Exploring Cross-Device Web Use on PCs and Mobile Devices

Shaun K. Kane[1], Amy K. Karlson[2], Brian R. Meyers[2], Paul Johns[2], Andy Jacobs[2], and Greg Smith[2]

[1]The Information School, DUB Group, University of Washington, Seattle, WA 98195 USA
skane@u.washington.edu
[2]Microsoft Research, One Microsoft Way, Redmond, WA 98052 USA
{karlson, brianme, pauljoh, andyj, gregsmi}@microsoft.com

Abstract. In this paper, we explore whether sharing a user's web browsing activity across their computing devices can make it easier to find and access web sites on a mobile device. We first surveyed 175 smartphone users about their web use across multiple devices. We found that users shared web information between devices, but generally used cumbersome manual methods to do so. In a second study, we tracked the web sites visited by 14 participants on their PC and mobile phone, and used experience-sampling surveys to determine whether sharing sites across devices would be useful. We found that participants visited many of the same sites on both their mobile device and PC, and that participants were interested in viewing additional sites from their PC on their mobile device. Our results suggest that automatically sharing web activity information between devices has potential to improve the usability of the mobile web.

Keywords: Mobile web, cross-device user experience, activity logging, experience sampling method.

1 Introduction

Mobile web browsers have become a common feature of many smartphones and mobile devices. While some earlier mobile devices supported only specially formatted mobile web pages, many current mobile devices offer full-featured web browsers that allow access to any web page. These mobile web browsers provide users with the ability to quickly look up facts, exchange messages with friends, read news articles, find maps or directions, and access other information from anywhere and at any time.

Despite the benefits of mobile web access, mobile web usability is fundamentally limited by the constraints of the user's mobile device. Mobile devices typically have slow connections, small screens, and tiny keyboards. One particular challenge to using the mobile web is the difficulty of navigating to new web sites. Entering a web site address on a mobile device requires the user to type a significant amount of text on a small mobile device keyboard, which can be slow and error prone. This presents an obstacle to visiting new sites on the mobile web. Therefore, making it easier for

mobile web users to access web pages has the potential to substantially improve the user experience of web browsing on mobile devices.

One approach to improving access to mobile web sites is to automatically suggest web pages that a user might wish to visit. Prior research has shown that a user's context, such as their location, can be a useful predictor of their information needs [1]. Prior mobile search prototypes have used location information to auto-complete mobile search queries and improve search efficiency [2]. However, this previous work has focused primarily on a single type of context—location—and has ignored other sources of contextual information. In this paper we introduce a new source of context to enrich the mobile web browsing experience: the web activities that a user performs on their other devices, including their home and work PCs. Examining a user's web activity on these other devices may reveal which sites they frequently visit, what topics they are currently interested in, or what activities they are planning.

To understand how PC and mobile web browsing are connected, we performed two studies with current mobile web users. In the first study, we surveyed 175 smartphone users about their web browsing habits. We found that users sometimes shared information between their devices, but generally did so using manual methods such as emailing themselves or copying URLs on paper. In a second study, we used activity-logging software to determine whether users viewed the same sites on their mobile devices as on their PCs. We also used experience-sampling surveys to ask participants whether specific web pages from their PC browsing history would be useful on their mobile device. We found that 75.4% of the domains that participants visited on their mobile devices were also visited on their PC, and that 17.4% of the PC web pages suggested in surveys would also be useful on the participant's mobile device. Overall, our results offer strong evidence that users' web browsing activities may be similar across their desktops, laptops and mobile devices. These results suggest that supporting web activities across multiple devices can reduce barriers to accessing web content when using constrained mobile device interfaces.

2 Related Work

2.1 Mobile Web Use

Prior studies have shown that users' mobile web needs and behaviors are closely related to their current activities and context. Sohn et al. [3] used mobile surveys to capture users' information needs while using their mobile devices, and found that users had a variety of information needs which were often driven by their current context. Demumieux and Losquin [4] installed a logging application on users' mobile phones, and found that users performed a variety of information activities on their mobile devices. Cui and Roto [5] examined users' mobile web access logs, and found that mobile web use could be classified into four categories: information seeking, communication, transactions, and personal space extension. Lee et al. [6] conducted a diary study in which users documented their experiences when using the mobile web, and found that users viewed a variety of sites in a variety of contexts. Other studies [7, 8] have identified mobile search patterns from web search query logs. Our

research adopts a different perspective than these prior studies by exploring the relationship between users' web browsing activities and information needs on both a PC and a mobile device simultaneously.

