Need for Non-Visual Feedback with Long Response Times in Mobile HCI

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ABSTRACT

When browsing Web pages with a mobile device, the system response times are variable and much longer than on a PC. Users must repeatedly glance at the display to see when the page finally arrives, although mobility demands a Minimal Attention User Interface. We conducted a user study with 27 participants to discover the point at which visual feedback stops reaching the user in mobile context. In the study, we examined the deployment of attention during page loading to the phone vs. the environment in several different everyday mobility contexts, and compared these to the laboratory context. The first part of the page appeared on the screen typically in 11 seconds, but we found that the user's visual attention shifted away from the mobile browser usually between 4 and 8 seconds in the mobile context. In contrast, the continuous span of attention to the browser was more than 14 seconds in the laboratory condition. Based on our study results, we recommend mobile applications provide multimodal feedback for delays of more than four seconds.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User and machine systems – *human factors.*

General Terms

Human Factors, Experimentation

Keywords

Multimodal feedback, Attention, Mobility, Mobile Web, Usability

1. INTRODUCTION

When moving a browser or other office applications into mobile devices, designers typically focus their user interface renewal efforts on information visualization on a small screen and on interaction with the application without the use of a mouse. When concentrating on the device limitations, designers often forget the requirements that the mobile environment itself introduces. Several "mobility tasks" such as walking, navigating, avoiding collisions, safety, taking care of personal space, and social interaction compete for the scarce attentional resources of the user [12]. Therefore, the best applications for a mobile context provide a Minimal Attention User Interface [9]. The user should be able to focus attention primarily on the environment and minimally to the application.

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Web browsers are available even for mobile phones and can be used at a bus stop, in a train, on an escalator, while walking on the street, or even while driving a car. A Minimal Attention User Interface would definitely help the user in these contexts, but it will be very hard to provide a non-visual user interface for a highly visual Web browser. We can start tackling the problem at the easiest point: minimizing the attention needed during long page download times.

1.1 Page Download Phases

Although the network connection used for mobile browsing is becoming faster with 3G and other hotspot networks, Web browsing on a mobile device will continue to suffer from page download times of more than 5 seconds. The network connection speed is not the only bottleneck. The processing power of the

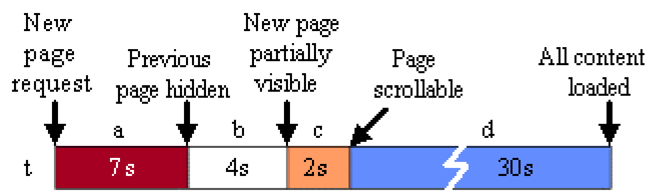

Figure 1. Mobile browser responses during a typical Web page download.

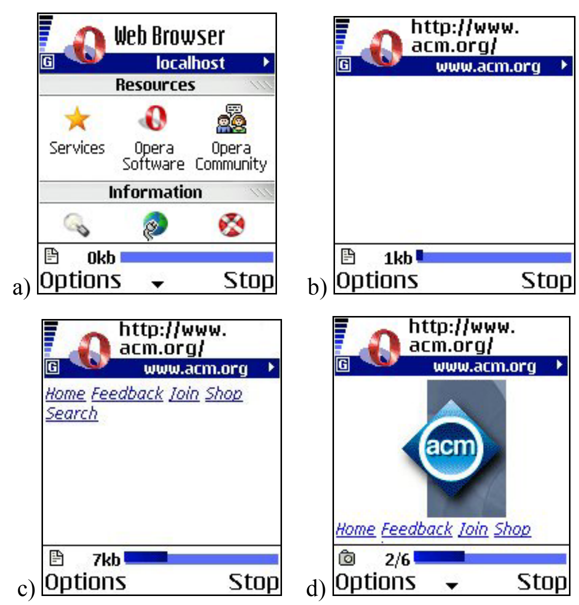

Figure 2. Opera browser user interface changes during the four download phases of Figure 1.

device makes page rendering onto a small screen much slower than on a PC.

