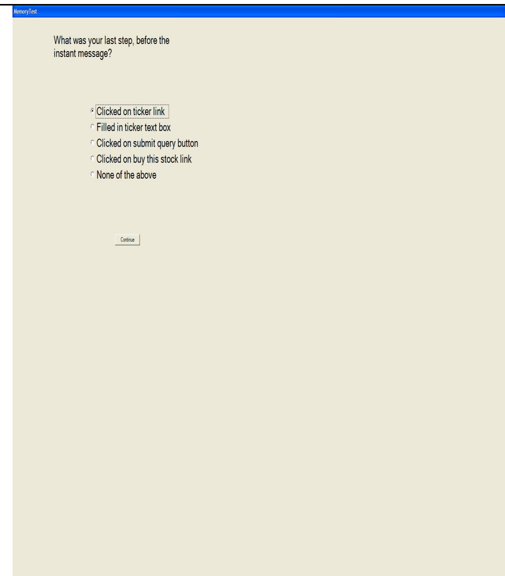

Figure 4.20. Desktop PC memory test

Material and Equipment

All Web and IM tasks were administered on a HP5550 or Dell desktop PC (see section 4.6.4 for details).

Procedure

The participants received the same study introduction, Web task and IM training and debriefing as in the first two studies. In addition, the participants were introduced to the memory questions that were presented on screen along with a practice session for answering the instant messages and memory questions.

As in the first two studies, the participant read a scenario and then began the Web tasks. The participants completed four types of tasks, Web tasks with an interruption task followed by a memory question, Web tasks only with a memory question, and Web tasks with and interruption and Web tasks with no interruption.

For the tasks with an interruption and/or memory question, after answering the instant messages, the participant received a “Done” message, then resumed and completed the primary task or answered a memory question (e.g., recognizing task place or task content) by selecting the correct answer from a multiple choice list and finally returning to complete the Web task. An example of the memory for place question, “What was your last step, before the instant message? The participant would make one selection by clicking a radio button for one of the following answers. 1) Clicked on purchase button, 2) Filled in number of shares, 3) Clicked on buy this stock link, 4) Clicked on submit query button, 5) None of the above. An example of the memory for content questions, “Which company stock did you purchase last?" A radio button was selected for one of the following 1) Prolog, 2) Perini corp, 3) Prologis, 4) Steelcase, 5) None of the above. For tasks without an interruption, the participant completed the Web task or is presented with a memory question (e.g., recalling task place or task content, similar to questions above), then completed the task. When the Web task was completed the participant continued with the next Web task.

4.8.5 Results

The mean performance scores for correctly answering a memory question were analyzed using repeated measures ANOVA (alpha = .05). There were no significant differences for performance between the pocket PC and desktop PC condition (figure 4.21 and 4.22). There was a main effect for tasks with interruptions $\underline{F}$ (1, 22) = 24.0, $\underline{p} < .001$. The mean percentage of correctly answered memory questions for interrupted tasks ($\underline{M}$ = 76%, $\underline{SEM}$ = 2%) was lower than for tasks without interruptions ($\underline{M}$ = 84%, $\underline{SEM}$ = 2%). There was no significant interaction effect between interruptions and platform.
There was also a main effect for type of information for Web tasks $\underline{F}$ (1,22) = 13.0, $\underline{p} < .001$. The mean percentage of correctly answered questions for task place ($\underline{M}$ = 74%, $\underline{SEM}$ = 3%) was lower compared to task content ($\underline{M}$ = 87%, $\underline{SEM}$ = 2%). There was no significant interaction effect between type of information and platform.

There was an interaction effect for interruption and task type $\underline{F}$ (1,22) = 11.5, $\underline{p} < .001$ (figure 4.23). An IM interruption has a greater negative effect on performance for remembering task place, whereas performance for remembering a Web task without an interruption task is relatively the same for task place and task content.

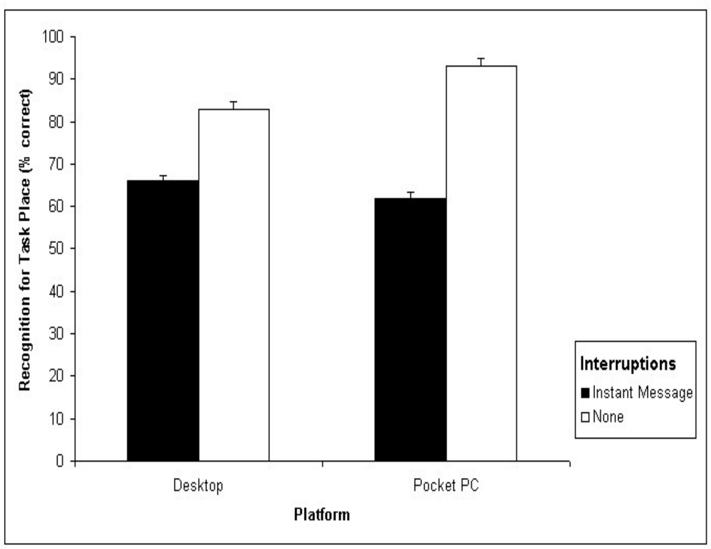

Figure 4.21: Task place

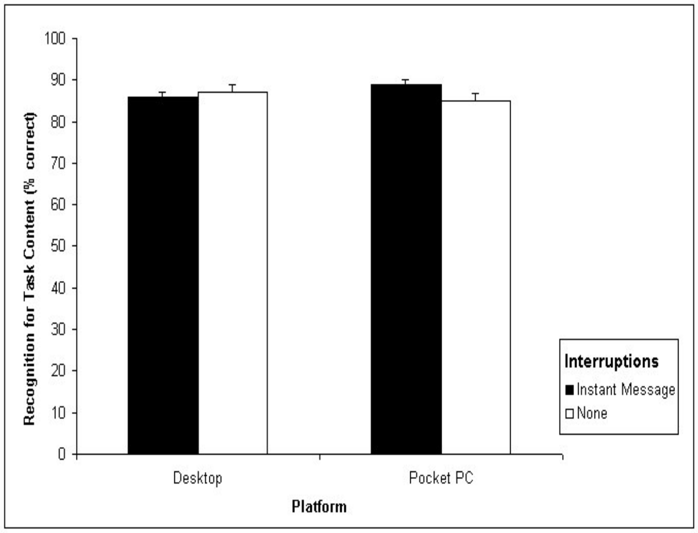

Figure 4.22: Task content

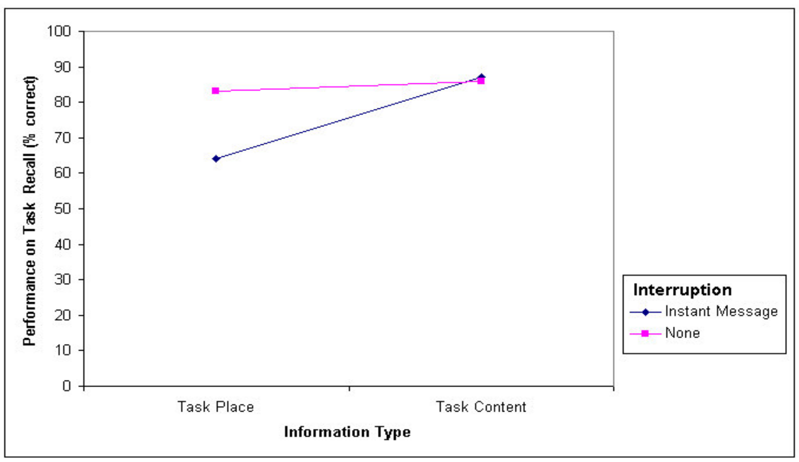

Figure 4.23: Recognition for information type with interruption

4.8.6 Conclusions

Our first hypothesis, that people have more difficulties with resuming a primary a Web task on a pocket PC, than on a desktop PC was not supported. This suggests that the intensive user interaction for navigation and scrolling does not necessarily lead to a weaker memory representation for resuming a primary task when compared to a desktop PC with a single-screen display. Controlling for user interaction using a single-screen display on the desktop PC to be similar to the pocket PC reduced differences between the platforms.

The second hypothesis, pertaining to the generally disruptive nature of interruptions on Web task performance on the desktop PC and pocket PC was supported. The participants had problems with remembering aspects of the Web task when experiencing an IM interruption task. The IM interruption negatively influenced the participants recognition of the Web task, more so than when no interruptions were received during a task. The disruption of the interruption task is attributed to the decay of working memory and (switch costs) interference created by the interruption. This leads to difficulty in reconfiguring a task for resumption resulting in poor memory performance.

The data supported our third hypothesis regarding type of information recognition. Remembering the last step in a task is generally more difficult than remembering the content of a task. There is a weaker memory representation for remembering the last step in a task. Retrieving information on a step in a task is more difficult and less intuitive to users, due to having to remember a sequence of steps or process to resume a task. In order to achieve a goal, users are often forced into an unfamiliar sequence of steps to complete the Web task, making it difficult to remember an exact place to resume the task. Whereas, users find it easier to remember contents of a task since it is related to a specific goal.

The data also support our fourth hypothesis on interruption and type of information recognition. The interaction effect suggests that Web tasks with an IM interruption were more disruptive to memory for resuming a specific place in a task, when compared to remembering task content. After completing an interruption task, remembering the last step in the primary Web task is even more difficult. This is due to switching between tasks using a single screen display, creating confusion and short term memory decay. The disturbance of the interruption task creates interference and slows the general processing of the resumed Web task, which can lead to poor Web task performance.

4.8.7 Discussion

There was no influence of computing platform on memory for a Web task. In this experiment, controlling for the number of steps in switching between the Web and IM application may have contributed to the absence of differences in memory performance between the pocket PC and desktop groups. We speculated that in the situation of serial switching between the IM and Web tasks, users on both platforms had worse memory performance due to a lack of orientation on the Web page. The interaction with the desktop PC when switching between the IM and Web site was made similar to the switching interaction of the pocket PC. In general the interaction in switching between an IM and Web task can be difficult for users on both large or small screens. The results show that memory for a Web task on a pocket PC and desktop PC can be generally problematic when a task is interrupted. Since no differences were found between platforms for remembering the primary task, this suggests that switch costs related to the interruption task was the primary contributing factor that negatively impacts memory, as opposed to the interaction with navigation and scrolling that can weaken the memory trace of the primary task.

Memory for a Web task can be supported by attention and memory cues (e.g., visual, auditory), by providing users with information to continue at a specific place in the task. Computing reminders of the task content can be used to support resumption of a primary task, although reminders of this sort are time consuming increasing the amount of time spent on the task.

Other factors that can influence memory for the primary task, includes the way users interpret Web tasks that influences memory. Memory for content of a task can be more easily recognized due to the associations made between goals of the tasks and the larger events taking place to complete a task. For example, when searching for a Jamie Oliver cookbook the goal of the task is clear and can be associated with the event of buying the book. The sequence of steps to purchase the book (e.g., click on next page, submit ticker symbol etc.) are prescribed by the business process or model of the Web task in order to get users to their end goal. Users do not typically internalize the sequence of steps in completing a Web task, which makes it difficult to remember a step in a task.

This experiment tested a users memory of the Web task by providing a multiple-choice list of items to measure recognition. Although the normal distribution of data showed that participants were comfortable selecting an answer from a list of items, it was not the ideal format to measure recognition in resuming the Web task. One could also argue that recognition from a list of items is more difficult and not equivalent to recognizing the last step from the Web page to continue a task. It would have been better to show users various images of the same Web screen and to have them indicate on the screen their last step. Several factors weighed against using Web screen images. Due to our interest in simulating the mobile context the Web sites were not extensive and the tasks were short. Using Web screen images would have been repetitive and too easy.

Does an IM interruption task influence memory for task place and task content for a primary Web task? After completing an interruption task, remembering the last step in the primary Web task was more difficult, than with no interruption task. We argue that difficulties in remembering the place of resumption after an interruption task are a result of the following: 1) A user's lack of Web page orientation related to serial switching between tasks. 2) The effects of an interruption related to decay of short-term memory for the primary Web task that is essential to move a user's attention from one task to the next. 3) The confusion a user experiences when moving between similar types of tasks. 4) The users generalized knowledge of Web task processes, which does not promote memory for specific steps in a task. The disturbance by the interruption task slows the general processing of the resumed

Web task, which can lead to a longer amount of time needed to complete a Web task. Understanding user recognition for specific steps in a Web task or the content of a task after an interruption provides insight into the type of assistance needed by users, for successful and timely completion of Web tasks. We follow up on these issues and give further theoretical explanations in chapter 6 section 6.2.2.

4.9 General Conclusions

Our experiments have shown that Web tasks on a mobile device take longer to perform due to constraints of using a mobile device (e.g., difficult data entry and inadequate Web design for a small screen requiring intensive scrolling), than on a desktop platform. Interruptions generated from a handheld or desktop computing platform, with a single-screen display having serial switching interaction, are disruptive to a Web task, when compared to Web tasks without interruptions. This type of serial switching between tasks, results in costs to performance that negatively influence a user's attention and memory creating problems for resuming the primary task. These are considered to be contributing factors that negatively influence performance on a Web task.

When handling interruptions the switch costs are related to the increase in Web task performance time. The increase in performance time is attributed to memory decay and interference (e.g., serial switching and similarity in interaction between tasks), leading to confusion for resuming the primary task. There are specific attributes of the primary task that are more easily disrupted such as recognizing a specific place in a task more so than recognizing the content of the task, resulting in poor memory performance. Remembering a place in a task is critical to resuming the primary task. This aspect of a task may be more vulnerable due to the cumulative burdens of memory decay and interference from an interruption.

