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Title	A large scale study of European mobile search behaviour
Authors(s)	Church, Karen; Smyth, Barry; Bradley, Keith; Cotter, Paul
Publication date	2008-09
Publication information	MobileHCI 2008 : Proceedings of the 10th International Conference on Human-Computer Interaction with Mobile Devices and Services
Conference details	Mobile HCI 2008, Amsterdam, 2-5 September 2008
Publisher	ACM Press
Link to online version	http://doi.acm.org/10.1145/1409240.1409243
Item record/more information	http://hdl.handle.net/10197/1211
Publisher's version (DOI)	10.1145/1409240.1409243

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A Large Scale Study of European Mobile Search Behaviour

Karen Church and Barry Smyth
Adaptive Information Cluster
University College Dublin
Belfield, Dublin 4, Ireland
{firstname.lastname}@ucd.ie

Keith Bradley and Paul Cotter
ChangingWorlds
NovaUCD
Belfield, Dublin 4, Ireland
{firstname.lastname}@changingworlds.com

ABSTRACT

Recent evidence suggests that mobile search is becoming an increasingly important way for mobile users to gain access to online information, especially as off-portal content continues to grow rapidly. In this paper we study the characteristics of mobile search by analysing approximately 6 million individual search requests generated by over 260,000 individual mobile searchers over a 7-day period during 2006. We analyse the patterns of queries used by mobile searchers and focus on key characteristics such as the click-thru rates of mobile searches in order to understand, for the first time, just how well mobile search engines are responding to user queries. Moreover, we compare our results to a number of recent mobile studies and highlight some of the key differences between mobile search and traditional Web search behaviours.

Categories and Subject Descriptors

H.3 [Information Systems]: Information Storage and Retrieval

General Terms

Experimentation, Human factors, Measurement

Keywords

Mobile Internet; Mobile Search; Search Behaviour; Click-Thru; Log Analysis

1. INTRODUCTION

A recent report by Ipsos Insight shows that mobile phones are outpacing PCs as the primary mode of information access [9]. As of July 2007, the number of mobile phone subscribers reached an astonishing 3 billion [8]. According to the Ipsos Insight study, globally, 28% of mobile phone subscribers have used their phones to browse the Internet. Given the continued growth in the number of mobile subscribers worldwide and the increase in mobile information access usage, it is likely that the Mobile Internet will rapidly become a vital source of anytime, anywhere access to information for hundreds of millions of users [9].

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MobileHCI September 2-5, 2008, Amsterdam, the Netherlands.
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When it comes to finding information on the Web there is no doubt that search engines dominate as the primary mode of information access with just under 10 billion search queries submitted in November 2007 to the leading search engines [19]. It has not always been this way, however. The early (let's call it the 'pre-Google') Web was characterised by quite a different set of behaviours, with Web portals serving as the primary mode of information access: portals like Yahoo! presented early Web-users with manually-categorised collections of content and most users located content by navigating through the portal's hierarchy of content categories. It is interesting to note that a similar trend exists on the Mobile Internet. Up until recently, the most popular mobile sites were accessed via the branded portals of mobile operators. However, a new report by the Mobile Marketing Association (MMA) shows that the popularity of off-portal content has increased significantly in recent times. For example, in more established mobile markets such as Japan, there are more than 80,000 off-portal sites on NTT DoCoMo's i-mode network while in some European markets, notably the UK and Germany, off-portal data revenues contribute up to 70% of total content revenues [17].

As Web search engines evolved to become better adapted to the search patterns of Web users, the information access behaviour of Web users shifted to rely mainly on query-based search rather than portal navigation. Mobile search has become an increasingly popular way to locate content on the Mobile Internet, especially as off-portal content continues to grow. Today mobile search still only accounts for a small fraction of mobile information access but there is an obvious opportunity for mobile search engines to play a much greater role in the near future. For this to happen, however, we need to better understand the characteristics of mobile search. Mobile search is not the same as traditional Web search, and the reasons for this go far beyond simple explanations such as screen size. Mobile users, on the move, are likely to be interested in locating different types of content, for example. And limitations in screen size, and the type of interactions and input that mobile devices can support, play an important role in shaping the way that mobile users use mobile search engines.

In this paper we describe the results of a detailed analysis of mobile search behaviour of approximately 2.6 million European mobile subscribers, of which 260,000 (approximately 11%) executed at least one search request. This is not the first such mobile search study (see [1, 6, 14, 15]) but it is the most comprehensive study to-date, analysing more than 6,000,000 mobile searches in terms of query patterns and click-thru behaviour. This study is unique in that it is the first to analyse the click-thru behaviour of mobile searchers: where recent analyses have focused on analysing query patterns, this current study investigates how searchers respond to mobile search results in terms of how often the select results and

their navigation behaviour beyond these selected results.

In the following sections we will describe our analysis methodology and highlight our key results. Moreover, we will compare these results to related mobile search studies in order to better understand how mobile search is evolving and we will also compare these results to those of earlier Web search studies in order to understand some of the similarities and differences between mobile and Web search patterns.

2. RELATED WORK

Over the course of the past decade there has been a significant effort devoted to analysing search engine trends and search behaviours with a view to better understanding how users tend to search for information and, ultimately, how search engines might be adapted to better serve these users. For example, Jansen et al. has analysed the query patterns of large numbers of Web searchers, looking in particular at how search behaviour has evolved over the years. See, [11, 12, 13, 23, 24, 26]. Silverstein et al. [20] looked at key query patterns in the AltaVista search engine. More recent research by Beitzel et al. [4] examines the temporal patterns of Web queries while the latest research by Teevan et al. [25] looks at the occurrence of repeat queries in Yahoo! search logs.

As mobile search continues to accelerate there is a similar need to understand the behaviour of mobile searchers and the performance of mobile search engines. Key differences exist between the Mobile Internet and the traditional Web in terms of content, devices, and user needs, and we can expect these differences to impact the way that mobile users seek out information on the move through their mobile devices. Not surprisingly, the emergence of mobile search as new and important information access tool has led to a number of recent complimentary reports on the state of mobile search; see Table 1.