The most important response comes with the first visible part of the page, not after images and other components have arrived. The time between “New page request” and “New page partially visible” in Figure 1 defines the system response time in our study. Because the user can start reading, scrolling, and selecting links after this point, many users start to download the following page before receiving “All content loaded”. Thus, the “All content loaded” point is irrelevant in many cases and is ignored in our response time figures.

After the user has requested a new Web page, the Opera browser on Nokia 6600 mobile phone shows first a progress bar below the old page (Fig. 2a), and when the first parts of the HTML file arrive, the browser empties the page area and starts processing the markup (Fig. 2b). Opera renders the page incrementally, so that the first content displays before the whole markup file has arrived (Fig. 2c). The images appear one by one, and the progress indicator shows the number of images loaded (Fig. 2d).

1.2 Need for Multimodal Feedback

In the present paper, we investigate the need for non-visual feedback with long system response times, particularly when downloading Web pages to mobile devices. Long response times are not solely an issue with the browser, but our findings can be applied generally to functions with long response times, like uploading, downloading, sending, saving, or opening material with a limited processor or limited connection speed.

In earlier mobile browsing studies, we noticed that the user’s attention shifts away from the browser before the page arrives, even in a laboratory environment [11]. While waiting for the first part of the page, users must glance at the screen constantly to execute a task as soon as possible after the display completes.

By using multimodal feedback, the need for visual attention decreases. For example, a mobile browser could capitalize on the features built into a handheld device and provide tactile feedback when the page arrives. By tactile feedback, we mean indicators that a user can feel, rather than seeing or hearing. The vibrating alert, available in many mobile phones, is a typical example of vibrotactile feedback: when the phone is in “silent” mode, the vibrating alert lets you feel when a message arrives. Tactile feedback is well suited to handheld devices and to long system response times, because the user often holds the device or keeps it close.

However, it may be annoying if vibrotactile feedback is used for all functions, no matter how quickly the system responses. The vibrating alert should be limited to functions with relatively long response times, when the user has probably taken his/her eyes off the screen. Although it is clear that multimodality is beneficial for mobile use, it is not clear when it should be implemented as a feedback technique. This leads us to our main research question: W*hile waiting for a response, how long does the user typically continue to look at the screen in a mobile context?*

One of the well-known response time heuristics for *office* applications states that ten seconds is “about the limit after which a user turns away from the dialogue to other activities” [7]. Nielsen recommends providing a progress indicator in the form of percent-done whenever the response time is expected to exceed ten seconds - this enables the user to estimate how long a function will take and to turn to other activities. A percentage-type progress indicator would also be beneficial in the mobile context, but the key would be the multimodal feedback that requires minimal visual attention.

Our hypothesis was that in the mobile context, the continuity of attention would break down sooner than in an office environment. We tested the hypothesis in a user study with 27 participants browsing the full Web on a mobile handset in nine different mobile situations. In this paper, we present the method and results of that study, and discuss the implications for mobile browser development.

2. RELATED RESEARCH

Our topic spans on several research areas: user behavior with different response times; characteristics and study methods of mobile context; and multimodal feedback.

The system response time studies related to user behavior can be divided roughly into examinations of acceptable waiting times and studies of the human attention with regard to different system delays. Acceptable waiting times for the loading of Web pages are defined according to user expectations: the faster the Web connection becomes, the shorter the time that the users are willing to wait [6]. Hence, acceptability changes rapidly as the connection speed increases. In the case of mobile Web browsers, response times are rapidly decreasing and most probably the response time of about 10 seconds in our study will be history by the time this paper is published. We did not examine the acceptability of response times; instead, we concentrated on how people focus their attention while waiting for the responses during long delays. Although attitudes and expectations change over time, the basic capability of human attention has not changed during the decades [5,2], so we believe the results of our study will be relevant long after the year 2005.