Our research suggests that by changing or enhancing certain characteristics for receiving and handling of interruption may facilitate attention and memory for resuming and completing a Web. Anticipation of an instant message, promoted expectation for receiving an interruption leading to efficient Web task actions to resume the primary task. Although the user did not know when the interruption task would be received during the primary task, by receiving some information on the interruption task beforehand, this helped the user to handle the interruption leading to faster resumption and continuation of the primary Web task.

By examining the influence of the content characteristics of an interruption task, we found that a simple interruption task requiring repetitive interaction for completing an interruption task was more disruptive than a complex interruption with less repetitive interaction. This suggests that an interruption task does not have to require a high amount of cognitive processing to be disruptive. However, a high amount of interaction can be disruptive to the primary task.

As for the use of a specific modality for handling the interruption task, using the same keyboard modality for the interruption and primary task is less disruptive than switching between voice for the interruption task and use of the keyboard for the primary task. The use of a speech interface is not common and may not be an appropriate modality of choice for handling of IM interruptions on a mobile devicel. A learning overload situation may also exist for the user when switching between two modalities, resulting in a negative impact on the primary task, especially for new users to the mobile Web.

Cognitive switching ability and desktop Internet experience were indicated as predictors on user Web performance when handling interruptions. These predictor variables provide some guidance for predicting user performance for interruption handling on a mobile device. Further research is needed to include users who have experience with the mobile Internet to provide better insight into user task performance for interruption handling, on a mobile device. In light of the results that experience from the desktop Internet does not transfer to use of the mobile Internet, platform specific models need to be developed to appropriately assess and predict user performance for handling interruptions.

Chapter 5 Usability of Attentive Indicators with the Mobile Web

Abstract

Interruptions are disruptive to user performance on a mobile device. We propose the use of visual markers such as an automated point of return indicator (PRI) and a user controlled interactive suspension point (ISP) to support a user with resuming a primary task after an interruption. The use of an attentive indicator was evaluated for an interrupted Web task on a handheld device, during a sitting and walking condition. When compared to a control group with no support, use of the PRI indicator showed a positive trend in reduction of Web task performance time, in the walking and sitting condition. Use of the ISP in a walking situation is beneficial; whereas, using the ISP while sitting in an office is less beneficial to performance. Study participants generally found the ISP and PRI easy to use. However, the utility of the indicators were not always recognized. We also found that cognitive switching ability is a predictor of user performance when using the support concepts. Cognitive switching ability may be included in a user model to predict user performance.

5.1 Introduction

People experience problems remembering where to resume a task that was interrupted on a mobile device, due to confusion from switching between tasks, loss of orientation cues when paging between Web screens or when moving between applications. In chapter 4, our third experiment showed that interruptions influence memory for continuing a task. An interruption was more disruptive to memory for recognizing a specific place in a task (point of resumption on a primary task), when compared to recognizing task content (task information). This finding indicates that memory for resuming an interrupted Web task can be problematic. Guiding a users attention and memory within a task may aid performance in handling interruptions when using a mobile device. The focus of this study is to investigate the influence of attention indicators on mobile Web task performance. The theoretical basis for the attention indicators has been discussed in the subsection 4.1 in relationship to task switching, multitasking, attention and memory.

There are general methods to aid a users memory to return to a specific location when using the Web. A search history is used to locate a Web page that a user has previously searched for and visited. Most Internet browsers have a history list that shows all the locations that a user has visited and the search keywords typed by the user. Use of the history list often requires additional steps in searching through and selecting from a list of relevant and irrelevant Web pages and not all the details of browsing can be captured by a search history. For example, if browsing a list of items or a table, a search history does not capture a specific line of information of which the user is focused on unless it can be first selected in some fashion and then recorded by the history list. Bookmarking is a more general form of marking a Web page in order to return to the Web page at a later time. The search history and bookmark method have been very successful in returning users to a specific page of interest on the Web. Herder (2006) has suggested more advanced automated forms of updating bookmarks, based on highly frequently visited pages. For less frequently visited Web pages a search history that recognizes previous queries, or an annotation that reconstructs a trail for to find a previously visited Web page. Similar to how these methods return a user to a Web page, we focus on specific ways to aid in resuming a specific place or step in a task after an interruption.

By aiding memory, the effects of an interruption are minimized and users reactions are facilitated (McCrickard et al., 2003). Cues that highlight information using color, shape and motion can help to detect and recognize information in short quick glances. Work done on notification systems as a secondary display have utilized various techniques for capturing the attention of the user. Some examples of these techniques include use of Rapid Serial Visual Presentation (Oquist & Goldstein, 2003) and Search Mobil (Rodden et al., 2003) (see section 2.5 for further description). A series of experiments by McCrickard et al. (2003) found that animation such as a scrolling ticker (i.e. a company stock symbol and stock price) or an in place fading ticker display, can be used in a secondary display with little disruption to a user's primary task. This suggests that it is also possible to use color, shape or motion for cueing a user's attention to resume a primary task without disruption to the user.

The Use of Visual Markers with Interrupted Tasks

A study by Czerwinski, Cutrell and Horvitz (2000b) examined the effects of instant message interruptions on a book title search task on a desktop computer. This study investigated whether there were harmful effects of IM interruptions on a primary task for visual scan, target identification or remembering the goal of the task. A displayed marker was used as a reminder for returning to a primary search task. It was concluded that notifications from IM demonstrated harmful effects on a search task, and that a marked position in a search list for "verbatim" book titles did not improve subjects performance, when compared to search of a title by "gist" (given the main theme of the book). It was not clear as to whether difficulty in visually reorienting to a task resulted from the disruption caused by the IM notification.

The first issue raised by Czerwinski et al., (2000b) concerns the resulting costs to performance time from interruptions and the implications on use of the marker. This experiment by Czerwinski et al., (2000b) suggests that costs to performance on a primary task can involve difficulty with memory when continuing with a primary task. When a computing task was interrupted users more often requested reminders for the task (e.g., reminding them of what they were searching for) than in situations without instant message interruptions. A request for a task reminder was more likely if an instant message was sent early on in the task compared to tasks that were interrupted at a later stage.

The second issue is the use of the displayed marker by participants to identify a location in the search task. Czerwinski et al., (2000b) gave three reasons for the inefficient use of the marker during the search tasks. 1) A confound navigation for use of the arrow keys in the marked condition and the page up and down keys in the non-marked condition possibly masked the positive effects of the marker. 2) The participants may not have actively employed the cursor for position management. 3) The search screen was continuously displayed.

These issues were addressed in a follow-up experiment by Cutrell, Czerwinski and Horvitz (2001) resolving the navigation confound and better overall control for timing of notifications and automated data collection. The search task was not provided at the top of the screen as in the previous study and the search task was more difficult by having the user explicitly request a search task reminder via a button press. The marker was displayed as a reminder for where the participant left off in their primary task. This study investigated the value of the marker as a reminder to the participant and the effects of interruptions during an evaluation of a list of results in a Web search task for visual scan, target identification or remembering the task. It was concluded that the notification trials were much slower than trials without notification. Reminders were requested more in the gist condition with notifications compared to searching for titles with notifications. The notifications sent early on in the search task were more likely to request a reminder. There was no observed effect of markers.

The Czerwinski et al., (2000b) and Cutrell et al., (2001) experiments used a desktop size screen affording the display of more than one window. By having both the search task screen and instant message screen fully or partially visible, leads to a concurrent type of interaction where both tasks are easily kept active in working memory, possibly rendering the marker less effective. Concurrent interaction between two displayed screens for a primary task and interruption task may have less of a disruptive effect on performance than having to serially switch between two screens presented one at a time on a display. Other influences include that an active window or mouse cursor may act as a contextual cue that aids a person to resume a primary task (Trafton et al., 2003). For example, when a user manipulates two windows, the window in the foreground can be used as a cue to direct a user's attention to return to information on the window in the background.

Although the studies by Czerwinski et al. (2000b) and Cutrell et al. (2001) did not find a positive effect of the markers on interrupted task performance on a desktop, we expect that visual markers will have a positive effect on interrupted performance on a handheld due to the single-screen display and serial switching interaction constraints of the handheld device.

5.2 Experiment 4: Use of Attentive Indicator Support During Interrupted Web Tasks in a Walking and Sitting Context

An attentive indicator can be a visual marker, voice cue or some form of a guide that attracts a user's attention to resume a task after an interruption. A users memory for remembering a location on a page can be weakened due to scrolling on a small screen.

Dillon, Richardson and McKnight (1990) showed evidence that visual memory is established for a specific location of an item within printed text based on spatial location. Therefore fixed relationships are stored in memory between an item and a position on a given page. When scrolling, or switching between screens relationships of positional cues are weakened. An attention indicator is expected to focus a users attention to a specific place on a Web page and cue memory to help a user with remembering where to continue a task. Research by Nagata (2003) and Nagata and van Oostendorp (2004), have suggested two attention indicators: the Point of Return Indicator (PRI) and the Interactive Suspension Point (ISP).

Point of Return Indicator

The PRI is automatically produced by the system to direct a user's attention back to a point in a task that has been suspended due to an interruption. This specific form of an attention indicator, can be utilized for tasks that are structured to follow a sequence of steps. Filling in forms for purchasing an item, personal information and financial transactions are examples of tasks that are done in a stepwise fashion on the Web. The computing system can track a users location when following a predictable and organized series of steps, and presents a PRI after the user experiences a computing interruption (e.g., IM, calendar reminder). For example, on a handheld device a user is filling in a form to transfer money to savings, a beep is heard and the user answers an Instant message, when returning to the form the user continues the task (e.g., a highlighted text box) as indicated by the PRI. In figure 5.1, a customer is typing in a company name and then receives a computing interruption on the device. In figure 5.2 the customer has returned to the same screen and a PRI cues the customer to resume the task. In this first example the automated marker cues the user by indicating the resumption point in the task. The PRI pinpoints the location to continue the task aiding attention and memory for what still needs to be done for the transaction.

In our study we tested the PRI by showing the resumption point in the task. There are several variations of the PRI indicator that can be presented to the customer. A second example, the PRI can indicate the users last step in the task prior to the interruption. The PRI cues working memory for the last step in the task, which indicates what the user had already done in the task. The third example of a PRI can indicate to the user each step that is being done throughout the task. The indicator follows a users progress on a fill-in form moving from one step to the next. This type of PRI can be used for longer forms to help the user track each step and recover from interruptions. These last two examples can provide guidance of attention to the last place in a task (Neerincx, 2003). There are considerable constraints to attention and working memory when multitasking (Cutrell, et al., 2001; Miyata & Norman, 1986; Oulasvirta & Saariluoma, 2004; Trafton et al. 2003). By placing the PRI at a specific point in a task, this will cue a user's attention and memory to continue a task (see section 4.1.).

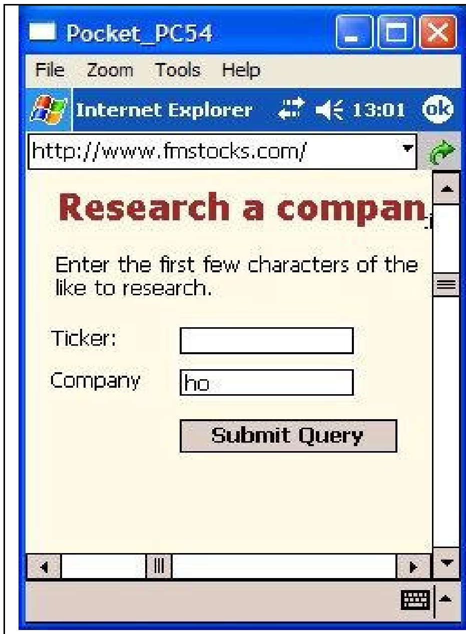

Figure 5.1: Find company Home Depot before interruption task

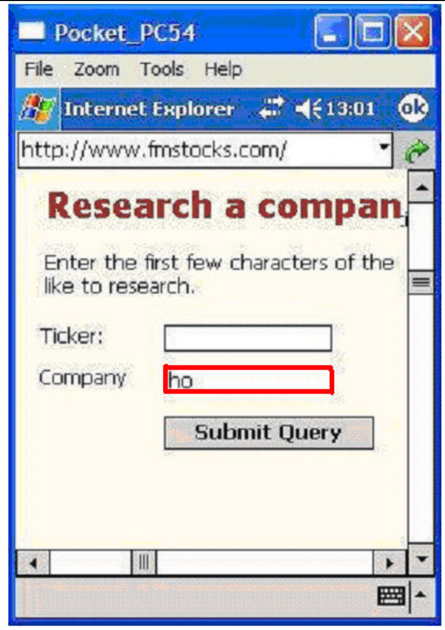

Figure 5.2: Form fill in with PRI after interruption task

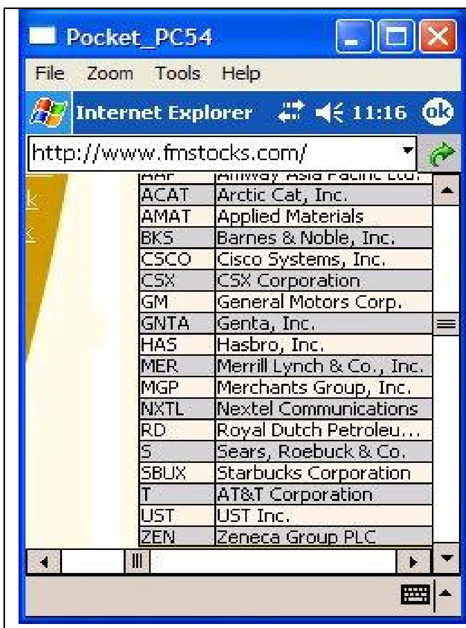

Figure 5.3. Browsing items in a table

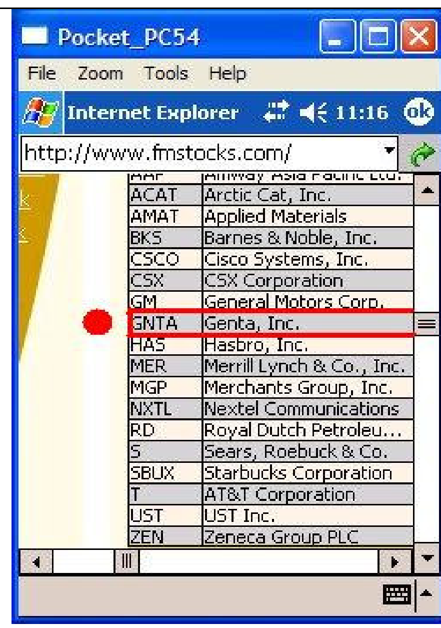

Figure 5.4. An ISP marker indicating a specific place to return to

Interactive Suspension Point

The ISP is an attentive indicator that assists the user to interact with the information on a Web page, by setting a marker on a specific place to resume a task. The user selects the resumption point by tapping the screen to produce a marker. When the user continues a task, the indicator directs the user's attention back to that specific marked point in the task.