Some research projects have leveraged the contextual nature of mobile web use to provide easier access to the mobile web, such as by dynamically suggesting web sites based on a user's context or stated interests. Kamvar and Baluja [2] developed a mobile search page that used location information to predict and auto-complete mobile search queries. Cohen et al. [9] developed a personalized pocket directory that allowed users to select categories of interest, and then populated these categories with suggested sites from a public web site directory. Panayiotou and Samaras [10] developed a personalized web portal that considered users' preferred topics and location, and then automatically downloaded relevant web sites. Our research extends this prior work by exploring how a user's web activity on other devices can be used to suggest web sites on a mobile device.

2.2 Computing on Multiple Devices

Recent studies by Oulasvirta and Sumari [11] and Dearman and Pierce [12] examined how knowledge workers perform tasks that span multiple devices. Knowledge workers may use a combination of desktops, laptops, and mobile devices to perform tasks throughout the day. These studies suggest that managing information across devices can be difficult, and recommend that designers provide better tools for sharing and synchronizing information across users' devices. These studies did not explore issues specific to web use as we do here.

Other projects have investigated the usefulness of syncing web information between devices. WebPod [13] used a portable USB storage device to share a user's browsing session, including open windows, web history, and bookmarks, between PCs. Mozilla Weave[1] performs a similar function over the network, allowing a user to resume a browsing session on a different PC. However, prior work has not fully explored what types of web information are most useful to share between PCs and mobile devices. Our research therefore attempts to identify which, if any, web information would be useful to share between a user's various devices, taking into account differences in how each device is used.

3 Study 1: A Survey of Multi-Device Web Use

Is sharing web information between devices useful? To answer this question, we investigated whether users currently share web information between their devices, and what methods they use to do so. We conducted a survey of current smartphone users that focused on their present-day web usage habits on their PCs and mobile devices.

[1] http://labs.mozilla.com/projects/weave/

3.1 Method

Informants. We recruited 175 (146 male, 29 female) mobile phone users with a mean age of 36 years (Standard Deviation, *SD*=7.3). All informants were employees at a technology company and used the web frequently on their mobile phones. Informants were randomly selected from a list of company employees, and were recruited via email. Informants who completed the survey were entered into a prize drawing.

Procedure. Informants completed a web-based survey from their home or office. The survey covered topics such as the types of web sites that they visited on their PCs and mobile devices, how they shared information between devices, and difficulties they encountered in using the web on their mobile devices. Completing the survey took between 15 and 30 minutes. Survey responses were stored in a database, and were later analyzed using Microsoft Excel.

3.2 Results

Web Browsing on PCs and Mobile Devices. Our informants' browsing habits differed considerably between their devices. Informants visited many more web sites on their PCs than on their mobile devices. The majority of informants (64.6%) viewed more than 10 web sites per day on their PC, while most informants (85.1%) viewed 5 or fewer sites per day on their mobile device.

We were also interested in how mobile web users accessed web sites on their mobile devices. Informants reported that they used bookmarks much more frequently than they typed in URLs. Most informants (59.4%) used bookmarks stored on their phone to load pages at least several times per week, and 28.6% used these bookmarks daily. In contrast, 41.7% of informants manually entered URLs several times per week, and only 14.3% manually entered URLs daily. Overall, we found that informants generally used bookmarks or links to access web content on their mobile device (Fig. 1), which is unsurprising given the difficulty of mobile text entry.

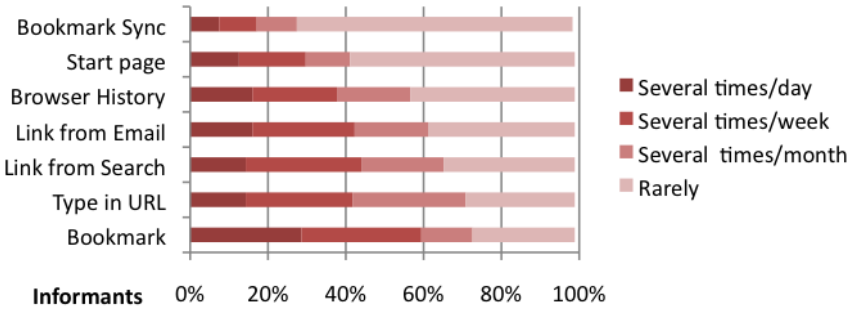

Fig. 1. Common methods used by our informants to load web pages on their mobile devices.