Although there have been claims to the contrary [4], we believe that testing outside of the lab is worthwhile and even necessary. As we will show, attentional resources differ radically between laboratory and real mobile contexts. This stems from the fact that mobility itself competes for the same scarce attentional resources as do the mobile devices. In our view, mobility tasks are not restricted to moving (navigating, avoiding collisions, way finding etc.) but include other, more social forms of action in the real world, all of which require some cognitive resources. For example, *waiting* for a metro to arrive is not simply a matter of sitting idly with all cognitive resources free for time killing activities. Waiting involves estimating when the metro arrives, moving to a position where an approaching metro can be perceived, continuously interpreting auditory sense data, monitoring how personal space is perhaps intruded upon by passers-by, and, occasionally, visually attending to the environment to see if the metro is coming [12].

Examining user behavior in a real-world mobile context is a difficult task. All equipment must be portable, weatherproof, unobtrusive, and of good quality. It is difficult to record the display of small handheld devices or a user’s face while walking. We have explained our study method in detail elsewhere [10], where we emphasized the uniqueness of our apparatus for investigating not only the user’s interaction with his/her mobile device but also the face of the subject, his/her field of vision ahead, and the surrounding environment.

We have been unable to locate any studies investigating the need for multimodal feedback with long response times in mobile

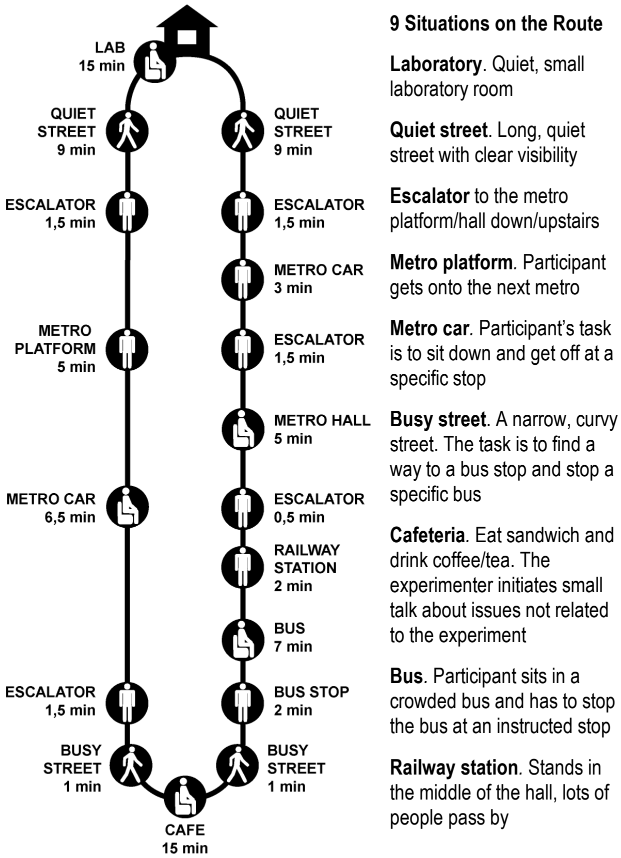

Figure 3. The route consisted of several places and transitory places between them.

context. Multimodal feedback studies show that tactile feedback works well with handheld devices. Unlike audio feedback, tactile feedback is personal and does not disturb people nearby [1]. Of course, when the device is not close to skin, tactile feedback may escape one's attention. When tactile feedback is used as the response to a user's action, it is more likely that the user will keep the device in hand and feel the feedback.

3. METHOD

To test whether users switch their attention away from a dialogue sooner in a mobile context than in a laboratory, we ran a user study with 27 participants. The participants moved around the city of Helsinki and executed Web browsing tasks on a mobile phone while moving. For comparison, we also executed similar tasks in a laboratory. Participants' behavior, action, and context during web page loading were recorded in different mobile situations. Special arrangements were needed due to mobility [10].

We were looking at several micro-level measures of attention after page loading started. Particularly, we were interested in how long it takes in different mobile contexts before the user's attention shifts from the mobile phone to the environment after page loading has begun.

3.1 Participants

Twenty-seven Finnish subjects participated in the experiment. Fourteen of them were between 20 and 26 years old and thirteen were between 41 and 47 years old. The gender distribution in both age groups was equalized, but in the middle-aged group we had 7 females vs. 6 males. They all knew some of the locations in Helsinki, but some parts of the route were new for most participants. All participants were familiar with browsing the Web on a PC, but they did not have any experience on browsing the Web on a mobile phone. When recruiting the participants, we explained they would have to carry cameras and a 4kg backpack.

