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Needs of Mobile Users**

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Contextual Queries and Situated Information Needs of Mobile Users

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Abstract

The users of mobile devices increasingly use networked services to address their information needs. Questions asked by mobile users are strongly influenced by contextual factors such as location, conversation and activity. We report on a diary study performed to better understand mobile information needs.

Participants' diary entries are used as a basis for discussing the geographical and situational context in which mobile information behaviour occurs. The suitability of user queries to be answered by a portable knowledge collection and web search are also considered.

We find that the type of questions recorded by participants varies across their locations, with differences between home, shopping and in-car contexts. These variations occur both in the query terms and in the form of desired answers. Both the location of queries and the participants' activities affected participants' questions. When information needs were affected by both location and activity, they tended to be strongly affected by both factors. The overall picture that emerges is one of multiple contextual influences interacting to shape mobile information needs. Mobile devices that attempt to adapt to users' context will need to account for a rich variety of situational factors.

1 Introduction

The popularity of mobile devices makes it now common to see people address their information needs in-situ, using services such as web search or digital maps. The growth of mobile activities has been accompanied by devices that can sense more features of their environment, including location, orientation, temperature and lighting. Designers combine this ambient information with other data to enable devices to adapt their capabilities to the user's context. In this paper, we examine the information needs of mobile users to inform the design of mobile information search applications.

Information needs are, by their nature, ubiquitous: they can arise on any topic, at any time and in any location. The rapid spread of mobile devices means that it is now common to see users attempt to address their needs as they occur, through services such as web search or digital maps. Previous work shows that many of these mobile information needs are never satisfied, often being postponed and abandoned [25]. Context-adaptation provides a potential mechanism for portable devices to bridge this gap between actual and satisfied needs. We use a diary study to investigate how contextual factors affect mobile information needs and how they can be exploited to enhance application effectiveness.

Library-specific mobile applications include digital reference services [19, 12], navigation aids for physical library environments [1] and portable knowledge collections [5, 13, 12]. Mobile devices allows users more flexibility in their information behaviour, but also provides new opportunities for library-based services.

In this paper, we explore mobile information needs through a diary study and discuss how the participants' geographical and situational context influences their queries.

Section 2 outlines previous work in the area. We then describe our study methodology in Section 3, followed by an analysis of the results from several perspectives in Section 4. In Section 5, we discuss the implications of the results for context-aware applications. We conclude with the key contributions and ideas for future work.

2 Background

Variable elements of contexts include location, time, social situations and the connectivity or services available from the device [15]. New device functionality enables users to change their behaviour, to plan activities less (as connectivity enables dynamic re-planning), to rely on device-maps (rather than paper ones) and to use their time in different manners (such as device use when commuting). When mobile users become accustomed to ubiquitous connectivity, they have the potential to satisfy their information needs through mobile web search (e.g. [2, 16]).

To understand mobile users' information search behaviour, researchers have followed two main paths: analysis of logs of actual mobile search queries (e.g. [16, 9]), and user-centred approaches such as diaries [25, 9, 2, 11, 15, 22], shadowing [21] and interviews [15, 10, 2]. Query logs are a valuable resource but the "numbers don't tell the story behind a user's experience—we know for what and when a user queried, but have no context for what inspired the search" [16]. To complement log analysis results, small-scale qualitative methods have been used to study the context of users' mobile queries (e.g. [25, 9, 2, 11, 20, 22]).

Kamvar and Baluja [16], using a million queries on Google Mobile, report that average queries were 2.56 words, 16.8 characters and estimate query construction at about 40 seconds. On average, sessions contained two queries and substantial iterative query refinement occurred. Query logs are a valuable re-

source but the “numbers don’t tell the story behind a user’s experience—we know for what and when a user queried, but have no context for what inspired the search” [16].

The importance of understanding the context of mobile device use is highlighted by Sohn et al’s [25] finding that 72% of their participants’ information needs “were prompted by some contextual factor”, including their location, the time, a conversation or their current activity. However, Nylander et al. [22] note that the “classic example” of “finding out something about the location you are in” represented only 15% of their data.

Mobile information studies often group users’ queries into broad categories (e.g., ‘information seeking’, ‘communication’ and ‘content’ [10]); ‘information seeking’ is then further divided into ‘fact-finding’, ‘information gathering’ and ‘casual browsing’. These categories vary across studies [22, 25], for example: ‘informational’, ‘geographical’ and ‘personal information management’ [9] or ‘fact-finding’, ‘information gathering’ and ‘non-goal oriented’ [2].

Studies of mobile information behaviour vary in their classification of topics. However, those frequently reported include: news, travel & transport, entertainment, trivia, shopping and food & drink [17, 22, 25, 9, 2, 11]. Mobile query log analyses also record ‘adult’ searches [17, 16], which appear not to be reported in the qualitative studies, thus illustrating the value of using a variety of research methods.

Despite the growth in mobile search, issues such as a lack of ubiquitous connectivity has a strong effect on users: “the top reason participants gave for deciding to address a need later, was the lack of internet access at the time (32%)” [25].

The importance of understanding the details surrounding mobile device use is highlighted by Sohn et al.’s [25] finding that 72% of their participants’ information needs “were prompted by some contextual factor”. Most of the participants in their study also admitted that their desire to satisfy their information need had led them to multi-task their device use with driving a vehicle. Church & Smyth noted that geographical terms increased significantly when their participants were ‘mobile’ [9].

Lee et al. [18] reported that “most of the time mobile Internet services were used in a public place, without any social interaction, while not moving, and when off duty”, whereas more recent work emphasises the social influences on users’ usage (e.g. [25, 27, 11, 20]). Amin et al. [2] report that 2/3 of their participants’ (location-based) queries were to satisfy a “spontaneous need” and 75% were made in social situations.

Several studies [2, 9, 11, 25, 22] report that location context had a significant impact on their participant’s mobile information needs. Location can influence use in several ways: the choice of which device to use [22], the geographical terms used in queries [9] and the geographical areas most likely to be query targets [2]. Location context can be the most important factor driving contextual information needs [25], however Nylander et al. [22] report that the classic example of “finding out something about the location you are in” represents only 15% of their data.

Mobile query studies often group queries into broad categories, e.g. ‘information seeking’, ‘communication’ and ‘content’ [10]; ‘information seeking’ is then further divided into ‘fact-finding’, ‘information gathering’ and ‘casual browsing’. These categories vary across studies, for example: ‘informational’, ‘geographical’ and ‘personal information management’ [9] and ‘fact-finding’, ‘information gathering’ and ‘non-goal oriented’ [2]. However other studies use either more fine-grained or orthogonal categorisations [22, 25].

The distribution of mobile search topics reported in other studies is difficult to compare as different categories have been used; frequent topics typically include: news, travel & transport, entertainment, trivia, shopping and food & drink [17, 22, 25, 9, 2, 11]. Mobile query log analyses also record ‘adult’ searches [17, 16], which appear not to be reported in the qualitative studies; illustrating the value of using a variety of research methods.

Most of the studies agree that context and location matters, though they do not necessarily agree on their particular influence. A significant number of queries are found to be context-free (i.e., fact-finding) queries. The query topics that were identified in the studies vary, but a high degree of commonality can be observed. Overall, there is a lot of variation in the results that have been obtained by the studies. It is often hard to tell whether the differences between the studies are due to differing participant groups, or study methodology used for the study organisation, or the analytic approach.

Studies on information needs have generally used mobile devices that require connectivity to access remote services, the alternative approach of self-contained portable libraries has received relatively little attention [5, 6]. This alternative vision is simply: “imagine being able to carry a library around in your pocket. Full fingertip access through searching and browsing to millions of items: text, image, audio, video, wherever you are” [5].