Finally, we were interested in what types of sites informants viewed on their devices. We asked informants which categories of sites they viewed on each of their devices, using site categories adapted from prior research [14]. Informants viewed many

different categories of sites on both devices, although they viewed more diverse categories on their PCs (Fig. 2).

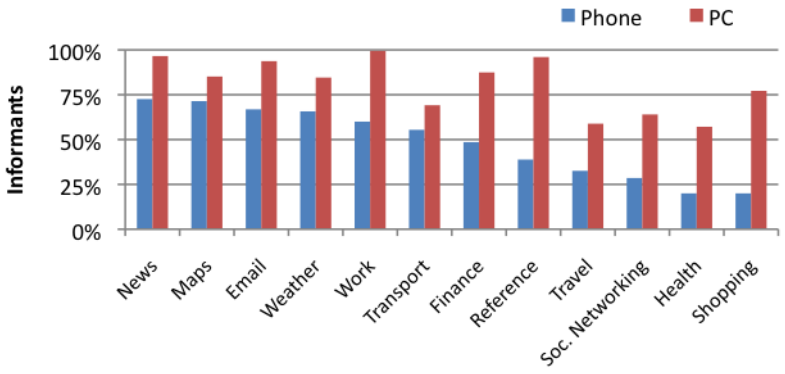

Fig. 2. Categories of web sites that our informants viewed regularly on their PCs and mobile devices.

Transferring Information Between Devices. Many of our informants transferred web information between their PCs and mobile devices, but often used cumbersome manual methods to do so. Most informants (80.0%) did not use bookmark synchronization software, but instead emailed information to themselves (69.0%), or typed in a URL directly after writing it down or making a mental note (65.1%). This reliance on manual methods is surprising given that the vast majority of our informants used either Windows Mobile Smartphones (88.0%) or iPhones (7.4%), both of which offer automatic bookmark synchronization between devices. This result suggests that current synchronization services are not satisfactory and are mostly not used.

Informants also indicated the major difficulties that they encountered while browsing the web on their mobile devices. Poor web page layout (60.0%), small screen size (58.9%), poor network connections (47.4%), and difficulty entering text (45.7%) were informants' most common complaints about their current mobile web experience.

In conclusion, while informants did use the mobile web, their use was limited compared to their web use on the PC. Informants viewed relatively few sites on their mobile phones, and manually entered new URLs rarely (Fig. 1). Informants sometimes transferred information between their devices, but generally used cumbersome manual methods to do so.

4 Study 2: Logging Web Activity on Multiple Devices

Our survey revealed that mobile web users frequently share web information between devices, but generally do so by hand. Mobile web users might therefore benefit from techniques that enable easier sharing of web information between devices. However,

our survey did not ask informants about the specific sites that they visited on each device, nor did it ask what additional sites informants would like to see on their mobile device. Therefore, we conducted a second study that focused on these issues.

This study was based on two primary research questions. First, are the web pages that users visit on their PCs related to the pages that they visit on their mobile devices? We used activity-logging software to capture the web pages visited by our participants on their PCs and mobile devices. This allowed us to capture much more detailed information than could be gathered through self-report. Then, we examined the URLs of web pages visited by participants on each device, and measured the degree to which these pages overlap.

Our second research question was: Are users interested in accessing web pages that they have previously viewed on their PC when using their mobile device? We used web surveys to ask whether participants were interested in viewing specific web pages, selected from their PC web browsing history, on their mobile device. Surveys were deployed using the experience-sampling method (ESM) [15], so that participants received surveys when they were away from their desk and likely to be carrying their mobile device. These surveys allowed us to explore which, if any, URLs from participants' PC browsing history would be useful on their mobile device.

4.1 Method

Participants. We recruited 14 participants (11 male, 3 female), with an average age of 33.2 years (*SD*=4.2). Participants were recruited through internal mailing lists at a technology company. All participants used Windows Mobile Smartphones and used the web browser on their phone for at least ten minutes per day. Participants were compensated for installing the software and for each week of participation. Participants were given additional compensation for completing more than 60% of the ESM surveys.

Apparatus. We installed web activity-logging applications on participants' work PCs and smartphones. On the PC, we installed PersonalVibe [16], a desktop activity-logging application that runs in the background of a Windows-based PC and records a user's activities. PersonalVibe generated a log of web page URLs, page titles, and view durations for every web page visited by each participant. On the mobile phone, we installed a new Windows Mobile activity-logging application, which also recorded a time-stamped log entry for each URL visited by the user from their phone. Logs were automatically uploaded daily to a central database.

