How People Use the Web on Mobile Devices

Yanqing Cui, Virpi Roto
Nokia Research Center
Itämerenkatu 11 – 13, Helsinki 00180, Finland
+358-71-8008000
{yanqing.cui, virpi.roto}@nokia.com

ABSTRACT
This paper describes a series of user studies on how people use the Web via mobile devices. The data primarily comes from contextual inquiries with 47 participants between 2004 and 2007, and is complemented with a phone log analysis of 577 panelists in 2007. We report four key contextual factors in using the Web on mobile devices and propose mobile Web activity taxonomy. The framework contains three user activity categories identical to previous stationary Web studies: *information seeking, communication,* and *transaction,* and a new category: *personal space extension*. The new category refers to the practice that people put their content on the Web for personal access, therefore extending their personal information space.

Categories and Subject Descriptors
H.5.2 [User Interfaces]: User-Centered Design

General Terms
Design, Measurement, Performance, Human Factors, Theory.

Keywords
Mobile Web, Activity Taxonomy, Information Seeking, Content Object Handling, Personal Space Extension.

1. INTRODUCTION
Mobile Web access is currently being hyped as the next big thing for both mobile devices and Web services [12]. People are becoming reliant on the Web for their everyday life, and expanding its access from all devices, including the always-carried mobile devices. The mobile Web is becoming a major revenue generator, following voice calls and text message services. For example, mobile phone Web users had already nearly equaled PC based Internet users in Japan by June 2007 [8].

Web use on a mobile device naturally has some similarities and some differences to Web use on a desktop computer [23, 25]. There have not been, however, comprehensive studies on what are the categories of users' activities on mobile Web. It is an interesting research question to examine if mobile Web use has the same taxonomy of activities as stationary Web. Our research consisted of a series of studies when we designed and implemented Nokia S60 Web browser and a few other Internet applications on a mobile phone. Such user studies played a vital role to inspire and inform new concepts.

WWW 2008, April 21–25, 2008, Beijing, China.
ACM 978-1-60558-085-2/08/04.

In this paper, we first examine some related research and our study methods, followed by the main section on emerging web user activities as well as some key contextual factors. Based on this discussion, we propose user activity taxonomy for mobile Web use and discuss the relevant design implications.

The terminology used in this paper is defined as follow. By "mobile device" we refer to pocket-sized computing devices, primarily mobile phones and personal digital assistants (PDAs). "Use the Web" refers to viewing Web pages with a browser. "The Web" not only covers mobile sites - Web content specifically tailored for mobile devices - but also full Web content and services. "Mobile Web" means using the Web on mobile devices, while "Stationary Web" means using the Web on conventional desktop or laptop computers.

2. RELATED RESEARCH
This section presents literature review on user Web activities. It starts from theoretical and empirical studies on the mobile Web, or the mobile Internet in general for some cases, followed by behavioral studies on stationary Web activity taxonomy.

2.1 Mobile Web Usage
In theory, a mobile device can be accessed anytime, anywhere; therefore the mobile Web occurs in more diverse contexts than its stationary counterpart. Kim et al (2002) and Lee et al (2005) classified mobile Internet use contexts into environmental and personal factors. *Personal context* was the state or condition of the mobile Internet user self, e.g. mental goals and body position. *Environmental context* was the full set of user outer circumstances, e.g. the physical distractions and other people present. After a diary study, they concluded that people usually used mobile Internet by one instead of two hands, in an indoor environment, with a static position [15, 16].

The above-mentioned papers were based on quantitative studies. Such methods, while shedding light on understanding general usage pattern, were not sufficient to inspire new designs [26]. They were likely to ignore the emerging but not-yet-notable trends and the nuanced differences between generic categories. Chae et al (1998) applied the same methodology, questionnaire survey more specifically, and concluded that mobile users wanted to access Web content with low intensity that had small amount of information delivered at one time, for example, news services [7].

There are also several constructive studies that proposed and evaluated new designs, particularly in the domain of Websites [4, 13], and mobile terminals [2, 19, 24, 27]. Reflection upon these empirical studies led to several research frameworks. Roto (2006) proposed a framework covering the major user experience factors in the mobile Web: remote Website, mobile terminal, and connections [23]. Palen et al (2002) summarized the wireless

system containing four socio-technical components: hardware, software, "*netware*" (operator services), and "*bizware*" (price issues) [22]. Jones et al (2006) emphasized the importance of information ecology - the device ecosystem where the mobile Web resides in [12].

2.2 Taxonomy of Stationary Web Tasks

The studies on stationary Web user tasks initiated from the Information Science community, especially in the field of Library Research. According to users' information goals, Web behavior was classified to a dichotomy of browsing or searching, and further expanded to more categories in between. In one of the first empirical studies, Catledge et al (1995) used log data mining to identify three Web navigation strategies: searcher, general purpose browser, and serendipitous browser [5]. In another empirical study, Choo et al (1998) combined the theories of scanning modes and information seeking, and detected four Web usage patterns: formal search, informal search, undirected viewing, and conditioned viewing [7]. Morrison et al (2001) ran a large scale survey and classified all Web activities into find, compare/choose, and understand [21]. All these studies examined Web behavior only from the angle of Information Science theories and ignored some categorization from other perspectives.

Table 1. Previous studies on Web activity taxonomies.

No.	Sellen et al (2002)	Kellar et al (2006)
#1	Finding	Fact finding
#2	Information gathering	Information gathering
#3	Browsing	Browsing
#4	Communicating	Communication
#5	Transacting	Transaction
#6	Housekeeping	Maintenance (others)

Sellen et al (2002) combined diary and interview method and explored Web activities of twenty four knowledge workers. The task taxonomy was drawn in bottom-up approach and six Web activity categories "emerged" from the data inspection (Table 1). *Finding* category was clearly goal oriented and using the Web to find something specific such as a phone number. *Information Gathering* was less specific but using the Web to purposefully research a specific topic. *Browsing* was to visit sites without specific goals but rather to be informed or entertained. *Transacting* was to execute a transaction with products or services through the Web, e.g., make a bank transfer, or fill out a questionnaire. *Communicating* was about using the Web to participate in chat rooms or discussion groups. *Housekeeping* was to check or maintain the accuracy and functionality of Web resources, e.g., check if the links work properly [26].