Although portable personal media libraries, as typified by iPod music collections, are common, they don’t provide the breadth or variety of resources necessary for most queries. One study of mobile information behaviour “found that Wikipedia emerged as a major fact-finding platform” [10]. The storage requirements of the compressed text of the roughly three million articles in the English Wikipedia can be stored in 10 GB [5] but storing all the multimedia objects is probably too costly for currently hand-held devices. A recent small study [13] used a text version of Wikipedia on an iPod, reporting that it was used infrequently and mainly for ‘recreational’ searches. A text-only version of Wikipedia has also recently been released in a dedicated portable device selling for US\$99, the WikiReader (thewikireader.com).

In summary, previous work indicates that information needs of mobile device users were often “postponed or unaddressed” [25] due to a wide variety of factors, including location and context. To further explore these factors influencing the design of both services and portable libraries, we use a diary study for investigating situated information needs.

3 Study Methodology

We performed a small pilot study and a full user study, both using paper diaries. The main difference of our study to the ones reported above is that we did not use the support of electronic devices, such as mobile phones or laptops.

Pilot study We used a small pilot study to explore our initial ideas. We devised a diary study to record date and location of the question, the query itself, the type of question, and whether or not the query is related to the current location. For the query type, we distinguished between (a) questions for which the participant needs the answer immediately and the answer affects the participant’s activity (for example, when driving to a restaurant and asking for the nearest free car park), and (b) questions that express the participant’s curiosity about something they saw, where the answer does not necessarily affect their current activity (for example, when sharing a cake with friends to enquire about the recipe of the cake).

The results of the initial study with three users encouraged us to do a diary study with more participants. We used the results of the pilot to improve the diary design: We observed that the relationship to the place cannot be adequately answered in a Boolean fashion. We instead introduced a 5-point scale indicating the strength of relationship between the question and the place. The question about query type seemed to be unclear and did not find clear agreement about the semantics. In the full study we therefore translated it into a question about the relationship between query and activity, thus moving the determination of the type of question from participant to analyst. We also reduced the size of the diary pages to pocket size (8.5 *14.5 cm) for ease of use.

Main User study Several previous studies [25, 2, 22] have used diary-study approaches based on mobile devices to investigate situated information needs. To encourage participants to make diary entries studies have used regular reminders (e.g., txt messages) [25, 2, 9, 11] or monetary incentives [25]. We chose to return to a paper-based diary methodology to attempt to remove influences from the devices themselves and not to interrupt or reward participants. Although paper diaries represent an additional item for participants to carry we hoped the net effect would be greater ecological validity in capturing information needs.

The user study explored which questions people would like to ask on mobile devices. In particular, we were interested in the relation of the question to user’s location and the degree to which the answers may influence the next user activity. Participants were given a paper diary as shown in Figure 1.

Participants were asked to record their (mobile) information needs by noting the question (see top part of the diary page) and the location they were at when they wished to ask the question (second line in diary page). In addition, we aimed to find out how much the question related to the place. The motivation was to find out if knowing the place one may predict questions, or if people at

Date: 01/07

✓ What is your question?
How old is the oldest known Maori artefact?

✓ Where did you have this question?
Waikato Museum.

✓ How strongly is the question related to the place where you had the question?
Not at all The place caused the question.

✓ How much does the answer influence your next actions?
Not at all My next actions depend on the answer.

Figure 1: Example diary page (completed)

the same place may find information about other people’s questions insightful. We gave a scale to describe the degree the question was related to the place (from 0 – not at all, to 4 – very strongly). For example, a question may have been directly inspired by the place (e.g., a museum’s exhibit), or it may be independent of the place and the user’s surroundings. As a result from the pilot study, we also gave a second scale for the degree to which the participant’s question related to their next activity. Both scales are given in the lower part of the diary page. Each page in the diary referred to one question.

4 Results

The participants were computer literate and familiar with mobile electronic devices. 12 people participated in the diary study, which was recorded over one week. A total of 220 unique entries were recorded, with an average of 18 entries per participant. The minimum number of entries in the diary was 8 and the maximum was 29. We analysed a number of different aspects for the diary entries, which are now discussed in turn.

Relationship to Place (Query/Location) We first explore the relation between question and location by analysing the user location and the references to locations in the query itself. We identified five categories of places: the participant’s home, a friend’s home, their work place, going out (e.g., shopping, dentist, airport), and being mobile in the road (e.g., in a car). Figure 17 shows the number of queries per category. We observe that almost half of all queries were asked at home; all other categories are locations away-from-home. Work and friends’s places are similar to home as the participants were mostly indoors. The low number of queries of mobile participants most likely reflects the difficulty of recording questions in a diary while driving.

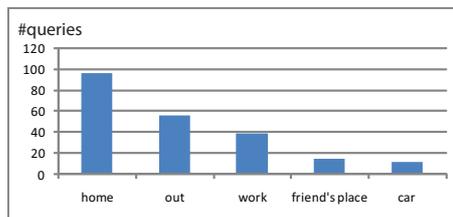


Figure 2: Query location by categories

The actual places of querying (i.e., location of the participant while querying) and the location scope of the query (i.e., location the answer refers to) are shown in Figure 16. For example, participant P10 recorded the query “Where is Koh Samui?” in Hamilton, but the scope of the query is Thailand.

The location of the user’s querying was taken from the user statement in the diary. The scope of the queries was determined by analysing the query text in the diary. It is not surprising to find that most queries were issued in Hamilton (‘home’ city of the study); the other three locations of queries are within 200km from Hamilton.

The location scope of the query was deduced from the queries: by place names explicitly mentioned (e.g., “Hong Kong”, “South Island”) or by landmarks mentioned (e.g., “Waitomo Caves”). The more general scope of ‘New Zealand’ was inferred from the query context (e.g., “What is the song [currently] playing on the radio?”). Factual queries mostly have no location reference (e.g., “What is the best chess tactic?”). From our analysis of the query text of the 220 queries, more than a third (80, 37%) have no location reference; 47 (21 %) had implicit place references (“how to predict the interest rate in the next month” is assumed to refer to a NZ context; “which restaurant is best” refers to a Hamilton context).

Question Type (question words used) We first analyse and distinguish questions submitted by the participants by the *question words* they used. Question words are the ones starting the question (e.g., ‘how’, ‘when’, ‘where’), a small number of which were corrected for grammar. The participants in our study gave complete questions, not just keywords (as common in web search).

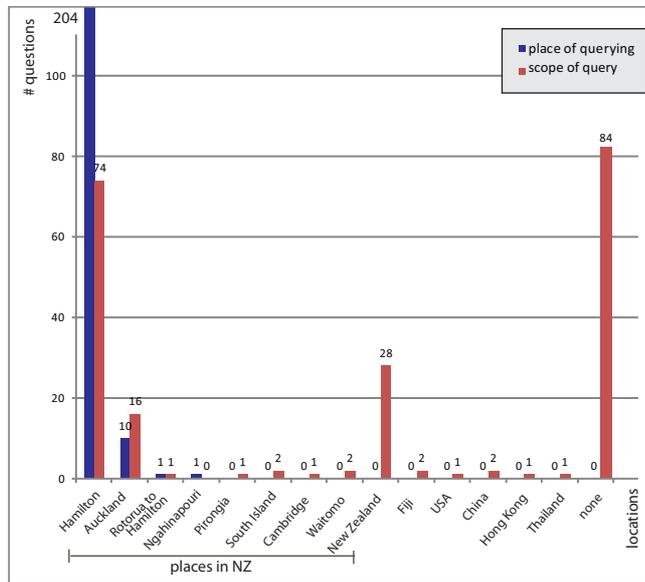


Figure 3: Location of querying vs scope of queries

Diary studies enable a focus on the participants' questions instead of a collection of system-influenced query terms. Paper diaries in particular do not suffer from input mechanisms influenced by the recording device.

