

A Large Scale Study of Wireless Search Behavior: Google Mobile Search

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ABSTRACT

We present a large scale study of search patterns on Google's mobile search interface. Our goal is to understand the current state of wireless search by analyzing over 1 Million hits to Google's mobile search sites. Our study also includes the examination of search queries and the general categories under which they fall. We follow users throughout multiple interactions to determine search behavior; we estimate how long they spend inputting a query, viewing the search results, and how often they click on a search result. We also compare and contrast search patterns between 12-key keypad phones (cellphones), phones with QWERTY keyboards (PDAs) and conventional computers.

Author Keywords

Mobile device, cell phone, wireless, search interface

ACM Classification Keywords

A1. Introductory and Survey

H5.4. Information interfaces and presentation (e.g., HCI):
Hypertext/Hypermedia

INTRODUCTION

Currently over 57% of the U.S. population owns a cellular phone; at the end of 2004, the Cellular Telecommunications and Internet Association (CTIA) estimated the number of cellular subscribers to be 169,467,393 [3]. The growth of cellular subscribers is explosive: trends from June – December 2004 indicate that the number of wireless subscribers in the U.S. has grown by over 2 million per month; the potential impact of wireless applications is

already enormous and is rapidly growing. Just as desktop search¹ has been a gateway to increased consumption of wired data, we believe wireless search – queries performed from a mobile device – will help meet user demands for data access at any time and at any place. Our goal in this paper is to present a snapshot of the current state of mobile search. Understanding the unique needs of mobile searchers and differences between wired and wireless search modes is crucial to improving this service.

In this study, we will present analyses of Google's XHTML search logs and Google's PDA search logs. The XHTML hits originate from conventional cellphones, the vast majority of which have 12-key keypads. The PDA search logs consist of hits from devices which have more sophisticated input mechanisms, such as QWERTY keyboard input or stylus input².

The data set consists of over 1 million page view requests randomly sampled during a 1 month period in 2005. Only English *Web* searches were included in this study³. To eliminate potential 'bot' spam traffic and confounding factors of network latency between different carriers, we restrict our examination to a single large U.S. carrier. All of our data is strictly anonymous; we maintain no data to match a user with an identity. All of the results we report are aggregate statistics.

¹ In this paper, we refer to desktop search as search that originates from either a desktop or laptop computer.

² Mobile users who access google.com will be redirected to either the XHTML site (www.google.com/xhtml) or the PDA site (www.google.com/pda) based on the user-agent reported in their http request. The PDA data set was 20% as large as the XHTML data set.

³ XHTML users are presented with the option of searching four information repositories: *Web*, *Local*, *Image* and *Mobile Web* and PDA users are given the option to search over *Web* and *Image* repositories. The fact that PDA users were not presented with a separate *Local* repository over which to search will be addressed later in this paper.

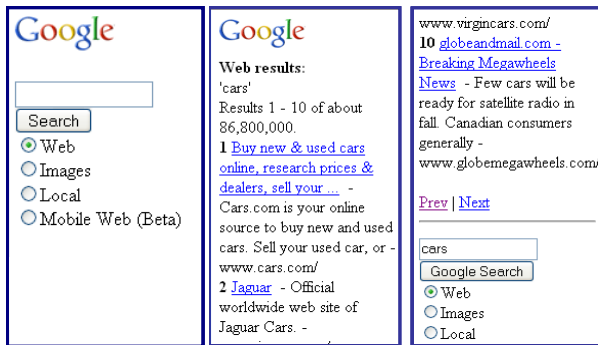


Figure 1: Google's XHTML search interface

RELATED WORK

Several large scale web search studies have been performed in the past [8] [12] [13]. These studies serve to point out the fundamental differences of conventional Information Retrieval (IR) and web search. Importantly, with respect to the study presented here, they provide us with a timeline of the evolution of conventional web search; in particular, they provide insights into query statistics and query categories. Numerous other studies, including those by Schneiderman [11] and Hearst [6], have developed guidelines for designing web search interfaces. Broder [1] and Rose [10] have each manually classified small samples of log data to determine the user-needs driving web queries.

The aforementioned studies have focused on web search with the implicit assumption that the queries were initiated from a conventional computer. Work has been conducted on the mobile web; for example, Jones [9] and Buchanan [2] suggest improvements for the display of information in mobile web searches. However, these are based on small user studies.

The goal of our study is to provide insight, through large scale log analysis, of how and for what purposes the typical user is using mobile-web search. We provide a large number of quantitative statistics to help understand mobile-search usage, and also provide insight, through automatic query categorization, of what topics are searched.