A recent study by Kellar et al (2006) concluded with a similar taxonomy through different methods. Based on literature review, they proposed an initial structure, which was further developed by pilot user study, focus group interview, and field study. In the week-long field study, they logged user Web activities and asked the participants to categorize them according to a predefined scheme. They started with a construct consisting of four categories: Fact finding, Information gathering, Browsing, and Monitoring, and ended up with an almost identical structure to Sellen's, apart from terminological differences and an uncategorized "Others", later named as "*Maintenance*" [14].

It was of note that each individual type had different weights in the taxonomy [14, 26]. Both studies emphasized the importance of the first three activities (see #1-3, Table 1) but largely ignored the last item (see #6, Table 1). The importance of Communication and Transaction fell in between (see #4-5, Table 1), although Sellen et al chose to exclude Email communication from their research [26].

Sellen et al (2002) predicted the future of the mobile Web by examining stationary Web activity taxonomy [25]. They argued that Fact finding and Browsing could fit into mobile context, but Information gathering would be "entirely unsuitable" for mobile devices. We did not spot relevant empirical researches to prove the prediction so far. That motivated us to test the taxonomy through examining actual mobile Web usage data.

2.3 Our Approach

Our study followed a constructive approach in gathering user data, understanding existing user practices and emerging trends to guide concept designs. We did not assume a pre-defined framework before the study. Instead, all the frameworks emerged from user data inspection, affinity diagram analysis, and brainstorming sessions. Apparently, this method could suggest interwoven categories. Therefore, we inspected all the emerging themes rigidly to produce the Mobile Web Activity Taxonomy.

3. USER STUDIES

The qualitative data discussed in this paper originated from a series of user studies in our mobile internet research project. We complemented the data with a quantitative log analysis study with a larger group of users.

3.1 Field Exploration

We ran the field exploration studies in six different cities over the past four years, aiming at exploring the user practice in the mobile Web, and examining its implications to future designs.

3.1.1 Primary Participants

47 active Web users participated in the study (see Table 2), 39 primarily using mobile devices to access the Web. The remaining eight participants used a laptop in public WLAN hotspots, so their Web use was not tied to traditional stationary contexts either.

Table 2. 47 users from six cities participated in the study.

City	Time	Participants and Connections
Boston	Oct, 2004	3 Females, 6 males, WLAN
Helsinki	Mar, 2005	0 Females, 6 Males, WLAN
Tokyo	May, 2005	3 Females, 4 Males, Cellular
London	Nov, 2005	0 Females, 7 Males, Cellular
Beijing	Jun, 2006	1 Female, 7 Males , Cellular
Bangalore	Mar, 2007	2 Females, 8 Males, Cellular

The participants' age ranged from 17 to 63 with the average of 32 years. There were significantly more men than women (man/women: 38/9) participating our studies because of recruitment difficulties. It reflects the fact that more men are actively using the mobile Web than women [23].

3.1.2 Data Gathering and Analysis

The study method was based on *contextual inquiry* that aims to gather data in the real environment observing and interviewing users as they are using the examined system [3]. In the case of mobile Web, the usage sessions are short and take place relatively seldom, so it is very difficult to go and observe users real-time. Instead, we picked one location where the participant typically used mobile Web and asked them to describe and replay the recent mobile Web use cases as vividly as possible (see Figure 1). With a few exceptions, the contextual interviews were arranged in fixed locations, for example, the participants' homes and offices, or public places such as coffee shops and restaurants. All interviews were conducted in participant's native languages and later transcribed, and translated into English. Each interview lasted for up to three hours.

Figure 1. A scene from contextual inquiry.

Figure 2. Affinity wall under development.

The interviews were structured around the mobile Web sessions that the participant recently did. For each session, we asked what, when, where, with whom, and why the participant used the Web, how long it lasted, if they faced any problems, and how they solved them. The *critical incident collection* technique was used to identify usage patterns [10]. The participants needed to repeat some sessions when necessary. In Bangalore, each participant also kept a diary for four days before interview.

For the analysis of the qualitative data, we used *affinity diagram* technique [10] (see Figure 2). This was followed by brainstorming sessions, where we reviewed the data patterns, distilled the user insight, and proposed new design solutions.

3.2 Smart Phone Logging Study

Smartphone 360 is a logging study that records selected user actions on a mobile phone. Each recruited panelist downloads and installs the logging tool to their mobile phones. During the study, panelists also receive questions from the system to report their opinions about the used functions. The tool does not log the exact URL addresses or the content of messages, images or other material for privacy reasons.

This paper cites data from a panel held in UK, France, and Germany from March to May, 2007. The study involved 547 Nokia S60 Smartphone users. Their ages ranged from 16 to 78 with the average of 31.5 years old. 90% of the panelists were male. The logging duration for each panelist ranged from 21 to 69 days.

The log data consisted of 20,854 visited URLs, and generated 5.2 GB data traffic. Mobile Web took 8% of the time that the panelists spent on mobile phones (48 minutes a day in average).

4. CONTEXT OF USE

The field exploration research data came from six cities with significant regional differences in term of terminals, infrastructure, and Web content [23]. Each study location had different service offerings, and the service was always in local languages and formats.

The technologies available in developing countries were somewhat lagging behind the ones in developed countries. For example, we observed hardly any working public WLAN networks in Bangalore and more relatively old smart phones in use in Beijing. We also saw that PCs were not available everywhere, so mobile devices were often used at workplaces and schools instead of desktop or laptop computers. Despite the differences in the available technology, the user activities in these cities were very similar to the developed countries.

