Liisa-Maija Keinänen

Touch Screen Mobile Devices Invading the Internet:
UX Guidelines Towards One Web

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Thesis supervisor:

> Prof. Marko Nieminen

Thesis instructor:

> M.Psy. Raino Vastamäki

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Aalto University
School of Electrical
Engineering

Author: Liisa-Maija Keinänen

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Supervisor: Prof. Marko Nieminen

Instructor: M.Psy. Raino Vastamäki

This thesis provides a needed update for mobile web browsing user experience research, as the state of the mobile Web has changed substantially in the last few years. The emergence of new-generation phones, such as the iPhone, started an unparalleled rise in the number of mobile page views of websites. These devices combine full-featured browsers and, in many cases, touch screen interfaces. As for interaction with the Web, mobile touch screen devices differ from desktop devices to a large extent. Instead of a big screen, mouse, and keyboard, a pocket-size screen displays the pages, which are zoomed and scrolled with finger or stylus gestures. No physical buttons are provided for writing in many devices, but a virtual full QWERTY keyboard pops up on the screen when needed.

A study consisting of an expert evaluation of several websites with different mobile devices by 3 specialists, and a usability test with 18 mobile Web users using 6 mobile and desktop devices was carried out. The study found that there are clear website design factors that deteriorate the mobile Web UX even when a high-end device is used. Classic website usability issues were emphasized, and new issues were presented by small screens and touch interfaces. As a result, 60 UX guidelines were defined. Utilizing these allows for providing a better UX for the mobile users of full websites. The guidelines consist of recommendations concerning website layout and navigation, heavy content and incompatibilities, content demanding input, and factors related to device detection and separate mobile interfaces. However, in contrast to the findings of previous related studies, the road of enhancement is not that long, as the overall pleasantness of mobile browsing was considered rather high.

Keywords: mobile Internet, mobile Web, One Web, browsing, touch screen, user
          experience (UX), usability

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Ohjaaja: PsM Raino Vastamäki

Tämä työ tarjoaa päivitettyä tietoa mobiilin Web-selailun käyttökokemuksesta, mikä on tarpeen, sillä mobiilin Webin tila on muuttunut huomattavasti viime vuosina. Mobiilien sivunlatausten määrä lähti voimakkaaseen kasvuun uuden sukupolven puhelinten kuten iPhonen myötä. Näissä laitteissa yhdistyvät täysimittainen selain sekä useissa tapauksissa kosketusnäyttökäyttöliittymä. Vuorovaikutus Webin kanssa kosketusnäytöllisillä mobiililaitteilla eroaa suuresti tietokoneselailusta. Suuren näytön, hiiren ja näppäimistön sijaan sivuja katsellaan taskukokoiselta näytöltä, ja sivuja vieritetään ja zoomataan sormi- tai piirrineleillä. Monissa laitteissa ei ole fyysisiä kirjoitusnäppäimiä, vaan täysi QWERTY-näppäimistö ponnahtaa ruudulle tarvittaessa.

Käyttökokemusta tutkittiin asiantuntija-arvion ja käytettävyystestin avulla. Useita verkkosivuja arvioitiin erilaisilla mobiililaitteilla 3 asiantuntijan voimin, ja testissä 18 mobiilin Webin käyttäjää käytti Webiä 6 mobiili- ja pöytälaitteella. Tutkimuksessa löydettiin selkeitä verkkosivutekijöitä, jotka huonontavat mobiili-Webin käyttökokemusta jopa edistyneimmillä laitteilla. Tyypilliset Webin käytettävyysongelmat korostuivat, ja pienet näytöt sekä kosketuskäyttöliittymät osoittivat uusia haasteita. Tuloksena muodostettiin 60 käytettävyyssuositusta, joita hyödyntämällä mobiilikäyttäjien käyttökokemusta Webissä voidaan parantaa. Suositukset käsittelevät verkkosivun ulkoasua ja navigointia, raskasta sisältöä ja epäyhteensopivuuksia, syötettä vaativia sisältöjä sekä tekijöitä, jotka liittyvät laitetunnistukseen ja erillisiin mobiilikäyttöliittymiin. Mutta toisin kuin aikaisemmat tutkimukset osoittavat, tie parannukseen ei ole kovin pitkä, sillä mobiiliselailu koettiin kokonaisuudessaan melko miellyttävänä.

Avainsanat: mobiili Internet, mobiili Web, Yksi Web, selailu, kosketusnäyttö, käyttökokemus, käytettävyys

Preface

It has been an interesting and absorbing experience to write my thesis of such a current topic. The mobile Web and touch screen phones have been very popular recently, both in the media and in the academic research. The study itself with several mobile Web users, and reporting and presenting the results to numerous interested people have both given me a lot to think and have been remarkable learning experiences.

First of all, I want to thank my employer Adage for having given me this chance to finalize my master's studies and also work in an effective work environment, where new things can be learnt every day. Mostly, I'd like to thank Raino, my boss and my instructor, for giving me the initial idea to study this subject in my thesis.

Secondly, I wish to express my gratitude to my supervisor Marko Nieminen who, regardless of all his busy schedules, had a lot of time to instruct and encourage me in my work.

Finally, I also thank Juuso for giving me inspiration and new perspectives, being honestly interested in my work process, and helping me in practical issues from the start to the end.

Helsinki, 21 March 2011

Liisa-Maija Keinänen

Contents

Abbreviations

AJAX	Asynchronous JavaScript And XML
cHTML	Compact HTML
CSS	Cascading Style Sheets
HCI	Human-Computer Interaction
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HVGA	Half VGA
PCT	Projected Capacitive Touch
PPI	Pixels Per Inch
QVGA	Quarter VGA
UI	User Interface
URL	Uniform Resource Locator
UX	User Experience
VGA	Video Graphics Array
WAP	Wireless Access Protocol
WML	Wireless Markup Language
W3C	World Wide Web Consortium
XHTML-MP	Extensible HTML Mobile Profile
XML	Extensible Markup Language

1 Introduction

1.1 Web browsing today and the One Web vision

Traditionally, starting with the first Internet services for handheld devices in the late 1990's, there has been a division between services for mobile and desktop users. When Internet services for mobile devices started to use HTML-based standards for delivery, the term 'Mobile Web' arose. And along with the mobile Web, content designed for desktop computers began to be called 'the Desktop Web' or 'the Full Web'. Even though the leading edge of the Web does not make such a distinct division into full and mobile Web anymore [1, 2, 3], the terms have somewhat stuck in our minds. We consider mobile Web services as something that is scaled back of the services seen on desktop screens. However, in terms of technology, mobile devices have been able to deliver full Web content to users for many years.

To ensure that the terminology is used and understood consistently, the different Web terms need to be specified. In this thesis, 'mobile Web' is considered to consist of all Web services that are available for mobile devices. 'Desktop Web', in contrast, is the Web used with a desktop computer. 'Full Web', and more specifically, 'full websites' are Web services that are primarily, or only, designed for desktop Web users. The term 'mobile-optimized' or 'mobile-tailored' is used for services designed for mobile device users.

As for browsing the Web, actions of accessing websites and web pages on the Internet requiring a web browser are considered. As Web technologies and devices have developed, web browsing has also changed a great deal. During the last few years, with the rush of touch screen mobile devices on the market, mobile web browsing has increased notably, more than 100 % per year [4], all over the world, and it keeps growing. There are several reasons for this, e.g. more capable devices and broader connections. These have, among other benefits, enabled also developing areas of the world to access the Internet, as it was not possible before due to the lack of desktop devices. This is seen as one of the primary business areas, as Nokia's chief executive officer, Stephen Elop, announced that the company wants to bring the next billion people online by mobile devices, connecting the disconnected [5].

Seen that the Web is more and more used with mobile devices, it becomes a question how Web content should be delivered to these small gadgets, differing extremely from their desktop counterparts in screen size and interaction functionalities to mention a few. Since 2005, the World Wide Web Consortium (W3C) has had its vision of 'One Web' introducing the importance of enabling Web on everything and for everyone [6]. The One Web postulate was a part of the Mobile Web Initiative that has also been working on the Mobile Web Best Practices, discussing e.g. overall service behaviour, navigation and links, page layout and content, and user input in detail [3]. However, the best practices have not been updated after the grand market invasion of touch screen devices, such as the iPhone and Android devices, and the One Web idea, unfortunately, seems to have been left aside since its announcement. As devices have developed to better respond to the noble vision, it is time to reconsider the possibility of One Web from the user's point of view.

1.2 User Experience

User experience (UX) is a concept of much debate these days. User experience is a fuzzy term that incorporates several characteristics and dimensions, defined in many different ways in the field of human-computer interaction (HCI). What describes very well the academic polemic and attention of user experience, is the fact that in the relatively small Finnish HCI research community, seven doctoral dissertations on the topic have already been completed [7].

Let's look at a few user experience definitions provided by different HCI professionals: "*User experience encompasses all aspects of the end-user's interaction with the company, its services, and its products. The first requirement for an exemplary user experience is to meet the exact needs of the customer, without fuss or bother. Next comes simplicity and elegance that produce products that are a joy to own, a joy to use. True user experience goes far beyond giving customers what they say they want, or providing checklist features. In order to achieve high-quality user experience in a company's offerings there must be a seamless merging of the services of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design.*" Nielsen Norman Group [8]. "*Mobile phone experience is not only dependent on the functionality of the device (utility) and efficiency of use (usability). Rather, we claim that hedonic elements, such as the visual attractiveness of the device and the hedonic quality and pleasure determine a user's willingness to use it.*" Duda [9]. "*A consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.), and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)*" Hassenzahl and Tractinsky [10].

Each of the above definitions demonstrates the two-sided view on user experience. On the other side is the user and on the other is the product, service, or system. Some also define the context, i.e. the environment in which the interaction occurs, an aspect of user experience. Usability is mentioned as a factor of user experience. The ISO 9421-11 standard defines usability as "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" [11]. Thus, there are common aspects in user experience and usability, but usability is mostly considered as a forming factor of the more complex concept of user experience.

Most literature on user experience discusses the topic in context of web browsing. Garret (2002) defines website user experience by investigating site strategy, scope, structure, and surface [12]. However, the mobile context is very different from the stationary desktop environment, and therefore the user experience characteristics concerning web browsing may not be enough to evaluate the mobile browsing user experience. Reviewing the wide array of definitions for user experience and how its different aspects affect each other, Roto's (2006) conclusion on user experience is best adapted to the scope of this thesis. Roto bases her model on Hassenzahl and Tractinsky's [10] definition, where the user's internal state, context of use, and the system being used are the main elements [13]. According to Roto's studies, the char-

acteristics of user experience in mobile browsing are: user, context, mobile device, browser, connection, and websites. These characteristics have several subfactors forming the overall user experience. Roto's user experience concept is visualised in Figure 1.
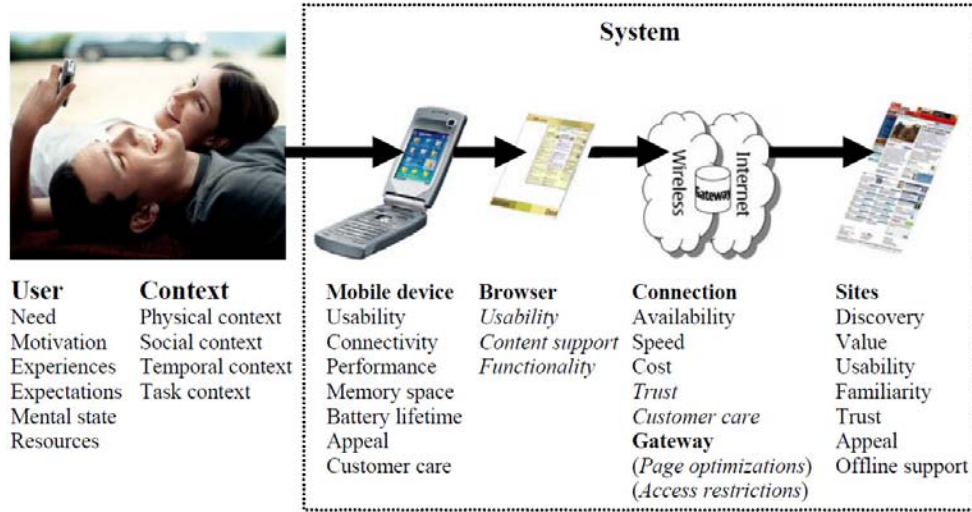
Figure 1: Characteristics of mobile browsing user experience. [13]

The importance to define the term 'user experience' this strictly is justified by both avoiding misunderstandings for readers, and being able to select the right methods for empirical studies. The definition visualised in Figure 1 will be used as the definition of user experience in this thesis. The emphasis will be on the system side of user experience (right side in Figure 1), as the aim of this thesis is to discover devices' and websites' features that affect the mobile web browsing user experience.

1.3 Objective of the study and research questions

This thesis seeks to find the website and device factors that affect the mobile Web user experience the most. The devices that are used for mobile browsing in increasing quantities are touch screen mobile phones, which are a rather new technology but already very widely in use. The objective is to study what problems and inconveniencies users face when they browse the Web with their high-level mobile devices, and how website designers and developers could avoid creating poor services and provide good user experience for mobile users.

1. What needs to be taken into consideration when designing full websites for mobile users?

   This question is based on the assumption that full websites are used with both mobile and desktop devices, and that the user experience in mobile use is not on the same level as with desktop devices. What are the most important design guidelines for ensuring a decent browsing user experience for mobile Web users?

2. Are mobile-optimized websites needed, or can we move over to an all-applicable web design?

   The division between mobile-optimized and full websites partly contradicts the One Web vision. Is it possible that One Web is best attained by providing only one single design for all devices?

3. Which device types perform the best in web browsing in terms of user experience and why?

   The Web can be browsed with several devices, big and small, desktop and mobile, touch and non-touch. What are the optimal device factors for a good browsing user experience, especially in mobile devices?

4. How does web browsing UX differ between touch screen phones and touch screen tablets, i.e. what effects does the screen size have?

   Touch screen tablets are nearly the size of small laptops, whereas they are operated similarly as touch screen phones. Is there a difference in terms of user experience between touch screen phones and touch screen tablets when used for web browsing?

5. Are there enough UX guidelines provided for good web design for mobile users and how reliable is the information in different sources?

   As Mobile Web Best Practices show, there are important information sources for web designers and developers that have not been updated while mobile devices have taken huge leaps as web browsing devices. With the information given, do working UX professionals manage to build websites usable with mobile devices as well, or is there a lack of up-to-date guidelines?

1.4 Thesis structure

This thesis consists of theoretical and empirical parts. The theory related to the subject is discussed in Sections 2, 3 and 4, and the empirical study is presented in Section 5. In Section 2, present-date web browsing is reviewed, the emphasis being on mobile Web and browsing. Also, mobile Web evolution, current mobile browsers, and the One Web are discussed in detail. Section 3 discusses different device types and interaction with them, and presents the benefits and drawbacks of touch screen interfaces. Section 4 presents an extensive literature review on mobile web browsing UX and usability, and justifies the importance of this study and the selected study methods. Section 5 presents the objectives, methods, results, and conclusions of the empirical studies. And finally, in Section 6, the study findings are concluded and discussed, and future research areas are suggested.

2 Web browsing in 2010s

In this section, the current state of the Web and different web browsing alternatives are discussed. Browsing with desktop devices is introduced only briefly, but mobile browsing is discussed in more detail, presenting mobile Web evolution and its current state, mobile browsers, and other Internet services provided in mobile devices. The One Web postulate presented briefly in the introduction is discussed in more detail in this section.

2.1 Web in 2010s

During the last decade, the Web has gone through major evolutions. We are considered to be currently living the Web 2.0, 2.5 and 3.0 eras, and just about having left Web 1 in the history [1]. Web 2.0 has been the successor of the traditional Web and differs from Web 1.0 in being more dynamic and more interactive, concentrating on collaborative content creation and modification, and connecting people through social networks [14]. Eventually, Web 2.0 has become much more than it was when the term was first presented in 2004. O'Reilly and Battelle (2009), while listing Google, Amazon, Wikipedia, eBay, YouTube, and Facebook as a few main representatives of Web 2.0, state that the smartphone revolution has eventually moved the Web from our desks to our pockets [2]. For this phenomenon, years 2005 to 2009 were the time of burning the fuse and year 2010 was predicted to be the explosion [2]. And it was.

To visualize how the Web is used in terms of different web browsers, Figure 2 shows how Web usage is shared. These statistics are counted by StatCounter [15] which calculates hits from 3 million sites that use StatCounter for site analytics. These websites total more than 15 billion hits per month and no artificial weighting is used in the results [15].

Unlike O'Reilly and Battelle, Weber and Rech see the mobile revolution to be part of Web 2.5. This era is considered to have started in 2005 and is predicted to fade away in 2015. Web 2.5 services are described as (mobile) device-oriented, user-, link-, or time-sensitive, cross-site, content-moving, virtual-reality-based, or dynamic mashup services based on technologies supporting rich user interfaces and user-sensitive interfaces. Web 3.0, instead, is defined to be mainly based on semantically enriched websites, having started its march in the turn of the two decades. [1]

Or, ignoring the half steps of Web evolution, Web 3.0 can be considered to be a mix of semantic Web, sentient Web, social Web, mobile Web, and virtual reality, and even more. The Web is no longer a collection of static HTML pages that describe something in the world, but the Web is the world, as everything and everyone casts an information shadow. [2]

The following chapters present how websites and Web services nowadays show themselves for users in both desktop and mobile ends. The current state of the Web is discussed briefly for desktop and more broadly for mobile devices.
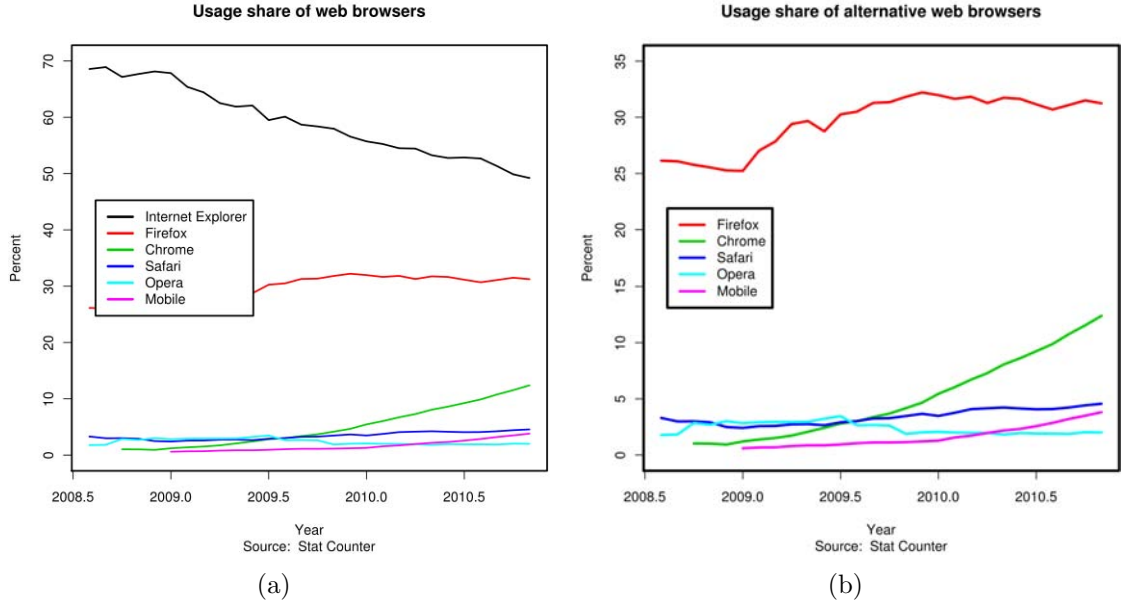
Figure 2: (a) Usage share of different web browsers, including mobile browsers shown as a whole. (b) The same graph as on the left, but with Internet Explorer removed to better visualize the alternative browsers' shares. As can be seen, mobile browsers are reaching towards the usage of the Safari desktop browser. [15]

2.1.1 Full Web design

Full Web refers to the Web designed for desktop devices. Full Web is the traditional form of websites. Full Web has some basic interaction patterns that are widely used and that are mostly based on common interaction design patterns, guidelines, and best practices. Although the Web is currently going in the more interactive and engaging direction of Web 3.0, most of the web pages still have some basic features, such as headers, navigation link lists, and content areas.

Welie.com [16] is a website containing a broad collection of best practices in interaction design. The site was built and has been updated by Martijn van Welie, a PhD in human-computer interaction, working as Senior Consultant at Philips Design. The design pattern list is collected under three main topics: user needs, application needs, and the context of design. The last updates on the site were made in September 2007.

User needs are discussed with patterns that meet a direct need of the user. Welie offers practices for navigation, basic interaction, searching, dealing with data, personalizing, shopping, making choices, input, and other miscellaneous relevant subjects. E.g. for navigation, different forms of navigational structures, such as directory, doormat, double tab, faceted, and panning are presented, and cases where these should or could be used are listed.

Application needs are patterns that help the application, or the designer, communicate better with the user. These consist of drawing attention, feedback, and simplifying interaction. The drawing attention section includes patterns for using

CAPTCHA, colour coded sections, grid-based layout, and liquid layout. [16]

Context of design discusses different site and page types and experiences. E.g. layouts and content type of Web-based applications, campaign sites, corporate sites, and news sites are presented. Article page, blog page, contact page, and homepage usage and examples are listed among other pages. [16]

None of the Welie patterns discusses mobile use and mobile devices' requirements for websites. However, on the homepage of Welie.com, linkage to other pattern libraries are offered, one of them being Mobile User Interface Design Pattern Library by Fluid Project [17]. But the design patterns on this website deal mostly with mobile application design and not web design for mobile use. [16] Therefore, the Welie patterns cover a great deal of Web interaction design, but the patterns do not take mobile users into account.

2.1.2   Mobile Web design

W3C provides best practices for delivering Web content to mobile devices. W3C's Mobile Web Best Practices (MWBP) are the result of the Mobile Web Initiative, and the recommendations refer to delivered content, not the processes by which it is created, nor the devices to which it is delivered [3]. The document includes 60 best practices, discussing e.g. overall behaviour, navigation and links, page layout and content, and user input in detail. The document was last updated in July 2008, and therefore the directions that mobile Web developers should consider might have changed considerably as the devices that the mobile Web is mostly used with have developed considerably.

The top ten ways to mobilize Web services according to MWBP are: 1. Design for One Web, 2. Rely on Web standards, 3. Stay away from known hazards, 4. Be cautious of device limitations, 5. Optimize navigation, 6. Check graphics & colours, 7. Keep it small, 8. Use the network sparingly, 9. Help and guide user input, and 10. Think of users on the go. [3]

However, not everyone sees that the W3C recommendations are to be followed. E.g. the debate related to the first item on the previous list, One Web, is further discussed in Chapter 2.3. But to present an example of responses to MWBP, Global Authoring Practices for the Mobile Web (GAPMB) by Passani (2010) can be discussed. Passani gives general guidelines for web developers and content authors who are searching for directions to help create sites for the mobile Web [18]. His objective is to explain how to get the best user experience out of an XHTML-MP 1.0 page, while he also encourages to explore techniques for delivering content in context-sensitive manners by adaption [18]. Passani provides a total of 36 practices, concentrating on responding to challenges created by small screens, limited input capabilities, limited processor power and memory, and limited bandwidth [18].

What differentiates W3C's MWBP and Passani's GAPMB is the tendency to design for all devices instead of designing for one single Web standard. Passani criticizes MWBP for not accepting the XHTML-MP standard as the standard for mobile Web and partly for this reason he created his own document of practices for mobile Web development [18]. In the next chapters, the mobile Web evolution and

its current state are discussed, and conclusions on which standards to support are drawn.