For example, Kamvar and Baluja [14] present the results of an analysis of two Google search logs from 2005: xHTML logs relate mainly to searches originating from mobile phone handsets with conventional input capabilities (e.g., a 12-key keypad); Google's PDA logs relate to searches originating on PDA-like devices with more sophisticated input capabilities (and typically larger screen sizes). The study analysed more than 1 million page view requests and focused on a number of high-level features such as the typical length of search queries, target content, and the relationship between queries and device characteristics. For instance, Kamvar and Baluja [14] highlight *Adult* content as the most popular target content among mobile searchers; a similar observation was made about Web search during its early years [13, 24]. The study also highlights how xHTML queries (generated by the 12-key keypad of traditional phone handsets) contain 2.3 terms on average compared to 2.7 terms for queries generated by PDA's, with their improved text input capabilities. The study also reported how mobile searchers tended to submit fewer queries (1.6 per search session) compared with Web searchers (> 2 queries per session).

More recent research by Kamvar and Baluja into the search patterns of Google mobile users is presented in [15]. Using a similar size dataset, this time dating from 2007, the authors show that mobile search is changing. For example, the average query length in the new dataset is longer (2.6 terms or 16.8 characters). Mobile queries are becoming less homogenous. For example, the top query in 2007 accounted for 0.8% of all queries as opposed to 1.2% in 2005 [14]. Although these findings indicate some signs of evolution in the mobile search space, the authors also found an increase in the volume of adult queries — a trend normally associated with nascent technology. Another interesting finding by the authors is that the percentage of queries which lead to at least one result-

selection rose to over 50% (compared to less than 10% in the previous Google study [14]). Although both the Kamvar and Baluja studies provide interesting insights into mobile search behaviour, in particular for the Google search engine, neither study provides any detailed analysis of search click-through behaviour.

A more recent analysis by Baeza-Yates et al. [1] is focused on the Japanese market, which represents a far more mature Mobile Internet market than either the US or Europe. The study looks at the characteristics of mobile search queries submitted to Yahoo! Japan's mobile search service. The study examines one million mobile queries and compares search behaviour to traditional desktop search behaviour based on a control set of one hundred thousand desktop search queries. The results of the study highlight a close correspondence between the number of terms in mobile queries (2.29 terms per query, on average) compared to desktop queries (2.25 terms per query). However, the study goes on to highlight a larger discrepancy when it comes to the average number of characters per query — 7.9 characters per query for mobile search compared to 9.6 characters per query for desktop search — suggesting that both the physical text input interface and language options have an important role to play. Interestingly, the authors also found significant differences in the type of content being searched for on Yahoo! Japan when compared to other mobile studies. In particular, the most popular mobile search queries related to *Online Shopping*, *Sports* and *Health* in Japan as opposed to the adult content that appears to dominate mobile search in other markets [6, 14, 15]. Once again it is worth highlighting the apparent similarity between this behaviour and search behaviour as it has evolved on the Web over the past few years, with the early dominance of adult content giving way to a broader range of queries relating to entertainment and e-commerce [23]. The Yahoo! Japan study presents some interesting findings about the mobile search behaviour of Japanese users. However, it does not provide any detailed query analysis such query modification trends and it does not provide any insights into the search click-through behaviour of mobile subscribers.

The study presented in this paper builds on previous work by Church et al. [6], which analyses the search habits of approximately 50,000 mobile searchers in late 2005. This previous study is important for a number of reasons. First and foremost, it is the only study to date to analyse the search habits of mobile searchers independently of any single search engine; in fact the study covers the usage of more than 30 different mobile search engines, from Google and Yahoo! to more specialised mobile specific engines [6]. This previous study reported an average of approximately 2.1 terms per mobile search query, overall, but noted a slightly longer query length for queries submitted to Google Mobile. Importantly, this study provided a more in-depth analysis of mobile search queries, exploring how mobile searchers tended to modify and adapt their queries within search sessions. For example, the study reported a high rate of query modification, compared to traditional Web search, with 23% of queries corresponding to modifications of previous queries, and almost half of these modifications involving simple term substitutions. As in the Google study, [14], the Church et al. study [6] also highlighted the prevalence of *Adult* content among the targets of mobile searchers; 50% of the top mobile search queries related to adult content. Finally, it is worth highlighting that the study [6] is unique in that it looks beyond mobile search behaviour to also include browsing or navigation-based information access to allow for a comparison between search and browsing. Importantly, the study was the first to highlight the early-stage nature of mobile search with the vast majority (94%) of mobile sessions devoted to browsing only. Indeed, only 8% of mobile users were found to engage in mobile search at all, although these

<i>Key Parameters</i>	<i>Kamvar & Baluja (2005) [14]</i>	<i>Kamvar & Baluja (2007) [15]</i>	<i>Church et al. (2007) [6]</i>	<i>Baeza-Yates et al. (2007) [1]</i>	<i>Current Study</i>
Coverage					
Regional	US	US	Europe	Japan	Europe
Search Engine	Google	Google	32 search engines	Yahoo!	32 search engines
Analysis Type					
Query (search input)	Y	Y	Y	Y	Y
Click-thru (Search output)	N	N	N	N	Y
Basic Statistics					
Number of Users	N/A	N/A	50,000	N/A	260,000
Number of Search Requests	1,000,000	1,000,000	420,000	N/A	6,000,000
Number of Unique Queries	N/A	N/A	91,000	1,000,000	600,000
Mean Terms per Query	2.3	2.7	2.1	2.3	2.2
Mean Chars per Query	15.5	16.8	13.0	7.9	13.8

Table 1: A comparison of summary statistics (approximate) for existing mobile search studies.

users tended to be involved in much richer sessions in terms of their time spent online, bytes downloaded, etc.

The research presented in this paper represents a significant extension of the Church et al. study [6]. To begin with, the data used corresponds to a much larger sample of usage, reflecting the access patterns of 2.6 million European mobile subscribers over a 7-day period in 2006, corresponding to more than 6 million individual search requests generated by approximately 260,000 unique users. As in the previous study [6] our interest extends beyond any individual search engine and the results reflect the usage of 32 different mobile search engines including Google, Yahoo, TagTag, Click4Wap and Moobl.