We also deployed ESM surveys that asked participants whether specific URLs from their PC browsing history would be useful on their mobile device. Survey requests were sent by SMS or email, and included a link to a web-based survey page. This survey page asked participants to "check all of the web sites that would be interesting or useful to have on [their] phone today" (Fig. 3). Because it would require too much time to ask participants about every URL that they viewed, our survey software generated lists of 25 URLs per survey. However, it was not immediately clear how we should select pages to include in surveys, as we did not know which sites would be most useful to participants. Would participants prefer sites that they

had viewed recently on their PC, or would they be interested in sites that they viewed most often on the PC? In order to answer this question, we developed a set of queries that were used to select pages from the web activity logs. These queries were intended to expose different aspects of web activity on the PC, including recently visited pages and frequently visited pages. Five queries were used to populate the surveys:

1. *Recently Visited.* Most recently visited web pages, ordered by time of the most recent visit.
2. *Frequently Visited.* Pages visited most frequently in the last 7 days, ordered by the number of visits.
3. *Search and Maps.* A combination of recent web search queries and map searches, ordered chronologically. Search and map sites were combined due to the low number of items in these data sets.
4. *Longest Viewed.* Pages viewed for the longest duration in the last 7 days, ordered by total time spent viewing the page.
5. *Grab Bag.* Randomly selected pages from PersonalVibe's web activity log.

Each survey contained the top 25 URLs from one of the five queries listed above, presented as a randomly ordered list (Fig. 3, left). Query order was counterbalanced such that participants received surveys from each query at different times per day. In addition to the surveys, we installed a bookmark in participants' mobile browsers that allowed them to view the top 10 items from each query as a web portal page (Fig. 3, right). This gave participants the opportunity to explore the URLs suggested in the surveys, although they were not required to do so.

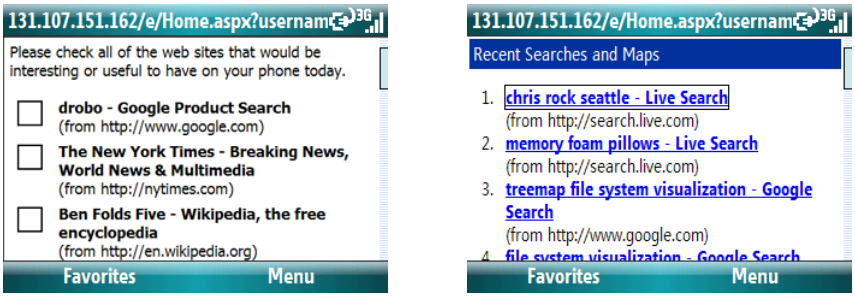

Fig. 3. Left: Example ESM survey on a Windows Mobile Smartphone. Right: Web portal view.

Adjustment to Data. In initial testing we discovered that the raw web activity logs contained pages that the participant did not intentionally visit, such as web page redirects. For this reason, web pages that the participant visited for less than 5 seconds were excluded from the web activity log. We also excluded intranet sites from the web activity logs, as these sites could not be reliably accessed by mobile devices.

Procedure. During the first week of the study, participants were instructed to go about their normal activities while the logging applications recorded their actions. Participants were aware that their computer and phone use was being monitored during this time, but we did not reveal our particular interest in web browsing.

After 7 consecutive days of activity logging, participants began receiving ESM survey requests. Participants received up to 6 survey requests per day. Survey requests were sent when PersonalVibe detected inactivity at the user's PC, indicating that the participant might be away from his or her desk, and therefore more likely to use their mobile browser. At this time, we also installed the web portal bookmark. Participants were never required to visit the portal page, although the survey web page did contain a link to the portal. Although we collected activity data during this second week, our analysis contains activity from the first week only, as participants' behavior might have changed once the surveys began.

Due to scheduling constraints, participants began the survey period on different days of the week, but always began on a weekday. Participants received survey requests for approximately 7 days, including weekends.

4.2 Results

Comparing Web Activity across Devices. During the logging period of the field study, we logged 15208 web page visits to 8087 unique URLs by 14 participants. As we found in the initial survey, log data revealed that participants browsed many more pages on their PCs than on their smartphones. Overall, participants made 10549 page visits on their PCs and 4659 on their smartphones. On the days they used their computer, participants visited a median of 71.5 pages (μ = 94.2) on their PC, including repeat visits. Participants viewed a median of 25.0 (μ = 32.8) pages on their mobile device per day, including repeat visits.