Four contextual factors emerged as the main themes from our qualitative analysis: spatial, temporal, social, and access factors. We discuss each of these in the following sections. Quotations are used to support the findings and print in *italics* for differentiation.

4.1 Spatial Factors: Mobile or Stationary

Our field exploration and the log study both provide evidence that stationary locations such as home are a common context in using the mobile Web. The typical scenarios included: check the mobile Web in living room while watching TV, in restaurant while having dinner, in bedroom while lying down. Figure 3 presents the findings from the log study of panelists' activity distribution during working days. The mobile Web usage peaked at late night, around 10 to 11 o'clock. In such contexts, the participants chose the mobile Web probably because it required lower engagement than the stationary Web. They accessed the mobile Web without necessarily interrupting their main activity, such as TV watching when lying on a couch.

> *"I sometimes go and watch TV. I'm a little lazy to go my laptop so I check my email on the phone." (Bangalore)*

> *"I used my Communicator to read newsfeeds…while sitting in the living room. Starting up the home computer would take too much time and disturb my wife." (Helsinki)*

On the other hand, the mobile Web allowed higher level mobility for our participants. For example, a home office worker visited a nearby coffee shop more often after he got the mobile Web. He could take a long break without worries of missing important messages. Some Indian participants used the mobile Web during

long distance travels. It was not guaranteed that the travel destinations would provide a wired Internet connection, but the mobile Web secured the connectivity. In the same way as messaging and voice call enables "*hyper coordination*" [18], the mobile Web further changes our perception of time and location.

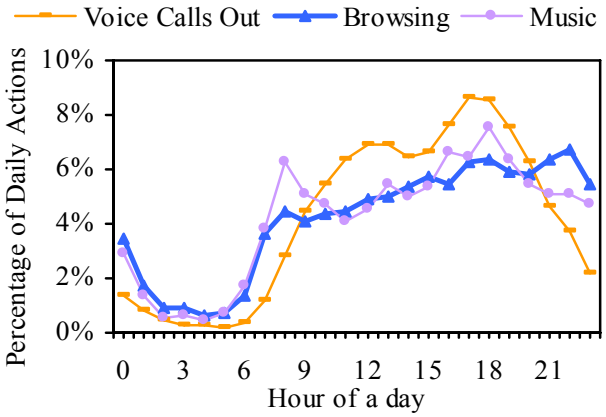

Figure 3. Mobile Web activities distributed in hours of a day.

4.2 Temporal Factors: Duration of Breaks

A "micro break" refers to the moments between planned activities, such as waiting for a bus to arrive or for friends to show up. All mobile functions, including the mobile Web, are competing to find their way to these moments. We observed that the participants used the mobile Web for short breaks, even when waiting for traffic light to change.

> *"I used Communicator to read news while waiting for my wife in front of the fitting room in shopping centre. I need to occupy myself with something during those 'odd little moments'." (Helsinki)*

Some mobile Web tasks were short enough for the micro breaks. For example, a participant could rather quickly check his Web mail on a dedicated mobile site. However, a lot more tasks need to be further simplified to fit such short breaks.

4.3 Social Factors: Alone or in a Group

Mobile phone is as a personal device so we assumed that mobile Web primarily supported solitary usage. To our surprise, mobile Web occurred quite often in social contexts. One recurring story was that participants used the mobile Web as a *conversation enhancer*. They used the mobile Web to start a new topic, expand an ongoing discussion, or settle a dispute. In Bangalore study, five out of ten participants reported they often accessed the mobile Web in such social contexts. The conversation topics ranged from "who was the father of the Internet", "when did a local band start", to "let me show you what I found".

> *"I once used home WLAN on my phone while watching TV to settle an argument with my girlfriend about the official height limit of a midget." (London)*

Certainly, mobile Web usage was not always socially appropriate. On most social occasions, it was an annoyance to others if one in the group focused his attention to the mobile Web; unless it related to other present people or other ongoing activities.

> *"Although a mobile device helps me browse discreetly, my wife gets irritated when it takes too much of my attention." (Helsinki)*

4.4 Access Factors: WLAN or Cellular Networks

WLAN and cellular telecommunication networks were the main connection types that enabled the mobile Web during our study. WLAN afforded a fast connection but limited mobility, typically in an indoor environment within a restricted area. Cellular networks enabled high mobility level, but supported rather low connection speed. Cellular network also generated cost for each piece of data traffic while WLAN connection did not. Figure 4 presents the median of data traffic and session duration from the panelists who had WLAN enabled phones in the log study. The sessions in WLAN context were bigger and longer than in cellular network.

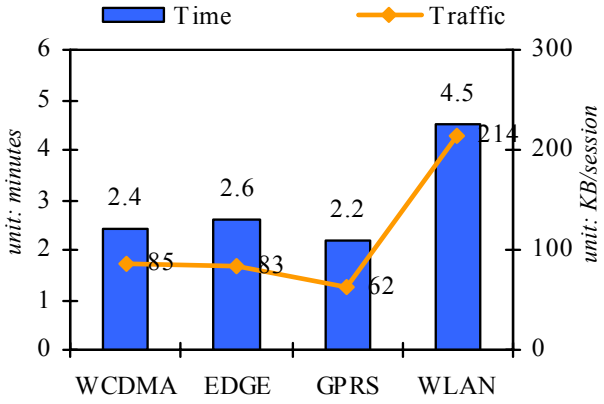

Figure 4.The effect of network types on mobile Web usage.

Because people wanted to save data traffic expenses, the usage patterns differed by connection type. With faster and cheaper WLAN connections available, the panelists engaged themselves in the activities that generated large traffic, for example, Web pod-casting. With cellular connection, users avoided downloading heavy Web pages.

> *"I have saved the start page of the train timetable site to my phone to minimize connection expenses." (Tokyo)*

5. USER ACTIVITIES

The affinity diagram analysis of our field exploration data revealed the following themes in mobile Web activities: *Information seeking, Communication*, and *Content object handling*. We also observed a handful of *Transactions* cases, i.e., the participants took online actions to secure a product or service, mainly purchasing books online in our study. However, a more common scenario was that participants gathered the background information for shopping decisions through the mobile Web. For example, a participant checked and compared air ticket prices on the Web, but the actual booking was done through phone call. We included this type of cases under Information seeking theme.

