MULTITASKING AND INTERRUPTIONS DURING MOBILE WEB TASKS

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Common traits of mobile computing are time critical tasks and interruptions that require multitasking. Essential for success of a mobile web task is quick and accurate performance. To facilitate performance in response to interruptions, an understanding of factors that influence multitasking during mobile computing is required. This study examines the effect of anticipation and origin (i.e. instant messaging, or phone and intercom) of an interruption on user web performance on a mobile device (iPAQ h3800 pocket PC) or desktop computer. Results show that instant messages can significantly disrupt web task performance time, contrary to popular belief that phones are more disruptive. Anticipated interruptions produce better web task performance particularly on a mobile platform. As expected, web tasks take 1.5 times longer to complete during interruptions on an iPAQ compared to a desktop.

INTRODUCTION

Conducting multiple tasks on a handheld device such as Internet ticket purchases and concurrently answering a cell phone or instant message adds a multitasking dimension to mobile computing. Multitasking can require a user to conduct several tasks within a time-period by alternating between tasks (Preece et al., 1994).

Tasks conducted on a mobile device can be triggered by people and events, have time constraints and require flexibility for completion (Vaananen Vainio – Matilla & Ruuska 2000). These tasks often have high rates of interruption that distract users from the main task influencing task performance. In addition, users must cope with mobile computing constraints that include, small screens, low bandwidth, slow processors, limited input capabilities and the physical environment (e.g. noisy location and awkward position of use) (Vaananen Vainio –Matilla & Ruuska, 2000). The use of design principles from previous media and the "one size fits all paradigm" (Ramsey & Nielsen, 2000) further complicates Internet use on a mobile device.

Multitasking on a handheld can result in usability issues with web task completion, disorientation, need for recovery during a web task and juggling of tasks while mobile computing. Thus, a need exists for the design of efficient human-computer interaction (HCI) between the user and handheld device to enhance web task performance during multitasking activities.

MULTITASKING WITH A HANDHELD

The literature on user interaction with small screens and user handling of interruptions on desktop computers is relevant to the study of multitasking on mobile devices. Studies using mobile screen simulations on a desktop computer indicate lower rates of web task completion with retrieval tasks, high demands on navigation, excessive scrolling (Jones, Marsden, Mohd-Nasir & Boone, 1999), and increased performance time for option selection (Buchanan et al., 2001).

Previous studies investigating the effects of interruptions during desktop computing tasks highlighted user performance issues. Interruptions have been shown to negatively affect user performance time, efficiency and increase in number of errors (Gillie & Broadbent, 1989). Interruption tasks that are complex or similar to the main task and requiring immediate attention can disrupt the main task, allowing users to rehearse or review their place in the task prior to an interruption does not mediate the disruptiveness of the interruption task (Gillie & Broadbent, 1989). Desktop computers with on-screen interruptions from Instant Messaging (IM) unrelated to ongoing web tasks result in longer completion times for an evaluation task and difficulty in resuming tasks (Cutrell, Czerwinski, & Horvitz, 2000).

McFarlane (1999) concludes that developing intervening methods for coordinating interruptions should focus on performance aspects for system success, therefore, not solely focusing on screen size. The research on small displays by Jones et al. (1999) using mobile screen simulations does not capture the full interaction of users on a mobile device. Understanding the context and tasks in which users experience interruptions are important to improving design for intelligent management of interruptions (McFarlane & Latorella, 2002). Assessing web task performance during user handling of interruptions on a handheld provides an understanding of multitasking behavior common to the mobile context.

Interruptions and Mobile Web Tasks

As mentioned, interruptions are common to mobile computing and problematic due to cognitive limitations of users. A high demand on attention can limit efficiency during multitasking on a mobile device. An interruption can influence a user to multitask by alternating or switching attention (task switching) from the task to the interruption placing an increased burden on attention and memory (Gillie & Broadbent, 1989). Serial attention is required when multitasking and involves adopting and maintaining a task set, shifting to a different task and back to the original task set (Altmann, 2000). For example, a user is buying tickets on the Internet with a pocket PC and is notified of an IM, the user answers the IM, than returns to the ticket purchase. Switching between tasks places demands on attention increasing cognitive workload and affecting performance (Neerincx, Van Doorne & Ruijsendaal, 2000).