To visualize how full and mobile-optimized websites look like and differ in general, Figure 3 shows two examples of some typical web designs.

(a)

(b)

(c)

(d)
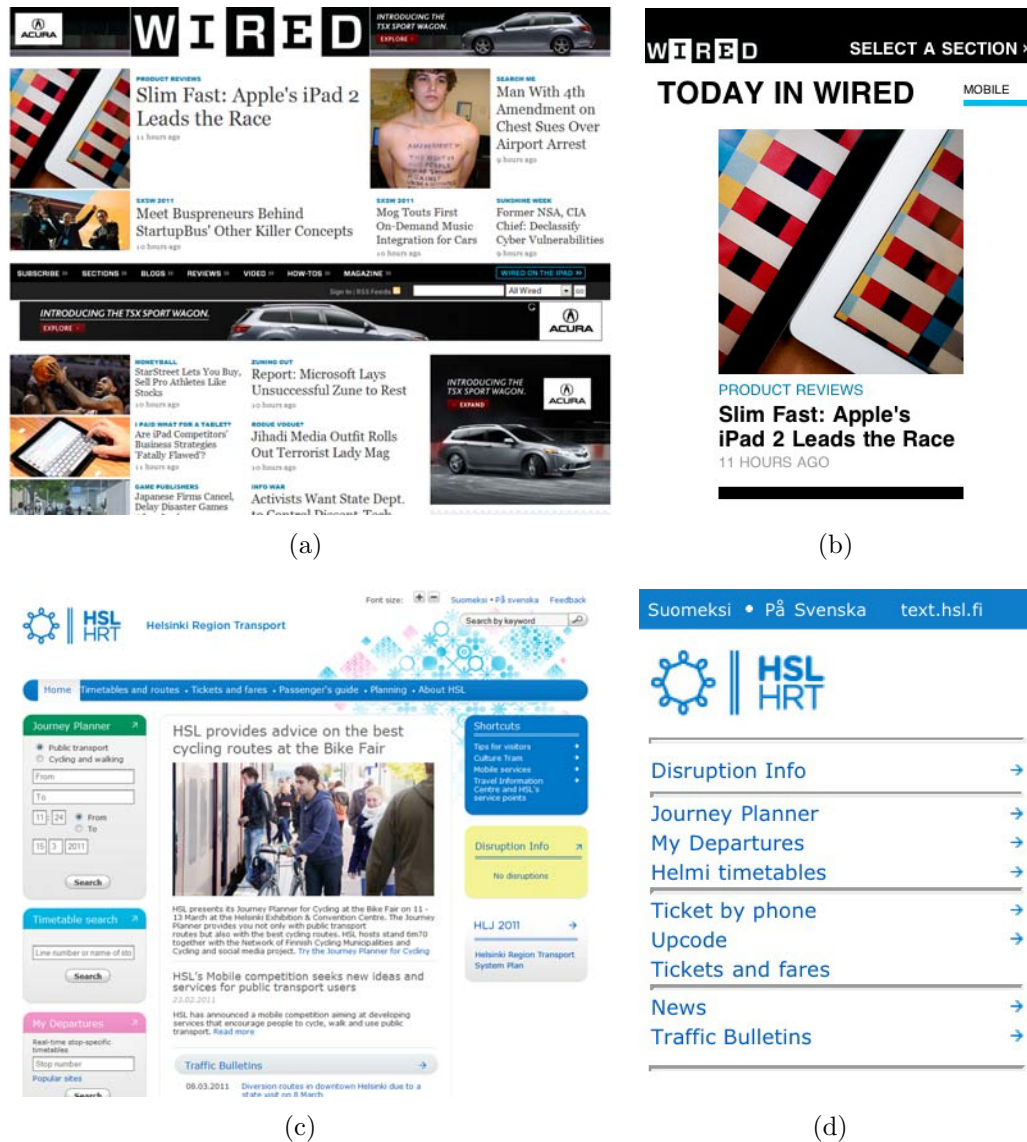
Figure 3: (a) Wired full website. On top of the page, headlines with images are shown, and content is on several columns. Some news are even lifted above the main navigation. (b) Wired mobile-tailored website. Only one headline with a rather big image can be seen in the top view. Other news can be seen when scrolled down. On top of the page, a link enables selecting sections. (c) Helsinki Region Transport full website. Content is divided into three columns which show navigation links, page content, and additional links. Colours and images are used richly. (d) Helsinki Region Transport mobile-tailored website. Links to main tools and information are provided on a very simplified layout. No images are included.

2.2 Browsing with mobile devices

Browsing the Internet with mobile devices has gone through major changes during the last decade. In late 1990's two modes for mobile Internet were presented: i-mode in Japan and the Wireless Application Protocol (WAP) in many other countries. Since then the mobile Internet has somewhat existed but has barely been utilized until Mobile Web 2.0, the age of the iPhone.

There are two main approaches to support the use of Internet services on a mobile device: mobile web browsers and mobile client applications, such as native web applications and mobile widgets. The following chapters discuss the evolution of mobile Internet services and usage, concentrating mainly on websites viewed with the device browser. Other mobile Web services are presented briefly.

2.2.1 Mobile Web Evolution

Released in 1998, WAP was based on WML (Wireless Markup Language), a version of XML (eXtensible Markup Language) designed for mobile devices. As WML was not compatible with HTML (HyperText Markup Language), the standard used for Web content, WAP devices communicated with operators' WAP gateways using WAP protocols. The gateways translated the communication to HTTP (HyperText Transfer Protocol) and sent it forward to the destination Web servers.

The second version of WAP, released in 2002, was called WAP2. Instead of using the WML, a new XHTML-MP (eXtensible HyperText Language Mobile Profile) standard allowed direct HTTP communication between devices and servers. Along with WAP2 the whole mobile Internet communication gradually started to be called 'Mobile Web' instead of 'WAP'.

In Japan, the i-mode services provided by the telecom operator NTT DoCoMo have been a great success in the country from the launch in 1999 until even recently. The operator masters the whole chain of compatible devices, connection, service user interface style and billing. As its markup language, the i-mode uses the Compact HTML (cHTML) standard. NTT DoCoMo has updated their services as technology has developed and celebrate their continuing success with over 48 million i-mode subscribers [19].

In the rest of the world, however, WAP was the starting point for mobile Web. As WAP2 services started to become more common, HCI research soon found that many information needs in real usage situations could not be satisfied with WAP based mobile-tailored content [20]. Therefore, in 2003, quite a few commercial mobile browsers accessing the full Web, that is, HTML based web pages, were already available for phones using the Nokia S60 operating system, the most famous of these being Opera's Opera mobile browser. As Vartiainen (2009) puts it, people wanted to access all the content in the full Web also on their mobile devices, even though the usability of WAP services might have been better [21].

A common feature for the first full web browsers was that they rendered the pages into a narrow layout. Roto and Kaikkonen studied the usability of current mobile browsers in 2003 to prove that users could not properly understand the structure of web pages and therefore get the information they were searching using the narrow

layout [22]. Although it was also possible to view web pages in their normal desktop layout, this was not a common use case as most users did not know how to adjust the browser settings [23]. Also, scrolling large pages on a very small screen (e.g. 176x208 pixels) was not a usable solution either.

In 2005 Nokia released their solution to the problems mobile browsers were struggling with, the Nokia Minimap browser. This browser enabled viewing a part of a full website and knowing what part of the page was viewed, as a miniature map of the page could be seen. Quite soon after the release of Minimap, in 2006, Opera released the new version of their mobile browser, the Opera Mini. To date, 5 versions of this famous mobile browser have already appeared, still very commonly in use in various types of phones.

Along with the release of new mobile browsers capable of rendering full websites to mobile-usable versions, in late 2006, the dotMobi (.mobi) top-level domain was approved by the Internet Corporation for Assigned Names and Numbers (ICANN). The dotMobi aimed to be the main domain for mobile Internet and it was supported by many big companies, e.g. Nokia. However, what was not ideal in the emergence of dotMobi, was that it created two Internets, one for the desktop Web and another for the mobile Web. Thus it was against the W3C proposition of moving towards One Web and probably for this reason it was not fully adopted as the mobile Web.

In 2007, in the era of several dozen browsers and markup languages, it was confusing and difficult for web developers to decide which standards to obey and who to serve. As Moll (2007) stated in his book: "*The choice to use WML, XHTML-MP, XHTML Basic, or cHTML can be an overwhelming decision, to say the least. And what about web addresses? Is it mobile.mysite.com, mysite.com/wap, mysite-mobile.com, mysite.mobi? Where does device detection and content adaptation fit in?*" [24]. Then, new directions to mobile Web development were introduced as new types of smartphones with great capabilities appeared on the market.

2.2.2 Mobile Web 2.0

Mobile Web 2.0 is thought to have begun in 2007 when the iPhone, Nokia N95, and Android devices became available [25]. These devices introduced WiFi support, 3G, full-featured browsers with HTML and CSS (Cascading Style Sheets) support, AJAX (Asynchronous JavaScript And XML) or Flash support, and video streaming capabilities in mobile phones. At the same time, the Web 2.0 with social networking and user-generated content portals started its ground-breaking way. These ingredients creating Mobile Web 2.0 undoubtedly launched a new era in mobile browsing, as Web usage statistics clearly prove. Figure 4 shows how the mobile Web situation has developed since 2007 and how it was in January 2011 regarding all web browsers, showing a clear portion of mobile browsers included in the traffic. The mobile Web share of the total Web usage from 2009 onwards was presented in Chapter 2.1 in Figure 2.

When considering the situation e.g. in Finland, the growth has been remarkable: in the yearly survey study of FICORA (Finnish Communications Regulatory Authority), mobile Internet usage was not studied yet in 2008, but in 2009 10 % of
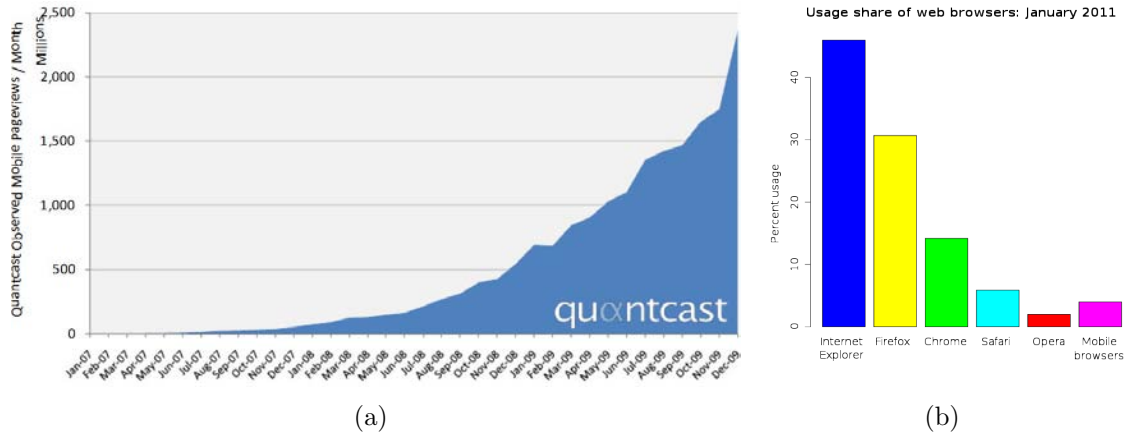
Figure 4: (a) Observed monthly mobile pageviews from January 2007 until December 2009 by Quantcast [26]. (b) Mobile browsers' share of all web browsing in 2011 was estimated at 4.45 %. The percentage is drawn upon 4 sources (Net Application, StatCounter, W3Counter, and Wikimedia) that measure different browsers' Web traffic [27]

respondents having a mobile phone reported using mobile Internet services [28]. In the same survey half a year later, 11 % of respondents were using these services [29]. In the interviews performed during November 2010, 32 % of respondents having a mobile phone reported using mobile Internet services [30]. The same can be seen in the amount of data running in the mobile device network: In 2007 the traffic consisted of less than 500 TB. During 2008 the traffic was more than tripled and the same went on during 2009. The amount grew 30 % between the end of 2009 and the beginning of 2010, being 13 000 TB during the first half of the year of 2010 [31].

The year 2010 has been addressed as the year of the mobile Web, and Firtman (2010) even claims that the Mobile Web 2.0 has beaten the Web 2.0 itself when it comes to providing advanced browsing experiences [25]. It can be concluded that the existence of mobile Web users is definitely not negligible. People are using Internet services on their mobile devices frequently, and it is no longer a case of only early adopters accessing the Web with their phones. What remains a question is whether service providers are aware and up-to-date of the situation.

2.2.3 Mobile browsers

As for current mobile browsers, they most commonly come preinstalled on the devices and are usually automatically upgraded with the device firmware updates. However, most devices do allow installing an alternative browser, and therefore the jungle of mobile browsers with different features is still rife. Firtman (2010) suggests a classification for mobile browsers based on four features:

1. Whether the browser uses WebKit or not. WebKit is an open-source layout engine for web browsers. It renders HTML and CSS websites and can execute

JavaScript. WebKit enables similar Web rendering in differing devices, with single markup and styles, which makes it easier for developers to produce Web content.

2. Zooming, and more explicitly, whether smart zoom is supported. Smart zoom enables viewing the web page at any zoom scale, and zooming affects the whole page including the font size and images. Switching between full-page view and paragraph view is also enabled by a gesture or a menu option. In addition, some browsers also reflow the text when zoomed in and out, so the user does not need to scroll horizontally for reading.

3. Whether the browser is proxied, i.e. if the browser can get content directly or if it needs a proxy server. Proxy servers e.g. reduce content, eliminate incompatible features, compress and re-render content, convert incompatible content, and encrypt or cache the content for quick access.

4. Navigation: focus, cursor, touch, or multitouch navigation. Focus navigation highlights the user's focus with e.g. a background colour or a border. Focus can be moved between focusable objects (e.g. links, text fields, buttons). Cursor navigation emulates a mouse cursor and can be freely moved with e.g. arrow buttons. Touch navigation enables finger or stylus gestures to perform actions. Multitouch navigation enables gestures as well as selecting many objects at the same time [25].

Table 1 presents current mobile browsers' main features using the classification presented above. Figure 5 visualizes how the mobile Web has been shared between different mobile browser providers during the last few years until recently.

A useful tool for web developers to follow which mobile browsers, and with what proportions, are browsing the Web currently, is Adobe's SiteCatalyst NetAverages [32]. With this tool, desktop and mobile browser activities can be followed, and different browsers' shares and activity per month can be tracked. The service has a separate tool for tracking mobile browsers, and developers are offered up-to-date shares of screen resolutions, operating systems, cookie support, manufacturers, device names, and HTML5 support.

As it is clear from the statistics, mobile browsing is no longer a clearly separate field of web browsing, compared to the WAP era for example, and should be considered an essential Internet media. Returning to the question left open in the previous chapter, mobile browsing history and the statistics today show that designing primarily for XHTML-MP browsers is not directing the services for today's mobile Web users. The devices that mostly access the Web in mobile context are the high-end devices, such as the iPhone, RIM and Nokia smartphones, and Android devices, and many of these have a touch screen interface. Therefore, Web content for mobile users should consist of services that are a joy to use with high-end mobile devices with full-featured browsers.

Table 1: Mobile browser features [25]

| Browser	WebKit engine	Smart zoom	Proxied	Navigation
Safari	Yes	Yes	No	Multitouch
Android browser	Yes	Yes	No	Multiple
Symbian / S60	Yes	Yes	No	Cursor, Touch
Nokia Series 40	Yes ($\geq$ 6th ed.)	No	No	Focus
WebOS	Yes	Yes	No	Touch
BlackBerry	Yes ($\geq$ 6.0)	Yes	Yes/No	Cursor, Touch
NetFront	No	No	No	Focus, Cursor
OpenWave	No	No	No	Focus
Internet Explorer	No	Yes ($\geq$ 6.5)	No	Focus, Touch
Obigo / Teleca	No	Yes ($\geq$ Q7)	No	Multiple
Motorola Internet Browser	No	No	No	Focus
Opera Mobile	No	Yes	Yes/No	Focus
Opera Mini	No	Yes	Yes	Cursor, Touch
Bada browser	Yes	Yes	No	Touch
MicroB for Maemo	No (Gecko)	Yes	No	Multiple
Firefox	No (Gecko)	Yes	No	Multiple
UC browser	No	Yes	Yes	Multiple

2.2.4 Other mobile Internet services

In addition to browsing the Web with the device browser, there are also other ways to access Web content on a mobile device. As this thesis concentrates on mobile web browsing with the device browser, these other Web services are only briefly reviewed. However, this does not suggest that Web use with the browser would be the primary use case for mobile users. On the contrary, native applications that are installed on the device and that show content from the Web seem to be increasingly the most popular means of accessing the Web in mobile context with a high-end mobile device [33, 34, 21].

Native applications, or mobile client applications, are separate applications installed on a device connected to an Internet service. They are implemented to run in the device environment enabling the access to the device resources. A mobile application is e.g. capable of optimizing network use and offering more immediate experience as it is directly connected to the corresponding service and does not fully rely on the request/response paradigm inherent in web browsers and sites. Native applications can offer graphically rich and highly interactive services in which focus indication, screen transitions, and navigation techniques are specifically designed for mobile use. These applications can also be used offline and the information can by
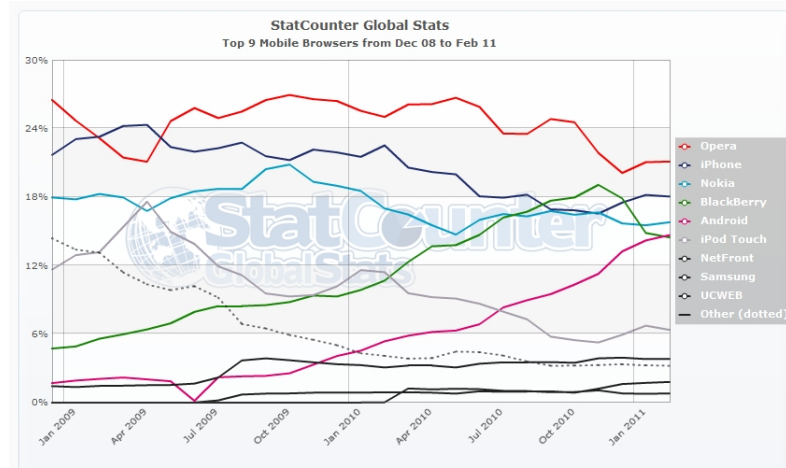
(a)
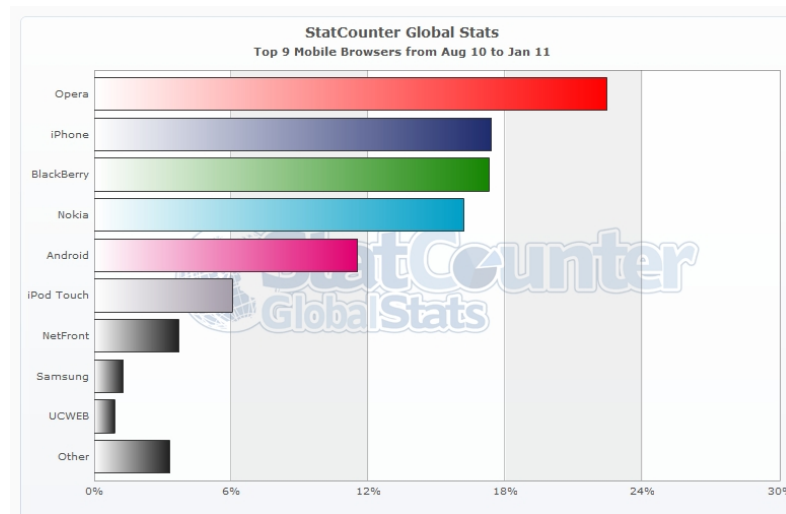
(b)

Figure 5: (a) Mobile browsers' share of the whole mobile Web usage from January 2009 until January 2011 and (b) during the last 6 months until January 2011 [15]. As the figures show, the top four presents the iPhone, and BlackBerry, Nokia, and Android devices. The Opera browser is not device-specific but can be used in almost any mobile device allowing Internet access.

synchronized with the Internet service when the connection is re-established. [21]

Services that fall somewhere between browser services and installed native applications are RSS feeds, podcasts, and mobile widgets. RSS (Really Simple Syndication) is used for news feeds, and it is a text-based service which enables users to read information that the service provides without needing to download any graphical content. RSS feeds are commonly used in news sites and in any website to send users information on updates. Podcasts are similar to RSS feeds, and can actually be delivered by RSS technology, but they comprise of audio files. Podcasts were originally broadcasts for the iPod, but as they can be consumed by other devices as

well, the term 'pod' has been later defined as 'portable on demand'. Podcasts are typically feeds from different radio stations or people's voice messages, and can be listened to when wanted.

Mobile widgets are not independent applications nor websites, but they run inside a widget engine that may determine the rules for capabilities, appearance, and interaction. Users may perceive mobile widgets as separate applications, even though they are not that in terms of technology. A widget engine can be implemented in different ways, most commonly solved by using the web browser as the engine and implementing mobile widgets with Web technologies such as HTML, JavaScript, and AJAX. Another approach is to implement the widget engine as a proprietary system. Mobile widget standardization is still work-in-progress, which introduces difficulties for developers as each widget engine offers different capabilities and features, and for users as they cannot use the same mobile widgets with different widget engines. However, mobile widgets allow an easy and quick access to Internet services even when offline. [21]

2.3   One Web

Mobile Web Best Practices define the One Web vision followingly: "*One Web means making, as far as is reasonable, the same information and services available to users irrespective of the device they are using. However, it does not mean that exactly the same information is available in exactly the same representation across all devices. The context of mobile use, device capability variations, bandwidth issues and mobile network capabilities all affect the representation. Furthermore, some services and information are more suitable for and targeted at particular user contexts.*" [3].

W3C has had its vision of 'One Web' since 2005, when Tim Berners-Lee, the inventor of the World Wide Web, introduced the importance of enabling Web on everything and for everyone. Providing Web on everything means that Web technologies provide the means of accessing and interacting with content with all devices, including computing, communications, entertainment, embedded, personal, home, transportation, industrial, health care, etc. systems worldwide [6]. That is, creating and obeying Web standards that are fully compatible with each other, and providing devices (e.g. mobile) with the needed technologies, are both included in the goal of One Web.

Originally, the One Web concept was set to be an objective of the Mobile Web Initiative presented in 2005 by W3C. Thus the main idea of it was to combine desktop and mobile Internet, and in the long run make Web available for any device. In the scope of Mobile Web Best Practices, W3C announces that the working group is well aware of the challenges and complexities stemming from the diversity of mobile devices, and that their immediate goal is to define a set of forward-looking best practices for making content accessible with equal ease of use for both desktop and mobile devices, which is expected to result in a positive user experience in both environments [3].

Not surprisingly, the idea of One Web has evoked lots of discussion and debate. First of all, not everyone sees the big picture in the same way and providing Web

on one hand on everything and on the other hand for everyone can often lead to contradictions. Fling (2008) concludes that a clear division between Web and Mobile communities can be observed [35]. Fling discusses how the One Web definition has changed as mobile devices and technologies have developed towards today. One Web was initially defined as follows: "*One Web means making the same information and services available to users irrespective of the device they are using.*" but after working closely with the mobile community, W3C revised the definition to include e.g. following additions: "*...as far as reasonable...*" and "*...does not mean that exactly the same information is available in exactly the same representation across all devices.*" [35].