The ISP is used for tasks that are structured by the user, such as browsing or searching for information. Often when a user is browsing or searching for information, the user's task of searching for information is dependent on many situational factors, such as the objective for browsing, amount of time available, and interest of the user, which can be difficult to define and track. Once a user finds an item or a piece of information, returning to the information or item again in a quick manner becomes crucial. Another factor is the layout of a Web site, which may require a heavy use of scrolling or paging to find a specific item. Even when using a search engine, there are lists of items that need to be sifted through in order to find specific information. Placing a marker gives the user a specific target for focus and reorientation to resume the primary task when the browse task is interrupted. There is a benefit to cueing working memory since there are no other guides available. In the PRI example, indicating the following step in the task is the most logical because there is a clear sequence of steps. With a browse task there is no sequence to return a user to a specific location, except when the user indicates a specific location in the task. The act itself of setting an ISP indicator is also a confirmation for deeper levels of processing to maintain the task in memory.

To expand on the idea of bookmarks, the ISP provides a more detailed point of return, to a specific line in a table or a specific item in a list of items that can be selected by placing an indicator (figure 5.3 and 5.4). It is expected that allowing a user to select a specific target on-screen using an ISP can be beneficial to user Web performance for browse and search types of tasks. Do the PRI and ISP support a user's attention and memory for resuming an interrupted Web task? To appropriately evaluate use of the attention indicators on a handheld, there is a need to consider the context and validity of use in a mobile context. The next section discusses the major issues concerning usability evaluations of handheld devices.

5.3 Evaluating Use of a Mobile Device in a Walking and Sitting Context

Due to the ubiquitous nature of mobile devices, people use their devices in different environments other than just sitting indoors. In reality mobile devices are used in different situations, sitting on a bus, at the shopping mall, while walking through a street or building etc. This calls for an extension of the traditional usability evaluation methods of sitting in the lab, in order to account for the various contexts in which a mobile device can be used.

Research on the usability of mobile devices in varying contexts of use has been concerned with the issue of relevance versus rigor, which is the trade-off between tightness of control and richness of reality. Comparisons have been made examining usability testing in a field setting (e.g., outside environment, and roaming) and laboratory setting. It is often complicated to establish controlled yet context rich studies. A study by Beck, Christiansen, Kjeldskov, Kolbe, and Stage (2003) described that in a field setting, control of the set up is limited and dependent on surrounding, special equipment is needed to capture good data and data collection is complicated when capturing usability evaluation techniques (e.g., think aloud protocol). In a laboratory setting there is control over the experiment but realism is lacking and there is a risk for irrelevant results (Lindroth & Nillson, 2001).

Three usability evaluation methods were investigated by Lindroth et al. (2001) to verify their usefulness for finding usability problems on mobile gadgets. The three methods were performance measurement, the co-discovery method and the pluralistic walkthrough. The results indicate that these techniques can provide information about usability problems on mobile devices in a controlled laboratory environment. However, these methods are not completely suitable to effectively capture usability problems in multi-context use. The study by Beck et al. (2003) investigated use of a mobile device in six different contexts: sitting, walking on a treadmill at constant speed, walking on a treadmill at varying speeds, walking on an 8-shaped track, walking on a changing track and finally walking on a simulated pedestrian street. They found significant differences in subjective measures of workload due to the different contexts and various speeds of movement. In the sitting condition the participants on a global level divided attention between two actions (e.g., solving a task and think aloud) and in the field the user will divide attention between three or more actions (e.g., solving task, think aloud, and walking). Unfortunately no single technique represented the workload equal to walking in a real pedestrian street. Walking in a pedestrian street is best simulated by factors that combine varying body motion (walking) and more conscious use of attention (sitting). The sitting condition was better than the other techniques for identifying usability problems, especially cosmetic issues. In the field condition more serious or critical problems were identified with interface layout, size and placements of elements.

Several studies have indicated the usefulness of walking experiments for mobile usability evaluation. Brewster (2002) has shown that usage of mobile devices in a walking situation significantly increases usability problems in terms of workload when compared to sitting in a usability laboratory context. The recommendation is given that testing of mobile devices should be performed in realistic situations apart from a merely controlled usability lab situation in order to get a good measure of a device's usability.

Test environments specifically for evaluating use of wireless devices are being examined. Melcher, Sefelin, Giller, & Tscheligi (2003) recognized that varying the context of use is an important issue in mobile usability. In order to adapt mobile applications to a fluid context a mobile test environment is needed to effectively study related issues in varying context of use while preserving data collection equivalent to a controlled lab situation environment. There are methods and tools being developed for measuring mobile device software/hardware parameters, user characteristics, geographic positioning, sound/light conditions, and social context. A thorough set of parameters collected by a mobile lab makes the lab usable both indoors (office or home environments) and outdoors (car, train, street), as well as providing online logging and monitoring tools.

In general, studies suggest that a balance is needed in mobile device research to ensure the rigor for reliability and validity of study results and the relevance for applicability to real life contexts of mobile device use. In our experiment a goal is to capture the Web performance time of a user on a handheld device during use of the attentive indicators in both a sitting and walking condition. Based on the goal of our study and current technical limitations of our lab in capturing data in an outdoor environment a laboratory setting was chosen for this study.

Hypotheses

H1: Use of the PRI on Web tasks with interruptions will be beneficial to Web task performance time. The PRI will focus a user's attention for resuming a task at a specific step in the task allowing for re-orientation to the task and stimulating memory on what needs to be done on the task.

H2: Use of the ISP on Web tasks with interruptions will be beneficial to Web task performance time. The ISP will focus a user's attention on a specific step in the task allowing for re-orientation to the task and stimulating memory on what needs to be done on the task.

H3: Use of the Web while walking and handling interruptions increases Web task performance time, compared to sitting and handling interruptions. Higher levels of attention to resume and complete a Web task are needed when walking and using the mobile Web.

5.4 Method

Participants

A total of 36 participants were recruited from the TNO research institute database. Participants received monetary compensation for 3 hours of participation and fulfilled the study criteria given in study 1. An additional requirement was that the participant had not participated in any of our previous studies. Participants were randomly assigned to a PRI group (n = 12), ISP group (n = 12) and control group (n = 12).

Design

This experiment consisted of a between group variable, support (ISP, PRI), and a within group variable, user state (sitting, walking) for a mixed repeated measures design. The dependent variable was measured as Web task performance time. The tasks consisted of information search and transaction tasks from a financial stock Web site (e.g., buy stock, find stock company information). A total of 24 tasks were administered, consisting of 12 tasks for the sitting condition and 12 tasks for the walking condition. The order of presentation for the user state (e.g., sitting/walking, walking/sitting) was counter balanced.

Half of the subjects began with the sitting or walking condition. The 12 tasks were presented as follows: for the groups with support (PRI, ISP) there were four interrupted tasks with presentation of the attention indicator, for example the PRI group received four interrupted tasks with the PRI attention indicator. There were also control tasks administered as interrupted tasks without the attention indicators. The instant message interruptions consisted of 3 or 4 simple math questions (subtractions/additions) that were delivered and paired with the tasks. There were eight other tasks that were control tasks with no interruptions.

Material and Equipment

All Web and IM tasks were administered on a HP5550 or Dell desktop PC (see section 4.6.4 for details). The Web site content was a financial Web site, Fitch and Mather from An Enterprise Sample of Visual Studio.Net developed by Microsoft. To maintain automated control of the PRI and ISP presentation and interruptions, the Web site was made into an application using Visual Basic and C-Sharp.

The Digit Span and Trail Making A and B tests were administered to participants (see section 4.5.4 materials and equipment). The user questionnaire assessed satisfaction on use of the ISP and PRI indicators. The participants rated use of the indicators based on a 7 point Likert scale.

Procedure

The participant first filled out a consent form and received a general explanation of the testing goals and the lab video recording and intercom set-up. The participant filled out a questionnaire and received a training session on use of the pocket PC, Web sites and two practice tasks, use of the attention indicators and instant messaging. The task instructions were presented in a separate task window on the handheld device. The participants were allowed to switch back and forth between the Web site and task instruction. The session consisted of the first scenario with Web tasks, and administration of the Digit Span Memory Test and the Trails A and B test, a short break was given followed by the second scenario with Web tasks and a short questionnaire.

To begin the testing session, the participant first read a short scenario describing the context (e.g., lunch break at work) and goals (e.g., diversifying stock portfolio) for completing the Web tasks. The participants were instructed to respond to the instant message as in a chat with the evaluator. Each participant began with either a sitting or walking scenario. For the sitting scenario the participants sat at a desk with the pocket PC and for the walking scenario the participants walked on a designated repeating path through three rooms. When conducting the Web tasks the participants either received an instant message that consisted of simple addition and subtraction math tasks (e.g., Give answer: 3 + 9 =___ or Give answer 13-8 =___) or was not interrupted. After the interruption, the participants returned to their primary Web task. The performance times and number of times that the task instructions were viewed was automatically collected and logged for analysis.

User performance was collected from the following: 1) beginning of primary Web task to the notification 2) interruption task, 3) primary Web task to completion. The data analysis consisted of the mean performance times for completion of the primary Web task, excluding the interruption task. The number of errors was recorded for typing errors and correct completion of tasks.

5.5 Results

The data was analysed in a 2 x 2 fashion comparing the ISP and PRI to control tasks in the sitting and walking condition[2]. Missing data points and outliers were assessed using histograms, Mahalanobis Distances and homogeneity. The missing and outlier data points were attributed to one task, which was eliminated from the data set. There are no reported results on performance errors due to issues with data collection and protocol (see section 5.7 for more detail).

The Web performance times were analyzed using repeated measures ANOVA (alpha = .05). All mean values are reported in seconds. There was no significant difference between the PRI and control group $\underline{F}$ (1, 20) = 1.02, $\underline{p}$ = .323. The descriptive statistics of the mean data reflect a trend that the PRI was beneficial for performance on Web tasks with interruptions in both the sitting and walking conditions (Table 5.1). In figure 5.5 the means for PRI and Control are graphed. There was a significant main effect of user state $\underline{F}$ (1, 20) = 15.35, $\underline{p}$ < .001. Overall, users were less disrupted by interruptions when performing tasks sitting at a desk ($\underline{M}$ = 110, $\underline{SEM}$ = 3) than walking ($\underline{M}$ = 129, $\underline{SEM}$ = 6). There was no significant interaction effect of user state and group.

There was no significant difference between the ISP and control group (Table 5.2). However, a strong interaction effect was found for user state and group $\underline{F}$ (1, 20) = 8.02, $\underline{p}$ < .01. Figure 5.6 shows that the effect of the ISP was detrimental to performance on Web tasks with interruptions in the sitting condition but beneficial in the walking condition.

Table 5.1: PRI mean Web task performance times

	User State	
	Sitting	**Walking**
PRI	105 sec, 5 SEM	126 sec, 8 SEM
Control	115 sec, 5 SEM	130 sec, 8 SEM

[2] An analysis comparing the PRI and ISP groups to each other was not warranted due to the attention indicators supporting different types of tasks (i.e. PRI supported transaction tasks, ISP supported information search tasks)

Table 5.2: ISP mean Web task performance times

	User State	
	Sitting	**Walking**
ISP	138 sec, 7 SEM	118 sec, 9 SEM
Control	119 sec, 7 SEM	129 sec, 9 SEM

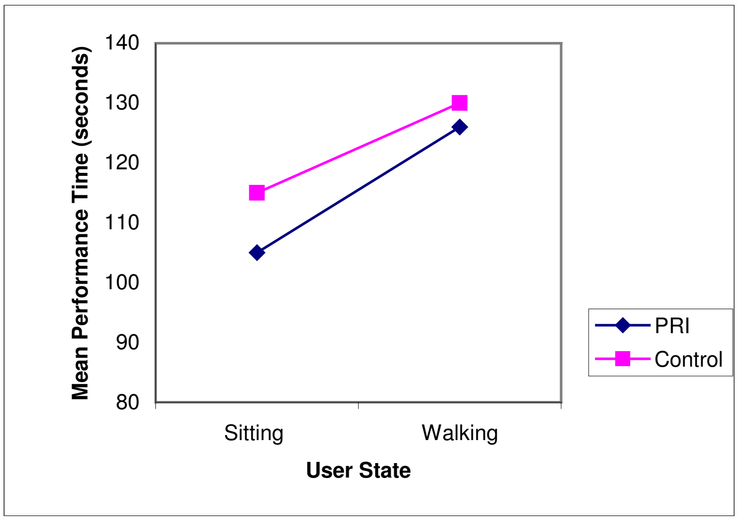

Figure 5.5: PRI and user state for interrupted Web tasks.