A user is often required to immediately handle an interruption during use of a handheld. Interruptions occur from external sources such as phone calls, overhead paging, beepers and computing based sources such as IM and chat programs, email and personal agenda notifications, advertising and in the future a proliferation of intelligent personal agents that communicate with and assist users with mobile computing tasks. The origin of an interruption such as internal computing (e.g. IM, email) or external (e.g. cell phone, intercom) interruption can influence a users web performance. Intelligent interruption management for a handheld needs to consider the origin of an interruption in a mobile context of use in consideration of the user, task, device, and environment.

In general design guidelines have been proposed for mitigating the impact of interruptions on user performance. However, formal design standards primarily recognize interruptions as a problem and rarely include advice for management of interruptions or explicit design directions (McFarlane & Latorella, 2002). The mobile context is an interruption-laden environment and especially lacking are design guidelines for intelligent handling and presentation of interruptions during use of a handheld. Design for interruptions on a handheld are currently addressed in a generic fashion. For example, design the task flow in a flexible enough way so that task switches and interruptions are allowed (Vaananen Vainio – Matilla & Ruuska 2000), or implicitly stated in design guidelines for stability, forgiveness and use of real world metaphors such as bookmarks.

More specifically, guidelines for handling of interruptions have been addressed in warning research and designing of alerts. Research on warnings suggests that advanced notice of interruptions has a positive effect on performance due to rehearsal for later resumption of task (Czerwinski, Chrisman and Schumacher 1991). Obermayer and Nugent (2000) created a design guideline for an alerting and attention management system, for a naval Multi-Modal Watchstation. Guidelines related to management of interruptions include the following: 1) presentation of an alert or alarm is an interruption and interruptions may cause errors, 2) manage attention and use multiple levels of "attention getting" in guiding the operator to the next step, 3) permit the operator a degree of control in delaying, deferring or canceling messages 4) manage simultaneous and competing messages.

McFarlane (1999) and McFarlane & 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 interact with it, b) negotiated solution, assistant announces need to interrupt the user then supports user negotiation for receiving interruption, c) mediated solution, not directly interrupt the user but contact person's handheld (e.g. Personal Digital Assistant) and request interaction, d) scheduled solution, a pre-arranged schedule is used to interrupt user. The negotiated solution, emphasizing support for human control over coordinating the onset of interruptions was best for supporting performance. The immediate solution produced the quickest user reaction to an interruption task, but was overall less efficient.

The proposed solutions for management of interruptions primarily focus on desktop computing. Designing for management of interruptions during use of the Internet on a handheld requires an understanding of how users deal with constraints of a mobile device while handling interruptions. This paper presents a study on multitasking and interruptions during mobile web tasks. This experiment was expected to replicate findings from previous studies on interruptions with desktop computers and provide empirical evidence to support development of design concepts for management of interruptions during use of a handheld. It was expected that IM would negatively influence user web task performance on a handheld. Furthermore, anticipation of an interruption would allow a user to prepare for an interruption, facilitating task switching and attention for a task, therefore reducing the amount of time spent on a handheld web task.

This study examined the effect of anticipation (i.e. expected, unexpected) and origin (i.e. IM, or phone and intercom) of an interruption on user web task

performance on a mobile device (iPAQ pocket PC) or desktop computer. The following hypotheses are proposed for this study:
1) Web tasks with interruptions will take longer to complete on a mobile device compared to a desktop computer, due to a smaller screen, limited input interaction and demands on attention.
2) IM interruptions are more disruptive to web performance than phone or intercom interruptions due to similarity in computing medium.
3) Anticipated interruptions facilitate attention, promoting efficient web task actions and less disruption on web performance than unanticipated interruptions, regardless to type of device or origin of interruption.
4) Anticipated interruptions will decrease web performance time, compared to non-anticipated interruptions particularly on a mobile device, regardless of origin.