What were seen as flaws for the One Web were that it assumed that content for multiple contexts will be the same, when it usually is not; cost per kilobyte to the user is minimal or non-existent; a persistent and high-speed data network will always be available; mobile browsers are smart and will support the same standards consistently, which is not the case; and that a technology-based principle should come before the needs of the user. Although Fling was confident that the first four assumptions will be outdated sooner or later, he stated the last one will always stay questionable. [35]

As mentioned earlier, Passani (2010) is also in opposition of the One Web concept: "*If I had to point to the largest issue with MWBP, that would have to be the One Web postulate. I understand that W3C is all about the Web and some may dream about a unified Web which can be accessed with equal ease by PCs and mobile devices, but this is just a dream: Web and mobile will remain separate media for many many years to come (probably more). There are three big reasons for this: technological, consumer-driven and industry related.*". Passani states that that it is impossible to catch up with the mobile Internet while keeping the form factor of a phone, that consumers prefer to wait to get to their desktop computers to access the full Web, and that industry is not convinced at all that that a converged web-mobile experience is the way to go. [18]

It can be noted that Passani has not fully understood how the mobile world is changing currently as he turns the One Web idea down so flatly. But his and Fling's concerns need to be taken into account as they probably present other web developers as well. Thus, as the One Web idea aims at providing the Web equally to everyone using any device with standardizing Internet protocols, is the Web user experience somehow forgotten in the process?

Referring to the scope document of MWBP, this should not be the case, as the members believe that minimizing the impact of any fixed vs. mobile differences and maximizing the benefits of all the similarities is in the interest of all the mobile value chain participants, from content authors to the end users [3]. Therefore, the One Web vision was set as the basis for this thesis, as finding how to provide mobile Web users a pleasant user experience was set as the objective of this thesis' studies.

3   Mobile devices and touch screen interfaces

This section categorizes different mobile devices into device types. These device types are referred to in all the remaining sections of this thesis. Interaction with device types of interest is discussed, presenting e.g. screen and keyboard properties of different devices. After the interaction technologies are presented, a few images of different devices are shown, with the essential product features explained. At the end of this section, interaction and interfaces on touch screen devices are discussed.

3.1   Mobile device categories

The trend is clear – mobile phones are more and more labelled as smartphones, and in general we nowadays talk of mobile devices instead of mobile phones. Voice calls are hardly the main function of our current portable devices. Let's take a look at different mobile devices and put them into categories.

There are several ways to categorize current mobile devices. The evolution of such devices has been enormous during the last few decades and therefore there have been several device categories, of which some have maintained their stable position (e.g. mobile phones and PDAs) and some have more or less transformed from one type to another during the development of mobile technologies (e.g. former communicators, presently smartphones). Below, three categorizations in the literature are presented, and as a conclusion, a device categorization for this thesis is listed.

Weiss (2002) presented three categories for mobile devices, or more accurately, for 'handheld devices'. At that time, the playground of devices operable without cables, in one's hand and not on a table, and allowing the addition of applications or Internet connectivity was notably narrower than today, and the three categories were named mobile phones, PDAs (personal digital assistant), and pagers. Phones were primarily used for voice calls, pagers for two-way e-mail, and PDAs for information storage and retrieval. [36]

Arriving at the end of the previous decade, mobile devices had faced remarkable blending in features and primary use purposes. Budiu and Nielsen (2009) divided mobile phones capable of browsing the Internet in three groups: feature phones, smartphones and touch phones [37]. The categorization is mainly from the user's point of view, not device technologies', as phones with a tiny screen and a numeric keyboard were considered feature phones (accounting for around 85 % of the market), phones with a mid-sized screen and a full QWERTY keyboard were considered smartphones, and touch screen phones were considered touch phones [37].

Firtman (2010) presents a much wider set of categories, having a more technical viewpoint, but also concentrating on the web browsing factors. He labels devices as mobile phones (phones with call and SMS support), low-end mobile devices (phones with web browser, basic camera, basic music player, no touch support and limited memory), middle-end mobile devices (phones with medium-sized screen, basic HTML browser support, decent camera, music player, games, applications, and sometimes 3G), high-end mobile devices (non-multitouch phones with accelerometer, good camera, Bluetooth, good Web support, generally not sold with flat Internet

rates), smartphones (phones with multitasking OS, full desktop browser, WLAN, 3G, music player, and often GPS, digital compass, video-capable camera, and many others including e.g. touch support), and non-phone devices (small personal object technologies (SPOTs), tablets, netbooks, and notebooks, e.g. iPod and iPad) [25].

As these categorizations already show, e.g. the word 'smartphone' can have several varying definitions and the concept can be assumed to develop over time. Touch support was not considered a relevant factor in categorization for Firtman, but Budiu and Nielsen grouped all touch devices in one category. This thesis approaches mobile Web usability from the user's point of view, as did Budiu and Nielsen's study, and therefore whether websites are controlled directly via touch or whether actions are performed with buttons makes a big difference. Also other input methods significantly affecting the Web use, screen size, keyboard type, and connections are considered relevant for the categorization. Thus, in this thesis a following device categorization is considered:

- low-end mobile phone (supports voice calls and SMS)

- middle-end mobile phone (3G and WLAN support possible, small screen, numeric keyboard, may include touch devices with poor browsers and low screen resolution)

- smartphone (3G and WLAN support, medium-sized screen, full QWERTY keyboard)

- touch phone (3G and WLAN support, decent screen size, virtual and/or physical QWERTY keyboard)

- tablet (WLAN support, big screen, virtual and/or physical QWERTY keyboard).

The research questions in Section 1 stated that the focus of this thesis is in touch screen Web use because these devices form the majority of mobile Web usage. In addition, other research questions aim at comparing the effect of touch and non-touch devices, and small and big screens. Therefore the categories smartphone, touch phone and tablet should be investigated further when it comes to browsing the Internet with mobile devices.

3.2 Interaction with mobile devices

Casting a look at the modern mobile devices available on the market today, a notable variety of touch phones can be observed. There are several manufacturers for touch phones, such as Apple, Nokia, HTC, and Samsung, and thus there are also some key differences in the interaction possibilities provided. These differences are mostly related to the screen and the keyboard. As was stated in the previous chapter, in addition to touch phones also smartphones and tablets are of interest in this thesis, and therefore all these three device types' input technologies are reviewed.

3.2.1 Screen resolution and dimensions

Screen resolution and dimensions are one of the major challenges in mobile UI design, whether we design for Web, applications, or any content the user is supposed to interact with. Screen resolution affects both legibility and the amount of content that can be shown, and in case of touch phones also the input. However, the display resolution is not the same as touch accuracy, but this depends on the touch screen technology used on top of the screen. Display resolution is also not the same as the screen's physical dimensions. Both of these will be discussed shortly, but let's first list the screen resolutions available in most devices sold from 2007 on:

- Smartphones: 240x240, 240x320, 480x320, or 360x480 pixels

- Touch phones: 240x480, 320x480, 360x480, 480x800, 480x854, or 640x960 pixels

- Tablets: 1024x768, or 1024x600 pixels [25].

The most widely available screen resolution is 240x320 pixels, and it is also known as QVGA (Quarter Video Graphics Array), as the VGA standard is 640x480 pixels [25]. The resolution of the iPhone 3GS (320x480 pixels) is known as HVGA (Half VGA) [25]. In addition to the resolutions listed above, there are still a lot of devices with custom resolutions as well.

What can be summarized of screen resolutions is that they are a lot smaller than those of desktop screens (e.g. 1024x768, 1280x1024, or 1680x1050 pixels), except for tablets. Smartphones and touch phones some share the same resolution but they usually have different aspect ratios and different physical dimensions, that is, the screen is used either in landscape or portrait position and the screen sizes are varying. Touch phone resolutions clearly are varying, as 6 different options can be named as the most available ones. Tablet resolutions, however, are rather close to those of our desktop devices.

As important as the screen resolution are the physical dimensions of the screen, that is, the screen size. When both the resolution and the dimensions are known, the relation between them, the PPI (pixels per inch) can be defined. PPI actually tells more about the visibility of content on the screen than resolution or dimensions alone. The human retina has a limit of about 300 PPI at the distance a phone is usually viewed [25], and for this reason a PPI much higher than 300 is commonly of no use. Let's review the average screen sizes for our three categories:

- Smartphones: from 2.4 to 2.6 inches

- Touch phones: from 3.5 to 4 inches

- Tablets: from 7 to 9.7 inches [25].

Thus, it is clear that even though some smartphones have screen resolutions as high as some touch phones, they also have a higher PPI and do not necessarily offer

more visual information than smartphones with a lower resolution. Common touch phones are relatively similar in size, so in these the PPI is what mostly affects the visual experience of the device.

When considering how the screen resolution, dimensions and thus PPI affect the Web use with these devices, browsing full websites is definitely a different visual experience than that with a bigger desktop device. Something that cannot be compared to desktop Web use, however, are the touch features of the studied devices. Let's next focus on the touch screen properties.

3.2.2   Touch screen technologies

There are a variety of touch screen technologies used in many different devices, but the most commonly used technologies for mobile device screens are resistive and capacitive touch screens. Other touch technologies include e.g. surface acoustic wave, infrared, and optical imaging, but these will not be discussed in this thesis.

Resistive touch screens are touch-sensitive displays composed of two flexible sheets coated with an electronically resistive material and separated by an air gap or microdots. When contact is made to the surface, and these two sheets are pressed together, the horizontal and vertical lines in the layers register the precise location of the touch. The touch coordinates are produced by applying a unidirectional voltage gradient to the first sheet, and when the two sheets contact, the second sheet measures the voltage as distance along the first sheet, giving the X coordinate. The Y coordinate is acquired by applying the uniform voltage gradient to the second sheet, and the first sheet measures the distance. [38]

Capacitive sensing is a technology based on capacitive coupling, a technology used in many different types of sensors. Capacitive sensors can detect anything which is conductive or having dielectric properties. There are surface and projected capacitance sensors, of which the projected capacitance is used in mobile devices. Projected capacitive touch (PCT) permits accurate and flexible operation by etching the conductive layer in the sensor. An X-Y grid is formed either by etching a single layer to form a grid pattern of electrodes, or by etching two separate, perpendicular layers of conductive material with parallel lines or tracks to form the grid. The conducting layers can be coated with protective insulating layers, and operate under these screen protectors. [39]

PCT can be further divided into two types: self-capacitance and mutual capacitance. Mutual capacitance allows multitouch operation where multiple fingers, palms, or styluses can be tracked simultaneously. There is a capacitor at every intersection of each row and each column. A voltage is applied to the rows or columns. Bringing a conductive object close to the surface changes the local electrostatic field which reduces the mutual capacitance. The capacitance change at every individual point on the grid can be measured to determine the touch location by measuring the voltage in the other axis. In self-capacitance sensors the rows and columns operate independently. This method produces a stronger signal than mutual capacitance but is unable to resolve accurately more than one finger. In context of mobile devices, the term multitouch is commonly in use for capacitive touch screens. [39]

Resistive touch screens can sense input from contact with any object, and therefore this technology is also known as 'passive' touch screen technology. It works well with almost any stylus-like object, such as a pen, nail tip, or a plectrum. In some circumstances, using a stylus is preferred to using a fingertip, e.g. when fingers are gloved or the interaction needs to be very accurate e.g. for handwriting. However, due to the top layer of PCT being glass, a capacitive touch screen is a more robust solution than a resistive touch screen. But, as a drawback, gloved fingers may not be sensed, depending on the implementation and gain settings, and conductive smudges, such as sticky or sweaty fingers, can interfere with the performance. Resistive touch screens typically have a high resolution that provides accurate control. The need to use force for pressing, however, makes the screen less responsive than the capacitive ones. [38, 39]

As there are these two touch screen technologies both widely used in modern mobile devices, and they have notable differences in operation, the device category 'touch phone' needs to be further divided into two categories: 'touch phone' for resistive, and 'multitouch phone' for capacitive touch screen devices. It is reasonable to analyse these two types separately when studying touch screen effects on web browsing, to find possible differences between these different touch technologies. Examples of both kind of touch devices are presented in Chapter 3.2.4.

3.2.3 Keyboard

When browsing the Web, one needs to write URLs, logins and passwords, search words, and also in many cases, comments and postings in the Social Media. Therefore the device keyboard is an essential tool for interaction. Mobile devices come with a variety of solutions. Most mobile phones have a numeric keyboard, as they are usually used for voice calls. The devices reviewed in this section, smartphones, touch phones, and tablets, however, all have a full QWERTY keyboard, so let's take a look at different possibilities for full QWERTY implementation.

Currently, the full QWERTY keyboard is provided in the devices in at least one of the following ways: physical keyboard on the front, hidden slide-out physical keyboard, virtual keyboard on screen, and wireless or wired external keyboard. All smartphones have a physical keyboard on the front. Most touch phone models have only a virtual keyboard, but some have an additional slide-out keyboard. In some models, such as Nokia's touch phones, the virtual keyboard keys are numeric when held in portrait and QWERTY when held in landscape position. Tablets are mostly like big touch phones, and thus have similar solutions for keyboard. External keyboards are available for many devices, but they need to be bought separately, and are not considered as a part of the device. See the device examples in the next chapter for images of different assemblies.

3.2.4 Device examples

Device types relevant in this thesis, i.e. smartphones, touch phones, multitouch phones, and tablets, are presented with product images in this chapter. First, two models of smartphones can be found in Figure 6. The Nokia E71 [40] is a very widely

used business phone especially in Finland, having a full QWERTY keyboard and 3G and WLAN connections. The Nokia E71 has a 2.4 inch screen with a resolution of 320x240 pixels (QVGA). The Blackberry Bold 9000 [41] has sold a lot especially in the US and the UK. It has the same features as Nokia E71, but a slightly bigger screen of 2.6 inches with a notably higher resolution of 480x320 pixels.

(a)   (b)

Figure 6: (a) Nokia E71 [40] and (b) Blackberry Bold 9000 [41]

In the next category, touch phones, the device examples presented are the Nokia N97 [42] and the Samsung Omnia Pro [43]. These both phones have a slide-out full QWERTY keyboard and a resistive touch screen. Samsung Omnia Pro has a screen of 3.5 inches with a resolution of 480x800 pixels, and Nokia N97 has a screen of the same size but with a resolution of only 360x640 pixels. The devices are shown in Figure 7. Although these examples do have a slide-out keyboard, there are also devices with a resistive touch screen and no physical keyboard, such as the Nokia 5230.

(a)   (b)

Figure 7: (a) Nokia N97 [42] and (b) Samsung Omnia Pro [43]

In the category of multitouch phones, the Apple iPhone 3GS [44] and the Google Nexus One [45] are presented as examples. Both devices have virtual keyboards only. In addition, the iPhone has one physical button and the Nexus One has four touch-activated hard keys. The iPhone 3GS has a screen of 3.5 inches with a resolution of 320x480 (HVGA), and the Nexus One has a bigger screen of 3.7 inches and a 480x800 pixel resolution. The devices are shown in Figure 8. Although none of these examples has a physical keyboard in addition to the virtual one, there are also several multitouch phones with e.g. a slide-out keyboard, such as the Nokia E7 and some HTC devices.

(a)   (b)

Figure 8: (a) Apple iPhone 3GS [44] and (b) Google Nexus One [45]

And lastly, the tablet category is visualized with two examples, the Apple iPad [46] and the Samsung Galaxy Tab [47] in Figure 9. Both of these tablets have a multitouch screen and no physical keyboard attached. As the Figure 9 shows, the iPad is twice the size of the Galaxy Tab, having a 9.7 inch screen with a resolution of 1024x768 pixels. Galaxy Tab has a screen of 7 inches with a resolution of 1024x600 pixels.

3.3   Touch screen interfaces and interaction

Touch screen interfaces offer several benefits when compared to interfaces with physical buttons. Mainly, they are flexible with presentation and control, as different applications can provide optimized virtual buttons and other UI elements for controlling and interaction. Interfaces do not need to be based on a set of hardware controls provided with the device. With the adaptable interface comes also augmented discoverability – users do not need to remember input commands because touch screens allow direct manipulation.

(a)   (b)

Figure 9: (a) Apple iPad [46] and (b) Samsung Galaxy Tab [47]

One of the major drawbacks of touch screen interaction, however, is the lack of tactile feedback. Devices operated by physical keyboards always let the user know when an action is registered, and e.g. experienced users can write text without looking at the keys, as it is possible to know the right key is pressed based on the feel of the button. Touch screens also can present significant accessibility barriers to blind users, as most devices provide no audio or tactile feedback, making it difficult or even impossible to locate items on the screen [48]. Below, the main benefits and drawbacks of touch screen interfaces and interaction are discussed in a review of defined guidelines and related studies.

3.3.1   Related research review

SAP Design Guild (2000) presented an experimental interaction design guide for touch screen applications before mobile devices with touch screens were common. The guidelines presented in the document discuss mainly touch screen interfaces used in point-of-sale stations, in museums, as city guides, or at kiosks. The main interaction guidelines advise to use a simple point-and-click interface with buttons and to avoid dragging, double-clicks, scroll bars, dropdown menus, and multiple windows. Keyboards should be made switchable or even customizable for users with varying typing experiences. Text entry should be kept minimal or non-existent. For number entry, a 3x3 number arrangement should be used, telephone layout for untrained users and keyboard layout only for people who are used to it. Number entry should be minimized. Selection controls require a size big enough for fingertips, as pushbuttons do. Data entry by selection is well suited for touch screens as textual or numerical data input with virtual keys is not optimal. Selections may also be done indirectly via pushbuttons. Scrolling is easier by pointing than by dragging. Conventional scroll bars, even enlarged, are not recommended. Simple pushbuttons are easier to operate and they should have a repeat function for continual scrolling.

Scrolling should not be used for the screen itself, but only for data display, i.e. for fixed areas on the screen. At best, scrolling is not used at all. Simple gestures that are easy to remember can be used on stylus-operated touch screens. E.g. deleting items by striking them through or crossing them out, marking items by adding a cross, and identifying a user by his signature are convenient examples. Gestures are not well suited for finger-operated touch screens as the use of drag operations with fingers are not recommended. Buttons should give some feedback as to their state (on/off, active/inactive, etc.). Immediate feedback is critical, visual and sometimes auditory feedback is recommended. Mouseover effects cannot be implemented on touch screens and this should be noted. [49]

Touch interaction and interfaces have been studied also more recently. Saffer (2008) wrote his book about gestural interaction design as a result of being frustrated of the lack of proper information about the subject that was obviously important and growing fast, and interaction designers were in need of sources. The book introduces interactive gestures, touch screen mechanics, and ways for finding the right gestures for different actions. Human kinesiology and ergonomics are also discussed in detail, as gestural interfaces require a totally different set of movements and body and hand positions than indirectly controlled interfaces. The core of the book is a long list of design patterns for touch screen and interactive surfaces and interactive gestures. Patterns are presented in a traditional way, providing details on what the patterns is about, when, why and how it should be used, and examples on usage. In the end, the book also discusses how the gesture design process is included in the product development cycle, and how the gestures are e.g. prototyped and tested. [50]

There has also been quite active research on touch screen interfaces and usability lately. Koskinen (2008) studied tactile feedback for virtual buttons. The lack of tactile feedback makes the mobile device use challenging as the user can only rely on visual and audio feedback. Mobile devices are also often used in situations where the user cannot devote all his visual attention to the device and the audio feedback cannot be heard. Koskinen's studies show that virtual buttons with tactile feedback produced by piezo actuators provide the highest level of usability. A piezo actuator moves the screen window approximately 100 micrometres with a high speed, which makes it easily detectable to the human touch. Users experience an illusion of local actuation although in reality the entire screen moves. With piezo feedback, users performed tasks faster, made fewer errors, and were most pleased. Vibra feedback is the second best option for usable touch screen interaction. [51]

In the study of Balagtas-Fernandez et al. (2009), the authors state that even though touch screen capability facilitates certain actions on the device, the design of applications running on such devices is critical for the success of both the device and the application. Therefore they investigated overall interface layout, information input, and menu accessibility on a touch screen device. The group found that navigating using a scrollable view is significantly faster and perceived easier than navigating using a tabbed view. Editing is faster and easier using a virtual QWERTY keyboard than tapping pushbuttons on the screen when inserting a date. For a menu of action selections, the device menu is faster and easier compared to a context menu. [52]

Lee et al. (2010) compared a phone with a numeric keypad and a phone with only a touch screen in numeric entry and menu selection tasks. Finger movements were much simpler on the button keypad in both test tasks. On the touch screen, a larger number of unnecessary, inaccurate movements were made. A consistent result in which the button keyboard is superior in terms of usability was found in all of the measured metrics, except for intuitiveness and enjoyableness. With the button keyboard, tasks were done faster with more accurate movements, fewer errors, and a lower number of gaze fixations. [53]

Mauney et al. (2010) collected, classified, and analysed user-defined gestures for 28 common actions (such as scroll, open, rotate, zoom in, etc.) of 340 participants across 9 countries. More than half of all recorded gestures were swipes and single taps. While there are small differences between countries, the majority of the participants from different countries generated similar gestures for individual actions. E.g. going back on a browser page was performed by a 'swipe left' anywhere on the screen by more than a third of all participants, scrolling down was performed by a 'swipe up' by 48.5 %, and zooming in a map was made by spreading two or more fingers from the object by 39,5 %. 91 % of all gestures were classified as direct manipulations and the rest as symbolic in nature. Deviating from the rest of the results, China created more symbolic gestures than other countries. The study presents a starting point for a gesture set of the tested 28 actions, and further testing will be applied during 2011. [54]

Norman and Nielsen (2010) criticize the new gestural interfaces. They claim that well-tested and understood standards of interaction design are being ignored. The authors list fundamental principles of interaction design that are neglected in gestural interfaces: 1. Visibility. Perceived affordances and signifiers are non-existent or misleading. 2. Feedback. Both Apple and Google recommend multiple ways to return to a previous screen, but a back button should always be provided following the user's model of 'going back'. 3. Consistency and standards. Radio buttons and checkboxes are mixed – checkboxes can work any way the developer chooses. Manufacturers' detailed UI guidelines differ from one another. 4. Discoverability. No menus are offered and user needs to memorize a large set of gestures to find actions. 5. Scalability. There is a plethora of screen sizes, but gestures that work well for small screens fail for large screens, and vice versa. E.g. small checkboxes work well with a mouse or a stylus but are inappropriate for fingertips. Sensitive screens give many opportunities for accidental selection and triggering of actions. 6. Reliability. Gestures are invisible and users often do not know if they have made mistakes. Users lose their sense of controlling the system because they do not understand the connection between actions and results. The authors admit that the new interfaces can be a pleasure to use as gestures add a welcome feeling of activity to the otherwise joyless pointing and clicking. But developing usability guidelines that are based on solid principles of interaction for these systems is needed. [55]

4 Foundations for this thesis

This section presents a broad literature review on the topic, and thus justifies the need for this thesis' studies. Literature from both academic and commercial sources is presented, and also blogosphere publications are briefly discussed. At the end, the foundations and importance for this thesis are concluded and the empirical study methods are introduced.

4.1 Related research

This thesis is founded on the assumption that the newly released touch screen devices have a remarkable effect on Web usage and web browsing user experience worldwide, and that academic research has not yet been able to publish enough studies on how this phenomenon should be taken into account in web design. Some of the devices studied in this thesis were only published in 2010, and it is reasonable that research needs to take time to inspect these devices and how they are used. Secondly, it is a common assumption that companies running the mobile Web business do study their market and their users frequently, but the results of their research is seldom public. Instead, it is kept secret from the other companies to maintain competitiveness.