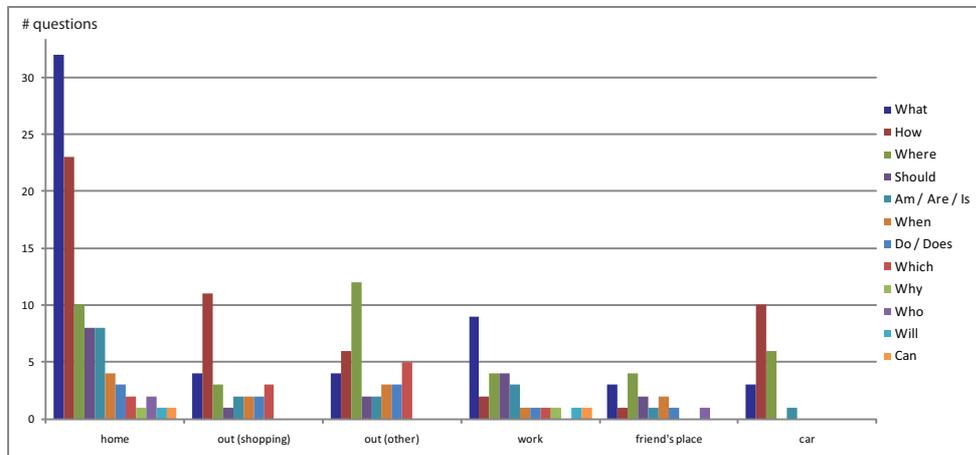


Figure 4: Questions words and locations

Figure 4 shows the participants' question words used at different places. Most questions are asked at home: one reason may be the ease of use of the diary at home. We immediately see that the two main questions asked at home

are of the form “what is this?” (e.g., P1: “What is the song playing on radio?” and “How to do this?” (e.g., P9: “How can I improve my thesis?”), asking for some kind of information and advice. Note that the ‘what’ questions still exist at the workplace, but the ‘how to’ questions are diminished. In this analysis, we further split the ‘out’ category into ‘public place’ and ‘shopping place’ to highlight an observation: If taken together in an ‘out’ category, the ‘how’ and ‘where’ questions occur in almost the same number. However, using our split category, we see that when shopping, the participants mainly ask ‘how’ questions and in other public places they use ‘where’ questions. Analysing the data, we find that queries in shopping places often refer to pricing and selection of goods (e.g., “How much does a Gibson guitar cost?”); whereas questions in public places mostly refer to geographical features (e.g., “Where is Pumice Cafe?”).

Question Type (categories) We identified two main categories of questions: problem solving (*problem*) and geographic references (*geographical*); for each we found a number of sub-categories, some of which were again subdivided (see Table in Figure 5). Our categories are related to those used in other studies [9, 2], but is chiefly influenced by the available user data.

Category	Sub-category	Explanation
Problem	Information	The answer is published by an authority or organization (e.g., bus timetable)
	Fact	There is only one answer for question (e.g., 2+2)
	Advice	The user is looking for reports of experiences others made (e.g., how to ...)
	Food	... concerning food or cooking
	Shopping	... concerning spending money on something
	Activity	... concerning an activity
	People	... concerning people
	Place	... concerning places
	Traffic	... concerning traffic
	PP	... concerning personal problems
	Health	... concerning health
	Beauty	...concerning skin care etc
	Skill	...concerning improvements of skills
	Gift	...concerning gift suggestions
	Entertainment	...concerning movies, trivals or books
	Geographical	Direction
Place		...to a particular place
Close by		...show/name all places near-by
Time		The answer is an estimate of time to reach a place
DA		Answer is direction combined with advice (e.g., what to do while waiting for tyre to be fixed)
Shortcut		Answer is a description of a quick way to get to a place.

Figure 5: Categories of Questions

Figure 6 shows how the question words relate to the categories we identified. We see that there is no simple mapping that related each question word to one meaning only. The figure also shows the distribution of question words used. The occupance of some questions words (e.g., ‘why’ and ‘will’) is so low that it is hard to draw conclusions about their contact of usage.

Using categories and subcategories, Figure 7 shows an overview of the questions asked by each of the 12 participants. We see, e.g., that participant P8 submitted overall 10 questions in two categories only (information and direction), and that participant P9 mostly asked for advice. Comparing the participants, we see personal preferences but no overall pattern regarding the categories used

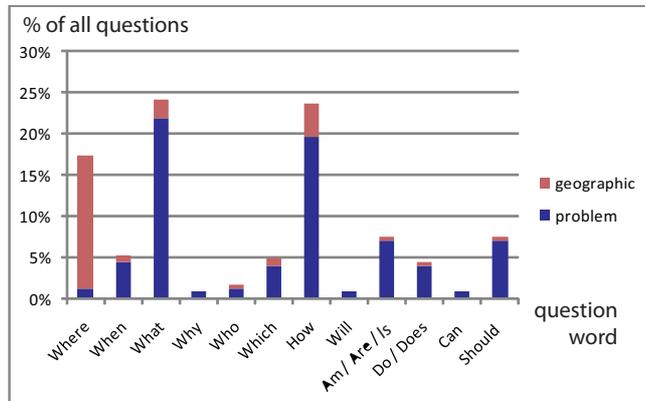


Figure 6: Relationship between question words and identified question type

emerges yet at this level.

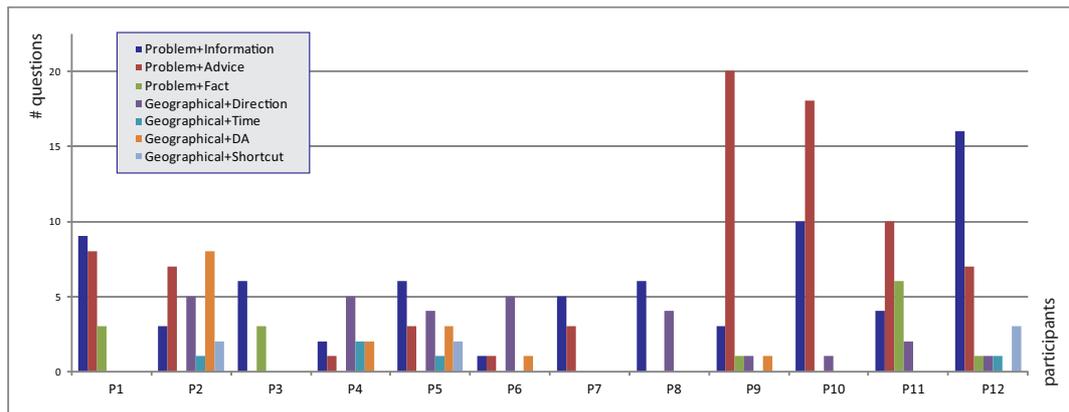


Figure 7: Question type over participants

This changes, once we compare question categories at different locations as shown in Figure 8. We can identify the following patterns: Problem-solving questions (asking for information, advice, or facts) are mainly asked at home. The only other place where fact-related questions are asked is at work; these questions occur in no other places. People express directional information needs (direction, DA and shortcut) mostly when they are out (10%) followed by home (5%), work and mobile (3% each).