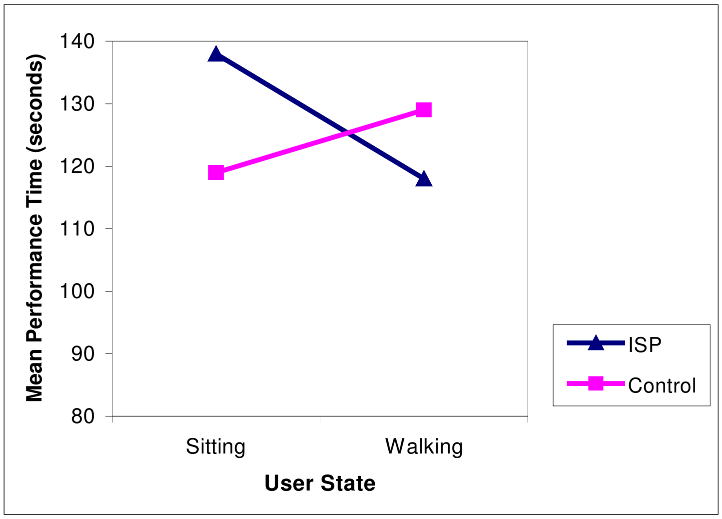

Figure 5.6: ISP and user state for interrupted Web tasks

Viewing of Task Instructions

An analysis of variance was used to examine the number of times users viewed instructions for a task. There was a significant difference between users viewing the task instructions in the ISP sitting condition (M = 3, SEM = .3) and the control condition (M = 2, SEM = .15), $F(1,22) = 4.87$, $p < .05$. There were no differences found for the ISP walking condition compared to the walking control group. There were also no differences found for the PRI walking and PRI sitting condition compared to the control group.

User Questionnaire

The questions related to use of the PRI and ISP and users responses are summarized in table 5.3 for the PRI and table 5.4 for the ISP. All participants using the ISP found that it was clear on how to use the ISP and 80% of users thought that the ISP was helpful in orienting them to their location in the Website. However, the participants were less sure as to whether the ISP helped them to remember where to resume the Web task after the interruption task. Also 80% of the participants felt that it was frustrating that the marker was visible when they were not using the ISP.

As for use of the PRI, more than 50% of the participants agreed that the PRI was noticeable on screen when a textbox or button was highlighted. Sixty percent of the users did not feel that the PRI helped them to remember where to resume the Web task after the interruption. The automatic presentation of the PRI frustrated more than half of the users.

Table 5.3: Participant ratings on use of PRI

It was clearly visible to me when a textbox or button was automatically highlighted	Disagree = 30% Neutral = 10% Agree = 60%
I feel the highlighting of textboxes or buttons helped me to remember what I was doing before an instant message.	Disagree = 60% Neutral = 0% Agree = 40%
I felt frustrated when parts of the website were highlighted without asking for it.	Disagree = 40% Neutral = 0% Agree = 60%

Table 5.4: Participant ratings on use of ISP

It was clear to me how to tap the screen to make the colored dot visible.	Disagree = 0% Neutral = 0% Agree = 100%
Using the colored dot helped in orienting myself on the website.	Disagree = 10% Neutral = 10% Agree = 80%
I feel that using the colored dot helped me to remember what I was doing before an instant message.	Disagree = 20 % Neutral = 35% Agree = 45%
I felt frustrated when the colored dot was visible when I had no use for it.	Disagree = 0% Neutral = 20% Agree = 80%

User Model for Predicting User Performance with Support Concepts

Regression analysis was used for the PRI (n = 12) and ISP (n = 12) groups to find variables that predict user performance when using support concepts with interrupted Web tasks. The variables included in the analysis were related to self rated level of computing experience, years of desktop Internet use, desktop weekly Internet use, mobile weekly Internet use, cognitive switching ability (i.e. Trails A & Trails B), memory ability (i.e. Digit Span) and spatial ability. The measure of cognitive switching ability was the only significant correlation shown with interrupted Web performance time, there were no other significant correlations with the other variables. Cognitive switching ability was a significant predictor variable for user performance with PRI in the sitting condition ($\underline{p} < .05$), adjusted $R^2 = .354$, Beta = .642 and for ISP in the walking condition ($\underline{p} < .05$), adjusted $R^2 = .323$, Beta = .620.

Table 5.5: Predictor variables for interrupted Web task performance, significance at $p < .05$. Adj R^2 =Adjusted R^2 is the amount of explained variance. The regression equation consists of the constant and the unstandardized beta coefficients for each predictor variable.

Platform	**Dependent Variable**	**Predictors**	**Adj R^2**	**Regression Equation**
Handheld	Performance time with PRI support (PTPRI)	cognitive switching ability (csa)	35%	PTPRI = .62.0 + 1.31*csa
	Performance time with ISP support (PTISP)	cognitive switching ability (csa)	32%	PTISP = 86.26 + .679*csa

With the use of PRI there was a significant correlations for Web performance time in the sitting condition with cognitive switching ability, r = .642 (p < .05). For ISP there was a significant correlation for Web performance time in the walking condition with Trails B, r = .620 (p < .05) (table 5.5).

5.6 Conclusions

In conclusion, the study results suggest that there are specific considerations that need to be taken into account based on the type of attention indicator and context of use. As stated in the first hypothesis, use of the PRI on Web tasks with interruptions will be beneficial to Web task performance time. The results did not indicate a significant positive effect of the PRI on interrupted Web tasks. However, the means did reveal a positive trend in reduction of time for Web task performance with use of the PRI saving 10 seconds in the sitting condition and 4 seconds in the walking condition, compared to the control group without aid. The trends in the means suggest that a further detailed study examining the PRI is needed.

The second hypothesis stated that use of the ISP on Web tasks with interruptions is beneficial to Web task performance time. The significant interaction effect showed that use of the ISP can be beneficial to Web task performance dependent on the specific context of the user. Use of the ISP in a walking situation is beneficial, whereas using the ISP while sitting in an office may be more harmful to performance. This suggests that in intensive situations where a user's attention resources are taxed, user interaction of consciously placing an ISP on the screen with a stylus can effectively cue working memory which leads to better performance on a search or browse type of Web task. Whereas, in the sitting condition use of the ISP lead to more time needed to perform a Web task and users had to view the task instructions slightly more often. Users may have felt that they had more time to complete tasks and used the ISP for other purposes such as a generic place marker when scrolling. Use of an ISP indicator with search or browse types of tasks was more beneficial to Web task performance in a walking or busy context that really taxes attention and working memory.

The third hypothesis considers use of the Web while walking and handling interruptions increases Web task performance time, compared to sitting and handling interruptions. Indeed a significant main effect was found for user state. This suggests that using the Web while handling interruptions is influenced by context of use and compounding the effects of the walking condition by increasing the amount of attention and workload involved in completing a Web task

As for user satisfaction on support assistance we conclude that it was straightforward to the users on how to use the PRI and ISP and that each indicator was clearly visible and attracted their attention. However, the users were not very sure if the support was helpful or useful to them for resuming the primary task and felt frustrated when the indicators were presented and not relevant for use during the task.

In deriving specific user characteristics pertinent for a user model for multitasking and interruption handling, cognitive switching ability can be used as a predictor for multitasking performance with the PRI in the sitting condition and ISP in the walking condition. Measuring cognitive switching ability can help to predict whether the user should receive interruption assistance and how the assistance influences the users task performance while sitting and using the PRI or while walking and using the ISP.

5.7 Discussion

Use of the PRI and ISP for supporting multitasking on a mobile device can be beneficial to user performance. An interesting trend can be seen in the results for the PRI indicating that automated user assistance can have some added value in terms of supporting a user’s attention when resuming a primary task after an interruption. Although the differences between use of the PRI and no support were not significant the means show some interesting savings in amount of time on the primary task.

The ISP indicator as a user-controlled marker is beneficial to users under certain conditions or situations. There are two possible explanations for the long task performance time when using the ISP in the sitting condition. The observation videos showed that users had other uses of the ISP, besides as a marker for indicating a resumption point after an interruption. The ISP was also used as a generic placeholder while scrolling or paging and not just for resuming the primary task after the interruption. The ISP was used as a tool for table browsing. For example, the ISP marker was used to mark a row of a table then scrolling horizontally or vertically making it possible to view all the information in the row of the table. In addition users had to view the task instructions slightly more often than in the control condition when using the ISP, contributing to a lengthier performance time. The extra use of the ISP and additional viewing of the task instruction contributed to an increase in Web performance time. In the walking condition there is an increase in demand on the user’s attention for walking and doing the Web task while receiving interruptions. The users had more efficient use of the ISP. The results showed that participants using the ISP perform 20 seconds faster on average in the walking condition than in the sitting condition. As the subjects were busy with doing more than two tasks, they used the ISP indicator more efficiently, by placing the ISP as a placeholder primarily as a resumption point after the interruption task, rather than as a generic placeholder while scrolling or paging.

Overall the users were fairly satisfied with the presentation of the PRI and ISP. However critical issues on use and meaning of the ISP and PRI need to be addressed. As mentioned in chapter 3, enhancing understanding for use of assistance can aid a user to feel more comfortable with the implemented use of assistance. The use of the ISP seems to help a user in orienting on the Web page; however users spend more time on a task when using the ISP while sitting.

Measuring task performance time provides insight on how long it takes for a user to complete a task, although it does not say anything about task accuracy. Making many errors in a short amount of time can be considered worse performance than making no errors at all in a longer amount of time. There were a few circumstances concerning the application for this experiment and errors made by the investigator that influenced collection of the error data. First, the users had to follow a certain path in the task so the support concept would be presented at the appropriate moment minimizing the chance of gross error. The tasks were also meant to be rather simplistic and short, which is more realistic of mobile Web tasks, which minimized the number of potential errors. Second, the automated data collection process logged the keystrokes for each task. Unfortunately, we could not distinguish the different keystrokes in a completely unambiguous way making the data unsuitable for analysis. Third, an error in our data collection protocol resulted in loss of information on errors. Future research should include error measurements to facilitate unequivocal results.

Examining the use of support in a sitting and walking context is essential to understanding how effective assistance support can be for managing interruption on a mobile device. As we have shown in our study not all support concepts are useful or helpful in every situation. Therefore, user validation on acceptance of specific concepts and measuring user performance for use of support in a specific context of use are invaluable for understanding when and how assistance should be provided to users.

The development of the PRI and ISP attention indicators are still in a conceptual stage. For our experiment the PRI was generated automatically at predefined points in the task sequence. In the future a user model could be used to generate the PRI based on knowledge of a user's cognitive switching ability. The cognitive switching measure can be used as an indicator linking multitasking performance and interruption handling. In this study using a measure such as Trails B provides a baseline measure on a person's ability to multitask, to assess whether users can benefit from a certain form of support. We have shown that there are direct relationships between the Trails B measure and use of the PRI and ISP support concepts.

It seems feasible that multitasking ability can be derived from information on user task switching to predict user performance on interrupted tasks. For example, task switching can be indicated by how long it takes a person to switch between applications on a mobile device. This information can be used for an implicit user model. With this information support concepts can be tailored for presentation to the user at the appropriate moment. In other research this approach has been taken for deriving user models for user navigation. Information like navigation history, preferences, device settings, user characteristics and other information can be gathered. This information can be gathered either explicitly, by asking the user about preferences using questionnaires, or implicitly by deriving user preferences by logging user behavior on the system. Juvina and Van Oostendorp (2004) have presented and verified a method for implicitly deriving user preferences from user navigational data. LSA (Latent Semantic Analysis) which was used to estimate the semantic similarity between user's navigational goals and semantic entities (e.g., link locations) on Web sites. Pragmatic information extracted from navigational data could be used to predict a user's explicit preferences. A similar method could be used for building user models for PALS, where the system can independently assist the user as he/she is using the system. In chapter 6 more details and further examples will be given that contribute to building a user model to address multitasking and assisting handling of interruptions in a mobile context.

Chapter 6 Conclusions

Abstract

During the development and researching of a personal mobile assistance interface concept, several conclusions have been reached: (1) The concept of mobile assistance can aid the user with Web tasks in a context that taxes the user's ability to handle multiple tasks. (2) An interruption task generated from the same device (same origin), having similar interactions (e.g., pointing with a stylus or mouse cursor and entering information on screens), with a single-screen display, leads to serial switching between tasks that negatively influences user performance. (3) The delays in interrupted primary task performance, we have attributed to disruption in the user's recognition of where to begin the task, due to memory decay and interference (e.g., from serial switching and similarity in interaction between tasks). This interference from interruptions negatively impacts working memory, leading to confusion and difficulty in reconfiguring a primary task for resumption.

In order to resolve these issues, interruption management assistance, such as with the Attentive Interface for Mobile Multitasking (AIMM), can be useful to aid users in handling interruptions. Our interaction design recommendations include assistance in using the mobile Web when multitasking and with interruptions. We suggest that assistance (e.g., PRI and ISP) is needed for supporting the user's attention and memory on the primary task. The user's handling of the interruption task can be improved by incorporating interruption transparency for enhancing the user's anticipation of an interruption. We also recommend the interceding of an interruption task, in the form of content summarization of a message.