Table 1 helps to highlight the contributions of our current work. Firstly, there are key regional differences in how people search for information online and it is important to understand mobile search behaviour from these different regions. Previous studies, for example, have looked at the search behaviour of the US [14] and Japan [1]. The focus of our work is on Europe. Another key difference relates to the type of analyses we have carried out. Most other studies of this nature have focused in the main on search inputs — that is basic query analyses — our current work looks at search outputs as well as search inputs. Specifically we look at detailed query behaviour like query modification and query similarity. More importantly we look at result-selection or click-thru behaviour in this paper - an area within the mobile space that has not been examined by anyone else to date.

The remainder of this paper is organised as follows. In the following section we describe the details of the data used in this study while Section 4 presents our key results. In addition to the usual analysis of search patterns (query statistics such as length, modifications, overlap, etc.) we also, have an opportunity to present an analysis of search click-thru behaviour for the first time, facilitating a detailed analysis of how users respond to mobile search results.

3. SOURCE DATA

The source data used in this study corresponds to the mobile internet activities of over 2.6 million unique European mobile subscribers over a 7-day period in 2006. Adopting similar terminology to [6], we distinguish between two types of mobile session: a *browsing session* corresponds to a sequence of requests generated by a mobile subscriber such that none represent interactions with a search engine; a *search session* refers to a session where there is at least some interaction with a search engine. Each session is made up of a sequence of *requests*, where a request may correspond to a standard page request (in the case of browsing and search sessions),

or the submission of a search query or the selection of a search result (in the case of search sessions). In total the data set includes in excess of 300 million requests made up of the following fields:

- *User ID*: a unique (anonymous) identifier for each user.
- *Timestamp*: the date/time (measured in hours, minutes, seconds and milliseconds) for each request.
- *Url*: the url requested by the subscriber.
- *Status*: the HTTP status code corresponding to the result of the request; including whether the request was successful, whether the user was redirected, etc.
- *Bytes*: the size of the requested page in bytes.
- *Device*: an identifier corresponding to the device used by the subscriber to make a given request. E.g. Nokia 6630, Siemens SK, Motorola V3, etc.

These 300 million requests correspond to approximately 10 million sessions generated by 2.6 million users. If we focus on search behaviour, we find 60 million requests¹ (21%) corresponding to 700,000 (7%) search sessions from 260,000 unique users. This represents a 17% relative increase on the proportion of search sessions reported by [6]². Moreover, it is worth noting that on average approximately 9% of users engage in some mobile search activity on a given day as compared with 8% of users, as reported by [6]; over the course of the full 7 days a total of approximately 10% of users engaged in some form of mobile search.

In this paper we are primarily interested in the search activities of mobile users and so, although the data set includes a wealth of browsing data, we will focus in the main on its 700,000 search sessions. These search sessions correspond to more than 6 million individual mobile searches (that is, 6 million query submissions) using 32 different mobile search engines, from the major services such as Google and Yahoo! to independent WAP search engines such as TagTag, Click4Wap, and Moobl, as well as operator-specific search services (offered through their portals) and specialised

¹A search session is a session that comprises of both browsing and search behaviour. Thus these 60 million requests will include some search-related requests like query submissions and result selections as well as other non-search (i.e. browsing) requests.

²For the purposes of our evaluation a session is defined as a series of web requests by a single user delimited by a 5 minute period of inactivity.

search services such as e-commerce services and ringtone search. The vast majority of the queries were submitted to Google, which captures approximately 85% of mobile search activity.

4. KEY RESULTS

For the purpose of comparison, Table 1 provides a high-level summary of the key statistics extracted from our data set that can be readily related to statistics generated by the recent mobile search studies discussed above [1, 6, 14, 15]. In the remainder of this section we will focus on important elements of search behaviour, specifically, the nature of mobile search queries, search topics, and click-thru behaviour.

4.1 Mobile Search Queries

To date most search studies, in particular recent mobile studies [1, 14], have concentrated almost exclusively on an analysis of the queries searchers use as they search, exploring factors such as query length and the use of advanced search features. In this section we will explore these basic characteristics, comparing European mobile search queries to other similar analyses [1, 14, 15].

4.1.1 Query Length

Table 1 includes summary information on the average length of search queries (terms and characters) found in our new mobile dataset (labeled *current study*) as compared with that found for the other previous mobile studies [1, 6, 14, 15]. Overall we have found mobile search queries to contain approximately 2.2 terms and 13.4 characters on average. This represents a slight increase in terms per query compared to the previous study by Church et al. [6] and is slightly less than the 2.3 terms per query found by the Yahoo! study [1] and earlier Google study [14]. Interestingly, when we focus on just the Google search queries contained within our dataset (representing approximately 85% of the total search queries) we find an average of 2.3 terms (or 14.5 characters) per query, suggesting that Google searches do seem to attract slightly longer queries than searches submitted to other mobile search engines. The average query length for all non-Google queries (i.e. all queries not submitted to Google) is much shorter — 1.5 terms or 9.6 characters. The vast majority of these non-Google queries are submitted via the operator specific search. We noticed that often mobile users availed of the operator-specific search engine as well as other local search engines as a shortcut to Google, submitting the single-term query ‘Google’ instead of directly typing the Google URL into their handset. Also, queries going through the operator specific search are likely to relate to on-portal content items, most of which correspond to high-level portal categories like ‘news’, ‘sport’, etc.

It is interesting to note that despite the text-input challenges presented by mobile devices, mobile searchers do appear to submit similar length queries to those used in Web search, at least during the early years of Web search when average query lengths were reported to be in the region of 2.3 terms [13, 24]. More recently there is some evidence of increasing query lengths in Web search [18].

For completeness, Figure 1 shows the frequency distribution of query lengths (in terms) across unique queries for our current study and previous work by Church et al. [6]. For our current study, the vast majority of our queries are between 1 and 3 terms, with 2-term queries being the most popular query length (approximately 37%). Again, this is consistent with previous findings [1, 6, 14]. Compared to the Church et al. study [6] there is a small decrease in the percentage of 2-term queries set against an increase in the frequency of longer queries with 4, 5, and 6 terms, perhaps suggesting that at least some mobile searchers are having to provide more detailed queries to locate relevant information.

