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Improving Web interaction on small displays

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Abstract

Soon many people will retrieve information from the Web using handheld, palmsized or even smaller computers. Although these computers have dramatically increased in sophistication, their display size is — and will remain — much smaller than their conventional, desktop counterparts. Currently, browsers for these devices present Web pages without taking account of the very different display capabilities. As part of a collaborative project with Reuters, we carried out a study into the usability impact of small displays for retrieval tasks. Users of the small screen were 50% less effective in completing tasks than the large screen subjects. Small screen users used a very substantial number of scroll activities in attempting to complete the tasks. Our study also provided us with interesting insights into the shifts in approach users seem to make when using a small screen device for retrieval. These results suggest that the metaphors useful in a full screen desktop environment are not the most appropriate for the new devices. Design guidelines are discussed, here, proposing directed access methods for effective small screen interaction. In our ongoing work, we are developing such 'meta-interfaces' which will sit between the small screen user and the 'conventional' Web page. © 1999 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

Handheld computers are becoming more and more popular. Marketing is persuading lots of us that we should take our offices and leisure information wherever we go. These new devices are far more sophisticated than their personal organiser ancestors. Most now offer various forms of Internet connectivity. As a minimum, users can access their remote email systems but many handhelds also allow Web access.

Some commentators (e.g. [9]) believe it is highly likely that many people will use handheld-like computers to access Web based materials — handheld access is the next big (small) thing for the Web. One can imagine all sorts of information that might be really helpful to the mobile user. Manufacturers and service providers have already started imagining the future: users can access online maps, entertainment guides, business news, travel advice and even their bank accounts.

Some of these sites have been specifically designed for particular browsers or even for particular devices (see **PocketInfo** [2] site from Psion). Such tailoring is not just out of line with the platform independent ethos of the Web, but also places a heavy

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[2] http://www.pocketinfo.org/

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burden on content providers who want as wide as possible access to their information.

But is such adaptation actually necessary? What happens when small screen users access a site designed for a conventional, large screen display? It seems obvious that there would be some sort of degradation in interaction time and user effort. However, an extensive literature survey revealed no published studies that have looked directly at such issues. The aim of this work is to gain insight into the impact of using small screen devices to look at unadapted sites. Reading manufacturers' marketing literature users could be easily misled into thinking that the world of information was quickly accessible from their handheld; our aim is to ground this 'vision' in the real world of usability.

This paper presents a study that we carried out as part of our project funded by the UK's Science Research Council (EPSRC) and in collaboration with the major online content provider, Reuters.

2. Handheld Web

There are a number of browsers for handheld computers already. Microsoft has converted their widely used Internet Explorer so that it runs on handheld PCs running the Windows CE operating systems. Meanwhile, keen enthusiasts have written clients for the popular PalmPilot.

These browsers can manage many of the 'static' information types found on Web pages — images, tables, frames, forms can all be displayed. In the near future, it is not difficult to envisage mass market handheld browsers that are almost identical to their full-size desktop cousins.

Identical that is in all but one, important respect — the display area real-estate. Display size is unlikely to change both because of technical limitations — we are still a long way off from the foldable display — and also the use requirements: these devices have to be small enough to be held in the hand, on the move [6]. 'Full width' (640 pixels) small screen displays can be achieved without too much difficulty from a technical and practical perspective; display heights though will remain much more limited.

In this work, we look at the effect of screen size on users as they try to achieve goals using small screen Web browsers. We leave it to others to consider important aspects such as the effect of slow data transfers and limited current display technologies (e.g. greyscale rather than full colour).

3. Previous work on screen size effects

3.1. Reading and comprehension

The impact of screen size on reading and comprehension was investigated thoroughly mostly during the 1980s and early 1990s (before the advent of the Web). Many studies looked at the effect on comprehension and reading time of varying the number of text lines displayed.