In the following section, we elaborate on the top three themes by referring to observations and quotations from field explorations and quantitative data from the phone logging study.

5.1 Information Seeking

Information seeking consisted of all the cases of using the Web to gain more *knowledge* or *entertainment*, no matter if a person knew exactly his target, just had a broad theme, or did not have any clear goals at all. Following the terminology in the previous research, we name these subcategories as *Fact finding, Information gathering,* and *Casual browsing*. Fact finding was by far the most common information seeking task in mobile Web, followed by Casual browsing and Information gathering. In this context, we define Information in its broad sense. It can either take the firm of knowledge or entertainment.

5.1.1 Fact Finding

Fact finding was about using the mobile Web to seek for a piece of small and specific information. The most commonly reported cases were to search for a specific fact such as a name, an address, a number, a word, or a qualification; or to monitor the status of a specific matter, such as the latest news, or weather.

> *"While waiting for my lunch to come, I checked from a bookmarked Website on my phone if the restaurant had a hygienic qualification." (Beijing)*

Fact finding tasks demanded immediate access to the relevant information. The searching fact itself might be time critical in itself or essential for next tasks that would start shortly. In our most recent study in Bangalore, we found that Wikipedia emerged as a major fact finding platform. For example, participants consulted Wikipedia, instead of search sites, as the first tool when they wanted to know "what the first game console was". The following aspects make Wikipedia advantageous to a search website.

- Wikipedia offers unambiguous answer to a query: either an immediate answer, or a straightforward 'No results found'. Instead, an Web search engine always produces a long list of candidates.
- Wikipedia is a collaborative platform where wrong information can be corrected. A search engine does not support such accountability checking mechanisms.
- Wikipedia summarizes the data on a topic from various sources, and puts it one click away. A search engine does not aggregate relevant data, and a user needs to go through more steps to gather the same amount of data.

> *"The results of a search tool were too long to be displayed on such a small screen… browsing through the results was particularly hard for me."(Tokyo)*

5.1.2 Information Gathering

Information gathering task was to collect information from multiple sources to achieve a broad goal, such as making a decision, or to collect knowledge around a topic. Sellen et al argued that the users would avoid such complicated tasks on mobile devices and postpone them until they had access to a conventional computer [26].

Our study partially supported Sellen's argument: Information gathering was not a common user task. The task only occurred when demanded by user goals and supported by context. For example, a participant needed to gather background information to support her purchase decision when she went shopping. Some Information gathering activities also evolved from Fact finding sessions. For example, a participant initially needed to find a restaurant number, but ended up doing background research on other restaurant candidates.

Information gathering tasks typically involve user gathering data from several sources and switching among them. Therefore, people must encode and hold the data in their working memory and further integrate the data from several sources. All these mental operations impose a heavy load on human working memory that has limited storage capability and subjects to data loss after delay or interferences [1]. People develop strategies to solve the memory problem on the stationary Web, such as opening several windows simultaneously or moving all data into a summary document [26]. However, neither of such strategies works well on the mobile Web. Few mobile Web browsers supported multiple windows or select, copy, and paste functions, so the participants were not using these strategies in our study.

> *"You cannot minimize a window on these devices, only X available for closing the window. I cannot go to the desktop without closing the application." (Boston)*

5.1.3 Casual Browsing

Casual browsing was the information seeking session where a person used the mobile Web to access general information but did not have a specific goal other than perhaps to be entertained or informed. Some previous studies classified such sessions generally as hedonic tasks [15].

Casual browsing was a relatively common task for the participants in our field exploration, especially for the ones with a 'flat-fee' plan. In Beijing, two flat-fee participants used the mobile Web for more than two hours every day during their "idle" working hours. They needed to stay in office but did not have immediate tasks at hand, for example, when a nurse was waiting for her next walk-in patient.

Casual browsing also occurred in social contexts when appropriate. We observed that some participants browsed the Web and looked for stuff to entertain the accompanied others. For example, when a couple was driving back home, the passenger browsed the mobile Web for the driver.

Another common use case was to access a set of regular Websites to keep updated. The case was documented as *monitoring* activity in some previous publications [14].

> *"I use the mobile Web to follow my favorites anywhere. …a Website on what's going on in town. It offers various recommendations such as top places to go." (Helsinki)*

5.2 Communication

Communication remains the first and foremost function of a mobile phone [11, 18] and its horizon has further expanded by Internet access. In our study, we spotted several cases of voice services such as Skype and Fring, but far more textual communications. Some of the Internet communication took place on Web sites, e.g. Web mail or online communities, some other outside the Web, e.g. push email, or instant messaging. In this section, we mainly focus on the Web-based textual communications, but also cover some non Web-based activities to present a complete picture of communication via the Internet.

5.2.1 Web Mail and Client Mail

The previous studies showed knowledge workers appropriated email as a "habitat", where they spent most of their working time in a wide range of activities such as checking messages, exchanging documents, and managing invitations [9]. Our study observed that the mobile Web further expanded the scope of such a habitat. Figure 5 shows that most phone log panelists used mobile email during the study period, either through Web browsers, built-in or add-on mail clients. The built-in client referred to the client software coming together with a mobile device, whereas add-on client was the one installed after purchase.