As the subject of this thesis is rather new and changing with a notable speed, it is important to know where web designers and developers find their background information on users for developing useful and working Web services. It can be presumed that skilled professionals are well aware of these new end devices used for browsing their services, but do they have enough information on how to take mobile users into account? How much research has been done on e.g. iPhone, Android and iPad Web user experience?

For establishing a base for this thesis, a wide background search was executed. Both academic and commercial research was targeted, as well as the big blogosphere, supposedly in frequent professional use among web developers. Papers, publications, reports, and postings were gathered, and their objectives, methods, and results were analysed.

Academic research papers were searched from the following scientific databases: Association for Computing Machinery (ACM), Institute of Electrical and Electronics Engineers (IEEE), Science Direct, and Springerlink. Google Scholar was used to scour the Web for relevant items, but all results including related research were eventually found in the aforementioned databases. Commercial studies and the blogosphere were hit with a number of Google searches using the same keywords as for the academic research. The keywords used for all related research searches were: *access, Android, browsing, computer, desktop, experience, guidelines, Internet, iPhone, iPad, mobile, multi, multitouch, One Web, screen, tablet, touch, touch-based, touch screen, usability, user, UX, Web*, and *W3C*. All in all, 26 different combinations of these keywords were used.

Not surprisingly, the academic research had little to offer for touch screen mobile device web browsing user experience. Mobile Web alone is studied enormously, but the reports date in general to the previous decade, in 2007 the latest. However, the

iPhone was released in the end of the year 2007, so studies published after that are considered more relevant. Only four papers discussing the effect of the iPhone were found. Papers studying iPad Web usage could not be found.

Commercial studies available were those of usability consulting and research companies. Nielsen Norman Group (NN/g) was found the only one to have studied touch screen phones and the iPad in web browsing. Also a few books on mobile Web development and programming deal with the subject of user experience, the most newly released being O'Reilly's *Programming the Mobile Web* [25].

Blogosphere publications were not considered as valid references for this thesis, but they need to be treated with special appreciation, and thus they were included in the background searches. Blogs and discussion forums are a primary source of information for many designers, programmers, and application developers, and there is a vast number of blogs dedicated to web design, including e.g. postings of usability guidelines and detailed code examples.

The following chapters present the findings of 4 academic studies, 3 commercial publications, and a set of blogs regarding mobile Web user experience focusing on touch screen use. Studies on touch screen interaction and interfaces in general were discussed in Chapter 3.3, but these studies did not incorporate Web usage and are therefore not listed here.

4.1.1 Academic research

Maurer et al. (2010) investigated whether mobile-optimized websites are still needed in addition to full websites, conducting a web survey with 108 participants and a follow-up user study with 24 participants. The team hypothesized that the technological development of the mobile Web would soon make mobile versions of websites outdated and unnecessary. The survey was filled in by people with varying mobile Web experience, from zero to daily users. 63 were touch phone users. People were asked to compare mobile-tailored and desktop-style websites, showing screenshots of the two versions. The user study was performed on an iPod touch with the Safari browser. Of the participants, 58 % had previously used a touch screen device. [56]

The survey results show that a growing number of users prefer original content to the mobile versions, especially for users of the highest-end devices, such as the iPhone and Android devices. The user study showed no significant performance increase when comparing a visual search task on the mobile and desktop versions of a website. Performance was measured by task completion times. The authors state that the trend to offer different websites for different kinds of devices seems debatable in the light of the findings, and that something should be done to allow proper display of Web content on all different screens. [56]

Schmiedl, Seidl and Temper (2009) studied mobile Web usage scenarios as well as the usability of mobile-tailored websites compared to that of full websites, targeting the use of latest generation devices. The study comprised of 12 hypotheses consolidated into 5 research questions and applicable methods were used to find answers for the questions. Firstly, they studied mobile Web users with a face-to-face survey. Secondly, they investigated how many of the topmost websites in Austria

have a mobile-tailored version. Thirdly, they searched what websites are available in a mobile-tailored version, whether these should provide the same information as the full site, or whether a limited set of functionalities is an advantage. Fourthly, they asked whether a mobile-optimized version has an advantage in comparison to the full version. With a usability test, they studied 5 websites with several different phones and with 9 users. And lastly, they studied which mobile phone type qualifies best for surfing the Web with another usability test. Four phones were tested and compared. [57]

The group found that the typical user is male, technically interested and/or educated and between 20 and 29 years. Arguments against mobile Web use were high cost and poor phone models. Of the websites accessed in mobile context, 70 % provide current or general information. 82 % of the top 50 and 34 % of the top 100 accessed sites in Austria do have at least one mobile version. 55 % of the found mobile versions were categorized as information services, 20 % as social networking, and 7 % as entertainment. The remaining 18 % consisted of several search engines, online shops and other non-categorized websites. In the usability test, users were 30-40 % faster when using mobile-tailored versions. All testers stated that the feature limitations of tailored versions were annoying even though the missing features are not likely to be used on a mobile phone. All users preferred touch screen devices and an additional keyboard was considered highly convenient. Using a pen was disliked. Task completion times did not identify a clear winner but devices with a physical keyboard showed significant advantages in data entry tasks. The study concludes that users still prefer and effectively benefit from mobile-optimized website versions. However, content providers do not always understand the mobile scenarios in which their sites are used and begin optimizing the functionalities at the wrong end. [57]

Kaikkonen (2008) wanted to investigate the huge difference between mobile Internet and computer Internet experiences. She executed a global online survey with 390 mobile Internet users and 23 face-to-face interviews in Hong Kong, London and New York in the spring 2007, just before the release of the iPhone. Based on the survey, mobile Internet users in Asia differed from users in other continents in being less technical, mainly female, and using the mobile Web more than full Web. North American and European users used the full Web more frequently and often had technical background, i.e. they can be defined as early adopters. There are clear use cases for accessing the full Web, but this does not mean that tailoring the Web for mobile use would be a temporary solution. The study shows that a good browser and fast and cheap access to networks increase full Web usage. In situations of quick small tasks, applets connected to Web may work better and quicker than the full Web. The full Web is used to get information that has no mobile tailoring and when users know where to find information. Tailored solutions are used either for specific tasks or killing time. [23]

Kaikkonen states that flat fees and WLAN are crucial for mobile Internet success. Also, good full web browsing requires fairly large displays, which probably are not comfortable to carry. The key issues for making services for the mass market in the mobile Web are awareness, accessibility and no extra costs for using the service. Kaikkonen also comments on the newly released iPhone and iPod saying that it

would be an interesting topic to study how much these devices have influenced the perception of mobile Internet and its use, and believes that the new features may be yet another issue that differentiates how the full Web and mobile-tailored solutions are designed. [23]

Shrestha (2007) performed a comparative usability study of mobile and desktop web browsing in a laboratory environment. All 12 participants used the same mobile device (SE W550i) and browser (Opera mini 2.0) for the test tasks. None of them had used the device before the test and 7 had no experience of mobile web browsing. Participants were taught to use the phone to prevent confusion or problems related to the device. Task completion times, types of incidents and occurrence times, success rates, and participants' comments were recorded. A post-test questionnaire was also applied to gather user perceptions of the tasks and mobile web browsing.

According to Shrestha, users expect similar Web user experience on mobile phones as on the desktop. The main incidents during the tasks included being visibly lost on long web pages and needing to scroll excessively. Users appeared very frustrated numerous times as the number of clearly negative comments on the tested pages was considerably high. Only one user was able to complete all four tasks. Average task completion times were less than 6 minutes for desktop and around 23 minutes for mobile devices. [58]

Shrestha states that it is very important to give users a feeling of control over the site. The browser should also give a clear indication of how long the page is and where on the page the user currently is. Eliminating or moving long link lists is one of the main design changes mobile-authoring guidelines suggest content providers should make. However, if the page has lots of collapsed sections, it can be difficult to find the needed section, especially if the user is not familiar with the page. It would be good to let users view the whole page first and collapse long sections as they scroll down. Desirable features include a find or search function, text copying to the clipboard, a bookmark manager using folders, a possibility to view the browser in landscape orientation, the ability to use other phone functions without exiting the browser, and saving web pages for offline viewing. Shrestha concludes that rendering content for mobile browsers is best attempted when rendering like a desktop browser. [58]

4.1.2 Commercial research

Firtman (2010) ambitiously describes his book as the most complete reference for the mobile Web available at this time, as it draws upon experience and detailed research and testing not available in other books, websites, or research papers about the mobile Web. Firtman discusses traditional myths of the mobile Web. He highlights that there is no need to separate mobile Web from the Web because in the end it is the same Web as the same network protocols are being used. However, developing for the mobile Web is very different as a diversity of devices are being targeted. Creating several versions of the same service and thus duplicating the work is, however, no objective. The objective is to make one product and the book gives many instructions on how to technically achieve this goal. Also, the assump-

tion that no changes need to be done to desktop websites, thanks to full-featured mobile browsers, is turned down. Users want the same experience on the mobile Web as on the desktop, and this is not achieved with traditional design. As for the 'One Web' vision, Firtman claims that it is to an extent possible to realize it today, but it is mostly for the poor devices that prevent the vision to come true. Firtman flatly turns down creating a WML file to fulfil mobile users' needs. WML belongs to the WAP era and is definitely not the mobile Web today. And neither is creating a single HTML file with a width 240 pixels. There are more than 3 000 mobile devices on the market, with almost 30 different browsers. One HTML file as a mobile website would be a very unsuccessfull project. [25]

To the assumption that native mobile applications will kill the mobile Web Firtman responds that all solutions have their advantages and disadvantages. The mobile Web and mobile widgets offer a great multi-device application platform without requiring an always connected Web with URLs and browsers. The finding that users do not use their mobile browsers is explained with the educated guess of being due to poor Web services offered for mobile users. Firtman supposes that mobile browsing will never become as popular as desktop browsing, but it will increase a lot in the following years. Firtman presents a long list of tips, design patterns, best practices, and guidelines for designing mobile websites. The lists comprise of details about navigation, context, progressive enhancement, different version approach, usability, and touch design patterns. Firtman also advices developers to review manufacturers' official UI guidelines when developing both mobile applications and mobile websites. [25]

Budiu and Nielsen (2010) on behalf of Nielsen Norman Group (NN/g) conducted an initial usability study of iPad apps and content a few weeks after Apple launched the device. 7 users with at least three months' iPhone experience participated in the study, one having iPad experience as well. Preliminary findings show that there are no standards and no expectations for iPad user interfaces. There are often no perceived affordances for how various screen elements respond when touched: users do not know where they can click. Where this problem culminates is in the inconsistent interaction design. Each application has a completely different UI for similar features. The iPad UIs suffer from three significant sources of confusion: low discoverability, low memorability, and accidental activation. [59]

NN/g found that for many applications, a strong print metaphor is used, i.e. swiping is used for the next article, and headlines on cover pages do not work as links, neither is there a homepage, even though users strongly desired homepage-like features. In electronic media, the linear concept of 'next article' makes little sense. NN/g suggest following directions towards better iPad user experience: 1. Add dimensionality and better define individual interactive areas. 2. Loosen up the etched-glass aesthetic. 3. Use consistent interaction techniques and abandon the hope of value-add through weirdness. 4. Support standard navigation, including a back feature, search, clickable headlines, and a homepage for most applications. The authors present that it will remain unanswered for a year or so whether people use the iPad mainly for more immersive experiences than the desktop and mobile Webs. [59]

In 2009, Budiu and Nielsen on behalf of NN/g studied the usability of websites accessed by mobile device with a combination of three methods: a diary study with 14 participants from 6 countries, user testing with 48 people in the US and in London, and a cross-platform review of 20 websites using 6 phones by three usability experts. They wanted to understand how people access the Web on their mobile phones and what challenges they face when using websites and web applications on their phones. Based on the study, they listed 85 design guidelines for better mobile usability of the Web. The authors describe the mobile user experience as miserable because it is neither easy nor pleasant to use the Web on mobile devices. The main factors causing problems are small screens, awkward input, download delays and mis-designed websites. In the tests, mobile-optimized websites performed better than full websites, averaging 64 % over 53 % in success rates. There was a clear difference between the US and the UK: The overall success rate was 64 % in the UK versus only 54 % in the US. The difference was essential for full sites: 74 % success over 43 % for the UK. The results suggest that full sites in the UK perform well in mobile use, but in the US the situation is different. Mobile websites were also perceived more pleasant as they gained higher subjective satisfaction ratings. On a 1–7 scale the overall average satisfaction rating was 4.3, mobile sites scoring 4.6 and full sites 3.72. For these reasons the results suggest building a dedicated mobile site if mobile users are considered important. [37]

However, in NN/g studies, users had trouble getting to mobile sites even when these were available. Therefore auto-sensing users' devices and auto-forwarding users to mobile sites is recommended. Clear links from the full site to the mobile site, and vice versa, should always be offered. For link labels, 'Mobile Site' and 'Full Site' are recommended. The mobile site's functionalities and focus should be on features that people are likely to use in a mobile scenario. When comparing devices, phones with bigger screens performed better, success rates being 38 % for feature phones, 55 % for smartphones and 75 % for touch phones (see NN/g's device categories in Chapter 3.1). One solution is to focus on smartphone and touch phone users who are more likely to use the website extensively. However, that is not the only solution. For services highly suited for mobile use, such as news or social networking, creating a dedicated feature-phone site, as well as a site optimized for higher-end phones is reasonable. For most other websites, concentrating on a single mobile site optimized for high-end phones is of value. If there are not a notable number of mobile users for a website, a separate mobile site is not justified. [37]

When counting task completion times, NN/g encountered a surprising result: users spent 38 % more time on average on specific tasks than they did in 2000 when a similar user test was carried out. Smartphone and touch phone users tended to be faster, but there was a lot of variation among individual users in all phone types. The group drew a conclusion that this was due to the changed usage environment. NN/g concludes that designing for mobile browsing is hard, and that technical accessibility is very far from providing acceptable user experience. Even touch phones that offer 'full-featured' browsers do not offer PC-level usability in terms of being able to actually get things done on a website. When designing for mobile devices, there is a tension between making content and navigation salient so that getting there is easy,

and designing for a small screen and for slow downloading speeds. Design decisions must be made in the context of the site being designed and all solutions do not work for all websites. [37]

4.1.3 Blogosphere publications

There are a myriad of blogs about web design and development on the Internet. Companies, associations, communities, working groups, individual professionals, and many other entities publish their views, and other's views, on current trends, guidelines, and requirements on web development. As can be expected, many of these have written several postings on mobile Web and touch screen web UX and usability as well. In this chapter, a brief overview of a few blogs is presented.

A List Apart [60] is a forum of A List Apart Magazine that explores the design, development, and meaning of web content, with a focus on web standards and best practices. They publish articles on code, content, culture, design, mobile, process, and user science. Recently, A List Apart has written e.g. about Mobile Applications vs. the Web and the smartphone browser landscape. These articles state that iPhone users feel most comfortable when they can use the standard controls they have become accustomed to in Apple's built-in applications, that users' needs and wishes have to be figured out before getting anywhere near implementation specifications, that users expect websites to work on their mobile phones, and that in two to three years, mobile support will become standard for any site, and testing with a reasonable number of devices is necessary already today.

LukeW Ideation + Design [61] is a website and a consultancy by Luke Wroblewski, an internationally recognized product design leader. Wroblewski writes articles about critical details and the big picture behind digital product design, and the articles cover e.g. Web and device strategy, interaction design, visual design, and usability. For the last four years, Wroblewski has frequently published reviews on articles regarding mobile Web published elsewhere, and also his own viewpoints on these subjects.

MobiForge [62], as part of a bigger collection of dotMobi services, addresses itself as the world's largest independent mobile development community. The site offers information on mobile Web opportunities and technologies for all product design phases, providing antennas, tips, blog postings, a forum, and a directory of related items. The blog has not been very active lately, the latest posting being published in October 2010, but until that there have been writings e.g. about the famous topic of applications vs. the Web, diversity of the mobile Web, device detection, mobile Web platform convergence, and Mobile Web 2.0.

Quirksmode [63], run by Peter-Paul Koch, mobile platform strategist, consultant, and trainer, is a source for browser compatibility information, offering compatibility tables where e.g. CSS and JavaScript capabilities, along with browsers' adherence to the W3C standards are listed. Quirksmode has a separate Mobile section, where browsers, the mobile market, WebKit, touch actions, and viewports are discussed. Based on Koch's easy-to-read compatibility tables, mobile Web developers can get a reasonably quick overview on current browsers and how web browsing works with

them, and also how this should affect website design. Koch also publishes a blog where recently added and updated information is referred to.

Six Revisions [64] is a website that seeks to publish practical and useful articles for designers and web developers. The authors aim at presenting exceptional, noteworthy tips, tutorials, and resources that web professionals appreciate. The latest postings of Six Revisions include e.g. a quick look at mobile web designs that presents a few key concepts to keep in mind when designing for the mobile Web, an article discussing mobile web design usefulness and need, mobile web design best practices with solution examples, and a review of 10 tools for testing a site on mobile devices.

UX Matters [65] is a web magazine that provides insights and inspiration to both user experience professionals and students. The authors, many of whom being leading experts in the field, teach UX best practices and influence the future directions of the UX community. The latest article published regarding mobile Web, by Shanshan Ma, is a response to Budiu and Nielsen's study [37] on mobile Web usability. In this writing, design for complex contexts of use and constraints of mobile websites are covered, in addition to the problems discussed in [37].

4.2   The importance of this study

As the review shows, the academic research on this thesis' topic is very brief, especially compared to the big blogosphere offering a large set of current and actual information on web design, development, and usability. For enabling the research to keep track of these new trends and directions, hugely affecting the Web usability and user experience in general, more research with users needs to be done. Also, users and users' skills and habits change with experience of new devices, and rules, guidelines, and best practices based on research performed two years ago is hardly fully valid anymore. Therefore new and continuous user research on mobile Web with touch screen devices needs to be carried out.

In addition to providing updated information for the academic UX community, design patterns and best practices, such as Welie's and W3C's, need to be updated. Mobile devices capable of browsing the full Web are not currently taken into account in full Web interaction design guides, but there still is a distinct division between the full and mobile Web. The One Web vision by W3C is a lot closer to reality today than it was e.g. a year ago, and this should show in the tools interaction and usability professionals are using.

For the aforementioned reasons, a user experience study of mobile web browsing was performed. The study aimed to answer the research questions presented in Chapter 1.3. The results were gathered and significant findings were concluded to address these questions.

4.3   Methods

For studying mobile web browsing user experience, an approach used in many usability studies at Adage was utilized. That is, pragmatic user research methods, expert evaluation and usability testing were adopted. Expert evaluation is a method for finding possible usability problems for developing the usability of a product. In expert evaluation, depending on the experience of the person performing the evaluation, also other aspects of user experience can be evaluated, and not only usability issues. Expert evaluation usually results in finding most of the usability issues related to the studied product, service, or system, but most findings are considered minor or moderate of importance. Usability testing is a method for studying the use of a product, service, or system with its real users. Testing with users is often considered the best way to detect crucial usability issues. Therefore, expert evaluation was first used for gathering issues that might cause irritation and dissatisfaction with mobile Web users, and usability testing with 18 participants was then applied for analysing these issues further, and to get a deeper insight into the problems users face. The application of the selected methods is described in detail in Sections 5.1.2 and 5.2.2.

5 User experience study of mobile web browsing

In this section, the empirical studies regarding this thesis are presented. The section is divided in two parts, 5.1 Expert evaluation and 5.2 Usability testing. Both parts present the objectives, methods, results, and conclusions of the related study method. The results of the whole user experience study are concluded in section 6.

5.1 Expert evaluation

The overall study was launched by evaluating several websites with several mobile devices by experienced professionals of usability and user experience. The results of the expert evaluation served as a base for the test tasks used in the usability test.

5.1.1 Objectives

The objectives of the expert evaluation were to find a significant part of usability and user experience issues related to browsing full and also mobile-optimized web pages with mobile devices, especially with touch screen devices. Also, differences between touch and non-touch, and small and big screens were seeked. The aim of the expert evaluation was to collect a set of use cases and tasks in which users might have problems to succeed. These use cases and specific tasks were needed to design the following phase of the study, the usability test.

5.1.2 Expert evaluation methods

An expert evaluation can be carried out by going through a set of use cases defined in advance, or the product can be examined using a free approach. All issues related to product usability and user experience found are written down, and their causes are identified. At the end of the evaluation, the findings are gathered, analysed, and often also prioritized by their severity.

In this study, the Adage method, based on the two most widely used methods, heuristic evaluation by Nielsen and Molich [66] and cognitive walkthrough by Lewis et al. [67], was used for the evaluation. Three user experience specialists at Adage, consisting of the author and two colleagues, browsed several different frequently used websites with several touch and non-touch devices. The devices and websites used in the expert evaluation are presented in Table 2. Other websites were also evaluated when linked to the websites listed above, but these were not systematically recorded. All browsing was performed using the devices' native browsers.

Personal professional experience based on usability heuristics and experience of working with different kinds of user interfaces were used for finding tasks and situations in which mobile Web users might have difficulties. Specialists evaluated the websites and the devices independently. Each specialist wrote their findings down and these were then discussed together in a group, after the evaluations were performed. The author, responsible for the project, analysed the findings and responded to the objectives set in the beginning, listing typical usability issues found and a classification between touch and non-touch, and small and big screens.

Table 2: Devices and websites used in the expert evaluation

Devices	Websites
Apple iPad	Facebook (facebook.com)
Apple iPhone 3GS	Google (google.com)
Newision 8 inch LCD	Helsingin Sanomat (hs.fi)
Nokia E51	Ilta-Sanomat (iltasanomat.fi)
Nokia E71	Nokia (nokia.com and nokia.fi)
Nokia N810	Polar (polar.fi)
Nokia N900	telkku.com
Google Nexus One	Wired (wired.com)

5.1.3 Results

As a result of the expert evaluation, the following factors, both device and website related, could be named to significantly affect the mobile browsing user experience:

1. Zooming

   - Direct (gestural) or indirect (via a button or a menu item)
   - Intuitive or needs learning
   - Accurate (cannot be mixed to other actions e.g. to scrolling or selecting items, applies for all non-touch devices) or inaccurate (can be mixed to other actions, applies for many touch devices)
   - One or multiple ways to zoom in and out
   - Zooming resets on every new page load, or user defines the zoom level that stays until changed

2. Scrolling

   - Scroll bar, or gestural swiping, or navigating on the page link by link with a navigation button
   - Reactive or needs to be repeated to activate (applies on many touch screen devices)
   - Accurate (cannot be mixed to other actions, applies for all non-touch devices) or inaccurate (can be mixed to other actions, applies for many touch screen devices)
   - Direct feedback or delayed changes on screen

3. Text input

   - Virtual or physical keyboard

- Capitalisation is selected for each letter at a time, or it can be set 'on', and/or it is automatically activated e.g. in the beginning of a sentence
- Error rate high or low, error feedback visible or subtle
- Keyboard is use case specific (e.g. URL, login, writing content), or the same keyboard is used in every use case
- Arrow keys provided for quick editing, or only backspace provided

4. Element size on screen

- Visible or unnoticeable (e.g. big or small text, links, or buttons)
- Objects smaller or bigger than pointer accuracy (pointer, stylus, or fingertip)
- Text row width adjusts to zoom level or stays static

5. Links

- Links can be recognized, or links look like images, text, or other non-selectable objects
- Link URL can or cannot be previewed

6. Browsing without touch functions

- Tabulator button, wheel, joystick, or arrow buttons provided, or no tabulator function
- Movable pointer available, or no pointer provided

7. New browser windows

- New windows noticeable by the user, or new windows not informed to user visually
- Moving between windows is simple or complicated

8. Compatibility

- Supports Flash, Flash lite, or does not support Flash at all
- Supports JavaScript fully, partly, or poorly (JavaScript effects can be utilized or are difficult to use)
- Supports or does not support AJAX features, or freezes with non-working AJAX

9. Mobile-optimized websites

- Mobile users are redirected or are not redirected to existing mobile version
- Content for mobile use cases only, or the same content as on full site, or less content than on full site but not optimized for mobile use cases

Based on the expert evaluation, the device and website features and factors listed above were assumed to cause the most and the least satisfaction for users in mobile browsing. After naming and listing these factors, devices were classified into four categories based on screen size and touch support, and these categories' main differentiating features related to browsing were appointed. For reference value, desktop computer browsing was also included in the categories. Figure 10 points out the main factors affecting web browsing user experience for the four device categories.