In the next section we describe the Google XHTML and PDA interfaces. We provide an overview of the salient distinctions between these interfaces and Google's desktop search. It is followed by a section detailing statistics related to queries – query length, categorization, etc. We then present an overview of an average user's search session, including timing results, and explore search patterns of users over multiple sessions. We close this paper with conclusions and suggestions for future work.

GOOGLE XHTML & PDA INTERFACES

Google's XHTML interface is shown in Figure 1. The search results presented on the XHTML interface are

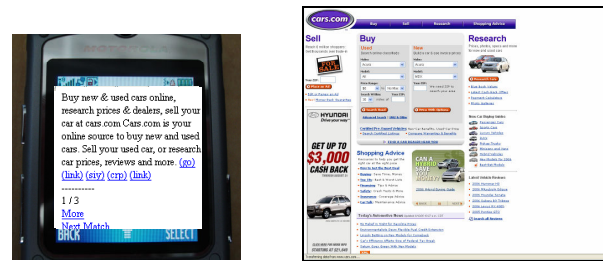


Figure 2: An example wml-transcoded click-through page (left) in contrast to its desktop equivalent

identical to those presented on the desktop (HTML) interface. Both desktop and XHTML interfaces present 10 search results per page. The main differences between the desktop and XHTML interfaces are as follows:

- The XHTML front page has radio buttons instead of tabs to represent the different search types. At the time of this study, *Web*, *Image*, *Local*, and *Mobile Web* searches were available.
- There are no advertisements or sponsored links on the XHTML site.
- The snippets corresponding to a search result may be shorter than those presented on the HTML site.
- XHTML search results have no cached or similar pages links, nor do they indicate page size.
- The user cannot jump to an arbitrary results page. Only the previous and next results pages are available as links.

The most striking difference between the XHTML interface and the desktop interface is the click-through experience. At the time of writing, a click on a search result would be transcoded – the original formatting is altered to fit on the screen with no horizontal scrolling, and a single html page is often split into multiple pages to reduce vertical scrolling. The transcoding also included stripping the resulting page of any non-textual information (Figure 2).

Google's PDA interface is similar to the XHTML interface. There are three main differences: the PDA interface only offers *Web* and *Image* searches, the PDA interface displays the same snippet as desktop search, and no transcoding is performed before displaying a clicked link.

QUERY ANALYSIS

In this section, we will examine the differences between wireless and desktop queries, in terms of content, variety, and descriptive statistics such as length and number of words.

Top-level statistics

To start our analysis, we look at the number of words that comprise typical queries. For the XHTML queries examined in this study, we found the average number of words per query to be 2.3 (median = 2, max = 30, standard

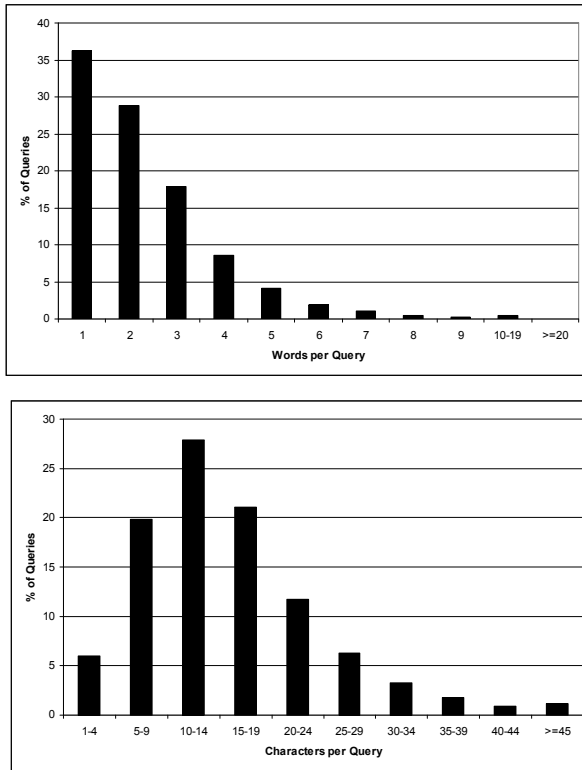


Figure 3: distribution of number of words per query and number of characters per query for XHTML queries

deviation = 1.6), with an average number of 15.5 characters per query (median = 14, max = 502, standard deviation = 9.18). See Figure 3 for the associated histograms.

Interestingly, this is very similar to the statistics published for desktop queries, where the average number of words per query reported are 2.35[8][12] (max = 393, standard deviation = 1.74)[12] and 2.6[13].⁴

As one would expect, PDA users seem to be less concerned about minimizing the length of query terms than cell phone searchers; PDA queries averaged 2.7 words (median = 3, max = 65, standard deviation = 1.5). The length of a query originating from a PDA averages 17.5 characters (median = 16, max = 396, standard deviation = 9.1).