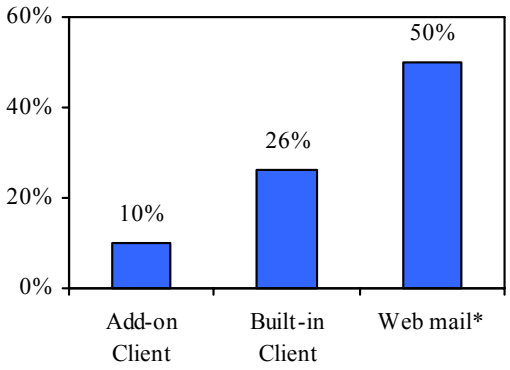

Figure 5. Mail types and their penetration.
* based on questionnaire respondents in logging study

"I first check emails. But once you get online, you start to do all sorts of things." (Boston)

The mobile client mail supported *Push mail*. It delivered a new message to mobile devices automatically and gave an immediate notification. Blackberry mail service and i-mode mobile mail are examples of push mail systems. I-mode mobile mail worked in a similar way as text messaging and supported long body text and attachments. Push mail behaved similarly as text messaging; therefore it invited the same etiquette. As a part of the effect, mobile mail was becoming a nearly synchronous communication channel at all times. Push mail users were prepared for a new message all the time, and Web mail users were constantly checking their accounts.

"I check my mail much more often than before. Usually I check my Web 20 times a day or so with this mobile phone." (Boston)

Mobile web is a technology that offers paradoxical user values. It grants people immediate access to their messages all the time, but potentially poses a distraction and even danger to their every day life [20].

Crackberry as one nickname to a popular mail device Blackberry reflects the fact that some of its users get so addicted to reading their emails that they check and reply to a message the moment it arrives, whatever the context is. We found the participants to handle mobile mails in the middle of a sleeping night, and locations such as in a movie theater. As an extreme case, one of our participants was described by her parents as "being married with her mobile".

There were another group of participants who did not appreciate mobile email supporting synchronous communication. They criticized that the notifications could come any time of a day and interrupted other ongoing activities. A few participants chose to turn off the push mail notification or only update their mail manually. By doing that, the participants gained more control over incoming interruptions.

5.2.2 Online Communities

We observed some participants were using online communities from the mobile Web. For example, some participants used mobile to update their own status and to monitor others'. Such behavior was not as common as email activities but had equally important indications for communication design. For example, online communities support pulling style communication. It enables unspecified audience to decide whether they are interested in it, and when they want to check it out. This development contributes to silent technologies that aim to minimize interruptions [12].

We observed one type of online community particularly common in Beijing: a bulletin board system (BBS). It was an online platform where people posted, read, and chatted. Some participants spent several hours every day in checking their favorite BBS. The active ones commonly competed to be the first to respond to a new post. The mobile Web would offer an advantage for the users on such an occasion.

"I usually log on to and hang out in the discussion forums whenever I start to use Web, mostly from computer but also from mobile." (Beijing)

5.2.3 Impact from Mobile Platforms

Mobile Web users seldom replied to emails on their mobile devices, other than a short reply to the urgent message. Figure 6 presents the finding from our logging study: the panelists altogether received 10,502 but only sent out 495 messages from their mobile mail clients.

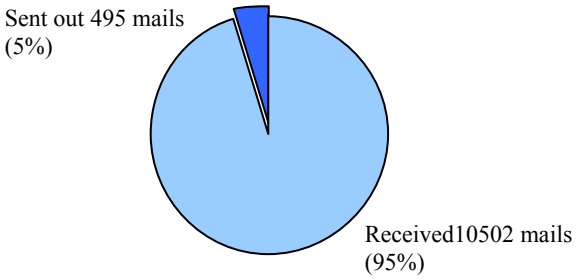

Figure 6. Low response on platform mobile mail.

The participants commonly postponed replying to a message until they had a decent keyboard available. In Tokyo, i-mode mobile mails were not accessible from the stationary Web; therefore, several Japanese participants forwarded their mobile mail to conventional email accounts for a proper reply.

"I never reply to Yahoo! emails on my mobile. I just read them, and go to a PC to reply." (Tokyo)

The mobile Web inherits the problem of handling multiple identities from the stationary Web. The participants used several services for similar purposes, or had several accounts under one

service. For example, a participant might have several email accounts from one or several providers. It is becoming more difficult to manage multiple identities on mobile devices as they do not support multiple windows, which disable people from putting several identities in use simultaneously. However, mobile also offers new possibilities that stationary web does not have, such as a unified contact book. We will explore more details on the topic in the following discussion section.

5.3 Content Object Handling

Content Object handling was the activity where participants used the Web to manipulate digital content in the same manner as every-day physical objects. Used in its restricted sense, an object was a perceivably discrete entity that can be manipulated independently of other such entities. It was either public data captured from the Web such as a ring tone or a wall paper, or personal content generated by the participants themselves such as a photo or a video clip.

5.3.1 Capturing Public Data

The participants captured objects from the public Web, primarily standalone items such as ring tones, wall papers, and add-on applications. In phone logging study, 86% of the panelists claimed it "important", "very important" or "extremely important" to install add-on applications, while only 5% gave negative responses on a seven-point scale. The popular add-on applications included Opera/Opera Mini, Adobe Readers, Anti-Virus, Nokia Life Blog, Tom Tom, and Yahoo! Go, etc. Digital discount coupon emerged as a common use case in Tokyo. Several Japanese participants downloaded discount coupons from the mobile Web and used them for offline shopping.

The participants seldom intentionally captured whole Web pages as individual objects to their mobile devices. Instead, they used bookmark as an alternative strategy to manipulate Web pages, typically perceived as non-object content. For example, some Japanese participants archived newsletters that embedded links to other mobile friendly web sites.

> *"I do not download Web pages. Um, probably, only once I downloaded a page of a long news story in order to read it in the plane." (Helsinki)*

A design should support the entire life cycle of captured objects, from capturing the data to mobile to removing it when no longer in use [27]. For example, a design should inform the participants whether the device supported a download, and offer a quick and safe way to remove the abandoned objects. When a device was full of useless objects, the participant would not be able to return to a clean system without a proper design in place

> *"I need a way to remove the Web services or applications that I no longer use. It takes up a lot of space." (Tokyo)*

5.3.2 Sharing With Others

Sharing referred to the use case that people used the mobile Web for transferring content objects to others, either *giving* them to one or several selected receipts, or *publishing* them for a large audience or the general public.