Geographical questions are the prevalent type of questions when being mobile – the number would probably have been higher when using different recording mechanism for questions (e.g., dictaphone). Direction and advice is almost only found when people are out. They are typically of the form “here is my

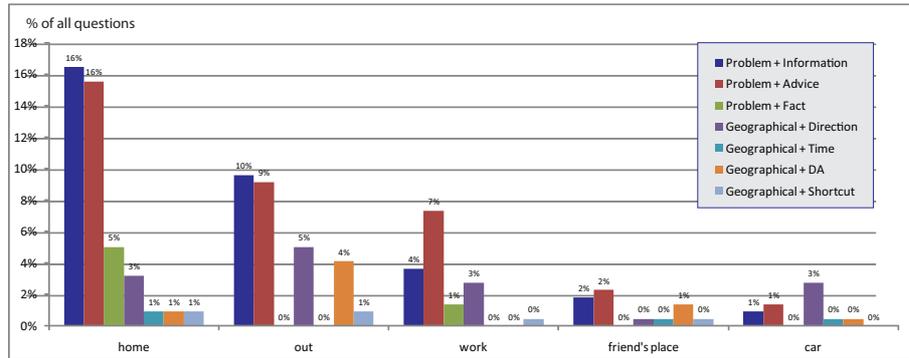


Figure 8: Question type over location of querying (categories)

problem, where do I go for a solution?” such as “Where can I buy a number for my mailbox?” (P4).

So far we only used categories and sub-categories in our analysis. As shown in Figure 5, the sub-categories of Advice and Direction have further distinctions.

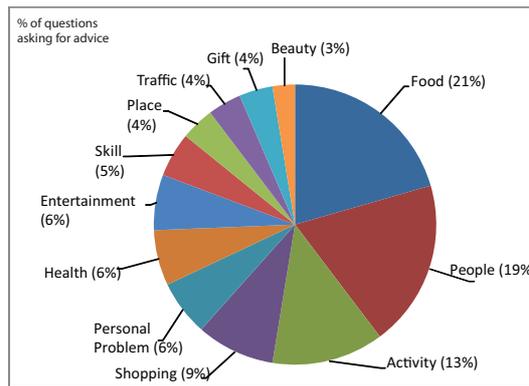


Figure 9: Topics occurring in questions asking for advice

Figure 9 shows the distribution for advice-questions: questions about food (e.g., “What can I cook for dinner tonight?”), people (e.g., “Which of my friends plays any music[al] instrument?”) and activity (e.g., “When will the roses need to be pruned again?”) were most common. Amongst the direction questions, 64% referred to places known to the participant (e.g., “Where is [the] Genesis office?”), whereas 36% asked for information about the location of nearby places (e.g., “Where is the nearest Garage?”, “Where is the nearest petrol station?”).

Expected Answers We analysed the questions for the expected length of the answers. Figure 10 shows the distribution of long answers, simple yes/no

decisions, numbers and selection for the given set of queries. Note that answers for problem-solving questions and geographical questions may have very different structures: For example, the long answer to a geographical question may be a map rather than a textual document as for the problem-solving question. Numerical answers to geographical questions typically answer questions for estimated travel times (e.g., P4: “How long it take to drive to Auckland airport?”).

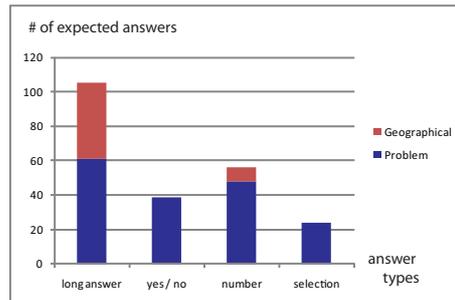


Figure 10: Distribution of answer types

Relationship to place and activity (numerical score) We now discuss the numerical aspects of the study relating to the two scales shown in the lower part of the diary page (see Figure 1). We identify four groups of questions: independent of location and activity (score 0 on both scales), relating to activity only, relating to location only, and relating to both activity and location.

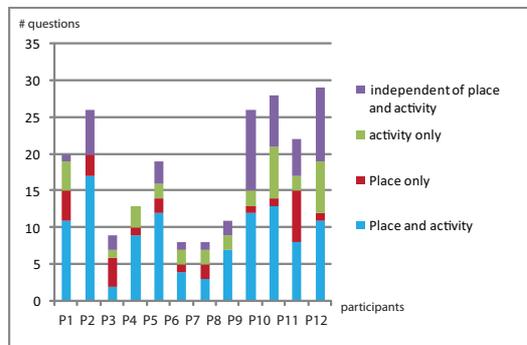


Figure 11: Relation between questions and the user's location (place) and current/next activity

Figure 19 shows the number of questions for each participant and their relation to place and activity. 109 out of 220 questions (50%, avg 9) referred to both location and activity; ranging from a minimum of 2 to a maximum of

13. This is the largest category in diary study. 34 queries relate to activity only (16% avg 3, max 7, min 0); 27 to location only (12 %, avg 2, max 7, min 0). 49 questions were independent (22%). Examples are: “What is Type II diabetes?”, and “[How much do] you have pay for on over-speed ticket?”.

On average, 22% of all questions did not relate to place nor activity. The number of independent questions per participant ranges from zero to 11. Note that the strength of the relationship (scores between 1 and 4) cannot be seen in Figure 19.

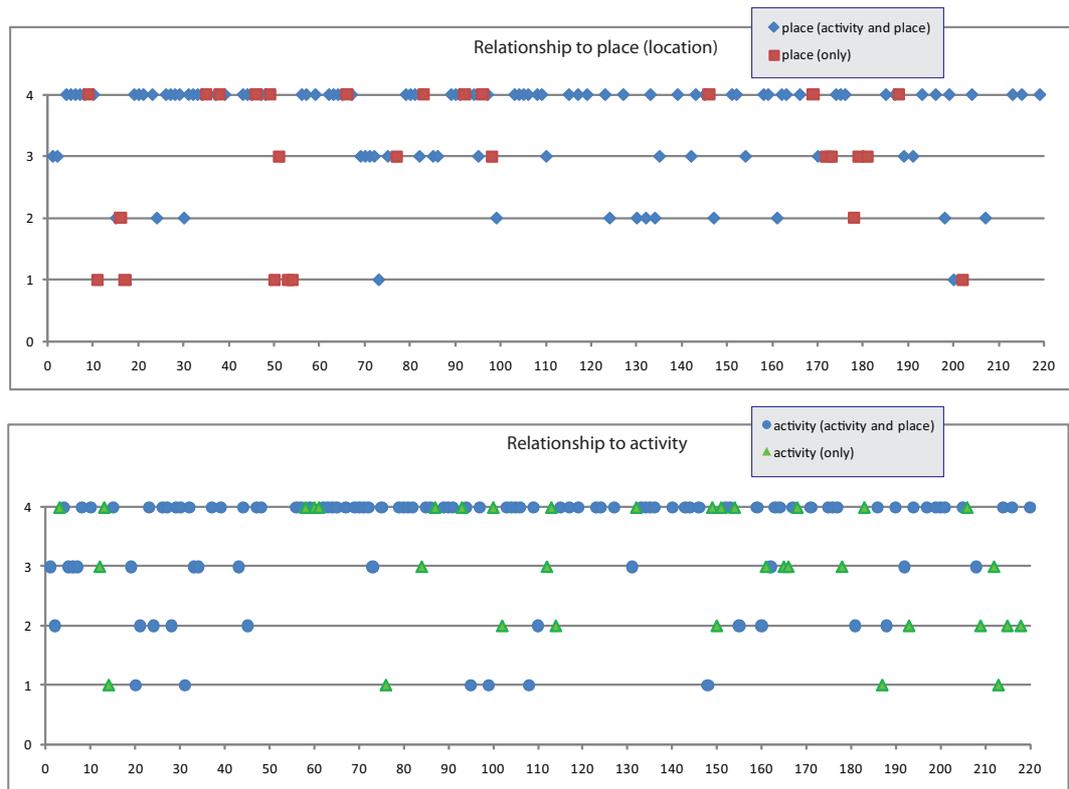


Figure 12: Scores for queries relating to place (top) and activity (bottom)

Scores between 1 and 4 describe how strongly the question relates to (a) the place and (b) how much the answer influences the next action (zero if independent of place/activity). The scores for place and activity relation are shown in the two diagrams in Figure 12. For clarity, independent queries (place and activity relationship zero) are not shown in this figure.