The similarity in median and mean query terms across search mediums, despite the drastically different input techniques used, may suggest that the number of terms per query is a ‘ground truth’ of web search. In fact, a small study done on a speech interface to search [4] also found that the average length of spoken queries to Google was 2.1 terms. Users may have learned how to form queries to get neither too many nor too few search results.

⁴ Note that since the previously published reports on query length appeared, we have seen that query length has increased for desktop searchers.

It is interesting to note that the amount of effort⁵ required to enter a word on a cell phone keypad is more than double the effort required to enter a query on a full QWERTY keyboard. It is impossible from these logs to determine which method of text entry was employed when using Google’s website (i.e. Tegic’s T-9 predictive entry system or multi-tap methods); however, we note anecdotally that many users do not use a predictive entry systems as they are unaware of its existence or prefer multi-tap methods. We found the average query length for queries that only contain the letters a-z and whitespaces (74.0% of our queries) was 14.5 characters. Assuming triple tap input methods, we computed the average number of *key presses* per query to be 30.7 (median = 28, max = 237, standard deviation = 17.8).

Queries which mix alpha-numeric characters and symbols (such as URLs) will necessitate a much larger number of key presses. An astounding 17% of XHTML queries were URLs⁶. This may indicate that users are using the search engine as a bookmark engine since the “address bar” is less discoverable on a phone than on a conventional browser or on a PDA (where only 2% of queries were found to be URLs).

In the future, given that 17% of mobile queries are URLs, it may be beneficial to build address-like behavior into the mobile search box – URL queries could result in going directly to the URL if it is valid instead of presenting the search results listing. This would save the user one click and one roundtrip on their mobile device.

Query Categorization

In this section, we examine the categories of searches users are performing.

Cellphone queries, which comprised 36.4 percent of the logs, were classified into 23 categories, see Table 1. PDA queries were classified using the same technique; the results are shown in Table 2.

The most popular type of query that users performed on the XHTML interface were Adult queries, which are most commonly pornographic queries. Sample queries from this set include: “porn”, “sex”, “free porn”, and “playboy”. Internet & Telecom, and Entertainment queries were popular in both XHTML and PDA search mediums. Internet & Telecom queries include ring tone and wallpaper and site-specific searches such as “free ringtones”, “ebay”, “aim”, “free wallpaper” and “gmail”. Entertainment queries include song lyrics and celebrity searches such as “paris hilton”, “movie times”, “imdb”, and “ticketmaster”.

⁵ Here, effort is measured by the number of keypresses required to enter the query.

⁶ Queries are considered URLs if they start with “http” or “www”, or contain “.com”, “.net”, “.org”.

Categorization	% of all queries	average length of a query	average number of words per query
Total	100	15.5	2.3
Adult	> 20	12.5	2.2
Entertainment	> 10	17.1	2.9
Internet & Telecom	> 5	15.1	2.4
Local Services	> 5	18.8	3.0
Games	> 2	17.5	3.0
Computers & Technology	> 2	14.7	2.4
Lifestyle & Communities	> 2	17.5	2.9
Sports	> 2	15.7	2.6
Health & Beauty	> 2	18.6	2.9
Travel & Recreation	> 2	16.1	2.5
Society	> 2	19.2	2.9
Automotive	< 2	15.7	2.6
Shopping & Consumer Services	< 2	15.2	2.4
Arts & Literature	< 2	18.3	2.9
Food & Drink	< 2	17.0	2.7
Hobbies	< 2	14.8	2.5
News & Current Events	< 2	16.8	2.7
Finance & Insurance	< 2	16.0	2.5
Science	< 2	16.5	2.8
Industries	< 2	15.9	2.5
Home & Garden	< 2	16.3	2.6
Real Estate	< 2	20.0	3.1
Business	< 2	17.2	2.7
Unclassified	> 15	14.4	1.1

Table 1: XHTML query statistics classified by category

In comparison to previously published wired search statistics, [13] ranked the top 3 categories of desktop search to be “Commerce, travel, employment or economy”, “People, places and things” and “Computer or Internet”. Pornographic queries only accounted for less than 10% of the queries. It is also interesting to note that [13] also found that the proportion of pornographic queries declined 50% from 1997 to 2000.