3.1.1. Reading text on small screen

In an early study, Duchnicky and Kolers [3] considered the effect on reading of window height and line widths. The full width display was read 25% faster than the screen which was 1/3 the width. The impact of varying the display height, however was very much less dramatic. Although very small window sizes (1–2 lines) gave poor performance, the optimal height was found to be just 4 lines. There were no significant improvements in comprehension when the display height was increased to 20 lines and reading times were only 9% slower on the small screen.

3.1.2. Comprehension rate on small screen

Dillon et al. [2] presented a 3500 text using a 20 and 60 line display window. Subjects were asked to read the texts and later summarise the main points. The study found that the comprehension rates on the smaller screen were as good as those on the larger.

3.1.3. Reading hypertext on small screen

Schneiderman [17] carried out a study involving hypertext materials. These materials were similar to Web materials in that users had to interact with the texts, selecting links as they progressed through the task. One group of users was shown 18 lines of text at a time, whereas the other group could view 34. No significant differences in time to complete the task were recorded. In another set of experiments [18] smaller screen sizes slowed down reading time, but not dramatically. In the experiments, users were asked to read program texts and answer questions. On a 22 line display this task took 9.2 minutes while on a 60 line display, it was some 15% faster.

3.1.4. Application to small screen Web browsing

All these reading and comprehension studies suggest that if users simply read/browse chunks of text on a Web page using the handheld devices, then their performance may not degrade very severely. The biggest reduction in effectiveness might be seen in browsers — like Pocket Internet Explorer for the new range of PalmPCs — with limited display width.

3.2. User interaction

3.2.1. Within page navigation

Dillon's study [2] highlighted two other effects of smaller displays. Firstly, users reading from the small displays interacted with the display window to a much higher degree than those with the larger window. Users paged backwards and forwards through the text much more in the small screen display. They may have done this in an attempt to orientate themselves, to provide context as they progressed through the text. Web pages, of course, usually contain far more structure than the texts presented by Dillon and others. We might expect, then, handheld Web browser users to make significant use of any scrolling and paging mechanisms in order to help them make sense of the page.

Secondly, Dillon also found that 75% of users who indicated they would have liked to have changed their screen size had used the small screen display. This suggests, perhaps, that even if objectively performance is not affected, first-time small screen Web users might perceive the systems as being less good than the conventional platforms.

3.2.2. Menu based systems on small screen

Users access Web sites to achieve goals; not just to read information. It is easy to imagine typical goals for handheld users — “find nearest motel”; “locate the bank with the best exchange rate” and so on. There is some literature on the effect of small screen sizes on interaction (as opposed to simple reading). Han and Kwahk [4] found that searching for menu items on single line displays (such as those commonly found on consumer electronic devices) was three times slower than when a conventional display was used. However, Swierenga [13] found that with larger than single line displays (she used 12 and 24 line windows), there was no significant effect on hierarchical menu search time with the smaller display. These studies might suggest that unless the handheld Web browser display is very small, then for simple menu selection tasks (e.g., from a home page) the impact of the small screen will not be catastrophic.

3.2.3. Web page scrolling

Conventional Web guru wisdom holds that long pages, requiring users to do a lot of within page navigation, hamper the user in the pursuit of their goals. Nielson [10], though, in his review of Web usability since 1994, no longer sees scrolling as a “usability disaster”. In early studies, he found that only 10% of users would ever scroll a page to see any links not on display. However, now, most users seem to scroll, if necessary. Nielson suggests that this change in behaviour is due to users experience with the Web.

Perhaps then, the scrolling required for small screens will not lead to ‘usability disasters’: perhaps users will get used to scrolling and find it easy to deal with. On the other hand, using a handheld browser, users will have to scroll much more often and to a larger degree than a user using the same site on a conventional desktop. In addition, handheld users will have to scroll to view pages that may have been carefully designed to fit on one conventional sized display window. Such problems motivate Nielson's design advice for WebTVs [11]. These devices also have a much smaller display space than a conventional monitor (this time due to the relatively low resolution quality of a TV screen and the distance that most users sit to view the information). Nielson suggests that each “page” should fit on a single WebTV screen.