	Small screen (< 5 ")	Big screen (> 5")
Touch screen	Zooming is necessary with full web pages Text input is awkward with a virtual keyboard No pointer provided in most devices Gestural scrolling is smooth and pleasant	Familiar browsing with the advantage of gestural controls Full web sites are necessary as mobile optimized sites are too small
Non-touch screen	Accurate and error-free interaction and input Full website text usually very small Scrolling is stiff and piecewise	More content visible in one view Indirect interaction with mouse and keyboard is familiar but not engaging

Figure 10: Device and website factors assumed to affect web browsing user experience the most, based on the expert evaluation. Factors are appointed for four different device types: touch phones (upper left corner), tablets (upper right corner), smartphones (lower left corner), and desktop PCs (lower right corner).

5.1.4 Conclusions of the expert evaluation

The expert evaluation resulted in a long list of usability issues related to mobile browsing, with and without touch screen in the device. Most issues were due to gestural and touch interaction with the device and with the web pages, such as zooming and scrolling, clicking on links or trying to avoid unwanted clicks, and writing with a virtual keyboard. Clear differences between different types of devices could be observed.

5.2 Usability testing

After the expert evaluation, usability testing was performed for mobile browsing with different mobile devices. Before the actual tests, pilot tests with 5 users from different target groups were carried out to examine the research setup's adequacy and to note if something relevant was missing. The objectives, methods and results of the actual test are presented below.

5.2.1 Objectives

The objectives of usability testing were to further analyse the findings of the expert evaluation, and to interview real mobile device users of their experience on mobile web browsing. Users were looked for in the following groups: smartphone users, touch phone users, and multitouch phone users. Tablet web browsing was also an interesting subject, and therefore the iPad was included in the tested devices. A desktop computer was tested for reference value of the web browsing user experience. In addition to testing the designed tasks and use cases with users, the aim was to gather quantitative user feedback of the browsing experience and expectations towards mobile browsing in general. Therefore the objective of this study phase was primarily to collect qualitative findings of mobile web browsing user experience, and secondly, quantitative data to support the qualitative results.

5.2.2 Usability testing methods

5.2.2.1 Study setup

The tests were executed in laboratory environment at Adage's study premises, as laboratory conditions are a lot more convenient for efficient data gathering and for getting test users to participate. As the system part of user experience was mainly studied along with a brief insight into the user side, laboratory conditions were justifiable. When differences in usability test results in the laboratory versus the real mobile situation have been studied, mobile context has not proven to provide better results than laboratory context, regarding basic software interaction related usability [68, 69]. In the laboratory, a constant wireless network connection was available for test users.

In the test, the same tasks were performed with different devices, going through the test sequence for each device at a time. Tasks consisted of browsing the web in several ways and on different websites (Helsingin Sanomat, Facebook, Google Maps, Polar, Google, and Nokia) defined beforehand, using the device's native browser. Comparing devices or websites, or asking user preferences was not applied, but comparison was made in the analysis phase of the study. Users were asked to think aloud during the whole test. Each test took approximately 2 hours and the test users were rewarded with a gift card. The usability test structure and test tasks can be found in Appendix B.

Real mobile Web, smartphone, touch phone, and multitouch phone users were targeted in the study to observe realistic issues and advantages of mobile browsing.

The testing was executed with 18 users in 3 6-user groups: smartphone users, touch phone users, and multitouch phone users. As Nielsen states, 5 is an adequate number of users for reaching the majority of usability issues related to the tested product [70], and therefore a group size of 6 users was justified. The users were aged between 20 to 42 years, 27 years on average, 7 being female and 11 male. All users had had their mobile device at least for a month, and all use it for web browsing at least weekly, except for one user. The user profiles selected for the study were well in line with the mobile Web user findings in [57]. Details on test users can be found in Appendix C1.

Test users for the groups smartphone and touch phone were best available from the users of the following devices: Nokia E71, N97, 5230, 5530 and 5800, as Nokia has an important market share in the test location. Multitouch phone users were recruited from iPhone users. Tablets were poorly available at the time of the tests, and therefore a company-owned iPad was used. For a comparison of different multi-touch devices, an Android phone, the Google Nexus One, was also tested. A desktop computer was tested for reference value. Each test user used their own phone and two other devices in the test. The order of devices during the test was randomized. Each device type was tested with a following number of data points: smartphone (E71) 6, touch phone (N97, 5230, 5530, 5800) 6, 1st multitouch phone (iPhone) 6, tablet (iPad) 12, 2nd multitouch phone (Nexus One) 12, and desktop computer (PC) 12. The test device orders for each participant are presented in Table 3.

Table 3: The order of test devices for each test participant

Participant group	No	1st device	2nd device	3rd device
Touch phone	1	own	PC	iPad
	2	PC	own	iPad
	3	PC	Nexus One	own
	4	Nexus One	PC	own
	5	iPad	own	Nexus One
	6	own	iPad	Nexus One
Smartphone	1	own	PC	iPad
	2	PC	iPad	own
	3	own	Nexus One	PC
	4	PC	Nexus One	own
	5	iPad	own	Nexus One
	6	Nexus One	own	iPad
Multitouch phone	1	own	PC	iPad
	2	PC	own	iPad
	3	own	Nexus One	PC
	4	PC	Nexus One	own
	5	Nexus One	iPad	own
	6	iPad	own	Nexus One

5.2.2.2 Measures

In terms of user experience, defined in Section 1, there are numerous factors of mobile Web user experience that can be studied. In this study setup, context and connection were constant for all users, and the device and browser were treated as an entity. Therefore, there were three main characteristics forming the user experience that could be measured: the user, the device, and the website. For this study, the following factors were chosen to be examined: device usability and performance, website usability, user's experienced pleasantness (supposed to be formed by all the different factors of user experience), and user's expectations. How the different devices were perceived as web browsing devices was also measured.

Device and website usability was mostly measured in qualitative terms. Users were observed by the moderator sitting next to the user. A video camera recorded events with mobile devices and a screen capture software recorded events on the PC screen. All significant, positive and negative, events and device and website features were written down, gathered, and analysed.

User's experienced pleasantness was measured with a 5-point scale questionnaire, where users chose a rating between pleasant and unpleasant for a set of predefined test tasks. The rating was facilitated by using emoticons instead of numbers as the evaluation scale. The emoticons used in the questionnaire are presented in Figure 11. Emoticons were chosen instead of plain numbers, because they have proven to be suitable for assessing emotion, as they are intuitive and easy to understand [71]. Isomursu et al. also state that emotions are at the heart of user experience, and self-report instruments provide feasible and lightweight tools for collecting this information [72]. Also, when reported, emoticons presumably have a more straightforward message to web developers than numbers, which can be more easily misinterpreted. The questionnaire used can be found in Appendix D. The 14 tasks among the task set that users rated were:

1. Typing a URL and downloading a page (hs.fi)

2. Scrolling a page (hs.fi)

3. Reading (hs.fi)

4. Navigating back in the browser (hs.fi)

5. Login (Facebook)

6. Form field: text (Facebook)

7. Form field: check box (Facebook)

8. Form field: menu (Facebook)

9. Copy pasting (Facebook)

10. Viewing a map by zooming and panning (maps.google.com)

11. Navigating with a dropdown menu (polar.fi)

12. Browsing information, no search task included (polar.fi)

Figure 11: Emoticons used in the evaluation form. The emoticons in the question-naire were validated with pilot users to ensure they each had the right message. One of the images was trimmed based on the validation.

13. Using a search engine (google.com)

14. Looking for specific information (nokia.com).

Device performance was measured with the success rates of the 14 tasks. As the aim of the study was to observe natural user behaviour in a laboratory environment, performing the tasks as quickly as possible, and thereby measuring task completion times, was not considered convenient. Also, as NN/g found in their study [37], with modern high-end devices, the task completion time is not necessarily proportional to user satisfaction of the device, and therefore this measure was not applied. A task was considered to have succeeded if the predefined goal was reached and the user felt like he had reached what he intended.

Users' expectations towards mobile web browsing were measured with an application of the Kano model. This model was developed for studying customers' expectations towards product features and for finding the features that customers need, those that are exciting, irrelevant features, and those that should not be implemented [73]. As this method has been used to study website interactivity and customer satisfaction [74], it was considered as an interesting new way to study users and their expectations in this subject as well. The Kano model consists of a two-way questionnaire, asking the users to evaluate their attitude if the feature is implemented and if it is not implemented. These questions are treated as the functional and the dysfunctional question. Of users' responses, the underlying attitude can be revealed using the table presented in Figure 12(a). Users were asked the functional and dysfunctional questions of the 14 tasks specified in a questionnaire (Appendix D).
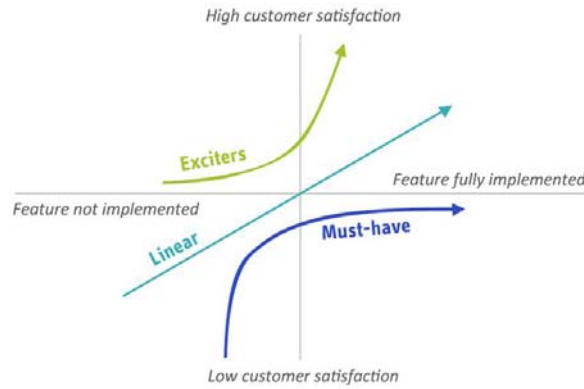
Finally, at the end of the test, users were asked to compare the three devices they had used in the test in terms of web browsing. The comparison was performed as an adaptation of the Repertory Grid method's [75] first phase, Triading. That is, users were supposed to compare two of the three devices to the third one, in turns, and name the features that differentiated the third from the two others. In this manner, the most tangible features of each device could be collected, supposing that users would name the devices' best and worst properties and web browsing experiences.

5.2.2.3 Statistical analysis

The data from subjective pleasantness evaluations was analysed with the two-tailed Welch's t-test, applied for two device samples at a time. Welch's t-test is an adaptation of Student's t-test intended for use with two samples having possibly unequal variances. The unequal variance t-test should be preferred to Student's t-test and

(a)

(b)

Figure 12: (a) Kano classes based on the responses to both functional and dysfunctional questions: Must-haves (M): Users expect that these features are implemented. Linear (L): The better implemented the better the experience, and vice versa. Exciters (E): Users do not expect these features, but when implemented they enhance the experience. Reverse (R): These features should not be implemented. Indifferent (I): Users do not care whether implemented. Questionable (Q): User's answers to the question are contradictory. (b) The graph visualizes how exciters, linear and must-have features affect customer satisfaction. [73]

the Mann-Whitney U test when comparing the central tendency of two samples of unrelated data with unknown variances [76]. For the analysis, the emoticons were coded numerically from 1 (unpleasant) to 5 (pleasant). The zero hypothesis was that the two samples, i.e. the subjective pleasantness values given for two devices, did not differ in mean. A p value of 0.05 was considered to announce a statistically significant difference between the samples. Also sample modes of the subjective pleasantness ratings were calculated for a subset of the test tasks, as the evaluation scale used in the questionnaire form could be considered both interval and nominal, and therefore also the frequency data of the ratings was interesting.

5.2.3 Qualitative results

Based on the usability test, a variety of qualitative findings related to mobile web browsing could be made. These findings are considered as a base for the UX guidelines derived from the whole study. The test with 18 users demonstrated following drawbacks and advances in mobile web browsing.

5.2.3.1 Page layout

When a web page is viewed with a small screen, the overall page layout is mainly invisible, and it is difficult for users to see the big picture. Scrolling sideways is what irritates users the most. When reading on a touch screen device, 50-60 characters per line is the average maximum that a person with normal vision can read easily. For page overall layout, portrait websites are preferred to landscape ones, as the phone is mostly used in the portrait position. An example of a wide page, difficult to browse on mobile devices, is presented in Figure 13.

(a)   (b)
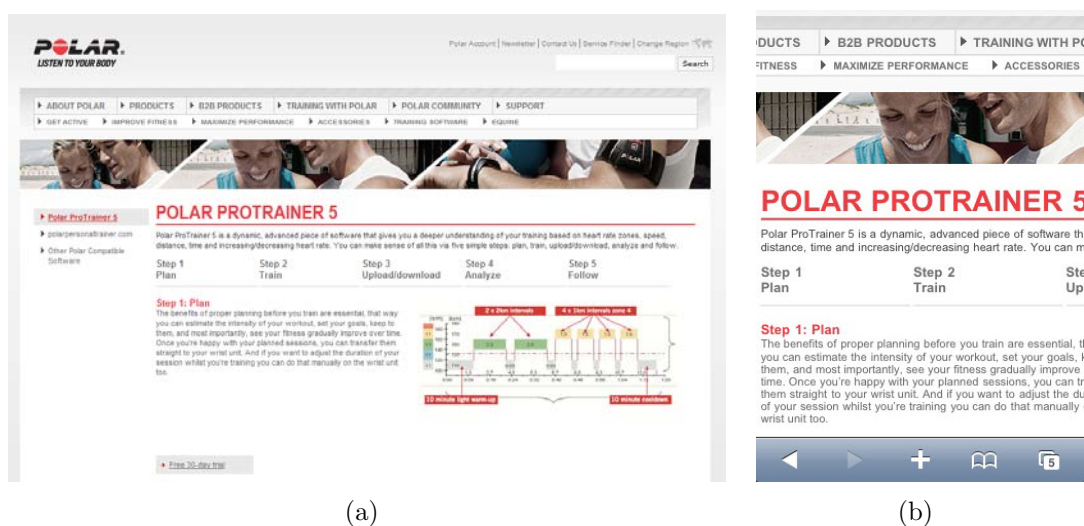
Figure 13: Even though users found Polar site's navigation structure clear and easy, the width of the overall page was considered difficult. The need for scrolling sideways for reading is frustrating, and understanding the text is challenging.

In most mobile touch screen device browsers, initially the whole page is shown, and the user can then zoom to an interesting part on the page. The need for clear and visible navigational elements, such as navigation bars, is thus emphasized. Compared to desktop use, front page touts and other visual elements often attract more attention than the navigation bar. It is usually possible to adjust the browser settings so that only the top left of the page is shown when a new site is downloaded, and for some devices this is the default setting. Thus, cues to all relevant content, such as page name or logo and navigation links, should always be shown in the upper left part of the page.

Pages consisting of several elements of different sizes are rather confusing and difficult to browse, as zooming in and out for each individual element is needed.

Also, websites consisting of pages with differing layouts are difficult. E.g. on the Nokia websites used in the tests, the pages and their layout vary a lot and the user always needs to scroll vertically and horizontally to discern the structure. In contrast, users were pleased with the steady column layout on the Helsingin Sanomat website. Columns can be zoomed with ease, and the page layout is also easily discerned. Issues related to the Nokia front page layout are visualized in Figure 14 and the Helsingin Sanomat page layout that pleased all users is shown in Figure 15.

(a)   (b)
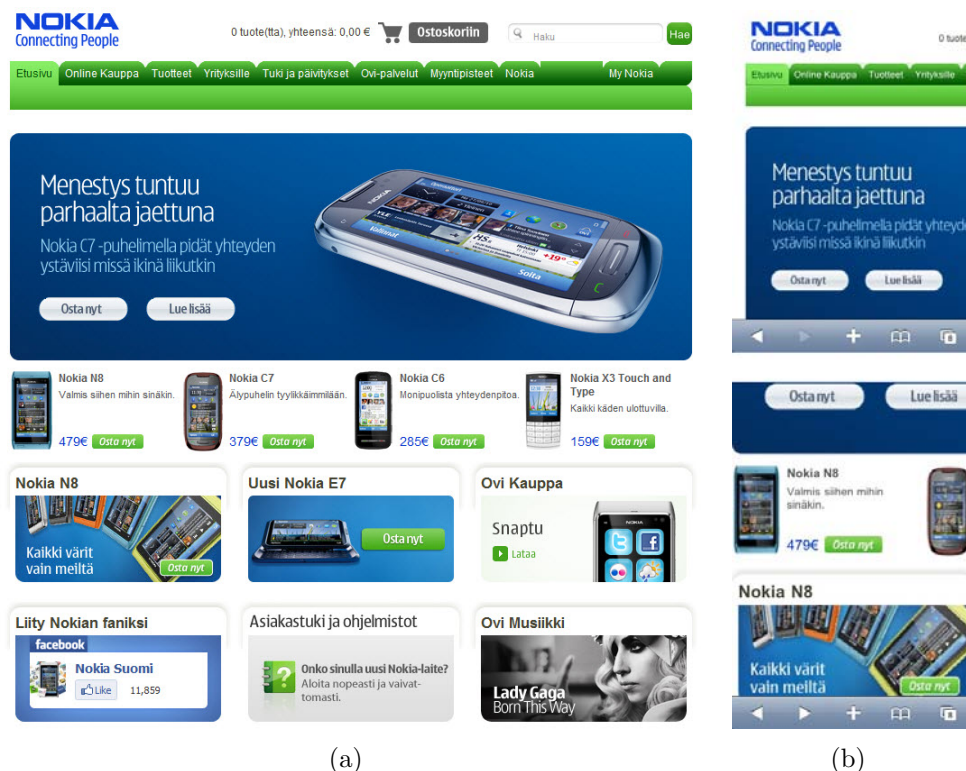
Figure 14: (a) The Nokia home page as it shows on a desktop browser. (b) Top: Situation where the top left corner is shown by default, i.e. nothing but a few navigation links and a part of the big banner can be seen. (b) Bottom: Browsing the page with elements of varying sizes is difficult as only one element is fully shown with one zoom level.

5.2.3.2 Navigation

Users were pleased with content in columns and navigation by a horizontal bar and vertical link lists. Vertical link lists are easier to browse, due to the undesirability of scrolling sideways. One or two-character buttons are too small to press with fingertips. The map controls on the Google Maps mobile version were buttons with '+', '-', '<', and '>' only, and were practically impossible to hit even with a pointer (if available). The mobile version of the site was also shown in Nokia touch phones, even though a specific touch screen mobile site exists. Users who did not have a
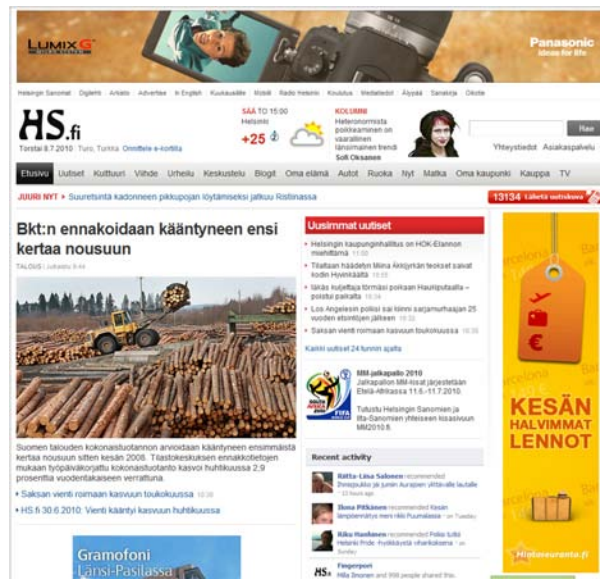
Figure 15: A column layout is easy to browse on a mobile device. Most touch screen devices have a smart zoom which adjusts the view width according to the element selected. In general, reading was a pleasant experience with all devices.

QWERTY keyboard with a navigation button, or did not think of using it were not able to use the site properly.

Link lists are too serried on all websites, except for mobile-optimized sites. Resistive touch screens' touch accuracy with fingertips is not always high enough for clicking the intended link, and users assume the same with capacitive touch screens as well, and therefore they zoom excessively for clicking, meanwhile hiding the rest of the page.

Dropdown menus have both benefits and drawbacks. Users like the fact that they do not need to download another page before selecting the target page: they can easily select from the menu that appears with a mouseover. However, in some devices the dropdown menus do not work as intended due to lacking JavaScript support, and users have big troubles when trying to navigate. Also, a mouseover action is not possible without a pointer. It was nearly impossible to get the dropdown menu visible and choose an item in the Nexus One browser. On Nokia phone browsers, the menu stayed on the screen unless an item was selected. This annoys the user if the menu is opened e.g. by an accidental click. On Polar.fi the menu was also too serried and the font was very small. Users needed to zoom considerably to manage to click on the intended link. The Polar navigational dropdown is shown in Figure 16.

5.2.3.3 Links

Good information scent in link texts is emphasized for mobile use. The mobile Web is mostly used for searching specific information on something. Users normally navigate on websites by links and expect to find the wanted content based on the
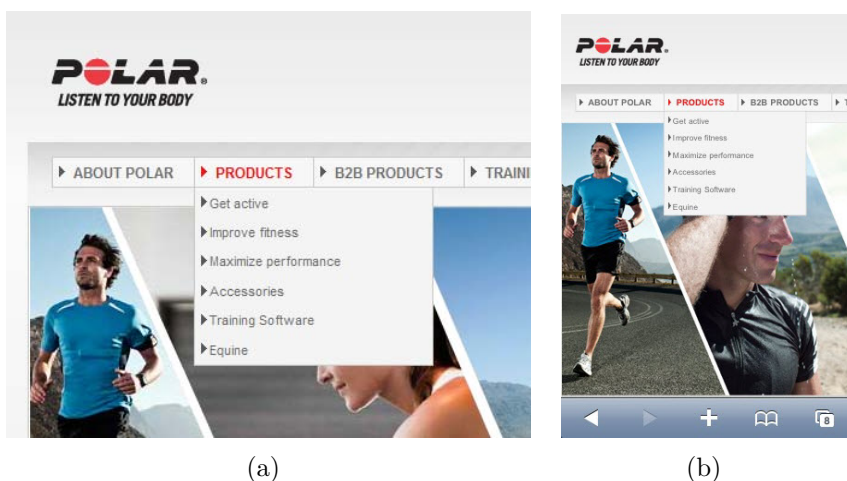
Figure 16: (a) Users like dropdown menus in navigation, if they work correctly. Especially in mobile browsing, all content that can be seen without downloading yet another page is always welcome. (b) However, in Nexus One and in Nokia phones the menu did not work properly and caused irritation.

link text. Misleading and non-informative link texts slow down the search. In mobile use, this is of special concern because users get frustrated much more easily than in PC use and quit browsing. Users prefer downloading as few pages as possible. Downloading 6 new views is often too much.

In touch screens, the affordance of links becomes even more important than with traditional browsing, that is, links should look clickable. Some touch screens are very sensitive for faulty clicks, and the user tries to avoid sweeping on links. This is difficult if the links are not easily noticed.

Contact information and a link to a mobile site are often looked for. Mobile users very often look for phone numbers, addresses and e-mail addresses. These items should not be hidden deep within the navigation.