3.2 Design

Participants from both age groups were assigned randomly to 1) a route direction (normal or reverse) and 2) a task order (normal or reverse). These counterbalanced sets were devised to tackle order effects (see also [10]).

3.3 Materials

The task consisted of retrieving a piece of information from a given website. Well-known leisure-related websites were selected, most of them by commercial or public services in Helsinki. At least one interaction step had to take place to perform the task. The need for text input was minimized. Altogether, 25 tasks were defined, and all websites were in Finnish.

In the experiment, the route itself was part of both stimulus material and the procedure. The route consisted of several places in the Helsinki city center. See Figure 3 for the locations, situations, transportation, and times. We deliberately included different contexts along the route (crowded vs. peaceful, indoors vs. outdoors), and places for sitting, standing, and walking.

3.4 Training and Procedure

Before the trials began, the experimenter greeted the participant, noted background information about her/him, and read aloud an overall description of the experiment (not revealing the purpose of the study). Next, participants were trained. They were shown how to use the mobile phone and its Web browser. Training was incremental, starting with simple tasks (e.g., opening the application menu) and ending with two full tasks (e.g., looking at whatis.com to see what "ITV" means).

After the training, the experiment started. The experimenter read aloud the task description to the participant. The instruction involved the task (e.g., "Find your favorite item from today's menu at the University restaurant") and the associated bookmark number in the browser (e.g., "Choose bookmark number 4"). Some contexts involved instructions for doing "mobility tasks" related to that location (see Figure 3, right column). Consequently, some tasks were done while moving (route was provided if the participant did not know it) and others while standing or sitting. When moving, the participant led the way and the experimenter shadowed a few steps behind without disturbing the participant. After accomplishing the task, the experimenter recorded the participant's answer and then gave new instructions.

Participants performed each task within one of the three instructed time pressure (ITP) conditions. 1) In the *hurry* condition, the task was to be accomplished as quickly as possible. 2) In the *baseline* condition, the task was to be done within a given (4 minutes) or implicit (before the metro comes) timeframe. The timeframe was sufficient to perform the task, but if exceeded, the experimenter stopped the task and gave instructions for the next task. 3) In the *waiting* condition, the participants waited for a metro (for example) and were told that they had plenty of time to carry out a single task. Typically, a single experiment lasted approximately 2 hours.

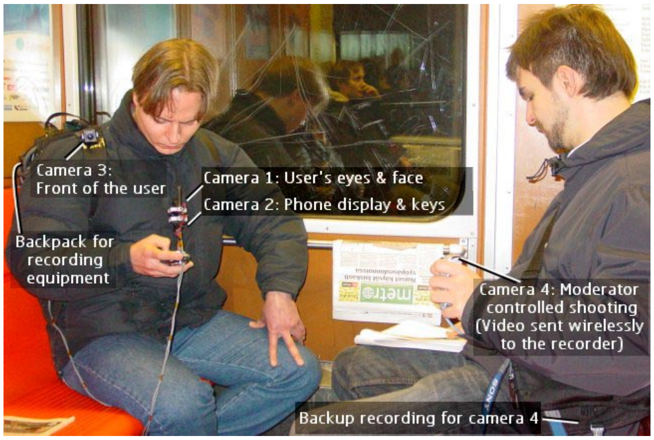

Figure 4. Configuration of recording equipment.

Figure 5. Output video data was integrated on the fly.

3.5 Apparatus

The participants performed tasks on a Nokia 6600 mobile phone running a mobile Web browser (Opera) over a GPRS connection. We did not examine the data transfer rates during the study, because we were interested only in the system response times. We assumed the average speed of a GPRS connection was about 20-30kbps.