The relatively high percentage of pornographic queries seen in wireless search may be attributed to several factors: Since wireless search is a newer concept than desktop search, it may indeed be following the same trend as with wired searches. The high percentage of pornographic queries may be on a declining curve; only a longitudinal study will verify this. Also, we speculate that people may feel more comfortable querying adult terms on private devices. Anecdotally, we have observed that users often consider their cell phone as a very personal and private device; perhaps even more so than their computer – the probability of others discovering their search behavior

Categorization	% of all queries	average length of a query	average number of words per query
Total	100	17.5	2.7
Local Services	> 15	19.9	3.1
Entertainment	> 5	17.7	3.0
Computers & Technology	> 5	17.0	2.9
Travel & Recreation	> 5	18.4	2.9
Internet & Telecom	> 5	15.4	2.5
Adult	> 5	15.0	2.5
Sports	> 5	17.1	2.8
Food & Drink	> 2	18.4	2.8
Health & Beauty	> 2	17.9	2.7
Society	> 2	20.2	3.0
Automotive	> 2	16.9	2.8
Shopping & Consumer Services	> 2	17.3	2.7
Lifestyle & Communities	> 2	18.1	2.8
Games	> 2	16.8	2.8
News & Current Events	> 2	15.3	2.5
Finance & Insurance	> 2	16.8	2.5
Arts & Literature	> 2	19.1	3.1
Hobbies	< 2	16.8	2.7
Industries	< 2	16.9	2.6
Home & Garden	< 2	19.4	2.9
Science	< 2	18.2	2.9
Real Estate	< 2	21.5	3.2
Business	< 2	19.5	2.9
Unclassified	> 5	13.3	1.5

Table 2: PDA query statistics classified by category

(through cached pages, auto-completion of query terms or URL’S) is smaller. Through user surveys, [5] has found similar user perceptions on the privacy of mobile communication.

There is a noticeable drop in Adult queries from the PDA interface. We suspect this is due the potentially different demographic of users on the site, and to the often business-oriented use cases of these devices.

The relatively small percentage of Local Services queries in XHTML *Web* search may be due to the fact that users would use the *Local* search option for such information, not the *Web* search option. Conversely, the high frequency of Local Services queries in PDA *Web* search may be due to the lack of a separate “Local” search option. It is interesting to note that for both XHTML and PDA queries, the percent

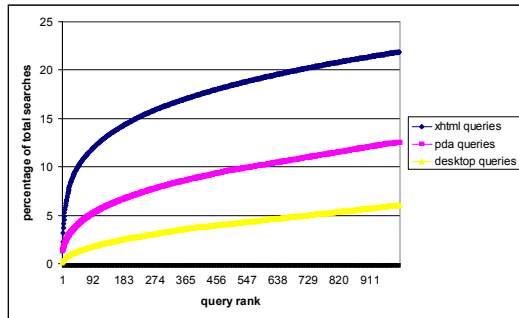


Figure 4: Cumulative percentage of total searches accounted for by the top 1000 queries

of queries which include a zip code⁷ is low; under 1% of all queries from either interface include a zip code. Typing the city and state are a more popular construct for specifying location. As typing city/state often requires more effort than typing 5-digit zip codes, this may indicate that users are performing local services searches outside their home area, where they are unlikely to know the zip code, or that they are simply unaware of the option of entering a zip code.

The average query length, number of words per query, and word length across each categorization are presented in Table 1. Of the categories with a significant percent of queries, the longest queries and most number of words were under in the Local Services category, most likely because a query term and location were entered in the search box. The shortest queries and lowest number of words were in the Adult category, and they tended to be generic pornographic queries.

Although the exact method for classification is beyond the scope of this paper, a brief description of the classification method is provided here. Categories were determined by analyzing interrelated clusters of terms that tend to occur together in www.google.com search sessions. A term within a cluster is weighted by how statistically important it is to the cluster. Clusters can have thousands of terms. The convention is to use the top-weighted terms in each cluster as the cluster name. The cluster name is then fed to a semantic recognition engine which will categorize it into a taxonomy. This type of classifier is used elsewhere in Google and was not created specifically for this study. The results should be considered indicative of percentages; some queries fit multiple categories while other queries did not fit into any category.