4. Our study

Motivated by the ‘uncertainty’ presented by our review of previous work, we felt that users, content providers and device producers needed to have some

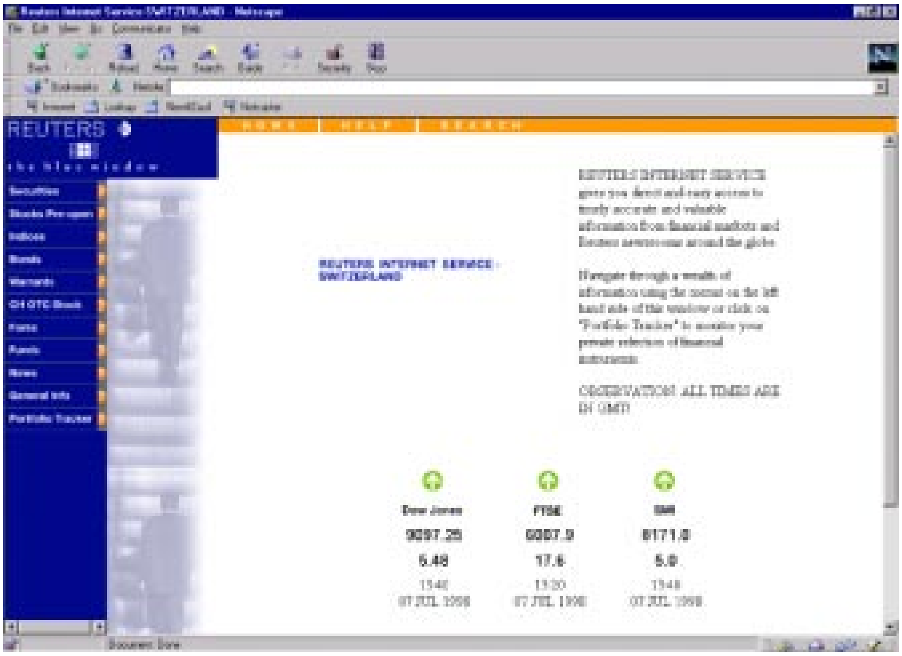

Fig. 1. Example Reuters Web page as viewed on a conventional large screen system.

certainty about the actual impact of smaller displays. On the one hand it seems obvious that problems will arise, leaving the users frustrated and failing in their tasks. On the other hand, it is too easy for all involved to get carried away with the excitement and positive 'drama' [16] of mobile Web access, overlooking potential interaction disasters.

4.1. Objectives

We had two aims in carrying out the study. First, we wanted to quantify the effect of small display space on Web-based task completion. Second, and importantly, we also wanted to be able to gain qualitative impressions on how reduced displays might affect the ways users approach Web-based information retrieval.

4.2. The experiment

Twenty computing science staff and student volunteers were recruited. The volunteers had similar user profiles in terms of computer expertise, financial knowledge and most importantly, none of the volunteers had previously used the system. There were both males and females and their age ranged between 18 and 45.

The volunteers were asked to use a beta version Web based information system developed by Reuters in Switzerland to complete two tasks. The information system has a design common to many commercial Web sites. As Fig. 1 shows, users are given a set of choices via a horizontal and vertical menu bar. Browsing/search results are displayed in the central portion of the screen.

The volunteers were assigned to one of two groups (10 in each group):

(1) One group accessed the site using a browser (Netscape 4.0) with its window display resolution set to 1074×768 pixels or approximately 30 lines of content. This display enabled the users to view the site as the designers intended (Fig. 1).

(2) The other group used the same site but this time the browser display capacity was set to 640×480 pixels or approximately 15 lines of viewable content — this system is referred to as the 'small screen' from here on (see Fig. 2).