5.2.3.4 Heavy content

On mobile devices the website download times are considerably longer. The user tries to continue browsing whenever it looks like it is possible, even though he knows that the page is still downloading. Changing content during downloading is confusing and often leads to erroneous clicks. This is an issue especially with touch screens, as accidental clicking happens quite often. The user gets confused about what page he is currently viewing. Also, clicking links during downloading can cause the browser to freeze or even crash, as it did often with the E71 in the tests.

Backward and forward browsing confuses the user if the view shown is not the same as it was when the page was left. This issue mainly appears on pages with dynamic content, where the content is downloaded before the link anchoring is shown.

5.2.3.5 Incompatibilities

Many mobile touch screen devices do not support Flash. Videos and news feeds are a decent way of providing a good user experience for web users, but when they do not work they make the experience poor. Videos do not function in most mobile browsers. Sites with Flash content are confusing. Users cannot be sure whether some elements are shown properly, and this sometimes makes finding information unreliable. Also, there can be huge blank areas on pages, and users get confused: they do not know if the page is fully downloaded or not. An example of a non-functional but disturbing Flash element is visualized in Figure 17.

(a)   (b)
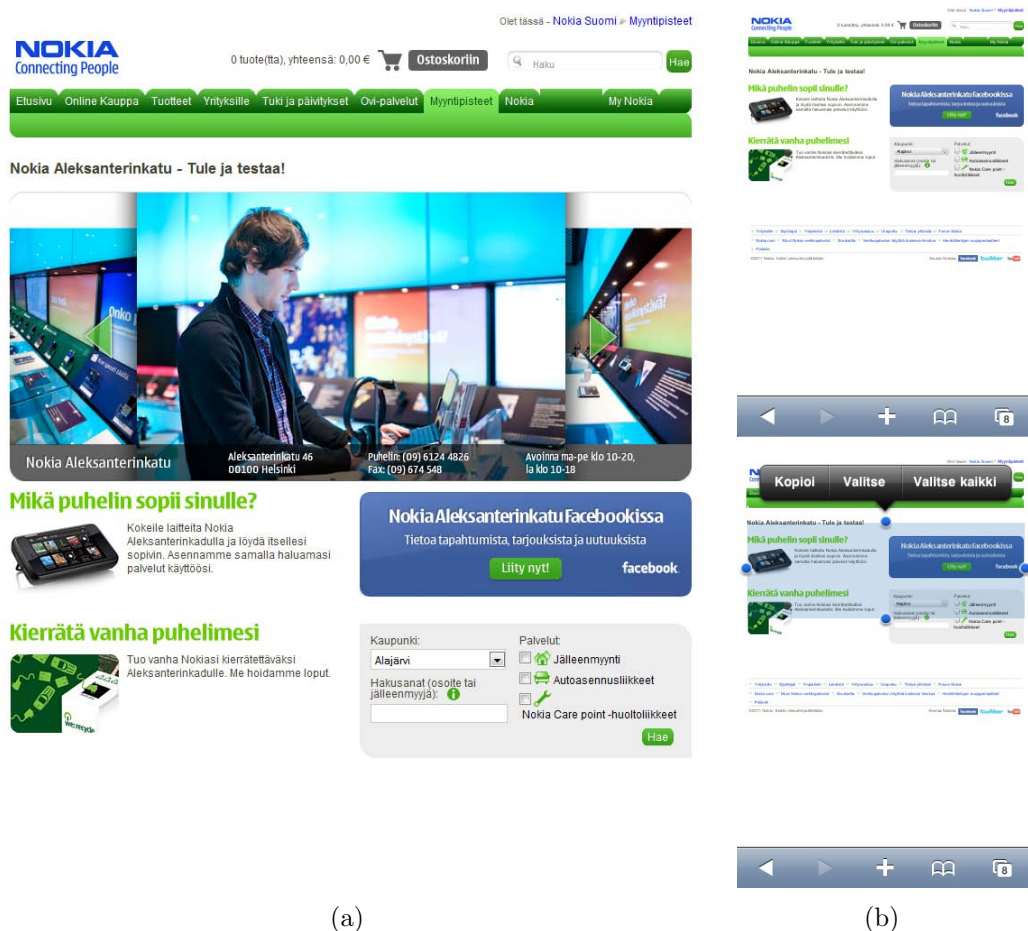
Figure 17: (a) A Flash banner is shown on top of the Nokia sales agency page. (b) Top: The banner is not shown when browsed with a browser that does not support Flash. (b) Bottom: But when user tries to select fields in the search element, the missing Flash element's frame prevents this.

Websites include lots of content that is not compatible with all mobile devices. Users were annoyed by texts saying that some feature does not work with some devices when they would have wanted to know which features and with which devices. Even if Flash is supported, downloading Flash content is slow. With connections in 3G or slower, download times become too long: users get frustrated or annoyed, or

even quit downloading. Dynamic JavaScript elements and features usually have a 'wow' effect, but they do not always work as intended.

5.2.3.6 Web forms and other input

Filling forms is tricky when using a touch screen device. Touch screen devices often lack a tabulator function, and thus the fields need to be selected separately by touching. Depending on the touch accuracy and the size and accuracy of the user's fingers, selecting the intended field is more or less difficult. Users get easily annoyed by incorrect clicks, especially if the click activates a process where something is saved, e.g. with a Send/Create/Continue button.

A virtual keyboard obscures half of the screen when visible. It is easy to lose track of what was intended and what was left hidden behind the keyboard. Fields with both writing and dropdown are difficult to fill in with the virtual keyboard. The dropdown cannot be used when half of it is hidden behind the keyboard. Examples of pop-up keyboards and the problems they cause on the iPad and the iPhone are shown in Figure 18.

(a)   (b)

Figure 18: (a) A combined date input and calendar widget on the iPad. Form fields that allow both writing and selecting are difficult with pop-up keyboards, as the keyboard obscures the other element. (b) A web form on the iPhone. The keyboard obscures over half of the screen, and discerning the form structure is difficult. This should be taken into account when designing form layouts. The image also visualizes the problem with cue texts on text fields. Users often activate the field before reading the text and after this it is impossible to know what to write.

Disappearing cue texts are difficult to use. Users normally do not read them, and try to find them when they have already selected the field. This is especially a problem with devices that have a tabulator function. An example of this is shown in Figure 18(b).

Mobile web forms are often split over several pages, and the user needs to navigate with Next and Previous buttons. It is difficult to remember what was written before,

if it cannot be viewed on the same page. Users do not want to save information in small pieces. They want to see the last field before they submit anything.

Check boxes and radio buttons are rather difficult to use with touch screen devices. The active touch area is usually very small, and the user is forced to zoom to hit the target. Even though the actual touch area would cover the label text as well, users do not realize this and tend to point at the checkboxes and radio buttons. Bigger boxes would make the selection easier. In the test, nearly half of the users failed to notice the check box selections, and one user said that she disliked check boxes in general. The checkboxes ignored in the test are shown in Figure 19(a).

Most touch screen devices have a pleasant functionality for dropdowns. Options are shown in a big list in the lower part of the screen, and users can easily scroll the list to find the target. Dropdowns that do not deploy the device's own list functionality are much more difficult to use. However, a dropdown that does not have all possible alternatives causes frustration in users. E.g. for date selection, a list of dates is reasonable only if there is a limited number of possible dates. Calendar widgets are the most pleasant option. An example of a non-pleasing date selection list on Facebook touch version is shown in Figure 19(b).

(a)   (b)

Figure 19: (a) For touch screen use, text boxes and radio buttons need to be at least twice the size they currently are. (b) Most users were irritated by the limited number of dates in the Facebook event creation.

Typing is rather unpleasant with all mobile devices, and especially with virtual keyboards. All users had troubles with filling in the text boxes when using a virtual keyboard. None of the users managed to write all text input as intended, even when using their own phones. Users were always pleased when they could select a suggestion from a list after starting to type. However, the suggestive text input of Apple iPhone and iPad caused irritation due to the erroneous corrections that were made automatically. Google Nexus One has a similar feature as the iPhone, but it is more pleasant and useful according to the few users who noticed it. With most touch screen devices, editing and removing written text is difficult.

5.2.3.7 Maps and lists

Maps and lists are often difficult to browse with touch screens. Map controlling with buttons is difficult to use with touch screen mobile devices. Usually, the map covers a large screen area and the buttons are too small. The user needs to zoom and scroll the view to reach the buttons, and this way it is easy to lose track of the location. Lists that need scrolling are difficult to use with all mobile devices. The biggest problem is that users often fail to realize that there is something to be scrolled.

5.2.3.8 Selecting text e.g. for copy pasting

On several websites, the text content cannot be selected due to the way the text is implemented. Copy pasting is part of most users' everyday web browsing, and typing things manually is more irritable than copy-pasting. The copy paste functionality exists in many touch screen devices, and users like using it if they have learnt how to do it. In the test, users tried to copy a street address on Facebook, but this was either impossible or inconvenient because the whole text box with other text as well was the only item users could select. In the PC Firefox browser the text could be selected freely.

Sometimes text content is implemented as an image, which makes the copying impossible. In some cases, the selecting is blocked by an invisible web frame (see example in Figure 17(b)). For users' delight, some phones even recognize phone numbers and addresses and offer alternatives for user actions, such as 'Call' and 'Add to contacts', or link them to a map service when clicked.

5.2.3.9 Device detection

Many websites do not redirect mobile users to mobile-optimized sites. Of the tested websites, Helsingin Sanomat and Nokia did not redirect the user to a mobile-optimized user interface even though one is available. Most of the Nokia phone users had complaints about this and would have wanted to navigate to the mobile site, and looked for the non-existing link in the header.

Nokia touch screen phones were recognized as mobile devices, but not touch devices, and therefore mobile versions of websites were shown instead of touch-optimized versions. This was the case with Facebook, Google Maps and Google. Users were annoyed as mobile UI's often have small buttons and do not work well in touch screens. In general, touch-optimized websites such as the Helsingin Sanomat mobile site and the Facebook touch site are easy to use on both types of mobile devices.

5.2.3.10 Different interfaces for different devices

The majority of the test users preferred mobile-optimized websites to full sites. Some iPhone users preferred full sites, as they assumed that mobile sites always have less content, and they also liked viewing images. None of the E71 users liked browsing

full websites with their device. In general, users who prefer full sites assume that some essential content is missing from mobile-optimized sites, and users who prefer mobile-optimized sites like it that images and other "useless" content is removed. For frequently used Web services, users mainly use downloaded applications. All users had a Facebook and a map application on their phone. Most users had a news application. When asked about the Web services users use on their mobile device, only the most technically oriented made a separation between services used as applications and services used in the browser. Most users did not consider any difference between these two types of providing web content.

5.2.3.11 Mobile site content

Many mobile-optimized websites are built in a rush, and the content is not very well designed. When people cannot find the information and properties they are looking for on the mobile version, they switch to the full site instead. One common lack on mobile sites is that the pages do not have a header that shows the site name. Nowadays most devices that are used for browsing have a rather big screen, and using as little space as possible is no longer a virtue. Mobile URLs are also difficult. When users were trying to access mobile versions of the studied websites, they were unaware of the URL. E.g. an address of the type 'm.site.com' was not familiar especially for the older users.

5.2.4 Quantitative results

5.2.4.1 Experience pleasantness evaluation of specified tasks

Users evaluated the experienced pleasantness of the 14 tasks specified before the tests. The tasks could be divided into three categories based on the primary source of the experience: 1. device-dependent tasks, 2. website-dependent tasks, and 3. device and website-dependent tasks. The test tasks presented in Chapter 5.2.2.2 could therefore be regrouped followingly:

1. Device-dependent tasks

    - Scrolling a page (hs.fi)
    - Navigating back in the browser (hs.fi)
    - Login (Facebook)

2. Website-dependent tasks

    - Browsing information, no search task included (polar.fi)
    - Using a search engine (google.com)
    - Looking for specific information (nokia.com)

3. Device and website-dependent tasks

    - Reading (hs.fi)
    - Typing a URL and downloading a page (hs.fi)
    - Form field: text (Facebook)
    - Form field: check box (Facebook)
    - Form field: menu (Facebook)
    - Copy pasting (Facebook)
    - Viewing a map by scrolling and panning (maps.google.com)
    - Navigating with a dropdown menu (polar.fi)

5.2.4.2 Users' phones compared

Figure 20 shows the mean subjective values for pleasantness of the evaluated tasks with the three user-owned phone types, smartphones (Nokia E71), touch phones (Nokia), and multitouch phones (Apple iPhone).

As the diagrams in Figure 20 visualize, the multitouch phone (iPhone) seems to have gained more positive pleasantness values than the two other phone categories. This was tested with the two-tailed t-test. The t-test was applied on all pairs within this group of three devices. Based on the test, the iPhone proved to have got significantly greater values in the evaluation compared to both the E71 ($p<0.001$) and the Nokia touch phone ($p<0.001$). The E71 and Nokia touch phone, however, did not significantly differ based on the test ($p=0,66$).
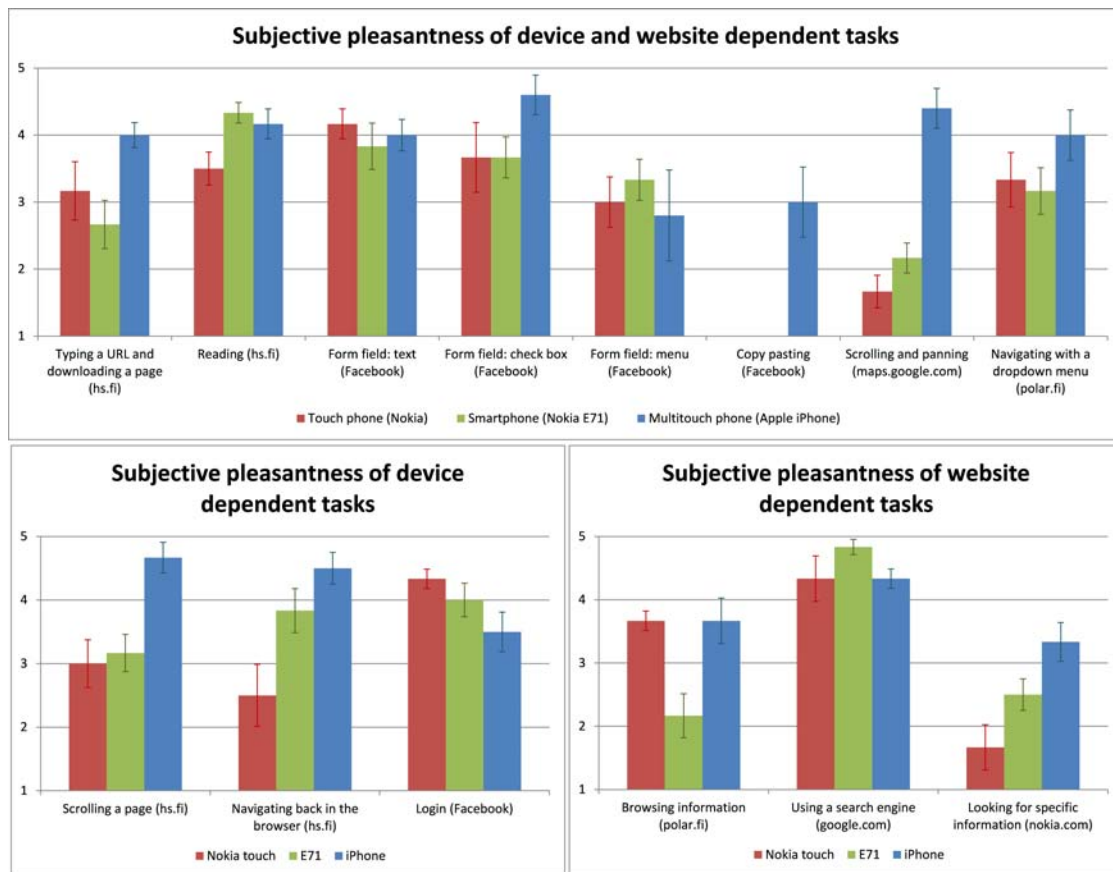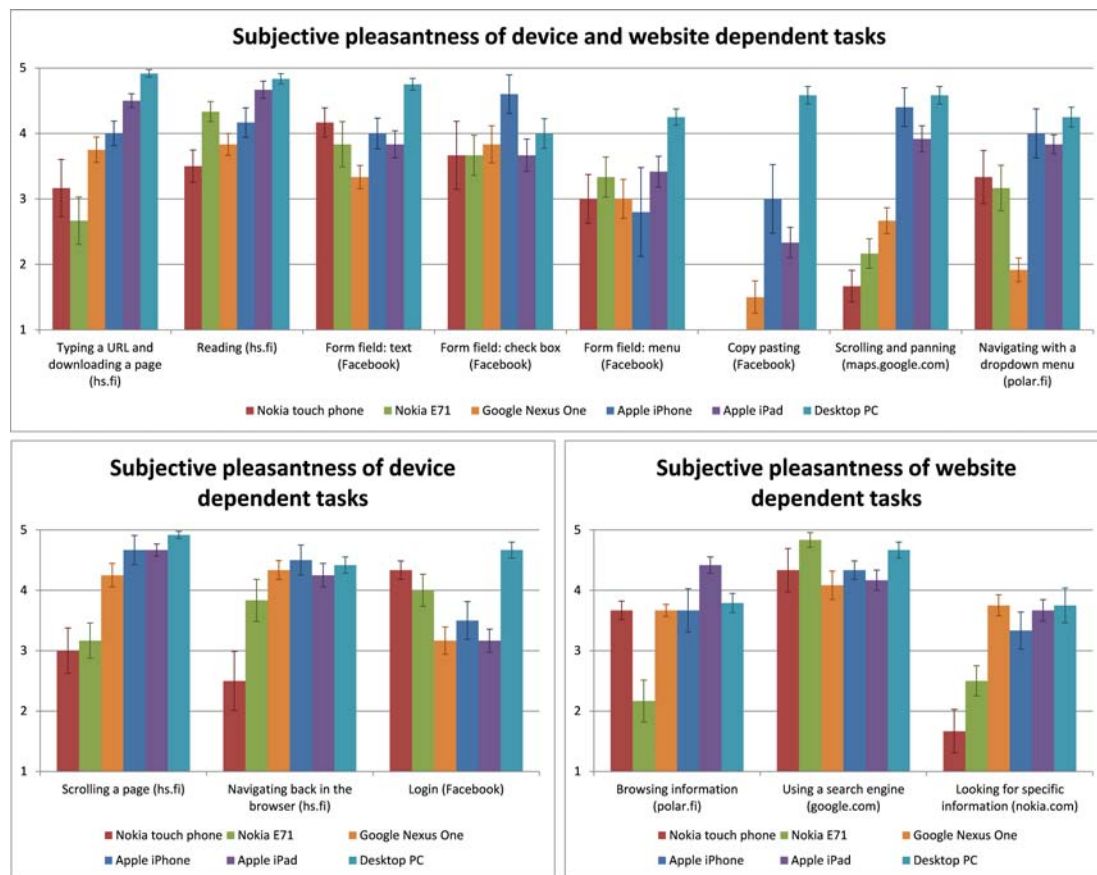
Figure 20: Bar diagram of users' mean experience ratings regarding their own device. 95 % confidence intervals are presented for each mean value.

Figure 20 also shows a few main features, where the iPhone has performed more pleasantly than the other two. Firstly, accessing a full web page with relatively heavy content (hs.fi) is considered more pleasant with the iPhone. On Facebook, the two Nokia devices were given the mobile version instead of touch version, and users considered using a checkbox less pleasant than with the iPhone and the touch optimized Facebook version. Copy pasting was impossible with the Nokia devices, and users rated it unanimously as unpleasant. Google Maps had the same defect as Facebook in detecting Nokia touch devices. Therefore using the non-touch optimized version of the maps was considered unpleasant, whereas the touch version shown on the iPhone was considered pleasant to use. The dropdown navigational element on polar.fi was easier to use on iPhone, and thus the two other devices scored less in pleasantness. Device and website specific task differences are discussed in the following chapter.

5.2.4.3 All devices compared

To visualize how each device performed in the test according to users, Figure 21 shows the subjective pleasantness of all devices, test tasks grouped similarly as in

Figure 20. As Figure 21 shows, the desktop PC gained the best ratings in most tasks, as expected. Testing whether the difference in means is significant, the t-test proves PC to have significantly the highest ratings ($p \ll 0.001$ with all devices). The seemingly second best rated are Apple's iPad and iPhone. The t-test proves these two not to have a significant difference. It needs to be taken into account that the iPhone was only rated by its everyday users and the iPad was rated by users of all three groups. Therefore the t-test was next applied separately to all groups' ratings. All ratings proved not to have a significant difference compared to the iPhone ratings. The Nexus One was rated more unpleasant than the iPhone ($p < 0.05$) but no significant difference was observed between the Nexus One and E71 or Nexus One and Nokia touch phone.

Figure 21: Bar diagram of users' mean experience ratings regarding all devices. 95 % confidence intervals are presented for each mean value. N.B. N=6 for Nokia touch phone, E71, and iPhone. N=12 for Nexus One, iPad, and Desktop PC.

Differences between device-dependent tasks and website-dependent tasks were also tested between and within devices to examine whether device or website features alone have a significant effect in the perceived pleasantness of the test tasks. The desktop PC and the iPad were excluded in these comparisons, and only mobile devices were compared. The iPhone was given significantly better pleasantness ratings than both Nokia phones in scrolling. Navigating back in the browser was

significantly more pleasant with the iPhone and the Nexus One than with the Nokia touch phone. In the login task, where the Nokia touch phone was given more pleasant values than the others, the difference was significant only with the Nexus One. In browsing information, the Nokia touch phone and the Nexus One were significanlty more pleasant than the E71. And finally, in looking for specific information, the iPhone and the Nexus One were significantly more pleasant than the Nokia touch phone, Nexus One also surpassing the E71.

Therefore, it can be stated that some device features, such as scrolling, page panning, and writing pleasantness, make the overall web browsing experience more pleasant, regardless of the website being browsed. Especially gestural actions are perceived more pleasant than actions performed by buttons, except for writing. However, as there was also one task where devices did not differ significantly at all, the Google task, it can be argued that the website design also has an impact on the pleasantness. Thus, the user experience and the subjective experienced pleasantness does depend on neither device pleasantness nor website pleasantness alone, but on the combinatory effect of these two factors.

The rated tasks can also be divided in two groups depending on whether the site used was a normal full website or a mobile-optimized site. This division results in groups presented in Figure 22, where all mobile phones' ratings are shown. Half of the tasks were performed on a mobile site and the half on a full site. All in all, two mobile sites and three full sites were tested and test tasks rated. Therefore the results are only indicative. However, in these tasks, only the Nexus One showed a significant difference between full and mobile site use pleasantness. For this phone, full sites were significantly more pleasant to use than mobile sites (p<0.05). For other mobile devices, on average, the use was as pleasant with both full and mobile websites.

For comparing devices' overall pleasantness, overall average ratings were calculated. The desktop PC was rated the highest, gaining an overall grade of 4.46, rounded down to correspond the second most positive emoticon. The second pleasant device was the iPhone, averaging 3.93 in pleasantness, rounded up to the second most positive emoticon as well. The iPad was rated almost as pleasant as the iPhone, gaining an average grade of 3.89, that is, the second most positive emoticon. Nexus One got a mediocre overall pleasantness value, 3.36, rounded down to the middle emoticon. E71 got a grade of 3.19, and Nokia touch phone a grade of 3.07, which were both also rounded down to correspond to the middle emoticon.