Overall, participants generally viewed different web pages on each of their devices, but visited many of the same web domains on both devices. Examining the overlap between devices, we found that participants viewed a median of 73.7% (μ = 72.4%) of pages only on their PC, and 21.2% (μ = 23.2%) of pages only on their phone. The rest of the pages were viewed on both devices. Of all pages visited on the PC, a median of 1.1% (μ = 2.0%) pages were also visited on the mobile device. Of all pages visited on the mobile device, a median of 7.8% (μ = 10.5%) pages were also visited on the PC. In examining this seemingly low overlap, we discovered that 82.8% of the 2216 unique pages viewed on a mobile device were mobile-formatted web pages. Therefore, even if participants viewed the same content on both their phone and their PC, the URLs would be different on each device, resulting in a low overlap. To account for this discrepancy, we manually mapped the URLs visited on the phone into the equivalent desktop web domain. We then measured the overlap between the mapped mobile domains and the original desktop domains to determine how often participants viewed information from the same web domain on both devices. Thus, if a participant read an MSNBC news article on their PC and then later read a different MSNBC article on their phone, we considered that a domain overlap, even if the page URL was not the same or if the phone was redirected to a mobile version of the MSNBC site. Using this metric, we found that a median of 75.4% (μ = 63.2%) of the domains viewed on the phone were also viewed on the PC, and a median of 13.1% (μ = 14.1%) of the domains viewed on the PC were also viewed on the phone.

Prior work has shown that PC users often revisit web pages throughout the course of a day [17], and we wished to see whether this effect was similar across devices. We

found that a median of 36.7% page visits per day were revisits to pages viewed earlier in the same day. Examining each device separately showed that revisitation patterns were consistent across devices, with a median of 32.3% revisits per day on the PC and a median of 32.2% revisits on the mobile device. We also found 32 instances in which a URL was visited on one device, and then visited on the same day on the other device.

Due to the focus of this study, we did not collect detailed information about the content of sites that users visited, or about more complex revisitation patterns between devices. These analyses present a promising direction for future work.

ESM Survey Results. Our 14 participants completed a total of 411 surveys, with each participant completing a mean of 3.3 surveys per day (*SD*=1.0). During the survey period, participants performed a total of 9777 ratings of 3073 web pages. Of the 9777 pages suggested to any participant, 1288 (13.2%) were rated as being useful. On average, each participant performed 698.4 (*SD*=222.9) ratings, and rated 92.0 (*SD*=71.4) of the suggested web pages as useful. Because we sometimes asked participants about a web page multiple times, it was possible that a participant would rate a page as useful in one instance, but not in another. This count, as presented above, is a conservative estimate of how many pages would be useful on the phone. Looking across surveys, participants reviewed a median of 192 distinct web pages, and rated 33.5, or 17.4%, of these as useful at least once.

Although the overall usefulness rating is somewhat low, comparing the different queries used to populate the surveys shows that certain types of web information were perceived as more useful. We calculated an average usefulness rating for each of the five queries, grouped by participant, and evaluated these average ratings using a nonparametric Friedman test. This test showed a significant difference between the usefulness ratings of the different query types ($\chi 2_{(4,N=14)} = 18.17$, p=.001). A post-hoc pairwise Wilcoxon test, using Holm's sequential Bonferroni procedure [18], revealed no pairwise differences. However, looking only at the top 5 items from each query, we found that the Frequently Visited pages and Longest Viewed pages were significantly more useful than Search and Maps or Grab Bag pages, all at $p < 0.01$ (Fig. 5). Recommendations from participants' top 5 most Frequently Visited pages on the PC were useful 30% of the time, suggesting that optimizing these queries or allowing users to customize their own queries could produce a higher percentage of useful pages.

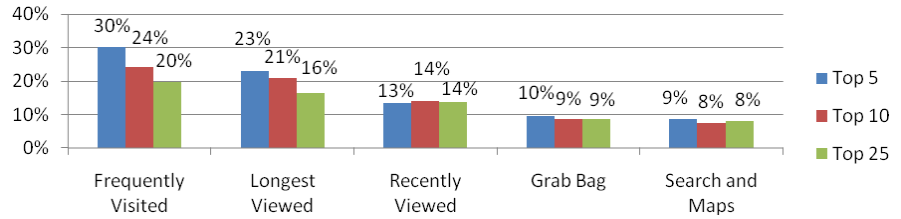

Fig. 4. Percentage of web pages rated as useful from each query type, averaged across users. Higher is better.