Although our simulated handheld computer display had a higher pixel resolution than found on typical devices, the viewable content area is very

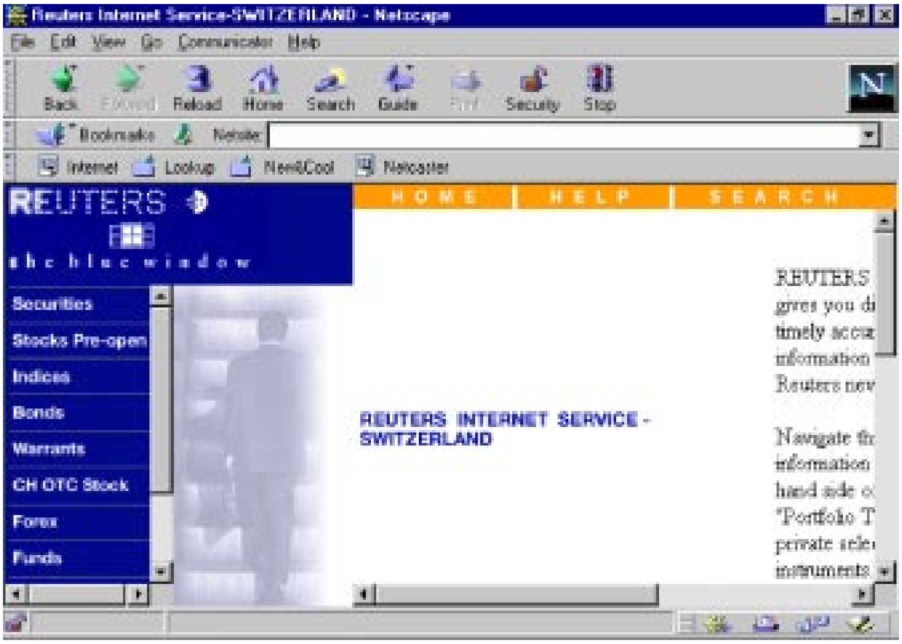

Fig. 2. Example Web page on small screen display.

similar to that found on many. In our experiment, the small display had an area of approximately 15 lines (height) and 75 characters (width). A review of two popular handheld browsers (CE version of Internet Explorer for the Casiopiea and a proprietary browser for the Psion series of computers) showed that the viewable content is approximately 11 lines (height) and 65 characters (width).

Both groups used standard keyboards and mice to interact with the Web site. The focus of our work was the impact of screen size changes — we did not want to introduce any effects caused by the different input devices used in conventional and small screen devices.

Reuter's development staff provided us with two tasks for the users to complete, in which each task is divided into two parts as shown in Table 1.

Users were given a maximum of 15 minutes to complete both tasks. They could choose how long to spend on each task but the experimenter warned users when they had used half of the time. Users recorded the answers to the tasks as they completed them.

As users attempted to complete the tasks, their actions were automatically logged. Analysis of this data was used to produce a series of performance measures — listed in Table 2 — relating to site and within page navigation.

At the end of the trial, users completed an extensive questionnaire on their perceptions of the system.

Although our user groups were small, following work by other hypertext and usability researchers [6,8,15] we were confident that the methodological design would prove useful in giving us a good impression of the usability impact of small screens.

Table 1
Information retrieval tasks presented to both groups of user

Task	Sub-task
Focused search	1(a) Find the share price for given company 1(b) Evaluate the performance over time of the same company
Less directed search	2(a) Find the continent with the most public holidays in May 1998 2(b) Select any intriguing public holiday

Table 2
Data recorded for each volunteer as they attempted to complete the two tasks on the large or small screen system

Action category	Measures
Site navigation activity	Number of link selections Number of backtrack actions, returning user to previous selections
Within page navigation activity	Number of scroll up/down actions Number of scroll left/right actions Number of page up/down button presses Number of line up/down scroll bar actions

5. Results and analysis

5.1. Task completion rates

Table 3 shows the success rates in completing the four subtasks by the two user groups.