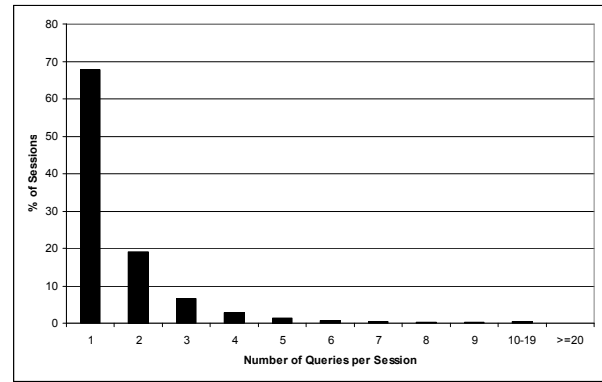


Figure 5: Queries per XHTML session

Query Distributions

Beyond simply looking at the query categorizations as we did in the previous section, we can also examine the variation in the queries. One method to measure this is to examine what percentage of the total query volume is accounted for by the top-N *unique* queries (independent of case and spacing). We took a random sampling of over 50,000 queries from desktop, xhtml and pda searches during a month; Figure 4 examines the distribution of the top N=1..1000 queries.

As can be seen from Figure 4, there is significant variation in the queries entered in wireless search. The top wireless query only accounts for approximately 1.2% of all wireless queries. However, we see that the desktop queries have significantly more variation. The top 1000 XHTML queries account for approximately 22% of all XHTML queries whereas the top 1000 desktop queries account for only approximately 6% of all queries.

One hypothesis is that the homogenous queries are related to the nascent state of the mobile web itself; people may have adapted their queries to those that return “usable” sites. Useable sites are those that have content that will display well on the search medium (e.g. adult content and ring tone sites are “usable” in mobile browsers). Accordingly, desktop browsers are the most advanced, which would lead to a more diverse set of queries. PDA browsers are less advanced, (they can often display HTML but not Javascript), whereas cell phone browsers are the least advanced, often capable of displaying only XHTML content. Another hypothesis for the decrease in query diversity across wireless mediums is that there is a smaller user base that may share similar profiles (e.g. xhtml searchers are likely to be technology savvy, and pda users may be more likely to share a corporate/business oriented profile).

⁷ We consider a term to be a zip code if it consists of 5 consecutive digits [XXXXX] or is of the format [XXXXX-XXXX]

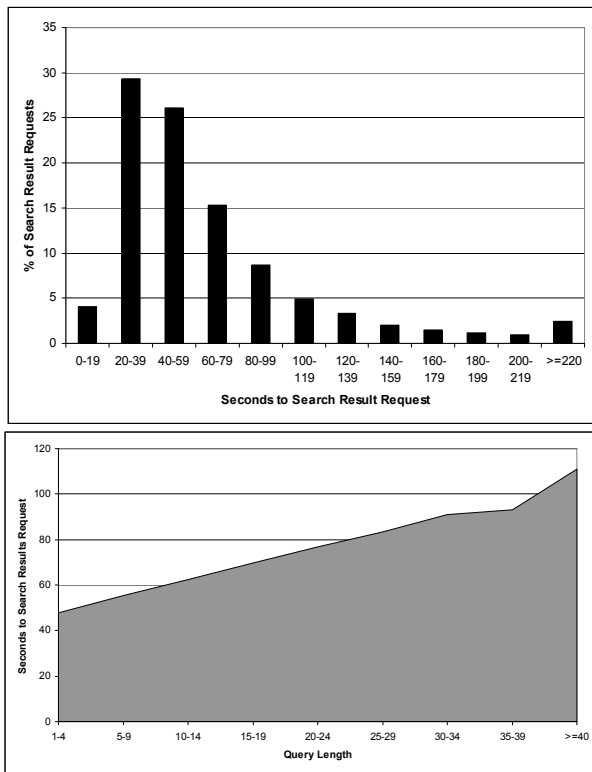


Figure 6: Seconds to result & time spent inputting query from XHTML interface.

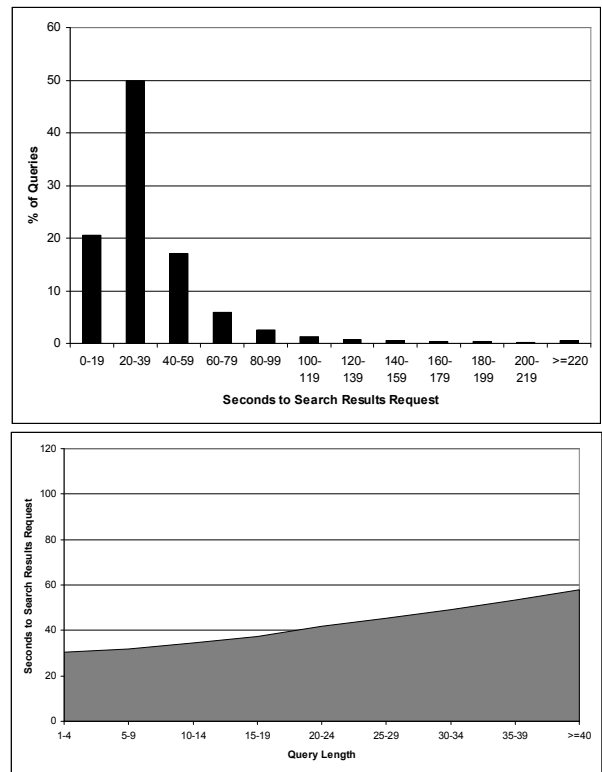


Figure 7: Seconds to result & time spent inputting query on a PDA.