We also looked at the categories of pages that paticipants rated as useful in the ESM surveys. We coded these pages manually using a modified version of the coding scheme used in Study 1 (as shown in Fig. 2)[2]. Overall, participants found News and Reference pages to be useful most often, but also found many Search, Shopping, and Social Networking pages to be useful. The number of pages chosen from each category are shown in Figure 5.

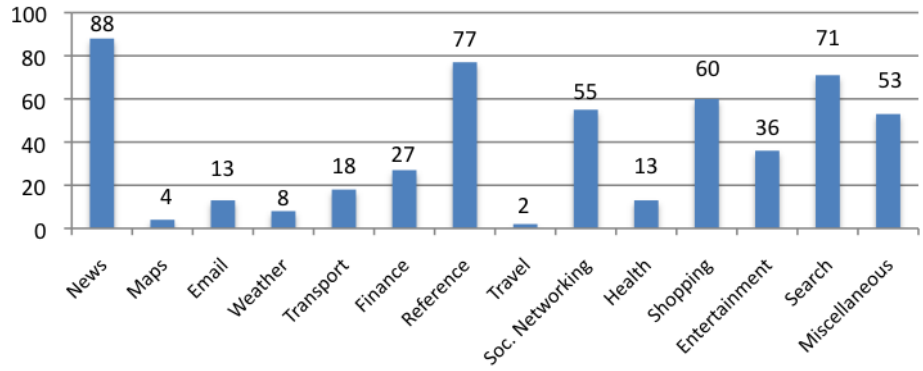

Fig. 5. Categories of the web pages that participants rated as useful in the ESM surveys. Categories were coded manually by the researchers.

In addition to completing the surveys, some participants also viewed the web portal page during the study, albeit rarely. Participants viewed the portal page a total of 110 times during the study, and clicked through to a destination page a total of 42 times. Overall, participants followed a link from the web portal on 38.8% of their visits. This suggests that participants are curious about the information presented by the portal, and might use such a portal if it were presented in a usable format.

Follow-up Survey. Eleven of the study participants (10 male, 1 female) with an average age of 33.4 years (*SD*=4.6) completed a web-based questionnaire that explored their responses to the ESM surveys. Participants were shown a list of web pages that they rated in surveys and were asked to describe why they rated the pages as useful or not useful. Their answers are summarized in Table 1. Pages were most often useful when participants wished to revisit them, and were not useful if the page was difficult to view on the mobile device or if the participant was "finished" with that page.

Each participant was also presented with a subset of 10 pages that they had rated as useful in at least one of the ESM surveys. Participants were asked to rate how useful each page was on a 5-point Likert scale (1=Very useful, 2=Somewhat useful, 3=Neutral, 4=Somewhat useless, 5=Very useless), and asked whether they had bookmarked the page on their phone either before or during the study. Among pages that the users had rated as useful, the mean usefulness rating was 2.48 (*SD*=0.8),

[2] The "Work" category from the original classification scheme was difficult to categorize without knowing details of the participants' work, and so we excluded this category. We added additional categories for Search and Entertainment based on examination of the data.

10.9% of these pages were already bookmarked prior to the study, and 10.0% were bookmarked during the study. Thus, while the pages varied in their overall usefulness, almost 90% of the pages that participants did find useful had not been bookmarked previously on the phone, suggesting that they would have been difficult to access without sharing URLs from the PC.

Table 1. Reasons why suggested web pages from the PC were/were not useful to participants.

Reasons pages were useful	Ppts
Interested in tracking page updates	7
Useful when away from the PC	4
Interested in viewing later	2
Interested in sharing with friends	1

Reasons pages were not useful	Ppts
Poor rendering on mobile device	7
Page content only needed once	6
Page content useful only occasionally	2
Already use another version on phone	1

6 Discussion

Our work here focused on one specific challenge to mobile web browsing: the limited input capability of mobile devices. The severity of this issue was confirmed in our first study: nearly half (45.0%) of our survey informants said that entering URLs was a significant problem. We found that informants accessed web pages using direct-link strategies, such as bookmarks, more often than they entered URLs manually. In addition, informants reported visiting fewer web pages on the phone than on the PC. These results suggest that mobile browser enhancements could help users find and navigate to web pages, removing one of the barriers to the use of the mobile web. We have proposed addressing this problem by using information from a user's other devices to improve their experience on a mobile device. Since users frequently divide their work among multiple devices [11], combining information from these devices could yield useful information about users' habits and activities. This may be especially helpful when considering mobile devices, as a user's interactions with a PC, which are relatively unconstrained by input barriers, can be used to provide suggestions or predictions on a mobile device, where input is considerably more difficult.