METHOD

Participants

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 Compaq iPAQ h3800 pocket pc group (n = 4) and desktop group (n= 4). The study procedures were conducted in a usability laboratory setting.

Design

The experiment consisted of a between group variable for device (iPAQ and desktop), 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. A Latin square design was used to counterbalance the four types of interruptions, unexpected external and unexpected internal, expected external and expected internal. Tasks were randomly 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 addition and subtraction questions. Control tasks were randomly presented without interruptions.

Web sites used for the study were a bookstore (Duwamish) and financial (Fitch and Mather) stock related web site, an Enterprise Sample of Visual Studio.Net developed by Microsoft. 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). Participants performed 16 tasks, divided into four blocks with four tasks in each block. To balance the website presentation two forms with tasks were administered to participants.

Procedure

Each participant was administered the following: a user questionnaire, training session with two practice tasks, the web tasks and a semi-structured interview. To begin the task phase 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 began the web task, responded to the phone call, intercom message or IM notification, completed the addition or subtraction questions and returned to the original task. Individual sessions were videotaped for data collection and analysis.

Performance was calculated from the time data for the following: 1) beginning of web task to the notification, 2) switch from web task to interruption task, 3) interruption task, 4) switch from interruption task to web task and 5) primary web task to end. The data analysis consisted of the mean performance times for completion of the primary web task (excluding switch time and interruption 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).

RESULTS

The results presented are based on an analysis for the total performance time in seconds to complete the web tasks, excluding time for switching and 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. There was a significant difference between the iPAQ and desktop groups $F\ (1, 6) = 20.42$, $p = .004$. Web tasks took longer to complete on the handheld iPAQ ($M = 465$, $SD = 70{,}72$) than desktop computer ($M = 297$ seconds, $SD = 23.28$) and there were few errors for the iPAQ ($M = 16$, $SD = 5$) and desktop ($M = 11$, $SD = 5$) groups. Therefore, an ANOVA was not used to further analyze the data on errors. Control tasks presented with no interruption were excluded from the repeated measures analysis. The mean performance times for the control tasks are shown in Figures 1 and 2.

Results also indicated a significant main effect for origin $F\ (1, 6) = 6.26$, $p = .046$ (Figure 1); an internal computing interruption (IM) increased the time to complete a web task compared to an external interruption (phone or intercom message) for both the iPAQ 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, $\underline{p} = .004$ (Figure 2). The expectation of receiving an interruption decreased performance time on a web task compared to no expectation of an interruption for the iPAQ and desktop platforms, particularly on a mobile platform.

Figure 1. Origin of Interruptions

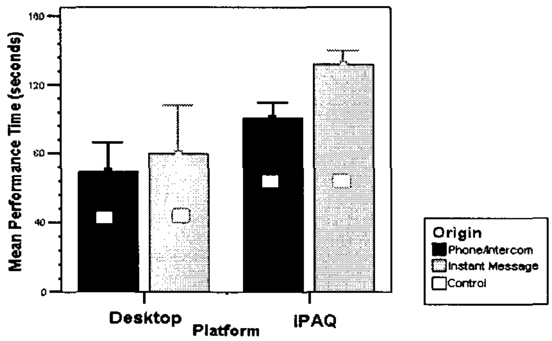
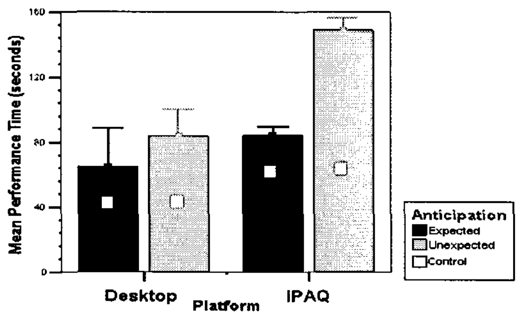


Figure 2. Anticipation of Interruptions



CONCLUSION

The results support the first hypothesis that 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. Interruptions, screen size and input interaction contributed to performance time differences between groups. Similar to the observations by Jones et al. (1999) for small screens, a high rate of scrolling on the iPAQ was observed for users to complete tasks. Navigation was not an issue during the tasks. The tasks constructed for the study were geared towards short tasks with specific end goals.