The average score on location (place) relationship for is 3.55 for queries that relate to both location and activity (88%), and 2.93 (73%) for those relating to place only. The average score for relationship to place is 3.53 (88%) for queries that relate to both location and activity, and 3.03 (75%) for those relating to

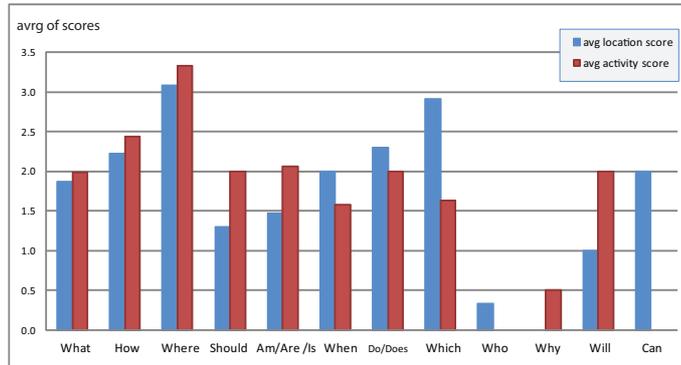


Figure 13: Relationship between question words and place score

activity only. We observe that if a question relates to both location and activity, this relationship is experienced as being stronger than if the question relates to only one of them.

Figure 13 shows the relationship between the question word used in the queries and the average scores for location and activity. We observe that ‘who’ and ‘can’ are not used for questions relating to the next activity. ‘Where’-questions often influence the next activity (as in, “Where is the nearest xyz?”), whereas ‘which’-questions relate more strongly to the location (often occurring in questions like “Which is the quickest way to place xyz?”).

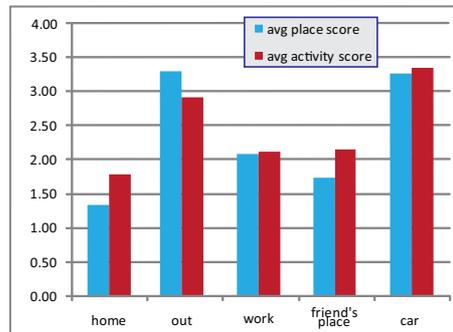


Figure 14: Relationship between activity and place score and the user location when querying

Places and location/activity scores Figures 14 and 15 show the relationship between the scores and the place of querying and the scope query, respectively. In Figure 14, we see that participants deemed the relationship between their activity and location to the question to be strongest when being mobile in a car. This matches the observation that questions for participants in a car

were mostly geographical (often queries for directions relating to their immediate surroundings). Again, we’d like to stress the observation that the data does not necessarily mean that people do not have any other information needs while driving, but that they did not record them.

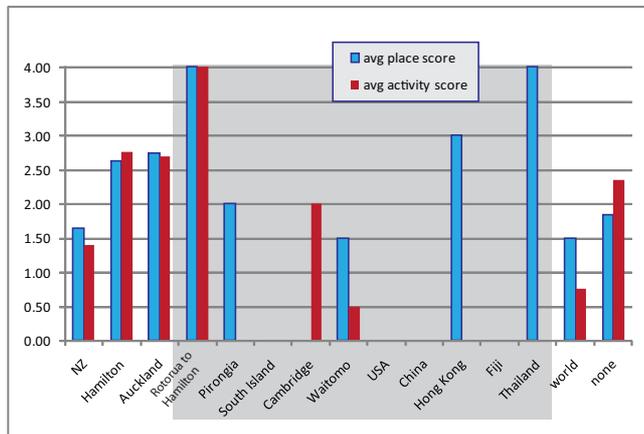


Figure 15: Relationship between activity and place score and the answer’s location (determined by users)

We observe that both at their own ‘home’ and at ‘friend’s homes’, participants asked questions more strongly related to their next activity than to their location. These two places also show the lowest overall scored for relation to place. One explanation could be that these places are seen as ‘default’ locations from which to start other activities; whereas work, going to the city, and driving, are seen as more explicit activities that may create their own questions. We also observe that there does not seem to be a dependency on how long/often people spent time in these places.

A number of observations can be made about the comparison between scores and location scope of the query (Figure 15). Firstly, we observe that the average scores in this Figure are not comparable as some of them represent single queries (indicated by gray background) and others more than 70 queries (as for Hamilton, or ‘none’). We can, however, see that individual queries mentioning places outside New Zealand are interpreted by their authors very differently: referring strongly to activity (as in the case of Thailand) or not at all (e.g., USA). For some queries referring to places in New Zealand (e.g., “Rotorua to Hamilton” and “Cambridge [New Zealand]”) are related to the user’s location. In the first example, the participant P8 was on the way from Rotorua to Hamilton, asking for the nearest petrol station on the way. In the second example, participant P12 was asking for the way from their home to Cambridge (with the intention to go there).

Some of the scores for queries in places categories such as “New Zealand”, “world”, and “none” appeared to contradict their query text. We believe that

these three categories have only very loose relationships to place. Examples are “Can you get puzzle quest on PS2?” (P12) with a NZ scope (for being able to buy the game in the country) and location and activity scores of zero. In this case, the views of participant and authors align. However, for a large number of cases, they do not (as shown in the high scores for location-relevance in these three place categories). Examples of such diverting views are P9: “Do I have to send any emails?” and P10: What is on TV tonight?, which were both given very high scores for location by the participants, however, no relationship to place could be inferred from the question alone (query location scope being ‘none’ and ‘NZ”).

Relationship to Place (Query/Location) Figure 16 shows the locations of participants’ queries alongside any geographical scope present in their queries. The ‘home’ city of the study (Hamilton, New Zealand) is the dominant location in the entries (204 out of 220). Participants used different terms to identify their location ranging from city-wide (“Auckland”), building-specific (“Chartwell Shopping Mall”), relative (“Near dentist”) and with varying degrees of precision (“in the car”, “Rotorua to Hamilton”). All data in Figure 16 has been grouped for ease of presentation, for example, references to specific suburbs or places are represented by their enclosing cities (e.g., Hamilton, Auckland).

Some queries contained explicit geographical terms (“How far is the Wesley Hotel from 1 Pacific Place, Hong Kong?”, “Where and when does train to New Lynn go?” and “Where is Koh Samui?”). Other queries contained implicit geographical scope, for example: the query “Where is the nearest the petrol station?” from a location of “Rotorua to Hamilton”. Queries with global or no related geographical scope (e.g., “What is a quadrilateral?”) are recorded as “none” whereas we found that 28 queries had a country-specific scope of New Zealand.