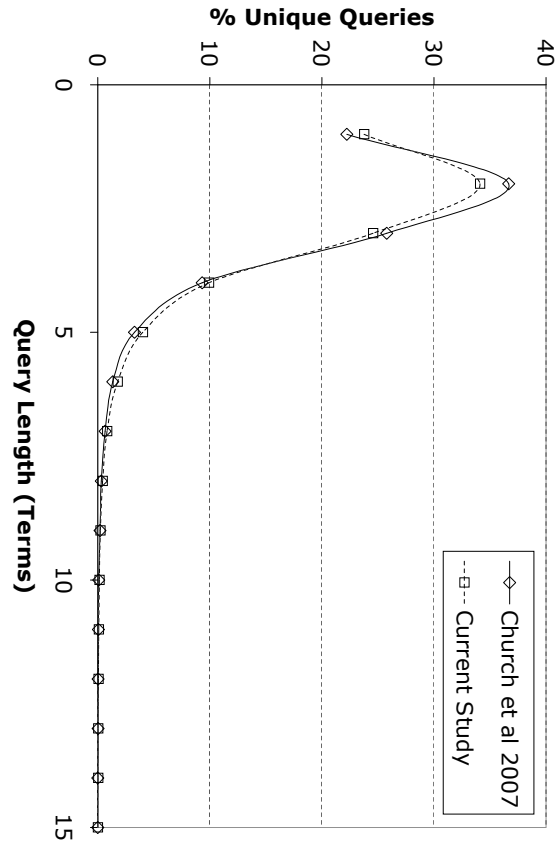


Figure 1: Percentage of unique queries of different lengths.

4.2 From Queries to Searches

It is interesting to analyse the sequences of queries that users submit when searching for information. Often users submit single queries in the hope of quickly locating the information they need. Sometimes however we find users submitting sequences of related queries as they adapt or modify their initial query in an attempt to improve the result-list returned. In this section we will look at this in the context of our mobile search data in order to better understand the typical search patterns of mobile users.

4.2.1 Searches per User per Day

To begin with, Figure 2 presents a graph of the distribution of the daily unique query submissions by users, averaged over the 7-day test period; bear in mind that these users represent only those mobile users (approximately 10% of the full user population) that have engaged in at least some search activity during the test period. The graph shows that more than 50% of these users submit just a single unique query per day – so even those mobile users that do use mobile search, do so on a relatively infrequent basis – with decreasing numbers of users engaging in additional daily search activities; for instance only 16% of search users submit at least 4 unique queries per day.

4.2.2 Query Modifications

The way that searchers modify their queries during a session has long been an interesting feature in Web search analyses [13, 24]. Previously Church et al. examined the query modification behaviour of mobile users [6] and in this section we report on a similar analysis on our much larger data-set to investigate whether there are any significant changes in such behaviour.

Generally speaking, sequences of queries within a single search

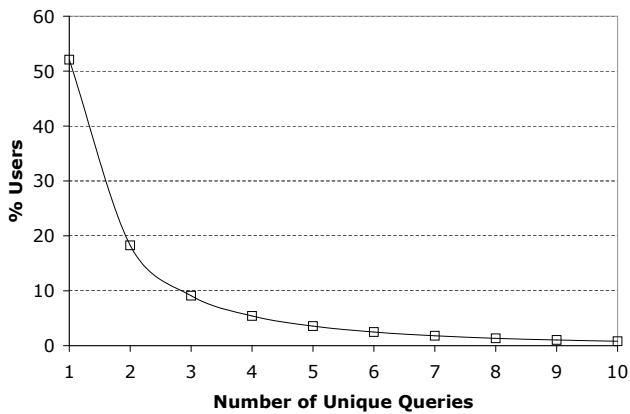


Figure 2: The percentage of users submitting different numbers of unique queries per session per day (averaged over 7-day period analyzed).

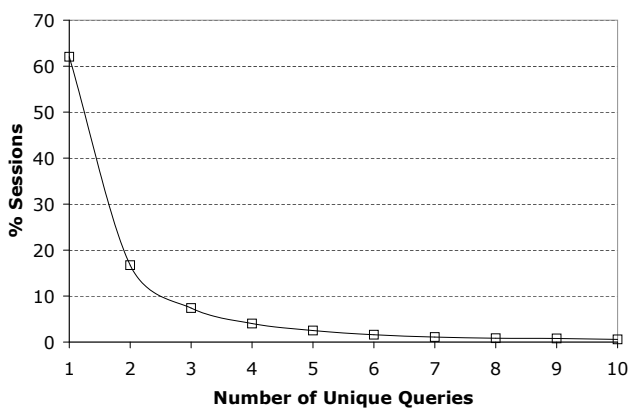


Figure 3: The percentage of mobile search sessions with different numbers of unique queries.

session tend to correspond to the searcher attempting to locate some piece of information by modifying the original query in different ways. In our data-set we found an average session to contain 8.6 queries. This represents a significant increase on the 5.8 queries per session reported by [6] perhaps reflecting that mobile searchers are finding it increasingly difficult to locate their target information. Remember these numbers refer to total query submissions and do not correspond to unique queries. Figure 3 shows the distribution of the number of unique queries per session and we can see that most sessions (approximately 60%) are made up of just a single unique query. This means that many identical queries are being submitted by the user, which largely corresponds, at least in our data-set, to the user selecting a new page of results rather than resubmitting the same query, which we will return to in a moment.

These results also mean that in approximately 40% of sessions, the user enters two or more unique queries highlighting that sequences of queries are quite common in the mobile space and suggesting that mobile users are often modifying or refining their queries throughout their session in order to find exactly what they are looking for. To examine this query modification more closely we classify search queries into one of a number of different types, according to the methodology adopted by [13, 24]:

- *Initial queries* correspond to the first query that occurs in a

search session.