SESSION CHARACTERISTICS

As defined in [12], a session is “a series of queries by a single user made within a small range of time”. We will refer to this range of time as the session delta. Following [12], we will use a session delta of 5 minutes – if no interaction happens within 5 minutes of the previous interaction, a user’s session is deemed closed. The next interaction is considered a separate session.

The cookies used to distinguish users do not contain information to determine the identity or phone number of the user. Not all phone browsers support cookies; 51.3% of our XHTML logs had cookie information. We restrict this section’s analysis to this subset of the logs. Cookies were present in all of the PDA logs.

Queries per Session

The average number of queries per session (disregarding sessions with no queries) for XHTML sessions, is 1.6 (median = 1, max = 43, standard deviation = 1.4). The distributions are shown in Figure 5. PDA queries per session did not vary significantly, but both differ significantly from the previously published desktop search statistics; which have reported 2.02[12], 2.3[13] and 2.84[8] queries per session.

We approximate that the user spends approximately 56-63 seconds inputting a query from a 12-key keypad. We

compute this number by examining the difference in times between the time a user first hits the Google XHTML home page, and the time the first query is received by Google. In detail, this number encompasses the time to download the google.com/xhtml page, to input the query, and to upload the HTTP request to the server. The average difference between the two times was found to be approximately 66.3 seconds (median = 51, max = 300.0, standard deviation = 49.3). We estimate the time to upload and download the content is 3-10 seconds combined. The distribution of timings to search results is shown in Figure 6.

We find that the time to query is proportional to length of query (also shown in Figure 6). Furthermore, we found that time to query is also proportional to ease of input; for queries entered on a PDA device (which often have QWERTY keyboards), the time to input a query decreased to 27 – 35 seconds (Figure 7). The average delta between front page request and search query is 37.8 seconds (median = 29, max = 287, standard deviation = 30.9).

Exploration of Result Links

The click-through rate across all categories was consistently low which suggests users are relying heavily on snippets in wireless search for their information. For those users who did click through, the number of clicks per query averaged 1.7 (median = 1, max = 37, standard deviation = 1.8).

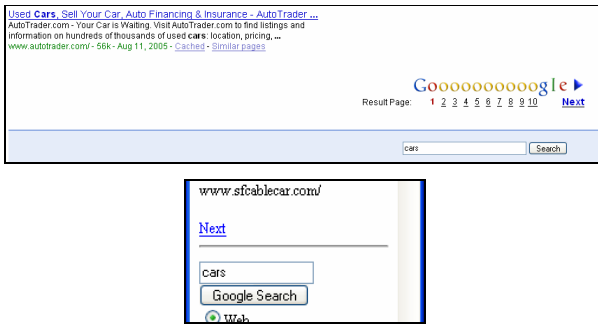


Figure 8: the “More Results” Facility on desktop (top) vs. wireless search (bottom).

Using the same approximation of data upload and download time of 3-10 seconds, we estimate that users who clicked on a request spent an average of 29 – 36 seconds on the search results page before clicking on their first link. The average delta between receiving a search-results request and receiving a click request is: 39.1 seconds (max = 299, median = 30, standard deviation = 36.1).

Only 8.5% of the queries had at least one “more search results” request. For queries that had at least one “more search results” request, the average number of requests viewed was 2.2 (median = 1, max = 82, standard deviation = 3.1) (this means that 3.2 search results pages were viewed per query). It should be noted that we believe this to be the lower bound of users who would like to request more search results; 31.7% of consecutive queries issued were the same query (not a request for more information). We believe users requesting the search results from the same query may be confusing the “Search” button for the “Next” link. As shown in Figure 8, the next link on the wireless page is much smaller and shown with much less context than its desktop equivalent.

Of the XHTML users who requested more search results for a query, they spent an average of 80 - 87 seconds on the search results page before requesting more results. The average delta between receiving a query and requesting more results is 90.7 seconds (median = 72, max = 300, standard deviation = 64.4).

PDA users requested more search results less often (for 3.5% of the queries, with an average of 1.9 and median of 1 “nexts” per query). It took PDA users approximately 15 seconds less to request more results. There seemed to be similar confusion between the next link and search button on this interface.