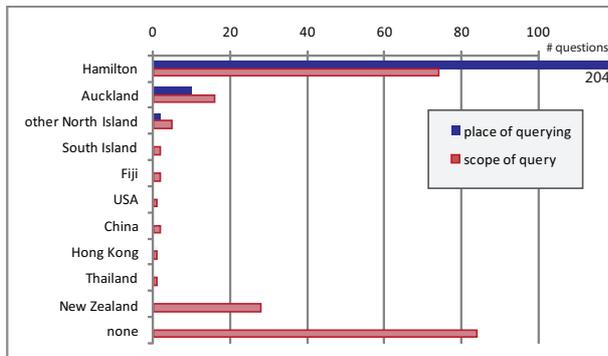


Figure 16: Location of querying vs scope of queries

Analysing the location of queries, we identified five categories of places: the participant’s home, a friend’s home, their work place, going out (e.g., shopping, dentist, airport), and being mobile (e.g., in a car). Figure 17 shows more

queries were made at home with relatively few in cars. Figure 17 also shows a break-down of queries involving simple fact-finding, advice, directions and geography/time (e.g., “How long does it take to walk to New Save from here?”). Perhaps unsurprisingly, directional queries are more common away from familiar locations and when in a car. Conversely, queries seeking advice are more common at home and at work.

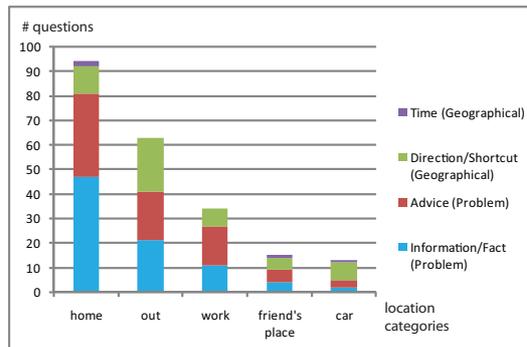


Figure 17: Location of querying and query categories

Query Topics The 220 queries were classified by topic into the categories used by Church and Smyth [9]; as their study is the methodologically closest to ours.

Figure 18 shows the results of the topic categorisation in the two studies. The first comparison (“entries”) is the percentage of queries that fell into each category. On the right (“users”) is the percentage of users posing queries from each category. Our participants recorded more queries in “General Shopping” and “Education”, and fewer in “Travel & Commuting” and “Entertainment”. These topic differences probably reflect both participant background (mainly students rather than professionals) and the study location (small city (Hamilton) versus large city (Dublin, Ireland)). A further difference is that we recorded more “Personal Info” queries, with all of our participants represented in this category. However, we found many of these questions were more about the subjective preferences of the participants rather than for specific informational items; we discuss this further in Section 5.

Query relationship to place and activity Two aspects of the diary template asked participants to relate their query to their location and their current/next activity. For both these questions, a five-point scale started from no connection (labelled “not at all”) and then had four items to indicate the strength of the connection. Figure 19 shows the distribution of responses to these questions. At the top of the Figure are the 49 queries (22%) which participants reported were independent of place and activity (e.g., “Who is Schweitzer and what did he do?”). In the middle are queries participants felt were related

Category	entries	users	
		Church & Smyth	Church & Smyth
General Shopping	20.9%	2.0%	92%
Personal Info	15.5%	1.2%	100%
Travel & Commuting	13.2%	20.2%	75%
Local Service	10.9%	24.2%	83%
Education	10.5%	0.5%	58%
General Information	9.5%	15.6%	50%
Entertainment	4.1%	12.8%	58%
Email & Social Networking	2.7%	3.2%	33%
Cooking, Recepies	2.3%	2.2%	25%
Finance	2.3%	1.7%	33%
News/Weather	2.3%	1.5%	42%
Auto	2.3%	0.5%	33%
Trivia	1.8%	6.4%	17%
To Do/ Schedule	0.9%	2.0%	17%
Sport	0.0%	3.5%	0%
Misc	0.0%	1.2%	0%
Employment	0.0%	0.5%	0%

Figure 18: Query topics in comparison with [9]

to their location (e.g., “Why do leaves turn red?” and ‘Are bees blind?’) or activity (e.g., “How do I exit out of full screen mode in Vmware Fusion?”), but not both. The largest category of queries, 109 out of 220, were connected to *both* the location and the participant’s activity (e.g., “What is the quickest [way] to go to ‘New World’ [a supermarket] from my house?”, “What is the Saturday night bus timetable?”, “Which vegetables are reasonably cheap today?”).

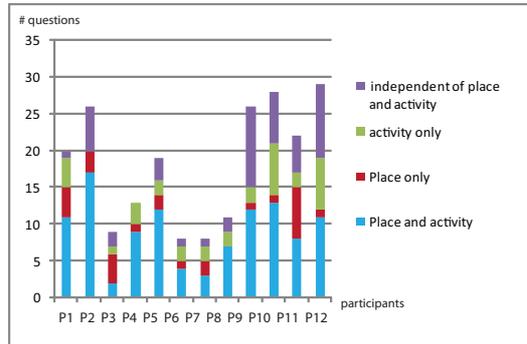


Figure 19: Relation between questions and the user’s location (place) and current/next activity

Posing Queries to Wikipedia & Google In Section 1, we suggested that there were three main methods for addressing information needs using library services on mobile devices: reference services, portable libraries and general web search/browsing. To further examine two of these options, we tested how Wikipedia (as an example of a portable knowledge collection [5, 13]) and Google dealt with the queries provided by our participants. As noted above, many of the questions are strongly connected to a location or a participant’s activities;

these context-dependent questions (e.g., “Where is the nearest free car park?”, “How many assignments do I have to do before the end of September?”) are essentially un-answerable without such information. However, if we exclude these questions, and others which involve personal information, we can create a set of 68, broadly factual, questions.

Posing these questions directly to Wikipedia and Google, we examined the first 10 hits and manually assessed whether the pages answered the questions. We also manually added geographical context (distinguishing Hamilton, New Zealand from Hamilton, Ontario) for some queries and rectified some spelling errors. Using this, admittedly approximate, criterion Wikipedia answered 13 queries (19%) and Google 48 (71%). Google often found pages that contained the exact question text along with an answer. For example, for the query “How to text very fast?”, Google found answers in all of the first three hits, whereas Wikipedia provided information about the technical background of SMS in the sixth hit. Sometimes the pages found were quite puzzling, for “Which restaurant is the best (in Hamilton)?”, Wikipedia linked to information about McDonald’s fast food.

Sometimes Google would provide as a first hit a link to the page that Wikipedia had also identified (e.g., for “Who is Schweitzer and what did he do?”). However, sometimes Google correctly found the Wikipedia link while Wikipedia itself did not find the page (e.g., “Which were the Kuomin Tang?” [sic]), Wikipedia did provide alternative spellings, but none lead to the correct page. For some queries, neither found the correct answer, but Google provided the most closely-related information (e.g., for “Is my bicycle tyre flat?”).

5 Discussion

We first compare our findings with those of earlier studies. Kamvar & Baluja expressed the desire to determine “what inspired [a] search” – our recording of query place and its relationship with place and activity give indication to those user motivations. However, we observed discrepancies between the participants judgement of strength of relationships and the results of our query analysis, which are hard to resolve without further data.

We observed an influence of location and activity on the query in 78% of all questions, which is comparable to Sohn et al.’s findings regarding context [25]. The proportion of queries asked in the car is low (6% of all queries), but 62% of these ask for directions or estimations of driving time. The lowest relative number of geographical questions were asked at home (14% and at work 21%). However, *explicit* references to locations (perhaps comparable to Church & Smyth’s ‘geographical terms’ [9]) were found in only 69 questions (31%). 52% of those occurred in geographical questions, and 48% in problem-solving ones. The reason may be that participants felt that their location context was somehow implicitly known. We observe that counting the explicit location references does not give a good indication of the type of the question. The question words used (as shown in Figure 6) provide a better indication but are not typi-

cally used in online searches, where log analysis studies indicate shorter average query length (2.56 words [16]). Explicit location references for users in the car were mentioned in 6 of 13 questions (46%), which is consistent with the greater frequency of geographical references reported in [9].