> *"Mobile email is readily up and running. It's my homepage on the Web. From there, I send photos and text to my Blog, and click links to other sites." (Tokyo)*

Participants only shared objects that carried appropriate value and were easy to handle, both for giving and accepting. Personal generated content composed most of the sharing objects. They usually reflected a particular moment in personal life and took the shape of discrete entities, such as photos, video clips, and text document. Public data sharing usually occurred through URL, which was a handy way to point others the relevant information. Such activities reflected a social gesture of caring and being cared; therefore, they were valued by both senders and recipients.

To certain extent, sharing activities also change interpersonal communication practice. For example, on a social networking site, people aggregate data from diverse sources to an online profile page, and reveal it to connected contacts. Such sharing activity changes how people get to know new people, and keep in touch with the old contacts.

5.3.3 Maintaining Content Online

We observed that participants used the Web to maintain content objects. They put these digital objects – captured from the public sites or generated by themselves – on the Web for personal access. The Web became a secondary storage as a *backup* medium, or a primary storage as a remote *working space*. For example, one restaurant owner used the mobile Web as the primary memory to track his business ledger.

> *<Why do you store the primary ledger in your Web mail?> "It is convenient as I always carry <my phone> with me, and secure as my workers will never get access to my phone. I need to make sure they cannot access the data." (Bangalore)*

People probably used the Web to manage personal content online ever since the Web was invented. But such a use case seemingly stood out recently with ever increasing multiple device ownership and all types of Web services. The use case fits well with mobile context in particular. As an always carried item, mobile device supports creating and accessing some content instantaneously. On the other hand, these devices had a high loss risk, which invites people to look for alternative storage mediums.

> *"I put my email inbox, contacts, calendar…on the Web server instead of my phone." (Tokyo)*

It was seemingly a growing trend to maintain personal content on the Web. We observed more cases in our recent sessions – Bangalore in particular – than in the early ones. But the chronological change needed to be interpreted cautiously as it could be biased by other factors in our study. For example, our recent field studies were mostly in developing countries, while the early ones were in developed countries.

6. DISCUSSION

6.1 Mobile Web Activity Taxonomy

In our user research through field exploration and smart phone log analysis, we identify several major mobile Web activity themes. That is, Information seeking, Communication, Transaction, and Content object handling.

Content object handling refer to the activities that participants perceive some content as discrete entities and manipulate them similarly as everyday physical objects. When we further analyze the themes, we notice that this theme is actually interwoven with

other user activities. We relate it to other mobile Web activities, as illustrated in Figure 7. Subcategories under Content object handling can be placed as special cases of other Web activity themes to their left when seeking or exchanging information are perceived or manipulated as objects.

Capturing public objects from the Web has a close relationship with Information seeking. Capturing a public object typically occurred as a byproduct when people performed information seeking tasks. *Sharing*, either public or personal content objects, was typically a part of interpersonal Communication or occasionally Transaction practices. The latter activities targeted at institute delegates, for example, when submitting a resume for an online job application. In summary, Capturing and Sharing can be well explained under the category of Information seeking, and Communication or Transaction respectively.

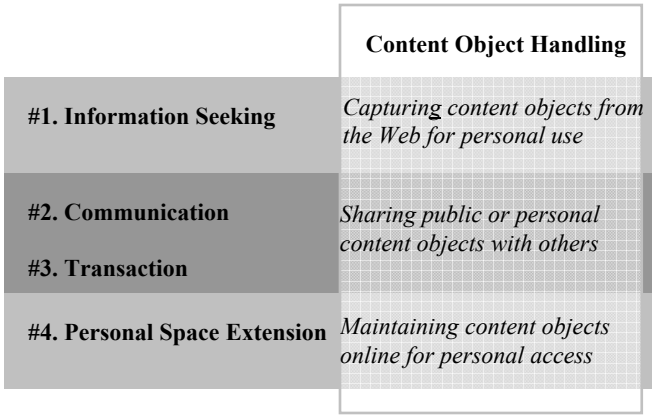

Figure 7. User activities on the mobile Web.

We add a new item *Personal space extension* into horizontal user activity categories as a counterpart to *Maintaining content objects online for personal access*. Such content objects used to be kept in "personal spaces" - local storage medium only accessible to its owner. The people reclaim public space and therefore extend their personal information space when putting personal data on the Web. We define *Personal space extension* as the activities that people put their content online for personal access. The new horizontal category is not limited to handling content objects but the content not necessarily perceived as objects as well. For example, people synchronize system data onto the Web, which are not packaged as meaningful units or even not targeted at human access at all.

In summary, mobile Web activity taxonomy consists of four categories: Information seeking, Transaction, Communication, and Personal space extension. These categories also intertwined with a vertical Web activity category: Content object handling.

6.2 Comparison with Stationary Web Studies

Most of the stationary Web user activities also occur on the mobile Web. *Fact finding, Information gathering,* and *Casual browsing* refer to activities that people purposefully seek for information about a topic or a broad theme through the mobile Web. We group them under a higher category *Information seeking* because all of the activities aim at changing user's knowledge state or making them entertained. Kellar et al argued for a similar regrouping [14]. *Communication* and *Transaction* consist of the activities that people exchange their data with others, either with individual persons to share experiences or knowledge, or with institute delegates to obtain products or services.

Two activity categories, *Housekeeping* and *Maintenance*, were reported on the stationary Web, but not in our research. Housekeeping was defined as "using the Web to check or maintain the accuracy and functionality of Web resources. E.g., Checking that information on a Web site was up to date, that links were working properly and so on" [26]. The category took about 5% of the user activities on the stationary Web. Given the smaller set of Web sites people accessed from mobile devices, we argue housekeeping need was reduced on the mobile Web. Maintenance did not have clear definition as it originated from not- defined "others" in Kellar's paper [14]. Therefore, we were not able to explain its absence in detail. The category took 4% of stationery Web activities in the above mentioned study.