The main goal of the research described in this body of work (see figure 1.1 chapter 1) was to develop an interface concept of mobile assistance for aiding users in handling interruption. Our approach consisted of concept development of mobile assistance, experiments on multitasking and interruptions, and on defining concepts for managing interruptions while using the Web on a mobile device.

Based on the research from this project the following conclusions have been made:

Concept Development

Current uses of the Internet are similar on a mobile device and desktop PC for information search and communication. However, experience with the desktop PC Internet does not fully transfer to benefit use of the mobile Internet. Future use of the mobile Internet for banking (e.g., transaction), travel (e.g., route information) and communication services will be used in a similar manner as the Internet on a desktop PC.

Mobile assistance that is personal, convenient, inexpensive and that is a representative model of customer service can aid use of the Web on a mobile device.

Interruptions from the environment (e.g., people, phone calls) are problematic when using the mobile Internet. In the future, interruptions (e.g., notifications, reminders, messaging) generated on the device itself will further negatively impact the user experience with the Internet on a mobile device.

User Experiments on Interruptions

Web tasks on a handheld take longer to perform due to compounding issues of the mobile interface (e.g., small screen, difficult data entry and inadequate Web design requiring intensive scrolling) than on a desktop platform.

IM interruptions were shown to be disruptive to Web task performance in comparison to Web tasks without interruptions on both platforms.

An interruption task generated from the same device (same origin) having similar interactions (e.g., pointing with a stylus or mouse cursor and entering information on screens) with a single-screen display leads to serial switching between tasks that negatively influences user performance.

Anticipating or expecting an interruption (compared to an unexpected interruption) can be beneficial to primary task performance on a handheld and desktop PC platform.

Maintaining the same keyboard modality on an interruption task is less disruptive than switching to a voice modality on a handheld and desktop PC platform.

A ‘simple’ interruption task requiring repetitive interaction for completing an interruption task is more disruptive to the primary Web task on a handheld and desktop PC platform than a ‘complex’ interruption with less repetitive interaction.

Remembering a place in a task is critical to resuming a primary Web task. After an interruption task a user’s recognition for resuming task place on a primary task has a weaker memory representation and more easily forgotten, than recognition of the content of a task. When controlling for use of a single-screen display, there was no difference between the desktop and handheld for recognition of resuming the primary task.

User Web task performance, when handling interruptions on a handheld, is best predicted by cognitive switching ability, general Internet experience and mobile Internet experience.

User Assistance Integrated Framework

Assistance (such as the Point of Return Indicator [PRI] and Interactive Suspension Point [ISP]) can improve user performance on an interrupted Web task. On a handheld, the automated PRI can be beneficial by reducing the amount of time needed to complete an interrupted primary task in a sitting and walking context. In a high demand situation (such as when walking), the user-controlled ISP marker is beneficial to user performance when handling interruptions. In a sitting context, the ISP is less beneficial.

In the next section, our conclusions are highlighted according to the research questions that were posed in the first chapter. Theoretical insights are presented with a specific emphasis on cognitive theories regarding multitasking and interruptions. We revisit and update the Attentive Interface for Mobile Multitasking (AIMM) framework, then present design guidelines for user assistance based on our research findings. Finally, research directions on mobile assistance and concluding remarks are given.

6.1 Answers to Research Questions

In this section, the answers to our research questions are presented as final conclusions on mobile assistance.

Concept Development

What concepts for human-computer interaction need to be considered in designing mobile assistance?

Mobile assistance is a general concept to aid the user of a handheld in a mobile context. As part of the PALS concept, a user framework was proposed for mobile assistance to improve the user experience of mobile Web services for the financial and travel domains. The framework consists of a "customer service" metaphor, using Directed, Solicited, Non-solicited, and Independent services to aid in building the user's mental model for understanding support of user interaction via the AIMM interface concept.

Directed (D) service, "Do what I say". The user submits a command for assistance (e.g., similar to a search engine request). For example, "find XYZ travel route not impeded by traffic".

Solicited (S) service, "Can you help me?" The user requests assistance. For example, "help me find real estate prices on the Web".

Non-solicited (NS) service, "Smart interaction": Assistance is provided automatically, which includes personalized interface presentation and interaction services. For example, "reminding the user of a current transaction history to help with completing a task".

Independent (I) services, "Relevant": Assistance from intelligent actions that are external to the device are conducted based on user profile information and other sources (e.g., calendaring, email etc.). For example, "Wakeup calls are generated by on the basis of predicted travel time and connections… than informing a hotel of the customer's arrival."

These service concepts are integrated into AIMM to aid a user's understanding of the types of assistance given and to help with managing interruptions. Assistance is provided to the user for task interaction through the use of support concepts (e.g., attentive interactive display), facilitating the user's completing of a Web task while handling an interruption.

What characterizes a user's experience with mobile devices, Web use and assistance?

The survey research in the PALS project has shown that users have similar needs when using the mobile Internet for information search, communication and financial and travel/leisure services, as used on the desktop PC. There is a high interest in the use of specific financial and travel Web services on a mobile device similar to current use on a desktop PC. Users experience problems when using Web services on a mobile device due to issues with the mobile interface and interruptions from people, telephones and online communication.

Users on a desktop PC already have difficulties with particular aspects of online shopping for checkout and finding items, often needing human assistance. Although on a desktop PC the preferred form of assistance is via human contact, people are open to other forms of Internet assistance, such as mobile assistance. Some of the reasons Internet assistance may be preferred include convenience, less human contact, lower cost and personalized results (which are valued more by women than men).

User Experiments on Interruptions

What effect does an interruption task with specific characteristics (e.g., origin, anticipation, complexity and modality) have on a user's Web task performance on a handheld device?

Experiments 1 and 2 showed that Web tasks done on a handheld device typically take longer to perform, due to compounding issues of using a mobile device (e.g., small screen, difficult data entry, inadequate Web design requiring intensive scrolling), than on a desktop platform. Our investigation has shown that Web tasks that are interrupted take longer to perform on a handheld than on a desktop platform. However, when comparing user performance on Web tasks with and without interruptions, the interruption is equally disruptive to a Web task, on both the handheld and desktop platform, when controlling for single-screen display interaction. This work confirms that use of a single-screen display is particularly problematic for a user on a handheld device when an interruption task is generated from the same device and having similar interactions in both tasks (e.g., pointing with a stylus or mouse cursor and entering information on screens). This type of serial switching between tasks, results in costs to performance that negatively influences a user's attention and memory, creating problems for resuming the primary task.

This research suggests that changing certain characteristics of receiving and handling interruptions can be beneficial for resuming and completing a Web task. Experiments 1 and 2 showed a user's anticipation of an interruption promoted an expectation for receiving an interruption, leading to efficient Web task actions to resume the primary task. When anticipating an interruption, the user knew that an interruption would be received during the task. However, the user did not know exactly when the interruption would occur. Receiving some information on the interruption task beforehand helped the user to better handle the interruption, leading to faster completion of the primary Web task.

Experiment 2 also showed that complexity and modality of an interruption task influenced Web task performance time. By examining the influence of an interruption task's content characteristics, we found that a 'simple' interruption task requiring repetitive interaction was more disruptive to the primary Web task than a 'complex' interruption with less repetitive interaction. This suggests that an interruption task does not require a high amount of cognitive processing to be disruptive. However, a high amount of repetition can be disruptive to the primary task.

As for use of a specific modality when handling an interruption task, using the same keyboard modality for the interruption and primary task is less disruptive than switching between voice for the interruption task and use of the keyboard for the primary task. The use of a speech interface is not common and may not be an appropriate modality of choice for handling of IM interruptions on a mobile device. This is due to the type of multitasking skill needed and interaction specific to using the handheld device. A learning overload situation may also exist for the user when initially learning to use a new modality (such as switching between voice and the keyboard). Switching between different modalities negatively impacted the primary task, especially for new mobile Web users.

In experiment 2, we examined predictors of interruption handling. Cognitive switching ability and desktop Internet experience were found to be good predictors of user handling of interruptions on the desktop PC. User Web task performance, when handling interruptions on a pocket PC, is best predicted by cognitive switching ability and general Internet experience. Mobile Internet experience is also an important factor that needs to be included to further validate the predictors of user performance for handling interruption. Handling interruptions while using the mobile Web on a pocket PC, involves more than just task switching and general Internet experience. A combination of cognitive switching ability and experience with the mobile Web both contribute to a user's skill in handling interruptions. These predictor variables give an indication of user performance on a primary task when handling interruptions on a mobile device.

Our results suggest that experience with the desktop Internet does not fully transfer to use of the mobile Internet. Platform-specific models need to be developed to appropriately assess and predict user performance of handling interruptions. Further research is needed on users who have experience with the mobile Internet to gain a better insight into user task performance for interruption handling on a mobile device.

What effect does an interruption have on user memory for resuming a primary Web task?

Experiment 3 showed that remembering a place in a task is critical to resuming a primary task. This aspect may be more vulnerable to being forgotten when interrupted, due to the cumulative burdens of memory decay and interference when switching between an interruption and primary task. We assumed that remembering where to resume a primary task on a handheld was more difficult than on a desktop PC. However, our results did not show differences between the handheld and desktop PC with a single-screen display for recognition memory for the primary task. Interruptions were shown to be disruptive to recognizing information on the primary task on both platforms. Remembering specific attributes of the primary task (such as a specific task step) is more easily disrupted by interruptions than recognizing the content of the task. We've attributed the time to delays on interrupted primary task performance to the following reasons: (1) disruption in memory for recognizing where to begin the task; and (2) memory decay and interference (e.g., from serial switching and similarity in interaction between tasks) that negatively impacts working memory, leading to confusion and difficulty in reconfiguring a task for resumption.

User Assistance Integrated Framework

What types of assistance support is beneficial to a user?

The user assistance proposed in our work is based on the idea that support is needed when attending to resuming a primary task after an interruption. We emphasize that assistance is not considered a replacement solution for good mobile Web design. But in addition to good Web design, assistance is needed to improve the user experience on a mobile device.

The automated PRI and user-controlled ISP indicators had an influence on interrupted Web task time. There was a positive trend saving 10 seconds in the PRI sitting condition and 4 seconds in the PRI walking condition, compared to the control group without aid. Use of the ISP was shown to be beneficial in a walking situation, whereas using the ISP while sitting at a desk lead to slower performance. In intensive situations where a user's attention resources are taxed, the action of consciously placing an ISP on the screen with a stylus can effectively cue working memory and reduce interference for better performance on a search or browse type of Web task. On the other hand, in the sitting condition, the users felt that they had more time to complete tasks and used the ISP for other purposes (such as a generic place marker when scrolling). The use of the ISP indicator with search or browse tasks were more beneficial to Web task performance in a walking or busy context.

In general, when providing support concepts in a sitting and walking situation, automated concepts such as the PRI may be beneficial to users. In intensive conditions (such as while walking and receiving interruptions) the ISP may be beneficial. A general measure of cognitive switching ability can help to predict whether the individual user should receive a support concept. The measure can provide and indication of how support influences user performance in a certain mobile situation.

At the present, we can only speculate on personalized presentation of support. Herder (2006) suggests that automated collection of user Web activity for user profiles over the long term results in overly generalized profiles that are limited in application for providing user support. Other research has shown that personalization generated from a user profile yields higher relevance for users when combined with other types of information such as document information (e.g., indexing, keywords etc.) for personalizing Web search (Teevan, Dumais & Horvitz, 2005).

It is unknown as to how interruptions should be managed and what types of assistance are supportive to users' primary activities when interrupted. Personalization of support concepts requires sophisticated user-modelling and adaptation techniques that are relevant for data acquisition for an adaptive system; this is beyond the scope of our current work. Our primary contribution is identifying factors to be included in a user model that influence how assistance for interruption management can be personalized to the user. We explore some avenues of personalizing support concepts in our AIMM framework. In section 6.3, examples are given for integration of AIMM support, based on significant factors that can be monitored and collected for user profile information.

In the next sections our study findings are related to current insights on the use of mobile devices, assistance for supporting use of a mobile device and theory on interruption and multitasking.

6.2. Mobile Assistance to Improve Web User Interface for Interruption Management

Our survey research shows that users have a broader perspective on their future needs of mobile Web services, beyond the current use of m-commerce types of tasks. However, today's mobile device users are characterized as "on the go users" who are interested in quick execution of short, goal-oriented tasks, such as purchasing tickets, finding movie locations, checking an account balance and infotainment services (Sadeh, 2002). We found that users want to use the mobile Internet in a way similar to how the desktop Internet is used. It seems that there is a discrepancy between what users really want to use in terms of Web services and the Web services that are currently offered and actually usable on the mobile Internet. The use of a mobile device has also expanded into work situations, which also extends the character of the mobile device user and types of services needed.

As covered in our literature review, a large contributing factor for the lack of use and adoption of services of a mobile device is due to users having difficulties with the mobile user interface (Sarker & Wells, 2003). Improvements in Web design for the mobile interface, accompanied by mobile assistance, can reduce the constraints for use of the mobile Web and the imposed limitations of multi-context use in an environment of disruption. A broad approach was used in this dissertation to identify appropriate user support via mobile assistance, as a means to better integrate the use of mobile devices with Web services.