5.2.4.4 Success rates

Using a more objective measure of device and website performance, success rates were also calculated. In 5 out of 14 tasks the success rate was 100 % and in only one task it was lower than 80 % on average, the full score for all devices being 93.8 %. Thus, the overall performance was rather good. The PC tasks were all performed with full success, and with iPad only 3 tasks scored 91.7 % and the rest scored 100 %, full score for iPad being 98.2 %. The least successful device was the Nokia E71, which scored 83.3 % in total. The Nokia touch phone scored 89.3 %, Google

Nexus One 91.7 %, and Apple iPhone 91.7 %. There was no clear difference between site type when used on a mobile device, as full websites' success rate was 89.0 % and mobile sites' 90.0 %. For touch screen mobile phones, there was no difference at all, as both site types had the same success rate 91.1 %.

Figure 23 visualizes the success rates in each task. It can be noted that even though the overall task success was very high, there were some instances where users could not fully proceed with the task. Most of these occurred with full websites. Downloading the full hs.fi front page could not be finished in most cases with the E71; navigating with a dropdown menu with the Nexus One was impossible for most users; and looking for specific information on the Nokia site could not be completed fully with four out of six devices. All the failures to succeed in tasks on full pages were due to website design, and not related to device properties.

As for mobile pages, only one task, copy pasting, failed notably. This was mostly due to the fact that in the Nokia phones this action is not supported. But also the website had an effect on the results. On Facebook touch version, the copied text was implemented in a difficult way and could not be easily copied even if there was a copy function available.
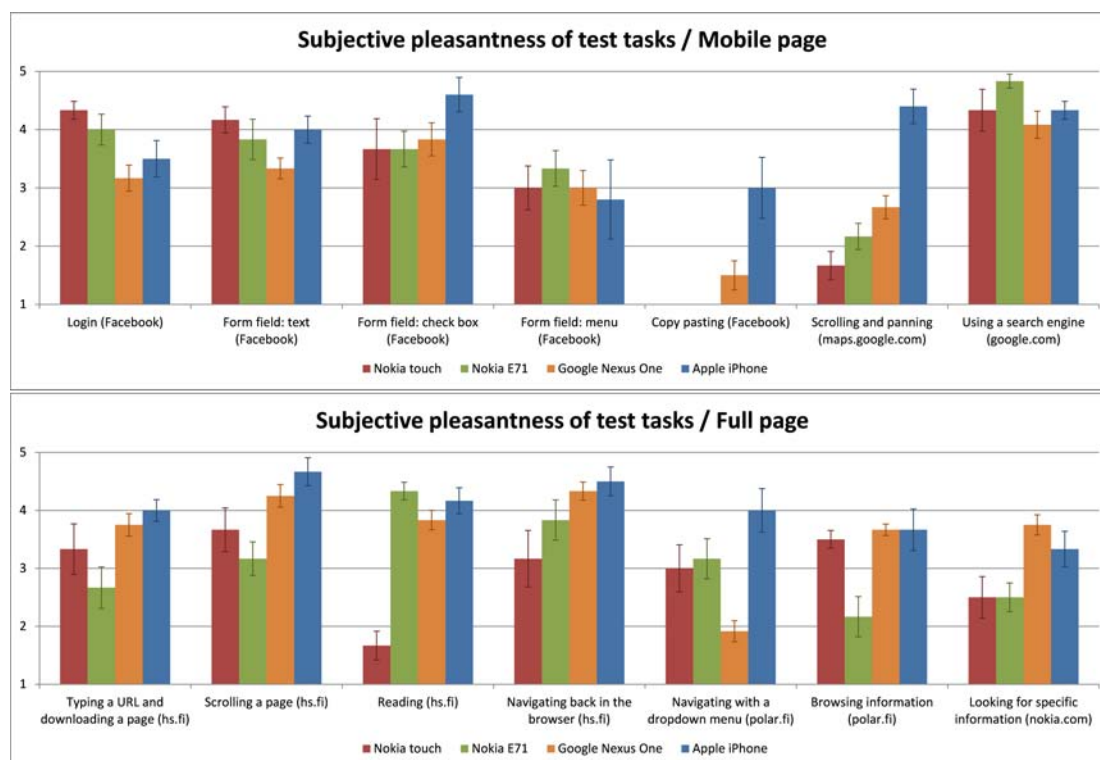
Figure 22: Bar diagram of users' mean experience ratings regarding all mobile phones. 95 % confidence intervals are presented for each mean value. N.B. N=6 for Nokia touch phone, E71, and iPhone. N=12 for Nexus One.
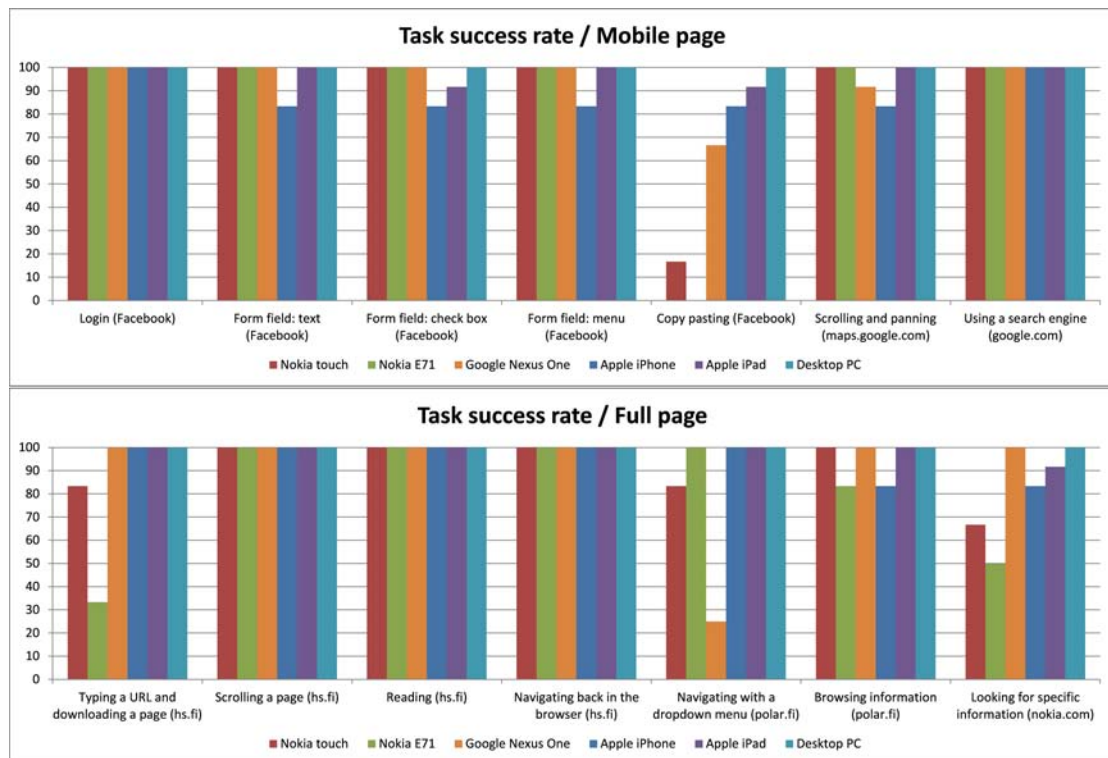
Figure 23: Success rates in percentages for each tested device in the 14 test tasks. N.B. N=6 for Nokia touch phone, E71, and iPhone. N=12 for Nexus One, iPad, and Desktop PC.

5.2.4.5 Users' expectations

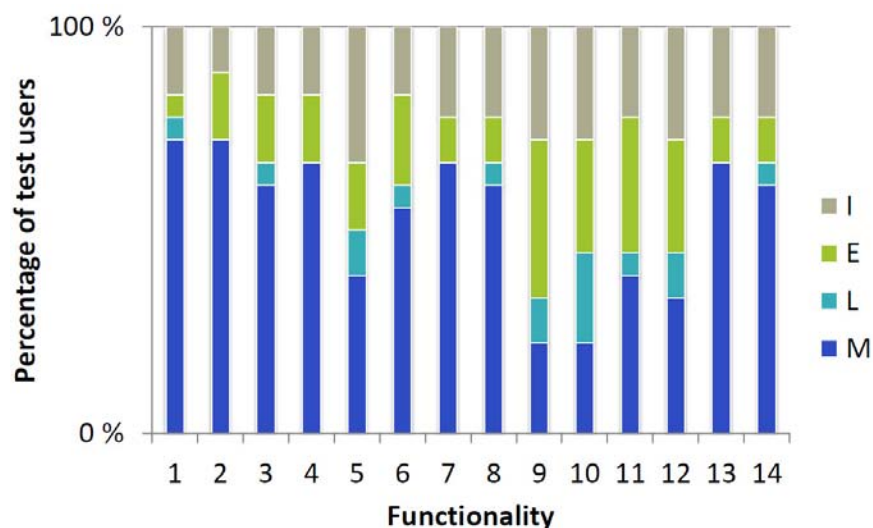The Kano model results for mobile users' expectations are visualized in Figure 24.

Figure 24: The Kano model classes calculated of users' responses to both the functional and dysfunctional questions regarding the 14 test tasks.

Based on users' responses to the Kano questionnaire, users rated the 14 tasks into different categories. The following functionalities were considered as must-haves. That is, users expect to be able to easily perform these tasks on mobile devices:

- Writing a URL and downloading the page (1)

- Scrolling the page (2)

- Browsing and reading news websites (3)

- Navigating back in the browser (4)

- Filling in a text field on a form (6)

- Checking a checkbox (7)

- Selecting a dropdown menu item (8)

- Searching information on Google (13)

- Searching information on mobile consumer websites (14)

The only clear exciter in this study and also partly seen as indifferent was copy pasting (9). People are glad if they can copy and paste text on a mobile device, but some users do not yet expect this to be possible.

One task was both a must-have and indifferent: Logging in on Facebook (5). In this case as well as with Google Maps the fact that people use their own phone's Facebook application for social networking may have affected the responses.

The following were considered all of the three: must-haves, exciters and indifferent:

- Viewing the map on Google Maps (10)

- Navigating with a dropdown menu (11)

- Browsing information on a random site (12)

This suggests that users have varying attitudes towards these tasks. Users probably consider Google Maps as indifferent because they have a working map application on their phone that they can use. However, mobile Google Maps is very well realized for some devices (PC, iPhone, iPad), and for this reason it is considered exciting. Maps are a necessary service for all mobile users, which on the other hand explains the must-haves. Dropdown menus in navigation are exciting if they work but negligible if they fail. However, some users might see them as a necessary part of navigation. The fact that the site (Polar.fi) was mentioned in the 12th question might have affected the user responses.

The Kano responses were mostly in line between the groups, but some differences arose. Nokia E71 users expect the least of a phone and categorized most of the tasks half must-have and half indifferent. None of the Nokia touch phone users expect to be able to copy-paste in their phone browser. Apple iPhone users rated more tasks as exciters than the other two groups.

5.2.4.6 Expectations and experienced pleasantness combined

The Kano model questionnaire revealed 9 web browsing tasks that users expect to be able to perform with their mobile device. The Figures 20 and 21 visualize how the tested devices performed in these tasks on average, but also response frequencies for each task should be taken into account. The most frequent ratings for 'must-haves' for each mobile device are presented in Figure 25. Desktop PC ratings were not included in this figure as the Kano questionnaire considered mobile web browsing only. For the sake of comparison, all 14 tasks got the highest frequencies in the two most positive emoticons for the desktop PC, 11 getting the most positive one.

Figure 25: The most frequent ratings for the 9 tasks considered as 'must-have' for the tested mobile devices. In cases where no single mode could be told, all ratings with the highest frequency are presented.

5 tasks (scrolling the page, browsing and reading news websites, filling in a text field on a form, checking a checkbox, and searching information on Google) out of 9 were mostly rated with one of the three most positive emoticons for all mobile devices and can therefore be considered as meeting users' expectations on the websites tested. The middle category emoticon is also treated as an approving one because most users thought of it as being neutral. 3 tasks (navigating back in the browser, selecting a dropdown menu item, and searching information on mobile consumer websites) scored the most negative emoticon for some devices.

The task 'selecting a dropdown menu item', shows inconsistency for the multi-touch phones, as the most frequent ratings are conflicting. This can be explained with the combination of pleasant device properties but unpleasant website properties, as the Facebook touch version did not offer all alternatives in the dropdown used, but the dropdown itself was pleasant to use. Judging by the table in Figure 25, the devices met users' Web use expectations in the presented order, the Nokia touch phone being the least satisfactory. The iPad can be considered as having passed the test fully, as none of the tasks was rated most frequently with a negative emoticon.

5.2.4.7   Device comparison

At the end of the test, users were asked to compare the three devices they had used in the test by telling which features differentiate one device from the two others. Users' answers were collected, similar responses were written out with the same words and everything was translated into English. E.g. "*helpommin sivut latautuu pidempään* (easily pages take a longer time to download)" and "*liian hidas selain* (browser is too slow)" were both translated as "*slow downloading*", and "*ubiikimpi kuin mikään muu* (more ubiquitous than any other)" and "*taskussa* (in the pocket)" as "*mobile*".

All features mentioned in all comparisons (N=54) were visualized using a free online service for building tag clouds, Wordle [77], removing common English words such as 'and', 'in' and 'the'. The result is shown in Figure 26.

Figure 26: Tag cloud of device features mentioned when comparing the tested devices. Common English words were removed.

As Figure 26 shows, screen was the most differentiating feature, regarding both its size and resolution, and touch properties. 'Good' is the second biggest word, presenting the importance of the quality of different features, whether they are good or bad, good qualities being mentioned much more than bad qualities (see the small word 'bad' in red on the left side). 'Easy', 'quick', 'mobile' and 'writing' come next, needless to explain how they affect the mobile Web user experience. The fourth frequent words that came up were 'browsing', 'keyboard', and 'slow'. This reflects the importance of a good and functional keyboard in web browsing.

None of the words shown in Figure 26 is new or surprising, and therefore no new features differentiating devices were found with this method. However, conclusions of the importance of each feature discussed in the study results can be drawn based on the number each feature was mentioned in the comparison. Device-specific features mentioned in the tests can be found in Appendix E as tag clouds. In these tag clouds, features are visualised as they were told and no common words are removed.

5.2.5 Conclusions of the usability test

The objective of usability testing in this study was to collect qualitative findings of mobile web browsing usability and user experience, and quantitative data to support these qualitative results. A large set of findings were gathered and the qualitative and quantitative results were in line with each other. In this chapter, the most relevant findings are summarized.

Users face problems in mobile web browsing mostly with web page layout, navigation, links, heavy content, incompatibilities, web forms and other input, maps and lists, selecting text and other objects, device detection, and different user interfaces for different devices. A clear and consistent page layout on websites is much more relevant in mobile use than in desktop use. Vertical instead of horizontal link lists are easier to navigate, but serried link lists are frustrating with touch screen devices. All links should be made manageable for fingertips, and they should be easily recognizable for both avoiding them and clicking on them. Users face issues with heavy content and slow download times. The iPhone manages these the best, whereas Nokia users are extremely unpleased with the heavy and difficult-to-use Nokia website. Missing and lacking Flash support in most devices causes confusion, and poor JavaScript support causes page elements to be difficult or impossible to use. In web forms, selecting small objects, struggling with the pop-up keyboard, and writing and understanding what to write is problematic. Nokia devices with physical keyboards are the most pleasant to use for text and other input tasks. Different user interfaces for different devices are difficult unless each version is optimized for one single device, e.g. the Facebook mobile version is considered worse than the Facebook touch version, especially when used with a touch screen device. Full and mobile pages are as pleasant on average, but users still tend to say they prefer mobile pages.

When comparing devices, a desktop PC is the most pleasant device for browsing the Web. But, based on this study, multitouch devices are close to becoming as pleasant. Among the tested mobile phones, the iPhone was ranked the most pleasant for web browsing. Along with the iPhone comes the iPad, which was rated similarly pleasant. The Nokia devices got the most negative results, but none of the devices performed poorly overall. The features that matter the most for users are the device screen properties, whether the device is easy or difficult to use, whether it is quick or slow, mobile or desktop, and what kind of writing properties it offers.

The task success rate was generally very high in the test, whereas the smartphone E71 did not succeed as well as the other devices. Therefore, the touch screen mobile devices, especially with a multitouch screen, are considered potent devices for browsing the Web. However, the user experience pleasantness depends always on both the device and the website, and the failures that occurred in the tests were mostly due to website design, and therefore the websites need to be enhanced for mobile device use. Users expect to be able to perform most Web tasks on a mobile device as well. Currently, only the iPad meets the expectations for Web use. Scrolling, reading news, writing text, checking boxes, and Googling are considered as working for each device, but that is not all that users need.

6 Conclusions and discussion

6.1 Conclusions of the UX study

The user experience study in this thesis was performed using two sequential methods: expert evaluation for gathering a pool of the most significant usability and user experience issues related to web browsing on mobile devices, and usability testing for studying the most common and presumably the most irritating usability and user experience issues with real users. The primary objective was to investigate how full websites respond to mobile users and which website properties cause the most issues. Also differences between devices with touch and non-touch, and small and big screens were collected.

The study showed that a full web page layout is difficult to discern on a mobile phone screen, and users often get disorientated. Navigation is difficult with horizontal and/or serried link lists, and the needed links are often hidden behind deep navigation. Unwanted links are clicked unintentionally because they do not look clickable. Heavy content slows page downloads down and can cause the browser to freeze or crash even on a WLAN connection. Incompatibilities with Flash and JavaScript effects cause bafflement and irritation. Web forms and input in general is difficult as traditional elements are not well-suited for mobile and touch use. Maps often offer the wrong kind of controls. Selecting text and other objects e.g. for copy pasting is difficult or impossible. Devices are incorrectly detected or not detected at all, and different user interfaces for different devices work only if the devices are detected correctly.

The desktop PC is the most pleasant device for browsing the Web, as the test results show. However, surprisingly, multitouch devices are close to becoming just as pleasant. Among the tested mobile devices, the iPhone was ranked best for web browsing, and the iPad, whether mobile or not, was rated as pleasant as the iPhone. The Nokia devices got the most negative results, but none of the devices performed poorly. The task success rate was generally very high in the test, whereas the smartphone E71 did not succeed quite as well as the other devices. Therefore, touch screen mobile devices, especially with a multitouch screen, are considered potent devices for browsing the Web. Based on the overall average pleasantness and the success rates of the test tasks, if weighted equally, the devices can be ranked followingly from best to worst in terms of web browsing user experience: the desktop PC, the iPad, the iPhone, the Nexus One, the E71, and the Nokia touch phone.

The features that matter the most for users are the device screen properties, whether the device is easy or difficult to use and whether it is mobile or desktop-oriented, whether web browsing is quick or slow, and what kind of keyboard and writing properties the device offers. However, the experience pleasantness always depends on both the device and the website, and the failures that occurred in the tests were mostly due to website design. Users expect to be able to perform most Web tasks on a mobile device as well. Currently, out of all the mobile devices tested, only the iPad meets the expectations of users, when considering web browsing.

6.2 Research questions

1. What needs to be taken into consideration when designing full websites for mobile users?

   There is a long list of issues that need to be taken into consideration when designing websites for desktop and mobile users. But first of all, the most important thing is to be aware of the need to take the requirements of the mobile devices into account. Only after web designers and developers recognize the mobile invasion of the Internet can changes start to happen.

   For ensuring a more pleasant user experience of websites on mobile devices, especially on touch devices, the following need to be reconsidered: page layout, navigation and links, heavy content on websites, incompatibilities, web forms and other input, maps and lists, device detection, possibility for separate mobile websites, and mobile website content. Details on how these should be enhanced for mobile use can be found in the list of 60 UX guidelines in Appendix A. A subset of the given guidelines can be considered the most essential, as ignoring these guidelines causes problems that are the most frequent, cause the most dissatisfaction, and are considered very unpleasant.

   - Important elements need to be visible when the page is only a couple of inches in size. Make navigation elements visible even when the page thumbnail is viewed, e.g. using noticeable colouring and shapes.
   - All elements should be comprehensible when fit on a 3.5" screen.
   - Let the browser adjust the text column width, i.e. use a liquid layout for text elements. However, define a maximum width at around 80 characters per line for good desktop legibility.
   - Prefer vertical navigation link lists to horizontal ones from the 2nd level on.
   - Make all link lists as loose as reasonable.
   - Invest on link affordances, i.e. make them look clickable, so that users can avoid swiping on them to avoid unwanted clicking.
   - Ensure that contact information can be found either on the front page or on the second level of navigation on a 'Contact' page or similar. All text that the users might want to select or copy, such as phone numbers, street addresses, product details, news etc. should be implemented as plain text.
   - Avoid building websites with heavy content if you have some number of mobile users. If the content cannot be reduced, provide a lighter version for slow network connections and for mobile use.
   - If you decide to use Web technologies with known incompatibilities, always test the solutions with several browsers and devices. E.g. test how the site works with non-Flash browsers and test your JavaScript effects to make sure they work as intended.

- If you decide to build a separate mobile website, do not build it blind-folded. Spending resources on developing a mobile site without studying the mobile users e.g. by site analytics is not worthy. Users very probably return to the full site if they cannot find the content and functionalities they need in mobile context.

2. Are mobile-optimized websites needed, or can we move over to an all-applicable web design?

Most test users preferred mobile-optimized websites to full sites when they were asked about it. But the pleasantness values and success rates of the usability test did not show any significant difference between mobile-optimized and full websites. This suggests that separate mobile websites are not necessarily needed, but the full sites need to enable mobile use in terms of user experience.

As many of the reviewed related studies show, however, there are specific cases where separate mobile-optimized websites are justified. These include the most often used services in mobile context: information services, social networking, and entertainment. Therefore, services clearly included in these categories, such as news sites, Facebook, and YouTube, are recommended to build separate sites for mobile users.

But, there is still the case of mobile applications, which was not studied in this thesis, but is recognized as an important source of Web content for mobile users. In many cases, it is reasonable to provide separate applications for different devices, as these can probably optimize the mobile user experience.

In the end, even though building a separate mobile service for mobile users is rational in some cases, most websites are not included in these services. And, there is an increasing number of users who prefer using full websites in their mobile browser. Therefore, it is recommended for all full website designers and developers to consider mobile users as a relevant part of their service's customers, and thus take the provided UX guidelines into account.

3. Which device types perform the best in web browsing in terms of user experience and why?

According to the test results, currently the most pleasant and best working device for web browsing is a desktop computer. However, mobile devices, especially tablets, with multitouch support are not far from desktop computers in terms of web browsing pleasantness, task success rates, and meeting users' expectations. The most important factor of practical and pleasant browsing on e.g. the iPhone is a capable browser that can render websites in a way familiar from desktop browsing, and offer smooth gestural actions. The touch support in phones and tablets also allows for a more engaging and interesting experience.

4. How does web browsing UX differ between touch screen phones and touch screen tablets, i.e. what effects does the screen size have?

Screen size has little effect on web browsing user experience. In the test, Apple's iPhone and iPad were used and rated. The devices carried the same operating system, iOS 3, and they also had the same browser, Safari. The only clear difference between them is the size of the screen, the PPI also being in the same range. The iPhone and the iPad gained very similar results in the experienced pleasantness, as no statistically significant difference could be found.

However, the iPad gained significantly more positive pleasantness ratings than the Nexus One and the Nokia touch phone. Therefore, it can be assumed that these differences arose mainly not from the screen size but from device and website performance.