The (implicitly assumed) location context of users is not always easy to measure. Location coordinates are not sufficient, as places and areas need to be identified. The opposite problem is easily solved (finding locations for a given place or building); identifying the context the user sees themselves in is not that simple. Given coordinates may indicate anything between ‘Bongo cafe’, ‘University of Waikato’, ‘North Island’, ‘South Pacific’, and ‘Planet Earth’. Deciding which of these nested location contexts is appropriate, requires further work [23].

We can confirm the observation that most queries were made when being “off-duty”[18] (assuming that we can infer the participants’ status from their location outside work). However, the strong concentration on public place could not be confirmed (only 28% of all queries were issued in a public place). The influence of social interaction was not explicitly addressed in our study. However, 20% of the questions explicitly mention other people or their places (“our visitor”, “my friend”, “Lesley’ telephone number”, “Sam’s place”).

Amin et al[2] reported that in searches within the participants’ vicinity, target locations were more often those regularly visited (that is, participants engaging in long-term planning). However, we discovered that most searches for places near-by were performed when being on the road (that is, an immediate information need is addressed). This observation is confirmed by an analysis of the queries issued: of the 10 searches explicitly mentioning “near-by” context, three referred to finding car parks and two to finding petrol stations (others: shops (2), restaurants (2), hospital (1)). Thus 50% of vicinity searches were issued in the car, all of which referred to car-related immediate issues.

Although there is a sizable minority of queries that are independent of location or activity, we found these factors had strong influence on participants queries. This is consistent with earlier studies: similar to [25], we found that 78% of queries were prompted by the participants’ situation. However, we found that 28% of the queries reported were seeking details about the present location of the user (compared to 15% by Nylander et al. [22]).

We analysed the queries for sources of possible answers (see Figure 20, top). The topics of 150 of the 220 questions (68%) were such that the answers, in our judgement, are likely to be available on the Internet. This includes queries that would have to be reformulated or extended by (currently implicit) context information. For a subset of 68 questions (31%), which did not contain references to current events (such as exhibitions), the answers may be obtainable from a digital library. Given that some questions may be answered by both, Internet and library, this leaves 63 questions (29%) that may not be answerable by such existing online services. A large number requested personal assistance in decision making such as “Should I pick up the pizza or use delivery?”. However, the majority of those queries contained references to user’s immediate surrounding, e.g., “Does this place sell dried peas?”. However, these observations need

strengthening by evaluation using actual online services.

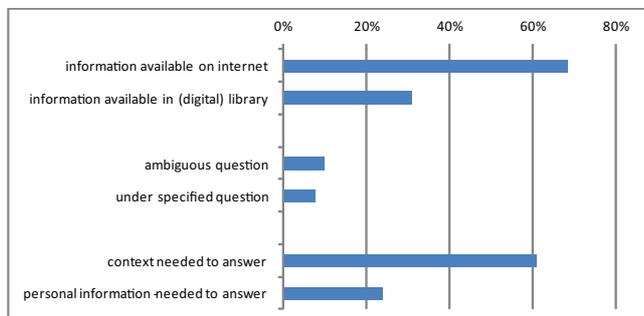


Figure 20: Quality/suitability of queries

We evaluated the completeness of the queries (see middle of Figure 20): 22 questions were ambiguous and 17 were under-specified. Ambiguous questions were deemed to be those it was not clear to the authors what an expected answer should be, for example: “Should driving age been raised to 18 years old?” (reflecting a current public discussion in New Zealand) and “Should I make a coffee?”. Under-specified questions were those that needed further information to be answerable that could not be automatically detected or observed (such as location would). Examples were “What is the postfee on this parcel (milk powder) to china?”, “Do they have a book I read about recently?” Amongst those with explicit location references, a number were under-specified (e.g., “the New World shopping centre”, “where should we meet at St Paul?”, “does *this place* sell dried peas?” – further information was needed to clarify which place was referred to). Under-specification mostly referred to location, but other instances of known context were also assumed, e.g., “Where else can we go have a look for vanity and bathroom applications?” assumes knowledge of the places that have been visited (history and shop identification), and “The best size of bath tub that can fit well to the main bathroom?” “Which is the best size of bath tub can fit well to the main bathroom?” assumes knowledge of the participant’s house layout; and “Is my server running?” assumes information about and access to a private server.

A large number of questions needed additional context information to be answered (see bottom of Figure 20). Not surprising for mobile queries, most of these contextual questions required information about the user location. Location context can be either direct coordinates (to answer all questions like “where is the nearest xyz?” and “How do I get to xyz from here?”), or information about the city and country (e.g., “How will tomorrow’s weather be like?” needs a place reference, and P1: “How many people have swine flu in Hamilton?” needs a country reference). Some questions require a personal scope as location reference, such as “Where can I catch the first glance of the sun on next Friday?”. Other contexts needed may be locations of shops or other people’s homes. The context is often temporal, not only asking for the current location

of the active user, but also questions that require knowledge about the current locations of other (mobile) people or items (e.g., “Where should I meet my friend in St. Paul?” and “where is my mouthgard?”). Surprisingly, there were no questions to locate other people, only items and shops (“Does this place sell dried peas? Where are they?”). The previous query also shows an example of needing to identify places by more than their location, that is, to identify their semantics (mostly as shops). References to places were: “they”, “this place”, “here”, “this car park building”, “this shop”.

Identification of persons is also part of context needed. Other people were often simply referred to by name, especially friends (e.g. in “Carole’s place”), which could be resolved by the system. Sometimes, however, people were referred to by indirect reference – as if they were pointing at the person (e.g. “what is this boy’s name?”). One query is particularly interesting in this respect: The query was “Is PolyMike leaving Uni?” (name changed to preserve anonymity), requiring knowledge about a person’s nickname. One way to obtain this context information could be a search in a list of personal friends, or an online search in personal home-pages held by staff members to map the nickname onto the person’s name to identify their location.

The definition of the categories and question types we used were driven by our research questions and the available data. They are similar to the ones used in other studies [17, 22, 25, 9, 2, 11], without attempting an exact match. We observe that some of the categories find an overlap, e.g., food, shopping, travel, whereas some significant categories found in other studies did rarely occur, e.g., ‘news’ and ‘(public) transport’.

We confirm the finding that a significant number of queries are context free, or appear to the participants to be so: 22% of queries were marked as being independent of location and activity. As noted earlier, some discrepancies were observed between user and author views. Further study is needed.

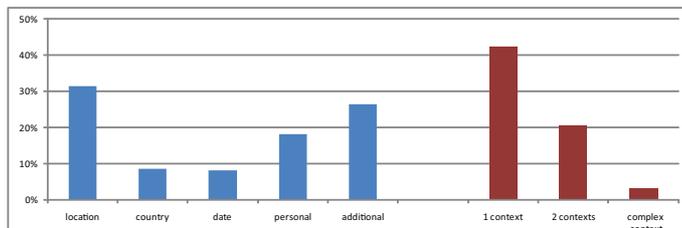


Figure 21: Context needed

Figure 21 lists types of typical context information required to answer the questions. 31% of all queries need at least information about the user’s location to be answered – the best example being (P8:) “Where am I?”, and the whole range of requests to identify the nearest petrol station, super market, car park etc. Sometimes the reference to the city or even only the country would be sufficient: typically here the users implicitly assumed a New Zealand context without stating so in the question (e.g., P1: “How many people have swine flu in

Hamilton?”). In all cases, the missing information could be obtained from the current position of the user, that is, participants assumed their current context to automatically hold for the query. Some queries require the current date/time to be answered, e.g., when asking for a song playing on the radio, movies being on at a cinema, the next bus to arrive, or estimated travel times by car.