- *Modified queries* are any subsequent queries entered by the same user as part of a given search session. By defining modified queries in this way we are assuming that all queries in a given search session correspond to the same general search objective. Nevertheless it is a reasonable assumption that has been shown to hold in many search sessions and it has been used in prior studies of this nature [13].
- *Identical queries* are queries that occur during a search session but that are the same as a previous initial or modified query. Because of the way in which we analyse our search data, the vast majority of in-session identical queries correspond to a user selecting the next page of search results for a given query, rather than signalling the re-entry of an identical query.
- *Zero-term queries* correspond to searches that are initiated with empty queries.

Query Type	Number of Queries	% of Queries
Initial	99,437	12%
Modified	117,586	14%
Identical	628,992	73%
Zero-term	16,939	2%

Table 2: Initial, modified, identical and zero-term queries (averaged over the 7-day period).

The first thing to note is that the percentage of queries which correspond to the user initiating or refining a search (i.e. initial or modified) has decreased significantly compared to the Church et al. study [6]. Church et al. found that 40% of queries were classified as initial or modified, however this has decreased to just 26% in our study. We can see from the results in Table 2 that mobile search is characterised by a high proportion of identical queries (73%) and is much higher than that found for traditional Web search (43%) [13]. The likely explanation for this is related to the limited screen-space available for result-lists on mobile devices. Remember, in the main these identical queries correspond to the searcher requesting another page of search results. In Web search the norm is for 10 results to be displayed per page. In mobile search it is usual for fewer results per page and thus a mobile searcher will have to request additional result-pages to receive a similar number of results as a Web searcher. Importantly this level of identical queries is significantly higher than the corresponding 58% figure reported by [6] for an early comparable mobile data-set, suggesting once more that mobile searchers are finding it increasingly difficult to locate their target results and having to access more result-pages to do so than was previously the case.

We find that 14% of the mobile search queries correspond to query modifications. This is a significant decrease in the level of relative query modification compared to [6] where 23% of queries were classified as modifications. It is worth examining more closely how searchers are actually modifying their queries. To do this we adopt the methodology used by [13] by counting the change in the number of terms between subsequent queries. Thus, a change of zero indicates that the user modified one or more terms but that the total query length remained the same; that is the user *swapped* one term for another term without changing the query length. Similarly an increase of one term means that one term was added to the preceding query and a decrease of one term means that one term was subtracted from the preceding query.

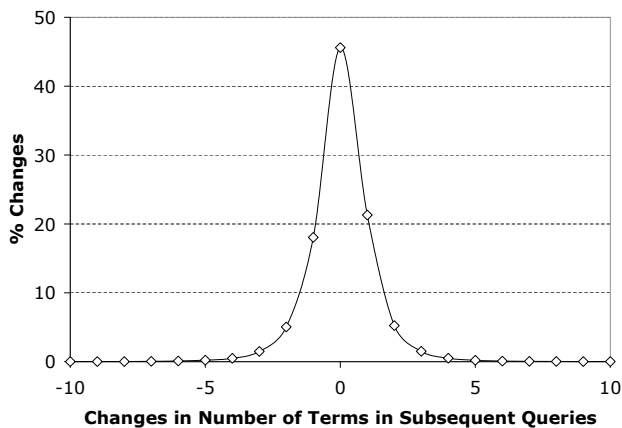


Figure 4: Patterns of query modifications.

For this analysis we concentrated on the 117,586 modified queries contained in our data-set. Figure 4 shows a zero-change for 46% of modified queries. Thus, almost half of the modifications involved the searcher simply *swapping* one term for another. Looking at the remaining modified queries we see that the searcher is adding terms to specialise their query about 28% of the time and removing one or more terms (or generalising their query) about 25% of the time.

In summary then, compared to [6], we have found that mobile searchers are searching through more result pages to locate their target results but they are modifying their search queries less often.

4.2.3 Query Overlap

Recent research has highlighted the importance of understanding the nature of the query vocabulary used by searchers and how this might be analysed in terms of the expected overlap between different queries. For example, the work of [22] highlighted how traditional generic Web search tended to be characterised by broad query vocabularies with limited query overlap. In contrast, niche or community-based search offers a much more limited search vocabulary with far higher query overlap and [22] highlighted how this type of overlap could be exploited to deliver improved search results by effectively harnessing previous search sessions.

In this section we examine this vocabulary issue in the context of mobile search. To measure the overlap between two queries, we compute the degree of overlap between their query terms using Equation 1 following the methodology of [3]. For example, if we take the queries *weather dublin* and *weather london*, we can see that these queries have one term in common out of three unique terms. Therefore, the *overlap* or *query similarity* between the two queries is 0.33.

$$Sim(q_T, q_i) = \frac{|q_T \cap q_i|}{|q_T \cup q_i|} \quad (1)$$

Figure 5 shows the percentage of queries that have overlaps above a certain similarity threshold. In general the results show a high degree of query overlap among mobile queries with approximately 50% of queries with a similarity of ≥ 0.5 . This points to a high level of query repetition and regularity among mobile searchers and suggests that searchers are often searching for similar content within a relatively narrow vocabulary space. While this is not surprising given the results of the next section (which show that certain information topics tend to dominate) it is also important to note that not only are users searching for similar information but they are doing so using similar queries. This regularity can potentially be ex-

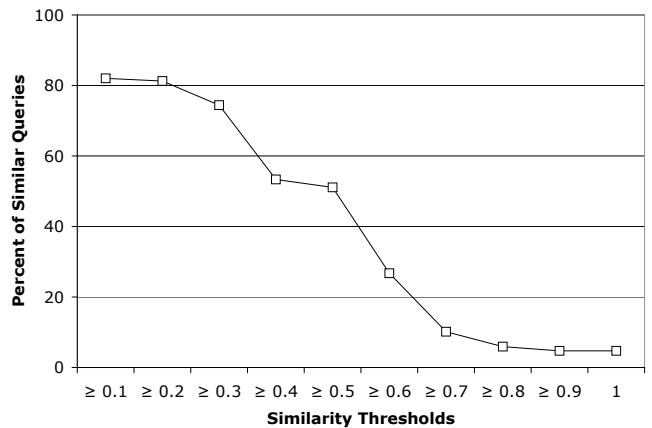


Figure 5: Query overlap: the percentage of similar queries at different similarity thresholds.

ploited and used to improve search performance, as shown by [21, 22] in Web search, and speaks to the value of similar approaches to improving mobile search.