Four 30g Watek WAT 230A minicameras were used for video recording. Two minicameras were attached to the test phone, one capturing the phone display and keyboard, and the other focused up towards the user's eyes. A third camera was attached to the backpack shoulder strap facing forward to record the field of vision ahead. Finally, the experimenter's minicamera (hidden in a phone shell) captured the user and/or the overall environment, including events at which the participant did not turn his/her attention but which might have affected his/her attention focus: for example, a street musician. The video stream from the experimenter's camera was sent wirelessly to a receiver in the participant's backpack. Since we knew that wireless video is susceptible to disruptions, we backed-up this view onto a tape carried by the experimenter. We aimed to make the recording operation non-intrusive and invisible to the subject and other people (Fig 4). That is why we did not place the participant's third camera on her/his forehead but we attached it to the shoulder strap instead. As well, our eye-tracking system would have been helpful in this study, but it could not be taken out into the wild.

The participants carried most of the equipment in a backpack. It contained a microphone, a video camcorder, batteries, a wireless link receiver, and a quad for creating a single video from four video streams (Fig. 5).

3.6 Coding

Five coders carefully watched the videos, with many pauses and playbacks, to code the taped actions and events on to a data sheet. They employed the following coding scheme:

- **Time stamp**: Time for the entry (accuracy of one second)
- **Task number**: 1–25
- **Location**: Café / Metro platform / …
- **Instruction on Time Pressure**: Hurry / Wait / Normal
- **Movement]**: Walk / Decelerated walk / Stand / Sit
- **Focus of user's attention**: Phone / Environment
- **Interaction**: Starts operating the phone / Stops it
- **Status of the application**: Loading / Scrollable with only text loaded / All content loaded
- **Crowd level**: No people around / Some people around (not moving) / Some people around (moving) / Many people moving, crowded.

The five coders held a preliminary meeting to agree on the coding scheme and practice on using it. Inter-rater agreement was not calculated as the events were deemed as "objective", that is, easily recordable from the data (e.g., time, location, instructions, posture of the person, starting/ending interaction with the device). An exception to this was crowd level, which required a more subjective opinion.

4. RESULTS

We analyzed 1761 page loadings in total. The response time from link activation to the display of the first part of the page was 13.2 seconds in average (median 11s), but the response times of successful page loadings varied as can be seen from Figure 6. Variation was due to different page sizes, variable load, and availability of GPRS connection during the mobile sessions. In some cases, the site did not respond and the user did not receive the page at all. These unsuccessful waiting times were ignored in the analysis. The participants could not estimate the response times in advance, which was important for the validity of our results.

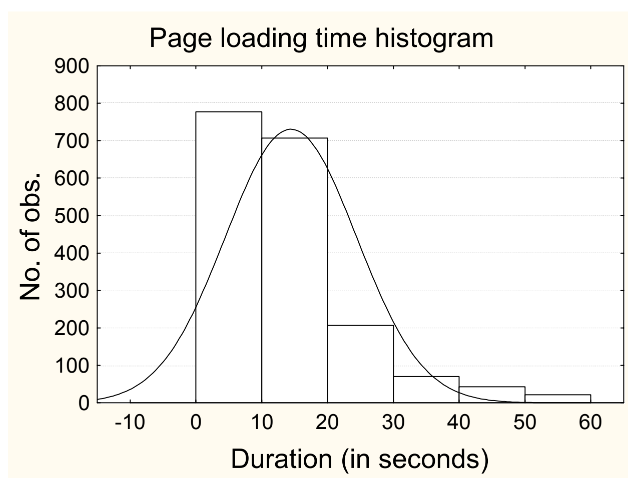

Figure 6. Page download response times

In Figure 7, we see the periods where the attention was continuously focused on the browser dialogue while waiting for a response in each of the nine different contexts. We found a very significant difference between the extreme mobile contexts and the laboratory. The average gaze time in the laboratory was 14.3 seconds, whereas the gaze times on the escalator and the busy street are both well below 6 seconds. This marks more than a three-fold difference in the duration of continuous attention between the two extremes, laboratory and busy street. In mobile context, the average gaze time to phone right after the page request was 6.8 seconds, with a median of 4.0 seconds and a standard error of 0.281.