There are forms of assistance for interruption handling, such as Attentive User Interfaces (Horvitz, et al. 2003, Vertegaal, 2003), interruption management (Ho et al., 2004, McFarlane, 1999) and warning systems (Obermayer & Nugent, 2000), that have strongly influenced our work. However, even with these forms of assistance there is a lack of user studies on interruption, attention and user interaction with real world computing and a lack of understanding as to what specific display presentations are effective and beneficial to users. This form of research for interruption management was specifically deficient in regards to the use of mobile devices. Therefore, our focus was to integrate results from user studies on interruptions and forms of support with a usage framework of assistance for presentation of support services into the mobile user interface in order to improve user performance with interruption handling. This approach is somewhat unique compared to previous instantiations of assistance. There have been various approaches to improving the user interface on a mobile device for optimizing navigation and information presentation (e.g., Buyukkokten et al, 2000, Bjork et al, 2000, Rodden, et al. 2003), input and multimodality (e.g., Lai, 2004, Oviatt, 2000, Jost, et al., 2005) and context and location of use for specific services (e.g., Abowd, et al. 1997, Cheverst et al. 2000).

These novel mobile interfaces and mobile systems being explored today (e.g., Powerview, Smartview, GUIDE, SmartKom etc) address many of the general interaction issues (e.g., reducing scrolling, improving navigation, improved data entry) and context issues (e.g., location aware services etc.) experienced by users on a mobile device. However, these interfaces do not incorporate support for tasks that are interrupted.

According to research done on mobile devices, interruptions are a common occurrence and influence use of a mobile device when in a mobile context (Oulasvirta et al., 2005). As we have shown in our study, even on short tasks (average of 1 minute) interruptions negatively influence performance. The issues that we have investigated in our work using an interruption and task-switching paradigm have not been directly examined in previous work on human computer interaction with mobile computing. Our research supports previous work, showing the benefits of automated support for interruption management (e.g., Ho et al. 2004, McFarlane, 1999, 2002).

Key issues related to a core understanding of user interaction on a mobile device include the following: performance differences between a desktop PC and mobile device, task switching due to interruptions resulting in switch costs, negative and positive influences of an interruption task on performance and user characteristics that influence multitask performance. By comparing user interaction with interruptions on a desktop and mobile platform we have a better understanding of user interaction. Our findings contribute to a better understanding of differences in performance, related to specific characteristics of an interruption task. The findings also contribute to understanding the underlying issues regarding cognitive overhead that are problematic in multitasking situations, as discussed in the following sections.

6.3 User Interaction with Interruptions Supports Need for Mobile Assistance

Within our theoretical framework of interruption and multitasking, this research gives us insight regarding switch costs from interruptions, the resulting effects on task performance and the influences of supporting attention and memory for resuming the primary task. In our studies, switch costs were evident in the slowing of performance time on the primary task (as a result of having to move from a primary task to an interruption task) and on resuming the primary task. For the handheld device, the slowing in performance was attributed to user difficulties with the mobile interface and disruption due to switching to and from the interruption task. The difficulties related to switching between tasks can be explained by the over-utilization of mental resources, resulting in time-sharing deficiencies and therefore decreases in performance (Wickens & Holland 2000).

For a specific theoretical examination, we focus on theories such as task set inertia (Allport et al. 1994), functional decay (Altmann, 2002) and the goal activation model (Trafton, et al. 2003), which regard task switching as a problem of memory. As for the aspect of the disruptiveness of the interruption of the primary task, switching between tasks is a primary contributor of interference in the user's memory system. This interference is due to a memory trace of the previous task that remains after the task switch of the same stimulus type (Allport et al, 1994). Attention and memory for the primary task is reduced due to interference from the interruption task. Interference can be attributed to similarities in the interface and interaction when serially switching between the interruption and primary task having to use a single-screen display. Some preliminary evidence includes the following:

1) In our first study, user performance was less disrupted during interrupted Web tasks on the desktop PC than on a mobile device. When using a single-screen display on the desktop, as we did in our second study, performance worsened in interruption handling on the desktop PC with an increase of 13 seconds, compared to the handheld with a 9 second increase, when comparing Web tasks with and without interruptions. When using a single-screen display on a desktop PC to handle an interruption task, this can have a large impact on performance. This provides some support for our argument (section 5.1) that the presentation of an instant message task in a smaller, partially visible screen leads to a more concurrent type of user interaction, which is much easier than serially switching between tasks using a single-screen display (which is a common form of interaction on the mobile device). In the study done by Czerwinski et al. (2000) and Cutrell et al (2001), the use of multiple screens lead to a more concurrent type of interaction, which probably contributed to the reason why the markers used in that study were ineffective for supporting a user in returning to a primary task after an interruption task on a desktop computer.

2) The similarity in interaction between the Web and instant message application can be a contributing factor to interference created by switching between tasks. From our study results we have learned that when using a modality such as voice for the interruption task with a different origin (e.g., phone) from the primary Web task, there is a positive influence on performance of the primary task. When a user switches between using the keyboard on the primary task and voice modality on the interruption task generated from the same platform, there is a negative impact on the primary task. Modality of the interruption task does play an important role on performance in the primary task. There were also other influences that could have influenced user performance when switching between the primary and interruption task, such as the unfamiliarity of using speech and a learning overload of having to learn a new modality (versus maintaining the same modality as described in section 4.7.7). At this point, based on our knowledge of this user group and the limited experience they possessed in using a mobile device, switching between the keyboard and voice is not recommended for people who have very limited experience with mobile devices.

As we found in our third experiment, users have more difficulty remembering the place to resume an interrupted task compared to remembering the content of an interrupted task. We speculate that when using the mobile device there is a build-up of interference with the user's memory and attention for reconfiguration of the primary task, due to user interaction with single-screen display and similarity in interaction between the primary task and interruption task being generated on the same device. There is faulty retrieval of memory due to less attention being paid to the primary task, resulting in an overall slowing of primary task performance.

In order to support user memory for resuming a primary task, we have focused on providing attention cues to help users with reorienting to the task. As viewed by the instance theory of automaticity, automatic processing is based on memory retrieval, where attention is needed at encoding and retrieval to form the cues for retrieval of memory (Johnson & Proctor 2004; Logan, 1988). The attention indicators have two functions: dampening or reducing interference, acting as cues for memory retrieval and helping to move a user from divided attention (e.g., maintaining the primary task and completing the interruption task) to focused attention, so a user can better reorient and reconfigure to carry on with the primary task.

6.4 The AIMM Framework for Mobile Assistance

The primary research question is answered as a cumulative result from our research on concepts of mobile assistance and experiments on interruption handling.

How can a user of a mobile device be supported with personalized assistance for use of the mobile Web when experiencing interruptions that stimulate multitasking?

We address this question based on our Attentive Interface for Mobile Multitasking framework. AIMM is proposed to support a user on a primary web task when handling interruptions, while allowing information and tasks from secondary sources to be acknowledged and processed in a timely fashion. The situation for using the Web on a mobile device is a complex environment that is highly interruptible and changing. The user's activities in a mobile context are based on a quick and accurate collection of information on a mobile device. Often the handheld device in combination with the Web is not suitable for use and impacts user Web performance, falling short of the user's expected results. The combination of user activities and a highly interruptible environment influences how users conduct tasks with a handheld that result in multitasking.

Assistance provided by AIMM is introduced to the user in the form of services (e.g., Directed, Solicited, Non-solicited and Independent) that can be associated with real-life experiences in receiving retail customer service. The solicited, non-solicited and independent services are exemplified in our AIMM framework. In the future these types of services are expected to be more common forms of assistance. However, these forms of computing assistance are difficult to instantiate in such a way that the user has a clear understanding of the help being provided.

In our AIMM framework, we present the attributes of the user and system that can be collected and stored on the PALS system. This information is used by AIMM to provide personalized support for users handling interruptions. For providing assistance with interruptions during a Web task, information on desktop Internet experience, mobile Internet experience, task switching information, information on user state (e.g., walking, sitting) and type of tasks (e.g., interruptions task, notification, reminder, messaging) are collected for a user model on interruption handling (figure 6.1). The user's characteristics, computing platform, tasks, location, and assistance services shape the type of support that the user receives from AIMM for interruption management. At the end of this section, examples are given within our AIMM framework of how these services are incorporated for aiding with the Point of Return Indicator, Interactive Suspension Point and other forms of interruption management that were derived from the literature and our user studies.

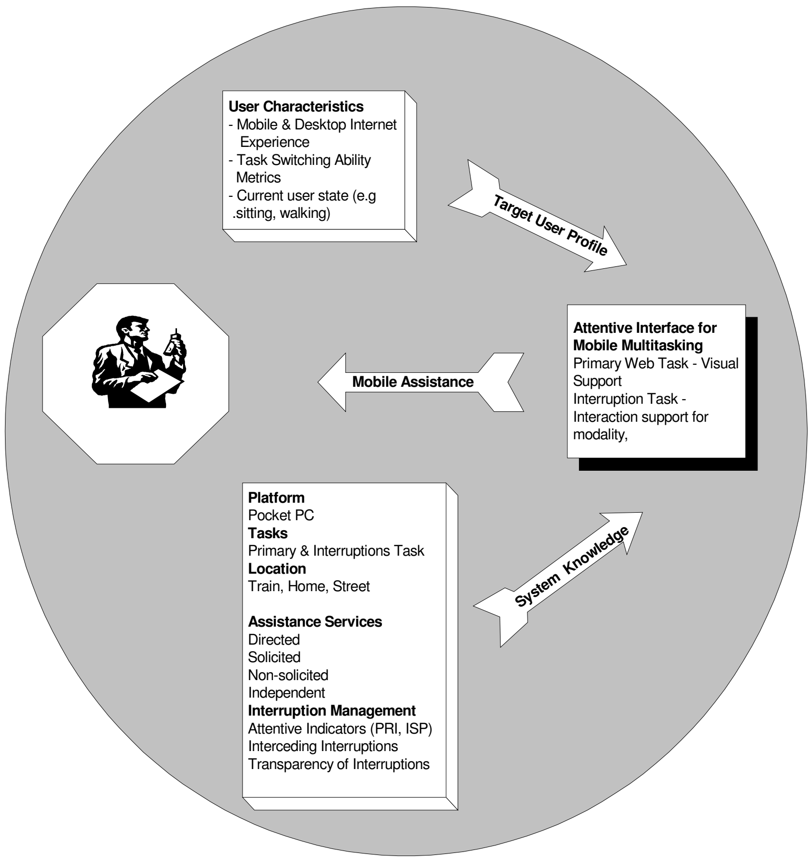

Figure 6.1. AIMM framework

Point of Return Indicator

In our study we examined a form of PRI that was visible to the user only after the interruption task was completed (figure 6.2a, 6.2b). The PRI is an automated attention indicator that can be presented to the user in several different fashions. Another type of marker presentation we have suggested, but was not investigated in our research, is to have a highlighted marker that is constantly visible to track the user's steps through a task. For example, as a user does a Web task, a PRI highlights in some fashion each step of the task as the user progresses through the task. This is similar to highlighting each text box as a user fills out a Web form. A PRI marker needs to be distinctive enough to grab the user's attention when the user returns to the primary Web task. This is combined with auditory sound presentations to locate the step in the task, or sounds can be used to remind the user to reengage the primary task. To enhance the user's understanding of this form of assistance, the PRI can be seen as a non-solicited service light indicator that people have had experience with in a shopping environment. Similar to how a clerk turns on a light at the checkout counter to guide shoppers to an open checkout counter, the PRI is shown as assistance to the user, showing where to resume the primary task. Another metaphor that can be taken from the retail world is the use of a service light that informs shoppers of a special sale item in a certain aisle location. A retail chain called K-Mart in the United States used a blue light to indicate items that were on-sale during a specific period of time.

Depending on the profile of the user, AIMM can provide PRI assistance that is either solicited by the user or a non-solicited feature that is presented automatically to the user. As can be extracted from our research, it is expected that less-experienced mobile Internet users with low cognitive switching ability would benefit from non-solicited PRI assistance. Therefore, the PRI would be automatically presented to the user when handling interruptions. Users with more extensive mobile Internet experience and good cognitive switching ability may solicit a request to AIMM for PRI support.