18% of all queries required information about personal data to be answered. Examples as questions about finances (P1, P10, P11, P12) or emails (P9) to be answered, but also information about friends and acquaintances (P6: “Which of my friends play a musical instrument?”, P11: “What is Lesley’s telephone number?”, and P11: “Has PolyMike left the uni?”), and personal advice (“Should I do cardio or weights?”, “What should I text my friend?”).

All our participants produced personal and subjective queries, following their own “motivations to seek information to help satisfy largely affective needs” [28]. Our diary study methodology is similar to earlier studies [25, 9, 2, 22] but they do not report queries such as “What gift I shoul[d] buy for my friend’s wedding?”, “Should I call my sister?” and “Should I sit outside and enjoy the sun?” We speculate that the simplicity of the paper diary format, the lack of reminders, absence of detailed templates and separation from any actual query terms presented to a system, have all combined to allow the participants to express themselves with more freedom. Some of these subjective queries, roughly equivalent to Taylor’s [26] ‘conscious need’, almost seem like precursors to a more focussed query (maybe “What is the UV level now?”). The remainder of the differences in query topics between our study and Church and Smyth [9] are likely to be due to the backgrounds of the different participant groups.

Although there is a sizable minority of queries that are independent of location or activity, we found these factors had strong influence on participants queries. This is consistent with earlier studies: similar to [25], we found that 78% of queries were prompted by the participants’ situation. However, we found that 28% of the queries reported were seeking details about the present location of the user (compared to 15% by Nylander et al. [22]).

Our study did not consider issues of automatic location identification. The automatic monitoring of a mobile user’s outdoor location as $\langle x, y \rangle$ or even $\langle x, y, z \rangle$ coordinates is easily done using a GPS. Indoor locations are harder to determine: a number of positioning methods have been suggested (e.g., using WLAN [8] or radio frequency [4]), but precision is lower than for outdoor locations (due to interference) and most buildings do not have the necessary equipment installed. However, *measuring* the location is not sufficient, as no user ever specifies their desired location in coordinates. Places and areas need to be identified. The opposite problem is easily solved (finding locations for a given place or building); identifying the context the user sees themselves in is not that simple. Given coordinates may indicate anything between ‘Annika’s office’, ‘University of Waikato’, ‘North Island’, ‘South Pacific’, and ‘Planet Earth’. Deciding which of these nested location contexts is appropriate, requires further work [23].

Some of the other contexts may be determined with the help of a user’s Personal Information Management Tool (PIM), which may provide information

about the user's friends, home address, bank details, email addresses, as well as due dates for assignments etc. Accessing those data and thus using several systems in collaboration, may enable us to resolve some of the references in user queries as well as identifying some of the user context. Personal advice as sought in some of the subjective queries will be harder to supply.

Wikipedia is a viable contender for a portable general purpose knowledge collection [5, 13] which could be used to address the minority of information needs that are not dependent on contextual information. Portability is a valuable attribute as it frees users from issues of connectivity, service availability and pricing [25]. Future work should include longitudinal user studies on portable versions of Wikipedia to assess how effectively it can be used for situated information needs. An important aspect of such a study will be to examine how ready access to such collections influences users' behaviour; does lowering the access costs induce more activity?

An alternative vision is one of ubiquitous connectivity where users engage with remote services via their portable devices. Our brief comparison of Google and Wikipedia showed that the general web, especially question and answer sites like Yahoo! Answers, are a good match for our participants' information needs as they were phrased *as questions*. For some queries Google provided a better indexing to Wikipedia than Wikipedia itself. We speculate that this is due to Google's use of the link-structure of the web, from which portable stand-alone collections would not benefit.

What is the role for reference services in mobile information needs? Although some of our participants' queries could be classified as traditional 'ready-reference' queries many of them were strongly dependent on context or private information. Indeed, many queries were simply thoughts we all experience everyday as we make decisions. Although mobile devices offer up the possibility of addressing users' queries wherever they occur, ubiquitous connectivity might well increase both the variety and scale of possible queries.

Jones & Buchanan propose a Questions-not-Answers system that provides users with information about the questions other people asked in the vicinity of the current user [14, 3]. Our study results show that this approach is not valid for all questions, users may ask given the significant proportion of independent questions. Additionally, geographical and problem-solving questions may have to be treated differently. For geographical questions, providing the location of the answers would be more meaningful. As an illustration, it is not hard to imagine a spot with unhelpful or missing road signs on the way to a favourite tourist location. If one happens to get lost at that point and wants to query for the location of the tourist site, seeing all other queries asking for that very site may not just be unhelpful but also misleading. However, one would hope that for the government body responsible for road signage, this information may be of high interest. The research reported here does not yet answer the question of when and where to display information about questions or answers, but explores the questions of the relationship between a query and the location of the user, and the relationship between query and the next action of the user.

Although there are some differences in methodology, between this study

and other diary studies of mobile information behaviour [25, 9, 2, 22], findings on the importance of context appear to be robust. Our study gives some suggestions that some study parameters appear not to significantly alter the results, including: the medium of the diary (paper or device), recording technology (pen or text input) and whether participants are explicitly reminded to record entries. However, we still believe that future similar studies would be valuable to confirm these methodological aspects and to further examine differences in participant background and device familiarity. In particular, we suggest that further studies utilising mixed recording methods [18], that allow participants flexibility in how they record entries, may help to improve validity. For example, Palen and Salzman suggest voice-mail diaries [24] whereas Brandt et al. propose txt messaging snippets for later clarification [7]. Finally, it is worth nothing that although we have attempted to study spontaneous information needs ‘in the wild’, it is of course the case that the presence of a new device with enhanced capabilities will necessarily change the users’ environment and their behaviour.

6 Conclusion

In this paper, we reported on the results of a diary study with mobile users. Participants recorded their information needs, the place and date, and how strongly their question was related to their location and next activity. We found that the questions asked by mobile users are strongly influenced by contextual factors; however, a significant portion of independent questions (without reference to location or activity) was found.

We found that the type of questions recorded by participants varies across their locations (home, work, at friends homes, out in the city and while driving). These variations occur both in the query terms and in the form of desired answers.

We observed that for detecting context (e.g., to identify location-related questions), analysis of query keywords alone is not sufficient. More information was gained by analysing the query words (e.g., when, how, what) – which requires the queries to be given as full questions (instead of keywords). A number of pre-processing steps would have been necessary to answer the user questions: correction of spelling; semantic resolution of references to people’s names and identification of places (“home”); as well as detection of (currently) implicit user context (e.g., location, date, people-near-by). For these steps, additional (personalised) services, such as PIMs and gazetteers may be employed.

Both the location of queries and the participants’ activities affected participants’ questions: when information needs were affected by both location and activity, they tended to be strongly affected by both factors.

The study here reinforces the roles of contextual factors, such as location and activities, in understanding and addressing users’ mobile information needs. We reported an unusual number of highly personal, affective and subjective queries in our participants’ diary entries; these queries seem less well-formed than those

of earlier similar studies [25, 9]. There is a potential role for portable knowledge collections in addressing general information needs. Wikipedia is a prime candidate for this role though a brief exploration indicated that general web search performs better, partially through accessing social question-answering web content.

Overall, we found that a number of interacting contextual influences shape a user's mobile information needs. None of the categories, topics, and other characteristics used to describe the user queries are strictly orthogonal, and none of them can be used in isolation to identify the users' information needs or context. Thus adaptation of devices and interfaces need to take into account a rich variety of situational factors.

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