We propose *Personal space extension* as a new category on the mobile Web user activity. It refers to the activities that people put their digital content on the Web for personal access. The new category was not reported as a distinctive user activity category in previous stationary Web research. We argue its emergence could be attributed to several reasons:

- The growing multiple device ownership requires a central place accessible from multiple devices, either from various personal computers in pockets, home, and office or from public computers in Internet cafes.
- The increasing capability enables people to generate, receive, or capture a lot of content on mobile devices [17]. People need a storage medium to secure such valuable data in case of device loss.
- Web content providers promote innovative applications and services that encourage participation, sharing, and collaboration. All such designs invite people to put their personal content online.

We propose that Personal space extension is not limited to mobile platform but exists on the stationary Web as well. Their primitive cases may have been spotted in early studies but grouped into other categories, such as maintenance or housekeeping. With the recent development of new Web applications and services, we argue it deserves to be listed separately in Web activity taxonomy.

6.3 Design Implications

6.3.1 Beyond Web Browser

Web browser still serves as the main window to Web content. We argue the browser's role may diminish in the future, given the diverse user activities that the mobile Web supports. The future mobile interaction designs demand hiding the unnecessary boundaries between mobile and the Web, and streamlining user interaction with online content.

> *"I am using many mobile applications and I want them to interoperate seamlessly for example, Email, browser, feed reader, and text messaging." (Helsinki)*

For the perspective of mobile interaction design, it is worthwhile to systemically explore alternative Web content delivery mechanisms beyond Web browser. For example, the recently

popular Internet widget is one step in this direction. A similar vision also existed in the work by Sellen et al [25]. They promoted designing mobile device as information appliances such as an Internet-connected watch that enabled quick access to the dedicated Web services.

From the Web design perspective, the Web content is also becoming more and more structured for third party developers to access, for example, through open APIs. Consequently, such movements will promote diverse Web access mechanisms and other innovations, both for conventional computers and mobile devices.

6.3.2 Design Examples

"*Wiki it*", named after Wikipedia, is a design that automatically turns a keyword into a hyperlink pointing to a relevant Web page. By hosting a local index, a mobile device is able to annotate keywords by comparing the message against the local database. The idea is based on the observation that Web tasks usually initiated from a contextual clue. For example, a received text invitation triggered people to search for location of the meeting point. "Wiki it" supports skipping interactions steps of launching browser, locating Website, and entering keywords, therefore simplifying the mobile Web interaction process.

"*Mobile vibes*" is a concept that regularly checks the selected set of Web services and constantly deliver updates to the user, e.g. from a Web mail site. The system would not require the site to provide a mobile client or RSS feed. The concept is designed for using the mobile Web during micro breaks. Under such contexts, the users need to quickly catch up and switch attention to other tasks.

The mobile Web inherits the legacy of managing multiple identities from the conventional Web, but it also offers new possibilities to solve the problem. To be more specific, contact book can bridge multiple identities used by others; message inbox can unify incoming data from all personal identities. In a latest trial of "*Unified inbox*", we aggregated the received content from different personal accounts- text messages, mails, and information feeds to one single pool. The initial evaluation proved its usefulness but also revealed some restrictions. For example, it should support grouping view because the different identities have different priorities.

7. CONCLUSION AND FUTURE WORK

7.1 Summary of Contributions

In this paper, we summarize a series of user research about when, where, how, with whom, and why people used the Web via mobile devices.

The participants often used the mobile Web in a stationary posture, in rather short sessions. They used the mobile Web alone as well as in a group. For example, the participants used the Web to enhance ongoing conversations. Technological factors played an important role in mobile Web. WLAN enabled longer and heavier Web sessions than the existing cellular connections.

We propose a mobile Web activity taxonomy that consists of four major categories: Information seeking, Communication, Transaction, and Personal space extension. The first three items are identical to the categories identified in the previous stationary Web activity studies. *Personal space extension* is a new category, which means that people put their content on the Web for personal access, and therefore extends their personal information space. We propose this new category based on the analysis of *Content object handling,* where people perceive some public or personal content as discrete entities, and use the mobile Web to manipulate them in a similar way as every-day physical objects.

7.2 Limitations and Future Work

The research was conducted in an industry setting and optimized for designing new systems. The constructive methodology could restrict its scientific rigidity, both of data gathering and analyzing. The field exploration data stretched for a span of four years; the user behavior pattern may have significantly changed over the time, but we did not fully examine its heterogeneity when consolidating the user data. Due to the same reason, we do not quantify the portions of each user activity category.

It is of note that mobile Web activity taxonomy classifies user activities instead of mobile Web services. A mobile Web service can support various user activities. For example, a location service supports Personal space extension when people mark their location online for future reference; it enables Information seeking when they just want to tell their current location, and enables Communication when people reveal their location to others.

We look forward to seeing further studies on mobile Web activity taxonomy in the future. It is also of interest to examine not only the Web, but all Internet-related activities on mobile devices. In the next step, we are going to run further user studies and analyze mobile Internet activities, for example, with the top-down approach proposed by Kellar [14]. We are also interested in innovations that facilitate user activities on the mobile Web, personal space extension in particular.

8. ACKNOWLEDGMENTS

We thank our colleagues who helped us to conduct the user studies, particularly Mika Rautava, Elina Vartiainen, Salla Myllylä, Anne Vaittinen, Jan Blom, Shruti Ramiah, and Gaurabh Mathure; three anonymous reviewers who offered valuable suggestions, and all the participants who generously shared their data and opinions with us.

9. REFERENCES

[1] Baddeley, A.D., and Hitch, G. 1974. *Working memory.* In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp. 47--89). New York: Academic Press.

[2] Baudisch, P., Xie, X., Wang, C., and Ma, W. 2004. Collapse-to-zoom: viewing Web pages on small screen devices by interactively removing irrelevant content. In *Proceedings of the 17th Annual ACM Symposium on User interface Software and Technology* (Santa Fe, NM, USA, October 24 - 27, 2004). UIST '04. ACM, New York, NY, 91-94.