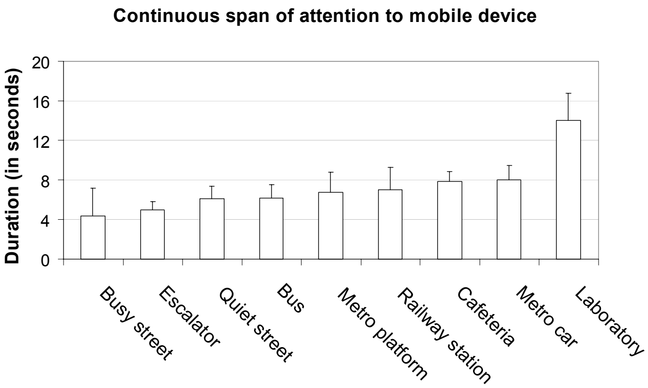

Figure 7. Duration of continuous attention to the mobile device during page loading. Error bars denote 95% confidence intervals (CI).

We also wanted to test if there were any differences in gaze patterns between young adults, aged 20-27 years, and middle-aged participants of 40-47 years. We found a significant difference in their gaze patterns during downloads: young adults looked at the display for 2.3 seconds shorter than the middle-aged participants (Fig. 8). These figures include the lengthy gaze periods of the laboratory tasks.

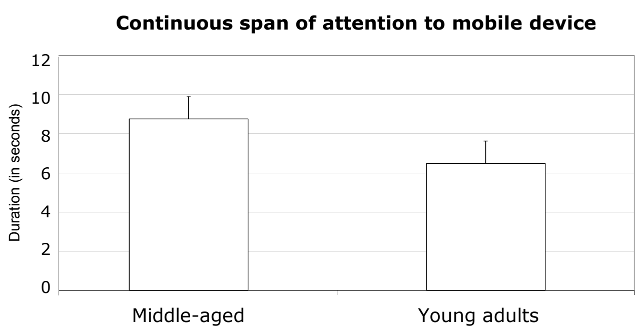

Figure 8. Young adults shifted attention to environment sooner than the middle-aged. Error bars denote 95% CIs.

The number of attention-switches away from the mobile device during a page loading was close to 8 in busy street but below 1 in laboratory, again a substantial difference (Fig. 9).

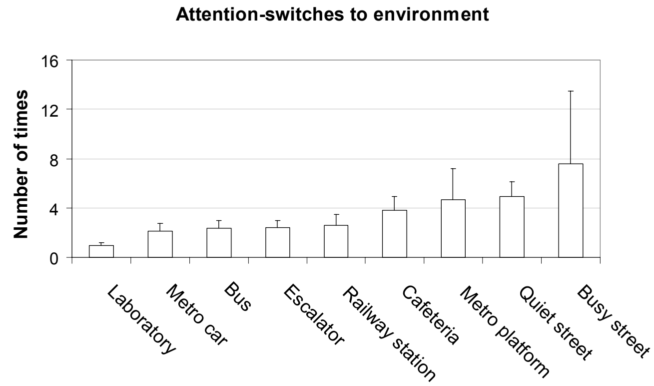

Figure 9. Number of attention-switches away from the mobile device during page loading. Error bars denote 95% CIs.

Switch-back durations (the time spent in attending to the environment before switching back to the mobile device) show differences in how long the environment needed to be attended to before switch-back was possible (Fig. 10). In the first group, laboratory, metro platform, railway station, and cafeteria, the switch-back durations were all in the range of 7 to 8 seconds. In the second group, escalator, quiet street, busy street, and metro car, the durations were in the range of 4 to 6 seconds. Bus and cafeteria fell between 6 and 7 seconds. The difference between the two extreme groups was significant.

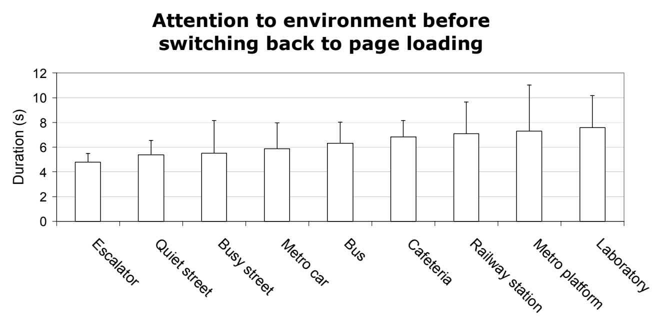

Figure 10. Switch-back times during page loading. Error bars denote 95% CIs.