The overall probability of a question being answered correctly (taking all tasks in both groups into account) was 37.5% ($N = 80$). Task 2(b) was the only task that most users could complete. This is not surprising as any answer the user supplied (as long as it was about the topic holidays) was allowed. These completion rates are similar to Nielson's benchmark figure. In his studies on top commercial sites, he found an average success rate of 42% [12].

The large screen group answered twice as many questions correctly than the small screen group. If there were no effect of screen size, we would expect approximately equal numbers of correct answers in each group. From the binomial distribution, the difference between the expected number of correct answers, based on the overall completion probability (37.5%), and the recorded number of correct answers was significant at the 5% level.

Questionnaire results reinforce the indication that the smaller screen size impedes task performance — 80% of small screen users indicated that they felt screen size impacted on their ability to complete the tasks; this compares with 40% of large screen users.

Table 3
Task success rates under both conditions

Condition	% 1(a)	% 1(b)	% 2(a)	% 2(b)
Large screen	40	30	50	80
Small screen	10	0	20	70

% gives percentage of users in group that gave correct answer to sub-task.

5.2. Site navigation

5.2.1. Quantitative analysis

We were interested in two measures:

- Average number of 'forward' link selections.
- Average number of returns to previously displayed information. We wanted to take account of the times a user navigated such that previously viewed information was displayed.

Tables 4 and 5 give the results with respect to these two measures.

Before the trial, one of our hypotheses was that users of the small screen system might have to make many more hyperlink selections to try and complete the tasks. We envisaged users making false selections

Table 4
Average number of hyperlink forward selections carried out by users in completing tasks

Condition	# Avg. link selections	
	Task 1	Task 2
Large screen	31	19
Small screen	27	19

Table 5
Average number of backtrack selections carried out by users in completing tasks

Condition	# Avg. backtrack	
	Task 1	Task 2
Large screen	11	10
Small screen	8	7

(for a whole range of reasons such as failing to see a useful link hidden at the end of a page) and having to backtrack extensively from garden-paths.

On inspection there was no striking difference between the hyperlink activity values for the two screen sizes, and this was confirmed by two significance test methods, neither of which showed a difference that was significant at the 5% level, for either task. Our small screen users, then, were not browsing through more information than their large screen counterparts. Further, the small screen users were not rapidly, randomly 'hunting' around the site.

5.2.2. Page access analysis

We analyzed the Web server log files, extracting the first ten accesses by each user and task. The key findings were:

- 80% of small screen users began by using the search options of the site.
- Small screen users selected search facilities twice as many times than large screen users.
- Large screen users showed a greater tendency to follow paths, exploring potential regions of the site. Path lengths for small screen users, however, were shorter, with users returning to search facilities more frequently.
- For both groups, we found the ten most frequently accessed pages. We compared these top hit lists and found that there was a 50% non-overlap of pages. Assuming the large screen users were making better choices (as witnessed by their higher success rate) we can suggest that although users might not make any more choices on a small screen (see Table 4), the smaller display could lead to these choices being poorer.

5.3. Within page navigation

We measured the amount of within page navigation carried out by the users. Within page navigation describes the number of up/down and left/right scrolling and paging activities the users performed to complete the tasks. Table 6 shows the average number of scroll 'events' (see Table 2 above for definitions) performed by users during the tasks.

We used the median test, with contingency table analyzed by Fisher's exact probability method, to test whether the values of the 'up', 'down', 'left' and 'right' samples were different between the large-screen and small-screen groups. All differences in median were significant at the 5% level. (Specific results are: up $p = 1.1\%$; down $p = 1.1\%$; left $p = 5 \times 10^{-5}$; and, right $p = 5 \times 10^{-5}$).

The results show that small screen carried out many more scrolling actions than their large screen counterparts. This in itself is not surprising. However, what is interesting is that most of the small screen scrolling actions were scroll down or scroll right. Scrolling, then, was used to a large extent to move the user linearly through the pages, to see things they could not view previously. There was relatively very few backtracking scroll actions (e.g., page up). Before the tests, we thought that users of small screens might carry out significant numbers of 'two-way' (e.g., down/up) scrolling actions to gain some notion of what was available on the pages. It does not seem that such orientation took place. A possible reason for this in our trial systems was the use of a series of menu bars fixed on the left hand most side of the display. These give users of both systems a good deal of information about the site and page structure without the need for lots of scrolling.