Both PDA and XHTML page views per query are significantly less than previously published desktop statistics which report the average number of screens viewed per query to be 1.3 (max = 78496, standard deviation = 3.74)[12], 2.21[8], and 1.70[13].

Increasing the session delta to 10 minutes, we get 26.1 % decrease in sessions with at least one query. As expected, the query rate increases to 1.8 queries per session with the median remaining at 1 query per session.

USER PERSISTANCE

In this section, we present two measures of how persistent users are in finding what they are looking for when using wireless search. In the first measure, we look at pairs of consecutive queries, and examine how many of them are refinements.

Of all consecutive queries within an XHTML session, 28.7% are considered a refinement of its previous query. We consider a pair of consecutive queries to be a refinement if:

- query-1 is a substring of query-2,
- query-2 is a substring of query-1,
- the edit distance between query-1 and query-2 is less than half the length of query 2.

In addition to the 28.7% that are refinements, we also consider the 14.0% of consecutive queries which are triggered by a spell check as refinements. As discussed earlier, approximately 31.7 % of consecutive queries are the same. In the remaining XHTML queries, approximately 25% (100.0-(14+32+29)), the second query is not considered to be directly related to the first. From this, we infer that the vast majority of wireless searchers approach queries with a specific topic in mind and their search topics do not often lead to exploration.

There is a similar breakdown for PDA query refinements: 33.6% of consecutive queries were manual refinements, and 11.9% were triggered by a spelling suggestion.

A second measure of persistence that we look at examines user behavior more broadly, by relaxing the requirement of refinements within the same session⁸. In our first experiment, we ask the following question: If a user makes a query in Category-A, what are the chances that the user will make another query in Category-B? Here, we restrict our examination to the set of users who make at least 2 queries within the one month time period that we have examined. Note that there is no requirement for the queries to occur in the same session. The results are shown in Table 3; the sum of the numbers along each row is 100% (only numbers above 3% are shown for clarity).

The most prominent statistics are those along the diagonal. These numbers represent the percentage of people who queried Category-A, then again queried Category-A. The most striking feature of the diagonal is that 34% of the users who queried in the Adult query made a subsequent

⁸ We only considered cell phone (XHTML) users in this analysis.

Category A	adult	entertainment	internet & telecom	local services	games	computers & technology	lifestyle & communities	sports	health & beauty	travel & recreation	society	automotive	shopping & consumer services	arts & literature	food & drink	hobbies	news & current events	finance & insurance	science	industries	home & garden	real estate	business	unclassified	total	
adult	34	11	7	4	3	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	100%	
entertainment	11	22	8	7	3	3	3	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	9	100%
internet & telecom	10	10	24	5	4	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	100%	
local services	6	10	6	18	-	4	4	3	-	4	4	-	-	-	3	-	-	-	-	-	-	-	-	8	100%	
games	9	10	9	5	20	4	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	100%	
computers & technology	7	9	10	7	3	12	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	9	100%	
lifestyle & communities	11	10	6	7	3	4	13	-	3	-	3	-	-	3	-	-	-	-	-	-	-	-	-	8	100%	
sports	8	10	5	8	4	3	3	15	-	3	-	-	-	3	-	-	-	-	-	-	-	-	-	8	100%	
health & beauty	7	10	5	7	-	4	5	-	14	3	4	-	-	3	-	-	-	-	-	-	-	-	-	8	100%	
travel & recreation	5	9	5	12	-	4	3	3	-	12	3	-	-	-	3	-	-	-	-	-	-	-	-	7	100%	
society	6	10	6	9	-	4	5	-	3	3	10	-	-	4	-	-	-	-	-	-	-	-	-	8	100%	
automotive	7	9	6	9	3	5	3	3	-	3	3	13	3	-	-	-	-	-	-	-	-	-	-	8	100%	
shopping & consumer services	8	9	7	8	3	5	4	3	3	3	3	3	11	-	-	-	-	-	-	-	-	-	-	8	100%	
arts & literature	7	12	5	7	3	4	5	3	3	-	4	-	-	10	-	-	-	-	-	-	-	-	-	7	100%	
food & drink	6	10	4	11	-	4	3	3	3	4	3	-	-	3	12	-	-	-	-	-	-	-	-	7	100%	
hobbies	8	11	6	8	3	4	4	-	3	3	3	-	3	3	-	10	-	-	-	-	-	-	-	8	100%	
news & current events	7	10	6	9	3	4	4	3	3	3	4	-	-	3	-	-	9	-	-	-	-	-	-	8	100%	
finance & insurance	4	7	7	9	3	5	3	-	3	3	4	3	-	3	-	-	-	10	-	-	-	-	-	8	100%	
science	6	11	6	8	3	5	4	-	4	3	3	-	-	3	3	-	-	-	9	-	-	-	-	7	100%	
industries	5	9	5	9	-	4	4	3	3	4	4	3	-	3	3	-	-	-	3	7	-	-	-	7	100%	
home & garden	6	9	4	8	-	5	4	3	3	3	4	3	3	3	3	-	-	-	-	-	9	-	-	7	100%	
real estate	5	8	6	13	-	4	3	-	3	4	4	-	3	-	-	-	3	-	-	-	-	7	-	8	100%	
business	5	9	7	9	3	4	4	-	3	3	4	-	3	3	-	-	3	-	-	-	-	-	5	9	100%	
unclassified	12	10	9	6	3	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	100%	