5. DISCUSSION

According to Nielsen [7], users usually wait 10 seconds for a response in a laboratory environment, after which they turn to other tasks. This 10-second rule is widely used in industry when performance or user interface requirements are set. There was an open question about how soon the attention typically shifts in a *mobile* context.

We realize there is no single reliable answer to our research question because of the variables in different mobile context, as well as in users' motivations and in temporal tensions. Our goal was to find out *average* or *typical* user behavior and demonstrate that mobile context is indeed different from the laboratory in this respect. To avoid generalization from restricted data, we varied the mobile context from vehicles and cafeterias to walking on the street, from crowded places to peaceful ones, and from indoors to outdoors. We also tested the behavior with different temporal tensions (baseline, hurry, wait), and compared young adults to middle-aged participants.

The evidence collected in the different circumstances shows that in a mobile context, user's attention shifts away from the mobile

Web browser much earlier than in a laboratory. The data we collected is influenced by the test situation where the users knew they were being watched and examined. They probably concentrated on the browser more than they would do in daily life, so the phone gazing times found in our study may be even shorter in real life.

It is interesting to note that whenever the participant was sitting, the gaze time was longer, but walking did not necessarily mean a shorter gaze time than standing. When walking on a quiet street, the gaze time was longer than when standing on a metro platform or on an escalator (Fig. 7). The amount of stimuli around and the temporal tension of waiting affected behavior more than their leg movement.

The variation between the two age groups (Fig. 8) means there can be notable differences in gaze patterns between individuals. Some multimodality studies have shown that middle-aged subjects benefit from multimodal feedback [3], so we believe providing multimodal feedback several seconds after the request will not disturb the middle-aged users even if they would still be looking at the display. We must remember, however, that these figures are from the case where no tactile feedback was available. It would be interesting to see how the figures develop when the system provides multimodal feedback.

The switch-back times (Fig. 10) ranging from about 4 to 8 seconds shows that the environment was not only briefly sampled visually but attended to monitor surrounding events and to control action. Had the switch-back times been shorter, we would have no reason to give tactile feedback as the page loading would be noticed anyway within just 1 to 2 seconds. One might ask whether 4 to 8 seconds is enough either. However, we want to emphasize that this figure (as most figures in this experiment) most likely underestimate the behavior in a non-evaluative situation.

5.1 Implications

We saw the average gaze times (from page request to the first glance away from the display) were between 4 and 8 seconds in the mobile contexts (Fig. 7), with the median being as low as 4.0 seconds. This result has several interesting implications, noted below.

First, the famous 10-second response time rule does not apply in a mobile context. We saw the rule applied in a laboratory, but there was a very significant difference in user's attention focus between laboratory and mobile context. This means developers should not obey the 10-second response time rule when developing applications for mobile context. We do not know, however, if the response time rules of 0.1 and 1 second [7] do apply in mobile context; our current hypothesis is that they do.

Second, we should increase the fluency and safety of mobile browsing by not forcing the user to glance at the screen repeatedly while waiting for pages to arrive, but by providing non-visual feedback for long response times. Tactile feedback is excellent for this purpose, because it is personal and does not disturb people nearby, unlike audio feedback. When the user keeps the device in hand, a short vibrating alert communicates that there is something relevant on the display and the user may check it when appropriate.

Third, we saw that users rarely move their focus of attention away from the dialogue within the first 2 seconds, so non-visual feedback is not needed for short response times. Excessively used tactile or audio feedback would be annoying, so we do not recommend using it with response times of shorter than 2 seconds on average. Of course, there are cases where the user has to turn away from the dialogue sooner than two seconds. In these cases, it is not necessary for the user to receive the vibration feedback, because the user will know the response has arrived when s/he turns back to the phone.