Interactive Suspension Point

The ISP is an attentive indicator that supports a user in interacting with the information on a Web page by allowing the user to set a marker to indicate a specific place to resume a task (figure 6.3a, 6.3b). The user can actively select a point of return by tapping the screen to produce a marker. The ISP is meant for tasks that are less structured, such as browsing and searching for information. An advantage of the ISP is that it gives the user the opportunity to use the ISP as needed. A disadvantage for using the ISP is that the user has to remember to place the ISP on a significant step or location for task resumption before attending to the interruption task. In our study we found that the ISP is beneficial for use in mobile walking situations versus more stationary situations. If the ISP is presented in a certain situation as a solicited service, the AIMM system does not automatically produce the set-up for use of the ISP. The user needs to request the ISP, since AIMM has determined

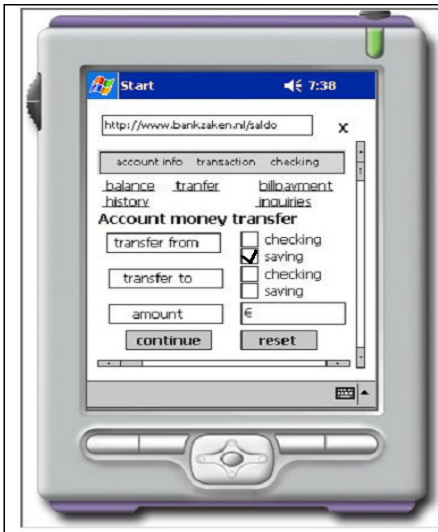

Figure 6.2a: Form fill in before interruption task

Figure 6.2b: Form fill in with PRI after interruption task

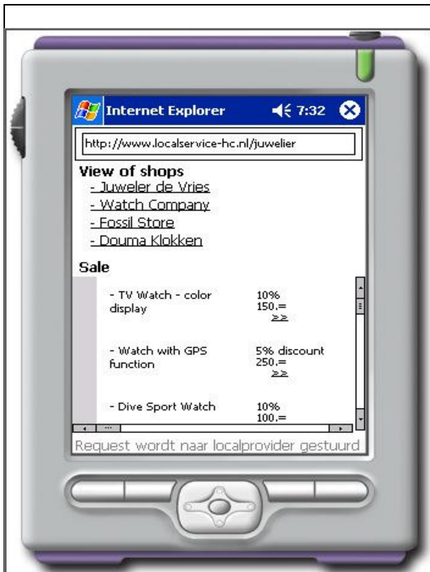

Figure 6.3a. Browsing a list of items

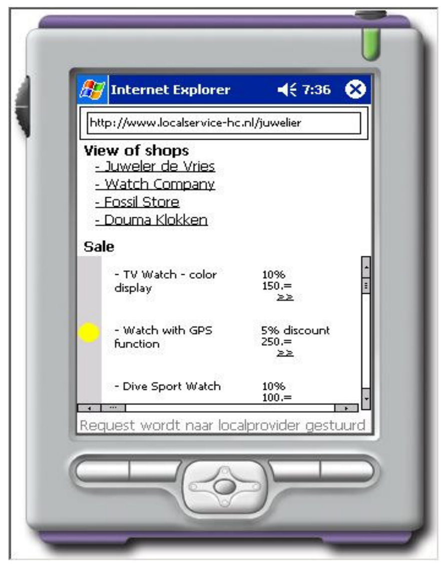

Figure 6.3b. An ISP marker indicating a specific place to return to

that use of the support may not be advantageous for the user in a certain situation, in a sitting situation for example. AIMM will also need to learn if there are other uses of the ISP that the user finds beneficial, besides supporting primary task performance.

We now present three other support concepts that modify user interaction with the interruption task to support Web task performance. These concepts have not yet been validated. In table 11 we present ideas for these design concepts in relationship to previous literature and our research findings on interruption handling based on our first three studies.

Input Modality

For now, the assistance on modality given via the AIMM interface is rather limited. It assists by maintaining a non-solicited same-input modality between the primary and interruption task, with more advanced users having a solicited option to switch modalities. As a specific modality of input (such as voice) becomes more widely available, there is a possibility for different variations in modality that can be explored between the primary and interruption task, where a mixture of voice, visual and keyboard input can be realized.

Interruption Transparency

One feature of AIMM assistance is focused on enhancing the transparency of an interruption by creating a situation that peaks the user's anticipation for receiving an interruption. A user's expectation for receiving an interruption can be heightened by having AIMM produce a pre-interruption message. This pre-interruption indicator (PII) signifies that a message will soon be delivered to the user, which is different from a notification. A notification typically signifies that a message has arrived and is waiting to be answered. The PII can be presented as an icon in the periphery of the screen or as a voice message and requires no action or intervention by the user, allowing continuation with the Web task until there is notification that the message has arrived. With instant messaging, if the receiver of the message is busy doing a task on the mobile device, the PII is triggered when the sender first selects the receiver's "buddy" name to transmit a message. Since anticipation is an overall beneficial aspect of interruption handling, the assistance with interruption transparency can be presented as an independent service, where AIMM will seek situations to inform the user of interruptions.

Interceding of Interruption Task

AIMM can intervene with the interruption task by presenting information in a more fluent manner. A form of text summarization can be used to collect and display several short pieces of information and display the text as one large message. When people send instant messages, they tend to communicate with very short and often incomplete sentences. This repetitiveness of the back-and-forth answer and response interaction during an IM session has a negative impact on performance. When a user is busy with a Web task, it is

Table 6.1: Personalized AIMM Interaction Modes

Profile	**Service**	**Support**			
	Solicited (S) Non-Solicited (NS) Independent (I)	Visual	Input Modality	Anticipation	Content
Platform **(pocket PC)**					
User 1 **-cognitive switching ability (poor)** **-mobile Internet exp (none)** **-desktop Internet exp (7 years)**					
Environment **(sitting in train)**					
Tasks **Primary Task** **Web bank transaction** **Finding a watch**	**Non-Solicited** **Solicited**	**PRI** **ISP w/ guidance**			
Interruption **Instant Message**			**NS-Keyboard**	**I-Interruption transparency**	**S-Interceding of interruption**
Environment **(walking on street)**					
Tasks **Primary Task** **Web bank transaction** **Finding a watch**	**Non-Solicited** **Non-Solicited**	**PRI** **ISP**			
Interruption **Instant Message**			**NS-Keyboard**	**I-Interruption transparency**	**S-Interceding of interruption**
User 2 **-cognitive switching ability (good)** **-mobile Internet exp (7 years)** **-desktop Internet exp (7 years)**					
Environment **(sitting in train)**					
Tasks **Primary Task** **Web bank transaction** **Finding a watch**	**Solicited** **Solicited**	**PRI** **ISP**			
Interruption **Instant Message**			**NS-Keyboard** **S-Voice**	**I-Interruption Transparency**	**S- Interceding of interruption**
Environment (walking on street)					
Tasks Primary Task Web bank transaction Finding a watch	**Solicited** **Non-Solicited**	PRI ISP			
Interruption Instant Message			**NS-Keyboard** S-Voice	I-Interruption Transparency	S- Interceding of interruption

advantageous for AIMM to intervene by compiling messages for a short 3-5 second period and sending one large message. There should be no large gap in communication, and the user receives the information in a timely fashion. The advantage of compiling the messages can also limit the number of times the user will need to go back and forth between the IM application and Web screen, which will reduce the number of switches between tasks. As expressed by users in our study on acceptance of assistance, they did not strongly desire assistance by interceding messages, so we present this as a solicited feature of AIMM. Examples of assistance support and services of AIMM are shown in table 6.1. Two examples are given of users with differing abilities and experiences and the types of AIMM support that would be given to the users. The table presents examples of the user profile information, system knowledge and assistance features that are a part of the foundation for support to be generated by AIMM. Our examples for use of the AIMM features are kept within the framework of use of the Web as the primary task and instant messaging as the interruption task. As shown in the table, User 1 is sitting in a train and using a handheld to do first a bank transaction then searching for a watch to buy. User 1 is characterized as having poor cognitive switching ability, no mobile Internet experience and has 7+ years of desktop Internet experience. Based on these characteristics, User 1 is supported by AIMM with a non-solicited PRI service for the banking task and a solicited ISP service when browsing for a watch. When an interruption is received, the keyboard modality is automatically used for the interruption (non-solicited), and interruption transparency is independently activated by AIMM using a pre-interruption message to inform the user. Interruptions are interceded only by request (solicited).

In applying our findings to other concepts of assistance developed in the PALS project, we focus on ways to adapt dialogue and facilitate continuity of interaction between the user and different computing platforms (such as the mobile and desktop computing platform). Communication meant to assist the user can also be seen as an interruption. Depending on the user's location and primary task, this can determine whether communicatian is given via speech or messaging. An example is when the user is engaged in a computing task and information that can assist the user is needed. Interruption transparency can be used where there is some pre-interruption warning to signal communication with the user.

As for assistance that enables continuity of interaction between the mobile and desktop platforms, using the attention indicators can serve an additional purpose, in terms of guiding users to resume a primary task on another platform. For example, if a user has begun a Web task on the handheld, is interrupted and unable to return to the task until later and would like to continue the task at home on a desktop PC, the attention indicator from the PRI or ISP could be shown at the resumption point to continue the task on the desktop PC. The attention indicator would assist with continuing the task where it was previously left off without having to redo the entire task or search through the task to find the resumption point.

In the next section our recommendations are presented as design guidelines for mobile assistance.

6.5 Recommendations for Interaction Design of Mobile Assistance

In this section we present recommendations that can be extracted from our study findings and experiences derived from concept development, user testing and user support. These recommendations provide general guidelines when designing the mobile assistance, with a specific emphasis on assistance for user interruption handling and multitasking. This section is focused on general design themes that are captured from the overall research outcomes and not on implementation of specific issues. There are three general areas that need to be considered when designing user interaction for mobile assistance:

(1) Primary Task Support

Attention Assistance – Provide visual and auditory assistance that directs attention and stimulates memory, such as with attentive indicators (e.g., Point of Return Indicator) and markers that promote flexible interaction (e.g., Interactive Suspension Point). This form of assistance can evoke intuitive interaction and support user performance with the primary tasks when interrupted and in general multitasking purposes. When using automated attentive indicators for managing interruptions, the indicator should identify the user's next step that needs to be completed within the sequence of the task. The attentive indicator needs to be adapted to the user's location and context of use to optimally enhance user performance within the specific context.

(2) Interruption Task Design

Interruption Transparency – Consider ways to inform the user of impending interruptions and tasks, prior to receiving the actual notification of an interruption task. In the computing domain, this information can often be determined well before the actual interruption task. The critical aspect is leveraging this information and presenting it to the user in a subtle way for the user to remain aware of the situation and to be prepared to receive an interruption task.

Interruption Mediation – Use interruption mediation sparingly, since users are wary of this form of assistance, and it may not be highly accepted by users. There are several forms of interruption mediation that can be considered for use as assistance. We suggested interruption mediation in the form of content summarization. Another form of support, is assistance for directly communicating with the other party to establish user availability. For example, when a user is busy with a task, an incoming instant message is intercepted and it is communicated to the sender that the user is busy at the moment and will respond in 30 seconds.

(3) Assistance Interaction

Assistance concepts – Use design concepts that contribute to a user's mental model for understanding assistance provided by a system. An appropriate metaphor provides a frame of reference that a user can relate to, such as the retail-shopping model. Other common metaphors of human assistance are an administrative assistant, tour operator and flight attendant.

Minimize use of interruption negotiation – Mobile users are often overburdened with the current interactions of dealing with the primary and interruption task, therefore minimize use of negotiating with the user or do not include additional steps where the user may have to request holding or receive an interruption during a primary task. For a user of a mobile device there are many constraints that already increase the amount of time to perform a Web task, and including additional negotiation interaction contributes to longer task times.

Interruption management - Consider a two-pronged approach for managing interruptions by supporting handling of both the interruption and primary task. Based on our research, several examples have been given of primary task support (e.g., ISP, PRI) and for interruption handling (e.g., interruption transparency, mediation of interruption.). With the growing use of mobile devices in work related situations, the interruption task may have equal or higher importance and be similar in content, which may be even more disruptive to the current task that is being done on the mobile device.

Context – Utilize information collected from user location and context situation to determine appropriate presentation of assistance. Contextual cues can be given in situations that may encourage use of one combination of support over another. For example, if an experienced mobile device user is walking through the city looking at both location information on his handheld and a hard copy map. When the user receives an instant message, audio/voice assistance is automatically engaged to handle the instant message.

6.6 Limitations and Future Research

In this section we discuss the limitations of our research approach and findings to draw relationships for future research directions.

Concept Development

Scenario Based Design (Carroll, 2000) was a method used in the PALS project for developing concepts of assistance for a future mobile system and for aligning a collaborative understanding of our research with business stakeholders and the research team. Looking back over the concept development process, it may have been advantageous to include users of mobile devices in the scenario process. However, there are competing viewpoints on whether this is an appropriate venue for a user to step in and be involved in this type of scenario-based design session. We believe that user input can always be used to gauge the realism of what is being proposed and investigated in early stages of a project.

In addition to scenario-based design, it would have also been intriguing to explore another method such as contextual design (Beyer & Holtzblatt, 1998). This additional method would have added to the understanding and further validated user issues that our team experts and stakeholder uncovered in our scenario workshop. With contextual inquiry while observing the participant experiencing certain issues while using the mobile device, questions on types of assistance that the user might or might not find appropriate and useful could have been introduced.

We have proposed some initial ideas on how to enhance user understanding of assistance, via a customer service approach and integrating these ideas within the framework of AIMM assistance and support. These services are presented in a broad fashion, and we do not address concepts for each type of service (e.g., Directed, Independent) in our research validation of support. Further research is needed to address Directed and Independent services; we expect that these types of assistance will have great value to users when using a mobile device. We also did not address the validity of the metaphor of customer service, on whether the presentation of assistance does indeed aid a user's mental model for clearly understanding and accepting support. Further research and testing is needed to validate the approach for user understanding of assistance and support provided by a mobile system.

Experiments on Interruptions

In our studies we investigated several characteristics of interruptions that influenced performance on the primary Web task. We found in our studies that desktop Internet experience and owning a mobile device cannot compensate for actual experience in using a mobile device with the mobile Internet. Future research and user testing need to include users with more extensive mobile experience for a better understanding of how this experience influences performance on a mobile device. Furthermore, a more elaborate examination of errors that occur during performance on the mobile Internet can also provide a clearer picture of how errors influence performance during interrupted tasks.

Contrary to current popular belief, we found that the use of voice on an interruption task was very disruptive to primary task performance. There were several limitations that have to be acknowledged: (1) Using voice during an IM computing task is not a common user interface situation; (2) There were higher costs of switching between different modalities either due to an overload situation of learning to use a new device and the use of voice in a new situation. The combinations of use of voice versus consistency of modality, when switching between tasks, need to be investigated further.

We did not follow-up on investigating a comparison of different sources of interruption in our study. We did speculate that origin of an interruption plays a large role on influencing performance on the primary task. We identified a lack of studies investigating interruption origin in HCI, and further research is needed to determine the disruptiveness of interruptions based on origin.