The difference in practice between touch phone and touch tablet browsing is in zooming. On the iPad, zooming is not needed for full websites, but it is necessary on touch phones. The Nokia touch phone users were relatively unsatisfied with the zooming properties of their device, and the Nexus One was not a familiar device for any of the users, which made finding the zooming features difficult. Therefore, it can be concluded that zooming has probably been one of the main reasons these devices gained poorer pleasantness ratings than the iPad.

5. Are there enough UX guidelines provided for good web design for mobile users and how reliable is the information in different sources?

The guidelines provided for mobile friendly web design are scattered across the Internet and literature. It is probably relatively easy for designers and developers to find instructions and tips in various blogs when they wish to provide a better user experience for mobile users. But if they do not search for help on this topic, and if they do not consider mobile users at all in the first place, the guidelines provided will be left unnoticed. Literature on this topic should start to cover design for all devices, and in this manner web developers would be more aware of the need to design for mobile users as well.

Currently, probably the most useful information for practical work in website design and development can be found in the blogosphere. Typically in scientific research these kinds of sources are not considered reliable, but on this topic a contrary statement can be expressed. Several user experience professionals maintain their own blog where they gather ideas from around the field and also write their own outlooks on the subject. It is therefore convenient to take these professionals' postings into account.

The academic research, although considered relatively reliable, is not up-to-date on this subject. Guidelines provided based on studies in 2007 do not take touch screen users into account at all, and these mostly instruct developers to build separate services for mobile users. Also the guidelines provided by W3C are still in the era of poor browsers on rather incapable devices.

6.3 Reliability and validity of the results

The qualitative research results can be considered valid and reliable. The methods used to obtain the results have proven to be effective in usability research, especially in business-oriented studies. Combining three methods, expert evaluation, usability testing, and questionnaires, and receiving similar results also suggests that the results are reliable. Also the studied users represented very well the typical users of the tested devices, and all users had adequate experience in mobile browsing.

However, it can be questioned whether the results are valid all over the world, as the study was performed with Finnish users and websites. Cultural differences have been noted in earlier studies, and therefore these results probably fully apply only in similar western countries with similar web browsing habits and mobile Web usage. Also, only three manufacturers' devices were tested, and it is questionable whether the results apply for all smartphones, touch phones, multitouch phones, and tablets. But it is probable that a significant majority of the found issues are encountered with other manufacturers' devices as well, as the browsers in those devices have many similarities with those tested.

The quantitative results presented are only indicative, as the samples were quite small and therefore the number of data points was as low as 6 at minimum and 12 at maximum. However, the 95 % confidence intervals show rather high consistence in most test tasks for all devices, and it can be assumed that with bigger samples similar results could be obtained. For the Kano model results, the responses given did not show very consistent attitudes and expectations, as many tasks were classified in different categories. Regardless of this, the results suggested that users expect most Web actions to be possible on mobile device.

As for users' skills, it can be assumed that the results only apply for quite a short period of time. E.g. tablets were not available on the market at the time of the tests, and therefore all users were novices in their use. If real iPad users were tested now, half a year later, the results might be different. Also the mobile touch screen device pool has increased in size and in capabilities, and probably the newest devices, such as the iPhone 4, HTC Desire, Samsung Galaxy S, and Nokia E7, would perform even better than the devices tested in this study. And not only have devices and users developed, but websites are also showing development in the right direction in increasing numbers. Comparing several websites today and a year ago, a clear trend towards more mobile pleasantness can be observed.

And when considering the results for the Nokia devices, it is questionable whether they apply for real Nokia device users. In the tests, quite a few users mentioned using the Opera Mini browser, as the device's native browser is rather poor in performance. However, the research setup was that only native browsers were used, and therefore for these users the usage did not match reality. If the users would have been allowed to use the browser they wished, the results might have been more positive than when forced to use the Nokia browser.

6.4 Discussion and future work

The results obtained in this study can be compared to those of previous similar studies. In his study in 2007, Shrestha found that only one out of twelve users was able to complete all test tasks on the mobile device, and the average task completion time was less than 6 minutes for desktop and around 23 minutes for mobile [58]. Schmiedl, Seidl and Temper (2009) found that users performed tasks 30-40 % faster with mobile-tailored websites than with full websites [57]. In 2010, Maurer et al. did not find any significant performance increase when comparing a visual search task on the mobile and desktop versions of a website [56], but Budiu and Nielsen found that mobile sites performed better than full sites, averaging 64 % over 53 % in success rate [37]. Compared to all previous studies, the average mobile success rates in this study, 89 % for full sites and 90 % for mobile sites, were considerably higher. Also no significant difference between site types' performance could be observed.

Shrestha's novice test users were lost on web pages, needed to scroll excessively, and appeared very frustrated numerous times [58]. Schmiedl, Seidl and Temper stated that the feature limitations of mobile websites annoyed the users, but mobile-optimized versions were still preferred [57]. Maurer showed, with users of varying experiences, that a growing number of users prefer original content to mobile versions, especially on the highest-end touch devices [56]. Budiu and Nielsen found that on a 1-7 scale the average satisfaction rating was 4.3, mobile-optimized sites scoring 4.6 and full sites 3.72 [37]. In this study, pleasantness values for mobile phones transformed to the 1-7 scale used in Budiu and Nielsen's study showed overall pleasantness at 4.74, mobile-tailored sites scoring 4.67 and full sites 4.82. Therefore, it cannot be stated that the results of this study support the claim that mobile sites would offer a better user experience than full sites. However, when asked, most users still preferred mobile sites to full sites, but the iPhone users tended to like full sites more than other user groups.

Schmiedl, Seidl and Temper's group, and Budiu and Nielsen also compared different devices. Both studies found that users prefer touch screen devices in web browsing [57, 37]. Shmiedl, Seidl and Temper measured task completion times, but these did not identify a clear winner, even though devices with a physical keyboard showed significant advantages in data entry tasks [57]. Budiu and Nielsen also found that task completion times did not vary as much between devices as between users, but phones with bigger screen performed better, success rates being 38 % for feature phones, 55 % for smartphones, and 75 % for touch phones [37]. In this study, the results suggest exactly the same. Touch screen devices with a multitouch screen perform better, and the bigger the screen the better the result. Physical keyboards, however, have a positive effect on the experience.

The SAP Design Guild guidelines for interfaces used in point-of-sale stations and at kiosks [49] apply quite well for touch screen mobile device interfaces as well. Only the guidelines about non-recommended dragging, screen scrolling, and finger gestures have been outdated. The results of this study also agree with the claim of Balagtas-Fernandez et al. when they state that the design of the application running on a touch device is critical for the success of both the device and the

application [52]. In this study, the poor properties of the Nokia browser affected the UX significantly, whereas the usage of the Opera Mini browser could have offered more positive results. Balagtas-Fernandez et al. also suggested using the device menu for selections instead of context menus, which is in line with this study's findings as well.

Lee et al. compared a button and a virtual keyboard in a number entry task and found that a button keyboard is superior in usability, except for intuitiveness and enjoyableness [53]. The same was shown in the text entry tasks of this study. Although the subjective pleasantness was not significantly higher for phones with a physical keyboard, the users kept telling that they find the virtual keyboard difficult and a physical one faster and easier during the tests.

It is widely agreed that mobile users expect a similar user experience for the Web on mobile devices as on the desktop. Mobile users are also showing in increasing numbers in web browsing statistics worldwide. Therefore, it is critical to define how Web user experience comparable to desktop devices could be attained with mobile devices. When it comes to mobile devices, huge steps have been taken in the technological development and these also apply for mobile browsers. In contrast, Web services are still lacking in providing mobile users the needed user experience level.

Mobile web applications that are installed on the device are currently probably the most successful solution for providing Web services for mobile use, as can be derived from the number of daily downloads from e.g. iTunes and Android market. However, it is not a suitable solution for every Web service, as there are a number of websites for which a download application would be excessive for the users' needs, or for which developing and maintaining several websites and applications is not an option because of the budget.

The results of this study offer a list of 60 guidelines for assuring a better user experience for mobile Web users. These guidelines are in most part addressed to full site design, but they also include tips for deciding whether separate mobile services are needed. As the long term goal is to reach the One Web, it is fully recommended that service providers do not develop separate services for desktop and mobile users, but that all services could be used via any device. Currently this suggests adapting user interfaces for optimized use on different devices. But for some services, a mobile-compatible full site can easily be the solution.

The UX guidelines suggested in this thesis should be applied to those of Welie's as well as to W3C's Mobile Web Best Practices. It is necessary that the full Web and mobile Web services are not built based on different information sources, but developer and design guides should cover both desktop and mobile use and interaction. Currently there is a strict division between full and mobile, which does not enable the One Web goal. The Web 2.5 and 3.0 are supposed to combine the full and mobile Web to a large degree, and user experience professionals should be in the frontline to enable this to happen.

Continuous research on this subject is needed to follow how users adapt to new devices and how Web services develop for the needs of mobile users. Adage plans to execute a follow-up study during 2011, to evaluate how the situation has changed

compared to this study's results. New devices will be included in the study to examine whether and how they surpass the devices studied in this thesis. One of the most interesting subjects, however, is to study whether users have learnt new ways of using Web services and how the Web is used on mobile devices.

Another interesting research item would be to study which kinds of services are best provided with a single full website, a full and a mobile-optimized website, a full site and mobile applications, or a full and a mobile-optimized website with mobile applications for different devices. Users are probably starting to have clear preferences for certain solutions for certain services, and these could be utilized to give web designers a classification with clear instructions on which services to develop.

However, the question of providing a combination of separate Web services or a single all-applicable Web service will not be given a final answer in the near future. There is currently a trend for even more complicated multimodal Web interfaces, where different devices, mobile phones, televisions, computers, and even refrigerators, act as different ends of a service. Time will show where the development will stabilize, or whether it ever will.

This study has offered practical profit for Adage's employees' and customers' expertise and know-how, as it offers design recommendations not based on assumptions but on real data collected by user research. The 60 UX guidelines serve as a tool when designing, testing, and evaluating website usability. Employing these guidelines in practical work adds to the quality of the company's services, and will hopefully be adopted also elsewhere for enabling a better mobile Web user experience worldwide.

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A UX Design Guidelines

Page layout

1. Prefer portrait websites over landcape websites.

2. Important elements need to be visible when the page is only a couple of inches in size. Make navigation elements visible even when the page thumbnail is viewed, e.g. using noticeable colouring and shapes.

3. All relevant content or cues to content should always show in the upper part of the page, preferably in the upper left corner.

4. Content layout and element sizes should not vary too much between different pages on a website. For mobile accessibility, it is recommended that the website layout is consistent.

5. Align the content vertically. Consider using a column-based layout for easy mobile browsing. This way users only need to scroll vertically when reading the content.

6. Do not use large banners if you have many mobile Web customers. If banners are needed, position them on top of the header, not between the header and content.

7. With a reasonable zoom level, users should be able to view text and images without scrolling sideways.

8. For a pleasant use of smart zoom, all elements should be comprehensible when fitted to a 3.5” screen.

9. In text, do not exceed a row width of 50-60 characters. Do not use elements of the page's full width for relevant content, especially for text. E.g. for advertisements the full width is acceptable.

10. Let the browser adjust the text column width, i.e. use a liquid layout for text elements. However, define a maximum width at around 80 characters per line for good desktop legibility.

Navigation and links

11. Prefer vertical navigation link lists to horizontal ones from the 2nd level on.

12. Make all link lists as loose as reasonable.

13. Invest in link affordances. Make all links look like links so that users can avoid swiping on them to avoid unwanted clicking.

14. Make all buttons big enough for fingertips even if the text or icon on the button is small. When viewed on a touch screen phone, the button is recommended to be approximately 1x1 cm in size, when the user has zoomed in to the related column width.

15. If using dropdown menus as navigational elements, ensure they work as intended on devices with poor JavaScript support. Consider providing an alternative solution for incapable devices.

16. If using mouseover dropdowns, ensure that there are other ways for navigating on the site. In all navigation, prefer on-click functionalities to hover functionalities.

17. Ensure that contact information can be found either on the front page or on the second level of navigation on a 'Contact' page or similar. All text that the users might want to select or copy, such as phone numbers, street addresses, product details, news etc. should be implemented as plain text.

18. Pay special attention to link texts' information scent if your site is often used by mobile users.

19. If the information on a website is location-specific and you have sites for many locations, allow the user to easily access other locations' contact information e.g. via the header or a contact page.

20. If you have a mobile site, show the link to the mobile site at least in the full site header. Also, provide a clear link back to the full site on the mobile site.

Websites with heavy content

21. Avoid building websites with heavy content if you have a steady number of mobile users. If the content cannot be reduced, provide a lighter version for slow network connections and for mobile use.

22. Show the page at once after the whole content is downloaded. Do not leave the styling as the last received package. Showing text-based link lists when it is not possible to click on them is confusing for users with a slow network connection.

23. When using anchored links on pages with changing content, show the correct part of the page already before the content starts showing.

Incompatibilities

24. If you decide to use Web technologies with known incompatibilities, always test the solutions with several browsers and devices. E.g. test how the site works with non-Flash browsers and test your JavaScript effects to make sure they work as intended.

25. If a part of your website cannot be used with some devices, tell it to the user. Define the devices which do not support the incompatible feature. Do not e.g. tell that 'There are some parts on this page which do not show in some devices'. Instead, provide useful information for these users.

26. If you decide to use Flash, always provide an alternative way for viewing the content.

27. Make sure that the missing Flash elements do not dislocate the page layout or functionality.

28. Flash content always adds to the page download time – use it sparingly.

29. Do not allow users to download incompatible software, i.e. disable the downloading for wrong devices.

Web forms and other input

30. It is recommended to make the form fields, spaces, buttons, and boxes as big as reasonable for easy selecting.

31. Always show the field titles as static labels next to or on top of the fields.

32. It is not recommended to use fields that incorporate both a widget and the keyboard, e.g. a combination of text input and calendar widget is difficult on touch-only devices.

33. Provide forms on a single page whenever suitable. Do not make the users do unnecessary back and forward clicking.

34. Consider implementing suitable checkbox and radio button selections with menus. For touch screen use, menus are a lot easier to notice and use. Always allow the device list functionality to show the menu content. E.g. instead a checkbox a yes/no menu can be applied, and instead a radio button a menu of choices can be applied. This applies especially for mobile-optimized websites directed to touch screen device users.

35. When using menus, ensure all possible options are shown in the list.

36. For date selections, use a calendar widget.

37. If both a start/leave and an end/return time are selected on a form, the fields should be linked, i.e. the other should change automatically according to the one selected. E.g. end/return time can be set at one hour or one day from the start/leave time, depending on the use case.

38. Use autofill, suggestion listing, and browser form history in text boxes whenever applicable.

39. Provide a clear button next to text boxes for easy written text removal.

40. If the user's current location is needed, use the phone's GPS coordinates for filling in the related fields.

41. Always put a confirmation button at the end of the form so that the user can safely edit the content of each field before submitting anything.

Maps and lists

42. Make sure that touch screen users can use your map. Pinch and sweep are the recommended ways for zooming and panning on touch screen, instead of buttons. However, for a map compatible with both touch and non-touch screens, both control types should be implemented.

43. If you use elements with scrollable lists, make the functionality visible. However, allowing the use of the device's own list functionality is always recommended instead of nested lists.

Device detection

44. If you have a separate mobile website, redirecting mobile users automatically is always recommended.

45. If you do not want to redirect your user, asking the user whether he wants to access the full or the mobile site is also a recommended option.

46. If you decide not to use redirecting at all, ensure that a link to the mobile site can be easilly found in the full page header when viewed on mobile devices.

47. It is recommended to make an effort to show the mobile site in search engine results when the search engine is used with a mobile device.

48. Test that devices are detected correctly, and offer touch compatible content for all touch devices, whether in form of an enhanced full site or a touch optimized mobile site.

Separate mobile websites

49. For most websites and Web services, developing a separate mobile website is not justifiable. Ensuring compatibility with mobile devices, especially with touch devices, is recommended.

50. Developing a single mobile site accessible by touch devices as well as non-touch devices can be a reasonable solution for a rather simple Web service.

51. If applications for different high-end devices are available and they have optimized functionalities, users do not need a separate mobile site in the browser. In these cases, a mobile site for the low-end devices can be built if mobile users are detected.

52. If the budget only allows for either an application for different devices, or a mobile-optimized website, develop the one you can make better. Users do not care whether the service is used via a browser or an application. Ensure that your mobile users are aware of the developed mobile service e.g. by announcing it on the full website.

Mobile website content

53. If you decide to build a separate mobile website, do not build it blindfolded. Spending resources on developing a mobile site without studying the mobile users, e.g. by site analytics, is not worth it. Users very probably return to the full site if they cannot find the content and functionalities they need in the mobile context.

54. Find out the things users might want to check on your website when browsing on a mobile device. Use site analytics to determine how much your site is accessed with mobile devices, and what the contents and functionalities mobile users view and use are.

55. If some content can only be found on the full site, tell it to the mobile user and offer a link to full site with a clear indication that it leads to the full site.

56. Name all links to the full site in a clear way so that the user does not leave the mobile site unintentionally.

57. Switching between the full and the mobile site in the navigation is irritating and confusing. Stick to the mobile interface by providing links only between mobile pages.

58. Ensure all the information on the mobile site is in line with the full site.

59. Use a header that tells the site name and provides a links to the site's full version.

60. Enabling as many of the address versions (m.site.com, site.com/mobile, site.mobi, mobile.site.com etc.) as possible is recommended for easy mobile access.

B   Usability test structure

1. Instructions

2. Filling in a questionnaire on background information

3. Test tasks and questions (repeated for each device)

   (a) Reading
       i. Launching the device browser and browsing to hs.fi (pleasantness evaluation)
       ii. Scrolling the front page to find an interesting article (pleasantness evaluation)
       iii. Reading the article (pleasantness evaluation)
       iv. Navigating to a related article
       v. Navigating back in the browser (pleasantness evaluation)

   (b) Filling in a web form
       i. Browsing to Facebook
       ii. Logging in with given login credentials (pleasantness evaluation)
       iii. Navigating to Events for creating an event
       iv. Writing the event name and place (pleasantness evaluation)
       v. Selecting the event as public or private (pleasantness evaluation)
       vi. Selecting the event date and time (pleasantness evaluation)
       vii. Leaving the event unsaved if possible

   (c) Map
       i. Navigating to a specific event on Facebook
       ii. Copying the event address on the clipboard if possible
       iii. Browsing to Google Maps
       iv. Pasting the copied address to search the field if possible (pleasantness evaluation)
       v. Searching the address on the map
       vi. Panning and zooming the map to locate the address (pleasantness evaluation)

   (d) Browsing product information
       i. Browsing to polar.fi
       ii. Navigating to Products / Training software page (pleasantness evaluation)
       iii. Navigating to Polar Protrainer5 page
       iv. Browsing product features freely (pleasantness evaluation)

   (e) Searching for information

        i. Googling for (pleasantness evaluation)
           A. instructions for updating the Nokia E75 firmware (1st device)
           B. the location of the nearest Nokia Care Point (2nd device)
           C. payment options in the Nokia webshop (3rd device)
       ii. Navigating to a link that leads to the Nokia website
      iii. Finding the requested information (pleasantness evaluation)

4. Kano model questionnaire

5. Discussing typical issues with mobile web browsing with the user's device

6. Comparing the tested devices

7. Thanking and rewarding the user with a gift card

C Usability test participants

Table C1: Table of test users.

User	Age	Gender	Education	Occupation	Phone	Uses the mobile Web
1	42	Female	M.Soc.Sc.	Director	E71	Several times a day
2	24	Male	B.Sc. (tech)	Student	N97	Several times a day
3	25	Female	M.Sc. (tech)	Research assistant	iPhone	Daily
4	24	Female	B.Sc. (tech)	Student	iPhone	Several times a day
5	25	Male	Undergraduate (tech)	Student	E71	Weekly
6	26	Male	MBA	Analyst	E71	Several times a day
7	29	Male	Undergraduate (tech)	Specialist	N97	Several times a day
8	28	Male	B.A.	Student	5230	Weekly
9	24	Female	B.Sc. (tech)	Student	E71	Several times a day
10	24	Male	Undergraduate (tech)	Student	E71	Several times a day
11	25	Male	B.Sc.	Student	5800	Weekly
12	32	Female	Nurse	Specialist	iPhone	Several times a day
13	32	Male	Baccalaureate	Restaurateur	iPhone	Several times a day
14	22	Male	Undergraduate (tech)	Student	E71	Daily
15	26	Female	Baccalaureate (media)	Editor	N97	Several times a day
16	35	Male	M.A. (music)	Musician/Teacher	iPhone	Daily
17	25	Male	Baccalaureate	Student	iPhone	Daily
18	20	Female	Baccalaureate	Student	5530	Less than monthly

D   Usability test questionnaires

Subjective pleasantness questionnaire

1.1 Verkko-osoitteeseen siirtyminen

pleasant   unpleasant

1.2 Tiedon etsintä vierittämällä

pleasant   unpleasant

1.3 Lukukokemus hs.fi

pleasant   unpleasant

1.4 Selaimen takaisin-toiminto

pleasant   unpleasant

2.1 Kirjautuminen

pleasant   unpleasant

2.2 Vapaa tekstikenttä

pleasant   unpleasant

2.3 Valintaruutu

pleasant   unpleasant

2.4 Valikko

pleasant   unpleasant

3.1 Kopioi + liitä

pleasant   unpleasant

3.2 Kartan käyttö

pleasant   unpleasant

4.1 Pudotusvalikko

pleasant   unpleasant

4.2 Tiedon selailu

pleasant   unpleasant

5.1 Tiedonhaku Googlella

pleasant   unpleasant

5.1 Tiedon etsintä

pleasant   unpleasant

Kano model questionnaire, page 1

1.1 Writing a URL and downloading the page

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

1.2 Scrolling the page

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

1.3 Browsing and reading news

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

1.4 Navigating back in the browser

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

2.1 Logging in on Facebook

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

2.2 Filling in a text field on a form

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

2.3 Checking a checkbox

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

2.4 Selecting a dropdown menu item

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

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3.1 Copy pasting

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

3.2 Viewing the map on Google Maps

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

4.1 Navigating with a dropdown menu

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

4.2 Browsing information on Polar

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

5.1 Searching information on Google

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able

to perform this on my phone.

5.2 Searching information on mobile consumer websites

A
1. I expect to be able
2. I like being able
3. I am neutral about being able
4. I can live with being able
5. I dislike being able

to perform this on my phone.

B
1. I do not expect to be able
2. I like not being able
3. I am neutral about not being able
4. I can live with not being able
5. I dislike not being able
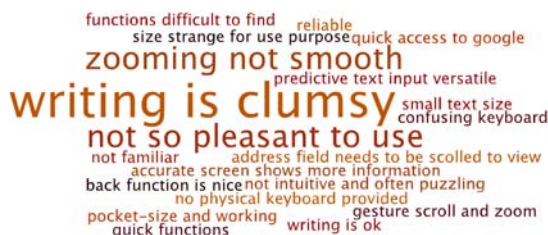
to perform this on my phone.

E   Differentiating features of tested devices
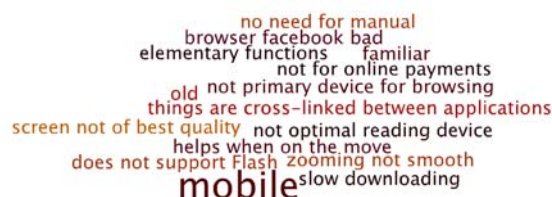

(a) Nokia touch phone features

(b) E71 features

(c) Nexus One features

(d) iPhone features

(e) iPad features

(f) PC features

Figure E1: Tag clouds of users' responses when comparing one device to the other two used in the test.