Results from our second study confirm that sharing web information between devices is a promising strategy. First, our activity logs showed that most of the web domains that participants viewed on their mobile phones were also viewed on their PC. This indicates that users often consult the same information sources across all of their devices. Providing easier access to a user's common information sources might therefore improve usability across devices. Second, during the ESM survey period, participants found 17.4% of the web pages suggested from the PC browsing history to be useful, even though most of these pages had not been previously bookmarked on the phone. We take this number as a conservative estimate of the utility of shared URLs, as participants noted in post-survey feedback that they had marked many pages as not useful because of formatting concerns, and because some of suggested pages, such as frequently visited pages, were found to be considerably more useful than this average rate. Improving the queries used to select URLs from the PC, either through further experimentation or machine learning, could substantially improve the value of

the shared URLs. We conclude from this evidence that a well-chosen subset of URLs from a user's PC can serve as a valuable launch point for a mobile web browser.

One remaining problem is how to select web pages from a PC to share with a mobile device. Improving our understanding of how mobile web users might utilize shared URLs will help us to identify when certain URLs will be useful. Our preliminary results suggest that users may in fact have multiple strategies for using shared URLs. For example, during the follow-up survey, 2 participants mentioned that they used their mobile device to look back at pages that they had already visited on the PC, either to finish reading an article or to look up information about a product that they were intending to purchase. Based on these comments, we might expect that mobile device users would like to revisit pages that they had previously seen on the PC. However, other participants noted that they had rated previously visited pages as not useful because they had already finished reading them. This suggests at least two possible uses for this proposed system: referring back to prior pages, and suggesting new pages or articles based on past history. Additional work is needed to understand the ways in which mobile device owners might use shared URLs, and how technology can support these multiple uses.

It is also important to consider that there may be some usability issues surrounding the integration of work, home, and mobile information spaces. In this study, we instrumented participants' work PCs, and linked this information with their personal mobile devices. In several cases, participants mentioned that they were not interested in having work-related URLs on their phone, although this was not always the case. Although we believe that sharing web information between devices will have a net benefit, future work in this area should explore ways to allow users to partition work and home life.

Finally, it is worth noting that participants frequently encountered difficulties accessing web pages due to poor formatting on their mobile device screen. This issue can often be addressed by using specially formatted mobile pages, which most participants used, or by using mobile web transcoding sites such as Skweezer[3], which were used only by a few participants in our study. Properly formatting mobile web pages remains a significant problem, and technologies that attempt to improve mobile web browsing should consider providing options for reformatting web content for small screens.

7 Future Work

We identify two primary areas for extending this work. First, we intend to use the logging infrastructure that we developed in this study to explore other aspects of cross-device interaction. We have already begun to use this data to explore temporal patterns of use between devices [19]. We might extend this investigation to look at the content of web pages and how they relate across devices, or to include other information tasks such as e-mail and calendar use. We might also compare this data to other contextual features, such as a user's location or the time of day, in order to

[3] http://www.skweezer.com/

reveal deeper patterns of cross-device use. Finally, in this study we were only able to instrument participants' mobile devices and work PCs. Extending this research to include home PCs and other devices may reveal interesting interactions between home, work, and mobile devices.

We are also interested in exploring the development of tools that support mobile web use by sharing web history information between devices. In this study we considered how URLs themselves could be shared, but there are many other ways in which this information could be used to enrich mobile web browsing. Information about a user's web activities on other devices could be used to suggest or complete search queries, provide maps and directions, or recommend reading material during a long trip. Combining web history information with knowledge of a user's context presents further possibilities. For example, a mobile phone application might detect that the user is at a hardware store and present a summary of her recent searches related to home improvement. The infrastructure that we developed for this study will allow us to explore multiple possible designs for such a tool.

8 Conclusion

As mobile devices gain larger screens and faster network connections, they will increasingly be used to search and browse the mobile web. While advances in hardware are improving the mobile web user experience, interaction with the mobile web remains constrained by the limited input capabilities of mobile devices.

In this paper, we have proposed sharing information about a user's activities across multiple devices to improve interactions with a mobile device. This technique allows users to leverage the improved input capabilities of desktop and laptop PCs and to potentially reduce input effort when interacting with a mobile device. The studies described in this paper have focused on sharing web page URLs, but this strategy may generalize to other contexts as well.