4.3 Search Topics & Information Needs

In this section we examine the topics mobile users search for and the actual intent behind their queries.

4.3.1 Search Topics

A key feature of previous Web search engine analyses has included an investigation of the type of information that users are searching for, with early analyses [13, 20, 24] pointing to the prevalence of searches for adult content but more recent studies highlighting the rapid rise of more mainstream information searches (e.g., entertainment, news, e-commerce) [23] as Web search matured and attracted a broader cross-section of searchers.

The earlier Church et al. mobile search study [6] provided a benchmark set of search target mobile search topics and highlighted the dominance of adult content searches with more than half of the top 500 most popular queries relating to adult content. In this study we adopt a similar methodology, extracting the top 500 queries (in terms of the submission popularity) and manually classifying them according to the content categories shown in Table 3; in fact Table 3 presents the results of the current analysis alongside those results from the earlier Church et al. study [6] for the purpose of comparison.

These latest results show a modest shift in search behaviour. Once again the most popular type of queries were for *adult-related* content, which accounted for 61% of the top 500 queries; interestingly this represents a near 20% relative increase on the previous results reported by [6]. This increase in adult searches is largely at the expense of more mainstream search categories, with searches for *entertainment, multimedia, and games* all showing marked declines in popularity. Interestingly, we do note the emergence of a new search category in these latest results, with 1.1% of searches relating to user-generated content (blogs, etc.); somewhat related *social* search topics such as *email, messaging & chat* and *socializing/dating* are also on the increase perhaps suggesting the beginning of an interesting trend.

In summary, while there seems to have been some shift in the search interests of users, it seems clear that mobile search is still in its infancy and that it is largely being used by a niche group of users with niche interests; not surprising given that mobile search

Category	% Top 500 Queries [6] (Church et al 2007)	% Top 500 Queries (Current Study)
Adult	53.5	61.2
Email, Messaging & Chat	8.4	9.1
Search & Finding Things	8.4	7.2
Entertainment	8.1	5.9
Multimedia	10.4	5
Socializing/Dating	1.8	2.2
Sport	1.1	2.2
Shopping & eCommerce	1.6	2.1
Games	2.5	1.5
User Generated Content (UGC)	0	1.1
Unknown/Unclassified	1.9	0.7
Mobile Applications, Websites & Technologies	1.4	0.7
Information	0.3	0.6
Auto	0.3	0.2
News/Weather	0.3	0.1
Employment	0.1	0.1
Local Services	0.3	0.1

Table 3: A comparison of the top 500 queries (averaged over 7-days) classified by query category for the current study and the Church et al. study.

still only accounts for just over 20% of all Mobile Internet activity (in terms of requests) and only between 8-10% of users avail of mobile search on a regular basis. Similar behaviour was of course the norm during the early days of Web search but rapidly gave way to more mainstream searches as Web search appealed to a broader user-base [23]. Many believe that a similar effect will come to be felt in relation to mobile search but whether this turns out to be true remains to be seen.

4.3.2 Classifying Information Needs

In this section we examine the user intent or goal behind the mobile search queries. Early work by Broder [5] classified Web queries according to their intent using three taxonomies: (1) Navigational, (2) Informational and (3) Transactional.

Navigational queries refer to a class of queries where the immediate intent is to reach a particular site. For example, queries that contain a company, business or organization names and queries that contain domain suffixes (.com, .net, etc) are all types of navigational queries. However, in our analysis we do not assign celebrity names into this category. The reason is that a search for a given celebrity is likely to result in a variety of websites, for example, fan club sites, media sites, news sites, etc. Thus it is unlikely that a user entering such a query has a single website in mind.

Informational queries are those that involve the user attempting to find information online - that is, the user is probably interested in reading this information online but no further interaction is expected. Finally *transactional* queries refer to queries in which the purpose is to visit a site where additional interactions will occur. For example, shopping, downloading files (images, videos, music, etc.), gaming, etc. In our analysis we also group all porn/adult-related queries into this category.

To carry out the taxonomy analysis, we chose a single day from our dataset at random, extracted the top 500 queries for the specified day and manually assigned each query to one of the three taxonomies mentioned above. We can see from Table 4 that the intent behind the majority of the top queries is *transactional* (> 60%). This is perhaps expected given the high volume of adult queries found within the top 500 in our dataset. The volume of transactional queries on the Web tends to be much lower (i.e. approx.

9% [10]). It is also interesting to note that a high proportion (> 29%) of queries are *navigational* in nature, that is where the user goal or intent is to reach a particular site or service of interest. In general Web search the percentage of navigational queries is significant. For example, recent work by Jansen et al. [10] shows that > 10% of queries are navigational in nature. However our results indicate that navigational queries in the mobile space may be even more important. Overall we found a low percentage of informational queries within our dataset (approx. 10%). It is likely that the reason for such a low proportion of informational queries is because people don't traditional search for general information online using their mobiles, but rather look for something very specific (transactional or navigational).

Taxonomy	% Top 500 Queries
Informational	10.2%
Navigational	29.4%
Transactional	60.4%

Table 4: Results of Classifying Queries by Search Goals/Intent

4.4 Query Variation

In this section we look at the variation among search queries to gain some insight into the current state of mobile search. Kamvar & Baluja [14, 15] previously examined variation among mobile queries in Google's XHTML search service. The approach followed by Kamvar & Baluja is to extract the top 1000 most popular queries from the dataset and calculate what percentage of the total query volume these top 1000 queries represent (independent of case). In the first Google study [14], they found the top query out of the entire dataset accounted for approx. 1.2%, while the top 1000 queries accounted for approx. 22%. In their subsequent analysis using data from 2007 [15], the authors found that the variation amongst queries decreased significantly showing that Google mobile queries are becoming less homogeneous. Thus the top query accounted for just 0.6% while the top 1000 queries accounted for approx. 17%.