As for examining the role of user's memory when interrupted, we acknowledge that using a multiple-choice list for assessing user recognition of task place versus task content was not an ideal format for measuring recognition to continue a Web task. We suggest that an ideal way to measure recognition for the Web task would have been to show users various images of the same Web screen and to have them indicate their last step on the screen. Using images would have more closely resembled the actual situation. A further examination is needed to improve methods related to assessing memory for real-world computing tasks.

User Assistance Integrated Framework

Our proposal for presentation of support concepts, generates the question of how users accept support concepts that are periodically changing (e.g., the use of the ISP being beneficial while walking but not while sitting). Varying presentation of the support concepts during use may be confusing to the user. There is also another issue that is closely related to interruption mediation or timing of interruptions, such as assistance that withholds an instant message until an appropriate moment. Based on our user study, this method of assistance was not found to be very useful (section 3.5, see also Brolman, 2004). The form of assistance that we have categorized as a non-solicited mediated service for managing interruption needs to be further investigated. The following questions need to be answered: What is acceptable to the user in regards to withholding an interruption when busy with a task? If the user can set priorities for different types of interruptions, is it more acceptable to withhold the presentation of an interruption?

As for personalized mobile user assistance, we have come across certain limitations regarding adaptations of the user interface for individual users. We have proposed general forms of interruption management that can be adapted to users based on certain user characteristics for cognitive switching ability and computing experience. However, there is still very little that is known about these specific support concepts, combinations of support that could be presented, how well these concepts work and in which situations, for a specific user. Limitations for presentation of support reside in having only a limited number of support concepts that may only aid certain users. Further research is needed on examining these specific support concepts and combinations of support and users' acceptance of the adaptations.

Our approach for understanding and validating mobile user assistance hasapplicable, yet limited application for supporting users when interrupted in the mobile context. A limitation of our studies was that we did not have the appropriate technical infrastructure to accurately capture data in a rich outdoor context. A further examination is needed for use of mobile assistance in a realistic mobile context.

Our research enables a better understanding of how support concepts can be used as assistance for use of the mobile Internet on a handheld device. Mobile assistance for interruption management should be considered as a means toward improving usability of the Internet from a mobile device.

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Samenvatting

Dit onderzoek richt zich op assistentie voor gebruikersinteractie bij het uitvoeren van meerdere taken (multitasking) als gevolg van onderbrekingen op een mobiel apparaat. Een belangrijke uitdaging daarbij is het verbeteren van de gebruikersbeleving bij het omgaan met onderbrekingen tijdens het gebruik van het mobiele internet. Het ontwerp van bestaande internet interfaces houdt geen rekening met de problemen die gebruikers hebben met de mobiele interface. Deze problemen zijn gerelateerd aan de kleine omvang van het scherm, lastige data invoer en onderbrekingen die zich voordoen in de context van mobiele apparaten.

Als onderdeel van ons raamwerk voor mobiele assistentie, stellen we een “Attentive Interface for Mobile Multitasking” (AIMM) voor. Deze interface past de vorm van ondersteuning dynamisch aan om de aandacht en geheugen van de gebruiker te ondersteunen tijdens het managen van onderbrekingen. Dit onderzoek draagt bij aan de opbouw van een conceptueel, theoretisch en empirisch fundament voor het ontwerpen van mobiele assistentie.

Het grote publiek heeft het gebruik van internet op mobiele apparaten nog niet omarmd. Onderzoek heeft aangetoond dat gebruikers problemen hebben met scrollen, omslaan van bladzijden, verhoogde zoekactiviteit, desoriëntatie, leesbaarheid en lastige data invoer. In hoofdstuk 2 laten we zien dat de gebruikersprestatie op het mobiele internet beter kan worden begrepen middels de vergelijking tussen een mobiel apparaat en een standaard pc wat betreft taken die op beide platforms kunnen worden uitgevoerd. Bovendien stellen we voor om de prestatie te bepalen door het mobiele internet en het apparaat als één geheel te bekijken (d.w.z. klein scherm, invoer interactie, web ontwerp) en niet slechts één geïsoleerd aspect. In dit onderzoek wordt gebruikersprestatie gedefinieerd als de tijdsduur die een gebruiker nodig heeft om de (primaire) taak te voltooien.

De problemen met de gebruiksvriendelijkheid van een mobiel apparaat (bijv. de intensieve navigatie) hebben een directe negatieve invloed op de gebruikersprestatie. De verminderde prestatie kan worden toegewezen aan cognitieve overbelasting, die zich uit in problemen met aandacht en geheugen. Er is onvoldoende onderzoek gedaan naar de problemen met aandacht en geheugen in relatie tot gebruikersprestatie bij mobiele apparaten. Er is ook onvoldoende interface ondersteuning voor gebruikers die meer dan één taak uitvoeren en daarbij omschakelen tussen taken, verschillende modaliteiten gebruiken en omgaan met onderbrekingen in de mobiele context.

In hoofdstuk 3 wordt een raamwerk voor multitasking en onderbrekingen ontwikkeld, om de aspecten te identificeren die relevant zijn voor het omgaan met onderbrekingen: gebruiker, taken, context, mobiele apparaat, gebruikersprestatie. Dit multitasking raamwerk wordt gebruikt als basis voor de ontwikkeling van assistentie om gebruikers te ondersteunen bij het omgaan met onderbrekingstaken op een mobiel apparaat. Ons onderzoek toont aan dat mensen vaak assistentie nodig hebben als ze gebruik van het mobiele internet combineren met andere computertaken. Zoals beschreven in hoofdstuk 3, kunnen we uit het PALS onderzoek concluderen dat een mobiel apparaat vergelijkbaar is met een standaard pc wat betreft het gebruik van internet voor zoekopdrachten en communicatie. Onderbrekingen door mensen, telefoontjes en de omgeving worden regelmatig omschreven als problematisch bij het gebruik van het mobiele internet.

Onderbrekingen die op het apparaat zelf worden gegenereerd, zoals notificaties, herinneringen en korte tekstberichten, zullen in de toekomst de gebruikersbeleving van het internet op mobiele apparaten verder negatief beïnvloeden. Mobiele assistentie die persoonlijk, gemakkelijk en goedkoop is een nuttig concept zijn om gebruik van het internet op een mobiel apparaat te ondersteunen. Deze assistentie biedt met name ondersteuning als een mobiel apparaat wordt gebruikt in de context van wisselende gebeurtenissen en situaties die belastend zijn voor het vermogen van de gebruiker om meerdere taken tegelijk uit te voeren.

Specifieke soorten assistentie voor gebruikers, zoals visuele indicatoren, werden door gebruikers acceptabel gevonden bij het omgaan met onderbrekingen gedurende mobiele handelingen. Echter, er is nog onvoldoende kennis van het omgaan met en presenteren van onderbrekingen bij het gebruik van een mobiel apparaat. Er is behoefte aan empirisch onderzoek bij gebruikers om beter te begrijpen welke specifieke mobiele schermpresentaties voor de gebruiker effectief en nuttig zijn bij onderbrekingen. In dit onderzoek worden deze kwesties empirisch bekeken door te onderzoeken hoe mensen omgaan met een onderbrekingstaak als ze het mobiele internet gebruiken, resulterend in multitasking.

In hoofdstuk 4 concentreren drie experimenten zich op het begrijpen van de invloed van een onderbrekingstaak op gebruikersprestatie bij mobiele webtaken. In het eerste experiment concluderen we dat de uitvoering van webtaken op een mobiel platform langer duurt dan op een pc platform vanwege de beperkingen van het mobiele apparaat (zoals lastige data invoer, ontoereikend web ontwerp voor een klein scherm en dientengevolge intensief scrollen). Op beide platforms bleken onderbrekingen door korte tekstberichten bij webtaken erg verstorend voor de gebruikersprestatie in vergelijking tot webtaken zonder onderbrekingen.

Het tweede experiment toonde aan dat een onderbrekingstaak bij een enkelvoudig scherm leidt tot hoge omschakelkosten en dus in een lagere gebruikersprestatie, met name als de onderbreking wordt gegenereerd vanuit hetzelfde apparaat (dezelfde oorsprong). Als een onderbreking wordt geanticipeerd of verwacht, dan werkt dat voordelig voor de prestatie op de primaire taak in vergelijking met een onverwachte onderbreking, op zowel een mobiel als een pc platform. Het handhaven van dezelfde modaliteit (toetsenbord) bij een onderbrekingstaak werkt minder verstorend dan de omschakeling naar spraakmodaliteit, op zowel een mobiel als een pc platform. Bij het uitvoeren van een primaire webtaak op een mobiel apparaat en een standaard pc, werkt een ‘simpele’ onderbrekingstaak die herhaaldelijk interactie vereist meer verstorend dan een ‘complexe’ onderbrekingstaak die minder vaak interactie vereist.

Experiment drie demonstreerde dat de omschakeling na een onderbreking een negatieve invloed heeft op de herinnering van de plaats in een taak, die juist kritisch is bij het hervatten van de primaire webtaak. Het lijkt dat de herinnering aan de plaats in een taak een zwakkere beeldvorming in het geheugen heeft en makkelijker wordt vergeten dan de herinnering aan de inhoud van een taak. Bovendien kan de gebruikersprestatie bij webtaken, wat betreft het omgaan met onderbrekingen op een mobiel apparaat, significant worden voorspeld op basis van cognitieve omschakelingsvermogen en algemene Internet-ervaring. Deze variabelen zijn mogelijke kandidaten die kunnen worden meegenomen als factor in een gebruikersmodel dat reguleert hoe assistentie voor onderbrekingsmanagement kan worden verpersoonlijkt per gebruiker.

Een vierde experiment wordt in hoofdstuk 5 gepresenteerd en behandelt het gebruik van visuele markeringen zoals de automatische ‘point of return indicator’ (PRI) en de door de gebruiker aangestuurde ‘interactive suspension point’ (ISP): beide bieden de gebruiker ondersteuning bij het hervatten van de primaire taak na een onderbreking. Het experiment is uitgevoerd zowel in een situatie waarbij de gebruiker zit als in een situatie waarbij de gebruiker loopt. We kunnen concluderen dat assistentie zoals door de PRI en de ISP waardevol zijn voor de gebruikersprestatie, doordat ze beide ondersteuning bieden bij het hervatten van de onderbroken primaire taak op een mobiel apparaat. De automatische PRI werkt voordelig voor de gebruikersprestatie door de tijdsduur van de onderbroken primaire taak te reduceren in zowel de zittende als de lopende context. De door de gebruiker aangestuurde ISP levert voordelen op voor de gebruikersprestatie in de lopende context, waarschijnlijk omdat er dan hoge eisen worden gesteld aan de gebruiker. In een zittende context levert de ISP relatief minder voordelen op.

Onze conclusies worden beschreven in hoofdstuk 6. Op basis van ons onderzoek kunnen we het volgende concluderen: mobiele assistentie die persoonlijk, gemakkelijk en goedkoop is en die een model van klantenservice voorstelt, kan een nuttig concept zijn om het gebruik van het internet op een mobiel apparaat te ondersteunen. Een onderbrekingstaak die gegenereerd wordt vanuit hetzelfde apparaat (gelijke oorsprong) en met hetzelfde type interacties als de primaire taak (zoals aanwijzen met een stylus of muis-cursor en informatie-invoer op een scherm) op een enkelvoudig scherm leidt tot seriële omschakelingen tussen taken en dat beïnvloedt de gebruikersprestatie in negatieve zin. We wijzen de vertragingen van de onderbroken primaire taak toe aan de verstoringen in het geheugen van de gebruiker, waardoor de gebruiker moeite heeft om zich te herinneren waar de taak hervat moet worden. Deze verslechtering en interferentie van het werkgeheugen wordt met name veroorzaakt door de seriële omschakelingen tussen taken, die leidt tot verwarring en problemen bij het hervatten van een taak.

Onze aanbevelingen voor een interactie-ontwerp omvatten assistentie voor het gebruik van het mobiele web bij multitasking met onderbrekingen. Wij stellen als onderdeel van het

‘Attentive Interface for Mobile Multitasking’ raamwerk voor, dat assistentie nodig is om de aandacht en het geheugen van gebruikers voor de primaire taak te ondersteunen, bijvoorbeeld d.m.v. de PRI en ISP. Gebruikers kunnen beter omgaan met onderbrekingstaken indien ondersteuning wordt geboden bij het anticiperen op de onderbreking (i.e. onderbrekingstransparantie). Ook de bemiddeling van onderbrekingstaken in de vorm van een inhoudelijke samenvatting van de boodschap wordt aanbevolen. Bovendien moet de assistentie van het onderbrekingsmanagement door de gebruiker zelf begrepen worden en op een juiste manier worden aangepast . Mobiele assistentie voor onderbrekingsmanagement moet worden beschouwd als een middel waarmee de gebruiksvriendelijkheid van het Internet met een mobiel apparaat kan worden verbeterd.

Curriculum Vitae

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1999-2001	**Intel Corporation**, Folsom, USA Human Factors Engineer, Information Technology
1998-2000	**California State University Long Beach**, Long Beach, USA Masters of Science Gerontology, emphasis in Aging, and Human Factors
1999-2000	**UCLA/VA Greater Los Angles Health Care System**, Los Angeles, USA Qualitative Research Specialist Geriatric Research, Education and Clinical Center
1995-1998	**University of California Irvine Medical Center**, Orange, USA Research Associate, Dept. of Pediatrics Center for Morphometric Analysis (CMA)
1989-1995	**University of California Irvine**, Irvine, USA Research Associate, Dept of Neuroscience Alzheimer's Disease and Down Syndrome Research Core & Clinic
1985-1989	**Chapman University**, Orange, USA Bachelor of Arts Major: Psychology: Minor:Biology

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