Table 3: The % likelihood that if an XHTML user made a query in category A (listed in the first column) that she also made a query in category B (listed in the top row).

Adult query. In comparison, the next highest category was "Internet & Telecom" with 24%. The lowest self-correlation occurred in the Business category, where only 5% of the users who queried in Business queried another term within that category.

The off-diagonal numbers provide an indication of which categories are often queried by the same people. Some of the strongest matches are between "Adult" and "Lifestyle & Communities", between "Games" & "Internet & Telecom" and "Computers & Technology" and "Internet & Telecom". It should be noted that these overlaps are expected, as the distinctions in the queries that are classified in each of these categories are sometimes quite small, and as mentioned earlier, the classifications themselves should be regarded as indicative of general trends, not necessarily exact fits for all queries.

CONCLUSIONS & FURTHER WORK

Using anonymous log data, we have presented an in-depth examination of wireless search patterns for a major carrier in the United States.

As noted in [8] it is important to mention the strengths weakness a large-scale logs analyses. The strengths lie in the breadth of data on which we perform our analyses. The weaknesses are that these numbers will not tell the story behind a user's experience – we know for what and when a user queried, but we have no context (physical, conversational) which indicates what inspired them to search. We do not know anything about the demographic of wireless users (do men and women approach the wireless web differently?) and not all interaction information is discernable from logs (e.g. input method).

Despite these caveats, this study has presented data on the current state of wireless search, and serves as a benchmark in the nascent world of mobile search. We provided a comparison between previously published desktop web studies and our mobile web study. We found that currently the diversity of queries in mobile is far less than in desktop, although many of the statistics such as words/characters per query remain fairly similar. Interestingly, the top query category is different for each medium used (desktop, pda, mobile). One of the most salient findings towards helping to decide where to focus effort in mobile usability is the enormous amount of effort (in terms of time and keypresses) it takes for users to enter query terms. We suspect that this difficulty may have been one of the major reasons that each session in mobile had significantly fewer queries than sessions initiated on the desktop.

Although query categorizations suggest that users for the most part are searching similar content as desktop queries, the percentage of Adult queries is vastly larger. It will be interesting to follow the wireless query categorization trends over time as wireless search becomes more accessible through cheaper data plans, and more prominent links on the carrier's homepage. Will wireless search categories follow the trend of desktop search queries? At present, we may simply be observing the types of queries that are favored in the early stages of adoption of new technological mediums.

Based on the results seen to date, searchers have directed search goals. Many queries are specific URLs, and within a session, there are few queries. If a session has multiple queries, the likelihood that the queries are a series of refinements suggest that there is currently little exploration in wireless search. This may be an indication that the time it takes to find information on a topic is prohibitively expensive for undirected exploration. If a user is not able to ascertain the information she needs after a single query, the user may be moving on to a different mode of information retrieval. Or, perhaps, the low rate of exploration may simply reflect a limited set of needs while mobile. Although impossible for us to know at this point, we conjecture that both the breadth and depth of information desired while mobile will increase as users become more familiar with the medium and the medium improves.

This study has also opened many questions and avenues for future experimentation:

- Which aspects of a search result (title, snippet, URL, click-through page) are the most important for a wireless user? This must be answered, especially in consideration of the long latencies associated with clicking a link.
- How does interface accessibility change search patterns? At the time of writing, Google's XHTML search interface was not prominently visible on the carrier's deck. It has since gained more visibility. Will this bring

in a wider, more diverse set of users; will they have different search patterns?

- It will be interesting to analyze click-through positions for the clicks – is there an overwhelming tendency to click only the first few search results links? How much does being “below the fold” (items that require a scroll action) reduce the click-through rate.

Finally, repeating this study in other geographies, to examine the differences between search behavior in the U.S. and other countries is the subject of a larger study.

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