We thought it would be interesting to carry out a similar analysis to determine if the queries within our dataset were more or less homogeneous when compared to the Google study. To carry out

this analysis we chose one of the days at random from the 7-day test period and focused on the top 500 rather than the top 1000 queries in our data set. Figure 6 shows that there is significant variation found within the mobile queries we analysed. We found that the top query for that day accounts for 2% of all queries while the top 500 queries account for approximately 26% of all queries. However, this also indicates that there is far less variation among queries in our dataset when compared to the Google study. The queries within our dataset appear more homogeneous. Homogeneous queries tend to relate to the nascent state of the mobile Web however, when we consider the fact that the query variation results for our study were much lower than even the earliest Google study (which used data generated in 2005), this might also indicate that European users are more likely to search for similar things or perhaps they have more similar interests when compared to US users.

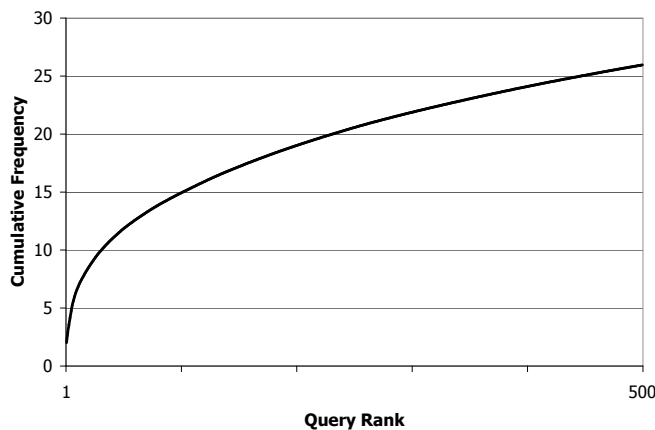


Figure 6: Query variation: shows the cumulative percentage of total queries accounted for by the top 500 queries

4.5 Click-Thru Analysis

Obviously there are two-sides to understanding search behaviour. On the one hand it is important to understand the queries that subscribers use, but on the other hand it is equally important to understand how they interact with the search results returned by a search engine. Past search analyses have tended to focus exclusively on the former, with relatively little analysis of the latter. In fact none of the previous mobile search studies have provided any detailed analyses of mobile search click-thru behaviour. One of the advantages of the data-set used in this study is that it includes click-thru data associated with Google's mobile searches (which corresponds to approximately 85% of the search activity) and as such accommodates a detailed analysis of the click-thru behaviour of searchers.

Click-thru or result-selection behaviour is important because it tells us about the perceived relevance of search results and the ability of search engines to deliver good results to searchers. Obviously, not every result that is selected is relevant to the searcher, but the lack of any selections at all is a strong indication that the search results have not provided the users with answers. To date very little is known about the result-selection behaviour of mobile searchers. How often mobile searchers select results and the position of their selections in the result-lists are just two of the questions that need to be considered.

4.5.1 Successful vs Failed Searches

Researchers often use click-thru information as a crude proxy for *search success*. The work of [22] refers to a query that fails to at-

tract any result selections as a *failed session*, where as the converse (where the search results in at least one result-selection) are referred to (somewhat optimistically) as *successful sessions*. Adopting the same terminology here we find that approximately 12% of the (Google) *queries* are *successful*; in other words for almost 90% of queries no results are selected. Examining the percentage of unique Google queries, we find approximately 24% lead to at least one click-thru suggesting that there is significant room for improvement.

In this study we refer to a session as a sequence of actions performed by the same user within some continuous period of time. When we focus on *sessions*, we find that 41% lead to the selection of at least one search results. While looking at the percent of users who click on at least one result, we find just 25% of users engage in click-thru behaviour.

This is clearly a negative result as the lack of result selections for almost 60% of sessions and 88% of queries strongly suggests that the vast majority of result-lists are failing to attract searcher attention. This is a significant departure from related studies in traditional Web search. For example, [21] suggests that the percentage of successful queries in Web search is 56% (out comparable figure was as low as 12%). One possible reason for the low percentage of click-thru in the mobile domain is that the searcher might locate the information that they are seeking without having to select a result – For example, perhaps the relevant information is present within a result snippet; or for adult-related searches, perhaps the information need is satisfied via a thumbnail image displayed on the result page. Although this is plausible in some cases, it seems unlikely that almost 90% of mobile searches can be answered without clicking on a result, especially considering our earlier query taxonomy results in which approximately 29% of the top 500 searches were navigational queries (see Section 4.3.2). Thus we would conclude that the above result most likely serves to highlight the limited service that mobile search engines currently provide mobile searchers.

4.5.2 Result Selections and Positions

When we examine successful search queries, thus focusing on those queries that did manage to attract at least one result selection, we find an average of 3.5 clicks per query (unique queries) and 5.4 clicks per user. Figure 7 shows the distribution of result-selection frequency across users. The graph clearly shows a skewed distribution with almost half of users selecting just one or two results.

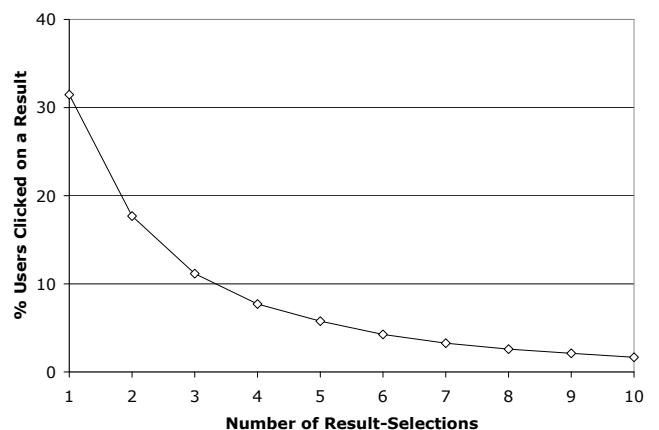


Figure 7: The distribution of result-selections across users who clicked on at least one result.