The results support the second hypothesis, that interruptions from IM are more disruptive to web task performance time compared to phone or intercom interruptions on both mobile and desktop platforms. Cutrell, Czerwinski & Horvitz, (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.

The results support the third hypothesis that an expectation of an interruption would have less of a negative effect on web performance compared to an unexpected interruption. Czerwinski, Chrisman and Schumacher (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.

The results also support the fourth hypothesis that an expected interruption during a web task on a mobile device particularly decreased performance time. 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 with multitasking and 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 mobile device web use.

DISCUSSION

Overall, similarity in computing mediums for task (IM, web task), input interaction and the small screen required additional scrolling with demands on attention for multitasking that subsequently prolonged total performance time on the iPAQ. Changes in performance time are attributed to the amount of attention involved and memory load of the tasks during multitasking. The memory load on the web and interruption tasks were low, and the cognitive limitations were attributed to demands on attention. It is speculated that costs to performance time observed when switching between a primary task and an unexpected interruption task may be due to attention tunneling, when switching back to the primary task. Since the interruption and primary tasks were not considered memory intensive, switching between tasks may benefit from cues to engage attention. Therefore, switching between tasks requires an attention cue enhancing recognition to direct the user to a place in the task. The expectation of an interruption is speculated to facilitate attention for a task, which promotes efficient actions and stimulates memory rehearsal for completing a task.

Our interest in web task performance and interruptions during multitasking is to develop an HCI concept for a personal assistant that mediates between the user, web service and device for the Personal Assistant for onLine Services (PALS) project (Lindenberg, Nagata,

& Neerincx, in press). This is the first in a series of studies that will be conducted for the PALS project.

IMPLICATIONS

Developing HCI concepts for the mobile context requires designing to guide attention and mediate interruptions to support tasks. We propose to develop and test the following concepts for the PALS assistant:

Attentive Interactive Display

Web tasks performed with interruptions on a handheld appear to last 1.5 times longer in comparison to use of a desktop. Attention indicators can reduce the amount of time spent on a mobile web task when receiving interruptions.

Point of Return Indicator directs a users attention to a suspended task after an interruption. For example, a highlight is presented around a text box as an indicator for a specific point in a task.

Interactive Suspension Point is a bookmark concept. With a stylus, a user can tap the screen to indicate to the system a point of return in a task. When returning from an interruption, PALS will then present a point of return indicator.

Mediating Interruptions

We propose an intelligent mediation solution as opposed to a negotiation solution for user handling of interruptions in a mobile context (McFarlane & Latorella, 2002). Handheld users may be time constrained and not have the cognitive wherewithal to negotiate with the system when presented with an interruption. Introducing intelligent mediation may reduce the performance costs associated with handling of computing interruptions.

Interceding Instant Messaging interruptions, for example, during a purchasing transaction the assistant handles IM interruptions. IM computing interruptions increase web performance task time when compared to phone or intercom interruptions for mobile and desktop computing.

Transparency of interruptions can reduce web task performance time. When an IM is interceded, the assistant can inform the user creating anticipation to deal with the interruption with a less negative impact on performance time than an unexpected IM interruption. The expectation of receiving an interruption on a handheld device decreased performance time on a web task compared to no expectation of an interruption.

Virtual assistant and user communication should be in a different presentation mode (e.g. voice) from the primary web task. Virtual assistant communication via a mobile screen is considered an interruption. A similarity in computing mediums for interruptions (e.g. IM and web task) seemed to prolong web task performance time.

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