[3] Beyer, H., and Holtzblatt K. 1997. *Contextual Design: A Customer-Centered Approach to Systems Designs.* Academic Press.

[4] Buchanan, G., Farrant, S., Jones, M., Thimbleby, H., Marsden, G., and Pazzani, M. 2001. Improving Mobile Web usability. In *Proceedings of the 10th international Conference on World*

Wide Web (Hong Kong, Hong Kong, May 01 - 05, 2001). WWW '01. ACM Press, New York, NY, 673-680.

[5] Catledge, L. D. and Pitkow, J. E. 1995. Characterizing Browsing Strategies in the World Wide Web. In *Proceedings of the Third International World-Wide Web Conference*, Darmstadt, Germany, 1065- 1073.

[6] Chae, M. and Kim, J. 2003. What's so different about the mobile Internet?. *Communication of ACM* 46, 12 (Dec. 2003), 240-247.

[7] Choo, C. W., Detlor, B., and Turnbull, D. 1998. A behavioral model of information seeking on the Web: preliminary results of a study of how managers and IT specialists use the Web. In *Proceedings of the 61st Annual Meeting of the American Society for Information Science,* Pittsburgh, PA, 290-302.

[8] ComScore. 2007. Mobile Phone Web Users Nearly Equal PC Based Internet Users in Japan. Available: *www.comscore.com/press/release.asp?press=1742.*

[9] Ducheneaut, N. and Bellotti, V. 2001. E-mail as habitat: an exploration of embedded personal information management. *Interactions* 8, 5 (Sep. 2001), 30-38.

[10] Hackos, J, and Redish, J. 1998. *User and Task Analysis for Interface Design.* Wiley & Sons, Inc.

[11] Harper, R. 2003. People versus Information: The Evolution of Mobile Technology. In *Proceedings of the 5th International Symposium on Human Computer Interaction with Mobile Devices and Services* (Mobile HCI'03): 1- 14, Udine, Italy. Springer-Verlag.

[12] Jones, M. and Marsden, G. 2006. *Mobile Interaction Design*. John Wiley & Sons, Chichester, UK.

[13] Kaikkonen, A. and Roto, V. 2003. Navigating in a mobile XHTML application. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Ft. Lauderdale, Florida, USA, April 05 - 10, 2003). CHI '03. ACM, New York, NY, 329-336.

[14] Kellar, M., Watters, C. and Shepherd, M. 2006. A Goal-Based Classification of Web Information Tasks. *In the Proceedings of the Annual Meeting of the American Society for Information Science and Technology, ASIS&T 2006*, Austin, TX.

[15] Kim, H., Kim, J., Lee, Y., Chae, M., and Choi, Y. 2002. An Empirical Study of the Use Contexts and Usability Problems in Mobile Internet. In *Proceedings of the 35th Annual Hawaii international Conference on System Sciences* (HICSS'02) 5 (January 07 - 10, 2002). IEEE Computer Society, 5, 132.

[16] Lee, I., and Kim, J. 2005. Use Contexts for the Mobile Internet: A Longitudinal Study Monitoring Actual Use of Mobile Internet Services. *International Journal of Human-Computer Interaction*, 18, 269--292.

[17] Lehikoinen, J., Aaltonen, A., Huuskonen, P., and Salminen, I. 2007. *Personal Content Experience: Managing Digital Life in the Mobile Age.* Wiley & Sons, Inc.

[18] Ling, R. 2004. *The Mobile Connection: the Cell Phone's Impact on Society*. Morgan Kaufmann Publishers Inc.

[19] MacKay, B., Watters, C. R. and Duffy, J. 2004. Web Page Transformation When Switching Devices. In *Proceedings of Sixth International Conference on Human Computer Interaction with Mobile Devices and Services* (Mobile HCI'04) (Glasgow, September 2004), LNCS 3160. Springer-Verlag, 228-239.

[20] Middleton, C.A. and Cukier W. 2006. Is mobile email functional or dysfunctional? Two perspectives on mobile email usage. *European Journal of Information Systems* 15, 252–260

[21] Morrison, J. B., Pirolli, P., and Card, S. K. 2001. A Taxonomic Analysis of What World Wide Web Activities Significantly Impact People's Decisions and Actions. In *CHI '01 Extended Abstracts on Human Factors in Computing Systems* (Seattle, Washington, March 31 - April 05, 2001). CHI '01. ACM Press, New York, NY, 163-164.

[22] Palen, L. and Salzman, M. 2002. Beyond the handset: designing for wireless communications usability. *ACM Transactions on Computer-Human Interaction.* 9, 2 (Jun. 2002), 125-151.

[23] Roto, V. 2006. *Web Browsing on Mobile Phones - Characteristics of User Experience.* Ph.D. Dissertation, Helsinki University of Technology, Espoo, Finland.

[24] Roto, V., Popescu, A., Koivisto, A., and Vartiainen, E. 2006. Minimap: a Web page visualization method for mobile phones. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Montréal, Québec, Canada, April 22 - 27, 2006). R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, and G. Olson, Eds. CHI '06. ACM, New York, NY, 35-44.

[25] Sellen, A. J. and Murphy, R. 2002. The future of the mobile Internet: Lessons from looking at Web use. *Hewlett-Packard Labs Technical Report,* HPL-2002-230.

[26] Sellen, A. J., Murphy, R., and Shaw, K. L. 2002. How knowledge workers use the Web. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Minneapolis, Minnesota, USA, April 20 - 25, 2002). CHI '02. ACM Press, New York, NY, 227-234.

[27] Vartiainen, E. Roto, V., and Popescu, A. 2007. Auto-update: A Concept for Automatic Downloading of Web Content to a Mobile Device. In *Proceedings of the 4th international Conference on Mobile Technology, Applications and Systems* (Singapore, September 10 - 12, 2007). Mobility '06, ACM, New York, NY, 691-697.