Another interesting characteristic of result selections is their po-

sition within the result-list. This is particularly important in the mobile space. Small screens and limited interaction capabilities means that scrolling through long results lists is a laborious and frustrating task and so mobile search engines must be especially careful to present relevant results close to the top of a result-list. We found that the average position of a result-selection is 6, with users having to navigate an average of 1.3 result-list pages before clicking on a result. When we examine the distribution of result-selections at various result-list positions (See Figure 8), we find that more than 60% of the result selections are among the top 3 positions³. This selection profile is similar to that found for Web search engines, although general Web search users are far more likely to select results in the first position in the result-list. For example earlier work by Baeza-Yates et al. [2] shows that in general Web search > 50% of result-selections occur at position one in the result-list. Whether this means that the Web search engines are correctly ranking results according to their relevance or that users are just inherently more likely to select top-ranked results remains to be seen. Certainly, recent analyses in Web search [16] suggest that the latter is often the case.

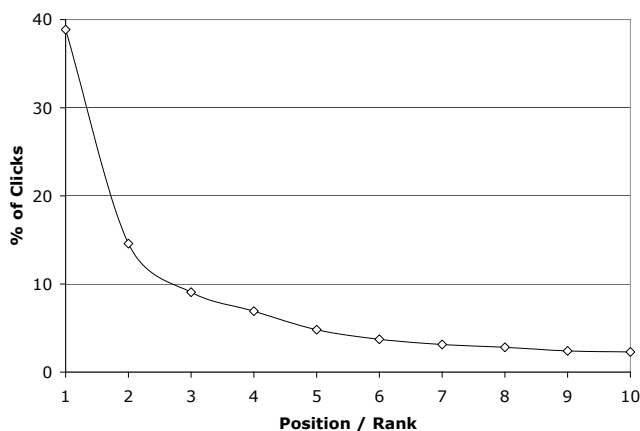


Figure 8: The distribution of the position or rank of user clicks.

4.5.3 Beyond the Results Page

In Web search it is well known that searchers often have to navigate beyond a relevant search result if they are to find the information they need. For example, it is not uncommon for searchers to follow a sequence of 2 or 3 links from a search result page before finding their target information [7]. Thus suggesting that Web search engines do a good job when it comes to “lead generation” but do not always bring users directly to the information they need. We refer to this type of behaviour as a *follow-on*, that is when a user selects a result from the set of results returned by a search engine, and then proceeds to navigate further beyond the search result page. It is interesting to investigate how frequently users exhibit follow-on behaviour during mobile search.

Figure 9 presents the distribution of follow-ons for successful search sessions. We can see that 35% of result selections lead to follow-on browsing with an average trail length of approximately 2.7 (standard deviation 8.8). We also find some dedicated users navigating over 10 links from the result page. However the graph

³The position of a result is calculated per-query, that is across multiple pages. So for example, a position of 3 is the third result on the first result page where as a position of 13 is the third result on the second result page (each result page displays 10 results).

also shows that for the majority of sessions (65%) the searcher selects a result and goes no further. Perhaps this indicates that the searcher does find their target information on the selected result page. Alternatively it may indicate that many users judge a result selection page to be irrelevant and quickly move on to another result in the result-list. Clearly there is a need for a more detailed investigation of this behaviour in order to better understand this user behaviour.

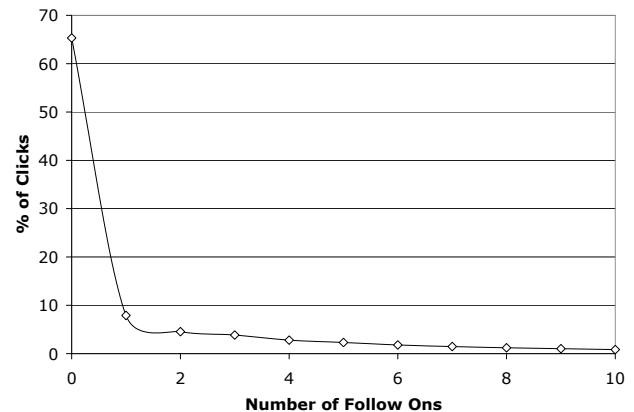


Figure 9: The distribution of the number of follow-ons per click.

In summary the above click-thru analysis suggests a very negative mobile search user experience for searchers: with almost 90% of searches failing to attract any result-selections at all, it looks like the search needs of mobile users are not being adequately addressed by current mobile search engines suggesting that the current approach of superficially adapting Web search engines to work on the mobile Internet is not proving to be fruitful.

5. CONCLUSIONS

In this paper we have presented a comprehensive study of mobile search, encompassing more mobile searchers, queries, and search engines than any other study to date. In addition we have gone beyond the traditional analysis of search queries to include a unique analysis of result click-thrus. Our overall conclusions can be summed up as follows:

1. Mobile search is still in its infancy: it is regularly used by only 8-10% of mobile internet users and represents just over 20% of all Mobile Internet activity.
2. The early adopters that are availing of mobile search have niche information needs and, as in the early days of Web search, adult queries dominate.
3. Mobile searchers tend to search in ways that appear to be similar (at least on the surface) to the way that they search on the Web: queries are short (even shorter than Web search queries) and users tend to focus on the first few search results (even more so than on the Web).
4. However, the topics and taxonomies (or user intent) of mobile queries are quite different. Adult-content is still prevalent and we found a high incidence of transactional and navigation queries in the dataset.
5. Mobile search engines have largely adopted a conventional Web-based approach to search, but this is failing to deliver a high-quality user experience: the vast majority of searches

(almost 90%) fail to attract result selections from the searcher, a strong indicator that the searcher is failing to find relevant information within the result-list.

Mobile search is on the rise but clearly there are significant challenges when it comes to delivering relevant results to mobile users. Certainly the high percentage of failed search sessions is a cause for concern but at the same time there is cause for optimism. We believe that many of the problems with the current generation of mobile search engines stem from their misguided adoption of a very traditional Web search interface, adapted to fit the small screen. To be successful mobile search interfaces must look beyond simple screen real-estate to embrace the many advantages that mobile devices have to offer. For example, the personal nature of mobile devices offers significant advantages when it comes to personalizing search. Moreover, location-sensing technologies allow new types of context to be introduced into the search experience. And of course the arrival of next-generation touch-based displays offers a whole new set of interaction modalities. By harnessing such features the new generation of mobile search engines will offer a more meaningful and relevant mobile service to users on the go.

6. ACKNOWLEDGEMENTS

This material is based on works supported by the Science Foundation Ireland under Grant No. 03/IN.3/I361.

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