The studies presented here provide strong support for sharing web information between PCs and mobile devices. Our survey of 175 smartphone users showed that users already share web information between devices, but rely on cumbersome methods to do so. Our second study showed that many of the web sites that users visit on their mobile devices are also visited on their PCs, and that some additional sites that are visited on the PC only would be considered useful on a mobile device. These results suggest that, even with existing mobile web browsers, sharing specific web information between devices can improve the usability of the mobile web by allowing users to more easily access interesting and useful web sites while on the go.

Acknowledgements. We thank A.J. Brush and Gina Venolia for their assistance in planning the two studies.

References

1. Church, K., Smyth, B.: Understanding Mobile Information Needs. In: MobileHCI '08, pp. 493-494. ACM Press, New York, (2008)
2. Kamvar, M., Baluja, S.: The Role Of Context in Query Input: Using Contextual Signals to Complete Queries on Mobile Devices. In: MobileHCI '07, pp. 405-412. ACM Press, New York, (2007)
3. Sohn, T., Li, K.A., Griswold, W. G., Hollan, J.D.: A Diary Study of Mobile Information Needs. In: CHI '08, pp. 433-442. ACM Press, New York, (2008)
4. Demumieux, R., Losquin, P.: Gather Customer's Real Usage on Mobile Phones. In: MobileHCI '05, pp. 267-270. ACM Press, New York, (2005)
5. Cui, Y., Roto, V.: How People Use the Web on Mobile Devices. In: WWW '08, pp. 905-914. ACM Press, New York, (2008)
6. Lee, I., Kim, J., Kim, J.: Use Contexts for the Mobile Internet: A Longitudinal Study Monitoring Actual Use of Mobile Internet Services. International Journal of Human-Computer Interaction, 18 (3), pp. 269-292. L. Erlbaum, Hillsdale, NJ, (2005)
7. Church, K., Smyth, B., Bradley, K., Cotter, P.: A Large Scale Study of European Mobile Search Behaviour. In: MobileHCI '08, pp. 13-22. ACM Press, New York, (2008)
8. Kamvar, M., Baluja, S.: A Large Scale Study Of Wireless Search Behavior: Google Mobile Search. In: CHI '06, pp. 701-709. ACM Press, New York, (2006)
9. Cohen, D., Herscovici, M., Petruschka, Y., Maarek, Y.S., Soffer, A.: Personalized Pocket Directories for Mobile Devices. In: WWW '02, pp. 627-638. ACM Press, New York, (2002)
10. Panayiotou, C., Samaras, G.: mPERSONA: Personalized Portals for the Wireless User: An Agent Approach. Mobile Networks and Applications, 9 (6), pp. 663-677. Kluwer, Hingham, MA, (2004)
11. Oulasvirta, A., Sumari, L.: Mobile Kits and Laptop Trays: Managing Multiple Devices in Mobile Information Work. In: CHI '07, pp. 1127-1136. ACM Press, New York, (2007)
12. Dearman, D., Pierce, J.S.: "It's on My Other Computer!": Computing with Multiple Devices. In: CHI '08, pp. 767-776. ACM Press, New York, (2008)
13. Potter, S., Nieh, J.: WebPod: Persistent Web Browsing Sessions with Pocketable Storage Devices. In: WWW '05, pp. 603-612. ACM Press, New York, (2005)
14. Morrison, J.B., Pirolli, P., Card, S.K.: A Taxonomic Analysis of What World Wide Web Activities Significantly Impact People's Decisions and Actions. In: Extended Abstracts of CHI '01, pp. 163-164. ACM Press, New York, (2001)
15. Consolvo, S., Walker, M.: Using the Experience Sampling Method to Evaluate Ubicomp Applications. Pervasive Computing, 2 (2), pp. 24-31. IEEE Press, New York, (2003)
16. Brush, A.J.B., Meyers, B.R., Tan, D.S., Czerwinski, M.: Understanding Memory Triggers for Task Tracking. In: CHI '07, pp. 947-950. ACM Press, New York, (2007)
17. Adar, E., Teevan, J., Dumais, S. T.: Large Scale Analysis of Web Revisitation Patterns. In: CHI '08, pp. 1197-1206. ACM Press, New York, (2008)
18. Holm, S.: A Simple Sequentially Rejective Multiple Test Procedure. In: Scandinavian Journal of Statistics, 6 (2), pp. 65-70. Almqvist and Wiksell Periodical Company, Stockholm, (1979)
19. Karlson, A.K., Meyers, B.R., Jacobs, A., Johns, P., Kane, S.K.: (2009). Working Overtime: Patterns of Smartphone and PC Usage in the Day of an Information Worker. To appear in: Pervasive '09. Springer-Verlag, Heidelberg, (2009)