Table 6
Average within page navigation activity carried out by users in attempting both tasks

Condition	# Avg. up activity	# Avg. down activity	# Avg. right activity	# Avg. left activity
Large	28	118	0	0
Small	88	297	70	38

6. Design lessons

Our investigations highlight some ways in which Web content can be adapted to make it more accessible to mobile handheld computing users. The overall aim of our ongoing project is to provide automatic adaptations of content so users can gain access to as wide a range of the material as possible. However, the guidelines we raise below are applicable to content which is to be specifically designed for small display platforms.

6.1. Provide direct access

Reading on the Web seems to be much more active than reading from the page — users are seeking out information, scanning for things that interest them [7]. When they are using handheld, small screen displays this appears to be especially true [5]. Small screen users seem to choose and prefer direct access strategies over less directed, browsing approaches. Handheld content should be adapted then in the following sorts of way:

- *Provision of search mechanism:* sites which are to be viewed by handheld users must provide one or more direct search features.
- *Structure information to provide focussed navigation:* this could be done by, for example, presenting the user with a list of goals they might want to achieve from the site or page. Adaptation agents (human or automated) need to consider why a user might be accessing the site or a particular page and present a framework which will facilitate such access. The **Wireless Application Protocol committee** [3] have proposed a markup language (compatible with XML) which embodies such a task-orientated approach for devices with very small screens (e.g. mobile 'phones). Theng [14] has also done some exploratory work with conventional hypertext systems in this area.

6.2. Reduce scrolling

It is clear that users will potentially have to carry far many scroll actions using small screen displays. Such activity will interrupt their primary tasks.

Scrolling can be reduced by:

- Placing navigational features (menu bars etc) near the top of pages in a fixed place. For example, our test site had the menus fixed on the left hand side of all pages.
- Placing key information at the top of pages.
- Reducing the amount of information on the page, making the content task focussed rather than verbose. Nielson suggests that this rule is applicable to all Web sites, arguing that users scan Web pages rather than read them word by word (in tests he found that 79% of users scan text and only 16% read word for word [7]).

There are some commercial products that can carry out some of these adaptations automatically. These filtering tools, such as Spyglass's **Prism** [4], transform pages by removing white space, shrinking or removing images and so on. Our initial investigations suggest that such syntactic changes will be useful but that rearrangements based on the semantics of the page (e.g., knowing that a list is a navigation element) would provide further benefits.

As others have suggested, style sheets for small screen platforms could also be used to reduce the amount of scrolling needed. For example, display space used by various elements, like main headings, could be shrunk to fit the available space.

7. Conclusions

This study was carried out to explore the actual effects of small displays on users' abilities to interact with Web pages originally designed for conventional, large screen displays.

Previous research suggests that if users simply want to browse text using the handheld browsers, their performance will not be too severely degraded. The research relating to tasks which are at a higher level than reading, does not seem to provide any conclusive evidence to support the usability or lack of usability of handheld browsers.

Our study indicates that information retrieval tasks will be harder to complete on devices with similar display height characteristics to those currently on the market. Users will make more incorrect choices when selecting from possible links and they will also waste time carrying out many more scroll-type activities than users with large screen displays.

In our ongoing work, we are looking at ways of automatically adapting pages to avoid such problems. We have built a tool to extract semantic-type information from pages in an attempt to capture the interaction elements available to the user. This information will help, for example, in identifying navigation objects so they can always be placed prominently on the small screen displays. This study

[3] http://www.wap.org/

[4] http://www.spyglass.com/

also showed that small screen users want to get to information in a quick, direct way. We will look, then, at the role search mechanisms can play in providing direct access to information.

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