Most likely, the availability of non-visual feedback will transform the attentional strategies as well. We believe that knowing that feedback will be given when the page is loaded would lower the threshold for attending to the environment during page loading. The number of glances at the phone as well as the total time spent staring at the phone screen during loading would then decrease dramatically. This is the goal of Minimal Attention User Interfaces, which are especially worthwhile in the mobile context.

As a result, if the average response time is long and if the user has learned to trust multimodal feedback, we cannot expect the user to watch the screen even for relatively short response times. Instead, the user may turn to other tasks immediately after entering a request. Because the user is counting on tactile or audio feedback in this case, the system should provide it (in addition to the visual feedback). Taken together, we conclude that *for functions with average response times of 4 seconds or more, the application should provide non-visual feedback.*

6. CONCLUSIONS

When designing products or services for truly mobile use, it is important to minimize the attention required by technology. With a mobile Web browser, the best starting point to decrease the need for visual attention is the user interface for communicating the status of page downloading. When the only relevant information on the screen is a progress indicator, the user should be able to concentrate on the environment. With plain visual feedback, however, the user needs to constantly glance at the display to see if the page has arrived.

As long as the average time from page request to display of the first part of the page is four seconds or more, the browser should provide non-visual feedback at the point when the new page becomes partly visible.

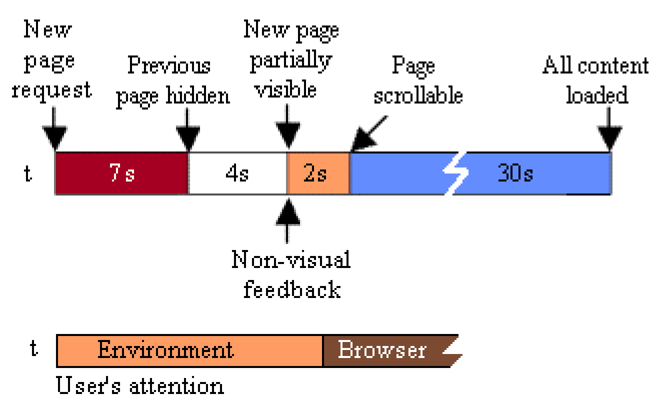

Figure 11. Multimodal feedback would allow the user to concentrate in the environment while waiting for the page.

Figure 11 illustrates the browser responses during page loading, and the corresponding user's focus of attention in an optimal case: the user can turn eyes away from the browser instantly after requesting a page, and just wait for the multimodal feedback to tell when the first parts of the page have arrived. It is then up to the user to decide when to check the page on the screen.

We hope our study encourages mobile browser developers to provide multimodal feedback for page loading whenever the device enables it. The end users will then benefit by having safer, more fluent, and hopefully a more entertaining mobile browsing experience.

7. FURTHER WORK

Human factors in mobile browsing is an interesting research topic with links to many different research areas. More multimodal interaction is needed for truly mobile browsing, plus novel information visualization methods for showing large pages on small screens. Technological developments are required to make page download times shorter, but meanwhile, user interface specialists could investigate how to make waiting time feel shorter and/or minimize the negative effects of waiting.

The design of tactile feedback during the different phases of long system response times is a topic that needs further investigation. A vibrating motor alone provides a range of options to provide tactile feedback. A rhythmic mild vibration during the whole loading period might be delightful, or it may be irritating. The waiting time could be entertaining if there was a rhythmic song 'played' by vibration during waiting. In any case, the user must be able to control whether he wants to have tactile feedback or not.

We are in the process of developing and performing usability tests on a mobile browser that provides a simple vibration alert when the first part of the page becomes visible. The study will not be as extensive as the present study, but we will gather subjective feedback from a long-term study with 10 participants, and hopefully run a quasi-experiment similar to this study with some participants after they have gotten used to browsing with vibration feedback.

Finally, the mobile context itself provides many unexamined topics for further studies: what are the characteristics of different types of mobile contexts, how to conduct reliable experiments out in the wild, and how people behave outside the laboratory. We continue examining a Resource Competition Framework introduced in [8], and welcome all related studies.

8. ACKNOWLEDGMENTS

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